

C166/ST10 v7.5

C CROSS-COMPILER USER'S GUIDE

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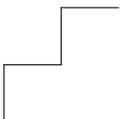
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MANUAL PURPOSE AND STRUCTURE

PURPOSE

This manual is aimed at users of the TASKING C166/ST10 C Cross-Compiler. It assumes that you are familiar with the C language.

MANUAL STRUCTURE

Related Publications

Conventions Used In This Manual

1. Software Installation
Describes the installation of the C Cross-Compiler for the C166/ST10.
2. Overview
Provides an overview of the TASKING C166/ST10 toolchain and gives you some familiarity with the different parts of it and their relationship. A sample session explains how to build a C166/ST10 application from your C file.
3. Language Implementation
Concentrates on the approach of the C166/ST10 architecture and describes the language implementation. The C language itself is not described in this document. We recommend: "The C Programming Language" (second edition) by B. Kernighan and D. Ritchie (1988, Prentice Hall).
4. Compiler Use
Deals with control program and C compiler invocation, command line options and pragmas.
5. Compiler Diagnostics
Describes the exit status and error/warning messages of the compiler.
6. Libraries
Contains the library functions supported by the compiler, and describes their interface and 'header' files.

7. Run-time Environment

Describes the run-time environment for a C application. It deals with items like assembly language interfacing, C startup code and stack/heap size.

APPENDICES

A. Flexible License Manager (FLEXlm)

Contains a description of the Flexible License Manager.

B. MISRA C

Supported and unsupported MISRA C rules.

C. Using CrossView Pro for Evaluation Boards

Describes how to use CrossView Pro evaluation boards.

D. Using Kontron Debuggers

Describes how to use Kontron debuggers.

E. Using Hitex HiTOP

Describes how to use the Hitex HITOP execution environment.

F. Using pls fast-view66

Describes how to use the pls *fast-view66* debugger.

G. CPU Functional Problems

Describes how the C166/ST10 toolchain can bypass some functional problems of the CPU.

H. User Stack Model Library Support

Describes the special coding methods used in the libraries and C166/ST10 C compiler to support a special stack frame.

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RELATED PUBLICATIONS

- The C Programming Language (second edition) by B. Kernighan and D. Ritchie (1988, Prentice Hall)
- ANSI X3.159–1989 standard [ANSI]
- C166/ST10 Cross-Assembler, Linker/Locator, Utilities User's Guide [TASKING, MA019–000–00–00]
- C166/ST10 C++ Compiler User's Guide [TASKING, MA019–012–00–00]
- C166/ST10 CrossView Pro Debugger User's Guide [TASKING, MA019–041–00–00]
- C166 User's Manual [Infineon Technologies]
- C167 User's Manual [Infineon Technologies]
- ST10 Family Programming Manual [STMicroelectronics]
- C166S v2.0 / Super10 User's Manual [Infineon Technologies / STMicroelectronics]

CONVENTIONS USED IN THIS MANUAL

The notation used to describe the format of call lines is given below:

{ } Items shown inside curly braces enclose a list from which you must choose an item.

[] Items shown inside square brackets enclose items that are optional.

| The vertical bar separates items in a list. It can be read as OR.

italics Items shown in italic letters mean that you have to substitute the item. If italic items are inside square brackets, they are optional. For example:

filename

means: type the name of your file in place of the word *filename*.

... An ellipsis indicates that you can repeat the preceding item zero or more times.

screen font Represents input examples and screen output examples.

bold font Represents a command name, an option or a complete command line which you can enter.

For example

command [*option*]... *filename*

This line could be written in plain English as: execute the command *command* with the optional options *option* and with the file *filename*.

Illustrations

The following illustrations are used in this manual:



This is a note. It gives you extra information.



This is a warning. Read the information carefully.



This illustration indicates actions you can perform with the mouse.



This illustration indicates keyboard input.



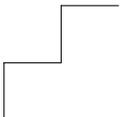
This illustration can be read as “See also”. It contains a reference to another command, option or section.

MANUAL STRUCTURE

CHAPTER

1

SOFTWARE INSTALLATION



1 | CHAPTER

1.1 INTRODUCTION

This chapter describes how you can install the TASKING C Cross-Compiler for the C166/ST10 on Windows 95/98/NT/2000, Linux and several UNIX hosts.

1.2 INSTALLATION FOR WINDOWS

Step 1

Start Windows 95/98/NT/2000, if you have not already done so.

Step 2

Insert the CD-ROM into the CD-ROM drive.

If the TASKING Welcome dialog box appears, skip to Step 5. Otherwise, continue from Step 3.

Step 3

Select the *Start* button and select the *Run . . .* menu item.

Step 4

On the command line type:

```
d:\setup
```

(substitute the correct drive letter for your CD-ROM drive) and press the **<Return>** or **<Enter>** key or click on the OK button.

The TASKING Welcome dialog box appears.

Step 5

Select a product and click on *Install*.

Step 6

Follow the instructions that appear on your screen.



You can find your serial number on the *Certificate of Authenticity* or *Product Update Form*, delivered with the product.

Step 7

License the software product as explained in section 1.5, *Licensing TASKING Products*.

1.2.1 SETTING THE ENVIRONMENT

After you have installed the software, you can set some environment variables to make invocation of the tools easier, when you invoke the tools from a command prompt. When you are using EDE all settings are configurable from within EDE. A list of all environment variables used by the toolchain is present in the section *Environment Variables* in the chapter *Overview*.

Make sure that your path is set to include all of the executables you have just installed, when you invoke the tools from a command prompt. If you installed the software under `c:\c166`, you can include the executable directory `c:\c166\bin` in your search path.



In EDE, select the `EDE | Directories...` menu item. Add one or more executable directory paths to the `Executable Files Path` field.

The environment variable `TMPDIR` can be used to specify a directory where programs can place temporary files. The compiler uses the environment variable `C166INC` to search for include files. An example of setting this variable is given below (this is only needed when you invoke the tools from a command prompt).



See also the section *Include Files* in the chapter *Compiler Use*.

Example Windows Command Prompt

Enter the following line when you use a Command Prompt window.

```
set C166INC=c:\c166\include
```

Example Windows 95/98

Add the following line to your `autoexec.bat` file.

```
set C166INC=c:\c166\include
```

Example Windows NT / 2000

1. Open the System Properties dialog.

You can do this by double-clicking on the System icon in the Control Panel (Start | Settings | Control Panel) or right-click on the My Computer icon on your desktop and select Properties.

2. Select the Environment tab.
3. In the Variable edit field enter:

```
C166INC
```

4. In the Value edit field enter:

```
c:\c166\include
```

5. Click on the Set button, then click OK.

1.3 INSTALLATION FOR LINUX

Each product on the CD-ROM is available as an RPM package and as a gzipped tar file. For each product the following files are present:

```
SWproduct-version-RPMrelease.i386.rpm  
SWproduct-version.tar.gz
```

Both files contain exactly the same information. When your Linux distribution supports RPM packages, you can install the `.rpm` file. Otherwise, you can install the product from the `.tar.gz` file.

1.3.1 RPM INSTALLATION

Step 1

In most situations you have to be "root" to install RPM packages, so either login as "root", or use the **su** command.

Step 2

Insert the CD-ROM into the CD-ROM drive. Mount the CD-ROM on a directory, for example `/cdrom`. See the Linux manual pages about **mount** for details.

Step 3

Go to the directory on which the CD-ROM is mounted:

```
cd /cdrom
```

Step 4

To install or upgrade all products at once, issue the following command:

```
rpm -U SW*.rpm
```

This will install or upgrade all products in the default installation directory `/usr/local`. Every RPM package will create a single directory in the installation directory.

The RPM packages are 'relocatable', so it is possible to select a different installation directory with the `--prefix` option. For instance when you want to install the products in `/opt`, use the following command:

```
rpm -U --prefix /opt SW*.rpm
```



For Red Hat 6.0 users: The `--prefix` option does not work with RPM version 3.0, included in the Red Hat 6.0 distribution. Please upgrade to RPM version 3.0.3 or higher, or use the `.tar.gz` file installation described in the next section if you want to install in a non-standard directory.

1.3.2 TAR.GZ INSTALLATION

Step 1

Login as a user.

Be sure you have read, write and execute permissions in the installation directory. Otherwise, login as "root" or use the `su` command.

Step 2

Insert the CD-ROM into the CD-ROM drive. Mount the CD-ROM on a directory, for example `/cdrom`. See the Linux manual pages about `mount` for details.

Step 3

Go to the directory on which the CD-ROM is mounted:

```
cd /cdrom
```

Step 4

To install the products from the `.tar.gz` files in the directory `/usr/local`, issue the following command for each product:

```
tar xzf SWproduct-version.tar.gz -C /usr/local
```

Every `.tar.gz` file creates a single directory in the directory where it is extracted.

1.3.3 SETTING THE ENVIRONMENT

After you have installed the software, you can set some of the environment variables to make invocation of the tools easier (when invoking the tools from the command line). A list of all environment variables used by the toolchain is present in the section *Environment Variables* in the chapter *Overview*.

Make sure that your path is set to include all of the executables you have just installed.

The environment variable `TMPDIR` can be used to specify a directory where programs can place temporary files.

1.4 INSTALLATION FOR UNIX HOSTS

Step 1

Login as a user.

Be sure you have read, write and execute permissions in the installation directory. Otherwise, login as root or use the **su** command.

Step 2

If you are a first time user decide where you want to install the product (By default it will be installed in `/usr/local`).

Step 3

For CD-ROM install: insert the CD-ROM into the CD-ROM drive. Mount the CD-ROM on a directory, for example `/cdrom`. Be sure to use a ISO 9660 file system with Rock Ridge extensions enabled. See the UNIX manual pages about **mount** for details.

Or:

For tape install: insert the tape into the tape unit and create a directory where the contents of the tape can be copied to. Consider the created directory as a temporary workspace that can be deleted after installation has succeeded. For example:

```
mkdir /tmp/instdir
```

Step 4

For CD-ROM install: go to the directory on which the CD-ROM is mounted:

```
cd /cdrom
```

For tape install: copy the contents of the tape to the temporary workspace using the following commands:

```
cd /tmp/instdir
tar xvf /dev/tape
```

where *tape* is the name of your tape device.



If you have received a tape with more than one product, use the non-rewinding device for installing the products.

Step 5

Run the installation script:

```
sh install
```

and follow the instructions appearing on your screen.

First a question appears about where to install the software. The default answer is **/usr/local**. On certain sites you may want to select another location.

On some hosts the installation script asks if you want to install SW000098, the Flexible License Manager (FLEXlm). If you do not already have FLEXlm on your system, you must install it; otherwise the product will not work on those hosts. See section 1.5, *Licensing TASKING Products*.

If the script detects that the software has been installed before, the following messages appear on the screen:

```
*** WARNING ***  
SWxxxxxx xxxx.xxxx already installed.  
Do you want to REINSTALL? [y,n]
```

Answering **n** (no) to this question causes installation to abort and the following message being displayed:

```
=> Installation stopped on user request <=
```

Answering **y** (yes) to this question causes installation to continue. And the final message will be:

```
Installation of SWxxxxxx xxxx.xxxx completed.
```

Step 6

For tape install: remove the temporary installation directory with the following commands:

```
cd /tmp  
rm -rf instdir
```

Step 7

If you purchased a protected TASKING product, license the software product as explained in section 1.5, *Licensing TASKING Products*.

Step 8

Logout.

1.4.1 SETTING THE ENVIRONMENT

After you have installed the software, you can set some environment variables to make invocation of the tools easier. A list of all environment variables used by the toolchain is present in the section *Environment Variables* in the chapter *Overview*.

Make sure that your path is set to include all of the executables you have just installed.

The environment variable TMPDIR can be used to specify a directory where programs can place temporary files.

1.5 LICENSING TASKING PRODUCTS

TASKING products are protected with license management software (FLEXlm). To use a TASKING product, you must install the licensing information provided by TASKING for the type of license purchased.

You can run TASKING products with a node-locked license or with a floating license. When you order a TASKING product determine which type of license you need (UNIX products only have a floating license).

Node-locked license (PC only)

This license type locks the software to one specific PC so you can use the product on that particular PC only.

Floating license

This license type manages the use of TASKING product licenses among users at one site. This license type does not lock the software to one specific PC or workstation but it requires a network. The software can then be used on any computer in the network. The license specifies the number of users who can use the software simultaneously. A system allocating floating licenses is called a **license server**. A license manager running on the license server keeps track of the number of users.



See the *Flexible License Manager (FLEXlm)* appendix for detailed information on FLEXlm.

1.5.1 OBTAINING LICENSE INFORMATION

Before you can install a software license you must have a "License Information Form" containing the license information for your software product. If you have not received such a form follow the steps below to obtain one. Otherwise, you can install the license.

Node-locked license (PC only)

1. If you need a node-locked license, you must determine the hostid of the computer where you will be using the product. See section 1.5.7, *How to Determine the Hostid*.

2. When you order a TASKING product, provide the hostid to your local TASKING sales representative. The License Information Form which contains your license key information will be sent to you with the software product.

Floating license

1. If you need a floating license, you must determine the hostid and hostname of the computer where you want to use the license manager. Also decide how many users will be using the product. See section 1.5.7, *How to Determine the Hostid* and section 1.5.8, *How to Determine the Hostname*.
2. When you order a TASKING product, provide the hostid, hostname and number of users to your local TASKING sales representative. The License Information Form which contains your license key information will be sent to you with the software product.

1.5.2 INSTALLING NODE-LOCKED LICENSES

Keep your "License Information Form" ready. If you do not have such a form read section 1.5.1, *Obtaining License Information*, before continuing.

Step 1

Install the TASKING software product following the installation procedure described in section 1.2, *Installation for Windows*.

Step 2

Create a file called "license.dat" in the c:\flexlm directory, using an ASCII editor and insert the license information contained in the "License Information Form" in this file. This file is called the "license file". If the directory c:\flexlm does not exist, create the directory.



If you wish to install the license file in a different directory, see section 1.5.6, *Modifying the License File Location*.



If you already have a license file, add the license information to the existing license file. If the license file already contains any SERVER lines, you must use another license file. See section 1.5.6, *Modifying the License File Location*, for additional information.

The software product and license file are now properly installed.



See the *Flexible License Manager (FLEXlm)* appendix for more information on FLEXlm.

1.5.3 INSTALLING FLOATING LICENSES

Keep your "License Information Form" ready. If you do not have such a form read section 1.5.1, *Obtaining License Information*, before continuing.

Step 1

Install the TASKING software product following the installation procedure described earlier in this chapter on the computer or workstation where you will use the software product.

As a result of this installation two additional files for FLEXlm will be present in the `flexlm` subdirectory of the toolchain:

<code>Tasking</code>	The Tasking daemon (vendor daemon).
<code>license.dat</code>	A template license file.

Step 2

If you already have installed FLEXlm v6.1 or higher for Windows or v2.4 or higher for UNIX (for example as part of another product) you can skip this step and continue with step 3. Otherwise, install SW000098, the Flexible License Manager (FLEXlm), on the license server where you want to use the license manager.

The installation of the license manager on Windows also sets up the license daemon to run automatically whenever a license server reboots. On UNIX you have to perform the steps as described in section 1.5.5, *Setting Up the License Deaemon to Run Automatically*.



It is not recommended to run a license manager on a Windows 95 or Windows 98 machine. Use Windows NT instead (or UNIX).

Step 3

If FLEXlm has already been installed as part of a non-TASKING product you have to make sure that the `bin` directory of the FLEXlm product contains a copy of the **Tasking** daemon (see step 1).

Step 4

Insert the license information contained in the "License Information Form" in the license file, which is being used by the license server. This file is usually called `license.dat`. The default location of the license file is in directory `c:\flexlm` for Windows and in `/usr/local/flexlm/licenses` for UNIX.



If you wish to install the license file in a different directory, see section 1.5.6, *Modifying the License File Location*.

If the license file does not exist, you have to create it using an ASCII editor. You can use the license file `license.dat` from the toolchain's `flexlm` subdirectory as a template.



If you already have a license file, add the license information to the existing license file. If the SERVER lines in the license file are the same as the SERVER lines in the License Information Form, you do not need to add this same information again. If the SERVER lines are not the same, you must use another license file. See section 1.5.6, *Modifying the License File Location*, for additional information.

Step 5

On each PC or workstation where you will use the TASKING software product the location of the license file must be known. If it differs from the default location (`c:\flexlm\license.dat` for Windows, `/usr/local/flexlm/licenses/license.dat` for UNIX), then you must set the environment variable **LM_LICENSE_FILE**. See section 1.5.6, *Modifying the License File Location*, for more information.

Step 6

Now all license information is entered, the license manager must be started (see section section 1.5.4). Or, if it is already running you must notify the license manager that the license file has changed by entering the command (located in the `flexlm bin` directory):

```
lmreread
```

On Windows you can also use the graphical FLEXlm Tools (**lmtools**): Start **lmtools** (if you have used the defaults this can be done by selecting Start | Programs | TASKING FLEXlm | FLEXlm Tools), fill in the current license file location if this field is empty, click on the Reread button and then on OK. Another option is to reboot your PC.

The software product and license file are now properly installed.

Where to go from here?

The license manager (daemon) must always be up and running. Read section 1.5.4 on how to start the daemon and read section 1.5.5 for information how to set up the license daemon to run automatically.

If the license manager is running, you can now start using the TASKING product.



See the *Flexible License Manager (FLEXlm)* appendix for detailed information on FLEXlm.

1.5.4 STARTING THE LICENSE DAEMON

The license manager (daemon) must always be up and running. To start the daemon complete the following steps on each license server:

Windows

1. Start the license manager tool by (Start | Programs | TASKING FLEXlm | FLEXlm License Manager).
2. In the Control tab, click on the Start button.
3. Close the program by clicking on the OK button.

UNIX

1. Log in as the operating system administrator (usually root).
2. Change to the FLEXlm installation directory (default `/usr/local/flexlm`):

```
cd /usr/local/flexlm
```

3. For C shell users, start the license daemon by typing the following:

```
bin/lmgrd -2 -p -c licenses/license.dat >>& \  
/var/tmp/license.log &
```

Or, for Bourne shell users, start the license daemon by typing the following:

```
bin/lmgrd -2 -p -c licenses/license.dat >> \
/var/tmp/license.log 2>&1 &
```

In these two commands, the **-2** and **-p** options restrict the use of the **lmdown** and **lmremove** license administration tools to the license administrator. You omit these options if you want. Refer to the usage of **lmgrd** in the *Flexible License Manager (FLEXlm)* appendix for more information.

1.5.5 SETTING UP THE LICENSE DAEMON TO RUN AUTOMATICALLY

To set up the license daemon so that it runs automatically whenever a license server reboots, follow the instructions below that are appropriate for your platform. steps on each license server:

Windows

1. Start the license manager tool by (Start | Programs | TASKING FLEXlm | FLEXlm License Manager).
2. In the Setup tab, enable the Start Server at Power-Up check box.
3. Close the program by clicking on the OK button. If a question appears, answer Yes to save your settings.

UNIX



In performing any of the procedures below, keep in mind the following:

- Before you edit any system file, make a backup copy.

HP-UX

1. Log in as the operating system administrator (usually root).
2. In the directory `/etc/rc.config.d` create a file named `rc.lmgrd` with the following contents. Replace *FLEXLMDIR* by the FLEXlm installation directory (default `/usr/local/flexlm`):

```
#!/sbin/sh
FLEXLMDIR/bin/lmgrd -2 -p -c FLEXLMDIR/licenses/license.dat >> \
/var/tmp/license.log 2>&1 &
```

After the `-c` option, you have to specify the correct location of the license file.

SunOS4

1. Log in as the operating system administrator (usually root).
2. Append the following lines to the file `/etc/rc.local`. Replace *FLEXLMDIR* by the FLEXlm installation directory (default `/usr/local/flexlm`):

```
FLEXLMDIR/bin/lmgrd -2 -p -c FLEXLMDIR/licenses/license.dat >> \
/var/tmp/license.log 2>&1 &
```

SunOS5 (Solaris 2)

1. Log in as the operating system administrator (usually root).
2. In the directory `/etc/init.d` create a file named `rc.lmgrd` with the following contents. Replace *FLEXLMDIR* by the FLEXlm installation directory (default `/usr/local/flexlm`):

```
#!/bin/sh
FLEXLMDIR/bin/lmgrd -2 -p -c FLEXLMDIR/licenses/license.dat >> \
/var/tmp/license.log 2>&1 &
```

3. Make it executable:

```
chmod u+x rc.lmgrd
```

4. Create an 'S' link in the `/etc/rc3.d` directory to this file and create 'K' links in the other `/etc/rc?.d` directories:

```
ln /etc/init.d/rc.lmgrd /etc/rc3.d/Snumrc.lmgrd
ln /etc/init.d/rc.lmgrd /etc/rc?.d/Knumrc.lmgrd
```

num must be an appropriate sequence number. Refer to your operating system documentation for more information.

1.5.6 MODIFYING THE LICENSE FILE LOCATION

The default location for the license file on Windows is:

```
c:\flexlm\license.dat
```

On UNIX this is:

```
/usr/local/flexlm/licenses/license.dat
```

If you want to use another name or directory for the license file, each user must define the environment variable **LM_LICENSE_FILE**. Do this in `autoexec.bat` (Windows 95/98), from the Control Panel -> System | Environment (Windows NT) or in a UNIX login script.

If you have more than one product using the FLEXlm license manager you can specify multiple license files to the **LM_LICENSE_FILE** environment variable by separating each pathname (*filepath*) with a ';' (on UNIX also ':'):

Example Windows:

```
set LM_LICENSE_FILE=c:\flexlm\license.dat;c:\license.txt
```

Example UNIX:

```
setenv LM_LICENSE_FILE  
/usr/local/flexlm/licenses/license.dat:/myprod/license.txt
```

If the license file is not available on these hosts, you must set **LM_LICENSE_FILE** to `port@host`; where *host* is the host name of the system which runs the FLEXlm license manager and *port* is the TCP/IP port number on which the license manager listens.

To obtain the port number, look in the license file at *host* for a line starting with "SERVER". The fourth field on this line specifies the TCP/IP port number on which the license server listens. For example:

```
setenv LM_LICENSE_FILE 7594@elliott
```



See the *Flexible License Manager (FLEXlm)* appendix for detailed information.

1.5.7 HOW TO DETERMINE THE HOSTID

The hostid depends on the platform of the machine. Please use one of the methods listed below to determine the hostid.

Platform	Tool to retrieve hostid	Example hostid
HP-UX	lanscan (use the station address without the leading '0x')	0000F0050185
SunOS/Solaris	hostid	170a3472
Windows	tkhostid (or use lmhostid)	0800200055327

Table 1-1: Determine the hostid



If you do not have the program **tkhostid** you can download it from our Web site at: <http://www.tasking.com/support/flexlm/tkhostid.zip> . It is also on every product CD that includes FLEXlm.

1.5.8 HOW TO DETERMINE THE HOSTNAME

To retrieve the hostname of a machine, use one of the following methods.

Platform	Method
HP-UX	hostname
SunOS/Solaris	hostname
Windows 95/98	Go to the Control Panel, open "Network", click on "Identification". Look for "Computer name".
Windows NT	Go to the Control Panel, open "Network". In the "Identification" tab look for "Computer Name".

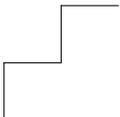
Table 1-2: Determine the hostname

INSTALLATION

CHAPTER

2

OVERVIEW



2 | CHAPTER

2.1 INTRODUCTION TO C C166/ST10 CROSS-COMPILER

This manual provides a functional description of the TASKING C C166/ST10 Cross-Compiler. This manual uses **c166** (the name of the binary) as the shorthand notation for 'TASKING C C166/ST10 Cross-Compiler'.

TASKING offers a complete toolchain for the Infineon C166 and STMicroelectronics ST10 microcontroller families and their derivatives. These derivatives can be based on C166/ST10x166 architectures (256K memory, 18-bit addresses), C167/ST10x167/ST10x262 extended architectures (16M memory, 24 bit addresses) and C166S v2.0 / Super10 extended architectures. This manual uses '80166' as the shorthand notation for these microcontroller families. The toolchain contains a C++ compiler, a C compiler, a control program, a macro preprocessor, an assembler, a linker/locator, a library manager, a program builder, a disassembler, a debugger and output format utilities.

The **c166** is not a general C compiler adapted for use with the C166/ST10 architecture, but instead it is dedicated to the microcontroller architecture of the C166/ST10 architecture. This means that you can access all special features of the C166/ST10 architecture in C: 16K page architecture (with full pointer support), bit-addressable memory, (extended) special function registers (I/O ports), interrupt support, scalable vector tables, (local) register banks and a number of built-in (intrinsic) functions to utilize special C166/ST10 architecture instructions. And yet no compromise is made to the ANSI standard. It is a fast, single pass, optimizing compiler that generates extremely fast and compact code.

The **c166** generates assembly source code using the Infineon assembly language specification, and must be assembled with the TASKING C166/ST10 Cross-Assembler. This manual uses **a166** as the shorthand notation for 'TASKING C166/ST10 Cross-Assembler'.

The object file generated by **a166** can be linked with other objects and libraries using the TASKING **l166** linker/locator. This manual uses **l166** as the shorthand notation for 'TASKING **l166** linker/locator'. With the link stage of **l166** you can link objects and libraries to one object. You can locate assembler objects, linked objects and libraries to a complete application by using the locate stage of **l166**.

The C166/ST10 toolchain also accepts C++ source files. C++ source files or sources using C++ language features must be preprocessed by **cp166**. The output generated by **cp166** is C166/ST10 C, which can be translated with the C compiler **c166**.



The C++ compiler is not part of the C compiler package. You can order it separately from TASKING. The C++ compiler package includes the C compiler as well.

With the TASKING **cc166** control program you can invoke the various components of the C166/ST10 toolchain with one call. This manual uses **cc166** as the shorthand notation for 'TASKING **cc166** control program'.

You can debug the software written in C, C++ and/or assembly with the TASKING CrossView Pro high-level language debugger. This manual uses XVW166 as the shorthand notation for 'TASKING CrossView Pro high-level language debugger'. A list of supported platforms and emulators is available from TASKING.

You can also use other debugging environments supporting the IEEE-695 format (e.g. Kontron, Hitex, Krohn & Stiller, Lauterbach, etc.).

2.2 PRODUCT DEFINITION

Name:

TASKING C C166/ST10 Family Cross-Compiler (**c166**)

Ordering Code:

TK019-002

Target Assembler:

TASKING C166/ST10 Cross-Assembler

Target Debugger:

TASKING C166/ST10 CrossView Pro debugger

Target Processors:

All C166/ST10x166 derivatives. Special function registers can be accessed by means of a user-definable 'sfr-file' (register definition files).

All C167 and derivatives (e.g. SAB C165) support is enabled with the '-x' option, extending addresses to 24 bits instead of 18 bits and enabling the extended instruction set of the C167. Extended special function registers are supported using the 'esfr' and 'esfrbit' data types.

All libraries are also present in an extended (ext) version.

All C166S v2.0/Super10 and derivatives support is enabled with the '-x2' option. All libraries are also present in an extended (ext2) version.

All enhanced C166S v2.0/Super10 and derivatives support is enabled with the '-x22' option. The ext2 libraries can be used.

2.3 GENERAL IMPLEMENTATION

This section describes the different phases of the compiler and the target independent optimizations.

2.3.1 COMPILER PHASES

During the compilation of a C program, a number of phases can be identified. These phases are divided into two groups, referred to as *frontend* and *backend*.

frontend:

The preprocessor phase:

File inclusion and macro substitution are done by the preprocessor before parsing of the C program starts. The syntax of the macro preprocessor is independent of the C syntax, but also described in the ANSI X3.159-1989 standard.

The scanner phase:

The scanner converts the preprocessor output to a stream of tokens.

The parser phase:

The tokens are fed to a parser for the C grammar. The parser performs a syntactic and semantic analysis of the program, and generates an intermediate representation of the program.

The frontend optimization phase:

This phase performs target processor independent optimizations by transforming the intermediate code. The next section discusses frontend optimizations.

backend:

The backend optimization phase:

Performs target processor specific optimizations. Very often this means another transformation of the intermediate code and actions like register allocation techniques for variables, expression evaluation and the best usage of the addressing modes. The chapter *Language Implementation* discusses this item in more detail.

The code generator phase:

This phase converts the intermediate code to an internal instruction code representing the C166/ST10 assembly instructions.

The peephole optimizer phase:

This phase uses pattern matching techniques to perform peephole optimizations on the internal code (e.g. deleting obsolete moves). It also performs pipeline optimizations, replacing NOP instructions with other instructions which do not interfere with the pipeline effects of the processor. Another task of the peephole optimizer is to convert JMPR instructions to JMPA instructions (or to reverse the condition of conditional bit jump instructions), if the destination label is not within the REL range (-128 to 127 words). Finally, the peephole optimizer translates the internal instruction code into assembly code for **a166**. The generated assembly does not contain any macros.

The instruction reordering phase:

This phase is only enabled for the ext2 architectures. It tries to reorder the instructions in order to keep the pipeline from stalling as much as possible. During this phase no instructions will be added or removed.

All phases (of both frontend and backend) are combined into one program: **c166**. The compiler does not use any intermediate file for communication between the different phases of compilation. The backend part is not called for each C statement, but is started after a complete C function has been processed by the frontend (in memory), thus allowing more optimization. The compiler only requires one pass over the input file, resulting in relatively fast compilation.

2.3.2 FRONTEND OPTIMIZATIONS

The following optimizations are performed on the intermediate code. They are independent of the target processor and the code generation strategy:

Constant folding

Expressions only involving constants are replaced by their result.

Expression rearrangement

Expressions are rearranged to allow more constant folding. E.g. $1 + (x - 3)$ is transformed into $x + (1 - 3)$, which can be folded.

Expression simplification

Multiplication by 0 or 1 and additions or subtractions of 0 are removed. Such useless expressions may be introduced by macros in C (`#define`), or by the compiler itself.

Logical expression optimization

Expressions involving `'&&'`, `'||'` and `'!'` are interpreted and translated into a series of conditional jumps.

Loop rotation

With `for` and `while` loops, the expression is evaluated once at the 'top' and then at the 'bottom' of the loop. This optimization does not save code, but speeds up execution.

Switch optimization

A number of optimizations of a switch statement are performed, such as the deletion of redundant case labels or even the deletion of the switch.

Control flow optimization

By reversing jump conditions and moving code, the number of jump instructions is minimized. This reduces both the code size and the execution time.

Jump chaining

A conditional or unconditional jump to a label which is immediately followed by an unconditional jump may be replaced by a jump to the destination label of the second jump. These situations frequently occur with nested control structures. This optimization does not save code, but speeds up execution.

Conditional jump reversal

A conditional jump over an unconditional jump is transformed into one conditional jump with the jump condition reversed. This reduces both the code size and the execution time.

Register coloring

Optimize register allocation within a C function. The compiler tries to keep as much local variables as possible in registers.

Constant/value propagation

A reference to a variable with a known contents is replaced by those contents.

Common subexpression elimination

The compiler has the ability to detect repeated uses of the same (sub-) expression. Such a "common" expression may be temporarily saved to avoid recomputation. This method is called *common subexpression elimination*, abbreviated CSE.

Dead code elimination

Unreachable code can be removed from the intermediate code without affecting the program. However, the compiler generates a warning message, because the unreachable code may be the result of a coding error.

Sharing of string literals and floating point constants

The ANSI X3.159-1989 standard permits string literals to be put in ROM memory. Strings in ROM cannot be modified, so the compiler overlays identical strings (within the same module) and let them share the same space, thus saving ROM space. Likewise, identical floating point constants are overlaid and allocated only once.

Common Tail Merging

Common pieces of code at the end of case labels and if-else constructions are replaced by a jump to single instance of the shared code. This will reduce code size.

2.4 COMPILER STRUCTURE

If you want to build a C-166 application you need to invoke the following programs:

- The C compiler (**c166**), which generates an assembly source file from the file with suffix `.c`. The suffix of this file is `.src`, which is the default for **a166**. However, you can direct the output to stdout with the **-n** option, or to another file with the **-o** option. C source lines can be intermixed with the generated assembly statements by means of the **-s** option. High level language debugging information can be generated with the **-g** option. You should not use the **-g** option, when inspecting the generated assembly source code, because it contains a lot of 'unreadable' high level language debug directives. **c166** makes only one pass on every file. This pass checks the syntax, generates the code and performs a code optimization.
- The **a166** cross-assembler which processes the generated assembly source file into a relocatable object file with suffix `.obj`. A full assembly listing with suffix `.lst` is available after this stage.
- The **l166** link stage which links the generated relocatable object files and C-libraries. The result is a relocatable link file with suffix `.ln0`. A linker task map file with suffix `.ln1` is available after this stage.
- The **l166** locate stage which locates the generated relocatable object files (from assembler or link stage). The result is a loadable file with suffix `.out`. A full application map file with suffix `.map` is available after this stage.
- The **iccc166** program which formats an `a.out` type file into a CrossView Pro load file.

The next figure explains the relationship between the different parts of the TASKING C166/ST10 toolchain:

The control program **cc166** can be used to build an absolute loadable file starting with an input file of any stage. C++ source programs are compiled by the C++ compiler. With a C source file as input, **cc166** calls **c166**, **a166** and **i166** with the appropriate command line arguments.

It is advised to use CC166 when compiling C++ source programs because of the complex nature of C++ compilation.

The global storage optimizer **gso166** is a program to optimize allocation of objects in memory spaces.

The macro preprocessor **m166** is a program to preprocess assembly files (suffix `.asm`).

The **ihex166** program formats the `a.out` file into an Intel Hex format file. You can load this output file into an EPROM programmer.

The **srec166** program formats the `a.out` file into a Motorola S Format for EPROM programmers.

The **ar166** program is a librarian facility. You can use this program to create and maintain object libraries.

A utility to disassemble absolute object files and relocatable object files is **d166**.

A utility to display the contents of an object file is **dmp166**.

The **mk166** program builder uses a set of dependency rules in a 'makefile' to build only the parts of an application which are out of date

For a full description of all available utilities, see chapter *Utilities* chapter 12, "Utilities" in the *C166/ST10 Cross-Assembler, Linker/Locator, Utilities User's Guide*.

The name of the C166/ST10 CrossView Pro Debugger is **xfw166**. For more information check the *C166/ST10 CrossView Pro Debugger User's Guide*. This manual uses **xvw166** as the general executable name.

2.5 ENVIRONMENT VARIABLES

This section contains an overview of the environment variables used by the C166/ST10 toolchain.

Environment Variable	Description
A166INC	Specifies an alternative path for STDNAMES files for the assembler a166 .
C166INC	Specifies an alternative path for #include files for the C compiler c166 .
CC166BIN	When this variable is set, the control program cc166 , prepends the directory specified by this variable to the names of the tools invoked.
CC166OPT	Specifies extra options and/or arguments to each invocation of cc166 . The control program processes the arguments from this variable before the command line arguments.
LINK166	Specifies extra options and/or arguments to each invocation of the link stage of l166 .
LM_LICENSE_FILE	Identifies the location of the license data file. Only needed for hosts that need the FLEXlm license manager.
LOCATE166	Specifies extra options and/or arguments to each invocation of the locate stage of l166 .
M166INC	Specifies an alternative path for include files for the macro preprocessor m166 .
PATH	Specifies the search path for your executables.
TMPDIR	Specifies an alternative directory where programs can create temporary files. Used by c166 , cc166 , a166 , m166 , l166 , ar166 .

Table 2-1: Environment variables

2.6 SAMPLE SESSION

The following example illustrates the use of **c166** in conjunction with the **a166/1166** package and the control program **cc166**. User command input is denoted by **bold** text.

The subdirectory `sieve` in the `examples` subdirectory contains a demo program for the C166/ST10 toolchain.

In order to debug your programs, you will have to compile, assemble, link and locate them for debugging using the TASKING C166/ST10 tools. You can do this with one call to the control program or you can use EDE, the Embedded Development Environment (which uses a project file and a makefile) or you can call the makefile from the command line.

2.6.1 USING EDE

EDE stands for "Embedded Development Environment" and is the MS-Windows oriented Integrated Development Environment you can use with your TASKING toolchain to design and develop your application.

To use EDE on the `sieve` demo program in the subdirectory `sieve` in the `examples` subdirectory of the C166/ST10 product tree follow the steps below. This procedure is outlined as a guide for you to build your own executables for debugging.

How to Start EDE

You can launch EDE by double-clicking on the appropriate icon in the program group created by the installation program. Or you can launch EDE by double-clicking on the EDE shortcut on your desktop.



The EDE screen provides you with a menu bar, a toolbar (command buttons) and one or more windows (for example, for source files), a status bar and numerous dialog boxes.

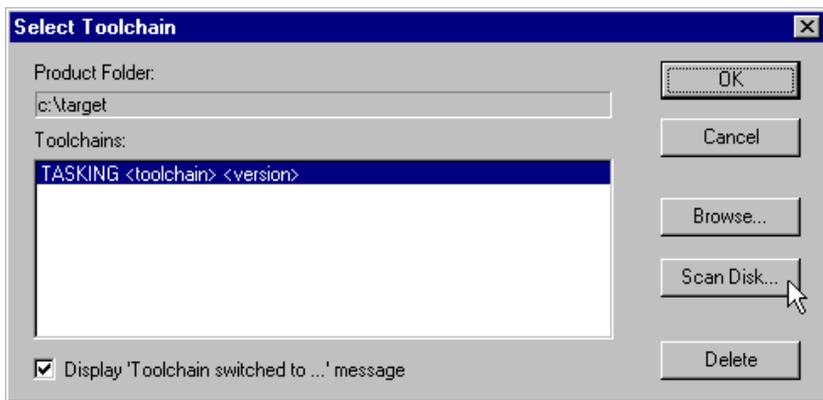


How to Select a Toolchain

EDE supports all the TASKING toolchains. When you first start EDE, the correct toolchain of the product you purchased is selected and displayed in the title of the EDE desktop window.

If you selected the wrong toolchain or if you want to change toolchains do the following:

1. Access the **EDE** menu and select the **Select Toolchain...** menu item. This opens the **Select Toolchain** dialog.
2. Select the toolchain you want. You can do this by clicking on a toolchain in the **Toolchains** list box and press **OK**.



If no toolchains are present, use the **Browse...** or **Scan Disk...** button to search for a toolchain directory. Use the **Browse...** button if you know the installation directory of another TASKING product. Use the **Scan Disk...** button to search for all TASKING products present on a specific drive. Then return to step 2.

How to Open an Existing Project

Follow these steps to open an existing project:

1. Access the **Project** menu and select **Open...**
2. Select the project file to open and then click **OK**. For the **sieve** demo program select the file **sieve.pjt** in the subdirectory **sieve** in the **examples** subdirectory of the **C166/ST10** product tree. If you have used the defaults, the file **sieve.pjt** is in the directory `c:\c166\examples\sieve`.

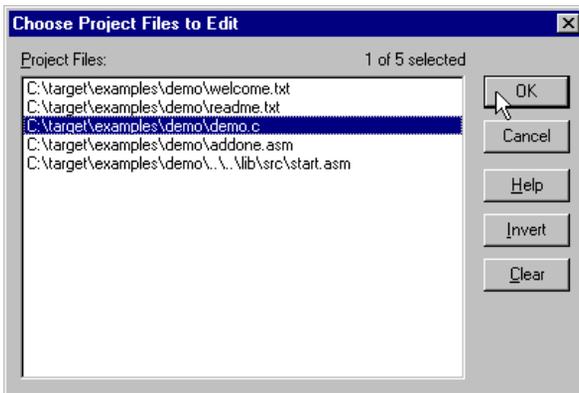
How to Load/Open Files

The next two steps are not needed for the demo program because the file `sieve.c` is already open. To load the file you want to look at.

1. In the **Project** menu click on **Load files...**

This opens the **Choose Project Files to Edit** dialog.

2. Choose the file(s) you want to open by clicking on it. You can select multiple files by pressing the **<Ctrl>** or **<Shift>** key while you click on a file. With the **<Ctrl>** key you can make single selections and with the **<Shift>** key you can select everything from the first selected file to the file you click on. Then press the **OK** button.



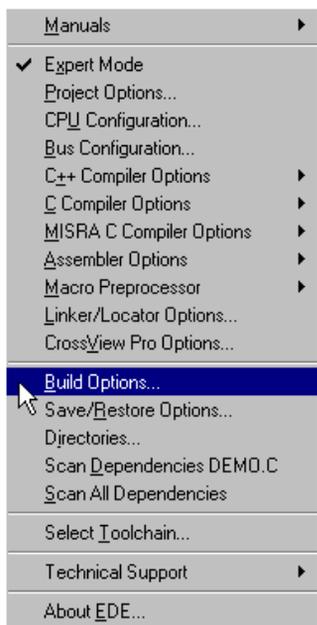
This launches the file(s) so you can edit it (them).

How to Build the Demo Application

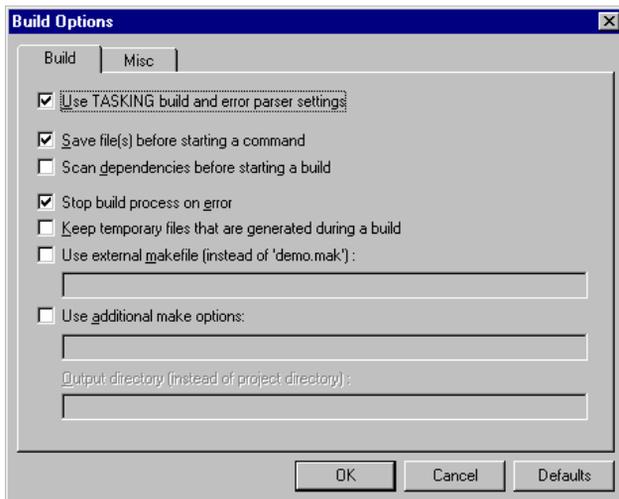
The next step is to compile the file(s) together with its dependent files so you can debug the application.

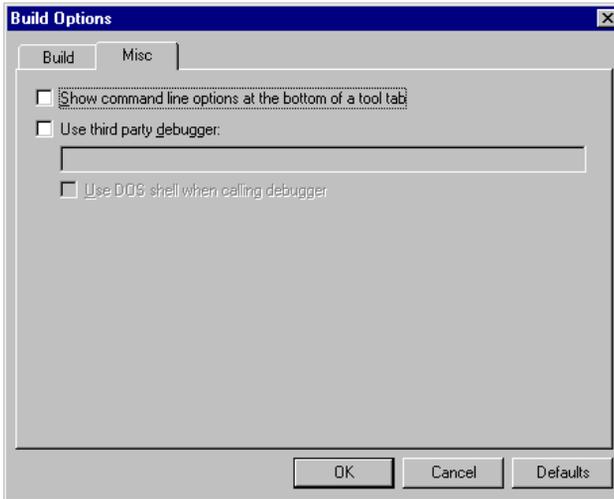
Steps 1 and 2 are optional. Follow these steps if you want to specify additional build options such as to stop the build process on errors and to select a command to be executed as foreground or background process.

1. Access the **EDE** menu and select the **Build Options...** menu item.

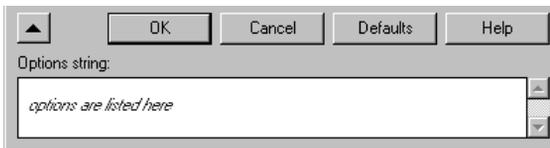


This opens the Build Options dialog.

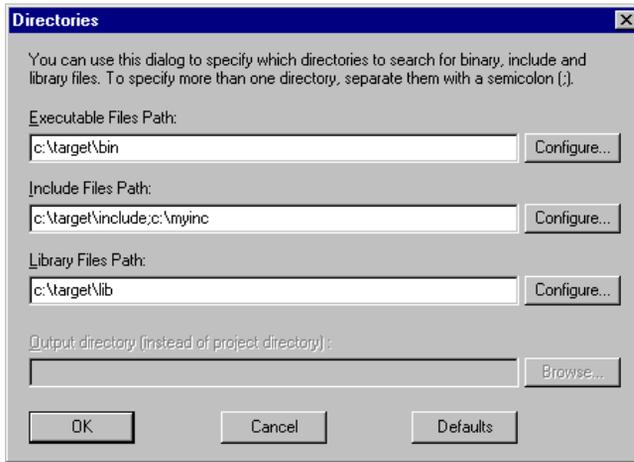




If you set the Show command line options at the bottom of a tool tab check box EDE shows the command line equivalent of the selected tool option. You can also click on the arrow button (left of the OK button) in a tool options dialog.



2. Make your changes and press the OK button.
3. Select the EDE | Directories menu item and check the directory paths for programs, include files and libraries. You can add your own directories here, separated by semicolons.



4. Access the EDE menu and select the Scan All Dependencies menu item.
5. Click on the Execute 'Make' command button. The following button is the execute Make button which is located in the toolbar.



If there are any unsaved files, EDE will ask you in a separate dialog if you want to save them before starting the build.

How to View the Results of a Build

Once the files have been processed you can inspect the generated messages.

1. In the Window menu select the Output menu item.

You can see which commands (and corresponding output captured) which have been executed by the build process in the Build tab:

```

ccl166 -c -g -I. -O3 -DMEASURE_TIME -DPRINT sieve.c
ccl166 -c -g -I. -O3 -DMEASURE_TIME -DPRINT c:\c166\examples\time\time.c
c:\tmp\mk2794a.tmp:
sieve.obj
time.obj
sieve.ilo
ccl166 -cf -ieee -o sieve.abs -f c:\tmp\mk2794a.tmp
C166/ST10 program builder vx.y rz      SN00000000-bid (c) year TASKING, Inc.

```

How to Start the CrossView Pro Debugger

Once the files have been compiled, assembled, linked, located and formatted they can be executed by CrossView Pro.

To execute CrossView Pro:

1. Click on the `Debug` application button. The following button is the `Debug` application button which is located in the toolbar.



CrossView Pro is launched. CrossView Pro will automatically download the compiled file for debugging.

How to Load an Application

You must tell CrossView Pro which program you want to debug. To do this:

1. Click on `File` in the menu bar and select the `Load Symbolic Debug Info...` item. This opens up the `Load Symbolic Debug Info` dialog box.
2. Click `Load`.

How to View and Execute an Application

To view your source while debugging, the `Source Window` must be open. To open this window,

1. Click on `View` in the menu bar and select the `Source->Source lines` item.

Before starting execution you have to reset the target system to its initial state. The program counter, stack pointer and any other registers must be set to their initial value. The easiest way to do this is:

2. Click on `Run` in the menu bar and select the `Program Reset` item.
3. Again click on `Run` in the menu bar and now select the `Animate` item.

The program `seive.abs` is now stepping through the high level language statements. Using the `Accelerator bar` or the menu bar you can set breakpoints, monitor data, display registers, simulate I/O and much more. See the *CrossView Pro Debugger User's Guide* for more information.

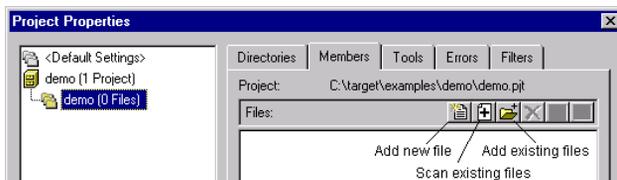
How to Start a New Project

When you first use EDE you need to setup a project space and add a new project:

1. Access the `Project` menu and select `Project Space | New...`
2. Give your project space a name and then click `OK`.
3. Click on the `Add new project to project space` button.
4. Give your project a name and then click `OK`.

The `Project Properties` dialog box then appears for you to identify the files to be added.

5. Add all the files you want to be part of your project. Then press the `OK` button. To add files, use one of the 3 methods described below.



- If you do not have any source files yet, click on the `Add new file to project` button in the `Project Properties` dialog. Enter a new filename and click `OK`.
- To add existing files to a project by specifying a file pattern click on the `Scan existing files into project` button in the `Project Properties` dialog. Select the directory that contains the files you want to add to your project. Enter one or more file patterns separated by semicolons. The button next to the `Pattern` field contains some predefined patterns. Next click `OK`.
- To add existing files to a project by selecting individual files click on the `Add existing files to project` button in the `Project Properties` dialog. Select the directory that contains the files you want to add to your project. Add the applicable files by double-clicking on them or by selecting them and pressing the `Open` button.

The new project is now open.

6. Click `Project | Load Files` to open files you want on your EDE desktop.

EDE automatically creates a makefile for the project. EDE updates the makefile every time you modify your project.

2.6.2 USING THE CONTROL PROGRAM

A detailed description of the process using the sample program `sieve.c` is described below for the C166/ST10. This procedure is outlined as a guide for you to build your own executables for debugging.

1. Make the subdirectory `sieve` of the `examples` directory the current working directory.
2. Be sure that the directory of the binaries is present in the `PATH` environment variable.
3. Compile, assemble, link and locate the modules using one call to the control program `cc166`:

```
cc166 -g -ieee -o sieve.abs sieve.c
```

The `-g` option instructs the compiler to generate symbolic debugging information. If you want to debug your program with the CrossView Pro high level language debugger, this option must be on.

The `-ieee` option specifies that the output file must be formatted in the IEEE Std. 695 format. The `-o sieve.abs` option specifies the output filename to be `sieve.abs`. The result of the command are the files `sieve.abs` which can be loaded and executed by CrossView Pro and `sieve.map` containing the locate map of the application.

You can specify the `-DMEASURE_TIME` option if you want to build the sieve benchmark program for time measurement. Note that this is done in the `makefile` which can be processed by `mk166`.

Now you have created all the files necessary for debugging with CrossView Pro with one call to the control program.

If you want to see how the control program calls the compiler, assembler, link stage, locate stage and formatter, you can use the `-v` option or `-v0` option. The `-v0` option only displays the invocations without executing them. The `-v` option also executes them:

```
cc166 -g -ieee -o sieve.abs sieve.c -v0
```

The control program shows the following command invocations without executing them (UNIX output):

```
C166/ST10 control program vx.y rz      SN00000000-bid (c) year TASKING, Inc.
+ c166 sieve.c -o /tmp/cc5882c.src -e -g
+ a166 /tmp/cc5882c.src TO sieve.obj NOPR
+ l166 LNK TO /tmp/cc5882d.lno sieve.obj 166/c166s.lib 166/fp166s.lib
  166/rt166s.lib NOWA
+ l166 LOC TO /tmp/cc5882e.out /tmp/cc5882d.lno PR(sieve)
+ ieeel166 /tmp/cc5882e.out sieve.abs
```

The **-e** option specifies to remove the output file if compiler errors occur. The **NOPR** control suppresses the list file generation of the assembler. The **TO** control has the same function as the **-o** option of the compiler, and specifies the output filename. The **PR** control of the locate stage specifies the basename of the map file.

As you can see, the tools use temporary files for intermediate results. If you want to keep the intermediate files you can use the **-tmp** option. The following command makes this clear.

```
cc166 -g -ieee -o sieve.abs sieve.c -v0 -tmp
```

This command produces the following output:

```
C166/ST10 control program va.b rc      SN00000000-bid (c) year TASKING, Inc.
+ c166 sieve.c -o sieve.src -e -g
+ a166 sieve.src TO sieve.obj NOPR
+ l166 LNK TO sieve.lno sieve.obj 166/c166s.lib 166/fp166s.lib
  166/rt166s.lib NOWA
+ l166 LOC TO sieve.out sieve.lno PR(sieve)
+ ieeel166 sieve.out sieve.abs
```

As you can see, if you use the **-tmp** option, the assembly source files and linker output file will be created in your current directory also.

Of course, you will get the same result if you invoke the tools separately using the same calling scheme as the control program.

As you can see, the control program automatically calls each tool with the correct options and controls.

2.6.3 USING THE SEPARATE PROGRAMS

If you want to call each tool separately instead of using the control program you can issue the following commands (steps 3–7 replace step 3 of the previous section).

3. Compile the module:

```
c166 -s -g -t sieve.c
```

The **-s** option puts the C source text as comments into the output assembly source file `sieve.src`. The other options are the same as explained by the invocation of the control program.

4. Assemble the module:

```
a166 sieve
```

The suffix `.src` is default and may therefore be omitted. The assembler produces a relocatable object file called `sieve.obj` and a list file called `sieve.lst`.

If you want to build a complete C166/ST10 executable application, the module containing the C function `main()` is treated like a reset task and therefore must be linked with the C startup code. When the Task Concept is followed, all tasks should be linked with a library, that contains, among run-time routines, functions such as `printf()`. When the Flat Interrupt Concept is followed the C startup code and the library is linked in the locate stage and the link stage is skipped. In this example we are using the Task Concept.

The C startup code is delivered in each run-time library for the memory model of the library and in assembly source code, because this file usually must be adapted to the target environment. The library is delivered for all memory models supported. In this case, we are using the small model, because this is the default memory model of **c166**. See the next chapter for detailed information on memory models.

The libraries are organised in 4 basic library sets: one set for the C166/ST10x166 architecture (subdirectory `166`), one set for the Gold architecture (subdirectory `goldp`), one set for the C167/ST10x167/ST10x262 architecture (subdirectory `ext`) and one set for the C166S v2.0 / Super 10 architectures (subdirectory `ext2`).

These 4 basic library sets are additionally organized in 2 variants: one standard variant (not available for the Gold architecture) and one variant with all silicon bug workarounds enabled. The subdirectories for this last variant are followed by the character 'p' (subdirectories `166p`, `extp`, `ext2p` and `goldp`).

All 7 library sets (4 basic, 2 variants, -1 for Gold architecture) are also available for the User Stack Model. All subdirectories for this extra variant are preceded with the character 'u'.

It depends on the hardware environment you are using, which library set must be used. By default the compiler assumes the C166/ST10x166 architecture without any silicon bug workarounds enabled. Therefore, the library set in the subdirectory `166` is used.

5. Link the module by typing:

PC:

```
1166 link sieve.obj 166\c166s.lib 166\rt166s.lib to  
sieve.lno
```

UNIX:

```
1166 link sieve.obj 166/c166s.lib 166/rt166s.lib to  
sieve.lno
```

By default the linker searches the `lib` directory for libraries. This way it finds the `c166s.lib` and `rt166s.lib` libraries. The `cstart.obj` C startup code is extracted from the `rt166s.lib` library because the compiler generates a reference to this module when the `main()` function is defined.

The result of this command is the linked task object module `sieve.lno`. When you use the **PRINT** control the file `sieve.lnl` is created, containing information about the linking stage: memory map, symbol table, register map. However, this is slowing down the process of linking and therefore turned off by default.

6. Locate the module by typing:

```
1166 locate sieve to sieve.out nocc
```

The result of this command is the absolute output file `sieve.out` and the file `sieve.map` containing the locate map of the application. The **nocc** control disables the checking on definition of class ranges, used to locate all parts of the application in user defined memory ranges.

In order to load this application into the CrossView Pro debugger, the output file must be formatted into IEEE Std. 695 format.

7. Format the output file by typing:

```
ieee166 sieve.out sieve.abs
```

The file `sieve.abs` can be loaded and executed by CrossView Pro.

2.6.4 USING A MAKEFILE

The `examples` directory contains several subdirectories with example programs. Each subdirectory contains a `makefile` which can be processed by **mk166** to build the example.

The `examples` directory also contains a `makefile` for building all examples. For building all examples, add the `bin` directory of the installed product to the search path and type:

```
mk166
```

For building one example program, make the directory containing the example the current working directory. Build the example by typing:

```
mk166
```

When the example has already been built before, only the parts which are out of date are rebuilt.

For more information see also the `readme.txt` files in the subdirectories of the examples.

To see which commands are invoked by **mk166** without actually executing them, type:

```
mk166 -n
```

All examples are by default built for the C166/ST10x166. The C examples are built in the small memory model by default. For screen I/O the C examples use the simulated I/O feature of CrossView Pro. By defining macros on the command line you can control the way the examples are built. A macro is defined by `<macroname>=<replacement>`. The following macros can be defined:

Macro	Description
EXT=	Translate with all derivative extensions on. I.e. translate for the C167.
LARGE=	Translate all C examples in the large memory model.
SERIO=	Translate all examples for using serial I/O
PORT=1	Use serial port S1 on the C166/ST10 instead of S0.
V=	Set verbose mode of the control program. If set it shows the invocations of the separate tools.

Table 2-2: Makefile macros

Example:

```
mk166 V= EXT= LARGE=
```

When you want to re-translate the examples with other settings you should first clean up the results of a previous translation. This can be done by:

```
mk166 clean
```

You can also use this when you just want to clean up the example directories.

2.6.5 SERIAL I/O MODULES

All examples which produce output use File System Simulation (default) or serial I/O (see section *Using a Makefile* in this chapter for more information). CrossView Pro users can see the *CrossView Pro Debugger User's Guide* for more information about File System Simulation.

For serial I/O the files `serio.c` and `serio.h` are included. The header file contains prototypes for the functions and definitions of registers used to setup and perform the serial communication, depending on the port. When you compile `serio.c` with `-DSER_PORT_1` serial port 1 of the processor is used. Otherwise serial port 0 is used. The module `serio.c` defines four functions you can use in your application:

void init_serio(void)

This function has to be called before any serial communication is done. This functions initializes all communication parameters. The default configuration is 9600 baud, 8 data bits and 1 stop bit.

int getch(void)

Reads one character from the serial channel.

int kbbit(void)

Returns 1 if a character is available, otherwise 0.

int putchar(int c)

Write a character to the serial channel. Return character written.

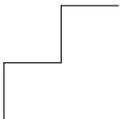
The module also defines the `_ioread()` and `_iowrite()` functions, called by the I/O functions in the C library.

You can find the files `serio.c` and `serio.h` in the subdirectory `io` in the `examples` directory. This directory also contains a makefile and a C source file for testing the I/O.

CHAPTER

3

LANGUAGE IMPLEMENTATION



3 | CHAPTER

3.1 INTRODUCTION

The TASKING C C166/ST10 cross-compiler offers a new approach to high-level language programming for the C166/ST10 family. It conforms to the ANSI standard, but allows the user to control the I/O registers, bit memory, interrupts and data page architecture of the C166/ST10 in C. This chapter describes the language implementation in relation to the 80C166 architecture.

The extensions to the C language in **c166** are:

_bit

You can use data type `_bit` for the type definition of scalars and for the return type of functions.

_bitword

You can declare word variables in the bit-addressable area as `fp`. You can access individual bits using the intrinsic functions `_getbit()` and `_putbit()`.

_sfrbit / _esfrbit

Data types for the declaration of specific, absolute bits in special function registers or special absolute bits in the SFR address space.

_sfr / _esfr

Data types for the declaration of Special Function Registers.

_xsfr

Data type for the declaration of Special Function Registers not residing in SFR memory but do reside in internal RAM. An example of these SFRs are PEC source and destination pointers. The compiler will use a 'mem' addressing mode for this data type whereas for an object of type `_sfr` a 'reg' or 'mem' addressing mode may be used.



These SFRs are not bitaddressable.

_at

You can specify a variable to be at an absolute address.

_atbit

You can specify a variable to be at a bit offset within a `_bitword` or bitaddressable `_sfr` variable.

_inline

Used for defining inline functions.

_usm / _nousm

With these function qualifiers you can force that a function is called using the user stack model calling convention or using the generic CALL/RET calling convention.

_bita

You can tell the compiler that a struct must be located in bitaddressable memory by using the `_bita` memory qualifier.

memory-specific pointers

c166 allows you to define pointers which point to a specific target memory. These types of pointers are very efficient and require only 2 or 4 bytes memory space.

special types

Apart from a memory category (extern, static, ...) you can specify a storage type in each declaration. This way you obtain a memory model-independent addressing of variables in several address ranges of the C166/ST10 (`_near`, `_far`, `_huge`, `_shuge`, `_system`, `_iram`).

interrupt functions

You can specify interrupt functions directly through interrupt vectors in the C++ language (`_interrupt` keyword). You may also specify the register bank to be used (`_using` keyword).

intrinsic functions

A number of pre-declared functions can be used to generate inline assembly code at the location of the intrinsic (built-in) function call. This avoids the overhead which is normally used to do parameter passing and context saving before executing the called function.

3.2 ACCESSING MEMORY

The C166/ST10 is available for two different address ranges. One version allows to access memory up to 256 KB via an 18 bit address, and the other version allows to access 16 MB using a 24 bit address. The processor does not use a linear addressing method (as the Motorola 68000 family), but uses a segmented approach of its memory (as the Intel 8086 family). Therefore, the difference in address range is only visible in the amount of bits in the segment/page registers.

The approach of data memory differs with the approach of code memory. Code memory is accessed in segments of 64K using a 16 bit offset and a 2 bit (or 8 bit) segment number. Because there is no translation done on this 2 bit (or 8 bit) segment number, code memory access is 'almost' linear. However, data memory is accessed within 16 KB pages. The 16 bit address is translated into an 18 bit (or 24 bit) address via one of four data page pointers, specified with bit 14 and 15. So, the 18 bit (or 24 bit) address is made out of the 14 bit page offset and the 4 bit (or 10 bit) contents of the selected DPP. **c166** and **a166** support both versions of address range. In the rest of this document we use the 24 bit addressing scheme in our examples. Read 18 bit instead of 24 bit for the 256K versions of the C166/ST10 architectures.

c166 has two methods of gaining greater control over how your program uses memory. These methods can be used together. First you can specify the 'memory model' for the program. The compiler allows you to choose from a number of different approaches. In the section *Memory Models* more detailed information is present. Second, you can use one of the keywords `_near`, `_system`, `_iram`, `_far`, `_huge` and `_shuge` in your program. Note that although these keywords are also used by other C compilers (for the 8086 family), they are not part of the standard C language. C is meant as a portable language.

In practice the majority of the C code of a complete application will be standard C (without using any language extension). This part of the application can be compiled without any modification, using the memory model which fits best to the requirements of the system (code size, amount of external RAM etc.). Therefore, **c166** has a number of features optimizing data access on standard C in all memory models. Note that a special section is present called *Efficiency in Large Data Models*.

Only a small part of the application will use language extensions. These parts often deal with items such as:

- I/O, using the (extended) special function registers



- high execution speed needed
- high code density needed
- access to non-default memory required (e.g. far/huge/shuge data)
- bit type needed
- C interrupt functions

3.2.1 MEMORY MODELS

c166 supports four memory models: tiny, small, medium and large. You can select one of these models with the **-M** option. If you do not specify a memory model on the command line, **c166** uses the small memory model by default. The memory models with their characteristics are represented in the following table:

Model	DPP usage	\$SEGMENTED control	CPU segmented mode	normal data size	code size	far/huge/shuge data allowed	near data allowed
tiny	linear	no	no	<64K	<64K	no	n.a.
small	linear	no	yes	<64K	>64K	yes	n.a.
medium	paged	yes	yes	>64K	<64K	yes	yes
large	paged	yes	yes	>64K	>64K	yes	yes
n.a. = not applicable							

Table 3-1: Memory models

The memory models can be described as follows:

3.2.1.1 TINY MEMORY MODEL

This memory model is the only model where the processor does not run in segmented mode, limiting the sum of code and data space to 64K. The DPP registers always contain their startup values thus allowing linear 64K access of data. This results in relatively high code density and execution speed. On interrupt the C166/ST10 does not have to save the CS register and an extra port (Port 4) is available, because address lines A16 - A17 (or A16 - A23) are not used. The usage of the `_far`, `_huge` and `_shuge` keywords is not allowed. The tiny memory model is meant for very small (even single-chip) applications.

Map example

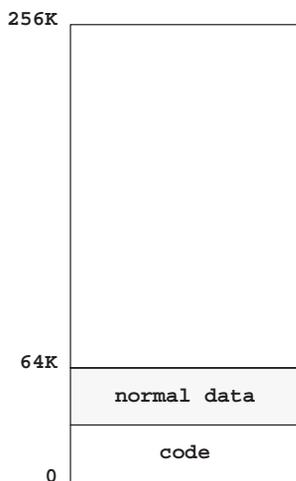


Figure 3-1: Tiny memory map example

Item	Usage	Comments
CPU	non-segmented	only model which runs non-segmented.
code	< 64K	limited to first segment of 64K.
normal data	< 64K	limited to first segment of 64K. Thus: (code + normal data) < 64K.
far data	not allowed	–
huge data	not allowed	–
shuge data	not allowed	–

Table 3-2: Tiny memory model

3.2.1.2 SMALL MEMORY MODEL

The small memory model is probably the most used memory model. It allows you to have a total code size up to 16M, up to 64K of fast accessible 'normal user data' in three different memory configurations and the possibility to access far/huge data, if more than 64K of data is needed.

The compiler does not assume the CSP register to contain something valid. Each call results in a far inter-segment code access, unless the `_near` keyword is used explicitly in the function prototype. We therefore recommend using the `_near` keyword with static functions when using the small or large model, since static functions are always in the same code section as their caller functions. This model allows code access in all segments up to 16M.

The small memory model supports 64K of 'normal user data' via fixed DPP values, specified at locate time. This results in high code density and execution speed. Note that the ROM data of an application (e.g. strings, floating point constants, jump tables, etc.) must also be allocated in this area of 64K of 'normal user data'. There are three memory configurations possible for this 64K of 'normal user data':

I (default)

The four DPP registers are assumed to contain their system startup value (0-3), providing one linear data area of 64K in the first segment (0-0FFFFh).

II Addresses Linear

DPP3 contains page number 3, allowing access to SYSTEM (extended) sfr registers and bitaddressable memory. DPP0 - DPP2 provide a linear data area of 48K anywhere in memory. You must specify the 'base-page-number' of this area at locate time via the **ADDRESSES(LINEAR(address))** locator control.

III SND

DPP3 contains page number 3, allowing access to SYSTEM (extended) sfr registers and bitaddressable memory. DPP0, DPP1 and DPP2 contain the page number of a data area of 16K anywhere in memory. These page numbers are specified at locate time via the **SND** locator control. When you use this configuration, the size of a single 'normal data' object is limited to 16K.

In variant I and II, the paging principle is not really used, so the size of a single 'normal data' object (e.g. array) can be greater than 16K (one page).

If you use the small memory model (default of **c166**), the compiler uses the section type 'LDAT' for normal user data. This means that a non-paged section (unless SND is used of course) must be allocated by the locator in either:

- I first segment of 64K (default)
- II linear area of 48K specified with ADDRESSES LINEAR or in page 3
- III one of the three possible areas of 16K specified with SND or in page 3

If you need more than 64K of data (or if you need a huge data object), you can use the `_far/_huge` keywords in the declaration of these variables.

Small model memory map examples

Example **I** Default

Example **II** Using locate control:

```
AD LINEAR( page 8 )
```

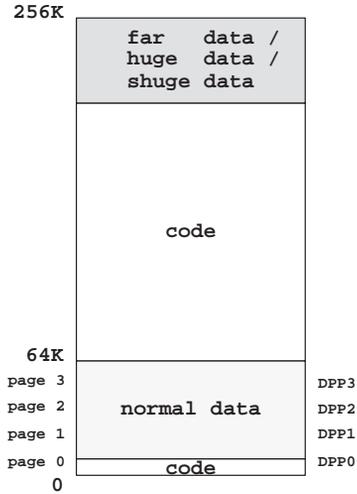
Example **III** Using locate control:

```
SND( DPP0(10), DPP1(12), DPP2(7) )
```

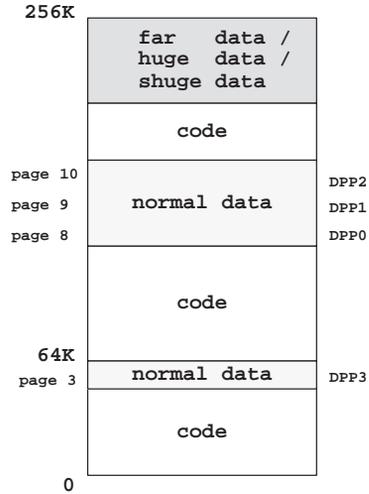


'normal data' sections can contain both RAM data and ROM data.

Map example I



Map example II



Map example III

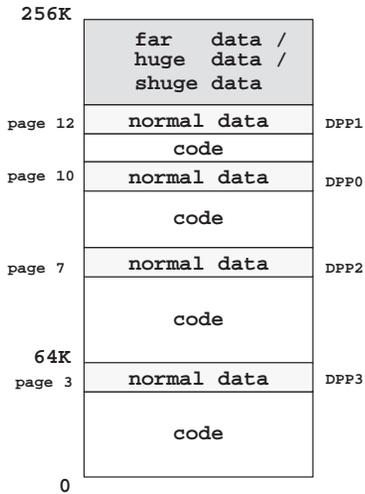


Figure 3-2: Small memory map examples

Item	Usage	Comments
CPU	segmented	–
code	>64K	allows code anywhere in 256K/16M.
normal data	< 64K	64Kb of fast accessible user data using direct MEM addressing mode. Except for map III (SND control), the size of a single user data object is not limited to 16K (16 bit address arithmetic). Also contains ROM data.
far data	allowed (optional)	supports far data (paged) access anywhere in 256K/16M. The size of a single far object is limited to 16K. Far data access is less fast than normal data access.
huge data	allowed (optional)	supports huge data access anywhere in 256K/16M. The size of a single huge object is not limited to 16K (32 bit address arithmetic). Huge data access is less fast than far data access. Size of one struct < 64K. Array of struct/any type > 64K
shuge data	allowed	supports shuge data access anywhere in 256K/16M. The size of a single shuge object is limited to 64K (16 bit address arithmetic). Shuge data access is as fast as huge data, but arithmetic on shuge addresses is faster.

Table 3-3: Small memory model



ROM data (e.g. strings, floating point constants, jump tables, etc.) is also present in LDAT sections and thus needs some space in the 64K of 'normal user data'. We recommend using page 3 for (external) ROM, allowing this ROM data (and code sections) to be allocated in this page and yet use DPP3 for SYSTEM (sfr) access. This means that the other three pages can be used for (external) RAM.

In the small model far/huge/shuge data access causes the compiler to emit code which, temporarily, overrules DPP0 with the page number of the far data. The DPP0 register is restored afterwards. DPP2 is sometimes used for far/near copy actions. During a task switch (interrupt) DPP0 and DPP2 are preserved and the correct page number is assigned to these DPP registers before activating the C code of this task, because a far access might be interrupted. When using the C167 (-x option), a more elegant solution is possible, using the special prefix instructions, which are treated by the processor as a prefix for a number of so called 'atomic instructions': thus uninterruptable.

If the C167 cannot be used, this method for far data access produces extra code and results into slow execution. Therefore accessing far data must be an exception within the application. The majority of the execution time of the application should be dealing with normal data, otherwise it is better to use the large model, allowing more efficient usage of far data.

Far data is allocated in 'PDAT' sections, telling the assembler/linker/locator that a 'paged section' (must be checked to be in-page) is needed, which can be anywhere in memory. Huge data is allocated in 'HDAT' sections, specifying that a 'non-paged' (no checking for 16K) is needed, which can be anywhere in memory. Shuge data is allocated in 'SDAT' sections, which have the same properties as HDAT sections. The difference is that address calculations on shuge data is done in 16 bit rather than in 32 bit as with huge data. This implies that no shuge object can exceed 64K.

The following scheme is used for the data section types:

Section type	NON-SEGMENTED DATA (tiny/small)		SEGMENTED DATA (medium/large)	
	meaning	location	meaning	location
DATA	paged (<16K)	1st segment: <64K	paged (16K)	anywhere
LDAT	linear(<64K)	tiny: 1st segment: <64K small: method I, II or III	-	-
PDAT	paged (<16K)	anywhere	-	-
HDAT	non-paged	anywhere	non-paged	anywhere
SDAT	-	-	non-paged	anywhere

Table 3-4: Small memory data section types



LDAT and PDAT section types are not allowed in segmented data mode. The only section type allowed in a DGROUP is the DATA type (not HDAT).

3.2.1.3 MEDIUM MEMORY MODEL

The compiler assumes that the CSP register contains the initial value of 0, which allows code access in the first 64K segment. The four DPP registers do not contain the system startup values. The DPP registers are used to access the 16M of data in 16K pages. Because the paging principle is used with 14 bit address arithmetic, data objects (e.g. arrays) cannot be greater than 16K (one page), unless the `_huge` or `_shuge` keyword is used. The `_huge` keyword tells the compiler to generate 24 bit address arithmetic. The `_shuge` keyword tells the compiler to generate 16 bit address arithmetic. Because paging is used, the processor must run in segmented mode. Exceptional access to code beyond 64K is possible declaring a huge function. However, it is not allowed for such a huge function to call any standard C (or run-time) library function, or any other 'near function' in the first segment. In section 3.2.1.6 some details are present about efficiency in large data models.

Map example

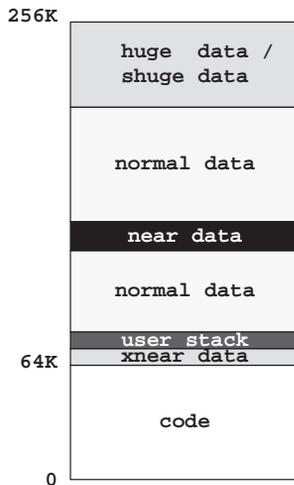


Figure 3-3: Medium memory map example

Item	Usage	Comments
CPU	segmented	–
code	<64K	limited to first segment of 64K.
xnear data	<16K	16K (per task) of fast accessible user data anywhere in 256K/16M via DPP1. This memory space shares DPP1 with the user stack, hence xnear data + user stack < 16K. Use the <code>_xnear</code> keyword.
normal data	>64K	paged data access anywhere in 256K/16M. The size of a single data object is limited to 16K.
near data	<16K	16K (per task) of fast accessible user data anywhere in 256K/16M via 'default data group'. Automatically utilized by c166 ! The keywords <code>_near</code> , <code>_system</code> and <code>_iram</code> also allow explicit user manipulation.
huge data	allowed	supports huge data access anywhere in 256K/16M. The size of a single huge object is not limited to 16K (24 bit address arithmetic). Huge data access is less fast than normal data access. Size of one struct < 64K. Array of struct/any type > 64K
shuge data	allowed	supports shuge data access anywhere in 256K/16M. The size of a single shuge object is limited to 64K (16 bit address arithmetic). Shuge data access is as fast as huge data, but arithmetic on shuge addresses is faster.

Table 3-5: Medium memory model

3.2.1.4 LARGE MEMORY MODEL

The compiler does not assume the CSP register to contain something valid. Each call results in a far inter-segment code access (unless the `_near` keyword is used explicitly in the function prototype). Therefore this model allows code access in all segments up to 16M. As in the medium model, all data accesses are far. The four DPP registers do not contain the system startup values. The DPP registers are used to access the 16M of data in 16K pages. Because the paging principle is used with 14 bit address arithmetic, data objects (e.g. arrays) cannot be greater than 16K (one page), unless the `_huge` or `_shuge` keyword is used. The `_huge` keyword tells the compiler to generate 24 bit address arithmetic. The `_shuge` keyword tells the compiler to generate 16 bit address arithmetic. Of course the processor must run in segmented mode. In section 3.2.1.6, *Efficiency in Large Data Models (Medium/Large)* some details are present about efficiency in large data models.

Map example

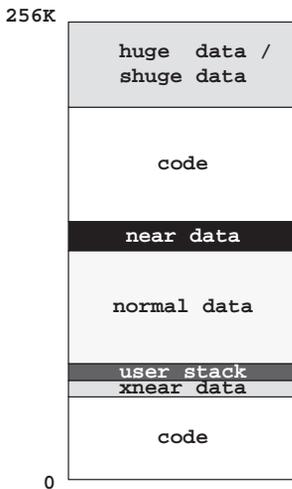


Figure 3-4: Large memory map example

Item	Usage	Comments
CPU	segmented	–
code	>64K	allows code anywhere in 256K/16M.
normal data	>64K	paged data access anywhere in 256K/16M. The size of a single data object is limited to 16K.
xnear data	<16K	16K (per task) of fast accessible user data anywhere in 256K/16M via DPP1. This memory space shares DPP1 with the user stack, hence xnear data + user stack < 16K. Use the <code>_xnear</code> keyword.
near data	<16K	16K (per task) of fast accessible user data anywhere in 256K/16M via 'default data group'. Automatically utilized by c166 ! The keywords <code>_near</code> , <code>_system</code> and <code>_iram</code> also allow explicit user manipulation.
huge data	allowed	supports huge data access anywhere in 256K/16M. The size of a single huge object is not limited to 16K (24 bit address arithmetic). Huge data access is less fast than normal data access. Size of one struct < 64K. Array of struct/any type > 64K
shuge data	allowed	supports shuge data access anywhere in 256K/16M. The size of a single shuge object is limited to 64K (16 bit address arithmetic). Shuge data access is as fast as huge data, but arithmetic on shuge addresses is faster.

Table 3-6: Large memory model

3.2.1.5 MODEL

c166 introduces the predefined preprocessor symbol `_MODEL`. The value of this symbol represents the memory model selected. This can be very helpful in making conditional C code in one source module, used for different applications in different memory models. See also the section *Portable C Code*, explaining the include file `c166.h`.

The value of `_MODEL` is:

tiny model	't'
small model	's'
medium model	'm'
large model	'l'

Example:

```
#if _MODEL == 'm' || _MODEL == 'l' /* medium or
                                large model */
...
#endif
```

3.2.1.6 EFFICIENCY IN LARGE DATA MODELS (MEDIUM/LARGE)

For programs compiled with the medium and large memory model, the compiler creates default data sections (member of the default data group) and additional far/huge/shuge data sections for each module. Since accessing data outside the default data page is slower than accessing data within the default data page, programs will run faster if as many of their variables as possible are declared in such a way that they are allocated in the default data page. There are a number of ways to control the allocation of data:

1. All **initialized static/public RAM data** will be allocated in these default data sections unless the `_far/_huge/_shuge` keyword is explicitly used in the declaration or the **-T** option is used for specifying a certain threshold value for this data.

All **non-initialized static/public RAM data having a size below a certain 'threshold' value** will be allocated in these default data sections unless the `_far/_huge/_shuge` keyword is used explicitly in the declaration.

Strings, floating point constants and jump tables are allocated in ROM and can never be in the default data sections.

The default data sections are member of a special DGROUP group which is (of course) limited to 16K. It is possible to have a DGROUP area (of max 16K) per task. DPP2 is ASSUMED to contain the page number of this group, which is assigned at system startup. During a context switch (interrupt) DPP2, and the scratch register DPP0, are saved, assigned new values and restored afterwards. However, you can also share the default data group area with the default data groups of each task (interrupt).

The sections of the DGROUP must be declared as a COMMON section: same name, same size and same contents. In that case the total size of the default data group area of the whole application is limited to 16K. This results in the following DPP-usage:

DPP0	far pointer dereferencing, external far variables
DPP1	user stack (R0 user stack pointer) / xnear data space
DPP2	default data group (C166_DGROUP)
DPP3	SYSTEM (sfr access, bit-addressable access, iram access and system access)

The threshold value is user definable via the **-T** option. The default value is 256 for non-initialized static/public RAM data. The major advantage of this approach is that better performance is achieved with existing C source code. However, addresses of these variables are still treated 'far' (4 bytes), for usage with (default far) pointers.

2. The introduction of the `_near` keyword.
Near forces allocation in the default data group. It also allows better pointer arithmetic, because a pointer to near (2 bytes instead of 4 bytes) is supported. And last but not least near public/external references are supported, assuming DPP2 is used with an external near variable. Of course a near address can be converted to a far address.
3. The introduction of the `_system` keyword.
System forces allocation in the system data group. The system data group C166_SGROUP is always located in the system page (page 3). It also allows better pointer arithmetic, because a pointer to system (2 bytes instead of 4 bytes) is supported. Public/external references are supported, assuming DPP3 is used with an external system variable. Of course a system address can be converted to a far address.

4. The introduction of the `_xnear` keyword.
The `_xnear` keyword forces data to be allocated in the data group 'C166_XGROUP'. Variables in the 'xnear' memory space have the same properties as 'near' variables. The C166_XGROUP contains variables in the xnear data space and the user stack. The size of xnear data and the user stack size cannot exceed 16Kb. Objects in the xnear data space are accessed through DPP1.
5. C supports so-called 'tentative declarations', which means that a declaration such as `'int i;'` remains tentative during the module until 'defining occurrence' is given (e.g. via `'int i=5;'`). If such does not happen, it is, for example, allowed to declare this variable to be external at the end of the module! Because this programming style is not very common (probably only needed for generated C source), the compiler option `-OT` is available, to assign 'defining occurrence' immediately to every tentative declaration, allowing more data to be optimized. This option is default on, using the medium/large model (lazy programmers often 'forget' the static attribute of public non-initialized variables which are only used in one module).

If the tentative property described above is really used in a C program, a double definition error will occur. In this case the option must be turned off (`-OT`) for this module (or the module must be edited of course).



Using `-OT` results in more code and slower execution.

If the cumulated size of all C166_DGROUP sections of a task exceeds 16K, there are four possibilities to solve it (to be tried in this order):

1. Declare 'near' variables as 'xnear' / 'system' variables.
2. Declare variables to be 'far' explicitly (using the `_far` keyword).
3. Decrease the 'threshold' values (`-T` option), so more variables are allocated in far data sections. If the threshold value is 0, only 'near' variables will be allocated in the default data sections.
4. Decrease the number of 'near' variables.

5. Use this possibility only if the other solutions cannot be used! Use the `-Ggroupname` option, to specify the group to be used by the compiler. So, for example, one set of C modules can allocate their default data in the first data group and all other modules allocate their default data in a second data group. If the `-G` option is used, the C compiler emits code at each public (not static) function entry point to preserve the current DPP2 value and assign the page number of the new correct data group to DPP2. At function exit the original DPP2 value is restored. This seems rather expensive, but the gain of code size by using DPP2 can be more than the loss introduced by these instructions.



This is the last alternative and certainly not recommended, because it might introduce some dangerous, hard to find side-effects, as described below in separate notes.



If you use this option, it is your own responsibility to declare 'extern near' variables within the same group! Therefore the compiler emits warnings for 'extern near' declarations if you use the `-G` option.



Be sure that functions called by this module do NOT use their own default data. Some C library functions might use default data too!

3.2.1.7 NEAR, XNEAR, FAR, HUGE AND SHUGE

As described before, a limitation of a predefined memory model is that, when you change memory models, all data and code address sizes are subject to change. Therefore **c166** lets you override the default addressing convention for a given memory model and access near, far, huge or shuge objects using special declarations. This is done with the `_near`, `_far`, `_huge` or `_shuge` keyword. These special type modifiers can be used with a standard memory model (except tiny) to overcome addressing limitations for particular items (either data or code) without changing the addressing conventions for the program as a whole.

The `_near`, `_xnear`, `_far`, `_huge` and `_shuge` keywords are not allowed with automatics and parameters (unless used as a target of a pointer of course).

The following explains how the usage of these keywords affects the addressing of code, data or pointers to code or data in all models:

tiny

In this model all normal data is implicitly `_near`, because the processor does not run in segmented mode. A linear 16 bit (64K) data area is achieved. The `_far`, `_huge` and `_shuge` keywords are not possible (and not allowed).

small

In this model all normal data is implicitly `near`. Address arithmetic is performed on 16 bit addresses (linear address space assumed). Therefore objects may be greater than 16K, unless the SND locator control is used, which introduces gaps in the address space of normal data. Besides 64K of normal data (including ROM data), `far` data is supported. `Far` data may be anywhere in memory, not assumed to be in the linear data area. You can reference `far` data using a 24 bit address. Address arithmetic is performed on 14 bit (page offset only). Therefore, individual data items (e.g. arrays) cannot exceed 16K (page) and cannot cross page boundaries if declared `_far`. If you use `far` objects greater than 16K, you must declare them `_huge` or `_shuge`. `Huge` data may be anywhere in memory and you can also reference it using a 24 bit address. However, address arithmetic is done using the complete address (24 bit). `Shuge` data may also be anywhere in memory and you can also reference it using a 24 bit address. However, address arithmetic is done using a 16 bit address.

All function calls are assumed to be `_huge` (maybe in another code segment of 64K). However, an intra-segment call is supported via a `_near` function (the keyword `_near` must be present in the function prototype). In fact you could declare (and define) all static functions as `near` functions, because they are always allocated in the same code section as the functions they are called by. You cannot apply the `_far` keyword to functions.

medium

In this model 'near data' means data allocated into a special page for fast access. See section 3.2.1.6, *Efficiency in Large Data Models (Medium/Large)* for more details on the 'default data group'. Address arithmetic on `near` and `far` data is always 14 bit. As in the `small` model, `huge` and `shuge` data access is supported.

This model also supports 'xnear' data. This data is allocated together with the user stack in DPP1. The access to this memory space is just as fast as to 'near' data. Address arithmetic on 'xnear' data is done in 14 bits. See section 3.2.1.6, *Efficiency in Large Data Models (Medium/Large)* for more details on the 'C166_XGROUP' data group.

All function calls are assumed to be in the same (first) segment of 64K. However, an inter-segment call is supported via a huge function (the keyword `_huge` must be present in the function prototype). The `_huge` function may not call any standard C library function, run-time library or any normal `_near` function in another segment. You cannot apply the `_far` keyword to functions.

large

In this model 'near data' means data allocated into a special page for fast access. See section 3.2.1.6, *Efficiency in Large Data Models (Medium/Large)* for more details on the 'default data group'. Address arithmetic on near and far data is always 14 bit. As in the small and medium model, huge and shuge data access is supported.

This model also supports 'xnear' data. This data is allocated together with the user stack in DPP1. The access to this memory space is just as fast as to 'near' data. Address arithmetic on 'xnear' data is done in 14 bits. See section 3.2.1.6, *Efficiency in Large Data Models (Medium/Large)* for more details on the 'C166_XGROUP' data group.

All function calls are assumed to be `_huge` (in another code segment of 64K), unless you use the `_near` keyword in the function prototype. In fact you could declare (and define) all static functions as near functions, because they are always allocated in the same code section as the functions they are called by.

The `_near`, `_xnear`, `_far`, `_huge` and `_shuge` keywords modify either objects or pointers to objects. When using them to declare data or code (or pointers to data or code), the following rules must be kept in mind:

- The keyword always modifies the object or pointer immediately to its right. In complex declarations such as

```
char _far * _near p;
```

think of the `_far` keyword and the item to its right as being a single unit. In this case, `p` is a pointer to a far char, and therefore contains a 24 bit far address.

- If the item immediately to the right of the keyword is an identifier, the keyword determines the storage type of the item: whether it must be allocated in the default data section or a separate data section. In this case the pointer `p` is explicitly declared to be allocated in normal data (if tiny/small model is used) or in the default data group (if medium/large model is used).

- If the item immediately to the right of the keyword is a pointer (a `*` (star)), the keyword determines the logical type: whether the pointer will hold a `_near` address (2 bytes), a `_far` address (4 bytes), a `_huge` address (4 bytes) or an `_shuge` address (4 bytes). For example,

```
char _far * _near p;
```

allocates `p` as a `_far` pointer to an item of type `char`. The pointer `p` itself is allocated in near data.

- The memory model used determines the default logical type of a pointer. In:

```
int *p;
```

`p` is a far pointer when you use the medium or large model, otherwise a near pointer. The storage type of `p` itself is near in tiny and small, and, depending on the threshold value, probably also near in medium and large.

- You cannot apply the `_far` keyword to functions.

3.2.1.8 SYSTEM, IRAM AND BITA

As described before, **c166** lets you override the default addressing convention for a given memory model and access near, far, huge or shuge objects using special declarations. But also special declarations are supported by **c166** to access data objects in the SYSTEM page, like internal RAM data, overall system data or bitaddressable memory. This is done with the keywords `_system`, `_iram` and `_bita`. These special type modifiers can be used in all memory models to overcome addressing 'limitations' for particular near data items.

The `_system`, `_iram` and `_bita` keywords are not allowed with automatics, functions and constants unless used as a target of a pointer.

_system

Objects declared with the keyword `_system` are allocated in system data sections (see paragraph *Section Allocation*). The system data sections are member of the special group `C166_SGROUP` which is limited to the size of the SYSTEM page (16K-SFRs). `DPP3` is ASSUMED to contain the page number of this group which is equal to the SYSTEM page number (page 3) and is assigned at system startup.

_iram

Objects declared with the keyword `_iram` are allocated in IRAMADDRESSABLE data sections (see paragraph *Section Allocation*). The locator places IRAMADDRESSABLE sections in the internal RAM of the C166/ST10.

Addressing of `_iram` objects is exactly the same as addressing `_system` objects because the internal RAM is located in the SYSTEM page. Both `_iram` and `_system` are addressed via the SYSTEM data page pointer DPP3 which is assigned to the system page at system startup.

The `_iram` sections are limited to 1024 bytes internal RAM for the C166 and 2048 bytes internal RAM for the C165/C167. By default the `_iram` section size is limited by the compiler to 1024 bytes. When compiled with the `-x[ifmp]` command line option this limit is 2048 bytes. But you can always set your own `_iram` sections size limit with the `-m mem=size` compiler option (e.g. `-mIR=512`). See for more information the section *Detailed Description of the C-166 Options*.

_bita

When using bit fields in structures that are located in bitaddressable memory the compiler can take advantage of the bit and bit field instructions of the processor. You can tell the compiler that a struct must be located in bitaddressable memory by using the `_bita` memory qualifier.

Example:

```
_bita struct {
    unsigned  bf1:1;
    unsigned  pit:2;
    unsigned  bf2:1;
} s;
```

The compiler will allocate the struct in a bitaddressable section. For nested structures and unions `_bita` can only be applied to the outer level. When `_bita` is used for structure members the compiler ignores this.

Example:

```
struct m {
    int  m1:2;
    int  m2:3;
} mm;
```

```

struct n {
    _bita struct m n1; // _bita ignored
    struct m n2;
} nn;

```



Even with the `_bita` keyword structures will be word aligned. Also the structure members are aligned as they would be without the `_bita` qualifier; i.e., byte addressable members (signed/unsigned `char`) are byte aligned and word addressable members (such as `int` and pointers) are word aligned.

The `_bita` keyword can also be applied to global or static variables of type `char`, `int` and `long`. In bitaddressable memory chars will be word aligned. When accessing single bits in these variables like:

```

_bita int w;

w |= 0x4000;
if (w & (1 << 10))
{
    w &= 0xFFEF;
}

```

then the compiler will use bit instructions:

```

    BSET _w.14
    JNB  _w.10,_3
    BCLR _w.4
_3:

```

For non-static local variables the `_bita` keyword is not allowed. Most local variables will be placed in registers automatically, making them bitaddressable anyway. See also the pragmas **autobita** and **autobitastruct** in section *Pragmas*.

3.2.2 SECTION ALLOCATION

Unlike some other microcontrollers, the C166/ST10 microcontroller does not have different memory spaces with the same address. This means that a non-automatic object can be referred to solely by its starting address, because the address represents a unique memory location. There is also no difference in assembly code accessing internal RAM, external RAM, internal ROM or external ROM (within the same page/segment).

The processor, however, distinguishes memory access in execution speed. Code access to internal ROM is faster than access to external ROM. Data access to internal RAM is faster than access to external RAM. So, a piece of assembly code executes faster if the code is allocated in internal ROM instead of external ROM. And the same piece of code gets an even higher execution speed if the data structures accessed are allocated in internal RAM instead of external RAM.

In C-166 the code generator does not have to know if internal or external RAM is accessed, because the same code can be generated. Execution speed is in fact a matter of allocating sections in internal memory instead of external memory. The allocation of sections is done by the locator stage of **1166**, and can be manipulated by specifying a memory range for each 'class' of sections.

c166 allows you to control the class, align type and combine type of a section with a command line option (e.g. **-RcINB=NEARRAM** changes the class of non-initialized near data to 'NEARRAM' for this module). The disadvantage of this method is that the changed attributes are used for the complete C module.

However, using pragmas, **c166** allows more flexibility of storage specification within a C module. In this approach it is possible to declare for example only a few C variables of a module to be allocated in a special section which must be PEC-addressable and the rest in normal data sections. Or only one function of the module in internal ROM and the rest in external ROM.

Naming convention

c166 uses a naming convention for the generated sections. In general the following modifications are applied to a filename:

- whitespace and dots are converted to underscores
- filenames are converted to uppercase.
- if a filename starts with a digit, the first digit is replaced by an underscore.

Everything after (and including) the last dot is stripped from the filename. Thus, the filename: "long file.name.c" will result in the following string to be used as a basis for the section name (in the text below referred to as "*module*"):

```
"LONG_FILE_NAME"
```

The length of a filename is unlimited. Furthermore, the section naming is divided into three categories as described below:

I Non-initialized Data Sections/Normal Sections/Romdata Sections

For non-initialized data sections, normal sections and romdata sections the section name is generated as follows:

```
module_number_mem
```

where,

module is the module name in uppercase (without suffix) of the .c file

number is a unique number.

mem is a memory abbreviation code as shown in the next table.

You may change the section attributes of this category.

c166 uses the following table for its defaults (e.g. compiling mod.c):

Description	mem	type		align type	combine type	class	example section name
		-Mm/ -MI	-Mt/ -Ms				
bits	BI	BIT	BIT	BIT	PUBLIC	CBITS	MOD_1_BI
strings/floating point constants ¹	CO	DATA	LDAT	WORD	PUBLIC	CROM	MOD_2_CO
bitwords	BA	DATA	LDAT	WORD	PUBLIC	CBITWORDS	MOD_3_BA

Description	mem	type		align type	combine type	class	example section name
		-Mm/ -MI	-Mt/ -Ms				
near data	NB	DATA	LDAT	WORD	PUBLIC	CNEAR	MOD_4_NB
xnear data	XN	DATA	—	WORD	PUBLIC	CUSTACK	MOD_15_XN
far data	FB	DATA	PDAT	WORD	PUBLIC	CFAR	MOD_5_FB
huge data	HB	HDAT	HDAT	WORD	PUBLIC	CHUGE	MOD_6_HB
shuge data	XB	SDAT	SDAT	WORD	PUBLIC	CSHUGE	MOD_7_XB
functions	PR	CODE	CODE	WORD	PUBLIC	CPROGRAM	MOD_8_PR
near romdata	NC	DATA	LDAT	WORD	PUBLIC	CNEAR ²	MOD_9_NC
xnear romdata	XR	DATA	—	WORD	PUBLIC	CUSTACK	MOD_16_XR
far romdata	FC	DATA	PDAT	WORD	PUBLIC	CFARROM	MOD_10_FC
huge romdata	HC	HDAT	HDAT	WORD	PUBLIC	CHUGEROM	MOD_11_HC
shuge romdata	XC	SDAT	SDAT	WORD	PUBLIC	CSHUGEROM	MOD_12_XC
system data	SB	DATA	DATA	WORD	PUBLIC	CSYSTEM	MOD_12_SB
internal ram data	IR	DATA	LDAT	IRAM- ADDRESS- SABLE	PUBLIC	CIRAM	MOD_14_IR

¹ See also section 3.2.4, *Constant Romdata Section Allocation*, for small model only.

² CNEARROM when tiny/small model is used.

Table 3-7: Section names (non-initialized data, normal and romdata)



When using the medium or large model, near data, xnear data or system data always remain a member of the default data group or system data group. So for these memory areas, it is not possible to change all section attributes.

II *Initialized Ramdata Sections*

For initialized data the section name is generated as follows:

```
module_IR_mem
module_ID_mem
module_ER_mem
module_ED_mem
```

where,

module is the module name in uppercase (without suffix) of the .c file

mem is a memory abbreviation code as used by non-initialized ramdata sections (SB, IR, BI, BA, NB, FB, HB or XB).

You can NOT change the section attributes of this category.

c166 uses the following table for its defaults:

Description	type		align- type	combine type	class	example section name
	-Mm/ -MI	-Mt/ -Ms				
iramdata (ROM copy)	DATA	LDAT (t) PDAT (s)	WORD	PUBLIC	CINITROM	MOD_IR_NB
iramdata (RAM space)	DATA	LDAT	WORD	PUBLIC	CINITIRAM	MOD_ID_NB
eramdata (ROM copy)	DATA	LDAT (t) PDAT (s)	WORD	PUBLIC	CINITROM	MOD_ER_NB
eramdata (RAM space)	DATA	LDAT	WORD	PUBLIC	CINITERAM	MOD_ED_NB

Table 3-8: Section names (initialized romdata)

III Specials

The following special section names exist:

C166_INIT	init table for initialized RAM
C166_BSS	clear table for non-initialized RAM
C166_US	user stack
C166_US0	user stack for local register bank 0.
C166_US1	user stack for local register bank 1.
C166_INT	scalable interrupt vector table.
?C166_HEAP	heap section for memory allocation (linker or locator generated)
?INTVECT	interrupt vector table (locator generated)

You can NOT change the section attributes of this category.

c166 uses the following table for its defaults:

Description	type		align- type	combine type	class	(fixed) section name
	-Mm / -MI	-Mt / -Ms				
user stack	DATA	LDAT	WORD	GLBUSRSTACK	CUSTACK	C166_US
user stack	DATA	LDAT	WORD	GLBUSRSTACK	CUSTACK	C166_US0
user stack	DATA	LDAT	WORD	GLBUSRSTACK	CUSTACK	C166_US1
init table	DATA	LDAT (t) PDAT (s)	WORD	GLOBAL	CINITROM	C166_INIT
clear table	DATA	LDAT (t) PDAT (s)	WORD	GLOBAL	CINITROM	C166_BSS
heap	HDAT	LDAT	WORD	PUBLIC	?CHEAP	?C166_HEAP
vector table	CODE	CODE	WORD	PUBLIC	C166_VECTAB	C166_INT

Table 3-9: Section names (specials)

You can only change the section attributes of non-initialized data sections, normal sections and romdata sections (category I), using the *mem* code listed in the table.

You can tell the compiler to use other class names, combine types and align types instead of the defaults listed above by means of the following pragmas. Each pragma, has an equivalent command line option that can be used if the complete module must use the changed attributes.

```
#pragma class mem=name      /*      use name as class for
                               section of area mem */
#pragma combine mem=ctype   /*      use ctype as combine type
                               for section of area mem */
#pragma align mem=atype    /*      use atype as align type
                               for section of area mem */
#pragma default_attributes /*      use default attributes as
                               listed above */
```

atype is one of the following align types:

B	Byte alignment
W	Word alignment
P	Page alignment
S	Segment alignment
C	PEC addressable
I	IRAM addressable

ctype is one of the following combine types:

L	private ('Local')
P	Public
C	Common
G	Global
S	Sysstack
U	Uusrstack
A <i>address</i>	Absolute section AT constant <i>address</i> (decimal, octal or hexadecimal number)

Examples:

1. The C module is called 'test.c'. The example illustrates how to allocate one array in a special section with the class 'SLOWRAM' and the rest of the data in data section with default attributes. The generated code is listed below:

C:

```
#pragma class nb=SLOWRAM
int array[1000];

#pragma default_attributes
int j;
```

Generated code:

```
TEST_1_NB SECTION LDAT WORD PUBLIC 'SLOWRAM'
TEST_1_NB_ENTRY LABEL BYTE
_array LABEL WORD
        DS      2000
        PUBLIC _array
TEST_1_NB ENDS

TEST_2_NB SECTION LDAT WORD PUBLIC 'CNEAR'
TEST_2_NB_ENTRY LABEL BYTE
_j LABEL WORD
        DS      2
        PUBLIC _j
TEST_2_NB ENDS
```

2. The C module is called 'test.c'. The example illustrates how to allocate one C variable on a fixed memory location (address 8000H) and the rest of the data in a data section with default attributes. As described in the "TASKING C166/ST10 Cross-Assembler, User's Guide", AT is considered as an additional align-type and implies the default combine type PRIVATE.

C:

```
#pragma combine nb=A32768
volatile int    cntrl_reg;
    /* e.g. an I/O register of peripheral chip */

#pragma default_attributes
int i;
```

Generated code:

```
TEST_1_NB SECTION LDAT WORD AT 08000h 'CNEAR'
TEST_1_NB_ENTRY LABEL BYTE
_cntrl_reg LABEL WORD
    DS 2
    PUBLIC _cntrl_reg
TEST_1_NB ENDS

TEST_2_NB SECTION LDAT WORD PUBLIC 'CNEAR'
TEST_2_NB_ENTRY LABEL BYTE
_i LABEL WORD
    DS 2
    PUBLIC _i
TEST_2_NB ENDS
```

3.2.3 CODE MEMORY FRAGMENTATION

By default the compiler uses one section per module that contains the code. You can change this behavior with the following pragmas:

```
#pragma fragment
#pragma fragment resume
#pragma fragment continue
```

The **#pragma fragment** causes the compiler to generate each single function in its own section. The compiler will continue to do so until it encounters either **#pragma fragment resume** or **#pragma fragment continue**.

In case of **#pragma fragment resume** the compiler will resume code generation in the last active section (with the same attributes) before **#pragma fragment**.

In case of **#pragma fragment continue** the compiler will start a new continuous code.

These pragmas are especially useful in combination with the smart linking feature of the linker/locator. When you use smart linking, the linker will only link sections that are referenced. Thus if each function has its own section, only functions that are actually called (referenced) are linked rather than all functions in an `.obj` file at once.

Example:

```
void func1( void ) { }           /* Code section 1          */

#pragma fragment
void func2( void ) { }         /* Code section 2          */
void func3( void ) { }         /* Code section 3          */

#pragma fragment resume
void func4( void ) { }         /* Resume in code section 1 */

#pragma fragment
void func5( void ) { }         /* Code section 4          */

#pragma fragment continue
void func6( void ) { }         /* Continue in code section 5 */
void _near func7( void ) { }   /* Code section 5          */

#pragma fragment resume        /* No effect: Code section 5 */
void func8( void ) { }
#pragma fragment continue      /* No effect                */

#pragma fragment
_near void func9( void ) { }   /* Code section 6          */

#pragma fragment resume
void main( void )              /* Resume in code section 5 */
{
    func9();
    func7();
    return;
}
```

3.2.4 CONSTANT ROMDATA SECTION ALLOCATION

In the small memory model **c166** default allocates all constant romdata for strings, floating point constants, initialization of aggregates and jump tables in normal data (near in small memory model), which is limited to 4 pages of 16K. When you do not want to sacrifice a normal data page for ROM, you should use the **-Oe** option of **c166**.

When the **-Oe** option is enabled the following changes are in effect for the small memory model:



- **c166** allocates string and floating point constants in a far romdata section (PDAT). During startup this data is copied from far ROM to near RAM like initialized ramdata. The code generated for accessing these constants is not changed. This means no change in execution speed. The disadvantage is that the memory for these constants is allocated twice: once in far ROM and once in near RAM. The ROM sections have class 'CINITROM' and the RAM sections have the class 'CINITERAM' or 'CINITIRAM', depending on the **#pragma eramdata/iramdata**.
- constant data for initialization of automatic aggregates and jump tables is allocated in far ROM. **c166** generates different code for accessing this data as far data, which implies a minor draw-back in code execution performance.

When you use the **const** keyword for normal data, this data is placed in near ROM, even with the **-Oe** option.

To move jump tables separately from string and floating point constants to various locations, you can use the following pragmas:

#pragma switch_tabmem_far

For the small memory model, jump tables are placed in far ROM. The location of string and floating point constants is still controlled by the **-Oe/-OE** option as described above. The ROM section where the jump tables are placed have class 'CFARROM'. The code generated for accessing the jump table in far ROM is slightly slower compared to the situation where jump tables reside in near ROM.

#pragma switch_tabmem_near

For the small memory model, jump tables are placed in near ROM. The location of string and floating point constants is still controlled by the **-Oe / -OE** option as described above. The ROM section where the jump tables are placed have class 'CNEARROM'.

#pragma switch_tabmem_default

This is the default. Use this pragma to return the control of the jump table locations back to the **-Oe / -OE** command line option as described above.

The pragmas **switch_tabmem_far**, **switch_tabmem_near** and **switch_tabmem_default** can be used anywhere in the source file. The location of the jump table is affected by the last pragma before a switch statement.

The pragmas can be passed through the command line by using the `-zpragma` command line option.

The delivered small C libraries do not support constant romdata as far data, because it is not commonly used. All C library functions are compiled with the default option `-OE`, to allocate constant romdata 'CROM' in linear data sections (LDAT). You have to re-compile the C-library functions which contain constant romdata 'CROM' with the option `-Oe` if you do not want near ROM. You can rebuild the small C libraries (`c166s.lib` and `c166ss.lib`) using the makefiles in the library directories.

All library modules are re-compiled and the libraries are rebuilt by these makefiles.

String constants are in:

```
_doprint.c, _doscan.c
```

The `const` keyword is in:

```
_ctype.c
```

Floating point constants are in:

```
_fltpr.c, _getflt.c, _acos.c, _asin.c, _atan.c,  
_atan2.c, _cos.c, _cosh.c, _exp.c, _floor.c,  
_fmod.c, _ldexp.c, _log.c, _log10.c, _pow.c,  
_satan.c, _sinh.c, _sinus.c, _sqrt.c, _strtod.c,  
_tan.c, _tanh.c, fpmnull.asm,  
_asctime.c, _gmtime.c, _mktime.c, _strftm.c
```

Before running these makefile you should have rights to write to the library files `c166s.lib` and `c166ss.lib`.

Restriction:

When the `#pragma initeram` or `#pragma initiram` is used, only the last pragma in the source file affects the section attributes of the near ram data sections for string and floating point constants.



3.2.5 THE `_AT()` ATTRIBUTE

In **c166** it is possible to locate a global variable at a specified address. This can be done with the `_at()` attribute. The syntax is:

```
_at( address )
```

where, *address* is the location in memory of the variable.

In the tiny memory model, the address is limited to 64Kbytes. In all other models, the address space of the used device is the limit.

The `_at()` attribute can only be used on non-initialized global variables. Variables, which are declared constant, using the `const` modifier can be initialized and they will be placed in a rom section. Depending on the memory modifier, this will be near-, far-, huge- or shugeron.

If a variable meets the **autobita** or **autobitstruct** pragma requirements and the `_at()` keyword is specified, the `_at()` attribute overrules the **autobita/autobitstruct** pragmas.

The `_at()` attribute has no effect on variables which are declared extern.

In the segmented memory models, variables which have the `_at()` attribute are not moved automatically to near memory. However, you can explicitly specify an absolute variable to be near.

For near variables, the locator automatically assigns the correct page to the correct DPP register. Note that all other relocatable variables in the concerning page will also be moved. The dynamic assignments of DPP registers can be overruled by the linker/locator controls. However, in case of absolute variables, this will usually lead to errors because there is only one valid DPP-register / page-number combination.

If two sections overlap, or if not all near sections can be located the linker/locator will generate an error message.

The `_at()` attribute cannot be used with the `_bit`, `_system`, `_bita`, `_sfr`, `_esfr`, `_xsfr` and `_iram` memory modifiers.

Examples:

```
_near int i _at(0x29000);
_far const char ch _at(0x2A900) = 100;
int j, * k _at(0x2B002);
int * (* * fptr)(int, int) _at(0x12344);
```

This will generate the following sections, when compiled in the small memory model:

```

TEST_1_NB SECTION LDAT WORD AT 029000h 'CNEAR'
TEST_1_NB_ENTRY LABEL BYTE
_i LABEL WORD
    DS 2
    PUBLIC _i
TEST_1_NB ENDS

TEST_2_FC SECTION PDAT BYTE AT 02A900h 'CFARROM'
TEST_2_FC_ENTRY LABEL BYTE
_ch LABEL BYTE
    DB 64h
    PUBLIC _ch
TEST_2_FC ENDS

TEST_3_NB SECTION LDAT WORD AT 02B002h 'CNEAR'
TEST_3_NB_ENTRY LABEL BYTE
_k LABEL WORD
    DS 2
    PUBLIC _k
TEST_3_NB ENDS

TEST_4_NB SECTION LDAT WORD AT 012344h 'CNEAR'
TEST_4_NB_ENTRY LABEL BYTE
_fptr LABEL WORD
    DS 2
    PUBLIC _fptr
TEST_4__NB ENDS

TEST_5_NB SECTION LDAT WORD PUBLIC 'CNEAR'
TEST_5_NB_ENTRY LABEL BYTE
_j LABEL WORD
    DS 2
    PUBLIC _j
TEST_5_NB ENDS

```

For example, in this case the linker/locator assigns a value of 0x0A to DPP2. This is the same as using the SND(DPP2(10)) linker/locator control.



When specifying a near address, bits 14 and 15 implicitly specify the DPP-register that will be used. DPP3 cannot be changed. This is because DPP3 points to the memory that contains SFRs and bit addressable memory. Therefore it is not possible to locate 'near' variables in the third page of any segment, other than segment 0.

3.2.6 THE `_ATBIT()` ATTRIBUTE

In **c166** it is possible to define bit variables within a `_bitword` or (bit-addressable) `_sfr` variable. This can be done with the `_atbit()` attribute. The syntax is:

```
_atbit( name, offset )
```

where, *name* is the name of a `_bitword` or `_sfr` variable and *offset* (range 0-15) is the bit-offset within the variable.

Examples:

```
_sfr P0;
_sfrbit P0_6 _atbit( P0, 6 );

_bitword bw; /* bitaddressable word */
_bit myb _atbit( bw, 3 );
```

Using the defined bit:

```
if ( myb )
    myb = 0;
```

generates the same code as:

```
if ( _getbit( bw, 3 ) )
    _putbit( 0, bw, 3 );
```

The first example defines an `_sfrbit` within a (bit-addressable) `_sfr` variable. The second example defines a bitaddress within a bitaddressable word. For more information on SFR variables see the section *Special Function Registers*. For more information on `_bitword` variables see the section *The Bitword Type*.

The storage class of the defined bit is ignored. The storage class is inherited from the `_bitword` variable instead.

3.2.7 INLINE C FUNCTIONS

With the `_inline` keyword, a C function can be defined to be inlined by the compiler. An inline function must be defined in the same source file before it is 'called'. When an inline function has to be called in several source files, each file must include the definition of the inline function. This is typically solved by defining the inline function in a header file.

Example:

```
_inline int
add( int a, int b )
{
    return( a + b );
}

void
main( void )
{
    int c = add( 1, 2 );
}
```

The pragmas `asm` and `endasm` are allowed in inline functions. This makes it possible to define inline assembly functions. See also the section *Inline Assembly* in this chapter.

3.2.8 USING PACKED STRUCTURES

When it is undesirable to have 'holes' between structure members, you can use the `_packed` qualifier. Since the code that is generated after the `_packed` qualifier is not efficient, use packed structures only when really needed, for example for data exchange with 8-bit processors. Consider in such case first other solutions like for example, mapping structures on character arrays. Packed structures can not cross segment boundaries.

Example:

```
_packed struct
{
    char    c1;    /* offset 0 */
    int     i1;    /* offset 1 */
    int     i2;    /* offset 3 */
} s;

_packed int * ip1;

void foo( void )
{
    s.i1 = 3;
    ip1 = &s.i1;
    s.i2 = *ip1;
}
```

You can only access packed structure members by byte instructions!

Example:

```
_packed struct
{
    char    c1;    /* offset 0 */
    int     i1;    /* offset 1 */
    int     i2;    /* offset 3 */
} s;

int * ip2;

void foo( void )
{
    ip2 = &s.i1;    /* Incorrect! Use _packed pointer
                    instead. */
}
```

3.3 TASK SCOPE

c166 supports both the 'Task Concept' and the 'Flat Interrupt Concept'. These two concepts are explained in the chapter *Software Concept* of the 'TASKING Cross-Assembler User's Guide'. We strongly recommend reading this section first!

When the Task Concept is strictly followed the entry point of each task is an interrupt function, either activated by hardware (interrupt) or by software (TRAP instruction). Each task has only one entry point and no code and data is shared. This implies that reentrancy of code does not exist. See the section *Interrupt* in this chapter for more details about interrupt functions.

In C the outermost level of scope is a public (non-static) variable. Via the `extern` keyword this variable can be accessed in other C modules. This scope level in C is treated by **c166** as the task scope (public) in the Task Concept. This means that all public/extern variables are not known outside the task. This allows each task to have its own I/O channels and administration (e.g. `printf()`), heap area (e.g. `malloc()`), floating point stack and public data. The public/extern variables are solved at the link stage of **I166**. In practice it is in a lot of cases possible to share code and data between several tasks or interrupt functions. The following ways exist to do this:

define code or data to be shared to 'COMMON'

In this case, the common section must be linked with each task needing access to the shared data/code. The 'COMMON' section attribute tells the locator to 'overlay' the section with another common section carrying the same name. The module referencing the shared data of another C module uses the normal keyword `extern` in the declaration. When using, a prototype of the function is enough. Similar to the normal C rules, the `extern` keyword may be omitted with functions. This approach is used by the C library, where a number of standard C functions (such as `strlen()` and `isdigit()`) are allocated in common sections. The ROM table used by `<ctype.h>` functions is allocated in a common data section. Therefore, the C library must be linked with each task.

The combine type of a section can be changed in two ways. Firstly a command line option (**-R**), resulting in shared code and data of the complete C module. Secondly via a pragma, allowing some data or code of a C module to be shared and the rest not.

Example:

C module is called `test.c`. The example illustrates how to declare a ROM table (array) as 'shared among several tasks' and the rest of the C data in a normal data section. The generated code is listed below.

```
#pragma save_attributes
#if _MODEL == 'l' || _MODEL == 'm'
#pragma combine fc=C
#define FAR _far /* far common data */
#else
#pragma combine nc=C
#define FAR /* normal common data */
#endif

/*
 * COMMON data section in ROM, linked with
 * each task and overlaid by the locator:
 * shared data among all tasks.
 */
FAR const char table[10] = { 0, 1, 2, 3, 4, 5, 6, 7, 8, 9 };

#pragma restore_attributes
/*
 * public within task scope: each task can have
 * it's own instance of the public variable i.
 */
int i; /* task scope */
/*
 * static within module scope: each module can have
 * it's own instance of the static variable s.
 */
static int s; /* module scope */

TEST_1_NC SECTION LDAT WORD COMMON 'CNEARROM'
_table LABEL BYTE
        DB 00h,01h,02h,03h,04h
        DB 05h,06h,07h,08h,09h
        PUBLIC _table
TEST_1_NC ENDS

TEST_2_NB SECTION LDAT WORD PUBLIC 'CNEAR'
TEST_2_NB_ENTRY LABEL BYTE
_i LABEL WORD
        DS 2
        PUBLIC _i
_s LABEL WORD
        DS 2
TEST_2_NB ENDS
```



The same object module (containing the common section) must be linked with all tasks using the shared data, because the module name is part of the section name. Of course it is not possible for shared code to access non automatic data which is not shared.

If the medium or large model is used, a shared 'near' data section will cause all near data sections of all tasks to be allocated in the same page, limiting the total near data area of the whole application to 16K. However, it is still possible to have both shared (common) and non-shared (public) near data sections of each task in this area.

If the feature of a 16K near data area for every task is needed, the shared data must be explicitly declared `_far` (or `_huge` or `_shuge`) as done in the example above.

use pragmas 'global' and 'public'

All public declarations in a source file following a pragma 'global' are defined by **c166** at the application (global) scope level in the Task Concept. This means that externs referencing these public variables have to be resolved at the locate stage of **1166**.

Example:

An application consists of two tasks `TASK_A` and `TASK_B`.

A module `mod_a.c` in `TASK_A` defines a variable which has to be accessed in `mod_b.c` in `TASK_B`. The variable (`gi`) is defined in `mod_a.c` as follows:

```
#pragma global
unsigned int gi;
#pragma public
```

The `#pragma global` promotes the scope of the variable `gi` from the task scope (public) to the application scope (global).

In `mod_b.c` in `TASK_B` the variable is declared via:

```
extern unsigned int gi;
```

When linking `TASK_B.LNO`, the linker will produce a warning about an 'unresolved external `_gi`'. However, you can tell the linker to check the unresolved externals with the object file (`mod_a.obj`) or the task object file (`TASK_A.LNO`), which should contain the corresponding global definition using the `CHECKGLOBALS(object_file)` linker control. If the corresponding global definition is found by the linker, no warning is emitted, because the external is resolved at locate time when both `TASK_A` and `TASK_B` are located. The linker and locator invocation may look like:

```
1166 LINK mod_a.obj TO TASK_A.LNO
1166 LINK mod_b.obj TO TASK_B.LNO "CHECKGLOBALS( TASK_A.LNO )"
1166 LOCATE TASK_A.LNO TASK_B.LNO TO tasks.Out
```

define more than one interrupt function in one task

This is the easiest way to share code and data between interrupt functions. It is in fact a step towards the Flat Interrupt concept. When a task has more than one entry point (several interrupt functions) reentrancy of the functions and data must be checked.

use the Flat Interrupt Concept

When the the Flat Interrupt Concept is used, the assembler objects are directly input for the locator and the linker stage is skipped. The public (Task) scope level of the Task Concept is promoted to the global (application) scope level by using the `PUBTOGLB` (abbreviation `PTOG`) locator control. The `PTOG` control can also be applied to a set of objects files, which makes it possible to mix the Flat Interrupt Concept with the Task Concept. When the `PTOG` is specified for an object file, all public (task scope) variables and functions are promoted to the application scope (global) as if they were defined after a `pragma 'global'`. See the section ***1166 Controls*** of the 'TASKING Cross-Assembler User's Guide' for more information about the **1166** linker/locator controls.

3.4 DATA TYPES

All (ANSI C) types are supported. In addition to these types, the `_sfr`, `_sfrbit`, `_esfr`, `_esfrbit`, `_bit`, `_xsfr` and `_bitword` types are added. Object size and ranges:

Data Type	Size (bytes)	Range
<code>_bit</code>	1 bit	0 or 1
<code>_sfrbit</code>	1 bit	0 or 1
<code>_esfrbit</code>	1 bit	0 or 1
signed char	1	-128 to +127
unsigned char	1	0 to 255U
<code>_sfr</code>	2	0 to 65535U
<code>_esfr</code>	2	0 to 65535U
<code>_xsfr</code>	2	0 to 65535U
signed short	2	-32768 to +32767
unsigned short	2	0 to 65535U
<code>_bitword</code>	2	0 to 65535U
signed int	2	-32768 to +32767
unsigned int	2	0 to 65535U
signed long	4	-2147483648 to +2147483647
unsigned long	4	0 to 4294967295UL
float	4	+/- 1,176E-38 to +/- 3,402E+38
double	8	+/- 2,225E-308 to +/- 1,797E+308
long double	8	+/- 2,225E-308 to +/- 1,797E+308
<code>_near pointer</code>	2	16 bits (64K) when using -Mt/-Ms 14 bits (16K) when using -Mm/-Ml (default data group)
<code>_xnear pointer</code>	2	14 bits (16K) when using -Mm/-Ml. Not allowed in non-segmented memory models.
<code>_far pointer</code>	4	14 bits (16K) in any page (16M)
<code>_huge pointer</code>	4	24 bits (16M)
<code>_shuge pointer</code>	4	24 bits (16M), but arithmetic is done 16-bit wide

Table 3-10: Data types



- **c166** generates instructions using (8 bit) character arithmetic, when it is correct to evaluate a character expression this way. This results in a higher code density compared with integer arithmetic. A special section *Character Arithmetic* provides details.
- The C166/ST10 convention is used, storing variables with the least significant part at low memory address. Float and double are implemented using IEEE single and double precision formats. See section *Floating Point Interfacing* in this chapter for more details.

3.4.1 ANSI C TYPE CONVERSIONS

According to the ANSI C X3.159-1989 standard, a character, a short integer, an integer bit field (either signed or unsigned), or an object of enumeration type, may be used in an expression wherever an integer may be used. If a `signed int` can represent all the values of the original type, then the value is converted to `signed int`; otherwise the value will be converted to `unsigned int`. This process is called *integral promotion*.

Integral promotion is also performed on function pointers and function parameters of integral types using the old-style declaration. To avoid problems with implicit type conversions, you are advised to use function prototypes.

Many operators cause conversions and yield result types in a similar way. The effect is to bring operands into a common type, which is also the type of the result. This pattern is called the *usual arithmetic conversions*.

Integral promotions are performed on both operands; then, if either operand is `unsigned long`, the other is converted to `unsigned long`.

Otherwise, if one operand is `long` and the other is `unsigned int`, the effect depends on whether a `long` can represent all values of an `unsigned int`; if so, the `unsigned int` operand is converted to `long`; if not, both are converted to `unsigned long`.

Otherwise, if one operand is `long`, the other is converted to `long`.

Otherwise, if either operand is `unsigned int`, the other is converted to `unsigned int`.

Otherwise, both operands have type `int`.



See also the section *Character Arithmetic*.



Sometimes surprising results may occur, for example when unsigned char is promoted to int. You can always use explicit casting to obtain the type required. The following example makes this clear:

```
static unsigned char a=0xFF, b, c;

void f()
{
    b=~a;
    if ( b == ~a )
    {
        /* This code is never reached because,
        * 0x0000 is compared to 0xFF00.
        * The compiler converts character 'a' to
        * an int before applying the ~ operator
        */
        ...
    }

    c=a+1;
    while( c != a+1 )
    {
        /* This loop never stops because,
        * 0x0000 is compared to 0x0100.
        * The compiler evaluates 'a+1' as an
        * integer expression. As a side effect,
        * the comparison will also be an integer
        * operation
        */
        ...
    }
}
```

To overcome this 'unwanted' behavior use an explicit cast:

```
static unsigned char a=0xFF, b, c;

void f()
{
    b=~a;
    if ( b == (unsigned char)~a )
    {
        /* This code is always reached */
        ...
    }

    c=a+1;
    while( c != (unsigned char)(a+1) )
    {
        /* This code is never reached */
        ...
    }
}
```

Keep in mind that the arithmetic conversions apply to multiplications also:

```
static int   h, i, j;
static long  k, l, m;

/* In C the following rules apply:
 *      int * int           result: int
 *      long * long        result: long
 *
 * and NOT int * int       result: long
 */
```

```

void f()
{
    h = i * j;           /* int * int = int */
    k = l * m;           /* long * long = long */

    l = i * j;           /* int * int = int, afterwards
                        * promoted (sign or zero
                        * extended) to long
                        */
    l = (long) i * j;    /* long * long = long */
    l = (long)(i * j);  /* int * int = int,
                        * afterwards casted to long
                        */
}

```

3.4.2 CHARACTER ARITHMETIC

c166 generates code using 8 bit character arithmetic as long as the result of the expression is exactly the same as if it was evaluated using integer arithmetic. This approach increases code density and execution speed (when character typed variables are used of course).

In strict ANSI-C, character arithmetic does not exist: all character variables are converted to integer before the operation is performed. However, if the integer result is not used (e.g. by assigning it to a character variable) the operation could have been evaluated using character arithmetic, giving the same result. This is how **c166** works.

There is one exception to this rule, dealing with the `sizeof` operator:

```

char a, b;
int i;

void
main()
{
    i = sizeof( 'A' );    /* -Ac: 1, -AC option: 2 */
    i = sizeof( a + b ); /* -Ac: 1, -AC option: 2 */
}

```

You can enable/disable character arithmetic with the **-Ac/-AC** command line option.

3.4.3 THE BIT TYPE

The `_bit` type is subject to the following rules:

1. A bit type variable is always placed in bit-addressable RAM.
2. A bit type variable is always unsigned.
3. A bit type variable can be exchanged with all other type-variables. The compiler generates the correct conversion.
4. Pointer to a bit-variable and array of bit is **not** allowed, because the C166/ST10 has no instructions to indirectly access a bit variable.
5. Structure of bit is supported, with the restriction that no other type than bit is member of this structure. Structure of bit is **not** allowed as parameter or return value of a function.
6. A union of a bit structure and another type is not allowed. The bitword type can be used for this purpose.
7. A bit type variable is **not** allowed as parameter. The allowed classes for bit are: automatic, static, public or extern.
8. A function may have return type bit.
9. The `sizeof` of a bit type is 1.
10. Functions returning bit can **not** have `huge/shuge/near` keyword in its prototype.
11. A bit typed expression is **not** allowed as switch expression.



The constants need a (bit) cast operator in order to enable bit operations such as '&', '^'. Of course this is not needed with (compound) assignments.

The following table shows which operators are allowed with bit type variables:

Allowed is:

```

==, !=, <, <=, >, >=
&&, ||, !, ~
? :, CALL, RETURN
&, |, ^
&=, |=, ^=
conversions to/from char/int/long/float/double
bit structures (bit members only)
unary plus

```

Not allowed is:

```

++, -- (post/pre increment/decrement)
unary minus
indirection (array/pointer/address)
+, -, *, /, %, <<, >>
+=, -=, *=, /=, %=, <<=, >>=

```

3.4.4 THE BITWORD TYPE

You can declare word variables in the bit-addressable area as `_bitword`. You can access individual bits using the intrinsic functions `_getbit()` and `_putbit()` or declare the individual bits of this `_bitword` variable using `_atbit`. A prototype for these functions is given in the include file `c166.h`.

For example:

```

_bitword bw1, bw2;      /* bitaddressable words */

if ( _getbit( bw1, 3 ) )
    _putbit( 1, bw2, 7 ); /* set bit 7 of bw2 */

```



See also the section *The `_atbit()` Attribute*.

The `_bitword` type is subject to the following rules.

1. A bitword type variable is always unsigned.
2. A bitword type variable can be exchanged with all other type-variables. The compiler generates the correct conversion.

3. Pointer to a bitword variable and array of bitword is allowed.
4. Structure of bitword is supported, with the restriction that no other type than bitword is member of this structure. Structure of bitword is **not** allowed as parameter or return value of a function.
5. A bitword type variable is not allowed as automatic or parameter. The allowed classes for bitword are: static, public or extern.
6. The `sizeof` of a bitword type is same as `int`.
7. A bitword typed expression is allowed as switch expression.

3.4.5 SPECIAL FUNCTION REGISTERS

c166 recognizes the keywords: `_sfr` and `_sfrbit`. If you specify the `-x` or `-xf` option, you can access the extended special function register area via the keywords `_esfr` and `_esfrbit`.

c166 also recognizes the keyword: `_xsfr`. The `_xsfr` keyword is used to access special function registers outside the (E)SFR areas but within internal RAM (DPP3). Variables declared as `xsfr` are not bitaddressable. Example: PEC source and destination pointers (SRCPx/DSTPx).

c166 emits the name of the special function register in the assembly code. A special include file named `reg166.h` is delivered with the package, which contains all `sfr`, `xsfr` and `sfrbit` declarations of the C166/ST10x166, using the same names as **a166** in MOD166 mode. **c166** does not perform any check whether the name is correct or not, but passes the name to **a166**. The assembler checks the validity of the name.

If the `-x` or `-xf` option is on, you can include the file `reg167.h`, `reg165.h`, etc., which contain all the `sfr`, `esfr`, `xsfr`, `sfrbit` and `esfrbit` declarations for each of the C167 derivatives individually. The compiler now emits `$NOMOD166` and `$STDNAMES(reg.def)` controls. By default **a166** searches files supplied to the `STDNAMES` control in the `etc` directory installed with the product. This way **a166** finds the file `reg.def` in that directory.

All `reg*.h` files consist of a number of parts, which are all included by default. However, if you do not need every part in your source file, you can omit each part by defining the appropriate macro before you include this file. These 'control' macros are described in the `reg*.h` files.

REG163_NOPORT	omit port I/O registers
REG163_NORS232	omit serial I/O registers
REG163_NOTIMER	omit timer registers
REG163_NOADINT	omit additional peripheral
REG163_NOEXTINT	omit fast external interrupt
REG165_NOCPU	omit cpu registers
REG165_NOPEC	omit PEC registers
REG165_NOPORT	omit port I/O registers
REG165_NORS232	omit serial I/O registers
REG165_NOTIMER	omit timer registers
REG165_NOADINT	omit additional peripheral interrupt registers
REG165_NOEXTINT	omit fast external interrupt registers
REG166_NOADC	omit analog/digital registers
REG166_NOCAPCOM	omit capture/compare registers
REG166_NOCPU	omit cpu registers
REG166_NOPEC	omit PEC registers
REG166_NOPORT	omit port I/O registers
REG166_NORS232	omit serial I/O registers
REG166_NOTIMER	omit timer registers
REG167_NOADC	omit analog/digital registers
REG167_NOCAPCOM	omit capture/compare registers
REG167_NOCPU	omit cpu registers
REG167_NOPEC	omit PEC registers
REG167_NOPORT	omit port I/O registers
REG167_NORS232	omit serial I/O registers

You can make your own version of `reg166.h`, but in that case you must supply the same names to **a166** by using `NOMOD166` and a `STDNAMES` file.

c166 and **a166** do not generate symbolic debugging information for special function registers, because the register names should be known by the debugger.

Because the special function registers are dealing with I/O, it is not correct to optimize away the access to these registers. Therefore, **c166** deals with special function registers as if they were declared with the `volatile` qualifier.

```

_sfr    var1; is treated like: volatile unsigned int var1;
_sfrbit var2; is treated like: volatile _bit var2;
_xsfr   var3; is treated like: volatile unsigned int var3;

```

3.5 FUNCTION PARAMETERS

A lot of execution time of an application is spent transferring parameters between functions. Therefore this is an area which is very interesting for optimization. The conventional CPU approach for parameter passing is via the stack, because C allows recursion and reentrancy (the stack sizes of each task are accumulated by the locator stage of **1166**).

Because it is very important to optimize parameter passing, **c166** uses a resource which a RISC processor like the C166/ST10 has plenty of: registers. The first parameters are placed in specific registers (R12– R15). Very often the parameter computation can be done directly in the appropriate register. In practice the bulk (80–90%) of the calls pass four or fewer (word-sized) parameters.

A special keyword `_stackparm` is introduced as a 'function qualifier' (like `_interrupt`) to tell the code generator to pass all parameters via the user stack. This keyword is very convenient for interfacing with (existing) assembly functions or when register usage must be minimized (e.g. `-r6` is used for a small C interrupt function calling another C function):

```

void stackparm assembly_function( char type,
                                long size );

```

Register parameter passing is NOT done if one of the following conditions is true:

- the 'dot arguments' of a function having a variable argument list (ANSI notation of prototype declaration, using three dots, e.g.: `void f(char *, ...);`)
- the called function has a prototype with the `stackparm` function qualifier.
- the register parameters are already full or one of the parameters cannot be passed in a register (explained below in more detail).



If a variable argument list function (e.g. `printf()`) is called without a valid prototype (`#include <stdio.h>`) run-time errors occur due to parameter **transfer** mismatches.



If a function prototype is used with a function call but NOT with the function body (or vice versa), run-time errors may occur due to parameter **type** mismatches.

A function that does not call any other function is called a 'leaf' function. If a function is a leaf function and the C code does not calculate the address of a parameter (via the & operator) the parameters of this function do not have to be saved. Thus, the parameters of such a function are left in the input registers. A lot of C library functions (such as `strlen()`, `strcpy()` etc.) meet these requirements.

Non-leaf functions must save the parameter registers on the user stack at function entry, as if they were pushed by the caller. However, the code generator tries to use the register copies of these parameters as long as possible. If automatic registers are available, these registers are used instead of the user stack.

If a parameter does not fit (anymore) in the parameter registers or the parameter is a float/double or a structure/union (not a pointer), it is passed via the (more conventional) user stack. All next parameters are passed via the stack to maintain correct stack offsets, even if one of these next parameters would fit in the register area. The following examples (small model) clarify this item:

Example 1:

```
void func1( long l1, int i, long l2, char *p );
/*          R12-R13 R14   stack   stack: not R15 */
```

better:

```
void func1( long l1, int i, char *p, long l2 );
/*          R12-R13 R14   R15     stack */
```

Example 2:

```
void func2( double d, double *p, int i );
/*          stack   stack   stack */
```

better:

```
void func2( double *p, int i, double d );
/*          R12       R13   stack */
```

3.5.1 STATIC APPROACH OF FUNCTION AUTOMATICS

Function automatics (not parameters) which can not be allocated to a register are present on the user stack. Compared to static variables these stack variables have the following disadvantages:

- Access to these variables is only possible via an 'indirect register plus offset' addressing mode. This addressing mode is supported in the following two instructions only:

- 1) MOV Rn,[Rm+#d16]
- 2) MOV [Rm+#d16],Rn

This means that all arithmetic operations (add, and, cmp, or, subb and xor) with a stack variable need an extra register move, before the operation can be done. With static memory variables a register move is not needed, because the operations mentioned above allow the usage of the MEM operand.

- Heavy usage of instruction 1) is slowing down execution time, because this instruction takes twice as much time as any other move instruction or arithmetic operation (200ns instead of 100ns at 40MHz).

Therefore, code size and execution speed can be improved if the non-register function automatics may be treated by the compiler as if they were static and it is possible to allocate these 'automatic' variables in the fast internal RAM of the 80C166 using a CLASSES or ADDRESSES(SECTIONS) locator control. Of course, this is not possible with recursive functions. Because function automatics do not have any interaction with other functions (unlike parameters), it is not necessary to introduce a special static model to support this optimization. It is even possible to enable this optimization for only one function in a module.

The compiler supports two ways of specifying function automatics can be treated in a static way:

1. command line option.

- S All functions of the C module are compiled using static memory for non register function automatics. This option may be useful for non recursive applications.

2. pragmas.

If only a few functions of the entire application are recursive, the following pragmas can be used to enable (or disable) this optimization:

pragma static Use static memory for non register function automatics.

pragma automatic Default (unless **-S** is used). Use stack approach for non register function automatics. Support recursion.

The usage of the **-S** option (or **pragma static**) does not change the semantic behavior of **c166** with automatics: explicit storage type specifiers (far, near, huge, shuge) remain illegal and the initialization of an automatic variable is done run-time (each time the function is entered).

3.6 REGISTER VARIABLES

Via the `register` keyword you are able to control which automatic variable must be allocated to a CPU register by the code generator. However, if the `register` keyword is NOT used, the front end phase of **c166** determines which C automatic variables might be allocated to a register by the code-generator (unless the **-OR** option is specified to turn this optimization off).

If a C function is a non-leaf function (i.e. calling another C function), four registers (R6-R9) are available to support C register variables. However, if the C function is a leaf function, not occupied registers of the parameter register area (R12-R15) can be used for automatic registers too. These registers do not have to be saved at entry and restored at exit. Thus, leaf functions allow up to eight registers to be used for register automatics!

The code generator of **c166** uses a 'saved by callee' strategy. This means that a function which needs one or more registers for register variables, must save the contents of these registers and restore before returning to the caller. The major advantage of this approach is, that only registers which are really used by the function are saved. If the function does not have any register variable, the registers of the caller function remain valid without being saved.

The code generator prefers to assign the register character type automatics to R6 or R7 (using RL6/RL7) and the other types to the rest in the order of their declaration.

A declaration like (`f()` being a non-leaf function):

```
void f()
{
    register int i;
    register char c;
    register long l;
    . . . . .
    func();
}
```

would have been allocated by the code generator in the following registers:

```
i ==> R9
c ==> RL6
l ==> R7-R8
```

If `f()` would have been a leaf function, the register automatics would have been allocated in the following registers:

```
i ==> R15
c ==> R14
l ==> R12-R13
```

All basic data types which are allowed as automatic variable are supported, except float/double/bit: char, int, long, near/far/huge/shuge pointer. Of course `_sfr`, `_sfrbit`, `_xsfr` and `_bitword` are not possible.

If register usage must be minimized (e.g. interrupt function/module), specify **-r6** on the command line (R0-R5 used in REGDEF). When the **-rnumber** option is used, the automatic register allocation scheme of **c166** is adjusted to meet the requirements of the user.

3.7 INITIALIZED VARIABLES

There are two types of initialized variables, which depend on the class of the variable: `static` or `automatic`. The implementation is described in the following sections.

3.7.1 AUTOMATIC INITIALIZATIONS

Automatic initialized variables are initialized (run-time) each time a C function is entered. Normally, this is done by generating code which assigns the value to the automatic variable.

In the old (K & R) language definition it was not allowed to initialize an automatic aggregate type (e.g. an array or structure), but only integral types. The ANSI standard also allows run-time initialization of automatic aggregate types. To support this feature, **c166** generates code to copy the initialization constants from ROM to RAM each time the function is entered.

3.7.2 STATIC INITIALIZATIONS

There is a lot of existing C source which use static initializations. Static initialized variables normally use the same amount of space in both ROM and RAM. This is because the initializers are stored in ROM and copied to RAM at start-up. In the task philosophy of **c166**, this ROM to RAM copy has to be performed at 'startup' for each task.

c166 takes care of a mechanism, which is completely transparent for the user. It performs initialization per task from system startup code, using compiler generated tables.

Static initialized variables use the same amount of space in both ROM and RAM. The only exception is an initialized variable residing in ROM, by means of either the `#pragma romdata` or the `const` storage type qualifier. For normal initialized RAM variables, you can specify the class name ('CINITIRAM' or 'CINITERAM') to be used with `#pragma iramdata` or `#pragma eramdata`. You can use the `CLASSES` locator control to affect the location of these variables. See the paragraph *Section Allocation* for details on section names and section attributes.

Example (using small model):

```
const char b = 'b';      /* 1 byte in ROM */
#pragma iramdata        /* default, may be omitted, unless pragma
                        romdata/eramdata was used before */
int i = 100;           /* 2 bytes in ROM, 2 bytes in IRAM */
char a = 'a';         /* 1 byte in ROM, 1 byte in IRAM */
char *p = "ABCD";     /* 5 bytes in ROM (for "ABCD") */
                        /* 2 bytes in ROM, 2 bytes in IRAM
                        (for p)*/

#pragma romdata        /* Needed for ROM only allocation */
int j = 100;          /* 2 bytes in ROM */
char *q = "WXYZ";     /* 5 bytes in ROM (for "WXYZ") */
                        /* 2 bytes in ROM (for p) */
```

c166 treats `romdata` variables as if they were declared with the `const` storage type qualifier.

3.8 NON-INITIALIZED VARIABLES

In some cases there is a need to keep variables unchanged even if power is turned off. In these systems some of the RAM is implemented in EEPROM or in a battery-powered memory device. In a simulator environment, clearing non-initialized variables might not be wanted too.

To avoid the 'clearing' of non-initialized variables at startup, one of the following things should be performed:

1. Define (allocate) these variables in a special C module and compile this module using the **-Ob** option. **c166** will omit these data sections, when building the C166_BSS section.
2. Define (allocate) these variables between **#pragma noclear** and **#pragma clear**. **c166** will omit these data sections, when building the C166_BSS section.



#pragma noclear before or in a function, applies to all static variables and return values (structs) of the function.

3. Use inline assembly to allocate the special variables in a special data section (NOT used by other C variables).
4. Make a separate assembly module, containing the allocation of these variables in a special data section.



It is not possible to remove the 'clearing code' from the startup file, because other C modules (and the C libraries) depend on it too.

3.9 STRINGS

In this section the word 'string' means the separate occurrence of a string in a C program. So variables initialized with strings are just initialized character arrays and are not considered as 'strings'. See the section *Initialized Variables* for more information on this topic.

Strings have static storage. The ANSI X3.159-1989 standard permits string literals to be put in ROM. Because there is no difference in accessing ROM or RAM, **c166** allocates strings in ROM only. This approach also saves RAM, which can be very scarce in an embedded (single chip) application.

As mentioned before, **c166** offers the possibility to allocate a static initialized variable in ROM only, when declared with the `const` qualifier or after a `#pragma romdata`. This enables the initialization of a (const) character array in ROM:

```
const char romhelp[] = "help";  
/* allocation of 5 bytes in ROM only */
```

Or a pointer array in ROM only, initialized with the addresses of strings, also in ROM only:

```
char * const messages[] = {"hello", "alarm", "exit"};
```

ANSI string concatenation is supported: adjacent strings are concatenated – only when they appear as primary expressions – to a single new one. The result may not be longer than the maximum string length (509 characters).

The Standard states that identical string literals need not be distinct, i.e. may share the same memory. To save ROM space, **c166** overlays identical strings within the same module.

3.10 INLINE ASSEMBLY

c166 supports an inline assembly facility by means of the following pragmas:

- #pragma asm** Insert the following (non preprocessor lines) as assembly language source code into the output file. The inserted lines are not checked for their syntax.
- #pragma asm_noflush** Same as **asm**, except that the peephole optimizer does not flush the code buffer and assumes register contents remain valid.
- #pragma endasm** Switch back to the C language.

You should realize that using these pragmas results into non portable and hard to 'simulate' code. Therefore, usage of these pragmas should be minimal.

C Variable Interface for Pragma asm

The pragma **asm** and **endasm** synopsis of the pragmas is as follows:

```
#pragma asm [(pseudo_reg[=varname][, pseudo_reg[=varname] ...)]
```

```
#pragma endasm [(varname=pseudo_reg[, varname=pseudo_reg] ...)]
```

The arguments of the pragmas are:

varname name of a C variable of type char or int, signed or unsigned,

pseudo_reg a pseudo register name with the synopsis:

```
@|w|b|i|num
```

w word register R0–R15

b byte register RL0–7, RH0–7

i indirect address register R0–R3, some addressing modes only support these registers

num a user defined number of the pseudo register. This number is not related to the register that is substituted by the compiler. The number must be in the range 0–15.

When no **w**, **b**, or **i** is given a word register is used.

Examples:

```
@1      word register pseudo
@w2     word register pseudo
@b3     byte register pseudo
@i4     word register pseudo
```

When a *pseudo_reg* is listed without assignment of a *varname*, the compiler will reserve a scratch register. When in the pragma **endasm** a *pseudo_reg* is listed that is not listed in the pragma **asm**, it will also be reserved as a scratch register.

Example:

```
#pragma asm( @w1=var1, @b2=var2, @i3=var3, @4 )
    EXTERN XVAL:WORD, BVAL:BYTE, YVAL:WORD
    MOV @4, @w1      ; fill temporary register
    MOV XVAL, @4    ; save in some memory location
    MOV BVAL, @b2   ; save in some memory location
    MOV @i3, #2     ; small instruction (Rn, #data4)
    MOV @w1, YVAL   ; get some memory location
#pragma endasm( retval=@w1 )
```

The compiler will take care that the requested registers are free to be used and that their original content is saved and restored if needed. When the compiler is not capable of allocating registers for the listed pseudos an error message will be issued. The number of pseudos that can be allocated for inline assembly depend on the complexity and size of the C code part of the function.

Defining inline assembly functions can be done by using the pragma asm interface in an inline C function.



See the section *User Defined Intrinsics* in this chapter.

Example:

```
_inline int swap_add( int a, int b )
{
    int rv;
#pragma asm ( @1=a, @2=b, @3 )
    MOV @3, @1
    MOV @1, @2
    MOV @2, @3
    ADD @3, @1
#pragma endasm ( rv=@3 )
    return rv;
}
```

Known restriction: The new implementation of the `pragma asm` may cause an inline assembly to be optimized away by the **c166** flow optimizations. For example:

```
void example(void)
{
    goto the_end;
#pragma asm
entry:
    ; assembly statements here will not be emitted by c166
    ; because it is considered 'not reachable', even when
    ; the assembly starts with a label.
#pragma endasm
the_end: ;
}
```

Workaround for this restriction: Replace C statements which seems to make the inline assembly not reachable by an assembly equivalent inside the `#pragma asm`:

```
void workaround(void)
{
#pragma asm
    jmp    the_end
entry:
    ; assembly statements here will be emitted by c166
the_end:
#pragma endasm
}
```



See also the section *Assembly Language Interfacing* in the chapter *Run-time Environment*.



The 'MODULE SUMMARY' of **c166**, reporting code size and data size of the module, is no longer valid if code or data has been added using inline assembly.

3.11 INTERRUPT

c166 supports both the 'Infineon Task Concept' and the 'Flat Interrupt Concept'. These two concepts are explained in the chapter *Software Concept* of the 'TASKING Cross-Assembler, Linker/Locator, Utilities User's Guide'. We strongly recommend reading this section first! See also the section *Task Scope* in this chapter.

In the Task Concept a Task is initiated via an interrupt or software trap. The 'reset task' is the task which defines main. The system startup file ('cstart.asm' in assembly code) delivered with the compiler, initializes the processor and each task and finally calls `main()`. In the Flat Interrupt concept an interrupt is an entry point in the code. The system startup code is such an entry point.

You can tell the compiler that a C function is an interrupt function with the keyword `_interrupt`. For example:

A task is initiated via an interrupt or a software trap. You can tell the compiler that a C function is an interrupt function with the keyword `_interrupt`. For example:

```
_interrupt( 0x22 ) void
timer( void )
{
    ...
}
```

The interrupt number `-1` is reserved for a so-called symbolic interrupt. This means that **c166** does not assign an interrupt number to this C function. The interrupt function can be bound to any interrupt number in the locate stage of **1166** by the INTERRUPT control.

c166 generates an interrupt frame inheriting the user stack pointer from the previous task, switching context to a new register bank, saving DPP registers and MDC, MDH and MDL registers. When the **-Oh** command line option is set (default) the compiler optimizes the interrupt frame so that it only contains the parts needed to save resources used by the interrupt function. You can also tell the compiler to omit the whole interrupt frame via the following pragma:

#pragma noframe

This allows you to make your own interrupt frame.

With the `_using` keyword you can tell the compiler to generate a new register bank for the interrupt function. For example:

```
_interrupt( 0x28 ) _using( ADCONV_RB ) void
ad_conv_complete( void )
{
    ...
}
```

This way you can define several interrupt functions in one module with each function having its own register bank. Or you can share a register bank between several interrupt functions which have the same interrupt level and thus can never interrupt each other. When several interrupt functions in a source module are 'using' a register bank with the same name, the compiler uses the same register bank for these functions. **1166** will 'overlay' register banks with equal names.

All interrupt functions without the `_using` keyword use a register bank with a name derived from the module name. This means that all interrupt functions in one C source file which do not have the `_using` keyword use the same register bank and therefore they should have the same interrupt level.

When the pragma `'regdef'` or the `-r` command line option is used, it affects all register banks in the module. With this pragma and option you can specify the number of registers in the register bank. When this number is set to 0 the compiler will not generate a register bank, even when the `_using` keyword is used.

3.12 EXTENSIONS FOR THE EXT2 ARCHITECTURES

The C166S v2.0 / SUPER10 architectures support fast register bank switching using local register banks. You can make use of this feature using the `_localbank` keyword. This keyword can only be applied on interrupt functions.

```
_localbank (num)
```

Where `num` can be one of the following:

- 2: Use local register bank 1 but assume the hardware automatically switches the register bank upon interrupt.
- 1: Use local register bank 0 but assume the hardware automatically switches the register bank upon interrupt.
- 0: Use global register bank as usual.
- 1: Use local register bank 0 and emit instruction in interrupt frame to select the correct local register bank.
- 2: Use local register bank 1 and emit instruction in interrupt frame to select the correct local register bank.

Only the `_localbank (0)` qualifier can be used in conjunction with the `'_using'` qualifier. The correct registerbank will not be selected when `#pragma noframe` is entered before the interrupt function.

Since local register banks are not memory mapped, the compiler can not copy the userstack pointer (R0) to the new register bank. Therefore each local register bank will have its own userstack area:

```
C166_US0: will be used together with register bank 0
C166_US1: will be used together with register bank 1
```

The compiler estimates the size of each separate stack based upon the code inside interrupt functions only. Userstack space occupied by functions which are called from the interrupt function are not taken into account.

The estimated userstack size can be adjusted using a new function qualifier:

```
_stacksize (num)
```

Where `num` specifies the userstack adjustment in bytes. A positive number increases the compiler estimates by `num` bytes, a negative value decreases it. If the sum of the compiler estimation and the stack adjustment is negative, a warning will be generated and the value will be truncated. The value of `num` must be even.

The `_stacksize` qualifier can only be used in combination with the local register banks (for example: `_localbank (0)` is NOT allowed) and interrupt functions.

User stacksize estimations will not be performed if `#pragma nocustack` was used. Of course it is still possible to adjust the size of the generated userstack sections at locate time using the `SECSIZE` control.

The complete definition of an interrupt function could look like this:

```
/*
 * Define an interrupt function using local register
 * bank 0 assuming the hardware automatically selects
 * local bank 0 upon interrupt. Increase the by the
 * compiler estimated user stacksize by 40 bytes. The
 * userstack will be allocated in section: C166_US0
 */
void _interrupt(0x10) _localbank(-1) _stacksize(+40)
ISR(void)
{
    return;
}
```

Another feature of the ext2 architectures is the scalable interrupt vector table. The compiler uses this feature by trying to inline as much code as possible inside the interrupt vector table. Small interrupt functions can be located inside the vector table completely. This will improve interrupt latency. The size of an entry in the interrupt vector table can be supplied to the compiler by the command line option:

```
-i<num>
```

Where `num` can be one of the following:

```
0-No scaling          (4 bytes/entry)
1-2x the normal size (8 bytes/entry)
2-4x the normal size (16 bytes/entry)
3-8x the normal size (32 bytes/entry)
```

When either option is supplied to the compiler, it will try to reorder and move code from the interrupt frame to the interrupt vector table. Where possible the context switch will be done just before the `JMPS` instruction which jumps to the ISR. By doing this, the execution time of the `JMPS` instruction will be hidden by the context switch.

the compiler will put all sections that have to be inlined in a special section called: "C166_INT" with class: "C166_VECTAB". An example of an inlined interrupt function is shown below:

```

; *****
; * Section which will be located at vector position
; * 0x10 by the locator, the scaling = 3
; * (32bytes/entry available in vector table)
; *****

C166_INT SECTION CODE WORD PUBLIC 'C166_VECTAB'
_3 PROC TASK SCALEDVE_TASK INTNO
    SCALEDVE_INUM = 010h SCALING 3 INLINE

    PUSH CP ;; 2 bytes
    SCXT MDC,#010h ;; 4 bytes
    PUSH DPP0 ;; 2 bytes
    MOV DPP0,#PAG ?BASE_DPP0 ;; 4 bytes
    PUSH DPP2 ;; 2 bytes
    MOV DPP2,#PAG ?BASE_DPP0 ;; 4 bytes
    PUSH MDH ;; 2 bytes
    MOV SCALEDVE_RB,R0 ;; 4 bytes
    MOV CP,#SCALEDVE_RB ;; 4 bytes
        ;; (Context switch right before JMPS)
    JMPS SEG _ISR1,_ISR1 ;; 4 bytes
    RETV ;; -----+
_3 ENDP ;; 32 bytes
C166_INT ENDS

; *****
; * Start of ISR
; *****

    SCALEDVE_1_PR SECTION CODE
_ISR1 PROC TASK ISR
    PUSH MDL

; *****
; * User code goes here
; *****

    POP MDL
    POP MDH
    POP DPP2
    POP DPP0
    POP MDC
    POP CP
    RETI
_ISR1 ENDP

```

A faster way to transfer control to an interrupt function is to make use of cached interrupts. To support this, the hardware of the ext2 architectures bypasses the interrupt vector table at all. In this case, the compiler can not inline any code of the interrupt function in the vector table. Therefore the `_cached` keyword has to be used on these interrupt functions. The following code fragment gives an example of the use of the `_cached` function qualifier:

```
void  _interrupt (0x10) _localbank(-1) _cached
      ISR(void)
{
    return;
}
```



The `_cached` function qualifier will basically overrule the `-i` commandline option causing none of the code to be located inside the interrupt vector table.

Examples:

1. The C module is called 'intrpt.c' (present in the examples/c directory). The example illustrates how to tell the compiler to omit the interrupt frame code. The C source and the generated code (large) is listed below:

```

#pragma global
bit b; /* interrupt handler sets a global bitvariable */
#pragma public

#pragma noframe /* minimal interrupt frame */
/* even no GPR's needed, so */
#pragma regdef 0 /* omit regdef definition */

interrupt (0x30) void
f()
{
#pragma asm
    NOP ; you can make your own entry code here
#pragma endasm
    b = 1;
#pragma asm
    NOP ; you can make your own exit code here
#pragma endasm
}

INTRPT_1_BI SECTION BIT BIT PUBLIC 'CBITS'
INTRPT_1_BI_ENTRY LABEL BIT
_b DBIT
GLOBAL _b
INTRPT_1_BI ENDS

INTRPT_2_PR SECTION CODE WORD PUBLIC 'CPROGRAM'
_f PROC TASK INTRPT_TASK INTNO INTRPT_INUM = 030h
    NOP ; you can make your own entry code here
    BSET _b
    NOP ; you can make your own exit code here
    BCLR IEN
    RETI
_f ENDP
INTRPT_2_PR ENDS

```

2. The C module is called 'intrpt.c' (present in the examples directory). The example illustrates the use of '#pragma regdef' and shows the code the compiler emits as interrupt frame using large memory model (DPP0 and DPP2 saving). The user stack pointer must be inherited and the multiply registers must be saved. The C source and the generated code is listed below:

```

#pragma regdef 6          /* MINIMIZE REGISTER USAGE to R0-R5 */

int stackparm ext_func( int ); /* stack parameter passing: NOT
R12-R15 */

interrupt (0x30) void
f()
{
    int i;                /* allocate on user stack: NOT R6-R9 */

    i = ext_func( 3 );
}

INTRPT_1_PR SECTION CODE WORD PUBLIC 'CPROGRAM'
_f PROC TASK INTRPT_TASK INTNO INTRPT_INUM = 030h
; Stack: 2
    MOV    DPP3:INTRPT_RB,R0
    SCXT   CP,#DPP3:INTRPT_RB
    SCXT   MDC,#00h
    PUSH   DPP0
    PUSH   DPP2
    MOV    DPP2,#PAG C166_DGROUP
    PUSH   MDL
    PUSH   MDH
    SUB    R0,#02h
    MOV    R4,#03h
    MOV    [-R0],R4
    CALLS SEG _ext_func,_ext_func
    ADD    R0,#02h
    MOV    [R0],R4
    ADD    R0,#02h
    POP    MDH
    POP    MDL
    POP    DPP2
    POP    DPP0
    POP    MDC
    POP    CP
    BCLR   IEN
    RETI
_f ENDP
INTRPT_1_PR ENDS

INTRPT_RB REGDEF R0-R5

```

Instead of using `#pragma regdef 6` you can also use the command line option `-r6`. When you use the `-r` command line option, you can also specify the register bank name to be used and whether this register bank should be COMMON or not.

Specifying `-r6,MYBANK,c` results into:

```
MYBANK REGDEF R0-R5 COMMON = MYBANK_RB
```

It is very useful to share the register bank of interrupt functions, which are at the same interrupt priority level, so they cannot be active simultaneously. This approach saves internal RAM space, which is a scarce resource.

3. The C module is called 'intrpt.c' (present in the examples directory). The examples illustrates the using keyword. The C code and the generated code (large memory model) is listed below:

```

int i;

interrupt (0x30) using (INTRPT_RB) void
f()
{
    i+=2;
}

        ASSUME        DPP3:SYSTEM
INTRPT_1_NB SECTION DATA WORD PUBLIC 'CNEAR'
        ASSUME        DPP2:INTRPT_1_NB
INTRPT_1_NB_ENTRY LABEL BYTE
_i      LABEL WORD
        DS            2
        PUBLIC _i
INTRPT_1_NB ENDS

INTRPT_2_PR SECTION CODE WORD PUBLIC 'CPROGRAM'
_f      PROC TASK INTRPT_TASK INTNO INTRPT_INUM = 030h
; Stack: 0
        MOV        DPP3:INTRPT_RB,R0
        SCXT      CP,#DPP3:INTRPT_RB
        PUSH     DPP2
        MOV      DPP2,#PAG C166_DGROUP
        MOV      R4,#02h
        ADD     _i,R4
        POP     DPP2
        POP     CP
        BCLR    IEN
        RETI
_f      ENDP
INTRPT_2_PR ENDS

C166_BSS SECTION DATA WORD GLOBAL 'CINITROM'
        DW        06h
        DPPTR    INTRPT_1_NB_ENTRY
        DW        02h
C166_BSS ENDS

C166_DGROUP DGROUP        INTRPT_1_NB
INTRPT_RB   REGDEF        R0-R15
        REGDEF        R0-R15
        END

```

3.13 SWITCH STATEMENT

c166 supports two ways of code generation for a switch statement: a jump chain or a jump table. A jump chain is comparable with an if/else-if/else-if/else construction. If all of the following conditions are true, a jump table is emitted:

1. type is not long (char, int, bitfield only)
2. at least five case labels are present
3. total number of 'gaps' between the case labels (when sorted) does not exceed the number of case labels.

It is obvious (especially with large switch statements) that the jump table approach executes faster than the jump chain approach. If speed is needed (e.g. an interrupt function) it might be acceptable to use a jump table, even if the number of gaps between the (sorted) case labels exceeds the number of case labels itself. Therefore the second and third requirement can be overruled by using:

```
#pragma switch_force_table
```

and restored using:

```
#pragma switch_smart
```

which is the default situation. The command line equivalents are **-Os** (switch_force_table) and **-OS** (default, switch_smart).

The location of jump tables in the small memory model can be controlled by using

```
#pragma switch_tabmem_far
```

which places jump tables in class 'CFARROM'.

```
#pragma switch_tabmem_near
```

which places jump tables in class 'CNEARROM'.

```
#pragma switch_tabmem_default
```

which places jump tables on the default location, which is controlled by the **-Oe/-OE** command line option. This is the default.



See section 3.2.4 *Constant Romdata Section Allocation* for details.

3.14 REGISTER USAGE

c166 uses the general purpose registers (GPRs) of the C166/ST10 as follows:

Register	Usage
R0	User Stack Pointer (USP)
R1–R5, R10, R11	General registers (codegen, temporary results, C return values)
R6–R9	C register variables and saved register parameters
R12–R15	Fast C parameter passing and C register variables

Table 3-11: General purpose registers

c166 uses the following registers for C function return types:

Return type	Register(s)
bit	PSW.6 (USR0)
char	RL4
short/int	R4
long	R4–R5 (R4 low word, R5 high word)
float	R4–R5
double	user stack and R4
structure	R4 or R4–R5 (near or far address)
near pointer	R4
far pointer	R4–R5 (R4 page offset, R5 page number)
huge pointer	R4–R5 (R4 segment offset, R5 segment number)
shuge pointer	R4–R5 (R4 segment offset, R5 segment number)

Table 3-12: Register usage for function return types

Special case single precision 0.0

0.0 is stored as:

s0000000000000000	0000000000000000
seeeeeeeemmmmmm	mmmmmmmmmmmmmmmm
s = sign, e = exponent, m = mantissa	

Notice that there is a +0.0 and a -0.0.

Special case single precision NaN (Not a Number)

Generated when the result of an expression is undefined e.g. 0.0 / 0.0.

NaN is stored as:

s1111111111111111	1111111111111111
seeeeeeeemmmmmm	mmmmmmmmmmmmmmmm
s = sign, e = exponent, m = mantissa	

According to the IEEE standard not all mantissa bits have to be set for a number to be handled as NaN.

Special case single precision INF (Infinity)

Generated when the result of an expression is larger than can be stored, e.g. 1.0e30f * 1.0e30f.

INF is stored as:

s1111111100000000	0000000000000000
seeeeeeeemmmmmm	mmmmmmmmmmmmmmmm
s = sign, e = exponent, m = mantissa	

Sign defines +INF or -INF.

Basic double precision format

Double precision numbers are stored comparable with single precision numbers.

Basic format double precision number:

seeeeeeeeeemmm	mmmmmmmmmmmmmmmm	mmmmmmmmmmmmmmmm	mmmmmmmmmmmmmmmm
s = sign, e = exponent, m = mantissa			

The formula for double precision floating point numbers is:

$$\text{value} = (-1)^s \cdot \left(1 + \frac{m}{2^{52}}\right) \cdot 2^{e-1023}$$

3.15.3 STORAGE IN MEMORY

Floating-point numbers are stored in IEEE754-format. Single precisions (float) and double precision (double) are stored in memory as shown below:

Address	+0	+1	+2	+3	+4	+5	+6	+7
Single	emmmmmmm	seeeeeee	mmmmmmmm	mmmmmmmm
Double	eeemmmmm	seeeeeee	mmmmmmmm	mmmmmmmm	mmmmmmmm	mmmmmmmm	mmmmmmmm	mmmmmmmm
s = sign, e = exponent, m = mantissa, . = not used								

Single precisions numbers can be stored in a register pair. In this case the format is:

First register	Second register
seeeeeeeeeemmmmmmm	mmmmmmmmmmmmmmmm
s = sign, e = exponent, m = mantissa	

Double precisions numbers are never stored in registers.

3.15.4 SINGLE PRECISION USAGE

Floats can be stored in memory and in registers. The floating point library subroutines pass operands and return value through registers.

3.15.4.1 FLOAT BASE EXPRESSION SUBROUTINES

Operands, return value

The first operand is stored in R4/R5 in IEEE-754 format:

R4	R5
seeeeeeeeeeeeeeeee	mmmmmmmmmmmmmmmm
s = sign, e = exponent, m = mantissa	

The second operand is stored in R10/R11:

R10	R11
seeeeeeeeeeeeeeeee	mmmmmmmmmmmmmmmm
s = sign, e = exponent, m = mantissa	

The result is stored in R4/R5 again:

R4	R5
seeeeeeeeeeeeeeeee	mmmmmmmmmmmmmmmm
s = sign, e = exponent, m = mantissa	

Available float base expression subroutines

Subroutine	Operation	Operands	Result
__adf4r	float addition	R4R5, R10R11	R4R5
__cmf4r	float comparison	R4R5, R10R11	R4
__dvf4r	float division	R4R5, R10R11	R4R5
__mlf4r	float multiplication	R4R5, R10R11	R4R5
__sbf4r	float subtraction	R4R5, R10R11	R4R5

Table 3-13: Float base expression subroutines

3.15.4.2 FLOAT CONVERSION SUBROUTINES

Operands, return value

The single precision operand or return value is stored in R4/R5:

R4	R5
seeeeeeeeemmmmmmm	mmmmmmmmmmmmmmmm
s = sign, e = exponent, m = mantissa	

Available float conversion subroutines

Subroutine	Operation	Operands	Result
__cff48r ^{*1}	float to double conversion	R4R5	[R10+#*]
__cff84r	double to float conversion	[R10+#*]	R4R5
__cfi42r	float to signed int conversion	R4R5	R4
__cfi44r	float to signed long conversion	R4R5	R5R4 ^{*2}
__cfu42r	float to unsigned int conversion	R4R5	R4
__cfu44r	float to unsigned long conversion	R4R5	R5R4 ^{*2}
__cif24r	signed int to float conversion	R4	R4R5
__cif44r	signed long to float conversion	R5R4 ^{*2}	R4R5
__cuf24r	unsigned int to float conversion	R4	R4R5
__cuf44r	unsigned long to float conversion	R5R4 ^{*2}	R4R5

Table 3-14: Float conversion subroutines



*1= Return value on the user stack

*2=R5R4 means that the most significant word is stored in R5.

There is no negation subroutine. Its functionality can be achieved by
"BMOVN R4.15, R4.15".

3.15.4.3 REGISTER USAGE SINGLE PRECISION

The only registers destroyed by the single precision subroutines are R1-R5 and R10-R11.

3.15.5 DOUBLE PRECISION USAGE

Double precision numbers are stored in memory. The floating point library passes operands and return values on the user stack.

3.15.5.1 DOUBLE BASE EXPRESSION SUBROUTINES

Operands, return value

The first operand is stored in IEEE-754 format on the user stack and referred to by R10:

[R10+#0]	[R10+#2]	[R10+#4]	[R10+#6]
seeeeeeeeeemmm	mmmmmmmmmmmmmmmm	mmmmmmmmmmmmmmmm	mmmmmmmmmmmmmmmm
s = sign, e = exponent, m = mantissa			

The second operand on the user stack is referred to by R11:

[R11+#0]	[R11+#2]	[R11+#4]	[R11+#6]
seeeeeeeeeemmm	mmmmmmmmmmmmmmmm	mmmmmmmmmmmmmmmm	mmmmmmmmmmmmmmmm
s = sign, e = exponent, m = mantissa			

The result is stored in the user stack area referred to by R10:

[R10+#0]	[R10+#2]	[R10+#4]	[R10+#6]
seeeeeeeeeemmm	mmmmmmmmmmmmmmmm	mmmmmmmmmmmmmmmm	mmmmmmmmmmmmmmmm
s = sign, e = exponent, m = mantissa			

Available double base expression subroutines

Subroutine	Operation	Operands	Result
__adf8r	double addition	[R10+#*], [R11+#*]	[R10+#*]
__cmf8r	double comparison	[R10+#*], [R11+#*]	R4
__dvf8r	double division	[R10+#*], [R11+#*]	[R10+#*]
__mlf8r	double multiplication	[R10+#*], [R11+#*]	[R10+#*]
__ngf8r	double negation	[R10+#*]	[R10+#*]
__sbf8r	double addition	[R10+#*], [R11+#*]	[R10+#*]

Table 3-15: Double base expression subroutines



3.15.5.2 DOUBLE CONVERSION SUBROUTINES

Operands, return value

The double precision operand or return value is referred to by R10:

[R10+#0]	[R10+#2]	[R10+#4]	[R10+#6]
seeeeeeeeeemmm	mmmmmmmmmmmmmmmm	mmmmmmmmmmmmmmmm	mmmmmmmmmmmmmmmm
s = sign, e = exponent, m = mantissa			

Available double conversion subroutines

Subroutine	Operation	Operands	Result
__cff48r *1	float to double conversion	R4R5	[R10+#*]
__cff84r	double to float conversion	[R10+#*]	R4R5
__cfi82r	double to signed int conversion	[R10+#*]	R4
__cfi84r	double to signed long conversion	[R10+#*]	R5R4 *2
__cfu82r	double to unsigned int conversion	[R10+#*]	R4
__cfu84r	double to unsigned long conversion	[R10+#*]	R5R4 *2
__cif28r *1	signed int to double conversion	R4	[R10+#*]
__cif48r *1	signed long to double conversion	R5R4 *2	[R10+#*]
__cuf28r *1	unsigned int to double conversion	R4	[R10+#*]
__cuf48r *1	unsigned long to double conversion	R5R4 *2	[R10+#*]

Table 3-16: Double conversion subroutines



*1 Return value on the user stack

*2 R5R4 means that the most significant word is stored in R5.

3.15.5.3 DOUBLE SUPPORT SUBROUTINES

Doubles can be stored anywhere in memory (near/far/huge/shuge) but the floating point library expects them to be on the user stack. This is why some library subroutines were implemented for fast copying of doubles to and from user stack.

`__load8n`, `__load8f` and `__load8h` copy doubles from near, far or (s)huge area to the user stack space allocated by these routines themselves. These routines change the user stack pointer and return a register pointer to the user stack.

`__store8n`, `__store8f` and `__store8h` copy doubles from the user stack to near, far, huge or shuge. These routines do not free the user stack space allocated by `__load8x`.

`__ld0f8r` and `__ld1f8r` allocate user stack similar to `__load8x` and copy the value 0.0 or 1.0 to this area.

Available double support subroutines

Subroutine	Operation	Operands	Result
<code>__load8f</code>	copy double to user stack (far)	R5R4 * ¹	R10
<code>__load8h</code>	copy double to user stack (huge/shuge)	R5R4 * ¹	R10
<code>__load8n</code>	copy double to user stack (near)	R4	R10
<code>__ld0f8r</code>	create 0.0 on allocated user stack	None	R10
<code>__ld1f8r</code>	create 1.0 on allocated user stack	None	R10
<code>__store8f</code>	copy double from user stack to far	R10, R5R4 * ¹	None, destroys R10
<code>__store8h</code>	copy double from user stack to huge/shuge	R10, R5R4 * ¹	None, destroys R10
<code>__store8n</code>	copy double from user stack to near	R10, R4	None, destroys R10

Table 3-17: Double support subroutines



*¹R5R4 means that the most significant word is stored in R5.

3.15.5.4 REGISTER USAGE DOUBLE PRECISION

The only registers destroyed by the normal double precision subroutines are R1–R5. The input operands [R10+##*] and [R11+##*] are destroyed. R10 and R11 keep their value though, except for routines converting to double.

Usually `__load8x` and `__store8x` are also called. `__load8x` changes R0–R5 and R10, `__store8x` changes R1–R5 and R10. The subroutines `__ldxf8r` change R0–R5 and R10.

3.15.6 FLOAT/DOUBLE USAGE FOR ASSEMBLY PROGRAMMERS

Example of float usage for assembly programmers

```

; Create functionality of C expression:
; flt1 += (float) 4 * PI;
    MOV    R4, #4           ; R4 contains int 4
    CALLA cc_UC, __cif24r  ; convert int 4 to float 4.0 (R4R5)
    MOV    R10, PI         ;
    MOV    R11, (PI+2)    ;
;
;                               ; R4R5: 4.0
;                               ; R10R11: PI
    CALLA cc_UC, __mlf4r   ; multiplication, result stored in R4R5
    MOV    R10, _flt1     ;
    MOV    R11, (_flt1+2) ;
;
;                               ; R4R5: 4.0 * PI
;                               ; R10R11: copy of _flt1
    CALLA cc_UC, __adf4r   ; addition, result stored in R4R5
    MOV    _flt1, R4      ;
    MOV    (_flt1+2), R5   ; save result

PI: DW    04049h, 00FDBh  ; 3.141592654 (IEEE754-format)

; Registers not destroyed in this code fragment: R0, R6–R9, R12–R15

```

Example of double usage for assembly programmers

```

; Create functionality of C expression:
; dbll += (double) 4 * PI;
        MOV    R4, #4           ; R4 contains int 4
allo1:  CALLA  cc_UC, __cif28r   ; convert int 4 to double 4.0
;                                     ; ([R10+#*])
        MOV    R11, R10        ; copy pointer to 4.0 to R11
        MOV    R4, #PI         ; pointer to PI (source address)
allo2:  CALLA  cc_UC, __load8n   ; copy PI to new allocated stack
;                                     ; ([R10+#*])
;                                     ; [R10+#*]: PI (user stack)
;                                     ; [R11+#*]: 4.0 (user stack)
        CALLA  cc_UC, __mlf8r   ; multiplication, result stored
;                                     ; in [R10+#*]
        MOV    R11, R10        ; copy pointer to 4.0 * PI to R11
        MOV    R4, #dbll       ;
allo3:  CALLA  cc_UC, __load8n   ; copy_dbll to new allocated stack
;                                     ; ([R10+#*])
;                                     ; [R10+#*]: copy of _dbl (user stack)
;                                     ; [R11+#*]: 4.0 * PI (user stack)
        CALLA  cc_UC, __adf8r   ; addition, result stored in [R10+#*]
        MOV    R4, #dbll       ; destination address in R4
        CALLA  cc_UC, __store8n ; copy result to _dbl1
        ADD    R0, #24         ; restore stack
;                                     ; stack allocated by lines allo*.

PI:     DW     04009h, 021FBh   ; 3.141592654 (IEEE754-format)
        DW     05452h, 04550h   ;

; Registers not destroyed in this code fragment: R0, R6-R9,
; R12-R15.

```

3.15.7 FLOATING POINT TRAPPING

Two sets of floating point libraries are delivered with the compiler, one with a floating point trapping mechanism and one without a floating point trapping mechanism (the chapter *Libraries* explains the naming conventions).

The floating point libraries with a trapping mechanism call a trapping routine which is in module trap.obj. You can replace this routine with your own trapping routine, or link your own trap routine to your application. Default, the trapping routine as delivered with the floating point libraries will never return. The infinite loop on a public label called `__FPTRAPLOOP` is easy to find in a debug session. See the listing of the trap handler in figure 3-5 of section 3.15.8, *Handling Floating Point Traps in a C Application*.

A floating point routine calls the trap routine if an error condition occurs. The type of error is specified by a trap code which is passed via register R1 to the trap routine. The result of a floating point operation is not undefined in an error situation. On error the result will be a special floating point number, such as infinite, not a number etc., except when a floating point underflow or overflow occurs.

The following table lists all the trap codes and the corresponding error description and result:

Error Description	Trap code	Result float/(unsigned) integer
Integer overflow	3	0x7FFF or 0x8000 (integer result) 0xFFFF or 0x0000 (unsigned integer result)
Floating overflow	4	+INF or -INF (float result)
Floating underflow	5	0.0 (float result)
Divide by zero	7	+INF or -INF or NaN (float result)
Undefined float	9	NaN (float result)
Conversion error	10	0 (integer result)
INF	Infinite which is the largest absolute floating point number.	
NaN	Not a Number, special notation for undefined floating point number.	

Table 3-18: Trap Codes

3.15.8 HANDLING FLOATING POINT TRAPS IN A C APPLICATION

This section explains how program execution can be continued after a floating point trap. And how floating point trap codes are passed from the floating point trap handler to a C application.

Only the floating point libraries which perform floating point trapping contain a floating point trap stub. This floating point trap stub loops infinitely, which is very helpful when you want to find a bug in your application. But when it is expected or allowed or even wanted that floating point operations generate results that are out of range, then program execution must continue after entering the floating point trap handler.

It is not possible to simply return from the floating point trap handler, because the floating point accumulator(s) contain a value which is out of range. In the same floating point operation or else in a next floating point operation there will be another call to the floating point trap handler, because the value in the floating point accumulator(s) remain out of range. This results in a succession of floating point traps.

It is impossible to assign a value to the floating point accumulator(s) which is in range and then continue program execution. If you try to assign a value to the floating point accumulators the result will always be undefined.

Interpretation of the error condition in the floating point trap handler and then continuing the floating point operation will result in most cases in a new error condition or unpredictable result. So, this is not a good solution to handle floating point error situations.

It is better to stop immediately the floating point operation which causes the floating point trap, by returning back to your application and there decide what to do with the floating point error condition. Therefore, you have to predefine an environment in your application to return to. Simply jumping back is not possible because the system-stack and user-stack are then corrupted. The floating point trap code must also be returned to the application to examine the cause of the trap.

An environment to return to in an application can be saved with the C library function `set jmp`. The C library function `long jmp` can be used in the floating point trap handler to return immediately to this saved environment. The `long jmp` restores the stack pointers, jumps back and passes the trap code to be processed.

The C listing below shows how to save an environment with `setjmp`. The assembly listing of the floating point trap handler below shows how `longjmp` is used to return to the saved environment.

There are several ways to write a C function which handles floating point traps using `setjmp` and `longjmp`. Always keep in mind that the `longjmp` function restores the environment saved by the most recent invocation of the `setjmp` function. And the environment must be saved before the `longjmp` function is called by the floating point trap handler, else program execution will be undefined.

```
/*
 * Example program which handles floating point traps by printing
 * the floating point trap code on stdout. See, also floating point
 * trap handler in module trap.asm
 */
#include <stdio.h>
#include <setjmp.h>

/* Floating point environment buffer declared in trap handler */
extern jmp_buf _FP_ENV;

void
main( void )
{
    int exception;

    /*
     * Do not use floating point operations before this if
     * statement, because there is no environment saved to jump to.
     * The trap handler loops infinite when a floating
     * point operation is called from this point which traps!
     */
    /*
     * When the setjmp function has saved the environment it returns
     * zero into the exception variable, so the floating point
     * operations are executed. But if a floating point trap occurs,
     * the trap handler calls the function longjmp.
     * The longjmp function restores the environment and returns the
     * trap code in the exception variable. The trap code is a
     * non-zero value, so the else part of this if statement will be
     * executed on a floating point trap.
     */
    if( !( exception = setjmp( _FP_ENV ) ) )
    {
        /*
         * Insert your floating point operations here.
         */
    } else
    {
        /* The exception code is a non-zero value. */
        printf("Floating point exception: %d\n", exception );
    }

    /*
     * When there is a floating point operation after this if
     * statement and it generates a floating point trap. Then the
     * program execution also continues in the else part of this if
     * statement, because the environment buffer was saved to it !
     */
}
}
```

Figure 3-5: Example floating point trap handling (C listing)



The floating point trap handler described by the assembly listing in figure 3-6 is archived in the floating point libraries.

```

$case
$genonly
;*****
;*
;* MODULE      : trap.asm
;*
;* APPLICATION : Floating point library 80166
;*
;* DESCRIPTION : Floating point trap handler which uses longjmp to
;*               return to a previous saved environment or loops
;*               infinite when no environment is save to return to.
;*
;* INPUT       : Register R1 contains the trap code
;*
;*   Trap code   R1,old  R1,IEEE  Description
;*   EIOVFL      4       3        ; Integer overflow
;*   EFOVFL      4       4        ; Float overflow
;*   EFUNFL      5       8        ; Float underflow
;*   EFDIVZ      7       2        ; Float division by zero
;*   EFUND/EFINVOP 9       1        ; Float invalid operation
;*   ECONV       10      32       ; Conversion error
;*   ESTKUN      11              ; Floating point stack underflow
;*   ESTKOV      12              ; Floating point stack overflow
;*   EFINEXCT   16              ;
;*
;* ANALIST      : Guus Jansman
;*
;* COPYRIGHTS   : Tasking B.V., Amersfoort 2000
;*
;*****
$INCLUDE( head.asm )

@IF( @NES(@MODEL,"TINY") & @NES(@MODEL,"SMALL") )
ASSUME  DPP2:__FP_ENV      ; near data addressed via DPP2
@ENDI

PUBLIC __fptrap8          ; public declaration trapping routine
                          ; for double precision.

PUBLIC __fptrap4          ; public declaration trapping routine
                          ; for single precision.

PUBLIC __FP_ENV           ; public declaration floating point
                          ; environment buffer

PUBLIC __FPTRAPLOOP      ; public declaration trap loop

@IF( @EQS(@MODEL,"TINY") | @EQS(@MODEL,"MEDIUM") )
EXTERN _longjmp:NEAR
@ELSE
EXTERN _longjmp:FAR

```

```

@ENDI

__FP_CODE SECTION CODE WORD PUBLIC 'CPROGRAM'

;*****
;*****
;* floating point trap handler
;*****
;*****
@IF( @EQS(@MODEL,"TINY") | @EQS(@MODEL,"MEDIUM") )
__fptrap8 PROC NEAR
@ELSE
__fptrap8 PROC FAR
@ENDI
__fptrap4: ; entry floating point trapping routine for single
           ; precision operations.

           : There is no environment to return to, when the longjump return

           ; address is not set in the floating point jump buffer.
           mov R12, (__FP_ENV) ;if( __FP_ENV.return_address == NULL )
@IF( @NES(@MODEL,"TINY") & @NES(@MODEL,"MEDIUM") )
           or R12, (__FP_ENV+2);
@ENDI
           jmp r cc_Z, __FPTRAPLOOP ; goto infinite loop

@IF( @EQS(@MODEL,"TINY") | @EQS(@MODEL,"SMALL") )
           mov R12, #__FP_ENV ; R12 passes environment address
           ; buffer to longjmp
           mov R13, fptrap ; R13 passes trap code to longjmp
@IF( @FPEXC_OP )
           mov R14, fpexcop ; R14 passes exception operation
@ENDI
@ELSE
           mov R12, #POF (__FP_ENV) ; R12-R13 passes environment address
           mov R13, #PAG (__FP_ENV) ; buffer to longjmp
           mov R14, fptrap ; R14 passes trap code to longjmp
@IF( @FPEXC_OP )
           mov R15, fpexcop ; R15 passes exception operation
@ENDI
@ENDI

; restore environment loaded in the environment buffer __FP_ENV and
; return the trap code by calling longjmp
@IF( @EQS(@MODEL,"TINY") | @EQS(@MODEL,"MEDIUM") )
           jmpa cc_UC, _longjmp
@ELSE
           @_STBUS1( _longjmp )
@ENDI

           ; loop infinite if no environment set to return to.
__FPTRAPLOOP:
           jmpa CC_UC, __FPTRAPLOOP

```

```

    RETV                ; virtual return

__fptrap8 ENDP

__FPCODE    ENDS

;*****
;* data section for floating point environment buffer which is
;* cleared
;* at startup with C166_BSS. jmp_buf _FP_ENV;
;*****
@IF( @EQS(@MODEL, "TINY") | @EQS(@MODEL, "SMALL" ) )
__FP_ENV_BUF SECTION LDAT WORD PUBLIC 'CNEAR'
@ELSE
__FP_ENV_BUF SECTION DATA WORD PUBLIC 'CNEAR'
@ENDI
__FP_ENV LABEL WORD
    DS 16                ; sizeof( jmp_buf )
__FP_ENV_BUF ENDS

@IF( @EQS(@MODEL, "TINY" ) )
C166_BSS SECTION LDAT WORD GLOBAL 'CINITROM'
    DW 05h                ; init code 05, linear data
    DW __FP_ENV           ; start address buffer
    DW 16                 ; number of bytes to clear
C166_BSS ENDS
@ENDI
@IF( @EQS(@MODEL, "SMALL" ) )
C166_BSS SECTION PDAT WORD GLOBAL 'CINITROM'
    DW 06h                ; init code 06, paged data
    DPPTR __FP_ENV        ; start address buffer
    DW 16                 ; number of bytes to clear
C166_BSS ENDS
@ENDI
@IF( @NES(@MODEL, "TINY") & @NES(@MODEL, "SMALL" ) )
C166_DGROUP DGROUP __FP_ENV_BUF ; add to default data group
C166_BSS SECTION DATA WORD GLOBAL 'CINITROM'
    DW 06h                ; init code 06, paged data
    DPPTR __FP_ENV        ; start address buffer
    DW 16                 ; number of bytes to clear
C166_BSS ENDS
@ENDI

@IF( @EQS(@MODEL, "TINY") | @EQS(@MODEL, "SMALL" ) )
    REGDEF R1, R12-R13
@ELSE
    REGDEF R1, R12-R14
@ENDI

    END

```

Figure 3-6: Floating point trap handling (assembly-listing)

The floating point trap handler checks if an environment is set in `__FP_ENV` to return to. When the return address contains a NULL pointer it is supposed that there is no environment set and the trap handler continues looping infinitely. When a return address is set, the address of the jump buffer `__FP_ENV` and the trap code are passed to `long jmp`. Calling the `long jmp` function at the end of the trap handler restores the environment saved in `__FP_ENV`.

The data section containing the floating point jump buffer `__FP_ENV` is cleared at startup. The initialization codes for it are stored in the `C166_BSS` sections.

There are two entry points available in the floating point trap handler, one for double precision floating point functions causing a trap, and one for single precision floating point functions causing a trap. This default trap handler is precision independent, but if you want to write a trap handler for each precision you need these two entry points.

You can use your own floating point trap handler by linking the object module, overruling the floating point trap handler of the floating point library. Or you can replace the floating point trap object module in the floating point library with the object module of your own floating point trap handler.

3.16 INTRINSIC FUNCTIONS

When you want to use specific C166/ST10 instructions that have no equivalence in C, you normally must write (inline) assembly to perform these tasks. However, **c166** offers a way of handling this in C. The **c166** has a number of built-in functions that are implemented as intrinsic functions. The advantage of this approach is that the same C source can be compiled by a standard ANSI C compiler for simulator purposes. See the section *Portable C Code* for details.

Because the ANSI specification states that public C names starting with an underscore are implementation defined, all intrinsic functions names have a leading underscore.

Several of the intrinsic functions have restricted operand types. There are two possible restricted types. The first is called ICE which denotes that the operand must be a Integral Constant Expression rather than any type of integral expression, this is because the BMOV instruction et al do not support otherwise. The second is called BITADDR which means that the operand must be a bit addressable integer (i.e. bitword, bitaddressable sfr or bitaddressable esfr) object.

c166 has the following intrinsic functions:

CoABS

```
void _CoABS( void );
```

Use the CoABS instruction to change the MAC accumulator's contents to its absolute value. Only available when the MAC instruction set is enabled with the compiler option **-xd**.

Returns nothing.

```
_CoABS( );  
CoABS
```

_CoADD

```
void _CoADD( long x );
```

Use the CoADD instruction to add a 32-bit value to the MAC accumulator. Only available when the MAC instruction set is enabled with the compiler options **-xd**.

Returns nothing.

```
_CoADD( arg1 );  
CoADD R12, R13
```

_CoADD2

```
void _CoADD2( long x );
```

Use the CoADD2 instruction to add a 32-bit value, multiplied by two, to the MAC accumulator. Only available when the MAC instruction set is enabled with the compiler option **-xd**.

Returns nothing.

```
_CoADD2( arg1 );  
CoADD2 R12, R13
```

_CoASHR

```
void _CoASHR( unsigned int count );
```

Use the CoASHR instruction to (arithmetic) shift right the contents of the MAC accumulator *count* times. Only available when the MAC instruction set is enabled with the compiler option **-xd**.

The CoASHR instruction has a maximum value for *count*. Check your CPU manual for the CoASHR behaviour for large arguments.

Returns nothing.

```
_CoASHR( 2 );  
CoASHR #02h
```

_CoCMP

```
unsigned int _CoCMP( long x );
```

Inline code is generated by the C compiler to compare the MAC accumulator contents with a 32-bit value. The returned value is a copy of the MSW register. Only available when the MAC instruction set is enabled with the compiler option **-xd**.

Returns copy of MSW register.

```
isequal = _CoCMP( arg1 ) & 0x0200;
CoCMP R12, R13
CoSTORE R4, MSW
AND R4, #0200h
```

_CoLOAD

```
void _CoLOAD( long x );
```

Use the CoLOAD instruction to copy a 32-bit value to the MAC accumulator. Only available when the MAC instruction set is enabled with the compiler option **-xd**.

Returns nothing.

```
_CoLOAD( arg1 );
CoLOAD R12, R13
```

_CoLOAD2

```
void _CoLOAD2( long x );
```

Use the CoLOAD2 instruction to copy a 32-bit value, multiplied by two, to the MAC accumulator. Only available when the MAC instruction set is enabled with the compiler option **-xd**.

Returns nothing.

```
_CoLOAD2( arg1 );
CoLOAD2 R12, R13
```

_CoMAC

```
void _CoMAC( int x, int y );
```

Use the CoMAC instruction to add the multiplication result of two signed 16-bit values to the MAC accumulator. Only available when the MAC instruction set is enabled with the compiler option **-xd**. Note that the MP flag influences the result (it is highly recommended to keep the MP flag cleared).

Returns nothing.

```
_CoMAC( arg1, arg2 );  
CoMAC R12, R13
```

_CoMACsu

```
void _CoMACsu( int x, unsigned int y );
```

Use the CoMACsu instruction to add the multiplication result of a signed 16-bit value with an unsigned 16-bit value to the MAC accumulator. Only available when the MAC instruction set is enabled with the compiler option **-xd**.

Returns nothing.

```
_CoMACsu( arg1, arg2 );  
CoMACsu R12, R13
```

_CoMACu

```
void _CoMACu( unsigned int x, unsigned int y );
```

Use the CoMACu instruction to add the multiplication result of two unsigned 16-bit values to the MAC accumulator. Only available when the MAC instruction set is enabled with the compiler option **-xd**.

Returns nothing.

```
_CoMACu( arg1, arg2 );  
CoMACu R12, R13
```

_CoMAC_min

```
void _CoMAC_min( int x, int y );
```

Use the CoMAC- instruction to subtract the multiplication result of two signed 16-bit values from the MAC accumulator. Only available when the MAC instruction set is enabled with the compiler option **-xd**. Note that the MP flag influences the result (it is highly recommended to keep the MP flag cleared).

Returns nothing.

```
_CoMAC_min( arg1, arg2 );  
CoMAC- R12, R13
```

_CoMACsu_min

```
void _CoMACsu_min( int x, unsigned int y );
```

Use the CoMACsu- instruction to subtract the mulatiplication result of a signed 16-bit value with an unsigned 16-bit value from the MAC accumulator. Only available when the MAC instruction set is enabled with the compiler option **-xd**.

Returns nothing.

```
_CoMACsu_min( arg1, arg2 );  
CoMACsu- R12, R13
```

_CoMACu_min

```
void _CoMACu_min( unsigned int x, unsigned int y );
```

Use the CoMACu- instruction to subtract the multiplication result of two unsigned 16-bit values from the MAC accumulator. Only available when the MAC instruction set is enabled with the compiler option **-xd**.

Returns nothing.

```
_CoMACu_min( arg1, arg2 );  
CoMACu- R12, R13
```

_CoMAX

```
void _CoMAX( long x );
```

Use the CoMAX instruction to change the MAC accumulator's contents if its value is lower than the argument's value. Only available when the MAC instruction set is enabled with the compiler option **-xd**.

Returns nothing.

```
_CoMAX( arg1 );  
CoMAX R12, R13
```

_CoMIN

```
void _CoMIN( long x );
```

Use the CoMIN instruction to change the MAC accumulator's contents if its value is higher than the argument's value. Only available when the MAC instruction set is enabled with the compiler option **-xd**.

Returns nothing.

```
_CoMIN( arg1 );  
CoMIN R12, R13
```

_CoMUL

```
void _CoMUL( int x, int y );
```

Use the CoMUL instruction to store the multiplication result of two signed 16-bit values in the MAC accumulator. Only available when the MAC instruction set is enabled with the compiler option **-xd**. Note that the MP flag influences the result (it is highly recommended to keep the MP flag cleared).

Returns nothing.

```
_CoMUL( arg1, arg2 );  
CoMUL R12, R13
```

_CoMULsu

```
void _CoMULsu( int x, unsigned int y );
```

Use the CoMULsu instruction to store the multiplication result of a signed 16-bit value with an unsigned 16-bit value in the MAC accumulator. Only available when the MAC instruction set is enabled with the compiler option **-xd**.

Returns nothing.

```
_CoMULsu( arg1, arg2 );  
CoMULsu R12, R13
```

_CoMULu

```
void _CoMULu( unsigned int x, unsigned int y );
```

Use the CoMULu instruction to store the multiplication result of two unsigned 16-bit values in the MAC accumulator. Only available when the MAC instruction set is enabled with the compiler option **-xd**.

Returns nothing.

```
_CoMULu( arg1, arg2 );  
CoMULu R12, R13
```

_CoNEG

```
void _CoNEG( void );
```

Use the CoNEG instruction to change the MAC accumulator's contents to its negated value. Only available when the MAC instruction set is enabled with the compiler option **-xd**.

Returns nothing.

```
_CoNEG();  
CoNEG
```

_CoNOP

```
void _CoNOP( void );
```

A CoNOP instruction is generated. Only available when the MAC instruction set is enabled with the compiler option **-xd**.

Returns nothing.

```
_CoNOP();
CoNOP [R0]
```

_CoRND

```
void _CoRND( void );
```

Use the CoRND semi-instruction to change the MAC accumulator's contents to its rounded value. Only available when the MAC instruction set is enabled with the compiler option **-xd**.

Returns nothing.

```
_CoRND();
CoRND
```

_CoSHL

```
void _CoSHL( unsigned int count );
```

Use the CoSHL instruction to shift left the contents of the MAC accumulator *count* times. Only available when the MAC instruction set is enabled with the compiler option **-xd**.

The CoSHL instruction has a maximum value for *count*. Check your CPU manual for the CoSHL behaviour for large arguments.

Returns nothing.

```
_CoSHL( 2 );
CoSHL #02h
```

_CoSHR

```
void _CoSHR( unsigned int count );
```

Use the CoSHR instruction to (logical) shift right the contents of the MAC accumulator *count* times. Only available when the MAC instruction set is enabled with the compiler option **-xd**.

The CoSHR instruction has a maximum value for *count*. Check your CPU manual for the CoSHR behaviour for large arguments.

Returns nothing.

```
_CoSHR( 2 );
CoSHR  #02h
```

_CoSTORE

```
long _CoSTORE( void );
```

Use the CoSTORE instruction to retrieve the 32-bit value, stored in the MAC accumulator MAH and MAL. Only available when the MAC instruction set is enabled with the compiler option **-xd**.

Returns 32-bit value from MAH and MAL.

```
x = _CoSTORE();
CoSTORE R13, MAH
CoSTORE R12, MAL
```

_CoSTOREMAH

```
int _CoSTOREMAH( void );
```

Use the CoSTORE instruction to retrieve the 16-bit value, stored in MAH. Only available when the MAC instruction set is enabled with the compiler option **-xd**.

Returns 16-bit value from MAH

```
x = _CoSTOREMAH();
CoSTORE R12, MAH
```

_CoSTOREMAL

```
int _CoSTOREMAL( void );
```

Use the CoSTORE instruction to retrieve the 16-bit value, stored in MAL. Only available when the MAC instruction set is enabled with the compiler option **-xd**.

Returns 16-bit value from MAL

```
x = _CoSTOREMAL();  
CoSTORE R12, MAL
```

_CoSTOREMAS

```
int _CoSTOREMAS( void );
```

Use the CoSTORE instruction to retrieve the 16-bit value, stored in MAS. Only available when the MAC instruction set is enabled with the compiler option **-xd**.

Returns 16-bit value from MAS

```
x = _CoSTOREMAS();  
CoSTORE R12, MAS
```

_CoSTOREMSW

```
int _CoSTOREMSW( void );
```

Use the CoSTORE instruction to retrieve the 16-bit value, stored in MSW. Only available when the MAC instruction set is enabled with the compiler option **-xd**.

Returns 16-bit value from MSW.

```
x = _CoSTOREMSW();  
CoSTORE R12, MSW
```

_CoSUB

```
void _CoSUB( long x );
```

Use the CoSUB instruction to subtract a 32-bit value from the MAC accumulator. Only available when the MAC instruction set is enabled with the compiler options **-xd**.

Returns nothing.

```
_CoSUB( arg1 );
CoSUB R12, R13
```

_CoSUB2

```
void _CoSUB2( long x );
```

Use the CoSUB2 instruction to subtract a 32-bit value, multiplied by two, from the MAC accumulator. Only available when the MAC instruction set is enabled with the compiler option **-xd**.

Returns nothing.

```
_CoSUB2( arg1 );
CoSUB2 R12, R13
```

_rol

```
unsigned int _rol( unsigned int operand,
                  unsigned int count );
```

Use the ROL instruction to rotate (left) *operand* *count* times.

Returns the result.

```
sj = _rol( ri, 4 );
MOV R5, R9
ROL R5, #04h
MOV _sj, R5
```

_ror

```
unsigned int _ror( unsigned int operand,
                  unsigned int count );
```

Use the ROR instruction to rotate (right) *operand* *count* times.

Returns the result.

```
    sj = _ror( si, pi );
MOV   R4,_si
ROR   R4,R12
MOV   _sj,R4
```

_testclear

```
_bit _testclear( _bit semaphore );
```

Read and clear *semaphore* using the JBC instruction.

Returns 0 if *semaphore* was not cleared by the JBC instruction, 1 otherwise.

```
    if ( _testclear( b ) )
BSET  USR0
JBC   _b,_7
BCLR  USR0
_7:
JNB   USR0,_3
    { /* success: semaphore 'b' was free (1)
      * and now used for our critical region
      * (set to 0). Note that the code of this
      * action may be longer than 127 words
      */
      g();
CALLA cc_UC,_g
      b = 1; /* end critical actions: free
              * semaphore */
BSET  _b
    }
_3:
```

_testset

```
_bit _testset( _bit semaphore );
```

Read and set *semaphore* using the JNBS instruction.

Returns 0 if *semaphore* was not set by the JNBS instruction, 1 otherwise.

```
        if ( _testset( b ) )
BSET  USR0
JNBS  _b,_8
BCLR  USR0
_8:
JNB   USR0,_5
    { /* success: semaphore 'b' was free (0)
      * and now used for our critical region
      * (set to 1). Note that the code of this
      * action may be longer than 127 words
      */
      g();
CALLA cc_UC,_g
      b = 0;      /* end critical actions: free
                  * semaphore */
BCLR  _b
    }
_5:
```

_bfld

```
void _bfld( BITADDR operand, ICE mask, ICE value );
```

Use the BFLDL/BFLDH instructions to assign the constant *value* to the bit-field indicated by the constant *mask* of the bitaddressable *operand*.

```
    _bfld( bw, 0x7f, 1 );
BFLDL _bw,#07Fh,#01h
    _bfld( SOCON, 0x7f00, 0x100 );
BFLDH SOCON,#07Fh,#01h
    _bfld( bw, 0x03c0, 0x80 );
BFLDH _bw,#03h,#00h
BFLDL _bw,#0C0h,#080h
```

_getbit

```
_bit _getbit( BITADDR operand, ICE bitoffset );
```

Returns the bit at *bitoffset* (range 0 – 15) of the bitaddressable *operand* for usage in bit expressions.

```
        b = _getbit( P0, 0 );
BMOV  _b,P0.0
        IEN = _getbit( barray[2], 4 );
BMOV  IEN,_barray+4.4
```

_putbit

```
void _putbit( _bit value, BITADDR operand,
             ICE bitoffset );
```

Assign *value* to the bit at *bitoffset* (range 0 – 15) of the bitaddressable *operand*.

```
        _putbit( 1, P0, 3 );
BSET  P0.3
        _putbit( si, P0, 2 );
MOV   R4,_si
BMOVN P0.2,Z
        _putbit( _getbit( P0, 0 ), P0, 1 );
BMOV  P0.1,P0.0
```

_int166

```
void _int166( ICE intno );
```

Execute the C166/ST10 software interrupt specified by the interrupt number *intno* via the software trap (TRAP) instruction. `_int166(0);` emits an SRST (Software Reset) instruction.

```
        _int166( 4 );
TRAP  #04h
        _int166( 0 );
SRST
```

_idle

```
void _idle( void );
```

Use IDLE instruction to enter the idle mode. In this mode the CPU is powered down while the peripherals remain running.

Returns nothing.

```

        if( save_power )
MOV     R5,_save_power
JMPR   cc_Z,_12
        _idle(); /* wait until peripheral interrupt
                 * or external interrupt occurs.
                 */
        IDLE
_12:

```

_nop

```
void _nop( void );
```

A NOP instruction is generated, before and behind the nop instruction the peephole is flushed. Code generation for _nop() is exactly the same as the following inline assembly.

```

#pragma asm
        nop ; inline nop instruction
#pragma endasm

```

Returns nothing.

```

        value = P0; /* read from port P0 */
MOV     R12,P0
        _nop(); /* delay for one cycle */
NOP
        P1 = value; /* write to port P1 */
MOV     P1,R12

```

_prior

```
unsigned int _prior( unsigned int value );
```

Use PRIOR instruction to prioritize *value*.

Returns number of single bit shifts required to normalize *value* so that its MSB is set to one.

```
register int value;
extern int leading_zeros;

leading_zeros = _prior( value );
PRIOR R4,R12
MOV _leading_zeros,R4
```

_pwrdn

```
void _pwrdn( void );
```

Use PWRDN instruction to enter the power down mode. In this mode, all peripherals and the CPU are powered down until an external reset occurs.

Returns nothing.

```
        if( standby_mode )
MOV     R4,_standby_mode
JMPR   cc_Z,_13
        _pwrdn(); /* CPU is powered down until
                   * an external interrupt occurs.
                   */
PWRDN
_13:
```

_srvwdt

```
void _srvwdt( void );
```

Use SRVWDT instruction to service the watchdog timer.

Returns nothing.

```

        _srvwdt(); /* service watchdog before
                   * it overflows.
                   */
SRVWDT

```

__diswdt

```
void __diswdt( void );
```

Use DISWDT instruction to disable the watchdog timer.

Returns nothing.

```

        __diswdt(); /* disable watchdog timer */
DISWDT

```

__einit

```
void __einit( void );
```

Use EINIT instruction to end the initialization.

Returns nothing.

```

        __einit(); /* end of initialization */
EINIT

```

__atomic

```
void __atomic( ICE number );
```

Use ATOMIC instruction to let interrupts be disabled for a specified number of instructions (*number*=[1..4]). Only available when the extended instruction set is enabled with the compiler option **-x**.

Returns nothing.

```

        __atomic( 3 ); /* next 3 instructions are
                       * not interrupted.
                       */
ATOMIC #03h

```

_mul32

```
long _mul32( int x, int y );
```

Use MUL instruction to perform a 16-bit by 16-bit signed multiplication and returning a signed 32-bit result. The overflow bit V is set by the CPU when the result cannot be represented in a long data type.

Returns the result when no overflow occurs.

_mulu32

```
unsigned long _mulu32( unsigned int x,  
                      unsigned int y );
```

Use MULU instruction to perform a 16-bit by 16-bit unsigned multiplication and returning a unsigned 32-bit result. The overflow bit V is set by the CPU when the result cannot be represented in a long data type.

Returns the result when no overflow occurs.

_div32

```
int _div32( long x, int y );
```

Use DIVL instructions to perform a 32-bit by 16-bit signed division and returning a signed 16-bit result. The overflow bit V is set by the CPU when the result cannot be represented in an int data type or when the divisor y was zero.

Returns the result when no overflow occurs.

_divu32

```
unsigned int _divu32( unsigned long x,  
                     unsigned int y );
```

Use DIVLU instructions to perform a 32-bit by 16-bit unsigned division and returning an unsigned 16-bit result. The overflow bit V is set by the CPU when the result cannot be represented in an int data type or when the divisor y was zero.

Returns the result when no overflow occurs.

_mod32

```
int _mod32( long x, int y );
```

Use DIVL instructions to perform a 32-bit by 16-bit signed modulo and returning a signed 16-bit result. The overflow bit V is set by the CPU when the quotient cannot be represented in an int data type or when the divisor y was zero.

Returns the result when no overflow occurs.

_modu32

```
unsigned int _modu32( unsigned long x,
                    unsigned int y );
```

Use DIVLU instructions to perform a 32-bit by 16-bit unsigned modulo and returning an unsigned 16-bit result. The overflow bit V is set by the CPU when the quotient cannot be represented in an int data type or when the divisor y was zero.

Returns the result when no overflow occurs.

```
int muldiv32( int arg1, int arg2, int divisor );
```

```
    long m32;
```

```
    int d32;
```

```
    if ( m32 = _mul32( arg1, arg2 ), V )
```

```
MOV   R8,R12
```

```
MUL   R8,R13
```

```
MOV   R9,MDH
```

```
MOV   R8,MDL
```

```
JNB   V,_14
```

```
        errno = OVERFLOW;
```

```
MOV   R4,#01h
```

```
MOV   _errno,R4
```

```
_14:
```

```
    if( d32 = _div32( m32, divisor ), V )
```

```
MOV   R15,R14
```

```
MOV   MDH,R9
```

```
MOV   MDL,R8
```

```
DIVL  R15
```

```

MOV    R15,MDL
JNB    V,_15
        errno = OVERFLOW;
MOV    R4,#01h
MOV    _errno,R4
_15:

        return( d32 );
MOV    R4,R15

```

_pag

```
unsigned int _pag( void * p );
```

Inline code is generated by the C compiler to get the page number of pointer *p*. Not available in tiny model.

Returns a 4-bit (10-bit for C167) page number.

```

        pag_hp = _pag( harray );
MOV    R4,#SOF _harray
MOV    R5,#SEG _harray
MOV    R12,R5
SHL    R12,#02h
BMOV   R12.0,R4.14
BMOV   R12.1,R4.15

```

_pof

```
unsigned int _pof( void * p );
```

Inline code is generated by the C compiler to get the page offset of pointer *p*. Not available in tiny model.

Returns a 14-bit page offset.

```

        pof_hp = _pof( harray );
MOV    R4,#SOF _harray
MOV    R5,#SEG _harray
MOV    R13,R4
AND    R13,#03FFFh

```

_seg

```
unsigned int _seg( void * p );
```

Inline code is generated by the C compiler to get the segment number of pointer *p*. Not available in tiny model.

Returns a 2-bit (8-bit for C167) segment number.

```
seg_fp = _seg( farray );
MOV   R4,#POF _farray
MOV   R5,#PAG _farray
MOV   R14,R5
SHR   R14,#02h
```

_sof

```
unsigned int _sof( void * p );
```

Inline code is generated by the C compiler to get the segment offset of pointer *p*. Not available in tiny model.

Returns a 16-bit segment offset.

```
sof_fp = _sof( farray );
MOV   R4,#POF _farray
MOV   R5,#PAG _farray
MOV   R15,R5
SHL   R15,#0Eh
OR    R15,R4
```

_mkfp

```
void _far * _mkfp( unsigned int pof,
                  unsigned int pag );
```

Inline code is generated by the C compiler to make a far pointer from a page offset *pof* and page number *pag*. The arguments *pag* and *pof* are expected to be in a valid range.

Returns a far pointer.

```

        fp = _mkfp( pof_hp, pag_hp );
MOV    R4,R13
MOV    R5,R12
MOV    _fp,R4
MOV    (_fp+2),R5

```

_mkbp

```

void _huge * _mkhp( unsigned int sof,
                   unsigned int seg );

```

Inline code is generated by the C compiler to make a huge pointer from a segment offset `sof` and segment number `seg`. The arguments `sof` and `seg` are expected to be in a valid range.

Returns a huge pointer.

```

        hp = _mkhp( sof_fp, seg_fp );
MOV    R5,R14
MOV    _hp,R4
MOV    (_hp+2),R5

```

_mksp

```

void _shuge * _mksp( unsigned int sof,
                    unsigned int seg );

```

Inline code is generated by the C compiler to make a shuge pointer from a segment offset `sof` and segment number `seg`. The arguments `sof` and `seg` are expected to be in a valid range.

Returns an shuge pointer.

Example:

The file `builtin.c` in the `c` subdirectory of the `examples` directory is a C source file demonstrating the **c166** intrinsic functions. Compile the file using the `-s` option to inspect generated code.

3.16.1 USER DEFINED INTRINSICS

It is possible to create user defined intrinsics. To do this you have to create a file called:

```
icall.h
```

the compiler tries to find this file in the same way as normal include files (`#include "icall.h"`) are searched. See section *Include Files*.

In this file you can specify the prototypes of the user defined intrinsics. An intrinsic function can be defined by using the `_intrinsic` keyword, for example:

```
_intrinsic float intrinsic_func(int*,long);
```

The `_intrinsic` keyword will only be recognized within this specific header file. It is not allowed to use preprocessor directives within this file. If this intrinsic function is called at C-level, for example:

```
f=intrinsic_func(&i,l);
```

The compiler forces all parameters to be kept in registers, except for the parameters of type `struct/union` and `double`. Those exceptions are passed on to the user stack. Finally, the compiler generates a macro preprocessor call:

```
@intrinsic_func(R8,R6,R7)
```

When a parameter is passed on to the user stack the stack offset of the parameter is filled in at the appropriate position, for example:

```
_intrinsic void i_func(double);
```

will result in:

```
@i_func(8)
```

indicating that the `double` parameter is located at stack offset 8. Parameters of the type `char` and `bit` will be passed to the macro call as 16-bit registers. Each `bit` parameter will be passed in `Rx.0`. An unsigned/signed `char` will be resp. zero or sign extended. The same applies to bitfield variables. The name of the macro call will always be equal to the name of the intrinsic function at C-level. The parameters will be evaluated in two groups:

1. parameters passed in registers
2. parameters passed on stack (only doubles and structs/unions)

The parameter order within these groups will not differ from the order at C-level. The parameters passed on the user stack will be passed (and evaluated) to the macro after the parameters that are passed in registers. For example:

```
_intrinsic void i_func( double, struct a, int, struct b );
```

will generate the following macro call:

```
@i_func( R12, 16, 8, 0)

      ^   ^   ^   ^
      |   |   |   |
      |   |   |   | +-- struct b (offset 0)
      |   |   |   | +----- struct a (offset 8)
      |   |   |   | +----- double (offset 16)
      |   |   |   | +----- int
      +-----
```

The macro call parameter assignments will be included in the output file as comment, similar to the following:

```
; Macro call parameter assignments:
;
;   i1 = R12
;   l1 = R13R14
;   d1 = offset 16
;   func(ifunc(i2), d2) = offset 8
;   d2 = offset 0
;
@function(R12,R13,R14,16,8,0)
```

If a parameter occupies more than one register, all registers will be passed separately to the macro. See the example above, where parameter 'l1' has type 'long int'. This parameter is passed in R13/R14 at position 2 and 3 in the parameter list. If there are more registers needed than available (max. 13) an error will be generated:

```
E 745: no registers left for expression
```

The following registers are not used for parameter passing:

- R0: cannot be used → User stack pointer
- R4: cannot be used → Used for return values/scratch
- R5: cannot be used → Used for return values/scratch
- USR0: cannot be used → Used for return values/scratch

The return value of the macro call must conform with the C166 calling convention:

Return type	Register(s)
bit	PSW.6 (USR0)
char	RL4
short/int	R4
long	R4–R5
float	R4–R5
double	(double accu on user stack)
near pointer	R4
far pointer	R4–R5
huge pointer	R4–R5
shuge pointer	R4–R5
structure	R4 or R4–R5 (near or far address)

Table 3-19: Register usage for C return types

The compiler assumes no registers to be destroyed in any case, except for the registers to pass the return value. (R4/R5/USR0 may also be used as a scratch register. You do not need to save/restore these registers).

When an intrinsic function returns a double precision floating point value, the compiler assumes this value at the top stack entry on return. Note that other stack space must be completely released.

The compiler will take care of copying this value to the stack location reserved for the return value, and for releasing the top stack entry. The stack space for the return value will also be reserved by the compiler before the intrinsic function is called. A typical code example is:

```

; test.c      30          r = double_func( f );
SUB          R0,#08h          ; stackspace for return value
SUB          R0,#08h          ; stackspace for parameter
MOV          R12,R0
MOV          R4,#_f
CALLS       SEG __load8n,__load8n ; load parameter on userstack
MOV          R4,R12
CALLS       SEG __store8n,__store8n ; store parameter
ADD          R0,#08h          ; release space allocated by __load8n

; Macro call parameter assignments:
;
;   f = offset 0
;
@double_func(0)                ; intrinsic macro call
MOV          R10,R0            ; load source address
MOV          R4,R0
ADD          R4,#010h          ; load destination address
CALLS       SEG __store8n,__store8n ; store return value
ADD          R0,#08h          ; release space for double return value
MOV          R4,R0
ADD          R4,#08h          ; pointer to return value
ADD          R0,#08h          ; release parameter stackspace
MOV          R10,R4
MOV          R4,#_r            ; destination address
CALLS       SEG __store8n,__store8n ; store
ADD          R0,#08h          ; release return value

```

For clarity, this example was compiled using `-OJ` (disabling the peephole). Normally the ADDs and SUBs on R0 are combined.

Intrinsic functions with a variable argument list are not allowed if this occurs, the compiler will generate an error:

```
E 771: variable argumentlist not allowed with
intrinsic function: "%s()"
```

In order to include a macro preprocessor include file the following pragma can be used:

```
#pragma m166include "include-file"
```

This pragma generates a `$INCLUDE` control in the output file. For example:

```
#pragma m166include "myinclude.inc"
```

will generate:

```
$INCLUDE(myinclude.inc)
```

On error, the following message will be generated:

```
E 744: bad #pragma m166include syntax
```



There are three points that should be considered:

1. Special care must be taken when pointers are passed to a user defined intrinsic. When default pointers are used, the size will differ when an application is compiled in an other memory model. It is therefore advisable to specify the memory the pointer refers to and thus the pointer will always have the same size.
2. It is not possible to define pointers to intrinsic functions.
3. Internal intrinsic functions cannot be redefined.

3.16.2 IMPLEMENTING OTHER _COXXX INTRINSICS USING THE _COXXX INTRINSIC FUNCTIONS

Many CoXXX instructions are automatically generated if a special sequence is recognized.

Examples

```
_CoLOAD( arg1 );
_CoABS();
```

generates the CoABS op1, op2 instruction.

```
_CoMUL( arg1, arg2 );
_CoRND();
```

generates the CoMUL op1, op2, rnd instruction.

```
_CoSUB( arg1 );
_CoNEG();
```

generates the CoSUBR op1, op2 instruction.

Note that the MP flag influences the result (it is highly recommended to keep the MP flag cleared).

The CoXXXus instructions are identical to the CoXXXsu variants with exchanged operands. For example, CoMACus op1, op2, rnd is identical to CoMACsu op2, op1, rnd.

The “missing” `_CoXXX` intrinsics can be defined as inline functions. For example:

```
_inline void _CoMUL_rnd( int x, int y )
{
    _CoMUL(x,y);
    _CoRND();
}
```

3.17 CODE MEMORY BANKING

c166 supports code memory banking. With this technique you can extend your code memory beyond 256Kb. This technique is only useful in the small and large memory model (code > 64Kb). You can specify parts (of any size) of the 256Kb of memory to use (EPROM) memory that is not addressable with a normal 18-bit address. The parts of this extra memory are called 'memory banks'.

You can use code memory banking in C by using the function qualifier:

```
bank(number)
```

where, *number* is any number in the range 1 to 255.

This function qualifier uses the same syntax rules as the other function qualifiers `interrupt(number)` and `stackparm`. A function qualifier is allowed in both the function prototype (for the caller) and the function body itself:

```
int bank(1) func_b1( char *, long ); /* prototype */

int bank(2)
func_b2( int parm ) /* function body */
{
}

```

You can also use a function qualifier when you declare function pointers. The following line of C code declares a table called 'fptable' of 6 function pointers, all containing addresses of functions which are located in bank 3 and expecting their parameters (2 int types) via the user stack and returning a long:

```
long stackparm bank(3) (*fptable[6])( int, int );
```

Although banked interrupt functions are allowed you should not use them because they are not called as a banked function from the interrupt vector. It is recommended to make a non-banked interrupt function and call a banked function from that interrupt function.

The default situation assumes that a function is in a non-banked portion of memory (in fact bank(0)). Valid bank numbers are 1 to 255.

When calling a banked function, from either non-banked memory or from a function having a different bank number, a call to a run-time library function is emitted by the C compiler instead of a regular function call. This run-time library function switches the code memory banks and calls the appropriate banked function indirectly. The code memory bank number and the inter-segment address of the banked function are passed, to the run-time library bank switch function called `__banksw`. The general purpose registers R3, R4 and R5 are used for passing these parameters. The code memory bank number of the banked function is passed in register RL3.

The current code bank number must also be passed to `__banksw`, because it might be needed to restore the code bank of the caller. Therefore the current code bank number is passed in register RH3. When RH3 is set to zero, the code bank does not need to be restored after the banked function returns. The contents of register R3 need to be saved on the user stack by the calling function, because saving it in the code bank switch function would cause a conflict with pre-calculated offsets for C function parameters and automatics. The inter-segment address of the banked function is passed in registers R4 and R5.

Code memory banking is only supported for inter-segment function calls (memory models small and large). Therefore, the `_near` keyword is not allowed with a banked function.

The following C listing displays a call to a banked function which is located in code bank 1 and called by a non-banked function. The code generated by the compiler is displayed below.

```
int bank(1) func_b1( char *, long );

int x;
char *p;
long l;

void main( void )
{
    ...
    x = func_b1( p, l );
    ...
}
```

```

.
.
MOV    R12,_p           ; pass character pointer
MOV    R13,_l           ; pass long value
MOV    R14,(_l+2)      ;
MOV    R4,#SOF _func_b1 ; pass inter-segment address of
MOV    R5,#SEG _func_b1 ; banked function.
MOV    R3,#0001H       ; pass code bank number and no
                        ; restore of current bank at
                        ; return
MOV    [-R0],R3        ; save code bank number(s)
                        ; on the user stack
CALLS  SEG __banksw, __banksw
                        ; call code bank switch function
ADD    R0,#2           ; Remove code bank number(s)
                        ; from the user stack
MOV    _x,R4           ; return result from banked
                        ; function
.
.

```

The default/startup situation assumes that a function is in a non-banked portion of code memory. The bank switch function and all other library functions must be located in non-banked memory, so library functions can be shared by both banked and non-banked functions.

The bank switch function may not introduce a conflict with the register usage and user stack usage implementation of C function parameter passing and C register variables. See section *Register Usage* for details. The registers which are used for fast C parameter passing (R12–R15) may not be used by the code bank switch function and also the registers which are used for C register variables (R6–R9) may not be altered without saving them at entry and restoring them at return of the bank switch function. Register R1–R5, R10 and R11 are free for use. However, registers R4 and R5 may contain a return value from the banked function. The user stack pointer (R0) may not be changed, otherwise compiler pre-calculated offsets are affected. Keep these restrictions in mind when writing your own bank switch function. The bank switch function is a run-time library function and not a C function !

The compiler emits a special class reflecting the bank number for the code section of a banked function (e.g. class 'BANK1'). You can use these class names with the locator OVERLAY control.

The bank switch function depends on the hardware implementation of the code banking mechanism. There are many possible hardware implementations for code memory banking (e.g. paged, segmented etc.), this makes it impossible to write a uniform bank switch function which can be appended to the run-time library functions. Therefore a bank switch function for simulating code banking on directly accessible memory is delivered in the library. This allows to test your application on an evaluation board without having the real hardware implementation available. Finally you can use the skeleton of the delivered assembly bank switch function to write your own bank switch function, supporting your hardware implementation.

The delivered simulation routine assumes the following situation: The different code banks are located in physical memory but they are treated as if they are located in virtual c.q. banked memory. The code banking is simulated by copying the page the banked code is located in to a reserved page where the code is executed from. In fact the code bank number is treated as a page number. So, a code bank is limited to the size of one page (16Kb). One page is reserved for execution of banked code. This page cannot be used for other code or data, because it contains the currently active code page. All the code banks are overlaid in this physical code page with the locator OVERLAY control.

The following listing shows the assembly code for simulating code banking. The number of code banks is restricted to the number of pages which are available for code banking. The physical page the code banks are overlaid in and executed from is defined by the equate CODE_PAGE. The default value of CODE_PAGE is page 15. The following locator control can be used:

```
OVERLAY ( 'BANK4', 'BANK5' ( RANGE(15) ) )
```

This control instructs the locator to overlay the classes BANK4 and BANK5 in page 15. Remember that, when using our simulation code, the code from bank 4 must be located in page 4 and the code from bank 5 must be located in page 5. You can use the regular CLASSES control to achieve this. See the description of the OVERLAY locator control in the assembler manual for a detailed example.

The actual bank switch is performed by `__pgbk`. In the simulation approach, the code bank number (passed via `RL3`) corresponds to the page number where the banked function is present. This page must be activated, which means copied to the physical page defined by `CODE_PAGE`. Now you can actually call the banked function, indirectly, using the run-time library function `__icall`. The inter-segment address of the banked function is passed in registers `R4` and `R5` to `__icall`.

The code bank number of the currently active code bank is pushed on the user stack and afterwards removed from it by the function calling the bank switch function. It is not possible to save the current code bank number on the user stack at function entry of the bank switch function, because this affects the user stack pointer, introducing a conflict with precalculated offsets for C function parameters and automatics. When code execution returns from the banked function, this code bank number is read from the user stack and, when needed, the previous code bank is reactivated by calling `__pgbk` again. This allows you to call a banked function from a banked function in a different code bank.

You can use the skeleton `bankswh.asm`, in the `bank` subdirectory of the `examples` directory, as a starting point to implement your hardware implementation of bank switching. In this case, you only have to replace the code from `__pgbk` with your own code, actually performing the hardware bank switch. It is obvious that your hardware bank switch approach is not limited to the size of a page.

Restriction: When a banked function (e.g. `f1`) calls a non-banked function (e.g. `f2`) which on its turn calls a banked function in another bank (e.g. `f3`), the original bank is not restored when returning from the non-banked function (`f2`).

3.18 MISRA C

Based upon the 'MISRA guidelines for the application of C language in vehicle based software', the TASKING MISRA C technology offers enhanced compiler error-checking that will guide the programmer in writing better, more coherent and hence intrinsically safer applications. Through this configurable system of enhanced C-language error checking, the use of error-prone C-constructs can be prevented. A predefined configuration for compliance with the 'required rules' described in the MISRA guidelines is selectable through a single click in the `EDE | MISRA C Compiler Options` menu. A custom set of applicable MISRA C rules can be easily configured using the same menu. It is also possible to have a project team work with a MISRA C configuration common to the whole project. In this case the MISRA C configuration can be read from an external settings file. This too, is easily selected through the `EDE | MISRA C Compiler Options` menu. In order to provide proof that installed company MISRA C requirements have in fact been adhered to throughout the entire project, the C166 Linker/Locator can generate a MISRA C Quality Assurance report. This report lists the various modules in the project with the respective MISRA C settings under which these have been compiled.

Unfortunately it has not been possible to implement support for ALL 127 rules described in the MISRA guidelines. The reason for this is that a number of rules are beyond the scope of what can be checked in a C-compiler environment. These unsupported rules are visible in the `EDE | MISRA C Compiler Options` menu dialog boxes, but cannot be selected (greyed out).

MISRA is a registered trademark of MIRA held on behalf of the Motor Industry Software Reliability Association.

Enabling MISRA C

From the command line MISRA C can be enabled by the following compiler option:

```
-misracn,n,...
```

where *n* specifies the rule(s) which must be checked.

Error Messages

In case a MISRA C rule is violated, an error message will be generated e.g.:

E 209: MISRA C rule 9 violation: comments shall not be nested.

See Appendix B for the supported and unsupported MISRA C rules.

3.19 MIGRATION FROM OLD SIEMENS CC166

This section is aimed at users of the Siemens **CC166** compiler who are going to use **c166** (we use '**CC166**' as a shorthand notation for the 'SIEMENS **CC166** compiler'). It deals with incompatibilities between these two implementations and describes how to migrate from **CC166** to **c166**.

A number of the items described here are present in the C source file `migrate.c` in the `examples` directory. It might be helpful to compile this file (using the `-s` option) and inspect the generated code.

Principles of Operation

c166 compiles an ANSI C program into an assembler source file which must be processed by the TASKING C166/ST10 assembler (**a166**). It is not possible to use the SIEMENS **ASM166** assembler to process this file, because assembly language extensions and high level language directives are generated, which are not supported by **ASM166**. Note, however, that **a166** is upwards compatible with **ASM166**, except that the macro preprocessor is a separate program (**m166**), i.e. not integrated in the assembler (as done with **ASM166**).

Unlike **CC166**, **c166** does not emit or use macros in the generated assembly file. **CC166** uses a separate preprocessing program (PASS1) and compiling program (PASS2) which are connected via an intermediate file. **c166** is not divided into separate programs. It also does not use any intermediate file. However, during optimization, the intermediate representation of a C function (in memory) is changed in several 'passes'. If preprocessor output is needed, the `-E` option can be used (instead of the `P` option of **CC166**). The suffix of the input file may be `.c` or `.i` and must be specified (there is no default).

Output Files / Preprocessor Controls

Unlike **CC166**, **c166** does not generate a source listing file. Therefore all the **CC166** command line options dealing with the list file (LIST, LI, NOLIST, NOLI, PAGELENGTH, PL, TITLE, TT) are not available. It is obvious that all the **CC166** 'preprocessor controls' (`$PAGELENGTH`, `$TITLE`, `$EJECT`, `$LIST` and `$NOLIST`, where the '\$' must be at the first column of the C source) are also not accepted by **c166**.

The output file has the extension `.src` (**CC166** uses `.a66`).

c166 sends the error-lines and error-messages to the `stderr` (standard error) device of the system. However, if the command line option **-err** is specified, all error information is written to an error list file with the extension `.err`. This option can be compared with the **CC166** 'ERL' option.

Supercomments

CC166 generates so called supercomments (containing debug information), unless the 'NOOMF' command line option is specified.

c166 also emits debug information, using the `?SYMB`, `?FILE` and `?LINE` assembler directives. However, this information is only generated if the **-g** command line option is present. So, default no high level language debug information is generated.

Memory models

c166 supports four memory models: tiny, small, medium and large. **CC166** has three memory models: small, medium and large. The following relationship between these models exist:

c166-tiny / CC166-small

The only model where the CPU runs in non-segmented mode (segmentation disabled), not supporting code/data access beyond 64K. Note that this is the **CC166** default memory model, but not the default memory model of **c166**.

c166-small/CC166-extended small

c166 also supports the so called 'extended small' model of **CC166**. See the section *Memory Models* for more information. Note that this model is the default memory model of **c166**.

c166-medium / CC166-medium

c166-large / CC166-large

These models are called 'large data' models. The medium and large model approach of Infineon and TASKING are functional equivalent. However, the usage of the DPP- registers is different:

	CC166	c166	comment
DPP0	scratch	scratch	e.g. far pointer dereferencing
DPP1	system	user-stack	
DPP2	copy	DGROUP	assumed with default data group
DPP3	user-stack	system	



See the section *Efficiency in Large Data Models* for more details regarding the utilization of the DPP- registers.

Command line Options

The following table shows the **c166** equivalent of the **CC166** command line option, if available:

CC166	c166	comment
TO <i>file</i>	-o <i>file</i>	
P	-E	
D	-D	
<i>Ipath</i>	- <i>Ipath</i>	
s	-Mt	Note other default memory models
m	-Mm	
l	-Ml	
NOOMF	default	Do <u>not</u> specify "-g"
NOSRC	default	Do <u>not</u> specify "-s"
ERL	-err	

Section allocation

CC166 uses the **D** option to control section attributes (for the whole C module), by overruling the default values defined in 'stdmac.h'. For example "**DDCLASS=MY_RAM**" changes the class name of a compiler generated RAM data section to 'MY_RAM'. **c166** uses the **-R** option. To get the same result, we have to specify (small memory model): "**-RcINB=MY_RAM**". However, **c166** also supports section attribute manipulation within a C module via the pragmas `#pragma class`, `#pragma align`, `#pragma combine` and `#pragma default_attributes`.



See the paragraph *Section Allocation* for more details.

bit Support

c166 also supports the `_bit` type and is less restrictive in the usage of bit variables. In the section *The Bit Type* all rules for bit manipulation and allowed operators are described.

sfr/sfrbit/xsfr/bitword Support

c166 also supports the keywords `_sfr`, `_sfrbit`, `_xsfr` and `_bitword`. Note that `sfr/sfrbit/xsfr` registers are implicitly 'volatile'. Like **CC166**, **c166** treats SFR registers unsigned.

However, **c166** performs a very strict storage class checking for `sfr/sfrbit/xsfr` declarations: `automatic`, `static`, `extern` and `register` are not allowed (because these CPU registers in fact have 'application-scope').

Note that static initialization of `sfr/sfrbit/xsfr` registers at system startup is not possible (also not allowed with **CC166**). Unlike **CC166**, the `sfr/sfrbit` declarations are not separated in different files. All C166/ST10 registers are declared in the file `reg166.h`. If you need access to a `sfr/sfrbit` register, you should include this file.

You can specify which part of this file must be skipped by defining special macros. See the section *Special Function Registers* for details on this topic.

Like **CC166**, **c166** allocates `_bitword` variables in bitaddressable memory and treats these variables as 'unsigned int'. However, **c166** uses intrinsic functions to access a single bit of a bitword variable (or `sfr` if there is no `sfrbit` register available). Note that these 'function calls' result in very compact inline code, using the special bit instructions of the C166/ST10. The following examples clarify how to migrate from the **CC166** notation to the **c166** implementation:

```
1) if ( sfrname.10 )           ==>  if ( _getbit( sfrname, 10 ) )
2) sfrname.3 = 1;              ==>  _putbit( 1, sfrname, 3 );
3) sfrname.4 = sfrname.3;      ==>  _putbit( _getbit( sfrname, 3 ),
                                     sfrname, 4 );
```

c166 uses another intrinsic function to support the BFLDL and BFLDH instructions of the C166/ST10. As with **CC166**, these instructions can only be used with `sfr` registers or bitword variables. The following example shows how to migrate from **CC166** to **c166**:

```
sfrname[0xf0] = 0x70;    ==>  _bflld( sfrname, 0xf0, 0x70 );
```

Semaphore Operations

Like **CC166**, **c166** supports semaphore operations with intrinsic functions: `_testset()` and `_testclear()`. The approach is similar, but far less restrictive:

1. The usage of these intrinsic functions is not limited to `if` and `while` constructs, but the result may be used like a function returning `_bit` (thus allowing negation of boolean result).
2. If these semaphore operations are used with control flow in C, **c166** performs full range checking and automatic jump-reversal if the target label is out of range ($-128/+127$ words).

c166 uses other names than the **CC166** semaphore functions, because the functionality of the return value is different. The following example shows how to migrate from **CC166** to **c166**:

```
if ( tst_set_sem( bit_id ) ) ==> if ( !_testset( bit_id ) )
if ( tst_clr_sem( bit_id ) ) ==> if ( !_testclear( bit_id ) )
```

PEC support

Infineon **CC166** uses a macro which generates inline assembly for the initialization of the PEC source and destination pointers. It is the responsibility of the user to allocate the buffer in the first 64K segment:

```
#include "pecc.h"

char  buffer[100];

void
f()
{
    LOADPEC (DSTP0,buffer);
}
```

TASKING **c166** supports the initialization of the PEC source and destination pointers using a `(int)` cast in C. See the section *PEC Support* for an example.

Assembly interface

The usage of registers is different. If existing assembly functions are used, the `_stackparm` keyword must be used in prototype of the assembly function to force usage of user stack for parameter passing.



See the section *Assembly Language Interfacing* in chapter *Run-time Environment* for all details.

Interrupt

The task concept of the C166/ST10 is supported by **CC166** using three macro definitions. The following table shows how to migrate from **CC166** to **c166**:

TASK(<i>n</i>)	==>	interrupt(<i>n</i>)
SYMTASK	==>	interrupt(-1)
RESETTASK	==>	not needed (just use main() and link cstart.obj)

Miscellaneous

- The **CC166** pragmas OMF/LABEL ON/OFF and the #pragma *\$assembler-directive* are not supported. **c166** ignores unknown pragmas.
- The **CC166** #pragma `INLINE { any assembler code }` copies the text between {..} to the output file. **c166** supports inline assembly in a similar way:

```
#pragma asm
any assembler code
#pragma endasm
```



See the section *Inline Assembly* for more information.

- unlike **CC166**, **c166** supports floating point data types.
- unlike **CC166**, **c166** supports static/public initialized RAM data.

3.20 PEC SUPPORT

c166 supports the initialization of the PEC source and destination pointers using a (int) cast in C. The following example shows how to allocate a PEC-addressable section for a buffer in the first 64K segment:

```
#include <reg166.h>

#if _MODEL == 'l' || _MODEL == 'm'
#pragma align fb=c          /* declare PECADDRESSABLE data section for
                             'far' data */
#pragma class fb=firstsegment /* assign a special class name to
                             this section */
char _far buffer[100];      /* explicitly '_far', otherwise
                             allocated in default data group */
#pragma default_attributes /* restore default section
                             attributes for '_far' data */
#else
char buffer[100];
#endif

void
f()
{
    DSTP0 = (int)buffer;    /* when you use the c++ compiler,
                             use a long cast instead of an
                             integer: DSTP0 = (long)buffer; */
}
```

If large model (**-Ml**) is used, the following code is generated:

```
PEC1_1_FB SECTION DATA PECADDRESSABLE PUBLIC 'firstsegment'
PEC1_1_FB_ENTRY LABEL BYTE
_buffer LABEL BYTE
    DS 100
    PUBLIC _buffer
PEC1_1_FB ENDS

    PUBLIC _f
PEC1_2_PR SECTION CODE WORD PUBLIC 'CPROGRAM'
_f PROC FAR
    MOV R4,#SOF (_buffer)
    MOV DSTP0,R4
    RETS
_f ENDP
PEC1_2_PR ENDS
```

The following example shows how to allocate a PEC-addressable section for a buffer in the SYSTEM page (page 3, 16K). The SYSTEM page is in the PEC-addressable range (segment 0). Therefore, it is not needed to declare the buffer data section PECADDRESSABLE with #pragma align sb=c.

```

#include <reg166.h>

char _system buffer[100];      /* explicitly '_system',
                               allocated in system page */

f()
{
    DSTP0 = (int)buffer;
}

```

If large model (**-MI**) is used, the following code is generated:

```

        ASSUME        DPP3:SYSTEM

PEC1_1_SB SECTION          DATA WORD PUBLIC 'CSYSTEM'
PEC1_1_SB_ENTRY LABEL BYTE
_buffer LABEL BYTE
        DS           100
        PUBLIC      _buffer
PEC1_1_SB ENDS

        PUBLIC      _f
PEC1_2_PR SECTION          CODE WORD PUBLIC 'CPROGRAM'
_f PROC FAR
        MOV R4,#SOF _buffer
        MOV DSTP0,R4
        RETS
_f ENDP
PEC1_2_PR ENDS

C166_SGROUP DGROUP PEC1_1_SB,SYSTEM

```

3.21 PORTABLE C CODE

If you are developing C code for the C166/ST10 using **c166**, you might want to test the code on the host you are working on, using a C compiler for that host. Therefore, the include file `c166.h` is delivered with the compiler, which must be included in your C programs.

This header file checks if the predefined macro `_C166` is defined (**c166** only). If not, all C-166 language extensions (read keywords) are redefined to ANSI C equivalents. Furthermore an adapted prototype of each C-166 intrinsic function is present, because these functions are not known by another ANSI compiler. If you use these functions, you should write them in C, performing the same job as the C166/ST10 processor and link these functions with your application for simulation purposes.

If you want to isolate all functions using **c166** language extensions in separate modules, you can use the **-A** option (disable language extensions) to check if **c166** keywords are still present.



You can enable/disable groups of language extensions separately. See the description of the **-A** option in the next chapter for more information.

3.22 HOW TO PROGRAM SMART WITH C166

If you want to get the best code out of **c166**, the following guidelines should be kept in mind:

1. Always include the appropriate header file before using a standard C library function. This is very important with variable argument list functions, such as `printf()`!

Note that you do not have to edit all the 'old style' function bodies of your application into 'new style' ANSI function bodies. You only have to add a full prototype declaration before any function is called and before any function definition.

The following example shows how to migrate from old style programs to new style without editing the function bodies of the program. The advantage of this method is, that if 'prototyping' is not possible (because the C program must be translated with a non-ANSI compiler), the program does not have to be changed:

```

#ifdef prototyping
#define FD(x) x          /* full function prototype */
#else
#define FD(x) ()        /* return type only: no arguments */
#endif

char* cg_var FD( (char *, int) );
void main FD( (void) );

void
main()
{
    char *p;

    p = cg_var( "text", 2 );
}

char *
cg_var( name, offset )
char *name;
int offset;
{
    return ( name + offset );
}

```

If 'prototyping' is enabled the function call to `cg_var` is using the full prototype and the function body of `cg_var` is treated like a 'new style' function, using the full prototype.

2. Try to use the 'unsigned' type modifier as much as possible, because it takes less code to convert an unsigned variable to a long variable than a signed variable.
3. Do NOT use the **-A** option. This option is implemented as strict ANSI conformance checking, disabling language extensions and character arithmetic code generation. This option may decrease code density and execution speed.
4. In most of the cases it is safe to use the **-Oa** option, which results in better code density. However, you have to check your application on 'aliases'. If this option is not used (default), **c166** 'forgets' all register contents bound to C variables if an indirect write operation (e.g. `MOV [R4],R5`) is performed.



See the section *Efficiency in Large Data Models (Medium/Large)*.

5. Use the **-Om** option (default) and non-protected library if multiply and divide instructions do not have to be protected against interrupts. This results in better code density and faster execution.

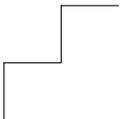
6. Use the intrinsic functions, if special C166/ST10 instructions are needed.
7. If you want to overrule the **c166** register allocation of C variables, you must use the register storage class specifier in the declaration of this (local) variable, because **c166** might allocate other C variables into the CPU registers, than the variables you prefer to be in registers.
8. Avoid static initialized bit variables (which must have the value '1' after startup), because this takes a lot of ROM space and is very time consuming during system startup.
9. Use the **-t** option, to inspect the size of the code generated. This is useful, when 'experimenting' with compiler options.
10. Use the **-Of** optimization option to prefer speed instead of code density (**-OF** is default).
11. Use the **-Ox** optimization option to enable extra inlining of C library functions when you prefer speed instead of code density.

LANGUAGE

CHAPTER

4

COMPILER USE



4 | CHAPTER

4.1 CONTROL PROGRAM

The control program **cc166** is provided to facilitate the invocation of the various components of the C166/ST10 toolchain. The control program accepts source files, options and controls on the command line in random order.

The invocation syntax of the control program is:

```
cc166 [ option ]... [ control ]... [ file ]... ]...
```

Options are preceded by a '-' (minus sign). Controls are reserved words. The input *file* can have any extension as explained below.



When you use a **UNIX** shell (Bourne shell, C-shell), arguments containing special characters (such as '(' and '?') must be enclosed with " " or escaped. The **-?** option (in the C-shell) becomes: **"-?"** or **-\?**.

The control program recognizes the following argument types:

- Arguments starting with a '-' character are options. Some options are interpreted by **cc166** itself; the remaining options are passed to those programs in the toolchain that accept the option.
- Arguments which are known by **cc166** as a control are passed to those programs in the toolchain that accept the control.
- Arguments with a **.cc**, **.cxx** or **.cpp** suffix are interpreted as C++ source programs and are passed to the C++ compiler.
- Arguments with a **.c** suffix are interpreted as C source programs and are passed to the compiler.
- Arguments with a **.asm** suffix are interpreted as assembly source files which are preprocessed and passed to the assembler.
- Arguments with a **.src** suffix are interpreted as preprocessed assembly source files. They are directly passed to the assembler.
- Arguments with a **.lib** suffix are interpreted as library file and passed to the link stage of **1166** when the **-cf** option is not specified. When the **-cf** is specified, the libraries are passed to the locate stage.
- Arguments with a **.ili** suffix are interpreted as linker invocation files and are passed to the link stage of **1166** with a leading '@' sign.
- Arguments with a **.ilo** suffix are interpreted as locator invocation files and are passed to the locate stage of **1166** with a leading '@' sign.

- Arguments with a `.out` suffix are interpreted as input files for the Motorola S formatter, IEEE formatter or Intel Hex formatter. Specify the formatter respectively with the options `-srec`, `-ieee` or `-ihex`.
- Everything else is considered an object file and is passed to the linker.

Normally, **cc166** tries to compile and assemble all files specified, and link and locate them into one output file. There are however, options to suppress the assembler, linker or locator stage. The control program produces unique filenames for intermediate steps in the compilation process. These files are removed afterwards. If the compiler and assembler are called in one phase, the control program prevents preprocessing of the generated assembly file. Normally assembly input files are preprocessed first.

The following options are interpreted by the control program **cc166**:

Option	Description
<code>-?</code>	Display invocation syntax
<code>-V</code>	Display version header and stop
<code>-Warg</code>	Pass argument directly to the assembler
<code>-W$carg$</code>	Pass argument directly to the compiler
<code>-W$cparg$</code>	Pass argument directly to the C++ compiler
<code>-W$farg$</code>	Pass argument directly to the object formatter
<code>-W$larg$</code>	Pass argument directly to the linker
<code>-W$marg$</code>	Pass argument directly to the macro preprocessor
<code>-W$oarg$</code>	Pass argument directly to the locator
<code>-W$plarg$</code>	Pass argument directly to the C++ pre-linker
<code>-c++</code>	Force <code>.c</code> files to C++ mode
<code>-c</code>	Do not link: stop at <code>.obj</code>
<code>-cc</code>	Compile C++ files to <code>.c</code> and stop
<code>-cf</code>	Skip the linking phase; call the locator directly
<code>-cl</code>	Do not locate: stop at <code>.lno</code>
<code>-cm</code>	Always also invokes the C++ muncher
<code>-cp</code>	Always also invokes the C++ pre-linker
<code>-cs</code>	Do not assemble: stop at <code>.src</code>
<code>-f $file$</code>	Read arguments from $file$ (" <code>-</code> " denotes standard input)

Option	Description
-gs	Pass -c1 to ieee166 , set compatibility mode to 1
-ieee	Produce an IEEE-695 output file
-ihex	Produce an Intel hex output file
-lib <i>directory</i>	Specify the location of user-built libraries
-libcan	Link CAN library
-libfmtio <i>variant</i>	Link MEDIUM or LARGE printf()/scan() library variants
-libmac	Link MAC optimized runtime library
-noc++	Force C++ files to C mode
-nolib	Do not link with the standard libraries
-o <i>file</i>	Specify the output file
-srec	Produce an S-record output file
-tmp	Keep intermediate files
-trap	Use a floating point library with trap handler.
-notrap	Use a floating point library without trap handler.
-v	Verbose option: show commands invoked
-v0	Same as -v , but commands are not started
-wc++	Enable C and assembler warnings for C++ files

Table 4-1: Control program options



For more detailed information about the control program `cc166`, refer to section `cc166` in Chapter *Utilities* of the *Cross-Assembler Linker/Locator; Utilities User's Guide*.

4.2 COMPILER

The invocation syntax of the C166 compiler is:

```
c166 [ option ] ... [ file ] ... ] ...
```

The input *file* must have the extension `.c` or `.i`. Options are preceded by a '-' (minus sign). Options cannot be combined after a single '-'. After you have successfully compiled your C sources, the compiler has generated assembly files, with the extension `.src` (the default for **a166**).



When you use a **UNIX** shell (Bourne shell, C-shell), arguments containing special characters (such as '(' and '?') must be enclosed with " " or escaped. The `-?` option (in the C-shell) becomes: `"-?"` or `-\\?`.

A summary of the options is given below. A more detailed description is given in the next section.

Option	Description
<code>-?</code>	Display invocation syntax
<code>-A[flag...]</code>	Enable/disable specific language extensions
<code>-B[flag...]</code>	Control bypasses
<code>-Dmacro[=def]</code>	Define preprocessor <i>macro</i>
<code>-E[m c i p x]</code>	Preprocess only
<code>-F[flag...]</code>	Control floating point
<code>-Ggroupname</code>	Use <i>groupname</i> to group near data sections (<code>-Mm</code> or <code>-MI</code> only)
<code>-Hfile</code>	Include <i>file</i> before starting compilation
<code>-Idirectory</code>	Look in <i>directory</i> for include files
<code>-M{t s m l}</code>	Select memory model: tiny, small, medium or large
<code>-Oflag...</code>	Control optimization
<code>-P[d]</code>	Use user stack model stack frame (calling convention) (to be used with special stack frame C library if 'd' is not specified)
<code>-R{cl co al}mem=new</code>	Change class name, combine type or align type of section for <i>mem</i>
<code>-S</code>	Static allocation of automatics
<code>-Tsize</code>	Use <i>size</i> as threshold before allocating data in default data group (<code>-Mm/-MI</code> only)

Option	Description
-T <i>[size],size2</i>	In addition to the previous option, you can also specify a threshold for initialized data. Default:infinite
-U <i>macro</i>	Remove preprocessor <i>macro</i>
-V	Display version header only
-c <i>size</i>	Specify maximum user stack space for CSE results (per function)
-e	Remove output file if compiler errors occur
-err	Send diagnostics to error list file (<code>.err</code>)
-exit	Alternative exit values
-f <i>file</i>	Read options from <i>file</i>
-g <i>[b f l s]</i>	Enable symbolic debug information
-gso	Enable GSO (acquire phase)
-gso = <i>file.gso</i>	Enable GSO (allocation phase)
-i <i>scale</i>	Specify scaling of interrupt vector table (needs -x2): 0 – for no scaling (default) 1 – for x2 2 – for x4 3 – for x8
-m <i>mem=size</i>	Specify memory <i>size</i>
-m <i>mem=[size],n</i>	Specify maximum section <i>size</i> for <i>mem</i> and in addition a threshold <i>n</i> for switching to a new section
-misrac <i>n,n,...</i>	Enable individual MISRA C checks
-n	Send output to standard output
-o <i>file</i>	Specify name of output <i>file</i>
-r <i>[nr[,name[,C]]]</i>	Omit REGDEF or specify number (<i>nr</i>) of GPR registers, the <i>name</i> of the register bank and C for common
-s <i>[i]</i>	Merge C–source code with assembly output
-t	Display module summary and write section information in output file
-u	Treat all 'char' variables as unsigned
-w <i>[number]</i>	Suppress one or all warning messages
-wstrict	Suppress warning messages 183,196 and 216

Option	Description
<code>-x[2 22 d i f m p]</code>	Allow all or some functions of the extended architectures (to be used with ext or ext2 library sets)
<code>-zpragma</code>	Identical to '#pragma pragma' in the C source

Table 4-2: Compiler options (alphabetical)

Description	Options
Include options	
Read options from <i>file</i>	<code>-f file</code>
Include <i>file</i> before starting compilation	<code>-Hfile</code>
Look in <i>directory</i> for include files	<code>-Idirectory</code>
Preprocess options	
Preprocess only	<code>-E[m c i p x]</code>
Define preprocessor <i>macro</i>	<code>-Dmacro[=def]</code>
Remove preprocessor <i>macro</i>	<code>-Umacro</code>
Allocation control options	
Use <i>groupname</i> to group near data sections (<code>-Mm</code> or <code>-MI</code> only)	<code>-Ggroupname</code>
Change class name, combine type or align type of section for <i>mem</i>	<code>-R{cl co al}mem=new</code>
Static allocation of automatics	<code>-S</code>
Use <i>size</i> as threshold before allocating data in default data group (<code>-Mm/-MI</code> only)	<code>-Tsize</code>
In addition to the previous option, you can also specify a threshold for initialized data. Default:infinite	<code>-T[size],size2</code>
Specify memory <i>size</i>	<code>-mmem=size</code>
Specify maximum section <i>size</i> for <i>mem</i> and in addition a threshold <i>n</i> for switching to a new section.	<code>-mmem=[size],n</code>
Code generation options	
Control cpu bug bypasses	<code>-B[flag...]</code>
Control floating point	<code>-F[flag...]</code>
Select memory model: tiny, small, medium or large	<code>-M{t s m l}</code>
Control optimization	<code>-Oflag...</code>

Description	Options
Use user stack model stack frame (calling convention) (to be used with special stack frame C library if 'd' is not specified)	-P[d]
Specify maximum user stack space for CSE results (per function)	-csize
Enable GSO (acquire phase)	-gso
Enable GSO (allocation phase)	-gso=file.gso
Specify scaling of interrupt vector table (needs -x2): 0 – for no scaling (default) 1 – for x2 2 – for x4 3 – for x8	-iscale
Omit REGDEF or specify number (<i>nr</i>) of GPR registers, the <i>name</i> of the register bank and C for common	-r[nr[,name[,C]]]
Allow all or some functions of the extended architectures (to be used with ext or ext2 library sets)	-x[2 22 d i f m p]
Identical to '#pragma <i>pragma</i> ' in the C source	-zpragma
Language control options	
Enable/disable specific language extensions	-A[flag...]
Treat all 'char' variables as unsigned	-u
Output file options	
Remove output file if compiler errors occur	-e
Send output to standard output	-n
Specify name of output <i>file</i>	-o file
Merge C-source code with assembly output	-s[i]
Diagnostic options	
Display invocation syntax	-?
Display version header only	-V
Send diagnostics to error list file (<i>.err</i>)	-err
Alternative exit values	-exit
Enable symbolic debug information	-g[b f s]
Enable individual MISRA C checks	-misracn,n,...



Description	Options
Display module summary and write section information in output file	-t
Suppress one or all warning messages	-w[<i>number</i>]
Suppress warning messages 183, 196 and 216	-wstrict

Table 4-3: Compiler options (functional)

4.3 DETAILED DESCRIPTION OF THE C-166 OPTIONS

Option letters are listed below. Each option (except **-o**; see description of the **-o** option) is applied to every source file. If the same option is used more than once, the first (most left) occurrence is used. The placement of command line options is of no importance except for the **-I** and **-o** options. For those options having a file argument (**-o** and **-f**), the filename may not start immediately after the option. There must be a tab or space in between. All other option arguments must start immediately after the option. Source files are processed in the same order as they appear on the command line (left-to-right).

-?

Option:

-?

Description:

Display an explanation of options at `stdout`.

Example:

`c166 -?`

-A

Option:

`-A[flags]`

Arguments:

Optionally one or more language extension flags.

Default:

`-A1`

Description:

Control language extensions. Without the `-A` option all **c166** language extensions are enabled. `-A` without any flags, specifies strict ANSI mode; all language extensions are disabled. This is equivalent with `-ACDFIKLMPSTUVWX` and `-A0`.

Flags which are controlled by a letter, can be switched on with the lower case letter and switched off with the uppercase letter. Note that the usage of these options might have effect on code density and code execution performance. The following flags are allowed:

- c** Default. Perform character arithmetic. **c166** generates code using 8-bit character arithmetic as long as the result of the expression is exactly the same as if it was evaluated using integer arithmetic. See also section *Character Arithmetic*.
- C** Disable character arithmetic.
- d** Default. Define storage for uninitialized constant rom data, instead of implicit zero initialization. The compiler generates a 'DS 1' for 'const char i[1];'.
- D** Uninitialized constant rom data is implicitly zero. The compiler generates a 'DB 1' for 'const char i[1];'.
- f** Default. 14-bit arithmetic is used for far pointer comparison instead of long 32-bit arithmetic. Only the page offset is compared. Far pointers do not cross page boundaries and if the objects pointing to are not members of the same aggregate or (union) object, the result is undefined. When far pointers are compared to NULL, 32-bit arithmetic is needed !

- F** 32-bit arithmetic is used for far pointer comparison.
- i** Default. Inlining of a selected group C-library functions is allowed. This option works together with the extra inlining optimization option **-Ox**. Note: It is not possible to take the address of an inline function, which is not conform to the ANSI-C standard.
- I** Disable inlining of C-library functions, to conform to strict ANSI-C mode.
- k** Default. The keywords `_atbit`, `bank`, `bit`, `bitword`, `esfr`, `esfrbit`, `far`, `huge`, `interrupt`, `iram`, `near`, `sfr`, `sfrbit`, `stackparm`, `system` and `using` are recognized as C language extensions. See the chapter *Language Implementation* for the explanation of these language extensions.
- K** Disable all keywords which are an extension of the C language.
- l** Default. 500 significant characters are allowed in an identifier instead of the minimum ANSI-C translation limit of 31 significant characters. Note: more significant characters are truncated without any notice.
- L** Conform to the minimum ANSI-C translation limit of 31 significant characters. This makes it possible to translate your code with any ANSI-C conforming C-compiler. Note: more significant characters are truncated without any notice.
- m** Default. When a 32 bit value is divided by a 16 bits divisor and only 16 bits of the result are being used, then the operation can be done by a `DIVL` or `DIVLU` instruction, depending on the signed/unsigned setting of the operands. The same applies for the modulo operator. When there are chances for overflow and the (truncated) result must still be conform ANSI, then it is better to switch this option off. Example:

```
long m32
short m16, divisor;

m16 = m32 / divisor;
m32 = (short)(m32 / m16);
```

See also the intrinsic functions `_div32`, `_divu32`, `_mod32` and `_modu32`.

- M** Perform divide/modulo operation always in 32 bits using run-time library calls.
- p** Default. Allow C++ style comments in C source code. For example:
- ```
// e.g this is a C++ comment line.
```
- P** Do not allow C++ style comments in C source code, to conform to strict ANSI-C.
- s** Default. `__STDC__` is defined as '0'. The decimal constant '0', intended to indicate a non-conforming implementation. When one of the language extensions are enabled `__STDC__` should be defined as '0'.
- S** `__STDC__` is defined as '1'. In strict ANSI-C mode (**-A**) `__STDC__` is defined as '1'.
- t** Default. Do not promote old-style function parameters when prototype checking.
- T** Perform default argument promotions on old-style function parameters for a strict ANSI-C implementation. `char` type arguments are promoted to `int` type and `float` type arguments are then promoted to `double` type.
- u** Default. Use type `unsigned char` for 0x80-0xff. The type of an unsuffixed octal or hexadecimal constant is the first of the corresponding list in which its value can be represented:

Character arithmetic enabled **-Ac**:

```
char, unsigned char, int, unsigned int, long,
unsigned long
```

Character arithmetic disabled **-AC** (strict ANSI-C):

```
int, unsigned int, long, unsigned long
```

- U** Do not use type `unsigned char` for 0x80-0xff. The type of an unsuffixed octal or hexadecimal constant is the first of the corresponding list in which its value can be represented:

Character arithmetic enabled **-Ac**:

```
char, int, unsigned int, long, unsigned long
```

Character arithmetic disabled **-AC** (strict ANSI-C):

```
int, unsigned int, long, unsigned long
```

- v Default. Allow type cast of an lvalue object with incomplete type `void` and lvalue cast which does not change the type and memory of an lvalue object.

Example:

```
void *p; ((int*)p)++; /* allowed */
int i; (char)i=2; /* NOT allowed */
```

- V A cast may not yield an lvalue, to conform strict ANSI-C mode.
- w Default. Allow propagation of `const` initializers. This optimization makes the following code possible:

```
const int one = 1;
int array [] = { one };
```

- W Disable propagation of `const` initializers.

- x Default. Do not check for assignments of a constant string to a non-constant string pointer. With this option the following example produces no warning:

```
char *p;
void main(void) { p = "hello"; }
```

- X Conform to ANSI-C by checking for assignments of a constant string to a non-constant string pointer. The example above produces warning W130: "operands of '=' are pointers to different types".

- 0 Same as **-ACDFIKLMPSTUVWX** (disable all).

- 1 Same as **-AcdfiklmpstuVwx** (default).

### Example:

To disable character arithmetic and C++ comments enter:

```
c166 -ACP test.c
```

# -B

## Option:

**-B**[flags]

## Arguments:

Optionally one or more cpu functional problem bypass flags.

## Default:

**-Babdefhijlmou**

## Description:

Enable/disable bypass for certain CPU functional problems. Without the **-B** option the default is **-Babdefhijlmou** (all bypasses off).

Flags which are controlled by a letter, can be switched on with the uppercase letter and switched off with the lowercase letter. The following flags are allowed:

- a** Default. Do not protect DIVx/MD[LH] sequences by an atomic instruction.
- A** Protect DIVx/MD[LH] sequences by an atomic instruction. The DIVx instruction and a read from MDL/MDH are not interruptable because they will be generated within the same atomic sequence. This is a bypass for the LONDON1751 CPU functional problem. Refer to Appendix G, *CPU Functional Problems* for details.
- b** Default. Do not place two NOP instructions after each instruction which does a byte write. This option is equivalent to the pragma **nofix\_byte\_write**.
- B** Place two NOP instructions after each instruction which does a byte write. These instructions are: ADDDB, ADDDCB, ANDB, CPLB, MOVDB, NEGB, ORB, SUBB, SUBCB, XORB. This is a bypass for CPU problem S1, as described in Appendix G, *CPU Functional Problems*. This option is equivalent to the pragma **fix\_byte\_write**.
- d** Default. Assume hardware environment is present, where there is no need to protect the execution of divide instructions against interrupts. Emit inline code (DIV) instead of a run-time library call.

- D** For 8xC166 derivatives, this option emits code using run-time library call for signed divide operations (which are protected against interrupts) instead of inline code. For C167 derivatives the protection will be generated inline using ATOMIC instructions. For inline protection, this option must be used in combination with option **-x[i]**. This is a bypass for the CPU problem 13, as described in Appendix G, *CPU Functional Problems*. Use the protected version of the library (`lib\[u]166p\*.lib`, `lib\[u]extp\*.lib` or `lib\[u]ext2p\*.lib`).
- e** Default. Never extend EXTEND sequence with one instruction.
- E** EXTEND sequences are extended with one instruction when addressing mode `Rn`, [`Rm + #data16`] is the last instruction of the EXTEND sequence.
- This is a bypass for the CPU.3 problem, as described in Appendix G, *CPU Functional Problems*.
- f** Default. Do not prevent the generation of `MOVB [Rn], mem` instructions.
- F** Disable the generation of `MOVB [Rn], mem` instructions when even 'const' objects are accessed. This is a bypass for the CPU.16 problem as described in Appendix G, *CPU Functional Problems*.
- h** Default. Do not prevent the generation of `Label_C: JMPR cc.xx, Label_A` instructions.
- H** Disable the generation of `Label_C: JMPR cc.xx, .Label_A` instructions. This is a bypass for the BUS.18 problem as described in Appendix G, *CPU Functional Problems*.
- i** Default. Do not place `BFLDH PSW, #0F0h, #0F0h` before `RETI` in interrupt functions
- I** Place the instruction `BFLDH PSW, #0F0h, #0F0h` before `RETI` in interrupt functions.
- This is a bypass for the CPU problem 17 as described in Appendix G, *CPU Functional Problems*.
- j** Default. Do not place `ATOMIC #2` before a `JMPS` instruction. Do not delete the return addresses from the system stack in interrupt functions.

- J** Place `ATOMIC #2` before a `JMPS` instruction. The `JMPS` instructions in the interrupt vector table will be replaced by `CALLS` instructions (linker / locator control: `FIXSTBUS1`). The compiler generates an `ADD SP, #04` instruction to delete the return address (generated by `CALLS`) from the system stack. This is a bypass for the `ST_BUS.1` problem as described in Appendix G, *CPU Functional Problems*.



The instruction to delete the return address from the system stack is part of the interrupt frame. If `#pragma noframe` was used, this instruction will not be generated, you have to do it manually.

- k** Default. Do not protect `BFLDH/BFLDL` instructions by an `ATOMIC` instruction.
- K** Protect `BFLDH/BFLDL` instructions by an `ATOMIC` instruction. This is a bypass for the `CPU.21` CPU functional problem. Refer to Appendix G, *CPU Functional Problems* for details.
- l** Default. Do not protect `JMPI/CALLI` instructions by an `ATOMIC` instruction.
- L** Protect `JMPI/CALLI` instructions by an `ATOMIC` instruction. This is a bypass for the `LONDON1` CPU functional problem. Refer to Appendix G, *CPU Functional Problems* for details.
- m** Default. Assume hardware environment is present, where there is no need to protect the execution of multiply instructions and divide instructions against interrupts. Emit inline code (`MUL`, `DIV`, `DIVU`, `DIVL`, `DIVLU`) instead of a run-time library call. You must use the non-protected version of the library (`lib\166\*.lib`).
- M** For `8xC166` derivatives, this option emits code using run-time library call for multiply/divide operations (which are protected against interrupts) instead of inline code. For `C167` derivatives the protection will be generated inline using `ATOMIC` instructions. For inline protection, this option must be used in combination with option `-x[i]`. Use the protected version of the library (`lib\166p\*.lib` or `lib\extp\*.lib`).

This is a bypass for many CPU problems, among which are problem 7, problem 13, problem 17, `CPU.2`, `CPU.11` and `CPU.18`. as described in Appendix G, *CPU Functional Problems*.

- n** Default. Do not avoid pipeline conflict after `CoSTORE` instruction.

- N** Avoid pipeline conflict after CoSTORE instruction. This is a bypass for the Kfm\_BR03 CPU functional problem as described in Appendix G, *CPU Functional Problems*.
- o** Default. Do not prevent the generation of MOV(B) Rn, [Rm+#data16] instructions.
- O** Disable generation of MOV(B) Rn, [Rm+#data16] instructions. The generation of this instruction is not disabled in some of the intrinsic functions since the source operand always refers to internal RAM here.

This a bypass for the CPU1R006 functional problem, as described in Appendix G, *CPU Functional Problems*.

- u** Default. Assume hardware environment is present, where there is no need to protect the execution of multiply instructions against interrupts. Emit inline code (MUL/MULU) instead of a run-time library call. You must use the non-protected version of the libraries (`lib\166\*.lib` or `lib\ext\*.lib`).
- U** For 8xC166 derivatives, this option emits code using run-time library calls for multiply operations (which are protected against interrupts) instead of inline code. For C167 derivatives the protection will be generated inline using ATOMIC instructions. For inline protection, this option must be used in combination with option `-x[i]`. Use the protected version of the libraries (`lib\.66p\*.lib` or `lib\extp\*.lib`).

This is a bypass for CPU problems CPU.11 and problem 17.

### **Zc166sv1cp**

Prevent pipeline problems after changing CP. This is a bypass for the CR105840 (preliminary number) functional problem, as described in Appendix G, CPU Functional Problems.

### **Zno\_c166sv1cp**

Default. Do not prevent pipeline problems after changing CP.

### **Zc166sv1div**

Do not generate unprotected division instructions. This is a bypass for the CR105893 (preliminary number) functional problem.

### **Zno\_c166sv1div**

Default. Allow generation of unprotected division instructions.

**Zc166sv1sp**

Prevent pipeline problems after changing SP. This is a bypass for the CR105685 (preliminary number) functional problem.

**Zno\_c166sv1sp**

Default. Do not prevent pipeline problems after changing SP.



See Appendix G, *CPU Functional Problems* for more details.

## -C

### Option:

*-csize*

### Default:

The compiler determines internally how much user stack CSE space is needed.

### Arguments:

The maximum amount of user stack CSE space which may be used by a function.

### Description:

With this option you can specify the maximum amount of user stack CSE space which may be used by a function. When no CSEs are found within a function, no space will be allocated for it. When you do not want the compiler to allocate user stack CSE space at all, specify a size of 0. This way, the compiler will check for CSE values and tries to place them in registers only.



**-Oc/-OC**

Pragma *cse size* in section *Pragmas*

## -D

### Option:

`-Dmacro[=def]`

### Arguments:

The macro you want to define and optionally its definition.

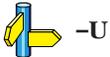
### Description:

Define *macro* to the preprocessor, as in `#define`. If *def* is not given (`=` is absent), `1` is assumed. Any number of symbols can be defined. The definition can be tested by the preprocessor with `#if`, `#ifdef` and `#ifndef`, for conditional compilations. If the command line is getting longer than the limit of the operating system used, you can use the `-f` option.

### Example:

The following command defines the symbol `NORAM` as `1` and defines the symbol `PI` as `3.1416`.

```
c166 -DNORAM -DPI=3.1416 test.c
```



## -E

### Option:

**-E**[**m** | **c** | **i** | **p** | **x**]

### Description:

Run the preprocessor of the compiler only and send the output to stdout. When you use the **-E** option, use the **-o** option to separate the output from the header produced by the compiler.

An overview of the flags is given below.

- m** – generate dependencies for make
- c** – don't strip comments
- i** – keep #include directives
- p** – don't generate #line source position info
- x** – disable macro expansion

The **m** flag overrules all other flags.

### Examples:

The following command preprocesses the file `test.c` and sends the output to the file `preout`.

```
c166 -E -o preout test.c
```

The following command generates dependency rules for the file `test.c` which can be used by **mk166** (the C166/ST10 'make' utility).

```
c166 -Em test.c
```

```
test.obj : test.c
```

**-e****Option:**`-e`**Description:**

Remove the output file when an error has occurred. With this option the 'make' utility always does the proper productions.

**Example:**

```
c166 -e test.c
```

## **-err**

### **Option:**

**-err**

### **Description:**

Write errors to the file *source.err* instead of `stderr`.

### **Example:**

To write errors to the `test.err` instead of `stderr`, enter:

```
c166 -err test.c
```

# **-exit**

**Option:**

**-exit**

**Description:**

Use alternative exit values in case warnings are reported. In case warnings are reported, the compiler returns an exit value as if there were errors reported.

# -F

**Option:**

**-F***[flags]*

**Arguments:**

Optionally a floating point control flag.

**Description:**

Control floating point. The flags which are controlled by a letter can be switched on with the lowercase letter and switched off with the uppercase letter. **-F** used without flags is the same as using **-Fs**. Currently the following flags are implemented.

- c** Enables the use of `float` constants.
- C** Default This flag is ignored when **-Fs** is set.
- s** Forces using single precision. Implies **-Fc**.
- S** Default

## -f

### Option:

**-f** *file*

### Arguments:

A filename for command line processing. The filename "-" may be used to denote standard input.

### Description:

Use *file* for command line processing. To get around the limits on the size of the command line, it is possible to use command files. These command files contain the options that could not be part of the real command line. Command files can also be generated on the fly, for example by the make utility.

More than one **-f** option is allowed.

Some simple rules apply to the format of the command file:

1. It is possible to have multiple arguments on the same line in the command file.
2. To include whitespace in the argument, surround the argument with either single or double quotes.
3. If single or double quotes are to be used inside a quoted argument, we have to go by the following rules:
  - a. If the embedded quotes are only single or double quotes, use the opposite quote around the argument. Thus, if a argument should contain a double quote, surround the argument with single quotes.
  - b. If both types of quotes are used, we have to split the argument in such a way that each embedded quote is surrounded by the opposite type of quote.

Example:

```
"This has a single quote ' embedded"
```

or

```
'This has a double quote " embedded'
```

or

```
'This has a double quote " and \
a single quote ''' embedded"
```

4. Some operating systems impose limits on the length of lines within a text file. To circumvent this limitation it is possible to use continuation lines. These lines end with a backslash and newline. In a quoted argument, continuation lines will be appended without stripping any whitespace on the next line. For non-quoted arguments, all whitespace on the next line will be stripped.

Example:

```
"This is a continuation \
line"
-> "This is a continuation line"

control(file1(mode,type),\
file2(type))
->
control(file1(mode,type),file2(type))
```

5. It is possible to nest command line files up to 25 levels.

### Example:

Suppose the file `mycmds` contains the following lines:

```
-err
test.c
```

The command line can now be:

```
c166 -f mycmds
```

## -G

**Option:**

`-Ggroupname`

**Arguments:**

The name for a group of near data sections.

**Description:**

With this option you can specify a name for a group of near data sections. This option can only be used in the medium and large memory model.



See the sections *Efficiency in Large Data Models (Medium/Large)* and *Interrupt* for more details.

# -g

## Option:

**-g**[**b** | **f** | **l** | **s**]

## Description:

Add directives to the output files, incorporating symbolic information to facilitate high level debugging. Note: using **-g** may turn off some peephole optimizations.

With **-gb** 'bit' type information and pointer behavior description is omitted for compatibility with old IEEE-695 consuming tools.

With **-gf** high level language type information is also emitted for types which are not referenced by variables. Therefore, this suboption is not recommended.

With **-gl** you disable lifetime information for all types.

With **-gs** user stack adjustment information is omitted for compatibility with old IEEE-695 consuming tools. If you use **-gs** it is also recommended to invoke **ieee166** with the **-c1** option. This combination gives the best compatibility with old IEEE-695 consuming tools. When you invoke the control program **cc166** with **-gs** this will also set **-c1** on invocation of **ieee166**.

## Examples:

To add symbolic debug information to the output files, enter:

```
c166 -g test.c
```

To add symbolic debug information to the output files but disable lifetime information for all types, enter:

```
c166 -gl test.c
```

# -gso

**Option:**

`-gso`  
`-gso=file.gso`

**Arguments:**

The name of a `.gso` file with object allocation information for the final build.

**Description:**

Enable the global storage optimizer. Please refer to Appendix *Global Storage Optimizer* for more details.

**Examples:**

```
c166 module.c -gso
```

Generates the file `module.sif` (Source Information File) with information on all global objects.

```
c166 module.c -gso=module.gso
```

Generates `module.c` with the global objects allocated as specified in the `module.gso` file.

## -H

**Option:**

**-H***file*

**Arguments:**

The name of an include file.

**Description:**

Include *file* before compiling the C source. This is the same as specifying `#include "file"` at the first line of your C source.

**Example:**

```
c166 -Hstdio.h test.c
```



**Option:***-iscale***Arguments:**

Specify scaling of the interrupt vector table.

**Description:**

The C166S v2.0 / Super10 architectures (ext2) allows a scalable interrupt vector table. This option can be used to specify the scaling factor:

| Scale | Factor | Size                             |
|-------|--------|----------------------------------|
| 0     | x1     | 4 bytes / vector<br>(no scaling) |
| 1     | x2     | 8 bytes / vector                 |
| 2     | x4     | 16 bytes / vector                |
| 3     | x8     | 32 bytes / vector                |

*Table 4-4: Scaling factor*

Depending on the size of an interrupt vector table entry, the compiler will try to place as much code from an interrupt function inside the vector table as possible.



This option can only be used in conjunction with the **-x2** option.

**Example:**

```
c166 -x2 -i3 test.c
```

Selects the C166S v2.0 / Super10 architectures (ext2) and specifies that each interrupt vector table entry is 32 bytes in size.

**-I****Option:***-Idirectory***Arguments:**

The name of the directory to search for include file(s).

**Description:**

Change the algorithm for searching #include files whose names do not have an absolute pathname to look in *directory*. Thus, #include files whose names are enclosed in "" are searched for first in the directory of the file containing the #include line, then in directories named in **-I** options in left-to-right order. If the include file is still not found, the compiler searches in a directory specified with the environment variable C166INC. C166INC may contain more than one directory. Finally, the directory `../include` relative to the directory where the compiler binary is located is searched. This is the standard include directory supplied with the compiler package.

For #include files whose names are in `<>`, the directory of the file containing the #include line is not searched. However, the directories named in **-I** options (and the one in C166INC and the relative path) are still searched.

**Example:**

```
c166 -I/proj/include test.c
```



Section *Include Files*.

## -M

### Option:

**-M***model*

### Arguments:

The memory model to be used, where *model* is one of:

- t** tiny (cpu in non-segmented mode)
- s** small
- m** medium
- l** large

### Default:

**-Ms**

### Description:

Select the memory model to be used.

### Example:

```
c166 -Ml test.c
```



Section *Memory Models*.

## -m

### Option:

`-mmem=size`

or

`-mmem=[size],threshold`

### Arguments:

A memory space with a memory size. *mem* can be one of:

| <i>mem</i> | Description                                       | Default size limit (bytes) |
|------------|---------------------------------------------------|----------------------------|
| <b>BI</b>  | bits                                              | 2048 (bits)                |
| <b>CO</b>  | strings / floating point                          | none                       |
| <b>BA</b>  | bitwords                                          | 256                        |
| <b>NB</b>  | near data                                         | none                       |
| <b>FB</b>  | far data                                          | none                       |
| <b>XB</b>  | shuge data                                        | none                       |
| <b>HB</b>  | huge data                                         | none                       |
| <b>PR</b>  | functions                                         | 65536                      |
| <b>SB</b>  | system data                                       | 16384                      |
| <b>IR</b>  | internal ramdata<br>if <code>-x[ifmp]</code> used | 1024<br>2048               |

Table 4-5: Memory spaces

A threshold value. The default is no threshold.

### Description:

Specify the memory *size* (limits) to be used by the compiler for checking static memory allocations of the module being processed. If the `-t` option is used the size allocated by the module is reported, when **c166** completes compilation.

When a section is equal or larger than the threshold size, the compiler will switch to a new section with the identical attributes and class for subsequent allocations. The threshold size is memory dependent. A size of zero means no threshold and this is the default. Specifying a threshold size is particularly useful when compiling very big modules or when there are too many initialized variables in a single module.

Example:

```
-mPR=0,4000
```

is suitable for compiling modules with more than 64Kb code without getting a too large number of sections.

Likewise:

```
-mFB=0,4000
```

allows more than 16Kb of initialized far data in a single module by switching to a new section after approximately 4Kb. However, it will result in numbered sections with different names, so it might be necessary to adapt the linker/locator invocation when locator controls refer to a particular section by name.

# -misrac

**Option:**

`-misrac $n$ , $n$ ,...`

**Arguments:**

The MISRA C rules to be checked.

**Description:**

With this option, the MISRA C rules to be checked can be specified. Refer to Appendix B *MISRA C* for a list of supported and unsupported MISRA C rules.

**Example:**

```
c166 -misrac9 test.c
```

Will generate an error in case 'test.c' contains nested comments.

## **-n**

**Option:**

**-n**

**Description:**

Do not create output files but send the output to `stdout`.

**Example:**

```
c166 -n test.c
```

## -O

### Option:

*-Oflags*

### Arguments:

One or more optimization flags.

### Default:

**-O1**

### Description:

Control optimization. By default **c166** performs as much code optimizations as possible (same as **-O1**).

Flags which are controlled by a letter, can be switched on with the lower case letter and switched off with the uppercase letter. These options are described together. An overview of the flags is given below.

- a** – relax alias checking
- b** – no clearing of non-initialized static and public variables
- c** – common subexpression elimination
- d** – data flow, constant/copy propagation
- e** – allocate (constant) romdata in PDAT instead of LDAT (only with **-Ms**)
- f** – optimize for speed (increases code size)
- g** – enable expression recognition
- h** – optimize interrupt frame
- j** – peephole optimization
- k** – register contents tracing
- l** – fast loops (increases code size)
- n** – NOP removal
- o** – code order rearranging
- p** – control flow optimization
- q** – use far pointer when converting to/from long
- r** – optimize allocation of register variables
- s** – use jump table for switch statement
- t** – turn tentative into defining occurrence
- u** – use user stack for interrupt

- w** – relax alias checking: assume no cross type aliasing
- x** – inline the intrinsic version of some C library functions

**Example:**

```
c166 -OAcDFhkLmprstVw test.c
```

# **-Onumber**

**Option:**

*-Onumber*

**Arguments:**

A number in the range 0 – 3.

**Default:**

**-O1**

**Description:**

Control optimization. You can specify a single number in the range 0 – 3, to enable or disable optimization. The options are a combination of the other optimization flags:

**-O0** – same as **-OABCDEFGHIJKLNOPQRSTUVWXYZ** (no optimization)

**-O1** – same as **-OABcdEFghjKLnopQrS\*UwX** (default)

**-O2** – same as **-OaBcdEFghjKLnopQrS\*UwX** (size)

**-O3** – same as **-OaBcdEfgHjklNopQrS\*Uwx** (speed)

\* = **t** for **-Mm/-Ml**, **T** for **-Mt/-Ms**

**Example:**

To optimize for code size, enter:

```
c166 -O2 test.c
```

# -Oa / -OA

**Option:**

-Oa / -OA

**Pragma:**

noalias / alias

**Default:**

-OA

**Description:**

With **-Oa** you relax alias checking. If you specify this option, **c166** will not erase remembered register contents of user variables if a write operation is done via an indirect (calculated) address. You must be sure this is not done in your C code (check pointers!) before turning on this option.

With **-OA** you specify strict alias checking. If you specify this option, the compiler erases all register contents of user variables when a write operation is done via an indirect (calculated) address.

**Example:**

An example is given in section *Alias* in this chapter.



Pragmas *noalias* and *alias* in section *Pragmas*.

# -Ob / -OB

**Option:**

**-Ob / -OB**

**Default:**

**-OB**

**Description:**

With **-Ob** the compiler performs no 'clearing' of non-initialized static and public variables.

With **-OB** the compiler performs 'clearing' of non-initialized static and public variables.



Section *Non-Initialized Variables*.

Pragma `noclear` and `clear` in section *Pragmas*.

# -O<sub>c</sub> / -O<sub>C</sub>

## Option:

**-O<sub>c</sub> / -O<sub>C</sub>**

## Default:

**-O<sub>c</sub>**

## Description:

With **-O<sub>c</sub>** you enable CSE (common subexpression elimination). With this option specified, the compiler tries to detect common subexpressions within the C code. The common expressions are evaluated only once, and their result is temporarily held in registers or on the user stack.



The size of the maximum used user stack area can be specified with the **-csize** option.

With **-O<sub>C</sub>** you disable CSE (common subexpression elimination). With this option specified, the compiler will not try to search for common expressions.

## Example:

```
/*
 * Compile with -OC -O0,
 * Compile with -Oc -O0, common subexpressions are found
 * and temporarily saved.
 */

char x, y, a, b, c, d;

void
main(void)
{
 x = (a * b) - (c * d);

 y = (a * b) + (c * d); /*(a*b) and (c*d) are common */
}
```



**-c**

Pragmas `cse resume` and `cse suspend` in section *Pragmas*.

# -Od / -OD

**Option:**

**-Od / -OD**

**Default:**

**-Od**

**Description:**

With **-Od** you enable constant and copy propagation. With this option, the compiler tries to find assignments of constant values to a variable, a subsequent assignment of the variable to another variable can be replaced by the constant value.

With **-OD** you disable constant and copy propagation.

**Example:**

```
/*
 * Compile with -OD -O0, 'i' is actually assigned to 'j'
 * Compile with -Od -O0, 15 is assigned to 'j', 'i' was
 * propagated
 */

int i;
int j;

void
main(void)
{
 i = 10;
 j = i + 5;
}
```

# -Oe / -OE

**Option:**

**-Oe / -OE**

**Default:**

**-OE**

**Description:**

With **-Oe** you enable allocation of constant romdata 'CROM' in paged data sections (PDAT). This option is explained in section *Constant Romdata Section Allocation*.

With **-OE** standard allocation of constant romdata 'CROM' in linear data sections (LDAT) is done.

These options only affect the code generation and section allocation in the small memory model.



Section *Constant Romdata Section Allocation*.

Pragmas `switch_tabmem_far`, `switch_tabmem_near` and `switch_tabmem_default` in section *Pragmas*.

# -Of / -OF

**Option:**

-Of / -OF

**Pragma:**

speed / size

**Default:**

-OF

**Description:**

With **-Of** you produce fast code. Favour execution speed above code density. Note that this option may increase code size.

With **-OF** you produce small code. Favour code density above execution speed. If **-OF** is specified, **c166** calls a run-time library routine for a number of operations.



Pragmas speed and size in section *Pragmas*.

# **-Og / -OG**

**Option:**

**-Og / -OG**

**Default:**

**-Og**

**Description:**

With **-Og** you enable expression recognition. Expressions for which very efficient code can be generated are recognized and optimal code is emitted.

With **-OG** you disable expression recognition. Handle expressions that could be recognized using the **-Og** option as generic cases.

# -Oh / -OH

**Option:**

**-Oh / -OH**

**Default:**

**-Oh**

**Description:**

With **-Oh** you enable optimization of interrupt frame code for C interrupt functions.

With **-OH** you disable optimization of interrupt frame code for C interrupt functions.



Section *Interrupt* in chapter *Language Implementation*.

# **-Oj / -OJ**

**Option:**

**-Oj / -OJ**

**Default:**

**-Oj**

**Description:**

With **-Oj** you enable peephole optimization. Remove redundant code.

With **-OJ** you disable peephole optimization.



Optimization option NOP removal **-On**.

# -Ok / -OK

**Option:**

**-Ok / -OK**

**Default:**

**-Ok**

**Description:**

With **-Ok** you trace the contents of registers and try to reuse the registers without reloading.

With **-OK** you disable register contents tracing.

**Example:**

```
/*
 * Compile with -OK -O0
 * Compile with -Ok -O0, register contents tracing,
 * one register is reused
 */
int a, c;

void f(register int b)
{
 a = 22;
 if (b)
 {
 c = 22;
 }
}
```

## **-OI / -OL**

**Option:**

**-OI / -OL**

**Default:**

**-OL**

**Description:**

With **-OI** you enable fast loops. Duplicate the loop condition. Evaluate the loop condition one time outside the loop, just before entering the loop, and at the bottom of the loop. This saves one unconditional jump and gives less code inside a loop.

With **-OL** you disable fast loops. The smallest code is generated for loops.

**Example:**

```
/*
 * Compile with -OL -O0
 * Compile with -OI -O0, compiler duplicates the loop
 * condition, the unconditional jump is removed.
 */
int i;

void
main(void)
{
 for(; i<10; i++)
 {
 do_something();
 }
}
```

# **-On / -ON**

**Option:**

**-On / -ON**

**Default:**

**-On**

**Description:**

With **-On** you enable NOP removal by peephole optimizer.

With **-ON** you disable NOP removal by peephole optimizer.

# **-Oo / -OO**

**Option:**

**-Oo / -OO**

**Default:**

**-Oo**

**Description:**

With **-Oo** you enable code rearranging in flow optimization.. Try to move (sub)expressions to get faster code. Some debuggers may have difficulties with such options.

With **-OO** you disable code rearranging.

# -Op / -OP

**Option:**

**-Op / -OP**

**Default:**

**-Op**

**Description:**

With **-Op** you enable control flow optimizations on the intermediate code representation, such as jump chaining and conditional jump reversal.

With **-OP** you disable control flow optimizations.

**Example:**

```
/*
 * Compile with -OP -O0
 * Compile with -Op -O0, compiler finds first time 'i' is
 * always < 10, the unconditional jump is removed.
 */
int i;

void
main(void)
{
 for(i=0; i<10; i++)
 {
 do_something();
 }
}
```

## **-Oq / -OQ**

**Option:**

**-Oq / -OQ**

**Default:**

**-OQ**

**Description:**

With **-Oq** you treat casting a pointer to long equal to casting a pointer to a far pointer.

With **-OQ** you treat casting a pointer to long equal to casting a pointer to a huge pointer.

# -Or / -OR

**Option:**

-Or / -OR

**Default:**

-Or

**Description:**

With **-Or** you retrieve better code. Enable automatic C register variable allocation, unless overruled by the **-rnr** option. If you do not want a certain automatic to be allocated in a register (e.g. `set jmp()`/`long jmp()` pair used), you can declare this variable to be volatile and yet still use the **-Or** option!

With **-OR** you disable automatic C register variable allocation.

# -Os / -OS

**Option:**

**-Os / -OS**

**Default:**

**-OS**

**Description:**

With **-Os** you force the compiler to generate jump tables for switch statements.

With **-OS** the compiler chooses the best switch method possible, jump chain or jump table. So, with **-OS** a jump table can still be generated.

**Example:**

```
/*
 * Compile with -OS, generate jump chain.
 * Compile with -Os, generate jump table.
 */
int i;

void
main(void)
{
 switch (i)
 {
 case 1: i = 0;
 case 2: i = 1;
 case 3: i = 2;
 default: i = 3;
 }
}
```



Section *Switch Statement*.

Pragmas `switch_force_table` and `switch_smart` in section *Pragmas*.

# -Ot / -OT

**Option:**

**-Ot / -OT**

**Default:**

**-Ot** (medium and large model)

**-OT** (tiny and small model)

**Description:**

With **-Ot** the compiler turns tentative declarations (such as `'int i;'`) into defining occurrences (e.g. `'int i=0;'`).

With **-OT** declarations remain tentative as long as possible.



Section *Efficiency in Large Data Models*.

# **-Ou / -OU**

**Option:**

**-Ou / -OU**

**Default:**

**-OU**

**Description:**

With **-Ou** the compiler uses the user stack instead of the system stack for task switch (interrupt).

With **-OU** the compiler uses the system stack for task switch (interrupt).

# **-Ow / -OW**

**Option:**

**-Ow / -OW**

**Default:**

**-Ow**

**Description:**

With **-Ow** the compiler relaxes alias checking, assuming there are no pointer aliases for different type. For example, when a pointer to an `int` is dereferenced (written), it is reasonable to assume that this cannot have any effect on `char` objects.

With **-OW** the compiler performs cross-type alias checking.

## **-Ox / -OX**

**Option:**

**-Ox / -OX**

**Default:**

**-OX**

**Description:**

With **-Ox** you enable extra inlining of C library functions. It is only worthwhile to inline C library functions which are very small and frequently used. Therefore, only the following C library functions are inlined in small and tiny memory model. Inlining C library functions is not conform the ANSI-C standard. Extra inlining will be disabled when compiling with inlining allowed, see option **-Ai/-AI**. Remember that you cannot take the address of an inline function and you cannot define one of these functions yourself when **-Ox** is active.

The next C library functions are inlined for tiny and small memory model:

strcpy(), strlen(), strchr(), strcmp(),  
strcat(), memset(), memcpy()

With **-OX** you disable extra inlining of the C library functions mentioned above.

## -o

### Option:

`-o file`

### Arguments:

An output filename. The filename may not start immediately after the option. There must be a tab or space in between.

### Default:

Module name with `.src` suffix.

### Description:

Use *file* as output filename, instead of the module name with `.src` suffix. Special care must be taken when using this option, the first `-o` option found acts on the first file to compile, the second `-o` option acts on the second file to compile, etc.

### Example:

When specified:

```
c166 file1.c file2.c -o file3.src -o file2.src
```

two files will be created, `file3.src` for the compiled file `file1.c` and `file2.src` for the compiled file `file2.c`.

## -P

**Option:**

-P[d]

**Description:**

Enable user stack model. See section *User Stack Model* for details. Requires linking with user stack model library unless **-Pd** is specified.



Appendix H, *User Stack Model Library Support*.

# -R

## Option:

`-R{cl|co|al}mem=new`

## Pragma:

`class / combine / align`

## Arguments:

*mem* is a two letter abbreviation indicating the memory area of a C program. *mem* can be one of:

| <i>mem</i> | Description                                       |
|------------|---------------------------------------------------|
| <b>BI</b>  | bits                                              |
| <b>CO</b>  | strings / floating point                          |
| <b>BA</b>  | bitwords                                          |
| <b>NB</b>  | near data                                         |
| <b>FB</b>  | far data                                          |
| <b>XB</b>  | shuge data                                        |
| <b>HB</b>  | huge data                                         |
| <b>PR</b>  | functions                                         |
| <b>SB</b>  | system data                                       |
| <b>IR</b>  | internal ramdata<br>if <code>-x[ifmp]</code> used |

Table 4-6: Memory spaces

*new* is the new class name, combine type or align type for *mem*.

## Description:

The compiler defaults to a section naming convention as described in the section *Section Allocation*. With this option you can change the class name, combine type or align type of a compiler generated section for *mem*.

In case a module must be loaded at a fixed address or a data section needs a special place in memory, the **-R** option enables you to generate a unique class name, combine type or align type with a section name. With **-Rclmem=new** you can specify a *new* class name for *mem* (same as pragma **class**). With **-Rcomem=new** you can specify a *new* combine type for *mem* (same as pragma **combine**). With **-Ralmem=new** you can specify a *new* align type for *mem* (same as pragma **align**). In this way the order **1166** allocates these sections can be specified in a locator command file.



Section *Section Allocation*.

Pragmas *align*, *class* and *combine* in section *Pragmas*.

## **-r**

### **Option:**

**-r**[*nr*[,*name*[,**C**]]]

### **Pragma:**

**regdef**

### **Arguments:**

*nr* is the number of GPR registers.

*name* is the register bank name.

### **Description:**

With the **-rnr** option you can specify the number of GPR registers assigned to this task. If the number is omitted, the compiler omits the REGDEF declaration. You can also specify the register bank *name* and if this register bank must be 'common' (**C**) or not.



Section *Interrupt*.  
Pragma *regdef* in section *Pragmas*.

## -S

**Option:**

-S

**Pragma:**

**static**

**Description:**

All functions of the C module are compiled using static memory for non-register function automatics. This option can be useful for non recursive applications.



Section *Static Approach of Function Automatics*

Pragmas `automatic` and `static` in section *Pragmas*.

## -S

### Option:

`-s [i]`

### Pragma:

`source`

### Description:

Merge C source code with generated assembly code in output file.

When the additional `'i'` sub option is specified, the C source of the include files will also be merged.

### Example:

```
c166 -s test.c
```

```
 NAME TEST_C
; test.c 1 int i;
; test.c 2
; test.c 3 int
; test.c 4 main(void)
; test.c 5 {
 PUBLIC _main
TEST_1_PR SECTION CODE WORD PUBLIC 'CPROGRAM'
_main PROC FAR
```



Pragmas `source` and `nosrouce` in section *Pragmas*.

## -T

### Option:

`-Tsize`

or

`-T[size], size2`

### Arguments:

The maximum threshold size in bytes (*size*). Or the threshold size for initialized variables (*size2*)

### Default:

`-T256`

### Description:

With this option you can specify a maximum *size* (threshold) for allocating data in default data sections. This is useful when you want to limit the size of the default data group. You can use this option in the medium and large model only.

Initialized variables have an infinite threshold by default. Unless a threshold is specified by a second argument to the `-T` option, they are always allocated in the default far data sections.

### Example:

To allocate values of maximum 128 bytes long in default far data sections, enter:

```
c166 -T128 -Mm test.c
```



Section *Efficiency in Large Data Models (Medium/Large)*.

# -t

**Option:**

-t

**Description:**

With this option the C compiler produces totals (a module summary) on stdout and writes section information in an output file.

**Example:**

```
c166 -t test.c
```

```
MODULE SUMMARY
```

|                                |   |    |
|--------------------------------|---|----|
| Code size (bytes)              | = | 8  |
| Constant size (bytes)          | = | 6  |
| Near data size (bytes)         | = | 2  |
| Far data size (bytes)          | = | 0  |
| Huge data size (bytes)         | = | 0  |
| Shuge data size (bytes)        | = | 0  |
| System data size (bytes)       | = | 0  |
| Internal ram data size (bytes) | = | 0  |
| Bit size (bits)                | = | 0  |
| Bit addressable size (bytes)   | = | 0  |
| User stack size (bytes)        | = | 0  |
| Register bank size (GPR's)     | = | 16 |

```
processed 13 lines at 1331 lines/min
```

```
total: tokens=34, symbols=226
```

# -U

## Option:

`-Uname`

## Arguments:

The name macro you want to undefine.

## Description:

Remove any initial definition of identifier *name* as in `#undef`, unless it is a predefined ANSI standard macro. ANSI specifies the following predefined symbols to exist, which cannot be removed:

|                       |                                                                                                                                                                                                                      |
|-----------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <code>__FILE__</code> | "current source filename"                                                                                                                                                                                            |
| <code>__LINE__</code> | current source line number (int type)                                                                                                                                                                                |
| <code>__TIME__</code> | "hh:mm:ss"                                                                                                                                                                                                           |
| <code>__DATE__</code> | "Mmm dd yyyy"                                                                                                                                                                                                        |
| <code>__STDC__</code> | level of ANSI standard. This macro is set to 1 when the option to disable language extensions ( <code>-A</code> ) is effective. Whenever language extensions are excepted, <code>__STDC__</code> is set to 0 (zero). |

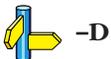
When `c166` is invoked, also the following predefined symbols exist:

|                     |                                                                   |
|---------------------|-------------------------------------------------------------------|
| <code>_C166</code>  | value represents the version of the TASKING C166/ST10 C compiler. |
| <code>_MODEL</code> | memory model used (see section <i>Memory Models</i> for details)  |

These symbols can be turned off with the `-U` option.

## Example:

```
c166 -U_MODEL test.c
```



```
-D
```

## **-u**

### **Option:**

**-u**

### **Description:**

Treat 'character' type variables as 'unsigned character' variables. By default `char` is the same as specifying `signed char`. With **-u** `char` is the same as `unsigned char`.

### **Example:**

With the following command `char` is treated as `unsigned char`:

```
c166 -u test.c
```

## **-V**

**Option:**

**-V**

**Description:**

Display version information.

**Example:**

```
c166 -V
```

```
C166/ST10 C compiler vx.y rz SN00000000-000 (c) year TASKING, Inc.
```

## **-W**

### **Option:**

**-w***[num]*  
**-wstrict**

### **Arguments:**

Optionally the warning number to suppress.

### **Description:**

**-w** suppress all warning messages. **-wnum** only suppresses the given warning. **-wstrict** suppresses extensive warnings 183, 196 and 216.

### **Example:**

To suppress warning 135, enter:

```
c166 file1.c -w135
```

## -X

### Option:

`-x[2|22|d|i|f|m|p]` extended architecture

### Arguments:

Optional features:

- d** support for the MAC co-processor
- i** extended instruction set (e.g. EXTP, EXTS)
- f** extended special function registers (esfr, esfrbit). Implies **-xi**.
- m** extended memory (24 bit addresses instead of 18 bit addresses)
- p** extended PEC pointers (0FCE0h instead of 0FDE0h)
- 2** C166S v2.0 / Super10 architecture
- 22** Enhanced C166S v2.0 / Super10 architecture

### Description:

Allow all or some features of the extended architecture. The **-x** option without any additional character enables all features of the C167/ST10x167/262 extended architectures.

Option **-x2** enables support for the C166S v2.0 / SUPER-10 architecture. This option automatically implies **-ximfp**.

Option **-x22** enables support for ext2 derivatives with an enhanced instruction set. This option automatically implies **-x2imfp**.

The ext2 version of the libraries must be used.

Furthermore, this option automatically enables instruction reordering. If this is not wanted, use **#pragma noreorder** to switch this feature off. (Or use the **-znoreorder** command line option).

Option **-xd** enables support for the MAC co-processor, which can be found in STx272, C166S v2.0 and Super10 architectures.

### Example:

To use the extended instruction set, enter:

```
c166 -xi file.c
```



Pragma reorder in section *Pragmas*.

## -Z

### Option:

`-zpragma`

### Arguments:

A pragma as listed in section *Pragmas*.

### Description:

With this option you can give a pragma on the command line. This is the same as specifying '#pragma *pragma*' in the C source. Dashes ('-') on the command line in the pragma are converted to spaces.

### Example:

To issue a '#pragma autobita 2' using the command line, enter:

```
c166 -zautobita-2 file.c
```

The '-' between autobita and 2 is converted to a space.



Section *Pragmas*.

## 4.4 INCLUDE FILES

You may specify include files in two ways: enclosed in `<>` or enclosed in `""`. When an `#include` directive is seen, **c166** uses the following algorithm trying to open the include file:

1. If the filename is enclosed in `""`, and it is not an absolute pathname (does not begin with a `'\'` for PC, or a `'/'` for UNIX), the include file is searched for in the directory of the file containing the `#include` line. For example, in:

PC:

```
c166 ..\..\source\test.c
```

UNIX:

```
c166 ../../source/test.c
```

**c166** first searches in the directory `..\source` (`../source` for UNIX) for include files.

If you compile a source file in the directory where the file is located (**c166** **test.c**), the compiler searches for include files in the current directory.



This first step is not done for include files enclosed in `<>`.

2. Use the directories specified with the **-I** options, in a left-to-right order. For example:

PC:

```
c166 -I..\include message.c
```

UNIX:

```
c166 -I../include message.c
```

3. Check if the environment variable `C166INC` exists. If it does, use the contents as a directory specifier for include files. You can specify more than one directory in the environment variable `C166INC` by using a separator character. Instead of using **-I** as in the example above, you can specify the same directory using `C166INC`:

PC:

```
set C166INC=..\include
c166 message.c
```

UNIX:

if using the Bourne shell (sh)

```
C166INC=../include
export C166INC
c166 message.c
```

or if using the C-shell (csh)

```
setenv C166INC ../include
c166 message.c
```

4. When an include file is not found with the rules mentioned above, the compiler tries the subdirectory `include`, one directory higher than the directory containing the **c166** binary. For example:

PC:

**c166.exe** is installed in the directory `C:\C166\BIN`  
The directory searched for the include file is `C:\C166\INCLUDE`

UNIX:

**c166** is installed in the directory `/usr/local/c166/bin`  
The directory searched for the include file is  
`/usr/local/c166/include`

The compiler determines run-time which directory the binary is executed from to find this `include` directory.

A directory name specified with the **-I** option or in `C166INC` may or may not be terminated with a directory separator, because **c166** inserts this separator, if omitted.

When you specify more than one directory to the environment variable `C166INC`, you have to use one of the following separator characters:

PC:

;  
; , *space*

e.g. `set C166INC=..\include;\project\include`

UNIX:

: ; , *space*

e.g. **setenv C166INC ../include:/project/include**

## 4.5 PRAGMAS

According to ANSI (3.8.6) a preprocessing directive of the form:

```
#pragma pragma-token-list new-line
```

causes the compiler to behave in an implementation-defined manner. The compiler ignores pragmas which are not mentioned in the list below.

Pragmas give directions to the code generator of the compiler. Besides the pragmas there are two other possibilities to steer the code generation process: command line options and keywords (e.g., `near` type variables) in the C application itself. The compiler acknowledges these three groups using the following rules:

Command line options can be overruled by keywords and pragmas. Keywords can be overruled by pragmas. Hence, pragmas have the highest priority.

This approach makes it possible to set a default optimization level for a source module, which can be overridden temporarily within the source by a pragma.

Most pragmas have a corresponding compiler option at the command line. When no corresponding option is mentioned here, you can use the **-z** option for this purpose. For example,

```
#pragma nocustack
```

can be specified at the command line by entering

```
-znocustack
```

When the pragma text consists of multiple tokens, they can be separated on the command line with dashes. For example,

```
#pragma class mem=name
```

would become

```
-zclass-mem=name
```

**c166** supports the following pragmas:

### ***alias***

Default. Same as **-OA** option. Perform strict alias checking. See also the section *Alias*.

***noalias***

Same as **-Oa** option. Relax alias checking.

***asm [args]***

Insert the following (non preprocessor lines) as assembly language source code into the output file. The inserted lines are not checked for their syntax. The *args* are an interface to the C language. See section *Inline Assembly* for details.

***asm\_noflush***

Same as **asm**, except that the peephole optimizer does not flush the code buffer and assumes register contents remain valid.

***endasm [args]***

Switch back to the C language. With the *args* variables can be passed to the C language. See section *Inline Assembly* for details.

***autobita threshold***

Move chars, (long) ints and struct/unions which are smaller than or equal to the threshold to bitaddressable memory. The declaration may **not** contain any memory modifiers. The default threshold value is set to zero bytes.

Pointers, arrays and function return values are not moved to bitaddressable memory. Local variables are only moved to bitaddressable memory when declared static or compiled with the **-S** option. See also *bita* in section 3.2.1.8.

***autobitestruct threshold***

Move struct/unions which contain at least one bitfield with length 1 to bitaddressable memory. This only applies for structs/unions which are smaller than or equal to the specified threshold. The declaration may **not** contain any memory modifiers. The default threshold value is set to 4 bytes.

Pointers, arrays and function return values are not moved to bitaddressable memory. Local structs/unions are only moved to bitaddressable memory when declared static or compiled with the **-S** option. See also *bita* in section 3.2.1.8.

***automatic***

Default. Use stack approach for non register function automatics. Support recursion.

***static***

Use static memory for non register function automatics. Same as **-S** option. See section *Static Approach of Function Automatics*.

***align mem=atype***

Same as **-Ral** option. Use *atype* as align type for section of area *mem*.

***class mem=name***

Same as **-Rcl** option. Use *name* as class for section of area *mem*.

***combine mem=ctype***

Same as **-Rco** option. Use *ctype* as combine type for section of area *mem*.

***cse size***

Same as **-c** option. Change the maximum user stack space allocation to store CSE values in.

***cse suspend******cse resume***

When the CSE optimization is switched on (**-Oc**) then a sequence of

```
#pragma cse suspend
#pragma cse resume
```

has the effect that expressions in between are not part of the CSE optimization. The pragmas have function scope and do not have any effect unless the CSE optimization is switched on. The CSE optimization for expressions can be switch off in a single function by placing

```
#pragma cse suspend
```

at the start of the functon body.

***custack***

Default. Generate a 'C166\_US' section estimating the stack usage of a module.

***nocustack***

Suppress the user stack estimation.

***clear***

Default. Same as **-OB** option. Perform 'clearing' of non-initialized static/public variables. See section *Non-Initialized Variables* for more information.

***noclear***

Same as **-Ob** option. No 'clearing' of non-initialized static/public variables. See section *Non-Initialized Variables* for more information.

***default\_attributes***

Default. Use default section attributes. See the section *Section Allocation* for details.

***save\_attributes***

Save the current section attributes. See the section *Section Allocation* for details about changing section attributes.

***restore\_attributes***

Restore the last saved section attributes. A warning is issued when no section attributes were saved. See the section *Section Allocation* for details about changing section attributes.

***eramdata***

Allocate all non automatic initialized variables in both ROM and RAM. The RAM data section has the class name 'CINITERAM' (unless part of the default data group where all sections must have the same class name). Copy from ROM to RAM at startup (transparent for the user). See section *Initialized Variables* for details.

***iramdata***

Default. Allocate all non automatic initialized variables in both ROM and RAM. The RAM data section has the class name 'CINITIRAM' (unless part of the default data group where all sections must have the same class name). Copy from ROM to RAM at startup (transparent for the user). See section *Initialized Variables* for details.

### ***romdata***

Allocate all non-automatic variables in ROM only. The ROM data section can have the class names 'CROM', 'CNEARROM', 'CFARROM' or 'CHUGEROM' (unless part of the default data group where all sections must have the same class name). See section *Initialized Variables* for details.

### ***fix\_byte\_write***

For all code following this pragma the compiler generates two NOP instructions after each instruction which does a byte write. These instructions are: ADDDB, ADDDCB, ANDB, CPLB, MOVDB, NEGB, ORB, SUBB, SUBCB, XORB. This is a bypass for the erroneous byte forwarding on internal RAM problem. This pragma is equivalent to the new command line option **-BB**.

### ***nofix\_byte\_write***

Default. For all code following this pragma the compiler does not generate two NOP instructions after each instruction which does a byte write. This pragma is equivalent to the new command line option **-Bb**. By default the generation of two extra NOP instructions after a byte write operation is disabled.

The pragmas **fix\_byte\_write/ nofix\_bytewrite** and the **-BB** option only have to be used for the steps of the SAB 88C166 (flash), which have the "Erroneous Byte Forwarding for internal RAM locations". Please refer to the Infineon errata sheets of your CPU step for more information.

### ***fragment***

#### ***fragment resume***

#### ***fragment continue***

Controls fragmentation of code memory. See section 3.2.3, *Code Memory Fragmentation* for details.

### ***global\_dead\_store\_elim***

Default. Enable dead store elimination on global and local static variables.

***no\_global\_dead\_store\_elim***

Disable dead store elimination on global and local static variables.

Example:

```
void func (void)
{
 enable=1;
 while (!activity);
 enable=0;
}
```

The first assignment will not be optimized away when this pragma was used.

***m166include "include-file"***

This pragma is intended to be used together with user defined intrinsics. This pragma will generate a:

```
$INCLUDE(header.asm)
```

control in the output file. This header file can be used to include the definition of macro (functions) emitted by the compiler when user defined intrinsics are used.

Example:

```
#pragma m166include "header.asm"
```

***macro***

Default. Perform macro expansion.

***nomacro***

Do not perform macro expansion.

***noframe***

Do not emit the interrupt frame code for C interrupt functions. See the section *Interrupt* for details.

***preserve\_mulip***

Make the MULIP bit available for use inside interrupt handlers by saving/restoring PSW in interrupt function prologue/epilogue respectively.

***public***

Default. Public C variables have task scope. See section *Task Scope* for details.

***global***

Public C variables have application scope. See section *Task Scope* for details.

***regdef number***

Same as **-r** option. See the section *Interrupt* for details. Specify 0 if the register bank definition must be omitted.

***reorder***

Enable instruction reordering for the C166S v2.0 / Super10 architecture (**-x2** option).

***noreorder***

Disable instruction reordering for the C166S v2.0 / Super10 architecture.

***savemac***

Save MAC SFRs in an interruptframe. You must use this pragma together with the **-xd** option.



This pragma will not save anything if used together with the **noframe** pragma.

***nosavemac***

Do not save MAC SFRs in an interrupt frame. You must use this pragma together with the **-xd** option.

***autosavemac***

Save MAC registers in an interrupt frame only when needed. You must use this pragma together with the **-xd** compiler option. If you use this pragma in conjunction with **#pragma noframe**, nothing will be saved.

***source***

Same as **-s** option. Enable mixing C source with assembly code.

***nosource***

Default. Disable generation of C source within assembly code.

***size***

Default. Same as **-OF** option. Favour code density above execution speed.

***speed***

Same as **-Of** option. Favour execution speed above code density.

***switch\_force\_table***

Same as **-Os** option. Allow number of gaps to exceed number of case labels and yet use a jump table. See section *Switch Statement* for more details.

***switch\_smart***

Default. Same as **-OS** option. Try to use jump table if it is worthwhile. See section *Switch Statement* for more details.

***switch\_tabmem\_far***

Place jump tables for the small memory model in far ROM. The ROM section where the jump tables are placed have class 'CFARROM'. See section *Constant Romdata Section Allocation* for details.

***switch\_tabmem\_near***

Place jump tables for the small memory model in near ROM. The ROM section where the jump tables are placed have class 'CNEARROM'. See section *Constant Romdata Section Allocation* for details.

***switch\_tabmem\_default***

Default. Jump tables are located as specified by the **-Oe/-OE** option. See section *Constant Romdata Section Allocation* for details.

***volatile\_union***

Treat unions as if declared `volatile`, prohibiting certain optimizations which clash with non-ANSI use of unions: Sometimes a union is used for converting data by writing one member but reading back another.

***novolatile\_union***

Default. Treat unions conform their definition.

## 4.6 ALIAS

By default the compiler assumes that each pointer may point to any object created in the program, so when any pointer is dereferenced, all register contents are assumed to be invalid afterwards.

When it is known that aliasing problems do not occur in the written C-source, alias checking may be relaxed (use the **-Oa** option or **#pragma alias**). Note that the option **-Oc** must be on to use this option. Relaxing alias checking may reduce code size.

### *Example 1:*

```
int i;

void
func()
{
 char * p;
 char c;
 char d;

 if(i)
 p = &c;
 else
 p = &d;

 c = 2;
 d = 3;

 p = 4; / may write to 'c' or 'd' */
 /* --> aliasing object 'c' or 'd' */

 i = c; /* '*p' might have changed the value of 'c', */
 /* so 'c' may not be used from register */
 /* contents, but MUST be read from memory */
 /* --> alias checking MUST be ON in this case */
}
```

**Example 2:**

```

int i;

void
func(char *p)
{
 char c;
 char d;

 c = 2;
 d = 3;

 p = 4; / cannot write to 'c' or 'd', but to some other
 object */

 i = c; /* '*p' cannot have changed the value of 'c', */
 /* so 'c' may be used from register contents */
 /* --> alias checking may be OFF in this case */
}

```

**Example 3:**

```

int array[2];

main()
{
 array[0] = 1;
 array[1] = -1;

 array[0] = array[0] + array[1];
 /* an interrupt might have changed the value */
 /* of 'array', so 'array' may not be used */
 /* from register contents, but MUST be read */
 /* from memory */
 /* --> alias checking MUST be ON in this case */
}

```

## 4.7 COMPILER LIMITS

The ANSI C standard [1-2.2.4] defines a number of translation limits, which a C compiler must support to conform to the standard. The standard states that a compiler implementation should be able to translate and execute a program that contains at least one instance of every one of the following limits, (**c166**'s actual limits are given within parentheses):

Most of the actual compiler limits are determined by the amount of free memory in the host system. In this case a 'D' (Dynamic) is given between parentheses. Some limits are determined by the size of the internal compiler parser stack. These limits are marked with a 'P'. Although the size of this stack is 200, the actual limit can be lower and depends on the structure of the translated program.

- 15 nesting levels of compound statements, iteration control structures and selection control structures (P > 15)
- 8 nesting levels of conditional inclusion (50)
- 12 pointer, array, and function declarators ( in any combinations ) modifying an arithmetic, a structure, a union, or an incomplete type in a declaration (12)
- 31 nesting levels of parenthesized declarators within a full declarator (P > 31)
- 32 nesting levels of parenthesized expressions within a full expression (P > 32)
- 31 significant characters in an external identifier (full ANSI-C mode),  
500 significant characters in an external identifier (non ANSI-C mode)
- 511 external identifiers in one translation unit (D)
- 127 identifiers with block scope declared in one block (D)
- 1024 macro identifiers simultaneously defined in one translation unit (D)
- 31 parameters in one function declaration (D)
- 31 arguments in one function call (D)
- 31 parameters in one macro definition (D)
- 31 arguments in one macro call (D)
- 509 characters in a logical source line (1500)
- 509 characters in a character string literal or wide string literal (after concatenation) (1500)

- 8 nesting levels for **#include** files (50)
- 257 case labels for a switch statement, excluding those for any nested switch statements (D)
- 127 members in a single structure or union (D)
- 127 enumeration constants in a single enumeration (D)
- 15 levels of nested structure or union definitions in a single struct-declaration-list (D)

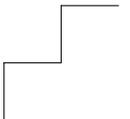
As far as the compiler implementation uses fixed tables, they will be large enough to meet the standards limits. However, most of the internal structures and tables of the compiler are dynamic. Thus the actual compiler limits are determined by the amount of free memory in the system.

# CHAPTER

# 5

## COMPILER DIAGNOSTICS

---



---

# 5 | CHAPTER

---

## 5.1 INTRODUCTION

**c166** has three classes of messages: user errors, warnings and internal compiler errors.

Some user error messages carry extra information, which is displayed by the compiler after the normal message. The messages with extra information are marked with 'I' in the list below and never appear without a previous error message and error number. The number of the information message is not important, and therefore this number is not displayed. A user error can also be fatal (marked as 'F' in the list below), which means that the compiler aborts compilation immediately after displaying the error message and may generate a 'not complete' output file.

The error numbers and warning numbers are divided in two groups. The frontend part of the compiler uses numbers in the range 0 to 499, whereas the backend (code generator) part of the compiler uses numbers in the range 500 and higher. Note that most error messages and warning messages are produced by the frontend.

If a (non fatal) user error occurs during compilation, **c166** displays the C source line that contains the error, the error number and the error message on the screen. If the error is generated by the code generator, the C source line displayed always is the last line of the current C function, because code generation is started when the end of the function is reached by the front end. However, in this case, **c166** displays the line number causing the error before the error message. **c166** always generates the error number in the assembly output file, exactly matching the place where the error occurred.

For example, the following program causes a code generator error message:

```
bit b;

void
err()
{
 b = 1; /* OK */
 b += 1; /* Not allowed */
}

test.c: 8: }
E 539: (line 7) '+=' not allowed on bit type
```

The output file contains:

```

 PUBLIC _err
TEST_1_PR SECTION CODE WORD PUBLIC 'CPROGRAM'
_err PROC NEAR
 BSET _b
 ERROR C166_ERROR_539
 RET
_err ENDP
TEST_1_PR ENDS

```

So, when a compilation is not successful, the generated output file is not accepted by the assembler, thus preventing a corrupt application to be made (see also the `-e` option).

Warning messages do not result in an erroneous assembly output file. They are meant to draw your attention to assumptions of the compiler, for a not correct situation. You can control warning messages with the `-w[number]` option.

The last class of messages are the internal compiler errors. The following format is used:

**S number: assertion failed - please report**

These errors are caused by failed internal consistency checks and should never occur. However, if such a 'SYSTEM' error appears, please report the occurrence to TASKING, using a Problem Report form. Please include a small C program causing the error.

## **5.2 RETURN VALUES**

**c166** returns an exit status to the operating system environment for testing.

### ***For example,***

in a BATCH-file you can examine the exit status of the program executed with ERRORLEVEL:

```

c166 -s %1.c
IF ERRORLEVEL 1 GOTO STOP_BATCH

```

In a bourne shell script, the exit status can be found in the `$?` variable, for example:

```
c166 $*
case $? in
0) echo ok ;;
1|2|3) echo error ;;
esac
```

The exit status of **c166** is one of the numbers of the following list:

- 0 Compilation successful, no errors
- 1 There were user errors, but terminated normally
- 2 A fatal error, or System error occurred, premature ending
- 3 Stopped due to user abort

or if the `-exit` commandline option was used:

- 0 Compilation successful, no errors/warnings
- 1 There were user errors/warnings, but terminated normally
- 2 A fatal error, or System error occurred, premature ending
- 3 Stopped due to user abort

### 5.3 ERRORS AND WARNINGS

Errors start with an error type, followed by a number and a message. The error type is indicated by a letter:

- I information
- E error
- F fatal error
- S system error
- W warning

#### **Frontend**

- F 1 evaluation expired

Your product evaluation period has expired. Contact your local TASKING office for the official product.

- W 2 unrecognized option: '*option*'

The option you specified does not exist. Check the invocation syntax for the correct option.

- E 4 expected *number* more '#endif'

The preprocessor part of the compiler found the '#if', '#ifdef' or '#ifndef' directive but did not find a corresponding '#endif' in the same source file. Check your source file that each '#if', '#ifdef' or '#ifndef' has a corresponding '#endif'.

- E 5 no source modules

You must specify at least one source file to compile.

- F 6 cannot create "*file*"

The output file or temporary file could not be created. Check if you have sufficient disk space and if you have write permissions in the specified directory.

- F 7 cannot open "*file*"

Check if the file you specified really exists. Maybe you misspelled the name, or the file is in another directory.

- F 8 attempt to overwrite input file "*file*"

The output file must have a different name than the input file.

E 9 unterminated constant character or string

This error can occur when you specify a string without a closing double-quote (") or when you specify a character constant without a closing single-quote ('). This error message is often preceded by one or more E 19 error messages.

F 11 file stack overflow

This error occurs if the maximum nesting depth (50) of file inclusion is reached. Check for #include files that contain other #include files. Try to split the nested files into simpler files.

F 12 memory allocation error

All free space has been used. Free up some memory by removing any resident programs, divid the file into several smaller source files, break expressions into smaller subexpressions or put in more memory.

W 13 prototype after forward call or old style declaration – ignored

Check that a prototype for each function is present before the actual call.

E 14 ';' inserted

An expression statement needs a semicolon. For example, after ++i in { int i; ++i }.

E 15 missing filename after -o option

The **-o** option must be followed by an output filename.

E 16 bad numerical constant

A constant must conform to its syntax. For example, 08 violates the octal digit syntax. Also, a constant may not be too large to be represented in the type to which it was assigned. For example, `int i = 0x1234567890;` is too large to fit in an integer.

E 17 string too long

This error occurs if the maximum string size (1500) is reached. Reduce the size of the string.

E 18 illegal character (*0xbexnumber*)

The character with the hexadecimal ASCII value *0xbexnumber* is not allowed here. For example, the '#' character, with hexadecimal value 0x23, to be used as a preprocessor command, may not be preceded by non-white space characters. The following is an example of this error:

```
char *s = #S ; // error
```

E 19 newline character in constant

The newline character can appear in a character constant or string constant only when it is preceded by a backslash (\). To break a string that is on two lines in the source file, do one of the following:

- End the first line with the line-continuation character, a backslash (\).
- Close the string on the first line with a double quotation mark, and open the string on the next line with another quotation mark.

E 20 empty character constant

A character constant must contain exactly one character. Empty character constants ( ' ' ) are not allowed.

E 21 character constant overflow

A character constant must contain exactly one character. Note that an escape sequence (for example, \t for tab) is converted to a single character.

E 22 '#define' without valid identifier

You have to supply an identifier after a '#define'.

E 23 '#else' without '#if'

'#else' can only be used within a corresponding '#if', '#ifdef' or '#ifndef' construct. Make sure that there is a '#if', '#ifdef' or '#ifndef' statement in effect before this statement.

E 24 '#endif' without matching '#if'

'#endif' appeared without a matching '#if', '#ifdef' or '#ifndef' preprocessor directive. Make sure that there is a matching '#endif' for each '#if', '#ifdef' and '#ifndef' statement.

E 25 missing or zero line number

'#line' requires a non-zero line number specification.

E 26 undefined control

A control line (line with a '*identifier*') must contain one of the known preprocessor directives.

W 27 unexpected text after control

'#ifdef' and '#ifndef' require only one identifier. Also, '#else' and '#endif' only have a newline. '#undef' requires exactly one identifier.

W 28 empty program

The source file must contain at least one external definition. A source file with nothing but comments is considered an empty program.

E 29 bad '#include' syntax

A '#include' must be followed by a valid header name syntax. For example, `#include <stdio.h` misses the closing '>'.

E 30 include file "*file*" not found

Be sure you have specified an existing include file after a '#include' directive. Make sure you have specified the correct path for the file.

E 31 end-of-file encountered inside comment

The compiler found the end of a file while scanning a comment. Probably a comment was not terminated. Do not forget a closing comment `*/` when using ANSI-C style comments.

E 32 argument mismatch for macro "*name*"

The number of arguments in invocation of a function-like macro must agree with the number of parameters in the definition. Also, invocation of a function-like macro requires a terminating `)` token. The following are examples of this error:

```
#define A(a) 1
int i = A(1,2); /* error */

#define B(b) 1
int j = B(1; /* error */
```

E 33 "*name*" redefined

The given identifier was defined more than once, or a subsequent declaration differed from a previous one. The following examples generate this error:

```
int i;
char i; /* error */
main()
{
}
```

```

main()
{
 int j;
 int j; /* error */
}

```

W 34 illegal redefinition of macro "*name*"

A macro can be redefined only if the body of the redefined macro is exactly the same as the body of the originally defined macro.

This warning can be caused by defining a macro on the command line and in the source with a '#define' directive. It also can be caused by macros imported from include files. To eliminate the warning, either remove one of the definitions or use an '#undef' directive before the second definition.

E 35 bad filename in '#line'

The string literal of a '#line' (if present) may not be a "wide-char" string. So, #line 9999 L"t45.c" is not allowed.

W 36 'debug' facility not installed

'#pragma debug' is only allowed in the debug version of the compiler.

W 37 attempt to divide by zero

A divide or modulo by zero was found. Adjust the expression or test if the second operand of a divide or modulo is zero.

E 38 non integral switch expression

A switch condition expression must evaluate to an integral value. So, char \*p = 0; switch (p) is not allowed.

F 39 unknown error number: *number*

This error may not occur. If it does, contact your local TASKING office and provide them with the exact error message.

W 40 non-standard escape sequence

Check the spelling of your escape sequence (a backslash, \, followed by a number or letter), it contains an illegal escape character. For example, \c causes this warning.

- E 41 `#elif` without `#if`  
The `#elif` directive did not appear within an `#if`, `#ifdef` or `#ifndef` construct. Make sure that there is a corresponding `#if`, `#ifdef` or `#ifndef` statement in effect before this statement.
- E 42 syntax error, expecting parameter type/declaration/statement  
A syntax error occurred in a parameter list a declaration or a statement. This can have many causes, such as, errors in syntax of numbers, usage of reserved words, operator errors, missing parameter types, missing tokens.
- E 43 unrecoverable syntax error, skipping to end of file  
The compiler found an error from which it could not recover. This error is in most cases preceded by another error. Usually, error E 42.
- I 44 in initializer "*name*"  
Informational message when checking for a proper constant initializer.
- E 46 cannot hold that many operands  
The value stack may not exceed 20 operands.
- E 47 missing operator  
An operator was expected in the expression.
- E 48 missing right parenthesis  
)' was expected.
- W 49 attempt to divide by zero – potential run-time error  
An expression with a divide or modulo by zero was found. Adjust the expression or test if the second operand of a divide or modulo is zero.
- E 50 missing left parenthesis  
'(' was expected.
- E 51 cannot hold that many operators  
The state stack may not exceed 20 operators.
- E 52 missing operand  
An operand was expected.

- E 53 missing identifier after 'defined' operator  
An identifier is required in a `#if defined(identifier)`.
- E 54 non scalar controlling expression  
Iteration conditions and 'if' conditions must have a scalar type (not a struct, union or a pointer). For example, after `static struct {int i;} si = {0}`; it is not allowed to specify `while (si) ++si.i;`.
- E 55 operand has not integer type  
The operand of a '#if' directive must evaluate to an integral constant. So, `#if 1.` is not allowed.
- W 56 '<*debugoption*><*level*>' no associated action  
This warning can only appear in the debug version of the compiler. There is no associated debug action with the specified debug option and level.
- W 58 invalid warning number: *number*  
The warning number you supplied to the `-w` option does not exist. Replace it with the correct number.
- F 59 sorry, more than *number* errors  
Compilation stops if there are more than 40 errors.
- E 60 label "*label*" multiple defined  
A label can be defined only once in the same function. The following is an example of this error:

```
f()
{
 lab1:
 lab1: /* error */
}
```

- E 61 type clash  
The compiler found conflicting types. For example, a `long` is only allowed on `int` or `double`, no specifiers are allowed with `struct`, `union` or `enum`. The following is an example of this error:

```
unsigned signed int i; /* error */
```

E 62 bad storage class for "*name*"

The storage class specifiers `auto` and `register` may not appear in declaration specifiers of external definitions. Also, the only storage class specifier allowed in a parameter declaration is `register`.

E 63 "*name*" redeclared

The specified identifier was already declared. The compiler uses the second declaration. The following is an example of this error:

```
struct T { int i; };
struct T { long j; }; /* error */
```

E 64 incompatible redeclaration of "*name*"

The specified identifier was already declared. All declarations in the same function or module that refer to the same object or function must specify compatible types. The following is an example of this error:

```
f()
{
 int i;
 char i; /* error */
}
```

W 66 function "*name*": variable "*name*" not used

A variable is declared which is never used. You can remove this unused variable or you can use the **-w66** option to suppress this warning.

W 67 illegal suboption: *option*

The suboption is not valid for this option. Check the invocation syntax for a list of all available suboptions.

W 68 function "*name*": parameter "*name*" not used

A function parameter is declared which is never used. You can remove this unused parameter or you can use the **-w68** option to suppress this warning.

## E 69 declaration contains more than one basic type specifier

Type specifiers may not be repeated. The following is an example of this error:

```
int char i; /* error */
```

- E 70 'break' outside loop or switch

A `break` statement may only appear in a `switch` or a loop (`do`, `for` or `while`). So, `if (0) break;` is not allowed.

- E 71 illegal type specified

The type you specified is not allowed in this context. For example, you cannot use the type `void` to declare a variable. The following is an example of this error:

```
void i; /* error */
```

- W 72 duplicate type modifier

Type qualifiers may not be repeated in a specifier list or qualifier list. The following is an example of this warning:

```
{ long long i; } /* error */
```

- E 73 object cannot be bound to multiple memories

Use only one memory attribute per object. For example, specifying both `rom` and `ram` to the same object is not allowed.

- E 74 declaration contains more than one class specifier

A declaration may contain at most one storage class specifier. So, `register auto i;` is not allowed.

- E 75 'continue' outside a loop

`continue` may only appear in a loop body (`do`, `for` or `while`). So, `switch (i) {default: continue;}` is not allowed.

- E 76 duplicate macro parameter "*name*"

The given identifier was used more than one in the format parameter list of a macro definition. Each macro parameter must be uniquely declared.

- E 77 parameter list should be empty

An identifier list, not part of a function definition, must be empty. For example, `int f ( i, j, k );` is not allowed on declaration level.

- E 78 'void' should be the only parameter

Within a function prototype of a function that does not except any arguments, `void` may be the only parameter. So, `int f(void, int);` is not allowed.

- E 79 constant expression expected

A constant expression may not contain a comma. Also, the bit field width, an expression that defines an enum, array-bound constants and switch case expressions must all be integral constant expressions.

- E 80 `#` operator shall be followed by macro parameter

The `#` operator must be followed by a macro argument.

- E 81 `##` operator shall not occur at beginning or end of a macro

The `##` (token concatenation) operator is used to paste together adjacent preprocessor tokens, so it cannot be used at the beginning or end of a macro body.

- W 86 escape character truncated to 8 bit value

The value of a hexadecimal escape sequence (a backslash, `\`, followed by a `x` and a number) must fit in 8 bits storage. The number of bits per character may not be greater than 8. The following is an example of this warning:

```
char c = '\xabc'; /* error */
```

- E 87 concatenated string too long

The resulting string was longer than the limit of 1500 characters.

- W 88 *"name"* redeclared with different linkage

The specified identifier was already declared. This warning is issued when you try to redeclare an object with a different basic storage class, and both objects are not declared extern or static. The following is an example of this warning:

```
int i;
int i(); /* error E 64 and warning */
```

- E 89 illegal bitfield declarator

A bit field may only be declared as an integer, not as a pointer or a function for example. So, `struct {int *a:1;} s;` is not allowed.

- E 90 *#error message*

The *message* is the descriptive text supplied in a `#error` preprocessor directive.

- W 91 no prototype for function "*name*"  
Each function should have a valid function prototype.
- W 92 no prototype for indirect function call  
Each function should have a valid function prototype.
- I 94 hiding earlier one  
Additional message which is preceded by error E 63. The second declaration will be used.
- F 95 protection error: *message*  
Something went wrong with the protection key initialization. The message could be: "Key is not present or printer is not correct.", "Can't read key.", "Can't initialize key.", or "Can't set key-model".
- E 96 syntax error in #define  
`#define id( requires a right-parenthesis )'.`
- E 97 "... " incompatible with old-style prototype  
If one function has a parameter type list and another function, with the same name, is an old-style declaration, the parameter list may not have ellipsis. The following is an example of this error:
- ```
int f(int, ...);
int f();          /* error, old-style */
```
- E 98 function type cannot be inherited from a typedef
A typedef cannot be used for a function definition. The following is an example of this error:
- ```
typedef int INTFN();
INTFN f {return (0);} /* error */
```
- F 99 conditional directives nested too deep  
'#if', '#ifdef' or '#ifndef' directives may not be nested deeper than 50 levels.
- E 100 case or default label not inside switch  
The `case:` or `default:` label may only appear inside a switch.

## E 101 vacuous declaration

Something is missing in the declaration. The declaration could be empty or an incomplete statement was found. You must declare array declarators and `struct`, `union`, or `enum` members. The following are examples of this error:

```
int ; /* error */

static int a[2] = { }; /* error */
```

## E 102 duplicate case or default label

Switch case values must be distinct after evaluation and there may be at most one `default:` label inside a `switch`.

## E 103 may not subtract pointer from scalar

The only operands allowed on subtraction of pointers is pointer – pointer, or pointer – scalar. So, scalar – pointer is not allowed. The following is an example of this error:

```
int i;
int *pi = &i;
ff(1 - pi); /* error */
```

E 104 left operand of *operator* has not struct/union type

The first operand of a `'.'` or `'->'` must have a `struct` or `union` type.

## E 105 zero or negative array size – ignored

Array bound constants must be greater than zero. So, `char a[0];` is not allowed.

## E 106 different constructors

Compatible function types with parameter type lists must agree in number of parameters and in use of ellipsis. Also, the corresponding parameters must have compatible types. This error is usually followed by informational message I 111. The following is an example of this error:

```
int f(int);
int f(int, int); /* error different
 parameter list */
```

## E 107 different array sizes

Corresponding array parameters of compatible function types must have the same size. This error is usually followed by informational message I 111. The following is an example of this error:

```
int f(int [][][2]);
int f(int [][][3]); /* error */
```

## E 108 different types

Corresponding parameters must have compatible types and the type of each prototype parameter must be compatible with the widened definition parameter. This error is usually followed by informational message I 111. The following is an example of this error:

```
int f(int);
int f(long); /* error different type
 in parameter list */
```

## E 109 floating point constant out of valid range

A floating point constant must have a value that fits in the type to which it was assigned. See section *Data Types* for the valid range of a floating point constant. The following is an example of this error:

```
float d = 10E9999; /* error, too big */
```

## E 110 function cannot return arrays or functions

A function may not have a return type that is of type array or function. A pointer to a function is allowed. The following are examples of this error:

```
typedef int F(); F f(); /* error */
typedef int A[2]; A g(); /* error */
```

## I 111 parameter list does not match earlier prototype

Check the parameter list or adjust the prototype. The number and type of parameters must match. This message is preceded by error E 106, E 107 or E 108.

## E 112 parameter declaration must include identifier

If the declarator is a prototype, the declaration of each parameter must include an identifier. Also, an identifier declared as a `typedef` name cannot be a parameter name. The following are examples of this error:

```

int f(int g, int) {return (g);} /* error */

typedef int int_type;
int h(int_type) {return (0);} /* error */

```

E 114 incomplete struct/union type

The struct or union type must be known before you can use it. The following is an example of this error:

```

extern struct unknown sa, sb;
sa = sb; /* 'unknown' does not have a
 defined type */

```

The left side of an assignment (the lvalue) must be modifiable.

E 115 label "*name*" undefined

A goto statement was found, but the specified label did not exist in the same function or module. The following is an example of this error:

```

f1() { a: ; } /* W 116 */
f2() { goto a; } /* error, label 'a:' is
 not defined in f2() */

```

W 116 label "*name*" not referenced

The given label was defined but never referenced. The reference of the label must be within the same function or module. The following is an example of this warning:

```

f() { a: ; } /* 'a' is not referenced */

```

E 117 "*name*" undefined

The specified identifier was not defined. A variable's type must be specified in a declaration before it can be used. This error can also be the result of a previous error. The following is an example of this error:

```

unknown i; /* error, 'unknown' undefined */
i = 1; /* as a result, 'i' is also
 undefined */

```

W 118 constant expression out of valid range

A constant expression used in a case label may not be too large. Also when converting a floating point value to an integer, the floating point constant may not be too large. This warning is usually preceded by error E 16 or E 109. The following is an example of this warning:

```
int i = 10E88; /* error and warning */
```

- E 119 cannot take 'sizeof' bitfield or void type

The size of a bit field or void type is not known. So, the size of it cannot be taken.

- E 120 cannot take 'sizeof' function

The size of a function is not known. So, the size of it cannot be taken.

- E 121 not a function declarator

This is not a valid function. This may be due to a previous error. The following is an example of this error:

```
int f() return 0; /* missing '{ }' */
int g() { } /* error, 'g' is not a
 formal parameter and
 therefore, this is not a
 valid function declaration */
```

- E 122 unnamed formal parameter

The parameter must have a valid name.

- W 123 function should return something

A return in a non-void function must have an expression.

- E 124 array cannot hold functions

An array of functions is not allowed.

- E 125 function cannot return anything

A return with an expression may not appear in a void function.

- W 126 missing return (function "name")

A non-void function with a non-empty function body must have a return statement.

- E 129 cannot initialize "name"

Declarators in the declarator list may not contain initializations. Also, an extern declaration may have no initializer. The following are examples of this error:

```
{ extern int i = 0; } /* error */
int f(i) int i=0; /* error */
```

W 130 operands of *operator* are pointers to different types

Pointer operands of an operator or assignment ('='), must have the same type. For example, the following code generates this warning:

```
long *pl;
int *pi = 0;
pl = pi; /* warning */
```

E 131 bad operand type(s) of *operator*

The operator needs an operand of another type. The following is an example of this error:

```
int *pi;
pi += 1.; /* error, pointer on left; needs
 integral value on right */
```

W 132 value of variable "*name*" is undefined

This warning occurs if a variable is used before it is defined. For example, the following code generates this warning:

```
int a,b;
a = b; /* warning, value of b unknown */
```

E 133 illegal struct/union member type

A function cannot be a member of a struct or union. Also, bit fields may only have type int or unsigned.

E 134 bitfield size out of range – set to 1

The bit field width may not be greater than the number of bits in the type and may not be negative. The following example generates this error:

```
struct i { unsigned i : 999; }; /* error */
```

W 135 statement not reached

The specified statement will never be executed. This is for example the case when statements are present after a return.

E 138 illegal function call

You cannot perform a function call on an object that is not a function. The following example generates this error:

```
int i, j;
j = i(); /* error, i is not a function */
```

- E 139 *operator* cannot have aggregate type

The type name in a (cast) must be a scalar (not a struct, union or a pointer) and also the operand of a (cast) must be a scalar. The following are examples of this error:

```
static union ui {int a;} ui ;
ui = (union ui)9; /* cannot cast to union */
ff((int)ui); /* cannot cast a union
 to something else */
```

- E 140 *type* cannot be applied to a register/bit/bitfield object or builtin/inline function

For example, the '&' operator (address) cannot be used on registers and bit fields. So, `func(&r6);` and `func(&bitf.a);` are invalid.

- E 141 *operator* requires modifiable lvalue

The operand of the '++', or '--' operator and the left operand of an assignment or compound assignment (lvalue) must be modifiable. The following is an example of this error:

```
const int i = 1;
i = 3; /* error, const cannot be
 modified */
```

- E 143 too many initializers

There may be no more initializers than there are objects. The following is an example of this error:

```
static int a[1] = {1, 2}; /* error,
 only one object can be initialized */
```

- W 144 enumerator "*name*" value out of range

An enum constant exceeded the limit for an int. The following is an example of this warning:

```
enum { A = INT_MAX, B }; /* warning,
 B does not fit in an int anymore */
```

- E 145 requires enclosing curly braces

A complex initializer needs enclosing curly braces. For example, `int a[] = 2;` is not valid, but `int a[] = {2};` is.

- E 146 argument *#number*: memory spaces do not match

With prototypes, the memory spaces of arguments must match.

- W 147 argument *#number*: different levels of indirection

With prototypes, the types of arguments must be assignment compatible. The following code generates this warning:

```
int i; void func(int,int);
func(1, &i); /* warning, argument 2 */
```

- W 148 argument *#number*: struct/union type does not match

With prototypes, both the prototyped function argument and the actual argument was a `struct` or `union`., but they have different tags. The tag types should match. The following is an example of this warning:

```
f(struct s); /* prototype */
main()
{
 struct { int i; } t;
 f(t); /* t has other type than s */
}
```

- E 149 object "*name*" has zero size

A `struct` or `union` may not have a member with an incomplete type. The following is an example of this error:

```
struct { struct unknown m; } s; /* error */
```

- W 150 argument *#number*: pointers to different types

With prototypes, the pointer types of arguments must be compatible. The following example generates this warning:

```
int f(int*);
long *l;
f(l); /* warning */
```

- W 151 ignoring memory specifier

Memory specifiers for a `struct`, `union` or `enum` are ignored.

- E 152 operands of *operator* are not pointing to the same memory space

Be sure the operands point to the same memory space. This error occurs, for example, when you try to assign a pointer to a pointer from a different memory space.

- E 153 `'sizeof' zero sized object`

An implicit or explicit `sizeof` operation references an object with an unknown size. This error is usually preceded by error E 119 or E 120, cannot take `'sizeof'`.

- E 154 `argument #number: struct/union mismatch`

With prototypes, only one of the prototyped function argument or the actual argument was a `struct` or union. The types should match. The following is an example of this error:

```
f(struct s); /* prototype */

main()
{
 int i;
 f(i); /* i is not a struct */
}
```

- E 155 `casting lvalue 'type' to 'type' is not allowed`

The operand of the `'++'`, or `'--'` operator or the left operand of an assignment or compound assignment (lvalue) may not be cast to another type. The following is an example of this error:

```
int i = 3;
++(unsigned)i; /* error, cast expression
 is not an lvalue */
```

- E 157 `"name" is not a formal parameter`

If a declarator has an identifier list, only its identifiers may appear in the declarator list. The following is an example of this error:

```
int f(i) int a; /* error */
```

- E 158 `right side of operator is not a member of the designated struct/union`

The second operand of `'.'` or `'->'` must be a member of the designated `struct` or union.

- E 160 `pointer mismatch at operator`

Both operands of `operator` must be a valid pointer. The following example generates this error:

```
int *pi = 44; /* right side not a pointer */
```

- E 161 aggregates around *operator* do not match

The contents of the structs, unions or arrays on both sides of the *operator* must be the same. The following example causes this error:

```
struct {int a; int b;} s;
struct {int c; int d; int e;} t;
s = t; /* error */
```

- E 162 *operator* requires an lvalue or function designator

The '&' (address) operator requires an lvalue or function designator. The following is an example of this error:

```
int i;
i = &(i = 0);
```

- W 163 operands of *operator* have different level of indirection

The types of pointers or addresses of the operator must be assignment compatible. The following is an example of this warning:

```
char **a;
char *b;
a = b; /* warning */
```

- E 164 operands of *operator* may not have type 'pointer to void'

The operands of *operator* may not have operand (void \*).

- W 165 operands of *operator* are incompatible: pointer vs. pointer to array

The types of pointers or addresses of the operator must be assignment compatible. A pointer cannot be assigned to a pointer to array. The following is an example of this warning:

```
main()
{
 typedef int array[10];
 array a;
 array *ap = a; /* warning */
}
```

- E 166 *operator* cannot make something out of nothing

Casting type void to something else is not allowed. The following example generates this error:

```

void f(void);
main()
{
 int i;

 i = (int)f(); /* error */
}

```

- E 170 recursive expansion of inline function "*name*"

An `_inline` function may not be recursive. The following example generates this error:

```

_inline int a (int i)
{
 a(i); /* recursive call */
 return i;
}
main()
{
 a(1); /* error */
}

```

- E 171 too much tail-recursion in inline function "*name*"

If the function level is greater than or equal to 40 this error is given. The following example generates this error:

```

_inline void a ()
{
 a();
}
main()
{
 a();
}

```

- W 172 adjacent strings have different types

When concatenating two strings, they must have the same type. The following example generates this warning:

```

char b[] = L"abc""def"; /* strings have
 different types */

```

- E 173 'void' function argument

A function may not have an argument with type `void`.

## E 174 not an address constant

A constant address was expected. Unlike a static variable, an automatic variable does not have a fixed memory location and therefore, the address of an automatic is not a constant. The following is an example of this error:

```
int *a;
static int *b = a; /* error */
```

## E 175 not an arithmetic constant

In a constant expression no assignment operators, no '++' operator, no '—' operator and no functions are allowed. The following is an example of this error:

```
int a;
static int b = a++; /* error */
```

## E 176 address of automatic is not a constant

Unlike a static variable, an automatic variable does not have a fixed memory location and therefore, the address of an automatic is not a constant. The following is an example of this error:

```
int a; /* automatic */
static int *b = &a; /* error */
```

W 177 static variable "*name*" not used

A static variable is declared which is never used. To eliminate this warning remove the unused variable.

W 178 static function "*name*" not used

A static function is declared which is never called. To eliminate this warning remove the unused function.

E 179 inline function "*name*" is not defined

Possibly only the prototype of the inline function was present, but the actual inline function was not. The following is an example of this error:

```

_inline int a(void); /* prototype */

main()
{
 int b;
 b = a(); /* error */
};

```

- E 180 illegal target memory (*memory*) for pointer

The pointer may not point to *memory*. For example, a pointer to bitaddressable memory is not allowed.

- E 181 invalid cast to function

This error is generated when attempting to cast an object to a function type as shown in the example below:

```

int i;
void main(void)
{
 i+=(int*(int))i;
 return;
}

```

- W 182 argument *#number*: different types

With prototypes, the types of arguments must be compatible.

- W 183 variable '*name*' possibly uninitialized

Possibly an initialization statement is not reached, while a function should return something. The following is an example of this warning:

```

int a;

int f(void)
{
 int i;

 if (a)
 {
 i = 0; /* statement not reached */
 }
 return i; /* warning */
}

```

- W 184 empty pragma name in `-z` option – ignored  
After the `-z` option you must specify an existing pragma. See the description of the `-z` option for details.
- I 185 (prototype synthesized at line *number* in "*name*")  
This is an informational message containing the source file position where an old-style prototype was synthesized. This message is preceded by error E 146, W 147, W 148, W 150, E 154, W 182 or E 203.
- E 186 array of type bit is not allowed  
An array cannot contain bit type variables.
- E 187 illegal structure definition  
A structure can only be defined (initialized) if its members are known. So, `struct unknown s = { 0 };` is not allowed.
- E 188 structure containing bit-type fields is forced into bitaddressable area  
This error occurs when you use a bitaddressable storage type for a structure containing bit-type members.
- E 189 pointer is forced to bitaddressable, pointer to bitaddressable is illegal  
A pointer to bitaddressable memory is not allowed.
- W 190 "long float" changed to "float"  
In ANSI C floating point constants are treated having type `double`, unless the constant has the suffix `f`. If you have specified an option to use float constants, a long floating point constant such as `123.12f1` is changed to a `float`.
- E 191 recursive struct/union definition  
A `struct` or `union` cannot contain itself. The following example generates this error:
- ```
struct s { struct s a; } b; /* error */
```
- E 192 missing filename after `-f` option
The `-f` option requires a filename argument.

E 194 cannot initialize typedef

You cannot assign a value to a typedef variable. So, `typedef i=2;` is not allowed.

W 195 constant expression out of range -- truncated

The resulting constant expression is too large to fit in the specified data type. The value is truncated. The following example generates this warning:

```
int i = 140000L;      /* warning, value is too large
                    to fit in an int */
```

W 196 constant expression out of range due to signed/unsigned type mismatch

The resulting constant expression is too large to fit in the specified data type. The following example generates this warning:

```
int i = 40000U; /* the unsigned value is too large
               to fit in a signed int */
/* unsigned int i = 40000U; is OK */
```

W 197 unrecognized -w argument: *argument*

The `-w` option only accepts a warning number or the text 'strict' as an argument. See the description of the `-w` option for details.

W 198 trigraph sequence replaced

The character set of C source programs is contained within seven-bit ASCII, but is a superset of the ISO 646-1983 Invariant Code Set. In order to enable programs to be represented in the reduced set, all occurrences of the following trigraph sequences are replaced by the corresponding single character. This replacement occurs before any other processing.

```
??= represents #
??/ represents \
??' represents ^
??( represents [
??) represents ]
??! represents |
??< represents {
??> represents }
??- represents ~
```

The compiler issues a warning when it performs a trigraph replacement to inform that something occurred which was probably not expected to occur.

F 199 demonstration package limits exceeded

The demonstration package has certain limits which are not present in the full version. Contact TASKING for a full version.

W 200 unknown pragma "*name*" – ignored

The compiler ignores pragmas that are not known. For example, `#pragma unknown`.

W 201 *name* cannot have storage type – ignored

A register variable or an automatic/parameter cannot have a storage type. To eliminate this warning, remove the storage type or place the variable outside a function.

E 202 '*name*' is declared with 'void' parameter list

You cannot call a function with an argument when the function does not accept any (void parameter list). The following is an example of this error:

```
int f(void);      /* void parameter list */

main()
{
    int i;
    i = f(i);     /* error */
    i = f();     /* OK */
}
```

E 203 too many/few actual parameters

With prototyping, the number of arguments of a function must agree with the prototype of the function. The following is an example of this error:

```
int f(int);      /* one parameter */

main()
{
    int i;
    i = f(i,i);  /* error, one too many */
    i = f(i);    /* OK */
}
```

- W 204 U suffix not allowed on floating constant – ignored
A floating point constant cannot have a 'U' or 'u' suffix.
- W 205 F suffix not allowed on integer constant – ignored
An integer constant cannot have a 'F' or 'f' suffix.
- E 206 '*name*' named bit-field cannot have 0 width
A bit field must be an integral constant expression with a value greater than zero.
- E 207 list of rule numbers expected after "--misrac" option.
A list of rule numbers is required after the '-misrac' option.
- W 208 unsupported MISRA C rule number %d.
Specified MISRA C rule number is not supported.
- E 209 +MISRA C rule %d violation: %s
A specified MISRA C rule is violated.
- E 212 "*name*": missing static function definition
A function with a `static` prototype misses its definition.
- W 213 invalid string/character constant in non-active part of source
This part of the source is skipped.
- E 214 second occurrence of `#pragma asm` or `asm.noflush`.
- E 215 "`pragma endasm`" without a "`#pragma asm`"
- W 216 suggest parentheses around assignment used as truth value
In the example below W 216 will be generated because of a suspicious assignment within an if condition.

```
int func( int a, int b, int c )
{
    if ( a = b )
    {
        return c;
    }
    return a;
}
```

Backend

- W 501 initializer was truncated
Some most significant bits are non-zero. Due to a cast, the most significant bits are stripped off.
- F 504 object doesn't fit in memory: *memory*
A memory overflow occurred. Use a larger memory model or specify a larger storage type. When *memory* is "program", then try to split the module into separate ones on function basis. It is usually sufficient to split the module into two separate ones, each having about the half of the program code of the original module. Program code of a single function is limited to 64Kb. When *memory* is "fstack", the allocation of automatic data exceeds 16K.
- E 519 no indirection allowed on bit type
Pointer to a bit variable and array of bit is **not** allowed, because the 80166 has no instructions to indirectly access a bit variable.
- E 531 restriction: impossible to convert to '*type*'
The structure or union cannot be casted to types `bit`, `char`, `int`, `long`, `float` or `double`.
- E 539 *operator* not allowed on bit type
See section 3.4.3, *The Bit Type*, for a list of operators that are allowed on type `bit`.
- E 540 bit type parameter not allowed
A `bit` type variable is **not** allowed as parameter. The allowed classes for `bit` are: `static`, `public` or `extern`. See also section 3.4.3, *The Bit Type*.
- E 541 bit type switch expression not allowed
A `bit` typed expression is **not** allowed as switch expression. See also section 3.4.3, *The Bit Type*.
- E 542 argument *number* is not an integral constant expression
The argument of the specified intrinsic function must evaluate to an integral value. See section 3.16, *Intrinsic Functions*, for the syntax of the specified intrinsic function.

- W 543 'extern near' might be in other data group: check 'Ggroupname' option is also used with module defining external
- If you use the **-G** option, it is your own responsibility to declare 'extern near' variables within the same group. See also section 3.2.1.6, *Efficiency in Large Data Models*.
- E 544 semaphore must be bit object
- The intrinsic functions `_testset()` and `_testclear()` must have a bit type argument.
- E 545 maximum interrupt number is 127
- Use an interrupt number less than 128.
- E 547 calling an interrupt routine, use '`_int166()`'
- An interrupt function cannot be called directly, you must use the intrinsic function `_int166()`.
- E 549 argument *number* is not bitaddressable
- The intrinsic functions `_getbit()`, `_putbit()` and `_bflld()` require a bitaddressable argument. See section 3.16, *Intrinsic Functions*, for the syntax of these intrinsic functions.
- E 550 assignment/parameter/return not allowed with bit-structure
- Structure of `bit` is supported, with the restriction that no other type than `bit` is member of this structure. Structure of `bit` is **not** allowed as parameter or return value of a function.. See also section 3.4.3, *The Bit Type*.
- F 551 too many sections (> *number*)
- A module can contain 255 sections at the most.
- E 552 '*memory_type*' is illegal memory for function: near or huge only
- The specified storage type is not valid for this function. The storage type of a function can be either `near` or `huge`. A function can also have return type `bit`.
- F 553 illegal memory model
- See the compiler usage for valid arguments of the **-M** option.
- F 554 illegal memory type specified
- See the description of the **-m** option for the correct syntax.

- F 555 invalid *option* option
The option must have a valid argument. See the description of the *option* for the correct syntax.
- F 556 illegal section qualifier in `-R` option
See the description of the `-R` option for the correct syntax.
- F 557 illegal number in option
You must specify a valid number (decimal or hexadecimal) to the option.
- W 558 maximum number of GPR's in a registerbank is 16 – ignored
If you specify a number of GPRs to the `-r` option or pragma **regdef** it must have a value in the range 6–16 (inclusive).
- W 559 obsolete option `-Om/-OM` – please use `-Bm/-BM`
The `-Om/-OM` option is no longer used in this version, use the `-Bm/-BM` option instead.
- E 560 static initialization of `sfr/sfrbit` `esfr/esfrbit` is not allowed
For example, the construction `sfr SYSCON = 2;` is not allowed.
- E 561 illegal storage class for `sfr/sfrbit`, `esfr/esfrbit`, `xsfr`
`[e]sfr/[e]sfrbit/xsfr` is not allowed as static, extern, automatic, register or parameter.
- E 562 it is not allowed to change the align type for internal ram data sections
Internal ram data sections are always IRAM addressable.
- E 563 `"function()": 0` is invalid interrupt number, use `"main()"`
An interrupt number must be in the range 0 to 127 or -1.
- E 564 section `"name"` may not be BYTE aligned
The section must be word, page, segment or PEC aligned.
- F 565 Illegal combine type
The combine type must be one of **L** (local), **P** (public), **C** (common), **G** (global), **S** (Sysstack), **U** (Usrcstack) or **A** *address* (absolute section AT constant *address*).

F 566 Illegal align type

The combine type must be one of **B** (byte), **W** (word), **P** (page), **S** (segment), **C** (PEC addressable) or **I** (IRAM addressable).

E 568 more than 16K initialized data for '*name*': use 'shuge' or use the -m option
more than 64K initialized data for '*name*': use 'huge' or use the -m option

Declare explicitly initialized variables in shuge or huge memory when the total size of those variables in a module exceeds 16K or 64K respectively. An alternative is to omit the initializer and to initialize the variable at runtime as far as needed. `cstart.asm` clears variables without explicit initializer automatically.



-m option

E 569 far/huge not allowed in tiny memory model

The `far`, `huge` and `shuge` keywords are not possible (and not allowed) in the tiny memory model, because all normal data is implicitly near.

E 570 allocation single data object exceeds 16K: use 'shuge'
allocation single data object exceeds 64K: use 'huge'

Variables greater than 16K or 64K must be declared 'shuge' or 'huge' respectively.

F 571 '*memory*' is illegal memory for #pragma romdata:
near/far/huge only

You can only use the `near`, `far`, `huge` and `shuge` keywords on `romdata` sections.

W 572 invalid option for this model: '*option*' – ignored

The **-G***groupname* and **-T***size* options are only allowed in the medium or large memory model.

W 573 conversion of long address to short address

This warning is issued when pointer conversion is needed, for example, when you assign a huge pointer to a near pointer.

W 575 c166 language extension keyword used as identifier

A language extension keyword is a reserved word, and reserved words cannot be used as an identifier.

- F 577 `-xchar` is invalid suboption
See the description of the `-x` option for the correct syntax.
- E 578 `esfr/esfrbit` only allowed when using `-x[f]`
You need to specify the `-xf` or `-x` option to enable the extended SFR area.
- E 579 'offset' must be a constant value between 0 and 15
The bit offset used in `_atbit` must be a constant value between 0 and 15 (the bit position in an integer).
- E 580 `REGDEF R0-Rnum` is too small for register arguments/parameter of "*name*": use 'stackparm'
The number of registers is too small for parameter passing. Pass the arguments over the user stack. You can use the `stackparm` keyword for this purpose.
- W 582 `REGDEF R0-R5` is minimum registerbank, if not omitted
If you specify a number of GPRs to the `-r` option or pragma **regdef** it must have a value in the range 6-16 (inclusive).
- F 583 `-Fchar` is invalid suboption
See the description of the `-F` option for the correct syntax.
- W 585 duplicate function qualifier - '*name (number)*' ignored
Only one function qualifier is allowed. The number within parentheses indicates which of the qualifiers is ignored, 0 being the first occurrence.
- W 586 duplicate function qualifier - '*name*'
Only one function qualifier is allowed. The duplicate qualifier is ignored.
- W 587 '*number*' illegal interrupt/bank number (*min* to *max*) - ignored
An interrupt number must be in the range 0 to 127 or -1. A register bank number must be in the range 1 to 255.
- W 588 '*name1*' not allowed with '*name2*' or '*name3*' - ignored
This is an illegal function qualifier combination. Functon qualifier *name1* is ignored.

- E 589 interrupt function must have void result and void parameter list
A function declared with `interrupt(n)` may not accept any arguments and may not return anything.
- E 590 bank function qualifier allowed in small/large model only (code >64K)
The `bank(n)` function qualifier cannot be used in the tiny and medium memory models. It is only allowed in the small or large memory model. See also section 3.17, *Code Memory Banking*.
- E 591 conflict in 'name' attribute
The attributes of the current function qualifier declaration and the previous function qualifier declaration are not the same.
- E 592 different 'name' number
The function prototype of an interrupt service routine must have the same vector number and using numbers as in the function definition. The same applies to the bank number of a banked function.
- W 593 function qualifier used with non-function
A function qualifier can only be used on functions.
- E 595 bank function qualifier not allowed with near function
Code memory banking is only useful in the small and large memory model (code > 64Kb).
- W 596 `#pragma switch_force_table (-Os)` ignored: jump table would exceed 16K
The jump table does not fit in 16K.
- E 597 indirect near call to function "*function()*" from huge function is not allowed
near call to run-time library function "*function()*" from huge function is not allowed
A huge function may not call any standard C (or run-time) library function, or any other 'near function' in the first segment.
- E 598 invalid number atomic instructions, atomic range is [1..4]
The `_atomic` intrinsic function only accepts a number in the range [1..4].

- W 599 nothing to restore, no section attributes are saved with `#pragma save_attributes`
Pragma `restore_attributes` was used without a previous pragma `save_attributes`.
- F 602 corrupt initialized variable: different size between initialized RAM and ROM section
The initialized RAM and ROM sections must have the same size. This may be due to a different level of indirection with an assignment.
- W 604 possible un-aligned access on byte-label '*name*'
Characters are not aligned. Functions and pointers are always aligned.
- E 605 `_atbit()` only possible on objects, not on constant addresses
Use `_atbit()` to define bit variables within a bitword or `sfr` variable with a previously defined name.
- E 606 `_atbit()` only possible for bit/sfrbit objects
Only `bit` and `sfrbit` objects can be declared with `_atbit()`.
- E 607 `_atbit()` only possible on bitword/sfr objects
`_atbit()` only accepts bitword or `sfr` objects as an argument.
- E 608 specified object not BIT-addressable
The object specified to `_atbit()` must be a bitword or `sfr` object.
- E 610 `sfrbit` object can only have `_atbit()` on `sfr` object
bit object can only have `_atbit()` on a bitword object
You cannot specify a `sfrbit` object with `_atbit()` on a bitword object, and you cannot specify a `bit` object with `_atbit()` on a `sfr` object.
- E 611 missing `#pragma endasm`
You cannot specify a `#pragma asm` or `asm_noflush` when inline assembly is already active. You have to use `#pragma endasm` first.
- E 612 missing `#pragma asm`
The `#pragma endasm` was found while inline assembly was not active. Remove the pragma or insert a `#pragma asm`.

- E 613 '(' missing in inline assembly pragma
Check the syntax of the pragma `asm/endasm`. '(' was expected. See section 3.10, *Inline Assembly*, for the correct syntax.
- E 614 ')' missing in inline assembly pragma
Check the syntax of the pragma `asm/endasm`. ')' was expected.
- E 615 illegal character '*character*' in inline assembly pragma
Check the syntax of the pragma `asm/endasm`. A '=' or '@' was expected.
- E 616 illegal pseudo register in inline assembly pragma
A pseudo register name has the following synopsis: `@[w|b|i]num`. See section 3.10, *Inline Assembly*, for more information.
- E 617 pseudo register "*@number*" already defined
A pseudo register cannot be defined twice. Use another name or number.
- E 618 illegal variable name in inline assembly pragma
The variable name specified after a pragma `asm/endasm` is not a valid identifier.
- E 619 "*name*" undefined in inline assembly pragma
A C variable with the name you specified to a pragma `asm/endasm` does not exist. Check if you specified the correct variable name.
- E 620 pseudo register "*@number*" undefined
The pseudo register must first be defined after a pragma `asm`.
- E 621 no registers anymore for "*@name*"
There were no free registers left to allocat this pseudo register.
- E 622 improper use of "*bita*"/"*bitword*" in declaration of "*name*"
The `bita` keyword is only allowed on structures, unions and integral types.
- W 720 `-OZ` no longer supported
This version of the compiler no longer supports the `-OZ` option.

- E 724 `_at()` requires a numerical address
You can only use an expression that evaluates to a numerical address.
- E 725 `_at()` address out of range for this type of object
The absolute address is not present in the specified memory space.
- E 726 `_at()` only valid for global variables
Only global variables can be placed on absolute addresses.
- E 727 `_at()` only allowed on non-initialized variables
Absolute variables cannot be initialized.
- W 728 `_at()` has no effect on external declaration
When declared `extern` the variable is not allocated by the compiler.
- W 729 `_at()` cannot be used on struct / union members (ignored)
- E 730 `_at()` cannot be used on bit, bita, system, sfr, esf, xsfr and iram
- E 731 `_at()` this type of object must be word aligned
- E 732 `_at()` address out of range for this memory model
The absolute address does not fit in the specified memory model. You might want to use a larger memory model.
- E 733 bad argument to `#pragma cse`, expect a number, "suspend" or "resume"
See the description of `pragma cse` for more information.
- E 734 `#pragma cse suspend/resume` has no effect outside function body
`Pragma cse suspend/resume` has a function scope.
- W 735 pointer conversion restricts arithmetic precision and alignment
When a huge pointer is converted to a shuge pointer, it may lead to incorrect code when the (huge) object it points to crosses a segment boundary. After the conversion, the compiler assumes that the object is 64Kb at most and won't cross a segment boundary. Both assumptions may be wrong. A similar problem arises when converting a shuge or huge pointer to a far pointer. Far objects are limited to 16Kb and never cross a page boundary.
- E 736 function "*name*" too big (should be \leq 64Kb code)
Break the function into smaller ones.

- E 737 function "*name*" doesn't fit in section, try `-mPR=0,4000`
See the description of the `-m` option for additional information.
- W 739 `ormask: 0xbexnumber` does not fit into `andmask: 0xbexnumber`
When the set bits in the `ormask` do not overlap the set bits in the `andmask`, these bits might be unintentionally set.
- F 740 `-schar` is invalid suboption
Only `'i'` can be used as a suboption. See the description of the `-s` option for additional information.
- E 744 bad `#pragma m166include` syntax
An error occurred when defining a macro-processor include file.
- E 745 no registers left for *expression*
There were no free registers left to pass *expression* to a user defined intrinsic.
- W 749 bypass option `-BJ` can only be used in combination with an extended instruction set

This warning is generated when bypass option `-BJ` is enabled and you did not select the extended instruction set using `-x` or `-xi`.
- E 750 `_atbit()` not possible on *type: "name"*
You cannot use: struct / union members, tags, labels, parameters or inline function locals as a base symbol to define bits in.
- E 752 `_localbank` qualifier only allowed with interrupt functions
You can only use the `_localbank` function qualifier in combination with the `_interrupt` function qualifier.
- W 753 `'name'` not allowed with `'name1'`, `'name2'` or `'name3'` – ignored
For example, the `localbank` function qualifier cannot be used in combination with `stackparm`, `bank` or `using` – ignored.
- E 754 *name* function qualifier can only be used in combination with `-x2`

The `localebank` and `stacksize` qualifiers can only be used with the C166S V2.0 / Super10 architecture.

- E 758 `stacksize` qualifier only allowed with interrupt functions using a local register bank

For example the following is not allowed:

```
void _interrupt(0x10) _localbank(0) _stacksize(20) ISR(void);
```

Because `_localbank(0)` indicates a global register bank.

- W 759 `stacksize` must be even – ignored
The value of the `stacksize` function qualifier must be even.

- W 760 negative stack size adjustment exceeds user stack size estimation, truncated

Suppose the compiler estimates that the occupied stack space for an interrupt function is 12 bytes. If '`_stacksize(-14)`' is added to the function definition, this warning is generated and the value of the `_stacksize` qualifier will be adjusted to -12.

- W 761 keyword '*name*' only allowed in combination with **-x2** – ignored

The used keyword is only valid for the C166S V2.0 / Super10 architecture and will be ignored if this chip is not selected. (Use **-x2**)

- E 762 option `-i` can only be used in combination with **-x2** – ignored

- E 763 `_cached` qualifier only allowed with interrupt functions

- W 764 `#pragma name` only allowed in small memory model with extended instruction set

- E 766 initialized ramdata sections don't support section attributes

- E 771 variable argument list not allowed with intrinsic function:
`"name()`"

- W 775 obsolete option **-Ff/-FF** – floating point library is reentrant by default

The **-Ff** / **-FF** option is no longer needed,

- W 781 `_at ()` has no effect on zero sized. object: "%s"

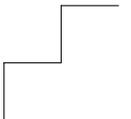
e.g. `int a[] _at (0x1234);`

- E 785 `_xnear` only allowed in medium/large memory model
 In the medium/large memory model, the `_xnear` keyword allows you to allocate variables in DPP1 which shares this page with the user stack. In the tiny/small memory model the user stack is located in `_near` memory where normal data is also located. Hence this memory space is already shared. Therefore there is no need for an `_xnear` memory space in the tiny/small memory model.
- F 787 bad argument in `-gso` option : *argument*
 The syntax of the `-gso` option is `-gso=file.gso` where *file.gso* is the name of a `.gso` file.
- E 788 GSO file not generated by 'gso166'
 Missing `$GSO166` directive in the `.gso` file.
- E 789 GSO file memory model mismatch
`$MODEL(modelname)` in the `.gso` file does not match the compiler memory model.
- E 790 – E 849 Reserved for gso166 errors.
 E 000 from gso166 maps on compiler error E 790;
 E 001 from gso166 maps on compiler error E 791;
 etc.
- F 850 cannot find object *object* in GSO file
 The name of a global object cannot be found in the `.gso` file for automatic storage assignment.
- W 851 `-T` option cannot be used in conjunction with `-gso`
 When you use **gso166** for building the application, **gso166** will assign storage to global objects. However, with the `-Tsize` option the compiler is not allowed to allocate global objects in `_near` memory that exceed the specified *size*.

CHAPTER

9

LIBRARIES



6 | CHAPTER

6.1 INTRODUCTION

c166 comes with libraries per memory model and with header files containing the appropriate prototype of the library functions. The library functions are also shipped in source code (C or assembly).

Seven sets of libraries are delivered to meet specific requirements for the various C166, Gold, C167/ST10x167/ST10x262, C166S v2.0 and Super10 microcontroller architectures. These sets are located in separate directories:

- 166 The non-protected libraries are the default libraries for the C166/ST10x166 and similar architectures.
- 166p The protected libraries provide a software workaround for CPU functional problems. They must be using in conjunction with the appropriate **-B** compiler option. For more details refer to appendix G: *CPU Functional Problems* for more information.
- goldp These protected libraries are the default libraries for the Gold and similar architectures which are based on C166/ST10x166 architectures but feature 24-bit extended addressing instead of 18-bit. Use these libraries in conjunction with the compiler option **-xm**.
- ext The extended libraries are needed for the C167/ST10x167/ST10x262 and similar architectures. These architectures feature the extended instruction set, extended special function registers, 24-bit addressing and extended PEC pointers. Use these libraries in conjunction with the compiler option **-x**.
- extp The protected libraries provide a software workaround for CPU functional problems. Use these libraries in conjunction with the compiler options **-x** and **-B**.
- ext2 The extended 2 libraries are needed for the C166S v2.0 / Super10 and similar architectures. These architectures feature jump prediction, scalable and relocatable interrupt vector table, local register banks and instruction reordering. Use these libraries in conjunction with the compiler option **-x2**.
- ext2p The protected libraries provide a software workaround for CPU functional problems. Use these libraries in conjunction with the compiler options **-x2** and **-B**.

Another seven sets of libraries are delivered to meet specific User Stack Model requirements for the various microcontroller architectures. These libraries must be used in conjunction with the additional compiler option `-P`. These sets are located in separate directories:

<code>u166</code>	The User Stack Model variant of the non-protected libraries.
<code>u166p</code>	The User Stack Model variant of the protected libraries.
<code>ugoldp</code>	The User Stack Model variant of the protected Gold architecture libraries.
<code>uext</code>	The User Stack Model variant of the extended non-protected libraries.
<code>uextp</code>	The User Stack Model variant of the extended protected libraries.
<code>uext2</code>	The User Stack Model variant of the extended C166S v2.0 / Super10 architectures non-protected libraries.
<code>uext2p</code>	The User Stack Model variant of the extended C166S v2.0 / Super10 architectures protected libraries.

Each library set contains the following libraries:

<code>c166?[s].lib</code>	C library. The optional <code>[s]</code> stands for single precision floating point (all floating point arithmetic is in single precision instead of ANSI double precision).
<code>fp166?[t].lib</code>	Floating point library. The optional <code>[t]</code> stands for trapping floating point (using boundary checking and the floating point trap mechanism).
<code>rt166?[s][m].lib</code>	Run-time library. The optional <code>[s]</code> stands for single precision floating point. The optional <code>[m]</code> stands for MAC optimized (use MAC instructions in some basic operations for optimization).

The question mark '?' in these library names must be replaced by a letter representing the selected memory model:

t tiny
s small
m medium
l large

All C library functions are described in the section *C Library Interface Description*. These functions are only called by explicit function calls in your application program. However, some compiler generated code contain calls to run-time library functions that would use too much code when generated as inline code. The name of a run-time library function always contains two leading underscores. For example, to perform a long (32 bit) signed division, the function `__sd1l` is called.

Because **c166** generates assembly code (and not object code) it adds a leading underscore to the names of (public) C variables to distinguish these symbols from 80166 registers. So if you use a function with a leading underscore, the assembly label for this function contains two leading underscores. This function name could cause a name conflict (double defined) with one of the run-time library functions. Therefore, you should avoid names starting with an underscore. Note that ANSI states that it is not portable to use names starting with an underscore for public C variables and functions, because results are implementation defined.

The code sections of the C166 library have the class 'CLIBRARY', 'SHAREDCLIB', 'RTLIBRARY' or 'SHAREDRTLIB' allowing the library to be allocated in a special memory area via the CLASSES control of **1166**.

6.2 SMALL, MEDIUM AND LARGE I/O FORMATTERS

The C library contains the SMALL I/O formatter version of the `printf()` and `scanf()` functions and their variants like `sprintf()`, `fprintf()`, etc. This SMALL version does not contain the required functionality to handle precision specifiers and floating point I/O which can be specified in the format argument of these functions.

The following extra libraries are included to support easy switching between the three I/O formatter versions:

MEDIUM I/O formatter library no floating point I/O supported
precision specifiers supported `fmtio?m.lib`.

LARGE I/O formatter library floating point I/O supported precision
specifiers supported `fmtio?![s].lib`.

The question mark '?' in these library names must be replaced by a character representing the selected memory model:

```
t  tiny
s  small
m  medium
l  large
```

These I/O formatter libraries are included in all library sets. The control program options **-libfmtiom** and **-libfmtiol** can be used to selected the MEDIUM and LARGE I/O formatter libraries.



If no **cc166 -libfmtio*** option is specified on the commandline, then the SMALL printf()/scanf() formatter variant is linked from the C library.

6.3 SINGLE PRECISION FLOATING POINT

In ANSI C all mathematical functions (`<math.h>`), are based on `double` arguments and `double` return type. So, even if you are using only `float` variables in your code, the language definition dictates promotion to `double`, when using the math functions or floating point formatters (`printf()` and `scanf()`). The result is more code and less execution speed. In fact the ANSI approach introduces a performance penalty.

To improve the code size and execution speed, the compiler now supports the option **-F** to force single precision floating point usage. If you use **-F**, a `float` variable passed as an argument is no longer promoted to `double` when calling a variable argument function or an old style K&R function, and the type `double` is treated as `float`. It is obvious that this affects the whole application (including libraries). Therefore special single precision versions of the floating point libraries are now delivered with the package. When using **-F**, these libraries must be used. It is not possible to mix C modules created with the **-F** option and C modules which are using the regular ANSI approach.

For compatibility with the old **-F** option, the **-Fc** option is introduced. This option only treats floating point constants (having no suffix) as `float` instead of `double`.

6.4 USER STACK MODEL

If you use the **-P** or **-Pd** option of **c166**, the compiler does not emit the regular CALL/RET instructions when calling a C function, but emits code using a jumping mechanism, specifying the return address on the user stack. The advantage of this approach is that the system stack is not used at all. The price paid for this feature is an execution speed penalty.

When using plain user stack model, special libraries are needed to support this feature. These user stack model libraries are an integral part of this product. If **-Pd** was specified at the command line, all calls to the library use the regular CALL/RET calling convention.

This behavior can also be forced for user defined functions using either the `_usm` or `_nousm` function qualifiers. If `_usm` is specified at the function definition, the function is called using user stack model calling conventions. If `_nousm` is specified, the function is called using the generic CALL/RET calling method, even if **-P** was specified on the command line.

-P option	Libraries	Def. func. qualifier	_USMLIB macro
none	default	<code>_nousm</code>	<code>_nousm</code>
-P	USM	<code>_usm</code>	<code>_usm</code>
-Pd	default	<code>_usm</code>	<code>_nousm</code>

Table 6-1: User stack model

There are two valid reasons to use this option (and libraries):

- Real-time Operation Systems

When using a real-time kernel, it is often not allowed to use the system stack area (in fact change SP), because this area is reserved for the kernel. Therefore, the **-P** option can be used, when using a kernel. Please refer to the documentation supplied with the kernel to verify if this option must be used.

- Heavy recursion

When the system stack area is getting too small and it is not possible to implement a circular system stack approach (using SOV/SUN exception handlers), the **-P** option can be used. In this case the compiler uses the user stack instead of the system stack. You must link the application with the user stack model libraries.

Using **-P** does not mean that you have to use a kernel. You can run the application as a standalone application, without any kernel.

6.5 CAN SUPPORT

The Infineon CAN protocol driver software routines including pre-built CAN libraries are supplied with the 32-bit Windows 95/98/NT version of this product. The file `ap292201.pdf` describes the usage of these libraries. This file is located in the `doc/pdf` directory.

The `can166?.Lib` CAN libraries are available for all memory models in the `ext`, `extp`, `uext` and `uextp` library sets. These libraries can be rebuilt using the corresponding makefiles.

6.6 HEADER FILES

The following header files are delivered with the C compiler:

- <assert.h>** assert
- <c166.h>** Special file for portability between **c166** and other C compilers. Contains macros to enable or disable the usage of TASKING C-166 Language extensions.
- <canr16x.h>**
CAN libraries function prototypes.
- <ctype.h>** isalnum, isalpha, isascii, iscntrl, isdigit, isgraph, islower, isprint, ispunct, isspace, isupper, isxdigit, toascii, _tolower, tolower, _toupper, toupper
- <errno.h>** Error numbers. No C functions.
- <float.h>** Constants related to floating point arithmetic.
- <limits.h>** Limits and sizes of integral types. No C functions.
- <math.h>** acos, asin, atan, atan2, ceil, cos, cosh, fabs, floor, fmod, frexp, exp, ldexp, log, log10, modf, pow, sin, sinh, sqrt, tan, tanh
- <reg*.h>** Special function register declarations for all supported derivatives.

- <**setjmp.h**> longjmp, setjmp
- <**stdarg.h**> va_arg, va_end, va_start
- <**stddef.h**> offsetof. Definition of special types.
- <**stdio.h**> clearerr, fclose, feof, ferror, fflush, fgetc, fgets, fopen, fprintf, fputc, fputs, fread, freopen, fscanf, fwrite,getc, getchar, gets, _ioread, _iowrite, printf, putc, putchar, puts, scanf, setbuf, setvbuf, sprintf, sscanf, ungetc, vfprintf, vprintf, vsprintf
- <**stdlib.h**> abort, abs, atexit, atof, atoi, atol, bsearch, calloc, div, exit, free, labs, ldiv, malloc, qsort, rand, realloc, srand, strtod, strtol, strtoul
- <**string.h**> memchr, memcmp, memcpffb, memcpffw, memcpfhb, memcpfhw, memcpfnb, memcpfnw, memcpfsb, memcpfsw, memcphfb, memcphfw, memcphhb, memcphhw, memcphnb, memcphnw, memcphsb, memcphsw, memcpnfb, memcpnfw, memcpnhb, memcpnhw, memcpnwb, memcpnww, memcpnsb, memcpnsw, memcpsfb, memcpsfw, memcpshb, memcpshw, memcpsnb, memcpsnw, memcpssb, memcpssw, memcpy, memmove, memset, strcat, _fstrcat, _hstrcat, _sstrcat, strchr, _fstrchr, _hstrchr, _sstrchr, strcmp, _fstrcmp, _hstrcmp, _sstrcmp, strcpy, _fstrcpy, _hstrcpy, _sstrcpy, strcspn, _fstrcspn, _hstrcspn, _sstrcspn, strlen, _fstrlen, _hstrlen, _sstrlen, strcat, _fstrcat, _hstrcat, _sstrcat, strncmp, _fstrncmp, _hstrncmp, _sstrncmp, strcpy, _fstrcpy, _hstrcpy, _sstrcpy, strpbrk, _fstrpbrk, _hstrpbrk, _sstrpbrk, strchr, _fstrchr, _hstrchr, _sstrchr, strspn, _fstrspn, _hstrspn, _sstrspn, strstr, _fstrstr, _hstrstr, _sstrstr, strtok, _fstrtok, _hstrtok, _sstrtok
- <**time.h**> asctime, clock, ctime, difftime, gmtime, localtime, mktime, _stime, strftime, _time, time, _tzset
- <**vt100.h**> VT100 Terminal Emulation escape sequences for use with the CrossView Pro FSS feature.

6.7 C LIBRARY INTERFACE DESCRIPTION

_fstrcat

```
#include <string.h>
char far *_fstrcat( char far *s, const char far *ct );
```

Concatenates far string *ct* to far string *s*, including the trailing NULL character.

Returns *s*

_fstrchr

```
#include <string.h>
char far *_fstrchr( const char far *cs, int c );
```

Returns a far pointer to the first occurrence of character *c* in the string *cs*. If not found, NULL is returned.

_fstrcmp

```
#include <string.h>
int _fstrcmp( const char far *cs,
              const char far *ct );
```

Compares far string *cs* to far string *ct*.

Returns <0 if *cs* < *ct*,
 0 if *cs* == *ct*,
 >0 if *cs* > *ct*.

_fstrcpy

```
#include <string.h>
char far *_fstrcpy( char far *s, const char far *ct );
```

Copies far string *ct* into the far string *s*, including the trailing NULL character.

Returns *s*

_fstrcspn

```
#include <string.h>
size_t _fstrcspn( const char far *cs,
                  const char far *ct );
```

Returns the length of the prefix in far string *cs*, consisting of characters not in the far string *ct*.

_fstrlen

```
#include <string.h>
size_t _fstrlen( const char far *cs );
```

Returns the length of the far string in *cs*, not counting the NULL character.

_fstrncat

```
#include <string.h>
char far *_fstrncat( char far *s,
                    const char far *ct,
                    size_t n );
```

Concatenates far string *ct* to far string *s*, at most *n* characters are copied. Add a trailing NULL character.

Returns *s*

_fstrncmp

```
#include <string.h>
int _fstrncmp( const char far *cs,
               const char far *ct,
               size_t n );
```

Compares at most *n* bytes of far string *cs* to far string *ct*.

Returns <0 if *cs* < *ct*,
0 if *cs* == *ct*,
>0 if *cs* > *ct*.

_fstrncpy

```
#include <string.h>
char far *_fstrncpy( char far *s,
                    const char far *ct,
                    size_t n );
```

Copies far string *ct* onto the far string *s*, at most *n* characters are copied. Add a trailing NULL character if the string is smaller than *n* characters.

Returns *s*

_fstrpbrk

```
#include <string.h>
char far *_fstrpbrk( const char far *cs,
                    const char far *ct );
```

Returns a far pointer to the first occurrence in *cs* of any character out of far string *ct*. If none are found, NULL is returned.

_fstrrchr

```
#include <string.h>
char far *_fstrrchr( const char far *cs, int c );
```

Returns a far pointer to the last occurrence of *c* in the far string *cs*. If not found, NULL is returned.

_fstrspn

```
#include <string.h>
size_t _fstrspn( const char far *cs,
                const char far *ct );
```

Returns the length of the prefix in far string *cs*, consisting of characters in the far string *ct*.

_fstrsr

```
#include <string.h>
char far *_fstrsr( const char far *cs,
                  const char far *ct );
```

Returns a far pointer to the first occurrence of far string *ct* in the far string *cs*. Returns NULL if not found.

_fstrtok

```
#include <string.h>
char far *_fstrtok( char far *s, const char far *ct );
```

Search the far string *s* for tokens delimited by characters from far string *ct*. It terminates the token with a NULL character.

Returns a pointer to the token. A subsequent call with *s* == NULL will return the next token in the string.

_hstrcat

```
#include <string.h>
char huge *_hstrcat( char huge *s,
                    const char huge *ct );
```

Concatenates huge string *ct* to huge string *s*, including the trailing NULL character.

Returns *s*

_hstrchr

```
#include <string.h>
char huge *_hstrchr( const char huge *cs, int c );
```

Returns a huge pointer to the first occurrence of character *c* in the string *cs*. If not found, NULL is returned.

_hstrcmp

```
#include <string.h>
int _hstrcmp( const char huge *cs,
              const char huge *ct );
```

Compares huge string *cs* to huge string *ct*.

Returns <0 if *cs* < *ct*,
0 if *cs* == *ct*,
>0 if *cs* > *ct*.

_hstrcpy

```
#include <string.h>
char huge *_hstrcpy( char huge *s,
                    const char huge *ct );
```

Copies huge string *ct* into the huge string *s*, including the trailing NULL character.

Returns *s*

_hstrcspn

```
#include <string.h>
size_t _hstrcspn( const char huge *cs,
                  const char huge *ct );
```

Returns the length of the prefix in huge string *cs*, consisting of characters not in the huge string *ct*.

_hstrlen

```
#include <string.h>
size_t _hstrlen( const char huge *cs );
```

Returns the length of the huge string in *cs*, not counting the NULL character.

_hstrncat

```
#include <string.h>
char huge *_hstrncat( char huge *s,
                    const char huge *ct,
                    size_t n );
```

Concatenates huge string *ct* to huge string *s*, at most *n* characters are copied. Add a trailing NULL character.

Returns *s*

_hstrncmp

```
#include <string.h>
int _hstrncmp( const char huge *cs,
              const char huge *ct,
              size_t n );
```

Compares at most *n* bytes of huge string *cs* to huge string *ct*.

Returns <0 if *cs* < *ct*,
 0 if *cs* == *ct*,
 >0 if *cs* > *ct*.

_hstrncpy

```
#include <string.h>
char huge *_hstrncpy( char huge *s,
                    const char huge *ct,
                    size_t n );
```

Copies huge string *ct* onto the huge string *s*, at most *n* characters are copied. Add a trailing NULL character if the string is smaller than *n* characters.

Returns *s*

_hstrpbrk

```
#include <string.h>
char huge *_hstrpbrk( const char huge *cs,
                    const char huge *ct );
```

Returns a huge pointer to the first occurrence in *cs* of any character out of huge string *ct*. If none are found, NULL is returned.

_hstrrchr

```
#include <string.h>
char huge *_hstrrchr( const char huge *cs, int c );
```

Returns a huge pointer to the last occurrence of *c* in the huge string *cs*. If not found, NULL is returned.

_hstrspn

```
#include <string.h>
size_t _hstrspn( const char huge *cs,
                const char huge *ct );
```

Returns the length of the prefix in huge string *cs*, consisting of characters in the huge string *ct*.

_hstrstr

```
#include <string.h>
char huge *_hstrstr( const char huge *cs,
                   const char huge *ct );
```

Returns a huge pointer to the first occurrence of huge string *ct* in the huge string *cs*. Returns NULL if not found.

_hstrtok

```
#include <string.h>
char huge *_hstrtok( char huge *s,
                    const char huge *ct );
```

Search the huge string *s* for tokens delimited by characters from huge string *ct*. It terminates the token with a NULL character.

Returns a pointer to the token. A subsequent call with *s* == NULL will return the next token in the string.

_ioread

```
#include <stdio.h>
int _ioread( FILE *fp );
```

Low level input function. The delivered library contains an 'empty' function. To perform real world I/O, this function must be customized by the user. *_ioread* is used by all input functions (*scanf*, *getc*, *gets*, etc.). See the file *serio.c* in the *examples io* directory demonstrating a serial I/O implementation of this low level input function.

_iowrite

```
#include <stdio.h>
int _iowrite( FILE *fp, int c );
```

Low level output function. The delivered library contains an 'empty' function. To perform real world I/O, this function must be customized by the user. *_iowrite* is used by all output functions (*printf*, *putc*, *puts*, etc.). See the file *serio.c* in the *examples io* directory demonstrating a serial I/O implementation of this low level output function.

_stime

```
#include <time.h>
void _stime( time_t *s );
```

Sets the current calendar time.

Returns nothing.

__strcat

```
#include <string.h>
char shuge *__strcat( char shuge *s,
                    const char shuge *ct );
```

Concatenates shuge string ct to shuge string s, including the trailing NULL character.

Returns s

__strchr

```
#include <string.h>
char shuge *__strchr( const char shuge *cs, int c );
```

Returns a shuge pointer to the first occurrence of character c in the string cs. If not found, NULL is returned.

__strcmp

```
#include <string.h>
int __strcmp( const char shuge *cs,
             const char shuge *ct );
```

Compares shuge string cs to shuge string ct.

Returns <0 if cs < ct,
0 if cs == ct,
>0 if cs > ct.

__strcpy

```
#include <string.h>
char shuge *__strcpy( char shuge *s,
                    const char shuge *ct );
```

Copies shuge string ct into the shuge string s, including the trailing NULL character.

Returns s

_sstrcspn

```
#include <string.h>
size_t _sstrcspn( const char shuge *cs,
                  const char shuge *ct );
```

Returns the length of the prefix in shuge string *cs*, consisting of characters not in the shuge string *ct*.

_sstrlen

```
#include <string.h>
size_t _sstrlen( const char shuge *cs );
```

Returns the length of the shuge string in *cs*, not counting the NULL character.

_sstrncat

```
#include <string.h>
char shuge *_sstrncat( char shuge *s,
                      const char shuge *ct,
                      size_t n );
```

Concatenates shuge string *ct* to shuge string *s*, at most *n* characters are copied. Add a trailing NULL character.

Returns *s*

_sstrncmp

```
#include <string.h>
int _sstrncmp( const char shuge *cs,
               const char shuge *ct,
               size_t n );
```

Compares at most *n* bytes of shuge string *cs* to shuge string *ct*.

Returns <0 if *cs* < *ct*,
0 if *cs* == *ct*,
>0 if *cs* > *ct*.

_sstrncpy

```
#include <string.h>
char shuge *_sstrncpy( char shuge *s,
                      const char shuge *ct,
                      size_t n );
```

Copies shuge string ct onto the shuge string s, at most n characters are copied. Add a trailing NULL character if the string is smaller than n characters.

Returns s

_sstrpbrk

```
#include <string.h>
char shuge *_sstrpbrk( const char shuge *cs,
                      const char shuge *ct );
```

Returns a shuge pointer to the first occurrence in cs of any character out of shuge string ct. If none are found, NULL is returned.

_sstrchr

```
#include <string.h>
char shuge *_sstrchr( const char shuge *cs, int c );
```

Returns a shuge pointer to the last occurrence of c in the shuge string cs. If not found, NULL is returned.

_sstrspn

```
#include <string.h>
size_t _sstrspn( const char shuge *cs,
                const char shuge *ct );
```

Returns the length of the prefix in shuge string cs, consisting of characters in the shuge string ct.

_sstrstr

```
#include <string.h>
char shuge *_sstrstr( const char shuge *cs,
                    const char shuge *ct );
```

Returns a shuge pointer to the first occurrence of shuge string ct in the shuge string cs. Returns NULL if not found.

_sstrtok

```
#include <string.h>
char shuge *_sstrtok( char shuge *s,
                    const char shuge *ct );
```

Search the shuge string s for tokens delimited by characters from shuge string ct. It terminates the token with a NULL character.

Returns a pointer to the token. A subsequent call with s == NULL will return the next token in the string.

_time

```
#include <time.h>
time_t _time( time_t *pt );
```

Low-level time function. To perform real-time clock support, you must customize this function. `_time` is used by the C library functions `clock` and `time`. See the file `time.c` in the `examples/time` directory demonstrating an implementation of this low-level time function.

Returns the processor time used. To determine the time used in seconds, the value returned must be divided by the value of the macro `TICKS_PER_SEC`, as defined in `time.h`

_tolower

```
#include <ctype.h>
int _tolower( int c );
```

Converts *c* to a lowercase character, does not check if *c* really is an uppercase character.

Returns the converted character.

_toupper

```
#include <ctype.h>
int _toupper( int c );
```

Converts *c* to an uppercase character, does not check if *c* really is a lowercase character.

Returns the converted character.

_tzset

```
#include <time.h>
int _tzset( const char *s );
```

Converts the widely used time zone format string pointed to by *s* to *tzone* format. That string takes the form EST05EDT, where the number in the middle counts the hours West of UTC.

Returns one if successful, or zero on error.

abort

```
#include <stdlib.h>
void abort( void );
```

Terminates the program abnormally.

Returns nothing.

abs

```
#include <stdlib.h>
int abs( int n );
```

Returns the absolute value of the signed int argument.

acos

```
#include <math.h>
double acos( double x );
```

Returns the arccosine $\cos^{-1}(x)$ of x in the range $[0, \pi]$, $x \in [-1, 1]$.

asctime

```
#include <time.h>
char *asctime( const struct tm *tp );
```

Converts the time in the structure $*tp$ into a string of the form:

```
Mon Jan 21 16:15:14 1993\n\n0
```

Returns the time in string form.

asin

```
#include <math.h>
double asin( double x );
```

Returns the arcsine $\sin^{-1}(x)$ of x in the range $[-\pi/2, \pi/2]$, $x \in [-1, 1]$.

assert

```
#include <assert.h>
assert( expr );
```

When compiled with NDEBUG, this is an empty macro. When compiled without NDEBUG defined, it checks if 'expr' is true or false. If it is false, then a line like:

```
"Assertion failed: expression, file filename, line num"
```

is printed.

Returns nothing.

atan

```
#include <math.h>
double atan( double x );
```

Returns the arctangent $\tan^{-1}(x)$ of x in the range $[-\pi/2, \pi/2]$. $x \in [-1, 1]$.

atan2

```
#include <math.h>
double atan2( double y, double x );
```

Returns the result of: $\tan^{-1}(y/x)$ in the range $[-\pi, \pi]$.

atexit

```
#include <stdlib.h>
int atexit( void (*fcn)( void ) );
```

Registers the function *fcn* to be called when the program terminates normally.

Returns zero, if program terminates normally.
non-zero, if the registration cannot be made.

atof

```
#include <stdlib.h>
double atof( const char *s );
```

Converts the given string to a double value. White space is skipped, conversion is terminated at the first unrecognized character.

Returns the double value.

atoi

```
#include <stdlib.h>
int atoi( const char *s );
```

Converts the given string to an integer value. White space is skipped, conversion is terminated at the first unrecognized character.

Returns the integer value.

atol

```
#include <stdlib.h>
long atol( const char *s );
```

Converts the given string to a long value. White space is skipped, conversion is terminated at the first unrecognized character.

Returns the long value.

bsearch

```
#include <stdlib.h>
void *bsearch( const void *key,
               const void *base, size_t n,
               size_t size, int (*cmp)
               (const void *, const void *) );
```

This function searches in an array of *n* members, for the object pointed to by *ptr*. The initial base of the array is given by *base*. The size of each member is specified by *size*. The given array must be sorted in ascending order, according to the results of the function pointed to by *cmp*.

Returns a pointer to the matching member in the array, or NULL when not found.

calloc

```
#include <stdlib.h>
void *calloc( size_t nobj, size_t size );
```

The allocated space is filled with zeros. The maximum space that can be allocated can be changed by customizing the heap size (see the section *Heap Size*). By default no heap is allocated.

Returns a pointer to space in external memory for *nobj* items of *size* bytes length. NULL if there is not enough space left.

ceil

```
#include <math.h>
double ceil( double x );
```

Returns the smallest integer not less than *x*, as a double.

clearerr

```
#include <stdio.h>
void clearerr( FILE *stream );
```

Clears the end of file and error indicators for *stream*.

Returns nothing.

clock

```
#include <time.h>
clock_t clock( void );
```

Returns the processor time used in seconds.

cos

```
#include <math.h>
double cos( double x );
```

Returns the cosine of *x*.

cosh

```
#include <math.h>
double cosh( double x );
```

Returns the hyperbolic cosine of *x*.

ctime

```
#include <time.h>
char *ctime( const time_t *tp );
```

Converts the calendar time **tp* into local time, in string form. This function is the same as:

```
asctime( localtime( tp ) );
```

Returns the local time in string form.

difftime

```
#include <time.h>
double difftime( time_t time2, time_t time1 );
```

Computes the difference between calendar times.

Returns the result of `time2 - time1` in seconds.

div

```
#include <stdlib.h>
div_t div( int num, int denom );
```

Both arguments are integers. The returned quotient and remainder are also integers.

Returns a structure containing the quotient and remainder of `num` divided by `denom`.

exit

```
#include <stdlib.h>
void exit( int status );
```

Terminates the program normally. Acts as if `'main()'` returns with `status` as the return value.

Returns zero, on successful termination.

exp

```
#include <math.h>
double exp( double x );
```

Returns the result of the exponential function e^x .

fabs

```
#include <math.h>
double fabs( double x );
```

Returns the absolute double value of *x*. $|x|$

fclose

```
#include <stdio.h>
int fclose( FILE *stream );
```

Flushes any unwritten data for *stream*, discards any unread buffered input, frees any automatically allocated buffer, then closes the *stream*.

Returns zero if the *stream* is successfully closed, or EOF on error.

feof

```
#include <stdio.h>
int feof( FILE *stream );
```

Returns a non-zero value if the end-of-file indicator for *stream* is set.

ferror

```
#include <stdio.h>
int ferror( FILE *stream );
```

Returns a non-zero value if the error indicator for *stream* is set.

fflush

```
#include <stdio.h>
int fflush( FILE *stream );
```

Writes any buffered but unwritten data, if *stream* is an output stream. If *stream* is an input stream, the effect is undefined.

Returns zero if successful, or EOF on a write error.

fgetc

```
#include <stdio.h>
int fgetc( FILE *stream );
```

Reads one character from the given `stream`.



See also ”_ioread()”.

Returns the read character, or EOF on error.

fgets

```
#include <stdio.h>
char *fgets( char *s, int n, FILE *stream );
```

Reads at most the next `n-1` characters from the given `stream` into the array `s` until a newline is found.



See also ”_ioread()”.

Returns `s`, or NULL on EOF or error.

floor

```
#include <math.h>
double floor( double x );
```

Returns the largest integer not greater than `x`, as a double.

fmod

```
#include <math.h>
double fmod( double x, double y );
```

Returns the floating-point remainder of `x/y`, with the same sign as `x`. If `y` is zero, the result is implementation-defined.

fopen

```
#include <stdio.h>
FILE *fopen( const char *filename, const char *mode );
```

Opens a file for a given mode.

Returns a stream. If the file cannot not be opened, NULL is returned.

fopen needs a heap size of at least 512 bytes.

You can specify the following values for mode:

"r"	read; open text file for reading
"w"	write; create text file for writing; if the file already exists its contents is discarded
"a"	append; open existing text file or create new text file for writing at end of file
"r+"	open text file for update; reading and writing
"w+"	create text file for update; previous contents if any is discarded
"a+"	append; open or create text file for update, writes at end of file

The update mode (with a '+') allows reading and writing of the same file. In this mode the function fflush must be called between a read and a write or vice versa. By including the letter "b" after the initial letter, you can indicate that the file is a binary file. E.g. "rb" means read binary, "w+b" means create binary file for update. The filename is limited to FILENAME_MAX characters. At most FOPEN_MAX files may be open at once.

fprintf

```
#include <stdio.h>
int fprintf( FILE *stream, const char *format, ... );
```

Performs a formatted write to the given stream.



See also "printf()" and "_iowrite()".

fputc

```
#include <stdio.h>
int fputc( int c, FILE *stream );
```

Puts one character onto the given stream.



See also ”_iowrite()”.

Returns EOF on error.

fputs

```
#include <stdio.h>
int fputs( const char *s, FILE *stream );
```

Writes the string to a stream. The terminating NULL character is not written.



See also ”_iowrite()”.

Returns NULL if successful, or EOF on error.

fread

```
#include <stdio.h>
size_t fread( void *ptr, size_t size,
              size_t nobj, FILE *stream );
```

Reads nobj members of size bytes from the given stream into the array pointed to by ptr.



See also ”_ioread()”.

Returns the number of successfully read objects.

free

```
#include <stdlib.h>
void free( void *p );
```

Deallocates the space pointed to by `p`. `p` Must point to space earlier allocated by a call to "calloc()", "malloc()" or "realloc()". Otherwise the behavior is undefined.



See also "calloc()", "malloc()" and "realloc()".

Returns nothing

freopen

```
#include <stdio.h>
FILE *freopen( const char *filename,
               const char *mode, FILE *stream );
```

Opens a file for a given mode associates the `stream` with it. This function is normally used to change the files associated with `stdin`, `stdout`, or `stderr`.



See also "fopen()".

Returns stream, or NULL on error.

frexp

```
#include <math.h>
double frexp( double x, int *exp );
```

Splits `x` into a normalized fraction in the interval $[1/2, 1>$, which is returned, and a power of 2, which is stored in `*exp`. If `x` is zero, both parts of the result are zero. For example: `frexp(4.0, &var)` results in $0.5 \cdot 2^3$. The function returns 0.5, and 3 is stored in `var`.

Returns the normalized fraction.

fscanf

```
#include <stdio.h>
int fscanf( FILE *stream, const char *format, ... );
```

Performs a formatted read from the given stream.



See also "scanf()" and "_iored()".

Returns the number of items converted successfully.

fwrite

```
#include <stdio.h>
size_t fwrite( const void *ptr,
               size_t size, size_t nobj,
               FILE *stream );
```

Writes nobj members of size bytes to the given stream from the array pointed to by ptr.

Returns the number of successfully written objects.

getc

```
#include <stdio.h>
int getc( FILE *stream );
```

Reads one character out of the given stream.



See also "_iored()".

Returns the character read or EOF on error.

getchar

```
#include <stdio.h>
int getchar( void );
```

Reads one character from standard input.



See also "_iored()".

Returns the character read or EOF on error.

gets

```
#include <stdio.h>
char *gets( char *s );
```

Reads all characters from standard input until a newline is found. The newline is replaced by a NULL-character.



See also ”_ioread()”.

Returns a pointer to the read string or NULL on error.

gmtime

```
#include <time.h>
struct tm *gmtime( const time_t *tp );
```

Converts the calendar time *tp into Coordinated Universal Time (UTC).

Returns a structure representing the UTC, or NULL if UTC is not available.

isalnum

```
#include <ctype.h>
int isalnum( int c );
```

Returns a non-zero value when c is an alphabetic character or a number ([A-Z][a-z][0-9]).

isalpha

```
#include <ctype.h>
int isalpha( int c );
```

Returns a non-zero value when c is an alphabetic character ([A-Z][a-z]).

isascii

```
#include <ctype.h>
int isascii( int c );
```

Returns a non-zero value when *c* is in the range of 0 and 127. This is a non-ANSI function.

isctrl

```
#include <ctype.h>
int isctrl( int c );
```

Returns a non-zero value when *c* is a control character.

isdigit

```
#include <ctype.h>
int isdigit( int c );
```

Returns a non-zero value when *c* is a numeric character ([0-9]).

isgraph

```
#include <ctype.h>
int isgraph( int c );
```

Returns a non-zero value when *c* is printable, but not a space.

islower

```
#include <ctype.h>
int islower( int c );
```

Returns a non-zero value when *c* is a lowercase character ([a-z]).

isprint

```
#include <ctype.h>
int isprint( int c );
```

Returns a non-zero value when *c* is printable, including spaces.

ispunct

```
#include <ctype.h>
int ispunct( int c );
```

Returns a non-zero value when *c* is a punctuation character (such as `'`, `,`, `!`, etc.).

isspace

```
#include <ctype.h>
int isspace( int c );
```

Returns a non-zero value when *c* is a space type character (space, tab, vertical tab, formfeed, linefeed, carriage return).

isupper

```
#include <ctype.h>
int isupper( int c );
```

Returns a non-zero value when *c* is an uppercase character ([A-Z]).

isxdigit

```
#include <ctype.h>
int isxdigit( int c );
```

Returns a non-zero value when *c* is a hexadecimal digit ([0-9][A-F][a-f]).

labs

```
#include <stdlib.h>
long labs( long n );
```

Returns the absolute value of the signed long argument.

ldexp

```
#include <math.h>
double ldexp( double x, int n );
```

Returns the result of: $x \cdot 2^n$.

ldiv

```
#include <stdlib.h>
ldiv_t ldiv( long num, long denom );
```

Both arguments are long integers. The returned quotient and remainder are also long integers.

Returns a structure containing the quotient and remainder of num divided by denom.

localtime

```
#include <time.h>
struct tm *localtime( const time_t *tp );
```

Converts the calendar time *tp into local time.

Returns a structure representing the local time.

log

```
#include <math.h>
double log( double x );
```

Returns the natural logarithm $\ln(x)$, $x > 0$.

log10

```
#include <math.h>
double log10( double x );
```

Returns the base 10 logarithm $\log_{10}(x)$, $x > 0$.

longjmp

```
#include <setjmp.h>
void longjmp( jmp_buf env, int val );
```

Restores the environment previously saved with a call to `setjmp()`. The function calling the corresponding call to `setjmp()` may not be terminated yet. The value of `val` may not be zero.

Returns nothing.

malloc

```
#include <stdlib.h>
void *malloc( size_t size );
```

The allocated space is not initialized. The maximum space that can be allocated can be changed by customizing the heap size (see the section *Heap Size*). By default no heap is allocated.

Returns a pointer to space in external memory of `size` bytes length. NULL if there is not enough space left.

memchr

```
#include <string.h>
void *memchr( const void *cs, int c, size_t n );
```

Checks the first `n` bytes of `cs` on the occurrence of character `c`.

Returns NULL when not found, otherwise a pointer to the found character is returned.

memcmp

```
#include <string.h>
int memcmp( const void *cs,
            const void *ct, size_t n );
```

Compares the first *n* bytes of *cs* with the contents of *ct*.

Returns a value < 0 if *cs* $<$ *ct*,
 0 if *cs* $==$ *ct*,
 or a value > 0 if *cs* $>$ *ct*.

memcpyfb

```
#include <string.h>
void memcpyfb( void far *dest,
               void far *src, size_t n );
```

Copies *n* bytes from far data pointed by *src* to far data pointed by *dest*. No care is taken if the two objects overlap and page boundaries are not checked. ($0 < n \leq 16384$)

Returns nothing

memcpyfw

```
#include <string.h>
void memcpyfw( void far *dest,
               void far *src, size_t n );
```

Copies *n* words from far data pointed by *src* to far data pointed by *dest*. No care is taken if the two objects overlap and page boundaries are not checked. ($0 < n \leq 8192$)

Returns nothing

memcpyfb

```
#include <string.h>
void memcpyfb( void huge *dest,
               void far *src, size_t n);
```

Copies n bytes from far data pointed by *src* to huge data pointed by *dest*. No care is taken if the two objects overlap. Page boundaries are checked for huge data but not checked for far data.

($0 < n \leq 16384$)

Returns nothing

memcpyfhw

```
#include <string.h>
void memcpyfhw( void huge *dest,
               void far *src, size_t n);
```

Copies n words from far data pointed by *src* to huge data pointed by *dest*. No care is taken if the two objects overlap. Page boundaries are checked for huge data but not checked for far data.

($0 < n \leq 8192$)

Returns nothing

memcpyfnb

```
#include <string.h>
void memcpyfnb( void near *dest,
               void far *src, size_t n);
```

Copies n bytes from far data pointed by *src* to near data pointed by *dest*. No care is taken if the two objects overlap and page boundaries are not checked. ($0 < n \leq 16384$)

Returns nothing

memcpynw

```
#include <string.h>
void memcpynw( void near *dest,
               void far *src, size_t n);
```

Copies n words from far data pointed by `src` to near data pointed by `dest`. No care is taken if the two objects overlap and page boundaries are not checked. ($0 < n \leq 8192$)

Returns nothing

memcpyfsb

```
#include <string.h>
void memcpyfsb( void shuge *dest,
                void far *src, size_t n);
```

Copies n bytes from far data pointed by `src` to shuge data pointed by `dest`. No care is taken if the two objects overlap. Page boundaries are checked for huge data but not checked for far data.
($0 < n \leq 16384$)

Returns nothing

memcpyfsw

```
#include <string.h>
void memcpyfsw( void shuge *dest,
                void far *src, size_t n);
```

Copies n words from far data pointed by `src` to shuge data pointed by `dest`. No care is taken if the two objects overlap. Page boundaries are checked for huge data but not checked for far data.
($0 < n \leq 8192$)

Returns nothing

memcpyfb

```
#include <string.h>
void memcpyfb( void far *dest,
               void huge *src, size_t n);
```

Copies *n* bytes from huge data pointed by *src* to far data pointed by *dest*. No care is taken if the two objects overlap. Page boundaries are checked for huge data but not checked for far data.

($0 < n \leq 16384$)

Returns nothing

memcpyfw

```
#include <string.h>
void memcpyfw( void far *dest,
               void huge *src, size_t n);
```

Copies *n* words from huge data pointed by *src* to far data pointed by *dest*. No care is taken if the two objects overlap. Page boundaries are checked for huge data but not checked for far data.

($0 < n \leq 8192$)

Returns nothing

memcpyhb

```
#include <string.h>
void memcpyhb( void huge *dest,
               void huge *src, size_t n);
```

Copies *n* bytes from huge data pointed by *src* to huge data pointed by *dest*. No care is taken if the two objects overlap.

($0 < n \leq 65535$)

Returns nothing

memcphhw

```
#include <string.h>
void memcphhw( void huge *dest,
               void huge *src, size_t n);
```

Copies n words from huge data pointed by `src` to huge data pointed by `dest`. No care is taken if the two objects overlap. ($0 < n \leq 65535$)

Returns nothing

memcphnb

```
#include <string.h>
void memcphnb( void near *dest,
               void huge *src, size_t n);
```

Copies n bytes from huge data pointed by `src` to near data pointed by `dest`. No care is taken if the two objects overlap. Page boundaries are checked for huge data but not checked for near data. ($0 < n \leq 16384$)

Returns nothing

memcphnw

```
#include <string.h>
void memcphnw( void near *dest,
               void huge *src, size_t n);
```

Copies n words from huge data pointed by `src` to near data pointed by `dest`. No care is taken if the two objects overlap. Page boundaries are checked for huge data but not checked for near data. ($0 < n \leq 8192$)

Returns nothing

memcphsb

```
#include <string.h>
void memcphsb( void shuge *dest,
               void huge *src, size_t n);
```

Copies *n* bytes from huge data pointed by *src* to shuge data pointed by *dest*. No care is taken if the two objects overlap.

(0 < *n* <= 65535)

Returns nothing

memcphsw

```
#include <string.h>
void memcphsw( void shuge *dest,
               void huge *src, size_t n);
```

Copies *n* words from huge data pointed by *src* to shuge data pointed by *dest*. No care is taken if the two objects overlap.

(0 < *n* <= 65535)

Returns nothing

memcpnfb

```
#include <string.h>
void memcpnfb( void far *dest,
               void near *src, size_t n);
```

Copies *n* bytes from near data pointed by *src* to far data pointed by *dest*. No care is taken if the two objects overlap.

(0 < *n* <= 16384)

Returns nothing

memcpyfw

```
#include <string.h>
void memcpyfw( void far *dest,
               void near *src, size_t n);
```

Copies *n* words from near data pointed by *src* to far data pointed by *dest*. No care is taken if the two objects overlap. ($0 < n \leq 8192$)

Returns nothing

memcpyhb

```
#include <string.h>
void memcpyhb( void huge *dest,
               void near *src, size_t n);
```

Copies *n* bytes from near data pointed by *src* to huge data pointed by *dest*. No care is taken if the two objects overlap. Page boundaries are checked for huge data but not checked for near data. ($0 < n \leq 16384$)

Returns nothing

memcpyhw

```
#include <string.h>
void memcpyhw( void huge *dest,
               void near *src, size_t n);
```

Copies *n* words from near data pointed by *src* to huge data pointed by *dest*. No care is taken if the two objects overlap. Page boundaries are checked for huge data but not checked for near data. ($0 < n \leq 8192$)

Returns nothing

memcpynb

```
#include <string.h>
void memcpynb( void near *dest,
               void near *src, size_t n);
```

Copies *n* bytes from near data pointed by *src* to near data pointed by *dest*. No care is taken if the two objects overlap and page boundaries are not checked. ($0 < n \leq 16384$)

Returns nothing

memcpynw

```
#include <string.h>
void memcpynw( void near *dest,
               void near *src, size_t n);
```

Copies *n* words from near data pointed by *src* to near data pointed by *dest*. No care is taken if the two objects overlap and page boundaries are not checked. ($0 < n \leq 8192$)

Returns nothing

memcpynsb

```
#include <string.h>
void memcpynsb( void shuge *dest,
                void near *src, size_t n);
```

Copies *n* bytes from near data pointed by *src* to shuge data pointed by *dest*. No care is taken if the two objects overlap. Page boundaries are checked for shuge data but not for near data. ($0 < n \leq 16384$)

Returns nothing

memcpysw

```
#include <string.h>
void memcpysw( void shuge *dest,
               void near *src, size_t n);
```

Copies n words from near data pointed by *src* to shuge data pointed by *dest*. No care is taken if the two objects overlap. Page boundaries are checked for shuge data but not for near data. ($0 < n \leq 8192$)

Returns nothing

memcpysfb

```
#include <string.h>
void memcpysfb( void far *dest,
                void shuge *src, size_t n);
```

Copies n bytes from shuge data pointed by *src* to far data pointed by *dest*. No care is taken if the two objects overlap. Page boundaries are checked for shuge data but not checked for far data. ($0 < n \leq 16384$)

Returns nothing

memcpysfw

```
#include <string.h>
void memcpysfw( void far *dest,
                void shuge *src, size_t n);
```

Copies n words from shuge data pointed by *src* to far data pointed by *dest*. No care is taken if the two objects overlap. Page boundaries are checked for shuge data but not checked for far data. ($0 < n \leq 8192$)

Returns nothing

memcpsbb

```
#include <string.h>
void memcpshb( void huge *dest,
               void shuge *src, size_t n);
```

Copies *n* bytes from shuge data pointed by *src* to huge data pointed by *dest*. No care is taken if the two objects overlap.

($0 < n \leq 16384$)

Returns nothing

memcpshw

```
#include <string.h>
void memcpshw( void huge *dest,
               void shuge *src, size_t n);
```

Copies *n* words from shuge data pointed by *src* to huge data pointed by *dest*. No care is taken if the two objects overlap.

($0 < n \leq 8192$)

Returns nothing

memcpsnb

```
#include <string.h>
void memcpsnb( void near *dest,
               void shuge *src, size_t n);
```

Copies *n* bytes from shuge data pointed by *src* to near data pointed by *dest*. No care is taken if the two objects overlap. Page boundaries are checked for shuge data but not for near data.

($0 < n \leq 16384$)

Returns nothing

memcpysw

```
#include <string.h>
void memcpysw( void near *dest,
               void shuge *src, size_t n);
```

Copies n words from shuge data pointed by `src` to near data pointed by `dest`. No care is taken if the two objects overlap. Page boundaries are checked for shuge data but not for near data.

($0 < n \leq 8192$)

Returns nothing

memcpysb

```
#include <string.h>
void memcpysb( void shuge *dest,
               void shuge *src, size_t n);
```

Copies n bytes from shuge data pointed by `src` to shuge data pointed by `dest`. No care is taken if the two objects overlap.

($0 < n \leq 16384$)

Returns nothing

memcpysw

```
#include <string.h>
void memcpysw( void shuge *dest,
               void shuge *src, size_t n);
```

Copies n words from shuge data pointed by `src` to shuge data pointed by `dest`. No care is taken if the two objects overlap.

($0 < n \leq 8192$)

Returns nothing

memcpy

```
#include <string.h>
void *memcpy( void *s, const void *ct, size_t n );
```

Copies *n* characters from *ct* to *s*. No care is taken if the two objects overlap.

Returns *s*

memmove

```
#include <string.h>
void *memmove( void *s, const void *ct, size_t n );
```

Copies *n* characters from *ct* to *s*. Overlapping objects will be handled correctly.

Returns *s*

memset

```
#include <string.h>
void *memset( void *s, int c, size_t n );
```

Fills the first *n* bytes of *s* with character *c*.

Returns *s*

mktime

```
#include <time.h>
time_t mktime( struct tm *tp );
```

Converts the local time in the structure **tp* into calendar time.

Returns the calendar time in seconds, or -1 if it cannot be represented.

modf

```
#include <math.h>
double modf( double x, double *ip );
```

Splits *x* into integral and fractional parts, each with the same sign as *x*. It stores the integral part in **ip*.

Returns the fractional part.

offsetof

```
#include <stddef.h>
int offsetof( type, member );
```

Be aware, `offsetof()` for bit structures/unions may give unpredictable results. Also the `offsetof()` of a bitfield is undefined.

Returns the offset for the given member in an object of type.

pow

```
#include <math.h>
double pow( double x, double y );
```

A domain error occurs if *x*=0 and *y*<=0, or if *x*<0 and *y* is not an integer.

Returns the result of *x* raised to the power of *y*: x^y .

printf

```
#include <stdio.h>
int printf( const char *format, ... );
```

Performs a formatted write to the standard output stream.



See also `”_iowrite()”`.

Returns the number of characters written to the output stream.

The format string may contain plain text mixed with conversion specifiers. Each conversion specifier should be preceded by a '%' character. The conversion specifier should be build in order :

- Flags (in any order):

- specifies left adjustment of the converted argument.
- + a number is always preceded with a sign character.
+ has higher precedence as space.

space a negative number is preceded with a sign, positive numbers with a space.

0 specifies padding to the field width with zeros (only for numbers).

specifies an alternate output form. For o, the first digit will be zero. For x or X, "0x" and "0X" will be prefixed to the number. For e, E, f, g, G, the output always contains a decimal point, trailing zeros are not removed.

- A number specifying a minimum field width. The converted argument is printed in a field with at least the length specified here. If the converted argument has fewer characters than specified, it will be padded at the left side (or at the right when the flag '-' was specified) with spaces. Padding to numeric fields will be done with zeros when the flag '0' is also specified (only when padding left). Instead of a numeric value, also '*' may be specified, the value is then taken from the next argument, which is assumed to be of type int.
- A period. This separates the minimum field width from the precision.
- A number specifying the maximum length of a string to be printed. Or the number of digits printed after the decimal point (only for floating point conversions). Or the minimum number of digits to be printed for an integer conversion. Instead of a numeric value, also '*' may be specified, the value is then taken from the next argument, which is assumed to be of type int.
- A length modifier 'h', 'l' or 'L'. 'h' indicates that the argument is to be treated as a short or unsigned short number. 'l' should be used if the argument is a long integer. 'L' indicates that the argument is a long double.

Flags, length specifier, period, precision and length modifier are optional, the conversion character is not. The conversion character must be one of the following, if a character following '%' is not in the list, the behavior is undefined:

Character	Printed as
d, i	int, signed decimal
o	int, unsigned octal
x, X	int, unsigned hexadecimal in lowercase or uppercase respectively
u	int, unsigned decimal
c	int, single character (converted to unsigned char)
s	char *, the characters from the string are printed until a NULL character is found. When the given precision is met before, printing will also stop
f	double
e, E	double
g, G	double
n	int *, the number of characters written so far is written into the argument. This should be a pointer to an integer in default memory. No value is printed.
p	pointer
%	No argument is converted, a '%' is printed.

Table 6-2: Printf conversion characters

The 'p' conversion character can be used to print pointers. In the tiny and small memory models, pointers will be printed as near pointers by default. In the medium and large memory models, pointers will be printed as far pointers by default. By specifying one of the length modifiers 'h', 'l' or 'L', a pointer will always be printed as near, far or huge respectively.

Because of the large overhead of the `printf()` function on small programs, three different versions of the formatter (`_doprint.c`) are delivered. The `LARGE` version is able to print everything as specified above. The `MEDIUM` version has no floating point formatting. When a floating point conversion character is found, `errno` is filled with the correct error number, `printf` stops immediately. The `SMALL` version does not print floating point, and does not accept flags, width specifier, period and precision. This formatter is considerably smaller in code size than the `MEDIUM` or `LARGE` version.

putc

```
#include <stdio.h>
int putc( int c, FILE *stream );
```

Puts one character onto the given stream.



See also ”`_iowrite()`”.

Returns EOF on error.

putchar

```
#include <stdio.h>
int putchar( int c );
```

Puts one character onto standard output.



See also ”`_iowrite()`”.

Returns the character written or EOF on error.

puts

```
#include <stdio.h>
int puts( const char *s );
```

Writes the string to `stdout`, the string is terminated by a newline.



See also ”`_iowrite()`”.

Returns NULL if successful, or EOF on error.

qsort

```
#include <stdlib.h>
void qsort( void *base, size_t n,
           size_t size, int (*cmp)
           ( const void *, const void * ) );
```

This function sorts an array of *n* members. The initial base of the array is given by *base*. The size of each member is specified by *size*. The given array is sorted in ascending order, according to the results of the function pointed to by *cmp*.



This function is recursive, and therefore may need an increased user stack section!

rand

```
#include <stdlib.h>
int rand( void );
```

Returns a sequence of pseudo-random integers, in the range 0 to RAND_MAX.

realloc

```
#include <stdlib.h>
void *realloc( void *p, size_t size );
```

Reallocates the space for the object pointed to by *p*. The contents of the object will be the same as before calling *realloc*(). The maximum space that can be allocated can be changed by customizing the heap size (see the section *Heap Size*). By default no heap is allocated.

Returns NULL and **p* is not changed, if there is not enough space for the new allocation. Otherwise a pointer to the newly allocated space for the object is returned.

scanf

```
#include <stdio.h>
int scanf( const char *format, ... );
```

Performs a formatted read from the standard input stream.



See also ”_iored()”.

Returns the number of items converted successfully.

All arguments to this function should be pointers to variables (in default memory) of the type which is specified in the format string.

The format string may contain :

- Blanks or tabs, which are skipped.
- Normal characters (not '%'), which should be matched exactly in the input stream.
- Conversion specifications, starting with a '%' character.

Conversion specifications should be build as follows (in order) :

- A '*', meaning that no assignment is done for this field.
- A number specifying the maximum field width.
- The conversion characters *d*, *i*, *n*, *o*, *u* and *x* may be preceded by 'h' if the argument is a pointer to *short* rather than *int*, or by 'l' (letter ell) if the argument is a pointer to *long*. The conversion characters *e*, *f*, and *g* may be preceded by 'l' if a pointer *double* rather than *float* is in the argument list, and by 'L' if a pointer to a *long double*.
- A conversion specifier. '*', maximum field width and length modifier are optional, the conversion character is not. The conversion character must be one of the following, if a character following '%' is not in the list, the behavior is undefined.

Length specifier and length modifier are optional, the conversion character is not. The conversion character must be one of the following, if a character following '%' is not in the list, the behavior is undefined.

Character	Scanned as
d	int, signed decimal.
i	int, the integer may be given octal (i.e. a leading 0 is entered) or hexadecimal (leading "0x" or "0X"), or just decimal.
o	int, unsigned octal.
u	int, unsigned decimal.
x	int, unsigned hexadecimal in lowercase or uppercase.
c	single character (converted to unsigned char).
s	char *, a string of non white space characters. The argument should point to an array of characters, large enough to hold the string and a terminating NULL character.
f	float
e, E	float
g, G	float
n	int *, the number of characters written so far is written into the argument. No scanning is done.
p	pointer; must be entered with 0x- prefix.
[...]	Matches a string of input characters from the set between the brackets. A NULL character is added to terminate the string. Specifying [^...] includes the ']' character in the set of scanning characters.
[^...]	Matches a string of input characters not in the set between the brackets. A NULL character is added to terminate the string. Specifying [^...] includes the ']' character in the set.
%	Literal '%', no assignment is done.

Table 6-3: *scanf* conversion characters

The 'p' conversion character can be used to read pointers. In the tiny and small memory models, pointers will be read as near pointers by default. In the medium and large memory models, pointers will be read as far pointers by default. By specifying one of the length modifiers 'h', 'l' or 'L', a pointer will always be read as near, far or huge respectively.

Two different version of the formatter (`_doscan.c`) are delivered. The LARGE version is able to scan everything as specified above. The SMALL version has no floating point scanning. When a floating point conversion character is found, `errno` is filled with the correct error number, `scanf` stops immediately.

Therefore the default formatter installed in the C library is the SMALL version.

setbuf

```
#include <stdio.h>
void setbuf( FILE *stream, char *buf );
```

Buffering is turned off for the `stream`, if `buf` is `NULL`. Otherwise, `setbuf` is equivalent to:

```
(void) setvbuf( stream, buf, _IOFBF, BUFSIZ )
```

Returns nothing.



See also "setvbuf()".

setjmp

```
#include <setjmp.h>
int setjmp( jmp_buf env );
```

Saves the current environment for a subsequent call to `longjmp`.

Returns the value 0 after a direct call to `setjmp()`. Calling the function "longjmp()" using the saved `env` will restore the current environment and jump to this place with a non-zero return value.



See also "longjmp()".

setvbuf

```
#include <stdio.h>
int setvbuf( FILE *stream, char *buf,
            int mode, size_t size );
```

Controls buffering for the `stream`; this function must be called before reading or writing. `mode` can have the following values:

```
_IOFBF  causes full buffering
_IOLBF  causes line buffering of text files
_IONBF  causes no buffering
```

If `buf` is not `NULL`, it will be used as a buffer; otherwise a buffer will be allocated. `size` determines the buffer size.

Returns zero if successful
 a non-zero value for an error.



See also "setbuf()".

sin

```
#include <math.h>
double sin( double x );
```

Returns the sine of `x`.

sinh

```
#include <math.h>
double sinh( double x );
```

Returns the hyperbolic sine of `x`.

sprintf

```
#include <stdio.h>
int sprintf( char *s, const char *format, ... );
```

Performs a formatted write to a string.



See also "printf()".

sqrt

```
#include <math.h>
double sqrt( double x );
```

Returns the square root of x . \sqrt{x} , where $x \geq 0$.

srand

```
#include <stdlib.h>
void srand( unsigned int seed );
```

This function uses *seed* as the start of a new sequence of pseudo-random numbers to be returned by subsequent calls to `srand()`. When `srand` is called with the same seed value, the sequence of pseudo-random numbers generated by `rand()` will be repeated.

Returns pseudo random numbers.

sscanf

```
#include <stdio.h>
int sscanf( char *s, const char *format, ... );
```

Performs a formatted read from a string.



See also "scanf()".

strcat

```
#include <string.h>
char *strcat( char *s, const char *ct );
```

Concatenates string *ct* to string *s*, including the trailing NULL character.

Returns *s*

strchr

```
#include <string.h>
char *strchr( const char *cs, int c );
```

Returns a pointer to the first occurrence of character *c* in the string *cs*. If not found, NULL is returned.

strcmp

```
#include <string.h>
int strcmp( const char *cs, const char *ct );
```

Compares string *cs* to string *ct*.

Returns <0 if *cs* < *ct*,
 0 if *cs* == *ct*,
 >0 if *cs* > *ct*.

strcpy

```
#include <string.h>
char *strcpy( char *s, const char *ct );
```

Copies string *ct* into the string *s*, including the trailing NULL character.

Returns *s*

strcspn

```
#include <string.h>
size_t strcspn( const char *cs, const char *ct );
```

Returns the length of the prefix in string `cs`, consisting of characters not in the string `ct`.

strftime

```
#include <time.h>
size_t strftime( char *s, size_t smax,
                const char *fmt,
                const struct tm *tp );
```

Formats date and time information from the structure `*tp` into `s` according to the specified format `fmt`. `fmt` is analogous to a `printf` format. Each `%c` is replaced as described below:

<code>%a</code>	abbreviated weekday name
<code>%A</code>	full weekday name
<code>%b</code>	abbreviated month name
<code>%B</code>	full month name
<code>%c</code>	local date and time representation
<code>%d</code>	day of the month (01-31)
<code>%H</code>	hour, 24-hour clock (00-23)
<code>%I</code>	hour, 12-hour clock (01-12)
<code>%j</code>	day of the year (001-366)
<code>%m</code>	month (01-12)
<code>%M</code>	minute (00-59)
<code>%p</code>	local equivalent of AM or PM
<code>%S</code>	second (00-59)
<code>%U</code>	week number of the year, Sunday as first day of the week (00-53)
<code>%w</code>	weekday (0-6, Sunday is 0)
<code>%W</code>	week number of the year, Monday as first day of the week (00-53)
<code>%x</code>	local date representation
<code>%X</code>	local time representation
<code>%y</code>	year without century (00-99)
<code>%Y</code>	year with century

%Z time zone name, if any
 %% %

Ordinary characters (including the terminating '\0') are copied into *s*. No more than *smax* characters are placed into *s*.

Returns the number of characters ('\0' not included), or zero if more than *smax* characters were produced.

strlen

```
#include <string.h>
size_t strlen( const char *cs );
```

Returns the length of the string in *cs*, not counting the NULL character.

strncat

```
#include <string.h>
char *strncat( char *s, const char *ct, size_t n );
```

Concatenates string *ct* to string *s*, at most *n* characters are copied. Add a trailing NULL character.

Returns *s*

strncmp

```
#include <string.h>
int strncmp( const char *cs,
             const char *ct, size_t n );
```

Compares at most *n* bytes of string *cs* to string *ct*.

Returns <0 if *cs* < *ct*,
 0 if *cs* == *ct*,
 >0 if *cs* > *ct*.

strncpy

```
#include <string.h>
char *strncpy( char *s, const char *ct, size_t n );
```

Copies string *ct* onto the string *s*, at most *n* characters are copied. Add a trailing NULL character if the string is smaller than *n* characters.

Returns *s*

strpbrk

```
#include <string.h>
char *strpbrk( const char *cs, const char *ct );
```

Returns a pointer to the first occurrence in *cs* of any character out of string *ct*. If none are found, NULL is returned.

strrchr

```
#include <string.h>
char *strrchr( const char *cs, int c );
```

Returns a pointer to the last occurrence of *c* in the string *cs*. If not found, NULL is returned.

strspn

```
#include <string.h>
size_t strspn( const char *cs, const char *ct );
```

Returns the length of the prefix in string *cs*, consisting of characters in the string *ct*.

strstr

```
#include <string.h>
char *strstr( const char *cs, const char *ct );
```

Returns a pointer to the first occurrence of string *ct* in the string *cs*. Returns NULL if not found.

strtod

```
#include <stdlib.h>
double strtod( const char *s, char **endp );
```

Converts the initial portion of the string pointed to by *s* to a double value. Initial white spaces are skipped. When *endp* is not a NULL pointer, after this function is called, **endp* will point to the first character not used by the conversion.

Returns the read value.

strtok

```
#include <string.h>
char *strtok( char *s, const char *ct );
```

Search the string *s* for tokens delimited by characters from string *ct*. It terminates the token with a NULL character.

Returns a pointer to the token. A subsequent call with *s* == NULL will return the next token in the string.

strtol

```
#include <stdlib.h>
long strtol( const char *s, char **endp, int base );
```

Converts the initial portion of the string pointed to by *s* to a long integer. Initial white spaces are skipped. Then a value is read using the given *base*. When *base* is zero, the base is taken as defined for integer constants. I.e. numbers starting with an '0' are taken octal, numbers starting with '0x' or '0X' are taken hexadecimal. Other numbers are taken decimal. When *endp* is not a NULL pointer, after this function is called, **endp* will point to the first character not used by the conversion.

Returns the read value.

strtoul

```
#include <stdlib.h>
unsigned long strtoul( const char *s,
                      char **endp, int base );
```

Converts the initial portion of the string pointed to by *s* to an unsigned long integer. Initial white spaces are skipped. Then a value is read using the given base. When *base* is zero, the base is taken as defined for integer constants. I.e. numbers starting with an '0' are taken octal, numbers starting with '0x' or '0X' are taken hexadecimal. Other numbers are taken decimal. When *endp* is not a NULL pointer, after this function is called, **endp* will point to the first character not used by the conversion.

Returns the read value.

tan

```
#include <math.h>
double tan( double x );
```

Returns the tangent of *x*.

tanh

```
#include <math.h>
double tanh( double x );
```

Returns the hyperbolic tangent of *x*.

time

```
#include <time.h>
time_t time( time_t *tp );
```

The return value is also assigned to **tp*, if *tp* is not NULL.

Returns the current calendar time in seconds, or -1 if the time is not available.

toascii

```
#include <ctype.h>
int toascii( int c );
```

Converts *c* to an ascii value (strip highest bit). This is a non-ANSI function.

Returns the converted value.

tolower

```
#include <ctype.h>
int tolower( int c );
```

Returns *c* converted to a lowercase character if it is an uppercase character, otherwise *c* is returned.

toupper

```
#include <ctype.h>
int toupper( int c );
```

Returns *c* converted to an uppercase character if it is a lowercase character, otherwise *c* is returned.

ungetc

```
#include <stdio.h>
int ungetc( int c, FILE *fin );
```

Pushes at the most one character back onto the input buffer.

Returns EOF on error.

va_arg

```
#include <stdarg.h>
va_arg( va_list ap, type );
```

Returns the value of the next argument in the variable argument list. Its return type has the type of the given argument type. A next call to this macro will return the value of the next argument.

va_end

```
#include <stdarg.h>
va_end( va_list ap );
```

This macro must be called after the arguments have been processed. It should be called before the function using the macro 'va_start' is terminated (ANSI specification).

va_start

```
#include <stdarg.h>
va_start( va_list ap, lastarg );
```

This macro initializes ap. After this call, each call to va_arg() will return the value of the next argument. In our implementation, va_list cannot contain any bit type variables. Also the given argument lastarg must be the last non bit type argument in the list.

vfprintf

```
#include <stdio.h>
int vfprintf( FILE *stream,
              const char *format, va_list arg );
```

Is equivalent to vprintf, but writes to the given stream.



See also "vprintf()" and "_iowrite()".

vprintf

```
#include <stdio.h>
int vprintf( const char *format, va_list arg );
```

Does a formatted write to standard output. Instead of a variable argument list as for `printf()`, this function expects a pointer to the list.



See also "printf()" and "_iowrite()".

vsprintf

```
#include <stdio.h>
int vsprintf( char *s, const char *format,
             va_list arg );
```

Does a formatted write a string. Instead of a variable argument list as for `printf()`, this function expects a pointer to the list.



See also "printf()" and "_iowrite()".

6.8 CREATING YOUR OWN C LIBRARY

There are several reasons why it is desired to have a specially adapted C library. Therefore all C sources of all library functions are delivered with the compiler. These files are placed in the directory `lib\src` (Windows) or `lib/src` (UNIX).

When creating your own library, the order of the objects in the library file is very important. To know the exact order in which the objects should be placed in the library, make a list of the order in which the delivered libraries are made by using the command '`ar166 t c166m.lib`', for example.

The easiest method to create your own library is to make a copy of the existing library (use the library in the same memory model you want to create) and replace the existing objects in it by your own made objects with the command '`ar166 crv libname objectname ...`'. This way the order of the objects in the library will be maintained. At link time you only have to link the newly made library to your application instead of a delivered library.

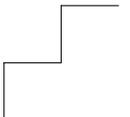
You can rebuild your library with **mk166**. To use the correct makefile, first make sure you are in the directory of the library you want to rebuild: `lib\src\architecture\library` (Windows) or `lib/src/architecture/library` (UNIX). Use **mk166** to rebuild your library now. (You may want to make a backup copy of the original library first.)

LIBRARIES

CHAPTER

7

RUN-TIME ENVIRONMENT



7 | CHAPTER

7.1 STARTUP CODE

When linking (Task Concept) or locating (Flat Interrupt Concept) the module containing `main()` which is an object module containing the C startup code has to be linked to the application. This module, called `start.obj`, is included in each C library with a system startup configuration default for the library it is included in. The compiler generates a reference to this module when it translates the definition of the `main()` function. This reference causes the `start.obj` to be extracted from the library by **1166**.

This file specifies the run-time environment of your C166 application. The file is delivered in assembly source (`start.asm`) in the directory `lib/src`. The file `start.asm` includes the file `cstart.asm`, `cstartx.asm` or `cstartx2.asm` depending on the selected architecture. Modifications to these files are not necessary since all parameters can be manipulated using macro preprocessor symbols.



When you want to control `start.asm` from within EDE, you first have to add `start.asm` to your project: Select the **Project | Properties** menu item, activate the **Files** tab, browse to `lib/src/start.asm` and add it to your project. You can specify all your startup settings in the **Startup** tab of the **CPU Configuration** dialog (select the **EDE | CPU Configuration...** menu item). You can specify CPU settings in the same dialog by selecting the **EDE | Bus Configuration...** menu item you can select the bus configuration settings that are appropriate. EDE automatically defines macros according to the selected settings.

When you are not using EDE, you must use **m166** before **a166** when a new version of the object file has to be created:

```
m166 start.asm DEFINE( MODEL, LARGE )  
a166 start noprint
```

You must specify the memory model for the preprocessing phase. Therefore you have to define the preprocessor symbol `MODEL`. You can do this with the **m166** command line control `DEFINE` by defining the memory model you are using. When preprocessing the startup file, `MODEL` is checked to select, skip or include certain pieces of code.

The new `start.obj` can be supplied to **1166** when linking the module containing `main()`. **1166** will use this object instead of the object from the library.

There are a number of other preprocessor symbols used, which can be enabled or disabled using the command line control `DEFINE` (Syntax: `DEFINE(identifier [, replacement])`).

In the startup file the following preprocessor symbols are used (please also review `cstart[x or x2].asm`):

<code>EX_AB</code>	Must be enabled (set to 1) if the C library function <code>exit()</code> or <code>abort()</code> is called by the application. Otherwise it must be cleared (set to 0). Default cleared, because the total code size is increased, due to assumptions about buffered file I/O, which must be flushed at exit.
<code>_EXT</code>	Must be enabled (set to 1) when an extended architecture (<code>ext</code> or <code>ext2</code>) needs to be initialized. It must be cleared (set to 0) when a non-extended architecture like the 166 needs to be initialized.
<code>FLOAT</code>	Must be enabled (set to 1) if floating point arithmetic is used (or floating point C library functions called) by the application. Otherwise it must be cleared (set to 0). Default set.
<code>BIT_INIT</code>	Must be enabled (set to 1) if initialized bit variables (<code>bit b = 1;</code>) are used, so the initialization is done at startup. Non-initialized bit variables are always set to 0. Default set to 0, because initialized bit variables are very seldom used and rather expensive in both ROM space and execution time during startup. Therefore, if possible, initialized bit variables should be avoided.
<code>NOBITCLEAR</code>	When set, skips clearing of the bitaddressable RAM.
<code>EVA</code>	Must be enabled (set to 1) when using the ROM/RAM monitor on evaluation boards as execution environment. Needed to force the tiny model to execute with the CPU segmentation enabled and to prevent the startup code to clear the bit-addressable area, which contains monitor data. It also starts the application with interrupts enabled and provides CrossView Pro with information about the configuration when the C167 is used. Default enabled.

- `_CPU` Must be set when one of the following directories is used: 165-UTAH (165Utah), 167CS-40 (167CS40), SDA6000 (sda6000). Set the `_CPU` symbol to the appropriate value mentioned between brackets. If none of these derivatives is used then `_CPU` does not need to be set.
- `_USRSTACK` Must be enabled (set to 1) to support the user stack model. Default disabled. See section *User Stack Model* for more details.
- `CALLINIT` Can be set to a function to be called before `main`. This function may not have any return value and may not have any arguments. This function can be used, for example, to initialize the serial port before `main` is called. This is useful for building benchmark programs without making any modifications to the original source.
- `CALLEINIT` Can be set to a function to be called before the `EINIT` instruction is executed, but after register initialization. Like the `CALLINIT` function, it may not have a return value or any arguments.
- `SSKENABLE` If set, initializes the system stack for C166S v2.0 / Super10 architectures using a modifiable `SYSSTACK` system.
- `__SSKSIZE` Determines the stack size in bytes on C166S v2.0 / Super10 architectures.
- `__SSKSEG` Determines the segment where the system stack is positioned on C166S v2.0 / Super10 architectures.

In the startup file a code section named `__CSTART_PR` is declared. In this code section the task procedure `__CSTART` is declared, using interrupt number 0, which is the power-on vector of the processor.

First the system is configured using a macro for each configuration item: wait states, read/write signal delay, system clock output, segmentation control, system stack size etc. You must specify these values using the appropriate macros, depending on the specific needs of your target system. Please review the appropriate startup file for an exact overview of initialized registers and macros used.



The system stack registers (overflow, underflow and stack pointer) are initialized using the predefined symbols `?SYSSTACK_BOTTOM` and `?SYSSTACK_TOP`. The assembler, linker and locator treat predefined symbols (all starting with a '?') in a special way. They give the assembler programmer access to information which is normally not available before the locate stage of the application.

After the context pointer register is set to the register bank of this task, write output is enabled and the 'end-of-initialization' instruction (EINIT) is executed.

All bit addressable memory is cleared, because this guarantees all non initialized bit variables of each task to have the value of 0.

The startup code also takes care of initialized static/public C variables of each task, residing in the different RAM areas (not const or #pragma romdata). All these initialized variables are allocated in both a ROM and RAM section for each category (bit, near, far, huge). See the section *Initialized Variables* for more details. The startup code copies the initial values of initialized C variables for the whole application (all tasks in the Task Concept) from ROM to RAM using a table (in the global `C166_INIT` section), which has been built by the compiler. The predefined symbol `?C166_INIT_HEAD` contains the start address of the table.

In ANSI-C all non-initialized static/public C variables must have the initial value of 0. Non-initialized bit variables are already cleared by previous code. Therefore, the startup code clears the non-initialized non-bit variables of the whole application (all tasks in the Task Concept) using a table (in the global `C166_BSS` section), which has been built by the compiler (unless the **-Ob** option has been used). The predefined symbol `?C166_BSS_HEAD` contains the start address of the table. See the section *Non-Initialized Variables* for more information.

Finally, the DPP registers are initialized, depending on the memory model used. DPP0 to DPP2 are initialized accordingly. The predefined symbols `?BASE_DPP0` to `?BASE_DPP2` are used to initialize DPP0 to DPP2.

Last but not least, the user stack pointer is initialized using the predefined symbol `?USRSTACK_TOP`.

When everything described above has been executed, your C application is called, using the public label `_main`, which has been generated by **c166** for the C function `main()`. When the C application 'returns', which is not likely to happen in an embedded environment, you can specify if the program uses the function `exit()`, `abort()` or `atexit()`.

At the assembly label `__EXIT`, the system stack pointer, the user stack pointer and the floating point stack (if floats are used) are restored and the program performs an endless loop setting the CPU in power down mode (IDLE instruction).

7.2 STACK SIZE

c166 maintains two types of stack: the system stack and the user stack.

The system stack is used for return addresses (CALL/RET instructions) and can be accessed via PUSH/POP instructions (using the SP register).

Because the system stack is very small (internal memory for the C166/ST10), **c166** tries to avoid it as much as possible. Code generator temporaries are pushed on the user stack. Via the **-Ou** option it is even possible to let a task switch (interrupt) use the user stack instead of the system stack. As described above, you must specify the size of the system stack size in the system startup code (SYSICON register), which is the system stack size for all tasks (the whole application).

For the C166S v2.0 / Super10 architectures, the system stack size is determined by specifying a SYSSTACK section of the required size and using the SSKDEF 7 directive option. The locator can relocate this section. Use the preprocessor macros SSKENABLE, __SSKSEG and __SSKSIZE to determine the correct system stack.

If **-P** is used, the system stack is not used at all. See section *User Stack Model* for details.

The user stack is the so-called 'C stack'. **c166** uses R0 as 'User Stack Pointer' and the [-R0]/[R0+] addressing modes perform push/pop sequences. If data paging is used (medium and large memory model), the user stack is limited to 16K (one page). In these models, **c166** uses DPP1 as 'user-stack page number'. The locator combines the user stack areas of each task to one global user stack area (with cumulated size). A context switch inherits the user stack pointer (R0) value in the new register bank and DPP1 remains unchanged.

c166 estimates the needed user stack size for each C module by adding the stack sizes of each function to each other. This amount of bytes is allocated in the data section called C166_US (see section *Section Allocation*). However, in most cases this is too big, because not all functions are active simultaneously. In other cases, the size will be too small, e.g. when recursive functions are present (note that `qsort()` is implemented as a recursive function).

You can modify the user stack size using the SECSIZE control of the locator.

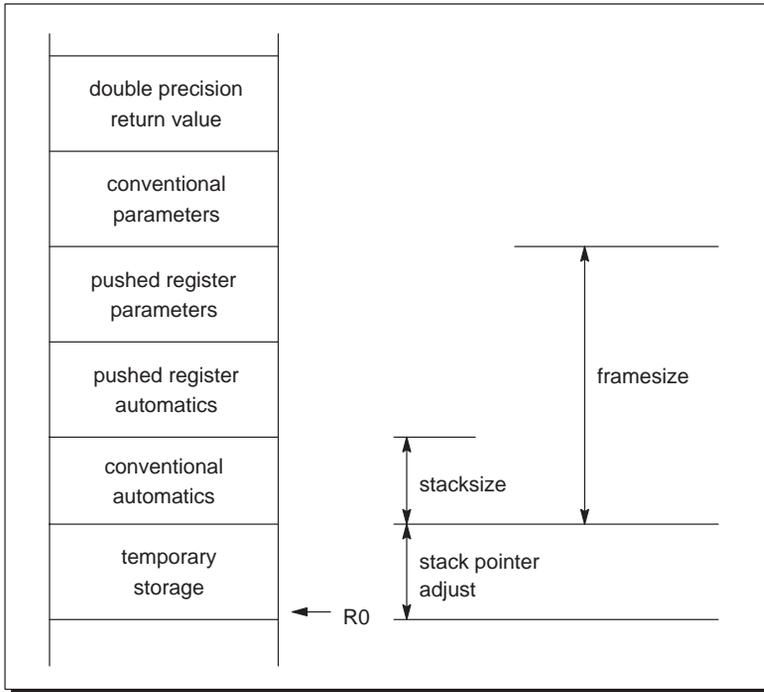


Figure 7-1: Stack diagram

Example:

```
1166 task t1.lno SECSIZE(C166_US(-50))
      task t2.lno SECSIZE(C166_US(-10))
      TO applic.out
```

7.3 HEAP SIZE

The heap is only needed when dynamic memory management library functions are used: `malloc()`, `calloc()`, `free()` and `realloc()`. The heap is allocated by the linker for each task in a special (public) section called `?C166_HEAP` with the class name `?CHEAP` having a default size of 0 bytes. If you are using one of the memory allocation functions listed above in a certain task, you must change the heap size for that task using the `HEAPSIZE` control at link stage.

When the Flat Interrupt Concept is used the link stage is skipped and the locator generates the ?C166_HEAP section when it is needed. You can use the HEAPSIZE control for changing the heap size at locate stage. The dynamic memory management library functions are not reentrant, because they use static data for the memory management. This means that when the memory management functions are used, it is not possible to interrupt them with an interrupt function which also uses the memory management functions. If reentrancy is needed with memory management functions, you should use the Task Concept where each interrupt can have its own memory management.

In tiny and small model the ?C166_HEAP section has the section type 'LDAT' allowing a total heap size up to 64K. Because paging is not used (except for the small SND variant, a linear 16 bit pointer is returned), the maximum amount of memory asked for is not limited to a page (16K).

In medium and large model the ?C166_HEAP section has the section type 'HDAT' allowing a total heap size greater than 64K. However, in these models paging is used: a far pointer is returned. This means that you cannot allocate (dynamically) a single buffer greater than one page (16K). Of course you can allocate the whole heap in pieces of (approximately) 16K. In these models, you should use memory allocation with great care, because the paging approach may introduce 'fragmentation' of the heap. For example, if you allocate two times 9K of memory, the second request does not fit in the same page as the first 9K. So 9K will be allocated in the next page, introducing a gap of approximately 7K, which only will be used for requests fitting in 7K.

7.4 ASSEMBLY LANGUAGE INTERFACING

Assembly language functions can be called from C-166 and vice versa. The names used by **c166** are case sensitive, so you must specify **a166** to act case sensitive too, using the \$CASE control. **c166** adds an underscore for the name of public C variables, to distinguish these names from the 80166 registers. So, any names used or defined in C-166 must have a leading underscore in assembly code.

In the section *Register Usage* of the chapter *Language Implementation*, the registers used for return values of functions are explained. Note that R0 is used as user stack pointer and must be used in the assembly function accordingly. If fast parameter passing is used with this assembly function or functions called by this assembly function, R12 to R15 can not be used as scratch registers. Note that if you want to use one of the registers R6 to R9, you must save it on the user stack at entry and restore at exit, because this register might contain a C register variable of another C function. Registers R1–R5, R10 and R11 are free.

In the section *Function Parameters* of the chapter *Language Implementation* is described how parameter passing is supported by **c166**. If you do not want parameter passing in registers (e.g. existing assembly function expecting parameters on the user stack) you must use the keyword `stackparm` (as function qualifier) in the full C prototype of the assembly language function. The quickest (and most reliable) way to make an assembly language function, which must conform to C-166, is to make the body of this function in C, and compile this module. If the assembly function must return something, specify the return type in the 'assembler function' using C syntax, and let it return something. If parameters are used, force code generation for accessing these parameters with a dummy statement (e.g. an assignment):

```
int stackparm
assem( char c, int i )
{
    return( c + i );
}
```

Now compile this module, using the correct memory model. The compiler makes the correct frame, and you can edit the generated assembly module, to make the real assembly function inside this frame.

A second method to create an interface to assembly is to use inline assembly in C. Assembly lines in the C source must be introduced by a `'#pragma asm'`, the end is indicated by a `'#pragma endasm'`.

For example:

```
int
inline( char c, int i )
{
    int j = i - c;

    if ( j > 5 )
    {
#pragma asm
        NOP ; do something in assembly
#pragma endasm
        j = 0;
    }
    return ( j );
}
```

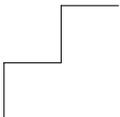
If the inserted assembly code does not change any registers, like in the example above, also `#pragma asm_noflush` may be used instead of `#pragma asm`. The advantage of this pragma is that the peephole buffer is not flushed, so the compiler will emit a `JMPR` instructions instead of a `JMPA` instruction for the condition above. Note that the inserted assembly is NOT interpreted, so code size reported is only the code generated for C statements. The disadvantage of the `#pragma asm_noflush` is that the distance checking for relative jumps becomes your responsibility !

Note that the compiler also does NOT recognize inline `CALL` instructions. If a function does not call any other function from C, it is treated like a 'leaf' function, so parameter registers of this function are not saved on the user stack at function entry. If a 'leaf' function calls another function using inline assembly, it is your responsibility to preserve the parameter registers (if any) of this 'leaf' function.

APPENDIX

A

FLEXIBLE LICENSE MANAGER (FLEXlm)



A | APPENDIX

1 INTRODUCTION

This appendix discusses Globetrotter Software's Flexible License Manager and how it is integrated into the TASKING toolchain. It also contains descriptions of the Flexible License Manager license administration tools that are included with the package, the daemon log file and its contents, and the use of daemon options files to customize your use of the TASKING toolchain.

2 LICENSE ADMINISTRATION

2.1 OVERVIEW

The Flexible License Manager (FLEXlm) is a set of utilities that, when incorporated into software such as the TASKING toolchain, provides for managing access to the software.

The following terms are used to describe FLEXlm concepts and software components:

feature	A feature could be any of the following: <ul style="list-style-type: none">• A TASKING software product.• A software product from another vendor.
license	The right to use a feature. FLEXlm restricts licenses for features by counting the number of licenses for features in use when new requests are made by the application software.
client	A TASKING application program.
daemon	A process that "serves" clients. Sometimes referred to as a <i>server</i> .
vendor daemon	The daemon that dispenses licenses for the requested features. This daemon is built by an application's vendor, and contains the vendor's personal encryption code. Tasking is the vendor daemon for the TASKING software.

license daemon

The daemon process that sends client processes to the correct vendor daemon on the correct machine. The same license daemon is used by all applications from all vendors, as this daemon neither performs encryption nor dispenses licenses. The license daemon processes no user requests on its own, but forwards these requests to other daemons (the vendor daemons).

server node A computer system that is running both the license and vendor daemon software. The server node will contain all the dynamic information regarding the usage of all the features.

license file An end-user specific file that contains descriptions of the server nodes that can run the license daemons, the various vendor daemons, and the restrictions for all the licensed features.

The TASKING software is granted permission to run by FLEXlm daemons; the daemons are started when the TASKING toolchain is installed and run continuously thereafter. Information needed by the FLEXlm daemons to perform access management is contained in a license data file that is created during the toolchain installation process. As part of their normal operation, the daemons log their actions in a daemon log file, which can be used to monitor usage of the TASKING toolchain.

The following sections discuss:

- Installation of the FLEXlm daemons to provide for access to the TASKING toolchain.
- Customizing your use of the toolchain through the use of a daemon options file.
- Utilities that are provided to assist you in performing license administration functions.
- The daemon log file and its contents.

For additional information regarding the use of FLEXlm, refer to the chapter *Software Installation*.

2.2 PROVIDING FOR UNINTERRUPTED FLEXLM OPERATION

TASKING products licensed through FLEXlm contain a number of utilities for managing licenses. These utilities are bundled in the form of an extra product under the name SW000098. TASKING products themselves contain two additional files for FLEXlm in a *flexlm* subdirectory:

Tasking	The Tasking daemon (vendor daemon).
license.dat	A template license file.

If you have already installed FLEXlm (e.g. as part of another product) then it is not needed to install the bundled SW000098. After installing SW000098 on UNIX, the directory `/usr/local/flexlm` will contain two subdirectories, `bin` and `licenses`. After installing SW000098 on Windows the directory `c:\flexlm` will contain the subdirectory `bin`. The exact location may differ if FLEXlm has already been installed as part of a non-TASKING product but in general there will be a directory for executables such as `bin`. That directory must contain a copy of the **Tasking** daemon shipped with every TASKING product. It also contains the files:

lmgrd	The FLEXlm daemon (license daemon).
lm*	A group of FLEXlm license administration utilities.

Next to it, a license file must be present containing the information of all licenses. This file is usually called `license.dat`. The default location of the license file is in directory `c:\flexlm` for Windows and in `/usr/local/flexlm/licenses` for UNIX. If you did install SW000098 then the `licenses` directory on UNIX will be empty, and on Windows the file `license.dat` will be empty. In that case you can copy the `license.dat` file from the product to the `licenses` directory after filling in the data from your "License Information Form".



Be very careful not to overwrite an existing `license.dat` file because it contains valuable data.

Example `license.dat`:

```
SERVER HOSTNAME HOSTID PORT
DAEMON Tasking /usr/local/flexlm/bin/Tasking
FEATURE SW008002-32 Tasking 3.000 EXPDATE NUSERS PASSWORD SERIAL
```

After modifications from a license data sheet (example):

```
SERVER elliot 5100520c 7594
DAEMON Tasking /usr/local/flexlm/bin/Tasking
FEATURE SW008002-32 Tasking 3.000 1-jan-00 4 0B1810310210A6894 "123456"
```

If the `license.dat` file already exists then you should make sure that it contains the DAEMON and FEATURE lines from your license data sheet. An appropriate SERVER line should already be present in that case. You should only add a new SERVER line if no SERVER line is present. The third field of the DAEMON line is the pathname to the **Tasking** daemon and you may change it if necessary.

The default location for the license file on Windows is:

```
c:\flexlm\license.dat
```

On UNIX this is:

```
/usr/local/flexlm/licenses/license.dat
```

If the pathname of the resulting license file differs from this default location then you must set the environment variable **LM_LICENSE_FILE** to the correct pathname. If you have more than one product using the FLEXlm license manager you can specify multiple license files by separating each pathname (*lfpath*) with a ';' (on UNIX also ':') :

Windows:

```
set LM_LICENSE_FILE=lfpath[;lfpath]...
```

UNIX:

```
setenv LM_LICENSE_FILE lfpath[:lfpath]...
```

If you are running the TASKING software on multiple nodes, you have three options for making your license file available on all the machines:

1. Place the license file in a partition which is available (via NFS on Unix systems) to all nodes in the network that need the license file.
2. Copy the license file to all of the nodes where it is needed.
3. Set LM_LICENSE_FILE to "*port@host*", where *host* and *port* come from the SERVER line in the license file.

When the main license daemon **lmgrd** already runs it is sufficient to type the command:

```
lmreread
```

for notifying the daemon that the `license.dat` file has been changed. Otherwise, you must type the command:

```
lmgrd >/usr/tmp/license.log &
```

Both commands reside in the `flexlm bin` directory mentioned before.

2.3 DAEMON OPTIONS FILE

It is possible to customize the use of TASKING software using a daemon options file. This options file allows you to reserve licenses for specified users or groups of users, to restrict access to the TASKING toolchain, and to set software timeouts. The following table lists the keywords that are recognized at the start of a line of a daemon options file.

Keywords	Function
RESERVE	Ensure that TASKING software will always be available to one or more users or on one or more host computer systems.
INCLUDE	Specify a list of users who are allowed exclusive access to the TASKING software.
EXCLUDE	Specify a list of users who are not allowed to use the TASKING software.
GROUP	Specify a group of users for use in the other commands.
TIMEOUT	Allow licenses that are idle for a specified time to be returned to the free pool, for use by someone else.
NOLOG	Causes messages of the specified type to be filtered out of the daemon's log output.

Table A-1: Daemon options file keywords

In order to use the daemon options capability, you must create a daemon options file and list its pathname as the fourth field on the `DAEMON` line for the **Tasking** daemon in the license file. For example, if the daemon options were in file `/usr/local/flexlm/Tasking.opt` (UNIX), then you would modify the license file `DAEMON` line as follows:

```
DAEMON Tasking /usr/local/Tasking /usr/local/flexlm/Tasking.opt
```

A daemon options file consists of lines in the following format:

```
RESERVE      number feature {USER | HOST | DISPLAY | GROUP} name
INCLUDE      feature {USER | HOST | DISPLAY | GROUP} name
EXCLUDE      feature {USER | HOST | DISPLAY | GROUP} name
GROUP        name <list_of_users>
TIMEOUT      feature timeout_in_seconds
NOLOG        {IN | OUT | DENIED | QUEUED}
REPORTLOG    file
```

Lines beginning with the sharp character (#) are ignored, and can be used as comments. For example, the following options file would reserve one copy of feature SWxxxxxxx-xx for user “pat”, three copies for user “lee”, and one copy for anyone on a computer with the hostname of “terry”; and would cause QUEUED messages to be omitted from the log file. In addition, user “joe” and group “pinheads” would not be allowed to use the feature SWxxxxxxx-xx:

```
GROUP        pinheads moe larry curley
RESERVE 1    SWxxxxxxx-xx USER pat
RESERVE 3    SWxxxxxxx-xx USER lee
RESERVE 1    SWxxxxxxx-xx HOST terry
EXCLUDE     SWxxxxxxx-xx USER joe
EXCLUDE     SWxxxxxxx-xx GROUP pinheads
NOLOG       QUEUED
```

3 LICENSE ADMINISTRATION TOOLS

The following utilities are provided to facilitate license management by your system administrator. In certain cases, execution access to a utility is restricted to users with root privileges. Complete descriptions of these utilities are provided at the end of this section.

lmcksum

Prints license checksums.

lmdiag (Windows only)

Diagnoses license checkout problems.

lmdown

Gracefully shuts down all license daemons (both **lmgrd** all vendor daemons, such as **Tasking**) on the license server.

lmgrd

The main daemon program for FLEXlm.

lmbostid

Reports the hostid of a system.

lmremove

Removes a single user's license for a specified feature.

lmreread

Causes the license daemon to reread the license file and start any new vendor daemons.

lmstat

Helps you monitor the status of all network licensing activities.

lmswitchr

Switches the report log file.

lmver

Reports the FLEXlm version of a library or binary file.

lmtools (*Windows only*)

This is a graphical Windows version of the license administration tools.

3.1 LMCKSUM

Name

lmcksum – print license checksums

Synopsis

lmcksum [**-c** *license_file*] [**-k**]

Description

The **lmcksum** program will perform a checksum of a license file. This is useful to verify data entry errors at your location. **lmcksum** will print a line-by-line checksum for the file as well as an overall file checksum.

The following fields participate in the checksum:

- hostid on the SERVER lines
- daemon name on the DAEMON lines
- feature name, version, daemon name, expiration date, # of licenses, encryption code, vendor string and hostid on the FEATURE lines
- daemon name and encryption code on FEATURESET lines

Options

-c *license_file*

Use the specified *license_file*. If no **-c** option is specified, **lmcksum** looks for the environment variable LM_LICENSE_FILE in order to find the license file to use. If that environment variable is not set, **lmcksum** looks for the file c:\flexlm\license.dat (Windows), or /usr/local/flexlm/licenses/license.dat (UNIX).

-k

Case-sensitive checksum. If this option is specified, **lmcksum** will compute the checksum using the exact case of the FEATURE's and FEATURESET's encryption code.

3.2 LMDIAG (Windows only)

Name

lmdiag – diagnose license checkout problems

Synopsis

lmdiag [**-c** *license_file*] [**-n**] [*feature*]

Description

lmdiag (Windows only) allows you to diagnose problems when you cannot check out a license.

If no *feature* is specified, **lmdiag** will operate on all features in the license file(s) in your path. **lmdiag** will first print information about the license, then attempt to check out each license. If the checkout succeeds, **lmdiag** will indicate this. If the checkout fails, **lmdiag** will give you the reason for the failure. If the checkout fails because **lmdiag** cannot connect to the license server, then you have the option of running "extended connection diagnostics".

These extended diagnostics attempt to connect to each port on the license server node, and can detect if the port number in the license file is incorrect. **lmdiag** will indicate each port number that is listening, and if it is an **lmgrd** process, **lmdiag** will indicate this as well. If **lmdiag** finds the vendor daemon for the feature being tested, then it will indicate the correct port number for the license file to correct the problem.

Parameters

feature Diagnose this feature only.

Options

-c *license_file*

Diagnose the specified *license_file*. If no **-c** option is specified, **lmdiag** looks for the environment variable `LM_LICENSE_FILE` in order to find the license file to use. If that environment variable is not set, **lmdiag** looks for the file `c:\flexlm\license.dat` (Windows), or `/usr/local/flexlm/licenses/license.dat` (UNIX).

-n

Run in non-interactive mode; **lmdiag** will not prompt for any input in this mode. In this mode, extended connection diagnostics are not available.

3.3 **LMDOWN**

Name

lmdown – graceful shutdown of all license daemons

Synopsis

lmdown [*-c license_file*] [*-q*]

Description

The **lmdown** utility allows for the graceful shutdown of all license daemons (both **lmgrd** and all vendor daemons, such as **Tasking**) on all nodes. You may want to protect the execution of **lmdown**, since shutting down the servers causes users to lose their licenses. See the **-p** option in Section 3.4, **lmgrd**.

lmdown sends a message to every license daemon asking it to shut down. The license daemons write out their last messages to the log file, close the file, and exit. All licenses which have been given out by those daemons will be revoked, so that the next time a client program goes to verify his license, it will not be valid.

Options

-c license_file

Use the specified *license_file*. If no **-c** option is specified, **lmdown** looks for the environment variable **LM_LICENSE_FILE** in order to find the license file to use. If that environment variable is not set, **lmdown** looks for the file `c:\flexlm\license.dat` (Windows), or `/usr/local/flexlm/licenses/license.dat` (UNIX).

-q

Quiet mode. If this switch is not specified, **lmdown** asks for confirmation before asking the license daemons to shut down. If this switch is specified, **lmdown** will not ask for confirmation.



lmgrd, lmstat, lmreread

3.4 LMGRD

Name

lmgrd – flexible license manager daemon

Synopsis

lmgrd [**-c** *license_file*] [**-l** *logfile*] [**-2 -p**] [**-t** *timeout*] [**-s** *interval*]

Description

lmgrd is the main daemon program for the FLEXlm distributed license management system. When invoked, it looks for a license file containing all required information about vendors and features. On UNIX systems, it is strongly recommended that **lmgrd** be run as a non-privileged user (not root).

Options

-c *license_file*

Use the specified *license_file*. If no **-c** option is specified, **lmgrd** looks for the environment variable `LM_LICENSE_FILE` in order to find the license file to use. If that environment variable is not set, **lmgrd** looks for the file `c:\flexlm\license.dat` (Windows), or `/usr/local/flexlm/licenses/license.dat` (UNIX).

-l *logfile*

Specifies the output log file to use. Instead of using the **-l** option you can use output redirection (`>` or `>>`) to specify the name of the output log file.

-2 -p

Restricts usage of **lmdown**, **lmreread**, and **lmremove** to a FLEXlm administrator who is by default root. If there is a UNIX group called "lmadmin" then use is restricted to only members of that group. If root is not a member of this group, then root does not have permission to use any of the above utilities.

-t *timeout*

Specifies the *timeout* interval, in seconds, during which the license daemon must complete its connection to other daemons if operating in multi-server mode. The default value is 10 seconds. A larger value may be desirable if the daemons are being run on busy systems or a very heavily loaded network.

-s *interval* Specifies the log file timestamp *interval*, in minutes. The default is 360 minutes. This means that every six hours **lmgrd** logs the time in the log file.



lmdown, lmstat

3.5 LMHOSTID

Name

lmhostid – report the hostid of a system

Synopsis

lmhostid

Description

lmhostid calls the FLEXlm version of `gethostid` and displays the results.

The output of **lmhostid** looks like this:

```
lmhostid - Copyright (C) 1989, 1999 Globetrotter Software, Inc.  
The FLEXlm host ID of this machine is "1200abcd"
```

Options

lmhostid has no command line options.

3.6 LMREMOVE

Name

lmremove – remove specific licenses and return them to license pool

Synopsis

lmremove [**-c** *license_file*] *feature user host* [*display*]

Description

The **lmremove** utility allows the system administrator to remove a single user's license for a specified feature. This could be required in the case where the licensed user was running the software on a node that subsequently crashed. This situation will sometimes cause the license to remain unusable. **lmremove** will allow the license to return to the pool of available licenses.

lmremove will remove all instances of “user” on node “host” on display “display” from usage of “feature”. If the optional **-c file** is specified, the indicated file will be used as the license file. Since removing a user's license can be disruptive, execution of **lmremove** is restricted to users with root privileges.

Options

-c *license_file*

Use the specified *license_file*. If no **-c** option is specified, **lmremove** looks for the environment variable `LM_LICENSE_FILE` in order to find the license file to use. If that environment variable is not set, **lmremove** looks for the file `c:\flexlm\license.dat` (Windows), or `/usr/local/flexlm/licenses/license.dat` (UNIX).



lmstat

3.7 LMREREAD

Name

lmreread – tells the license daemon to reread the license file

Synopsis

lmreread [*-c license_file*]

Description

lmreread allows the system administrator to tell the license daemon to reread the license file. This can be useful if the data in the license file has changed; the new data can be loaded into the license daemon without shutting down and restarting it.

The license administrator may want to protect the execution of **lmreread**. See the **-p** option in Section 3.4, *lmgrd* for details about securing access to **lmreread**.

lmreread uses the license file from the command line (or the default file, if none specified) only to find the license daemon to send it the command to reread the license file. The license daemon will always reread the file that it loaded from the original path. If you need to change the path to the license file read by the license daemon, then you must shut down the daemon and restart it with that new license file path.

You cannot use **lmreread** if the *SERVER* node names or port numbers have been changed in the license file. In this case, you must shut down the daemon and restart it in order for those changes to take effect.

lmreread does not change any option information specified in an options file. If the new license file specifies a different options file, that information is ignored. If you need to reread the options file, you must shut down (**lmdown**) the daemon and restart it.

Options

-c *license_file*

Use the specified *license_file*. If no **-c** option is specified, **lmreread** looks for the environment variable `LM_LICENSE_FILE` in order to find the license file to use. If that environment variable is not set, **lmreread** looks for the file `license.dat` in the default location.



lmdown

3.8 LMSTAT

Name

lmstat – report status on license manager daemons and feature usage

Synopsis

```
lmstat [ -a ] [ -A ] [ -c license_file ] [ -f feature ]
      [ -l regular_expression ] [ -s server ] [ -S daemon ] [ -t timeout ]
```

Description

License administration is simplified by the **lmstat** utility. **lmstat** allows you to instantly monitor the status of all network licensing activities.

lmstat allows a system administrator to monitor license management operations including:

- Which daemons are running
- Users of individual features
- Users of features served by a specific DAEMON

Options

-a Display all information.

-A List all active licenses.

-c *license_file*

Use the specified *license_file*. If no **-c** option is specified, **lmstat** looks for the environment variable LM_LICENSE_FILE in order to find the license file to use. If that environment variable is not set, **lmstat** looks for the file `c:\flexlm\license.dat` (Windows), or `/usr/local/flexlm/licenses/license.dat` (UNIX).

-f *feature*] List all users of the specified *feature*(s).

-l *regular_expression*]

List all users of the features matching the given *regular_expression*.

-s *server*] Display the status of the specified *server* node(s).

-S *daemon*] List all users of the specified *daemon*'s features.

- t** *timeout* Specifies the amount of time, in seconds, **lmstat** waits to establish contact with the servers. The default value is 10 seconds. A larger value may be desirable if the daemons are being run on busy systems or a very heavily loaded network.



lmgrd

3.9 LMSWITCHR (Windows only)

Name

lmswitchr – switch the report log file

Synopsis

lmswitchr [**-c** *license_file*] *feature new-file*

or:

lmswitchr [**-c** *license_file*] *vendor new-file*

Description

lmswitchr (Windows only) switches the report writer (REPORTLOG) log file. It will also start a new REPORTLOG file if one does not already exist.

Parameters

- | | |
|-----------------|--|
| <i>feature</i> | Any feature this daemon supports. |
| <i>vendor</i> | The name of the vendor daemon (such as Tasking). |
| <i>new-file</i> | New file path. |

Options

-c *license_file*

Use the specified *license_file*. If no **-c** option is specified, **lmswitchr** looks for the environment variable `LM_LICENSE_FILE` in order to find the license file to use. If that environment variable is not set, **lmswitchr** looks for the file `c:\flexlm\license.dat` (Windows), or `/usr/local/flexlm/licenses/license.dat` (UNIX).

3.10 LMVER

Name

lmver – report the FLEXlm version of a library or binary file

Synopsis

lmver *filename*

Description

The **lmver** utility reports the FLEXlm version of a library or binary file.

Alternatively, on UNIX systems, you can use the following commands to get the FLEXlm version of a binary:

```
strings file | grep Copy
```

Parameters

filename Name of the executable of the product.

3.11 LICENSE ADMINISTRATION TOOLS FOR WINDOWS

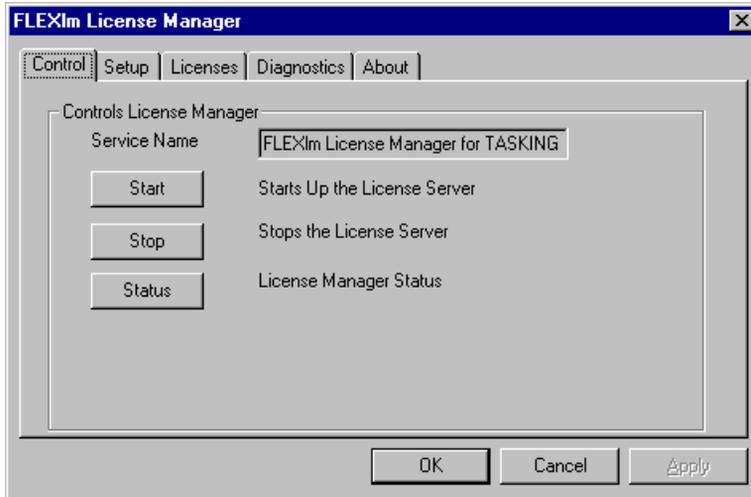
3.11.1 LMTOOLS FOR WINDOWS

For the 32 Bit Windows Platforms, an **lmtools.exe** Windows program is provided. It has the same functionality as listed in the previous sections but is graphically-oriented. Simply run the program (Start | Programs | TASKING FLEXlm | FLEXlm Tools) and choose a button for the functionality required. Refer to the previous sections for information about the options of each feature. The command line interface is replaced by pop-up dialogs that can be filled out. The central EDIT field is where the license file path is placed. This will be used for all other functions and replaces the "**-c license_file**" argument in the other utilities.

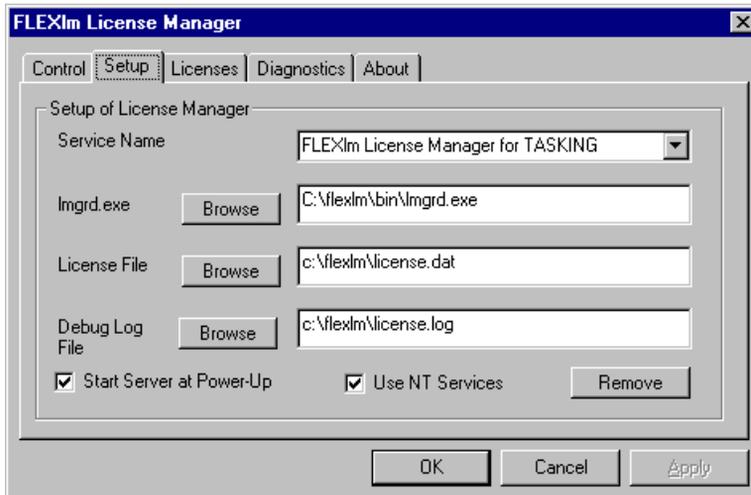
The HOSTID button displays the hostid's for the computer on which the program is running. The TIME button prints out the system's internal time settings, intended to diagnose any time zone problems. The TCP Settings button is intended to fix a bug in the Microsoft TCP protocol stack which has a symptom of very slow connections to computers. After pressing this button, the system will need to be rebooted for the settings to become effective.

3.11.2 FLEXLM LICENSE MANAGER FOR WINDOWS

lmgrd.exe can be run manually or using the graphical Windows tool. You can start this tool from the FLEXlm program folder. Click on Start | Programs | TASKING FLEXlm | FLEXlm Tools



From the Control tab you can start, stop, and check the status of your license server. Select the Setup tab to enter information about your license server.



Select the `Control` tab and click the `Start` button to start your license server. **lmgrd.exe** will be launched as a background application with the license file and debug log file locations passed as parameters.

If you want **lmgrd.exe** to start automatically on NT, select the `Use NT Services` check box and **lmgrd.exe** will be installed as an NT service. Next, select the `Start Server at Power-UP` check box.

The `Licenses` tab provides information about the license file and the `Advanced` tab allows you to perform diagnostics and check versions.

4 THE DAEMON LOG FILE

The FLEXlm daemons all generate log files containing messages in the following format:

mm/dd hh:mm (DAEMON name) message

Where:

mm/dd hh:mm Is the month/day hour:minute that the message was logged.

DAEMON name Either “license daemon” or the string from the DAEMON line that describes your daemon.

In the case where a single copy of the daemon cannot handle all of the requested licenses, an optional “_” followed by a number indicates that this message comes from a forked daemon.

message The text of the message.

The log files can be used to:

- Inform you when it may be necessary to update your application software licensing arrangement.
- Diagnose configuration problems.
- Diagnose daemon software errors.

The messages are grouped below into the above three categories, with each message followed by a brief description of its meaning.

4.1 INFORMATIONAL MESSAGES

Connected to node

This daemon is connected to its peer on node *node*.

CONNECTED, master is name

The license daemons log this message when a quorum is up and everyone has selected a master.

DEMO mode supports only one SERVER host!

An attempt was made to configure a demo version of the software for more than one server host.

DENIED: N feature to user (mm/dd/yy hh:mm)

user was denied access to *N* licenses of *feature*. This message may indicate a need to purchase more licenses.

EXITING DUE TO SIGNAL mm

EXITING with code mm

All daemons list the reason that the daemon has exited.

EXPIRED: feature

feature has passed its expiration date.

IN: feature by user (N licenses) (used: d:hh:mm:ss) (mm/dd/yy hh:mm)

user has checked back in *N* licenses of *feature* at *mm/dd/yy hh:mm*.

IN server died: feature by user (number licenses) (used: d:hh:mm:ss) (mm/dd/yy hh:mm)

user has checked in *N* licenses by virtue of the fact that his server died.

License Manager server started

The license daemon was started.

Lost connection to host

A daemon can no longer communicate with its peer on node *host*, which can cause the clients to have to reconnect, or cause the number of daemons to go below the minimum number, in which case clients may start exiting. If the license daemons lose the connection to the master, they will kill all the vendor daemons; vendor daemons will shut themselves down.

Lost quorum

The daemon lost quorum, so will process only connection requests from other daemons.

MASTER SERVER died due to signal *mm*

The license daemon received fatal signal *mm*.

MULTIPLE *xxx* servers running. Please kill, and restart license daemon

The license daemon has detected that multiple copies of vendor daemon *xxx* are running. The user should kill all *xxx* daemon processes and re-start the license daemon.

OUT: feature by user (N licenses) (mm/dd/yy hh:mm)

user has checked out N licenses of *feature* at *mm/dd/yy hh:mm*

Removing clients of children

The top-level daemon logs this message when one of the child daemons dies.

RESERVE feature for HOST name***RESERVE feature for USER name***

A license of *feature* is reserved for either user *name* or host *name*.

REStarted *xxx* (internet port *mm*)

Vendor daemon *xxx* was restarted at internet port *mm*.

Retrying socket bind (address in use)

The license servers try to bind their sockets for approximately 6 minutes if they detect *address in use* errors.

Selected (EXISTING) master node

This license daemon has selected an existing master (node) as the master.

SERVER shutdown requested

A daemon was requested to shut down via a user-generated kill command.

[NEW] Server started for: feature-list

A (possibly new) server was started for the features listed.

Shutting down xxx

The license daemon is shutting down the vendor daemon *xxx*.

SIGCHLD received. Killing child servers

A vendor daemon logs this message when a shutdown was requested by the license daemon.

Started name

The license daemon logs this message whenever it starts a new vendor daemon.

Trying connection to node

The daemon is attempting a connection to *node*.

4.2 CONFIGURATION PROBLEM MESSAGES

hostname: Not a valid server host, exiting

This daemon was run on an invalid hostname.

hostname: Wrong hostid, exiting

The hostid is wrong for *hostname*.

BAD CODE for feature-name

The specified feature name has a bad encryption code.

CANNOT OPEN options file "file"

The options file specified in the license file could not be opened.

Couldn't find a master

The daemons could not agree on a master.

license daemon: lost all connections

This message is logged when all the connections to a server are lost, which often indicates a network problem.

lost lock, exiting

Error closing lock file

Unable to re-open lock file

The vendor daemon has a problem with its lock file, usually because of an attempt to run more than one copy of the daemon on a single node. Locate the other daemon that is running via a **ps** command, and kill it with **kill -9**.

NO DAEMON line for daemon

The license file does not contain a DAEMON line for *daemon*.

No "license" service found

The TCP *license* service did not exist in `/etc/services`.

No license data for "feat", feature unsupported

There is no feature line for *feat* in the license file.

No features to serve!

A vendor daemon found no features to serve. This could be caused by bad data in the license file.

UNSUPPORTED FEATURE request: feature by user

The *user* has requested a feature that this vendor daemon does not support. This can happen for a number of reasons: the license file is bad, the feature has expired, or the daemon is accessing the wrong license file.

Unknown host: hostname

The hostname specified on a `SERVER` line in the license file does not exist in the network database (probably `/etc/hosts`).

lm_server: lost all connections

This message is logged when all the connections to a server are lost. This probably indicates a network problem.

NO DAEMON lines, exiting

The license daemon logs this message if there are no `DAEMON` lines in the license file. Since there are no vendor daemons to start, there is nothing to do.

NO DAEMON line for name

A vendor daemon logs this error if it cannot find its own `DAEMON` name in the license file.

4.3 DAEMON SOFTWARE ERROR MESSAGES

accept: message

An error was detected in the `accept` system call.

ATTEMPT TO START VENDOR DAEMON xxx with NO MASTER

A vendor daemon was started with no master selected. This is an internal consistency error in the daemons.

BAD PID message from mm: pid: xxx (msg)

A top-level vendor daemon received an invalid PID message from one of its children (daemon number `xxx`).

BAD SCONNECT message: (message)

An invalid “server connect” message was received.

Cannot create pipes for server communication

The `pipe` call failed.

Can't allocate server table space

A `malloc` error. Check swap space.

Connection to node TIMED OUT

The daemon could not connect to *node*.

Error sending PID to master server

The vendor server could not send its PID to the top-level server in the hierarchy.

Illegal connection request to DAEMON

A connection request was made to `DAEMON`, but this vendor daemon is not `DAEMON`.

Illegal server connection request

A connection request came in from another server without a `DAEMON` name.

KILL of child failed, errno = mm

A daemon could not kill its child.

No internet port number specified

A vendor daemon was started without an internet port.

Not enough descriptors to re-create pipes

The “top-level” daemon detected one of its sub-daemon’s death. In trying to restart the chain of sub-daemons, it was unable to get the file descriptors to set up the pipes to communicate. This is a fatal error, and the daemons must be re-started.

read: error message

An error in a read system call was detected.

recycle_control BUT WE DIDN'T HAVE CONTROL

The hierarchy of vendor daemons has become confused over who holds the control token. This is an internal error.

return_reserved: can't find feature listhead

When a daemon is returning a reservation to the “free reservation” list, it could not find the listhead of features.

select: message

An error in a select system call was detected.

Server exiting

The server is exiting. This is normally due to an error.

SHELLO for wrong DAEMON

This vendor daemon was sent a “server hello” message that was destined for a different DAEMON.

Unsolicited msg from parent!

Normally, the top-level vendor daemon sends no unsolicited messages. If one arrives, this message is logged. This is a bug.

***WARNING: CORRUPTED options list (o->next == 0)
Options list TERMINATED at bad entry***

An internal inconsistency was detected in the daemon’s option list.

5 FLEXLM LICENSE ERRORS

FLEXlm license error, encryption code in license file is inconsistent

Check the contents of the license file using the license data sheet for the product. Correct the license file and run the **lmreread** command.

However, do not change the last (fourth) field of a SERVER line in the license file. This cannot have any effect on the error message but changing it will cause other problems.

license file does not support this version

If this is a first time install then follow the procedure for the error message:

```
FLEXlm license error, encryption code in license file is
inconsistent
```

because there may be a typo in the fourth field of a FEATURE line of your license file. In all other cases you need a new license because the current license is for an older version of the product.

Replace the FEATURE line for the old version of the product with a FEATURE line for the new version (it can be found on the new license data sheet). Run the **lmreread** command afterwards. You can have only one version of a feature (previous versions of the product will continue to work).

FLEXlm license error, cannot find license file

Make sure the license file exists. If the pathname printed on the line after the error message is incorrect, correct this by setting the `LM_LICENSE_FILE` environment variable to the full pathname of the license file.

FLEXlm license error, cannot read license file

Every user needs to have read access on the license file and at least execute access on every directory component in the pathname of the license file. Write access is never needed. Read access on directories is recommended.

FLEXlm license error, no such feature exists

Check the license file. There should be a line starting with:

```
FEATURE SWiiiiii-jj
```

where "iiiiii" is a six digit software code and "jj" is a two digit host code for identifying a compatible host architecture. During product installations the product code is shown, e.g. SW008002, SW019002. The number in the software code is the same as the number in the product code except that the first number may contain an extra leading zero (it must be six digits long).

The line after the license error message describes the expected feature format and includes the host code.

Correct the license file using the license data sheet for the product and run the **lmreread** command. There is one catch: do not add extra SERVER lines or change existing SERVER lines in the license file.

FLEXlm license error, license server does not support this feature

If the LM_LICENSE_FILE variable has been set to the format *number@host* then see first the solution for the message:

```
FLEXlm license error, no such feature exists
```

Run the **lmreread** program to inform the license server about a changed license data file. If **lmreread** succeeds informing the license server but the error message persists, there are basically three possibilities:

1. The license key is incorrect. If this is the case then there must be an error message in the log file of **lmgrd**. Correct the key using the license data sheet for the product. Finally rerun **lmreread**. The log file of **lmgrd** is usually specified to **lmgrd** at startup with the **-l** option or with **>**.
2. Your network has more than one FLEXlm license server daemon and the default license file location for **lmreread** differs from the default assumed by the program. Also, there must be more than one license file. Try one of the following solutions on the same host which produced the error message:

- type:

```
lmreread -c /usr/local/flexlm/licenses/license.dat
```

- set LM_LICENSE_FILE to the license file location and retry the **lmreread** command.
- use the **lmreread** program supplied with the product SW000098, Flexible License Manager. SW000098 is bundled with all TASKING products.

3. There is a protocol version mismatch between **lmgrd** and the daemon with the name "Tasking" (the vendor daemon according to FLEXlm terminology) or there is some other internal error. These errors are always written to the log file of **lmgrd**. The solution is to upgrade the **lmgrd** daemon to the one supplied in SW000098, the bundled Flexible License Manager product.

On the other hand, if **lmreread** complains about not being able to connect to the license server then follow the procedure described in the next section for the error message "Cannot read license file data from server". The only difference with the current situation is that not the product but a license management utility shows a connect problem.

FLEXlm license error, Cannot read license file data from server

This indicates that the program could not connect to the license server daemon. This can have a number of causes. If the program did not immediately print the error message but waited for about 30 seconds (this can vary) then probably the license server host is down or unreachable. If the program responded immediately with the error message then check the following if the `LM_LICENSE_FILE` variable has been set to the format *number@host*:

- is the number correct? It should match the fourth field of a `SERVER` line in the license file on the license server host. Also, the host name on that `SERVER` line should be the same as the host name set in the `LM_LICENSE_FILE` variable. Correct `LM_LICENSE_FILE` if necessary.

In any case one should verify if the license server daemon is running. Type the following command on the host where the license server daemon (**lmgrd**) is supposed to run.

On SunOS 4.x:

```
ps wwax | grep lmgrd | grep -v grep
```

On HP-UX or SunOS 5.x (Solaris 2.x):

```
ps -ef | grep lmgrd | grep -v grep
```

If the command does not produce any output then the license server daemon is not running. See below for an example how to start **lmgrd**.

Make sure that both license server daemon (**lmgrd**) and the program are using the same license data. All TASKING products use the license file `/usr/local/flexlm/licenses/license.dat` unless overruled by the environment variable `LM_LICENSE_FILE`. However, not all existing **lmgrd** daemons may use the same default. In case of doubt, specify the license file pathname with the `-c` option when starting the license server daemon. For example:

```
lmgrd -c /usr/local/flexlm/licenses/license.dat \  
      -l /usr/local/flexlm/licenses/license.log &
```

and set the `LM_LICENSE_FILE` environment variable to the `license.dat` pathname mentioned with the `-c` option of **lmgrd** before running any license based program (including **lmreread**, **lmstat**, **lmdown**). If **lmgrd** and the program run on different hosts, transparent access to the license file is assumed in the situation described above (e.g. NFS). If this is not the case, make a local copy of the license file (not recommended) or set `LM_LICENSE_FILE` to the form `number@host`, as described earlier.

If none of the above seems to apply (i.e. **lmgrd** was already running and `LM_LICENSE_FILE` has been set correctly) then it is very likely that there is a TCP port mismatch. The fourth field of a `SERVER` line in the license file specifies a TCP port number. That number can be changed without affecting any license. However, it must never be changed while the license server daemon is running. If it has been changed, change it back to the original value. If you do not know the original number anymore, restart the license server daemon after typing the following command on the license server host:

```
kill PID
```

where `PID` is the process id of **lmgrd**.

6 FREQUENTLY ASKED QUESTIONS (FAQS)

6.1 LICENSE FILE QUESTIONS

I've received FLEXlm license files from 2 different companies. Do I have to combine them?

You don't have to combine license files. Each license file that has any 'counted' lines (the 'number of licenses' field is >0) requires a server. It's perfectly OK to have any number of separate license files, with different **lmgrd** server processes supporting each file. Moreover, since **lmgrd** is a lightweight process, for sites without system administrators, this is often the simplest (and therefore recommended) way to proceed. With v6+ **lmgrd/lmddown/lmddreread**, you can stop/reread/restart a single vendor daemon (of any FLEXlm version). This makes combining licenses more attractive than previously. Also, if the application is v6+, using 'dir/*.lic' for license file management behaves like combining licenses without physically combining them.

When is it recommended to combine license files?

Many system administrators, especially for larger sites, prefer to combine license files to ease administration of FLEXlm licenses. It's purely a matter of preference.

Does FLEXlm handle dates in the year 2000 and beyond?

Yes. The FLEXlm date format uses a 4-digit year. Dates in the 20th century (19xx) can be abbreviated to the last 2 digits of the year (xx), and use of this feature is quite widespread. Dates in the year 2000 and beyond must specify all 4 year digits.

6.2 FLEXLM VERSION

Which FLEXlm versions does TASKING deliver?

For Windows we deliver FLEXlm v6.1 and for UNIX we deliver v2.4.

I have products from several companies at various FLEXlm version levels. Do I have to worry about how these versions work together?

If you're not combining license files from different vendors, the simplest thing to do is make sure you use the tools (especially **lmgrd**) that are shipped by each vendor.

lmgrd will always correctly support older versions of vendor daemons and applications, so it's **always** safe to use the latest version of **lmgrd** and the other FLEXlm utilities. If you've combined license files from 2 vendors, you **must** use the latest version of **lmgrd**.

If you've received 2 versions of a product from the same vendor, you must use the latest vendor daemon they sent you. An older vendor daemon with a newer client will cause communication errors.

Please ignore letters appended to FLEXlm versions, i.e., v2.4d. The appended letter indicates a patch, and does NOT indicate any compatibility differences. In particular, some elements of FLEXlm didn't require certain patches, so a 2.4 **lmgrd** will work successfully with a 2.4b vendor daemon.

I've received a new copy of a product from a vendor, and it uses a new version of FLEXlm. Is my old license file still valid?

Yes. Older FLEXlm license files are always valid with newer versions of FLEXlm.

6.3 WINDOWS QUESTIONS

What Windows Host Platforms can be used as a server for Floating Licenses?

The system being used as the server (where the FLEXlm License Manager is running) for Floating licenses, must be Windows NT. The FLEXlm License Manager does not run properly with Windows 95/98.

Why do I need to include NWlink IPX/SPX on NT?

This is necessary for either obtaining the Ethernet card address, or to provide connectivity with a Netware License server.

6.4 TASKING QUESTIONS

How will the TASKING licensing/pricing model change with License Management (FLEXlm)?

TASKING will now offer the following types of licenses so you can purchase licenses based upon usage:

License	Description	Pricing
Node Locked	This license can only be used on a specific system. It cannot be moved to another system.	The pricing for this license will be the current product pricing.
Floating	This license requires a network (license server and a TCP/IP (or IPX/SPX) connection between clients and server) and can be used on any host system (using the same operating system) in the network.	The pricing for this license will be 50% higher than the node locked license.

How does FLEXlm affect future product ordering?

For all licenses, node locked or floating, you must provide information that is used to create a license key. For node locked licenses we must have the HOST ID. Floating licenses require the HOST ID and HOST NAME. The HOST ID is a unique identification of the machine, which is based upon different hardware depending upon host platform. The HOST NAME is the network name of the machine.



TASKING Logistics CANNOT ship ANY orders that do not include the HOST ID and/or HOST NAME information.

What if I do not know the information needed for the license key?

We have a software utility (**tkhostid.exe**) which will obtain and display the HOST ID so a customer can easily obtain this information. This utility is available from our web site, placed on all product CDs (which support FLEXlm), and from technical support. If you have already installed FLEXlm, you can also use **lmhostid**.

- In the case of a *Node locked license*, it is important that the customer runs this utility on the exact machine he intends to run the TASKING tools on.

- In the case of a *Floating License*, the **tkhostid.exe** (or **lmhostid**) utility should be run on the machine on which the FLEXlm license manager will be installed, e.g. the server. The HOST NAME information can be obtained from within the Windows Control Panel. Select "Network", click on "Identification", look for "Computer name".

How will the "locking" mechanism work?

- For node locked licenses, FLEXlm will first search for an ethernet card. If one exists, it will lock onto the number of the ethernet card. If an ethernet card does not exist, FLEXlm will lock onto the hard disk serial number.
- For floating licenses, the ethernet card number will be used.

What happens if I try to move my node locked license to another system?

The software will not run.

What does linger-time for floating licenses mean?

When the TASKING product starts to run, it will try to obtain a license from the license server. The license server keeps track of the number of licenses already issued, and grants or denies the request. When the software has finished running, the license is kept by the license server for a period of time known as the "linger-time". If the same user requests the TASKING product again within the linger-time, he is granted the license again. If another user requests a license during the linger-time, his request is denied until the linger-time has finished.

What is the length of the linger-time for floating licenses?

The length of the linger-time for both the PC and UNIX floating licenses is 5 minutes.

Can the linger-time be changed?

Yes. A customer can change the linger-time to be larger (but not shorter) than the time specified by TASKING.

What happens if my system crashes or I upgrade to a new system?

You will need to contact Technical Support for temporary license keys due to a system crash or to move from one system to another system. You will then need to work with your local sales representative to obtain a permanent new license key.

6.5 USING FLEXLM FOR FLOATING LICENSES

Does FLEXlm work across the internet?

Yes. A server on the internet will serve licenses to anyone else on the internet. This can be limited with the 'INTERNET=' attribute on the FEATURE line, which limits access to a range of internet addresses. You can also use the INCLUDE and EXCLUDE options in the daemon option file to allow (or deny) access to clients running on a range of internet addresses.

Does FLEXlm work with Internet firewalls?

Many firewalls require that port numbers be specified to the firewall. FLEXlm v5 **lmgrd** supports this.

If my client dies, does the server free the license?

Yes, unless the client's whole system crashes. Assuming communications is TCP, the license is automatically freed immediately. If communications are UDP, then the license is freed after the UDP timeout, which is set by each vendor, but defaults to 45 minutes. UDP communications is normally only set by the end-user, so TCP should be assumed. If the whole system crashes, then the license is not freed, and you should use '**lmremove**' to free the license.

What happens when the license server dies?

FLEXlm applications send periodic heartbeats to the server to discover if it has died. What happens when the server dies is then up to the application. Some will simply continue periodically attempting to re-checkout the license when the server comes back up. Some will attempt to re-checkout a license a few times, and then, presumably with some warning, exit. Some GUI applications will present pop-ups to the user periodically letting them know the server is down and needs to be re-started.

How do you tell if a port is already in use?

99.44% of the time, if it's in use, it's because **lmgrd** is already running on the port – or was recently killed, and the port isn't freed yet. Assuming this is not the case, then use '**telnet host port**' – if it says "*can't connect*", it's a free port.

Does FLEXlm require root permissions?

No. There is no part of FLEXlm, **lmgrd**, vendor daemon or application, that requires root permissions. In fact, it is strongly recommended that you do not run the license server (**lmgrd**) as root, since root processes can introduce security risks.

If **lmgrd** must be started from the root user (for example, in a system boot script), we recommend that you use the 'su' command to run **lmgrd** as a non-privileged user:

```
su username -c"/path/lmgrd -c /path/license.dat \  
-l /path/log"
```

where *username* is a non-privileged user, and *path* is the correct paths to **lmgrd**, `license.dat` and debug log file. You will have to ensure that the vendor daemons listed in `/path-to-license/license.dat` have execute permissions for *username*. The paths to all the vendor daemons in the license file are listed on each DAEMON line.

Is it ok to run lmgrd as 'root' (UNIX only)?

It is not prudent to run any command, particularly a daemon, as root on UNIX, as it may pose a security risk to the Operating System. Therefore, we recommend that **lmgrd** be run as a non-privileged user (not 'root'). If you are starting **lmgrd** from a boot script, we recommend that you use

```
su username -c"umask 022; /path/lmgrd \  
-c /path/license.dat -l /path/log"
```

to run **lmgrd** as a non-privileged user.

Does FLEXlm licensing impose a heavy load on the network?

No, but partly this depends on the application, and end-user's use. A typical checkout request requires 5 messages and responses between client and server, and each message is < 150 bytes.

When a server is not receiving requests, it requires virtually no CPU time. When an application, or **lmstat**, requests the list of current users, this can significantly increase the amount of networking FLEXlm uses, depending on the number of current users. Also, prior to FLEXlm v5, use of 'port@host' can increase network load, since the license file is down-loaded from the server to the client. 'port@host' should be, if possible, limited to small license files (say < 50 features). In v5, 'port@host' actually improves performance.

Does FLEXlm work with NFS?

Yes. FLEXlm has no direct interaction with NFS. FLEXlm uses an NFS-mounted file like any other application.

Does FLEXlm work with ATM, ISDN, Token-Ring, etc.?

In general, these have no impact on FLEXlm. FLEXlm requires TCP/IP or SPX (Novell Netware). So long as TCP/IP works, FLEXlm will work.

Does FLEXlm work with subnets, fully-qualified names, multiple domains, etc.?

Yes, although this behavior was improved in v3.0, and v6.0. When a license server and a client are located in different domains, fully-qualified host names have to be used. A fully-qualified hostname is of the form:

node.domain

where *node* is the local hostname (usually returned by the **'hostname'** command or **'uname -n'**) *domain* is the internet domain name, e.g. 'globes.com'.

To ensure success with FLEXlm across domains, do the following:

1. Make the sure the fully-qualified hostname is the name on the SERVER line of the license file.
2. Make sure ALL client nodes, as well as the server node, are able to 'telnet' to that fully-qualified hostname. For example, if the host is locally called 'speedy', and the domain name is 'corp.com', local systems will be able to logon to speedy via 'telnet speedy'. But very often, 'telnet speedy.corp.com' will fail, locally. Note that this telnet command will always succeed on hosts in other domains (assuming everything is configured correctly), since the network will resolve speedy.corp.com automatically.
3. Finally, there must be an 'alias' for speedy so it's also known locally as speedy.corp.com. This alias is added to the `/etc/hosts` file, or if NIS/Yellow Pages are being used, then it will have to be added to the NIS database. This requirement goes away in version 3.0 of FLEXlm.

If all components (application, **lmgrd** and vendor daemon) are v6.0 or higher, no aliases are required; the only requirement is that the fully-qualified domain name, or IP-address, is used as a hostname on the SERVER, or as a hostname in `LM_LICENSE_FILE port@host, or @host`.

Does FLEXlm work with NIS and DNS?

Yes. However, some sites have broken NIS or DNS, which will cause FLEXlm to fail. In v5 of FLEXlm, NIS and DNS can be avoided to solve this problem. In particular, sometimes DNS is configured for a server that's not current available (e.g., a dial-up connection from a PC). Again, if DNS is configured, but the server is not available, FLEXlm will fail.

In addition, some systems, particularly Sun, SGI, HP, require that applications be linked dynamically to support NIS or DNS. If a vendor links statically, this can cause the application to fail at a site that uses NIS or DNS. In these situations, the vendor will have to relink, or recompile with v5 FLEXlm. Vendors are strongly encouraged to use dynamic libraries for libc and networking libraries, since this tends to improve quality in general, as well as making NIS/DNS work.

On PCs, if a checkout seems to take 3 minutes and then fails, this is usually because the system is configured for a dial-up DNS server which is not currently available. The solution here is to turn off DNS.

Finally, hostnames must NOT have periods in the name. These are not legal hostnames, although PCs will allow you to enter them, and they will not work with DNS.

We're using FLEXlm over a wide-area network. What can we do to improve performance?

FLEXlm network traffic should be minimized. With the most common uses of FLEXlm, traffic is negligible. In particular, checkout, checkin and heartbeats use very little networking traffic. There are two items, however, which can send considerably more data and should be avoided or used sparingly:

- **'lmstat -a'** should be used sparingly. **'lmstat -a'** should not be used more than, say, once every 15 minutes, and should be particularly avoided when there's a lot of features, or concurrent users, and therefore a lot of data to transmit; say, more than 20 concurrent users or features.
- Prior to FLEXlm v5, the 'port@host' mode of the LM_LICENSE_FILE environment variable should be avoided, especially when the license file has many features, or there are a lot of license files included in LM_LICENSE_FILE. The license file information is sent via the network, and can place a heavy load. Failures due to 'port@host' will generate the error LM_SERVNOREADLIC (-61).

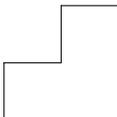
APPENDIX

MISRA C

B



TASKING



B | APPENDIX

Supported and unsupported MISRA C rules

1. no language extensions shall be used
- * 2. other languages should only be used with an interface standard
3. inline assembly is only allowed in dedicated C functions
- * 4. provision should be made for appropriate run-time checking
5. only use characters defined by the C standard
- * 6. character values shall be restricted to a subset of ISO 106460-1
7. trigraphs shall not be used
8. multibyte characters and wide string literals shall not be used
9. comments shall not be nested
- * 10. sections of code should not be "commented out"
11. identifiers shall not rely on significance of more than 31 characters
12. the same identifier shall not be used in multiple name spaces
13. specific-length typedefs should be used instead of the basic types
14. use 'unsigned char' or 'signed char' instead of plain 'char'
- * 15. floating point implementations should comply with a standard
- * 16. the bit representation of floating point numbers shall not be used
17. typedef names should not be reused
- * 18. numeric constants should be suffixed to indicate type
19. octal constants (other than zero) shall not be used
20. all object and function identifiers shall be declared before use
21. identifiers shall not hide identifiers in an outer scope
22. declarations should be at function scope where possible ("*static variable*")
- * 23. all declarations at file scope should be static where possible
24. identifiers shall not have both internal and external linkage



- * 25. identifiers with external linkage shall have exactly one definition
- 26. multiple declarations for objects or functions shall be compatible
- * 27. external objects should not be declared in more than one file
- 28. the 'register' storage class specifier should not be used
- 29. the use of a tag shall agree with its declaration
- 30. all automatics shall be initialized before being used
- 31. braces shall be used in the initialization of arrays and structures
- 32. only the first, or all enumeration constants may be initialized
- 33. the right hand side of && or || shall not contain side effects
- 34. the operands of a logical && or || shall be primary expressions
- 35. assignment operators shall not be used in Boolean expressions
- * 36. logical operators should not be confused with bitwise operators
- 37. bitwise operations shall not be performed on signed integers
- 38. a shift count shall be between 0 and the operand width minus 1
- 39. the unary minus shall not be applied to an unsigned expression
- 40. 'sizeof' should not be used on expressions with side effects
- * 41. the implementation of integer division should be documented
- 42. the comma operator shall only be used in a 'for' condition
- 43. don't use implicit conversions which may result in information loss
- 44. redundant explicit casts should not be used
- 45. type casting from any type to/from pointers shall not be used
- 46. the value of an expression shall be evaluation order independent
- * 47. no dependence should be placed on operator precedence rules
- * 48. mixed arithmetic should use explicit casting
- * 49. tests of a (non-Boolean) value against 0 should be made explicit

-
50. F.P. variables shall not be tested for exact equality or inequality
 - * 51. constant unsigned integer expressions should not wrap-around
 52. there shall be no unreachable code
 53. all non-null statements shall have a side-effect
 54. a null statement shall only occur on a line by itself
 55. labels should not be used
 56. the 'goto' statement shall not be used
 57. the 'continue' statement shall not be used
 58. the 'break' statement shall not be used (except in a 'switch')
 59. an 'if' or loop body shall always be enclosed in braces
 60. all 'if', 'else if' constructs should contain a final 'else'
 61. every non-empty 'case' clause shall be terminated with a 'break'
 62. all 'switch' statements should contain a final 'default' case
 63. a 'switch' expression should not represent a Boolean case
 64. every 'switch' shall have at least one 'case'
 65. floating point variables shall not be used as loop counters
 - * 66. a "for" should only contain expressions concerning loop control
 - * 67. iterator variables should not be modified in a "for" loop
 68. functions shall always be declared at file scope
 69. functions with variable number of arguments shall not be used
 70. functions shall not call themselves
 71. function prototypes shall be visible at the definition and call
 72. the function prototype of the declaration shall match the definition
 73. identifiers shall be given for all prototype parameters or for none
 74. parameter identifiers shall be identical for declaration/definition

75. every function shall have an explicit return type
76. functions with no parameters shall have a 'void' parameter list
- * 77. an actual parameter type shall be compatible with the prototype
78. the number of actual parameters shall match the prototype
79. the values returned by 'void' functions shall not be used
80. void expressions shall not be passed as function parameters
- * 81. "const" should be used for reference parameters not modified
82. a function should have a single point of exit
83. every exit point shall have a 'return' of the declared return type
84. for 'void' functions, 'return' shall not have an expression
85. function calls with no parameters should have empty parentheses
- * 86. if a function returns error information, it should be tested
87. #include shall only be preceded by another directives or comments
88. non-standard characters shall not occur in #include directives
89. #include shall be followed by either <filename> or "filename"
90. plain macros shall only be used for constants/qualifiers/specifiers
91. macros shall not be defined/undefined within a block
92. #undef should not be used
- * 93. a function should be used in preference to a function-like macro
94. a function-like macro shall not be used without all arguments
- * 95. macro arguments shall not contain pre-preprocessing directives
96. macro definitions/parameters should be enclosed in parentheses
97. don't use undefined identifiers in pre-processing directives
98. a macro definition shall contain at most one # or ## operator

- * 99 all uses of the #pragma directive shall be documented
- 100 'defined' shall only be used in one of the two standard forms
- 101 pointer arithmetic should not be used
- 102 no more than 2 levels of pointer indirection should be used
- * 103 no relational operators between pointers to different objects
- 104 non-constant pointers to functions shall not be used
- 105 functions assigned to the same pointer shall be of identical type
- 106 an automatic address may not be assigned to a longer lived object
- * 107 the null pointer shall not be de-referenced
- * 108 all struct/union members shall be fully specified
- * 109 overlapping variable storage shall not be used
- * 110 unions shall not be used to access the sub-parts of larger types
- 111 bit fields shall have type 'unsigned int' or 'signed int'
- 112 bit fields of type 'signed int' shall be at least 2 bits long
- 113 all struct/union members shall be named
- 114 reserved and standard library names shall not be redefined
- 115 standard library function names shall not be reused
- * 116 production libraries shall comply with the MISRA C restriction
- * 117 the validity of library function parameters shall be checked
- 118 dynamic heap memory allocation shall not be used
- 119 'errno' should not be used
- 120 the macro 'offsetof()' shall not be used
- 121 <locale.h> and the 'setlocale' function shall not be used
- 122 the 'setjmp' and 'longjmp' functions shall not be used
- 123 the signal handling facilities of <signal.h> shall not be used

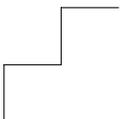
- 124 the <stdio.h> library shall not be used in production code
- 125 the functions atof/atoi/atol shall not be used
- 126 the functions abort/exit/getenv/system shall not be used
- 127 the time handling functions of library <time.h> shall not be used



* = Not supported by the TASKING C166 C-compiler

**USING CROSSVIEW
PRO FOR
EVALUATION
BOARDS**

**APPENDIX
C**



C | APPENDIX

When using an evaluation board, a monitor will be run from the memory where your application is loaded and running. You should use the **1166** RESERVE MEMORY locator control to prevent the locator from locating sections in the memory areas in use by the monitor. For example:

```
RESERVE MEMORY( 0FD00h to 0FD4Bh )
```

Please see the CrossView user's manual which areas are in use by the monitor that is used for your evaluation board.

In the `start.asm` file, the `@EVA` symbol must be enabled (set to 1).

When using a ROM monitor with a dual vector table, the vector table of your application should be located at the memory location where the monitor expects it to be. Use the **1166** VECTAB locator control to supply the vector table start location to the locator. For example:

```
VECTAB( 08000h )
```

Please refer to the CrossView user's manual for the required vector table location for the board and monitor that you use.

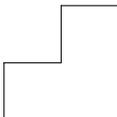
When using this dual vector table ROM monitor, you must also supply the `-startaddress` option to the **iee166** IEEE-695 object formatter. The `startaddress` should be address where you located the vector table with the VECTAB control. This address will be generated in the absolute file. CrossView will start execution at this address after a program reset.

EVALUATION BOARDS

APPENDIX

D

USING KONTRON DEBUGGERS



D | APPENDIX

When using Kontron debuggers, the following operation remarks exist:

- Use the TASKING **ieee166** converter program to generate an IEEE-695 output file from the absolute (located) output file. The Kontron **KSE695** filter program is needed to translate this IEEE-695 file into Kontron object and symbol files.
- You can use the compiler option **-g** to generate debug information for use by Kontron debuggers. Versions of **KSE695** previous to v4.3 (04) may require using the compiler option **-gb**. The **-gb** option prevents **c166** from emitting 'bit', 'bitfield' and '80166 pointer behavior' high level language information.
- The **KSE695** command line option '**-t t -x .**' must be used when converting IEEE-695 format to Kontron format.
 - t t** = Specify TASKING **c166** IEEE-695 format.
 - x** = Preserve filename and extension information found in the IEEE-695 file.
- Kontron debuggers supports all high level language debug information generated by **c166**.
- Kontron debuggers support debugging of TASKING **a166** assembly files at the source code level. You can use the Kontron **LINE166** utility before preprocessing source with TASKING **m166** or assembling with **a166**.

The **LINE166** utility has the following command line syntax:

```
LINE166 inputfile outputfile
```

where, *inputfile* is the file you would normally process with the TASKING macro preprocessor or assembler and *outputfile* is the instrumented output file. This output file is the file you must use for preprocessing/assembly. The input and output filename must differ.

Batch file when TASKING **m166** used Batch file when **m166** not used

```
@echo off
rem RELINE1.BAT
line166 %1.asm %1.a66
if errorlevel 1 goto end
ml66 %1.a66
if errorlevel 1 goto end
del %1.a66
a166 %1.src debug
if errorlevel 1 goto end
del %1.src
:end
```

```
@echo off
rem RELINE2.BAT
line166 %1.asm %1.a66
if errorlevel 1 goto end
a166 %1.a66 debug
if errorlevel 1 goto end
del %1.a66
:end
```

To use these batch files, simply enter either

```
reline1 asmfile
```

or,

```
reline2 asmfile
```



use *asmfile* without a file extension.

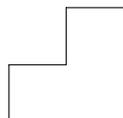
APPENDIX

E

USING HITEX HITOP



TASKING



π | APPENDIX

1 USING TELEMON 80C166

When using the Hitex telemon 80C166 execution environment, the following operation remarks exist:

- The following resources are used by the monitor:

07000h	–	08000h	monitor data
0FCF0h	–	0FD00h	register bank
0FA00h	–	0FA40h	system stack

You should use the **1166** RESERVE MEMORY locator control to prevent the locator from locating sections in these regions.

For example:

```
RE( ME( 07000hTO 08000h ),
    ME( 0FCF0hTO 0FD00h ) )
```

`cstart[x or 1].asm` uses `SSKDEF 0` (256 words) by default and initializes `SP` to the top of the system stack (`0FBFF`). So there is no conflict with the system stack area of the monitor.

- In the `start.asm` file, the `@EVA` symbol must be enabled (set to 1).
- The TASKING **ieec166** converter must be used to generate an IEEE-695 output file from the absolute (located) output file. The Hitex **sp166ta** symbolic preprocessor for Tasking 80166 is needed to convert this IEEE-695 file into Hitex format.

If you want to convert files based on C++ source code, you must use the switch **-PE ext** –where ext is the extension of the C++ source files– to display the C++ source code in the HiTOP List Window. For example, for sources with extension `.cpp`, use **-PEcpp**.

- Register automatics/parameters are not supported by HiTOP.
- Bit variables, bitword variables and bit fields are not supported by HiTOP, but not when using HiTOP with a telemon.

2 USING TELEMOM 80C16A

When using the Hitex telemon 80C16A execution environment, the following operation remarks exist:

- The following resources are used by the monitor:

0	-	221h	monitor vector table
10222h	-	193A9h	monitor
0FCE0h	-	0FCFFh	register bank
0FA00h	-	0FA3Fh	system stack

You should use the **I166** RESERVE MEMORY locator control to prevent the locator from locating sections in these regions.

For example:

```
RE( ME( 0TO 221h ),
    ME( 10222hTO 193A9h ),
    ME( 0FCE0hTO 0FCFFh ) )
```

`cstart[x or 1].asm` uses `SSKDEF 0` (256 words) by default and initializes `SP` to the top of the system stack (0FBFF). So there is no conflict with the system stack area of the monitor.

- In the `start.asm` file, the `@EVA` symbol must be enabled (set to 1).
- The TASKING **ieee166** converter must be used to generate an IEEE-695 output file from the absolute (located) output file. Use the Hitex **sp166ta** symbol preprocessor for Tasking 80166 to convert this IEEE-695 file into Hitex format.

If you want to convert a file based on C++ source code, use the switch **-PE ext** —where ext is the extension of the C++ source—to display the C++ source code in the HiTOP List Window. For example, to display C++ sources of the pattern `module.cpp`, use **-PE c pp**.

- Bit variables, bitword variables and bit fields are supported by HiTOP, but not when using HiTOP with a telemon.

3 USING TELEMON 80C167

When using the Hitex telemon 80C167 execution environment, the following operation remarks exist:

- The following resources are used by the monitor:

00000h	–	079FFh	monitor code
40000h	–	401FFh	monitor vector table
40200h	–	415FFh	monitor data
0FCE0h	–	0FCFFh	register bank
0FA00h	–	0FA3Fh	system stack

You should use the **1166** RESERVE MEMORY locator control to prevent the locator from locating sections in these regions.

For example:

```
RE(  ME( 00000hTO 079FFh ),
     ME( 40000hTO 401FFh ),
     ME( 40200hTO 415FFh ),
     ME( 0FCE0hTO 0FCFFh ) )
```

`cstart[x orl].asm` uses `SSKDEF 0` (256 words) by default and initializes `SP` to the top of the system stack (`0FBFF`). So there is no conflict with the system stack area of the monitor.

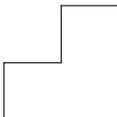
- In the `start.asm` file, the `@EVA` symbol must be enabled (set to 1).
- The TASKING **ieec166** converter must be used to generate an IEEE-695 output file from the absolute (located) output file. The Hitex SP166TA filter program is needed to translate this IEEE-695 file into Hitex format.
- Bit variables, bitword variables and bit fields are supported by HiTOP, but not when using HiTOP with a telemon.

HITEX HITOP

APPENDIX

F

USING PLS FAST-VIEW66



П | APPENDIX

When using the *fast-view66* debugger, the following operation remarks exist:

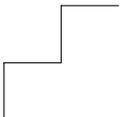
- Use the **-g** compiler option to generate debug information for use with *fast-view66*.
- *Fast-view66* supports all C/C++ language debug information generated by **c166/cp166**.
- You can use the absolute output file format (locator output file) for download to the C166/ST10 target hardware.

FAST-VIEW66

APPENDIX

G

CPU FUNCTIONAL PROBLEMS



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1 INTRODUCTION

Infineon Components regularly publishes microcontroller errata sheets for reporting both functional problems and deviations from the electrical and timing specifications.

For some of these functional problems in the microcontroller itself, TASKING's C166 compiler can provide workarounds. In fact these are software workarounds for hardware problems.

This appendix lists a summary of functional problems which can be bypassed by the compiler tool kit.

Please refer to the Infineon errata sheets for the CPU step you are using, to verify if you need to use one of these bypasses.

2 CPU FUNCTIONAL PROBLEM BYPASSES

Protecting multiply and divide against interrupts

Infineon reference: CPU.18

Use compiler option:

-BM

Use libraries:

```
lib\[u]166p\*.lib  
lib\[u]extp\*.lib  
lib\[u]ext2p\*.lib
```

This solution should be used where failures occur for interrupts during the MUL, MULU, DIV, DIVU, DIVL and DIVLU instructions:

- For C166 derivatives, the compiler option **-BM** emits code using run-time library calls for the multiply and divide operations. In these run-time library calls, the operations are protected against interrupts, so that the problems cannot occur.
- For ext and ext2 derivatives, multiply and divide operations are protected inline using ATOMIC instructions. In some cases, an additional NOP might be generated after the multiply or divide instruction. When you want to use the inline protection, you should use both the compiler options **-x[i]** and **-BM**.

-BM is a workaround for many MUL/DIV problems. Besides CPU.18 it fixes problem 7, problem 13, problem 17, CPU.2 and CPU.11.

When using the **-BM** option you should also link libraries in which the multiply and divide operations are protected.

Protecting divide only against interrupts

Infineon reference: Problem 13

Use compiler option:

-BD

Use libraries:

```
lib\[u]166p\*.lib  
lib\[u]extp\*.lib  
lib\[u]ext2p\*.lib  
lib\[u]goldp\*.lib
```

This solution should be used where failures occur for interrupts during the DIV, DIVL, DIVU and DIVLU instructions:

- For the GOLD chip, the compiler option **-BD** emits code using run-time library calls for the divide operations. In these run-time library calls, the operations are protected against interrupts, so that the problem cannot occur.
- For ext and ext2 derivatives, divide operations are protected inline using the ATOMIC instruction. In some cases, an additional NOP instruction might be generated after the divide instruction. When you want to use the inline protection of divide instructions, you should use both the compiler options **-x[i]** and **-BD**.

When using the **-BD** option you should also link libraries in which the divide operations are protected. The libraries in the directory `lib\goldp` have this protection. The libraries in the directories `lib\166p`, `lib\extp` and `lib\ext2p` also have the multiply protected against interrupts, but can be used safely to bypass this CPU problem.

Protecting multiply operations only against interrupts

Infineon reference: CPU.11

Use compiler option:

-BU

Use libraries:

```
lib\[u]166p\*.lib  
lib\[u]extp\*.lib  
lib\[u]ext2p\*.lib
```

This solution should be used where failures occur for interrupts during the MUL and MULU instructions:

- For C166 derivatives, the compiler option **-BU** emits code using run-time library calls for the multiply operations. In these run-time library calls, the operations are protected against interrupts, so that the problem cannot occur.
- For ext and ext2 derivatives, multiply operations are protected inline using ATOMIC instructions. In some cases, an additional NOP might be generated after the multiply instruction. When you want to use the inline protection, you should use both the compiler options **-x[i]** and **-BU**.

When using the **-BU** option you should also link libraries in which the divide operations are protected. The libraries in the directories `lib\166p`, `lib\extp` and `lib\ext2p` also have the divide protected against interrupts, but can be used safely to bypass this CPU problem.

Uninterruptable RETI

Infineon reference: Problem 17

Use compiler option:

-BI

Use libraries:

no solution in libraries required

When a multiply instruction has been interrupted, it may be completed incorrectly after return from interrupt if a higher priority interrupt or hardware trap is generated while the RETI instruction is executed. This problem does not occur with PEC transfers.

In this case the previously mentioned workaround can be used, but at the price of an increased worst case interrupt response time.

To avoid having to use the previous workaround, the problem can be bypassed by an adaption in the interrupt frame code (file `intrpt.c` in the `c` subdirectory of the `examples` directory).

In this file the RETI instruction is preceded by a `BFLDH PSW, #0F0h, #0F0H` instruction, when the compiler bypass option **-BI** is used. This will cause an interrupted multiplication or division to be correctly completed after RETI before a higher priority interrupt will be acknowledged.

Generate two NOP instructions after Byte Write instructions

Infineon reference: Problem S1

Use compiler option:

-BB

Use libraries:

```
lib\[u]166p\*.lib
```

This problem occurs on older steps of the FLASH EPROM version of the CPU. With the **-BB** option the compiler generates two NOP instructions after each instruction which does a byte write operation. These instructions are: ADDB, ADDCB, ANDB, CPLB, MOVVB, NEGB, ORB, SUBB, SUBCB, XORB. The pragma **fix_byte_write** and **nofix_byte_write** can be used to switch this option on the fly in your source code. To reduce the number of NOP instructions to be generated, the disassembler **d166** can be used to detect where for the CPU erroneous sequences are generated.



See the description of the disassembler in the *Utilities* chapter of the *C166/ST10 Assembler, Linker/Locator, Utilities User's Guide* for more information.

Extend EXTEND sequences with one instruction

Infineon reference: CPU.3

Use compiler option:

-BE

Use libraries:

```
lib\[u]extp\*.lib
```

On older C167 derivatives the last instruction in an extend sequence will use a DPP translation instead of the page or segment number supplied with the extend instruction (EXT:xx). This problem occurs only when the last instruction of this extend instruction uses the addressing mode Rn, [Rm+#data16]. When you use the **-BE** compiler option the compiler will lengthen the extend sequence with one instruction when it generates an instruction using this addressing mode.

Prevent generation of MOVB [Rn], mem for 'const' objects

Infineon reference: CPU.16

Use compiler option:

-BF

Use libraries:

```
lib\[u]166p\*.lib  
lib\[u]extp\*.lib  
lib\[u]goldp\*.lib
```

When the MOVB[Rn],mem instruction is executed, where (a) mem specifies a direct 16-bit byte operand address in the internal ROM/Flash memory, and (b) [Rn] points to an even byte address, while the contents of the word which includes the byte addressed by mem is odd, or [Rn] points to an odd byte address, while the contents of the word which includes the bytes addressed by mem is even, the following problem occurs:

1. when [Rn] points to external memory or to the X-Peripheral (XRAM, CAN, etc.) address space, the data value which is written back is always 00h.
2. when [Rn] points to the internal RAM or SFR/ESFR address space, (a) the (correct) data value [mem] is written to [Rn]+1, i.e. to the odd byte address of the selected word in case [Rn] points to an even byte address, (b) the (correct) data value [mem] is written to [Rn]-1, i.e. to the even byte address of the selected word in case [Rn] points to an odd byte address.

Since internal ROM/Flash/OTP data is referred to as 'const' data, the compiler will prevent generating the MOVB [Rn], mem instruction when even 'const' objects are accessed. The compiler is unaware of the exact location of these objects which is determined at locate time.

Disable generation of MOV (B) Rn, [Rm+#data16] instruction

Infineon reference: CPU1R006

Use compiler option:

-BO

Use libraries:

```
lib\[u]extp\*.lib
```

The opcode MOV (B) Rn, [Rm+#data16] can cause the CPU to hang. The problem is encountered under the following conditions:

- [Rm+#data16] is used to address the source operand
- [Rm+#data16] points to the program memory
- a hold cycle has to be generated by the `ir_ready` signal at the beginning of the operand fetch cycle

Since the compiler is unaware of the actual location the source operand [Rm+#data16] refers to, the generation of this addressing mode is completely suppressed.

Project JMPS instructions by ATOMIC #2 instruction

STMicroelectronics reference: ST_BUS.1

Use compiler option:

-BJ

Use libraries:

```
lib\[u]extp\*.lib
```

When a JMPS instruction is followed by a PEC transfer, the generated PEC source address is false. This results in an incorrect PEC transfer.

The compiler prevents the JMPS instruction from interfering with the PEC transfers by inserting an ATOMIC #2 instruction before a JMPS instruction. This bypass option can only be used in combination with the extended instruction set. Further more, all JMPS instructions in the interrupt vector table are replaced by CALLS instructions. The compiler will generate an ADD SP, #04h instruction in the interrupt frame to delete the return address generated by the CALLS instruction from the system stack.

The assembler contains the \$CHECKSTBUS1 control to check for this CPU problem.



The instruction to delete the return address from the system stack is part of the interrupt frame and will NOT be generated if **#pragma noframe** was used.

Signed Divisions may produce erroneous results in case of interruption

Infineon reference: Problem 13

Use compiler option:

-BD (**-BM** can also be used)

Use libraries:

```
lib\[u]l66p\*.lib  
lib\[u]extp\*.lib  
lib\[u]ext2p\*.lib  
lib\[u]goldp\*.lib
```

Signed divide operations may produce incorrect results when an interrupt (PEC, standard interrupt or hardware trap) occurs during an execution of the `DIV` or `DIVL` instruction. Note that this bug will not occur for unsigned divisions. When the **-BD** option is used the compiler will disable interrupts during a signed division. When the **-BM** option is used all multiply and divide instructions will be protected against interrupts. This bypasses several other CPU problems as well.

Protect DIVx/MD[LH] sequences by ATOMIC instruction

Infineon / STMicroelectronics reference: LONDON 1751

Use compiler option:

-BA

Use libraries:

```
lib\[u]ext2p\*.lib
```

In the following situation:

```
DIVU R12
ADD  R13, R14
...
MOV  MSW, .... will destroy the division
...
MOV  R13,MDH
..
```

Protect JMPI / CALLI instruction by ATOMIC instruction

Infineon / STMicroelectronics reference: LONDON1

Use compiler option:

-BL

Use libraries:

```
lib\[u]ext2p\*.lib
```

Description:

JMPI

When the program hits a breakpoint right before a JMPI instruction, the first instruction injected in the pipeline will not be processed by the core. This leads to a deny of all interrupts and OCE injection requests. The problem may also occur when single stepping right before a JMPI instruction.

CALLI

CALLI instruction is not working properly in some cases if it is followed by an injected interrupt. This results in causing a fault in the stack pointer management.

Disable generation of JMPR instruction at jump target address

Infineon / STMicroelectronics reference: BUS.18

Use compiler option:

-BH

Use libraries:

```
lib\[u]ext2p\*.lib
```

If a PEC transfer occurs immediately after a JMPR instruction the program counter can have a wrong value. There are many other requirements before this actually happens, among others the JMPR has to be reached by a jump instruction.

Disable generation of unprotected BFLDL/BFLDH instructions

Infineon / STMicroelectronics reference: CPU.21

Use compiler option:

-BK

Use libraries:

```
lib\[u]extp\*.lib
```

The result of a BFLDL/BFLDH instruction may be incorrect after a write to internal RAM. This only happens under very specific circumstances.

Avoid CoSTORE pipeline problem

STMicroelectronics reference: Kfm_BR03

Use compiler option:

-BN

Use libraries:

```
lib\[u]extp\*.lib
```

After a CoSTORE instruction with any destination (E)SFR, the (E)SFR cannot be read.

Wrong SP used if RETS, RETI or RETP follows an SP modifying instruction

Infineon (preliminary) reference: CR105685

Use compiler option:

-BZc166sv1sp

Use libraries:

```
lib\[u]extp\*.lib
```

Between an SP modifying instruction and a RETS, RETI or RETP instruction at least two instructions are needed.

Wrong CP used if a GPR using instruction follows a CP modifying instruction

Infineon (preliminary) reference: CR105840

Use compiler option:

-BZc166sv1cp

Use libraries:

`lib\[u]extp*.lib`

In many cases two NOPS are needed between a CP modifying instruction and a GPR using instruction.

Interrupted division corrupted by division in ISR

Infineon (preliminary) reference: CR105893

Use compiler option:

-BZc166sv1div

Use libraries:

`lib\[u]extp*.lib`

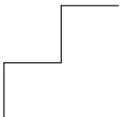
The results of an interrupted division are corrupt if the division is interrupted by an interrupt that uses a division instruction as well.

CPU PROBLEMS

APPENDIX

I

USER STACK MODEL LIBRARY SUPPORT



I | APPENDIX

1 INTRODUCTION

This appendix describes the special coding methods used in the libraries and C166/ST10 C compiler to support a special stack frame. This appendix describes a user stack model approach, which is used in a special version of the libraries.

If you use the **-P** option of **c166**, the compiler does not emit the regular CALL/RET instructions, when calling a C function, but emits code using a jumping mechanism, specifying the return address on the user stack. The advantage of this approach is that the system stack is not used at all. The price paid for this feature is a run-time execution speed performance penalty. The special libraries needed to support this feature are included in the C and C++ compiler packages.

There are two valid reasons to use this option (and libraries):

- RTOS

When using a RTOS kernel, it is often not allowed to use the system stack area (in fact change SP), because this area is reserved for the kernel. Therefore, the **-P** option **must** be used when using RTOS.

- Heavy recursion

When the system stack area is getting too small and it is not possible to implement a circular system stack approach (using SOV/SUN exception handlers), the **-P** option can be used. In this case the compiler uses the user stack instead of the system stack. You must link the application with the user stack model libraries.

Using **-P** does not mean that you have to use a RTOS. You can run the application as a standalone application, without any kernel.

The calling convention is explained in more detail in the next chapters.

The push and pop instructions are only allowed during hardware task switches. Nevertheless, with the C compiler option **-Ou**, it is possible to use the user stack instead of the system stack for hardware task switches. See the **-Ou** option in section 4.3 *Detailed Description of the C-166 options* in this manual.

The offset of structure components relative to the structure can be determined from the symbolic debug information, also needed for high level language debugging, generated by the C compiler when you use the command line option **-g**. The syntax for structure symbolic debug information is described in section 3.18 *Structure Type* of the document "Symbolic Debug Specification for 8051 and 80166".

The conventions for register and data page usage, as well as the calling conventions for functions, are fully documented in chapter 3 *Language Implementation*. Section 3.5 *Function Parameters* of chapter 3, describes when parameters are passed via registers and when they are passed via the user stack.

2 FUNCTION CALL AND RETURN

The next sections describe how function calls and function returns are implemented in the libraries and in the C compiler to support a special stack frame.

2.1 DIRECT INTRA-SEGMENT FUNCTION CALL AND RETURN

A direct intra-segment function call (near function call) is normally performed with a CALLA instruction and returned with a RETN instruction. But the direct intra-segment function call must be performed without using the system stack.

Therefore, the user stack is used to pass the return label to the near function. Then the near function is invoked using an absolute intra-segment jump. At exit, the near function return is implemented using an indirect jump on the contents of the user stack.

The following assembly listing displays the code the C compiler generates for an absolute near function call. The near function called is named `_f`. `Rn` is a register used by the C compiler for temporary results.

	code size	min. state times
.		
.		
mov Rn, #SOF __RETURN_LABEL	4	2
mov [-R0], Rn	2	2
jmpa CC_UC, _f	4	4
__RETURN_LABEL:		
.	--	--
.	10	8

The assembly listing described below displays the code the C compiler generates to return to the caller of the near function.

	code size	min. state times
.		
.		
mov R2, [R0+]	2	2
jmpa CC_UC, [R2]	2	4
retv ; virtual return	0	0
.	--	--
.	4	6

Temporary register R2 is used to pop the return address from the user stack and to continue program execution at the return label via an indirect jump on the contents of R2. The user stack pointer is updated by the called function before it returns (see [R0+]). This is not the regular method to handle the user stack pointer in a C function, but this saves one instruction. Register R2 can be used, because it is always free for use at function return. No parameters are returned via register R2.

2.2 INDIRECT INTRA-SEGMENT FUNCTION CALL AND RETURN

An indirect intra-segment function call (indirect near function call) must also be performed without using the system stack. The user stack is used to pass the return label to the near function. The (offset) address of the near function is determined at run-time. At exit, the near function returns the same way as described above.

The following assembly listing displays the code the C compiler generates for an indirect near function call. The near function called indirectly is in the function pointer array named `_fp`. `Rx` contains the index value. `Rn` is a register used by the C compiler for temporary results.

	code size	min. state times
.		
.		
mov Rn, #SOF __RETURN_LABEL	4	2
mov [-R0], Rn	2	2
mov Rn, [Rx+#_fp]	4	4
jmp_i CC_UC, [Rn]	2	4
__RETURN_LABEL:		
.	--	--
.	12	12

It is obvious that the code, needed to return from a near function, is always the same, because the function does not know whether it is called directly or indirectly. See previous section for the code the C compiler generates to return from a near function.

2.3 DIRECT INTER-SEGMENT FUNCTION CALL AND RETURN

A direct inter-segment function call (far function call) is normally performed with a CALLS instruction and returned with a RETS instruction, but now the system stack may not be used.

A direct inter-segment function can be invoked using a JMPS instruction, but the called function does not know where to return to on exit. Therefore, the user stack is used to pass the return label to the far function. Not only the segment offset of the return label is passed but also the segment number of the return label is passed, because the return label can be located in any segment.

The following assembly listing displays the code the C compiler generates for a far function call. The far function called is named `_f`. `Rn` is a register used by the C compiler for temporary results.

	code size	min. state times
.		
.		
mov Rn, #SOF __RETURN_LABEL	4	2
mov [-R0], Rn	2	2
mov Rn, #SEG __RETURN_LABEL	4	2
mov [-R0], Rn	2	2
jmp_s SEG _f, SOF _f	4	4
__RETURN_LABEL:		
add R0, #4	2	2
.	--	--
.	18	14

The user stack pointer must be increased with four bytes, when code execution continues at the return label, to remove the inter-segment return address from the user stack.

It is very likely that in a regular C application functions of the same task c.q. process are grouped together and therefore, also located in the same segment. So, for a regular C application more intra-segment calls than inter-segment calls are expected between functions. The execution speed performance increases when it is possible to return immediate with an intra-segmented jump to the return label, instead of returning with an inter-segmented jump to the return label. First is tested, at far function return, if the code segment pointer CSP is already pointing to the segment the return label is located in. An indirect intra-segment jump to the return label can be performed if the segment number of the return label is equal to CSP.

An indirect inter-segment jump on the contents of the user stack must be performed, at far function return, when CSP is not equal to the segment the return label is located in. But, there is no instruction available to do this. A so-called return table stub function `__iret` is invoked, at far function return, to set CSP. Setting CSP is performed by invoking a return stub function in the segment the return label is located in. When the return stub function is entered in the segment of the return label, an indirect intra-segment jump to return label can be performed. See also section 2.5, *Inter-segment Call and Return Table Stub Functions* and section 2.6, *Intra-segment Call and Return Stub Functions*.

Testing CSP to check if it possible to return immediate with an intra-segmented jump increases the code execution speed but decreases the code density, because the CSP test is generated at each far function return. For this reason it can be controlled with the compiler optimization option. The compiler generates default compact code (default compiler optimization is **-Of**). Fast code generation can be turned on with the compiler option **-Of**. All the libraries are generated for fast code execution (**-Of**)!

The assembly listing described below displays the code the C compiler generates for a far function to return to its caller, with compiler option **-Of** (fast code generation) and **-Of** (default: compact code generation).

<u>-OF</u>		code size	min. state times
.			
.			
mov	R2, [R0]	2	2
cmp	R2, CSP	4	2
jmp	cc_NE, __LBL	2	4
mov	R2, [R0+#02H]	4	4
jmp	mpi CC_UC, [R2]	2	4
<u>__LBL:</u>	jmps SEG (__iret), SOF (__iret)	4	4
retv	; virtual return	0	0
.		--	--
.	intra-segment return	18	16
.	inter-segment return	18	12
<u>-OF (default)</u>			min.
.		code size	state times
.			
mov	R2, [R0]	2	2
jmps	SEG (__iret), SOF (__iret)	4	4
retv	; virtual return	0	0
.		--	--
.	inter-segment return	6	6

Temporary register R2 can be used to compare CSP, because register R2 is free for use at function return. No parameters are returned via register R2.

2.4 INDIRECT INTER-SEGMENT FUNCTION CALL AND RETURN

An indirect inter-segment function call (indirect far function call) is normally performed with a run-time library function, and the far function called indirect returns with a RETS instruction. The segment number and segment offset are passed to this run-time library function to perform the inter-segment call, but it uses the system stack which is not allowed in this implementation of the library.

The far function cannot be invoked with an inter-segment jump, because the segment number and segment offset for the indirect call are determined run-time. A calculated segmented jump is not present in the instruction set. But the far function can be invoked with an indirect intra-segment jump when the code segment pointer is set to the segment the far function is located in. A so-called call table stub function `__icall` is used to set CSP. Setting CSP is done by jumping to the call stub function located in the same segment as the far function. This call stub function finally performs the indirect intra-segment jump to the far function.

The segment number and segment offset of the indirect far function are passed via register R4 and R5 to the stub functions. The segment number is passed via register R5 to the call table stub function and the segment offset is passed through via register R4 to the call stub function in the segment the indirect far function is located in. It is possible to pass the address of the indirect far function via general registers, because they are never used for parameter passing in C functions and C library functions. Remember that general registers are used for parameter passing in the run time library functions, but run-time library functions are never called indirectly! If you create an assembly function which is called indirectly, then no parameters can be passed to it via registers R4 and R5!

The segment offset and the segment number of the return label are passed via the user stack to the far function called indirectly. It is obvious that the code, needed to return from a far function is always the same, because the function does not know whether it is called directly or indirect. See previous section for the code the C compiler generates to return from a far function.

The next assembly listing displays the code the C compiler generates for an indirect far function call, using the call table stub function `__icall`. The far function called indirectly is in the function pointer array named `_fp`. Rx contains the index value. Rn is a register used by the C compiler for temporary results.

	code size	min. state times
.		
.		
mov Rn, #SOF __RETURN_LABEL	4	2
mov [-R0], Rn	2	2
mov Rn, #SEG __RETURN_LABEL	4	2
mov [-R0], Rn	2	2
mov R4, [Rx+#_fp]	4	4
mov R5, [Rx+#_fp+02H]	4	4
jmps SEG(__icall), SOF(__icall)	4	4
__RETURN_LABEL:		
add R0, #4	2	2
.	--	--
.	26	22

The user stack must be lowered with four bytes, when code execution continues at the return label, to remove the inter-segment return address from the user stack.

It is possible to check CSP if it is already pointing to the segment the indirect far function is located in. If so, an indirect intra-segmented jump can be performed immediate to the far function. But, it will not make much difference in execution speed if CSP is tested or not, because an indirect far call is not very frequently used in a regular C applications. And the code size increases for each indirect far call. This all makes it unprofitable to implement CSP testing for indirect far calls.

2.5 INTER-SEGMENT CALL AND RETURN TABLE STUB FUNCTIONS

The call and return table stub functions are called `__icall` and `__iret`. The call table stub function is only invoked for indirect far function calls and the return table stub function is only invoked at far function return if the code segment pointer CSP is not equal to the segment the return label is located in. These functions are invoked with a segmented jump, so they can be located in any segment.

The inter-segment call table stub function is needed to invoke the call stub function in the segment the indirect far function is located in. The segment number is passed via register R5 and used as offset for the jump table to invoke the call stub function in the right segment, which causes CSP to be loaded with the right segment number.

The assembly listing described below displays the code for the call table stub function.

		min.	
		code	state
		size	times
<code>__icall:</code>			
	<code>shl R5, #2</code>	2	2
	<code>add R5, #SOF(table)</code>	4	2
	<code>jmpj CC_UC, [R5]</code>	2	4
<code>table:</code>	<code>jmps SEG(__icall_0), SOF(__icall_0)</code>	4	4
	<code>jmps SEG(__icall_1), SOF(__icall_1)</code>	4	
	<code>jmps SEG(__icall_2), SOF(__icall_2)</code>	4	
	<code>jmps SEG(__icall_3), SOF(__icall_3)</code>	4	
	<code>retv</code>	0	0
		--	--
		24	12

Register R5 can be used to calculate the indirect jump in the inter-segment jump table, because there are no parameters passed to C functions via register R5. If you create an assembly function or you use inline assembly which is called indirectly, it may not use register R5 for parameter passing!

The return table stub function is needed to invoke the return stub function in the segment the return label is located in. The segment number is passed via register R2 and used as an offset for the jump table to invoke the return stub function in the right segment, which causes CSP to be loaded with the right segment number. The segment number of the return label is also passed via the user stack, but register R2 is already loaded with it for testing CSP at far function return. This makes reloading register R2 with the segment number from the user stack superfluous. See section 2.3 *Direct Inter-segment Function Call and Return*.

The assembly listing described below displays the code for the return table stub function.

		min. code size	state times
<code>__iret:</code>			
	<code>shl R2, #2</code>	2	2
	<code>add R2, #SOF(table)</code>	4	2
	<code>jmp CC_UC, [R2]</code>	2	4
<code>table:</code>	<code>jmps SEG(__iret_0), SOF(__iret_0)</code>	4	4
	<code>jmps SEG(__iret_1), SOF(__iret_1)</code>	4	
	<code>jmps SEG(__iret_2), SOF(__iret_2)</code>	4	
	<code>jmps SEG(__iret_3), SOF(__iret_3)</code>	4	
	<code>retv</code>	0	0
		--	--
		24	12

Temporary register R2 can be used to calculate the indirect jump in the inter-segment jump table, because register R2 is free for use at function call and at function return. No parameters are passed via register R2 ! All the library functions meet this requirement. If you create an assembly function or if you use inline assembly which uses register R2 and it must be preserved over a function call, then R2 must be saved on the user stack.

2.6 INTRA-SEGMENT CALL AND RETURN STUB FUNCTIONS

The intra-segment call stub function is called by the inter-segment call table stub function, to set the code segment pointer CSP to the segment of the indirect called far function. When the call stub function is entered in the segment of the far function, an indirect intra-segmented jump can be performed to the segment offset the indirect far function is located at. The segment offset of the indirect far function is passed to the call stub function via register R4.

The intra-segment return stub function is called by the inter-segment return table stub function to set the code segment pointer CSP to the segment of the return label. When the return stub function is entered in the segment of the return label, an indirect intra-segmented jump can be performed to the segment offset the return label is located at. The segment offset of the return label is passed via the user stack to the return stub function.

The assembly listing described below displays the stub code module for the call and return stub function. The same stub code module is located in all C166/ST10 segments. Only the entry names are different, they are related to the segment they are located in. SEG specifies the segment number, SEG can be 0 to 3 for the C166/ST10.

	code size	min. state times
__ICALLRET_SEG section code word common 'ICALLRET_SEG'		
__iret_SEG proc far		
mov R2, [R0+#02H]	4	4
jmp CC_UC, [R2]	2	4
retv	0	0
	--	--
	6	8
__icall_SEG:		
jmp CC_UC, [R4]	2	4
retv	0	0
	--	--
	2	4
__ICALLRET_SEG ends		

Register R4 can be used to pass the segment offset address of the indirect far function, because there are no parameters passed to C functions via register R4. If you create an assembly function or you use inline assembly which is called indirectly, it may not use register R4 for parameter passing!

Temporary register R2 can be used to get the segment offset of the return label from the user stack and to jump indirect to it, because register R2 is free for use at function call and at function return. No parameters are passed via register R2! All the library functions meet this requirement. If you create an assembly function or you use inline assembly which uses register R2 and it must be preserved over a function call, then R2 must be saved on the user stack.

In the C166/ST10 C library are four stub code modules archived, for each segment one. They have to be located in the right segments with a locator control. For example, with:

```
ADDRESSES ( SECTIONS (
    __ICALLRET_0 ( SEGMENT 0 + 0200H ) ,
    __ICALLRET_1 ( SEGMENT 1 ) ,
    __ICALLRET_2 ( SEGMENT 2 ) ,
    __ICALLRET_3 ( SEGMENT 3 )
) )
```

Each stub code module needs its own class name, because it also must be possible to locate the code stub modules in the right segments with the locator control "CLASSES(..)".

3 USING THE EXTENDED INSTRUCTION SET

3.1 INTRODUCTION

When an extended instruction set is available (e.g. C167) it is no longer needed to avoid the system stack for indirect inter-segment jumps. Because with the extended instruction ATOMIC the standard PEC interrupts and class A hardware trap can be disabled for a specified number of instructions.

To perform an indirect inter-segment jump the segment number and segment offset are pushed on the system stack and a RETS instruction is executed. Then the execution resumes at the inter-segment address pushed on the system stack. To avoid that these instructions are interrupted they are protected with an ATOMIC instruction.

The following assembly listing shows the code for an indirect inter-segment jump using the ATOMIC instruction. Rseg and Rsof contain the inter-segment address to jump to.

```

; code can be read as :
; mov CSP, Rseg
; mov IP, Rsof
atomic #3 ; protect against interrupts
push Rseg ; (SP) <- (SP) - 2 ; ((SP)) <- Rseg
push Rsof ; (SP) <- (SP) - 2 ; ((SP)) <- Rsof
rets      ; (IP) <- ((SP)) ; (SP) <- (SP) + 2
          ; (CSP)<- ((SP)) ; (SP) <- (SP) + 2

```

The advantage of using extended instructions to perform indirect inter-segment jumps is that there are no jump stubs needed anymore. This means that there are less user stack operations needed. However, a disadvantage of using the extended instructions is that the interrupt acknowledge performance decreases.

3.2 DIRECT INTER-SEGMENT FUNCTION CALL AND RETURN

Before an direct inter-segment jump can be performed to the far function, the segment number and segment offset of the return label must be stored on the user stack. The far function being invoked returns to its caller by getting the return label from the user stack and then performing an indirect inter-segment jump to the return label, as described in the previous section.

The next assembly listing displays the code the C compiler generates for a far function call when extended instructions are available.

The far function called is named `_f`. `Rsof` and `Rseg` are registers used by the C compiler for temporary results.

	code size	min. state times
.		
.		
mov Rsof, #SOF __RETURN_LABEL	4	2
mov [-R0], Rsof	2	2
mov Rseg, #SEG __RETURN_LABEL	4	2
mov [-R0], Rseg	2	2
jmps SEG _f, SOF _f	4	4
__RETURN_LABEL:	--	--
.	16	12
.		

The next assembly listing displays the code the C compiler generates for a far function to return to its caller.

	code size	min. state times
.		
.		
mov Rseg, [R0+]	2	2
mov Rsof, [R0+]	2	2
atomic #3	2	2
push Rseg	2	2
push Rsof	2	2
rets	2	4
.	--	--
.	12	14

3.3 INDIRECT INTER-SEGMENT FUNCTION CALL AND RETURN

Also now the segment number and segment offset of the return label must be stored on the user stack before an indirect inter-segment jump can be performed to the far function. The far function being invoked returns to its caller by getting the return label from the user stack and then performing an indirect inter-segment jump to the return label. The far function being invoked is determined run-time. So, an indirect inter-segment jump is needed. When segment number and segment offset of the far function being called is determined run-time, the same mechanism as described in section 3.2, can be used again to make the inter-segment jump.

The next assembly listing displays the code the C compiler generates for an indirect far function call when extended instructions are available.

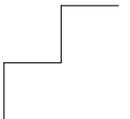
The far function called indirectly is in the function pointer array named `_fp`. `Rx` contains the index value. `Rseg` and `Rsof` are registers used by the C compiler for temporary results.

	code size	min. state times
.		
.		
mov Rsof, #SOF __RETURN_LABEL	4	2
mov [-R0], Rsof	2	2
mov Rseg, #SEG __RETURN_LABEL	4	2
mov [-R0], Rseg	2	2
mov Rsof, [Rx+#_fp]	4	4
mov Rseg, [Rx+#_fp+02H]	4	4
atomic #3	2	2
push Rseg	2	2
push Rsof	2	2
rets	2	4
__RETURN_LABEL:	--	--
.	28	26
.		

It is obvious that the code, needed to return from a far function is always the same, because the function does not know whether it is called directly or indirectly. See section 3.2 for the code the C compiler generates to return from a far function when extended instructions are available.

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