AT90S ASSEMBLER, LINKER, AND LIBRARIAN

Programming Guide

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WELCOME

Welcome to the AT90S Assembler, Linker, and Librarian Programming Guide.

This guide provides reference information about the IAR Systems Assembler, XLINK Linker, and XLIB Librarian for the AT90S family of microprocessors, and applies to both the Embedded Workbench and command line versions of these tools.

Before reading this guide we recommend you refer to the *QuickStart Card*, or the chapter *Installation and documentation route map*, for information about installing the IAR Systems tools and an overview of the documentation.

If you are using the Embedded Workbench refer to the *AT90S Windows Workbench Interface Guide* for information about running the IAR Systems tools from the Workbench interface, a simple tutorial, and complete reference information about the Workbench commands and dialog boxes, and the Workbench editor.

If you are using the command line version refer to the *AT90S Command Line Interface Guide* for general information about running the IAR Systems tools from the command line, and a simple tutorial to illustrate how to use them.

For information about programming with the AT90S C Compiler refer to the *AT90S C Compiler Programming Guide*.

If your product includes the optional AT90S C-SPY debugger refer to the *AT90S C-SPY User Guide* for information about debugging with C-SPY.

ABOUT THIS GUIDE

This guide consists of the following parts and chapters:

Installation and documentation route map explains how to install and run the IAR Systems tools, and gives an overview of the documentation supplied with them.

AT90S Assembler

The *Introduction* provides a brief overview of the AT90S Assembler.

The *Tutorial* explains how to use the most important features of the assembler to develop simple AT90S machine-code programs. It also describes a typical development cycle using XLINK and XLIB.

Assembler options summary explains how to set the AT90S Assembler options, and gives an alphabetical summary of the options.

Assembler options reference then gives reference information about each option.

Assembler file formats describes the source format for the AT90S Assembler, and the format of assembler listings.

Assembler operator summary gives a summary of the assembler operators, arranged in order of precedence.

Assembler operator reference then gives a complete alphabetical list of the AT90S Assembler operators, with a full description of each one.

Assembler directives summary gives an alphabetical summary of the AT90S Assembler directives.

Assembler directives reference gives complete reference information about the AT90S Assembler directives, classified into groups according to their function.

Assembler instructions lists the AT90S instruction mnemonics, with details of the addressing modes that can be used with each one.

XLINK Linker

XLINK Linker introduces the XLINK Linker, and describes the XLINK listing format.

XLINK options summary explains how to set the XLINK options, and gives an alphabetical summary of the options.

XLINK options reference then gives detailed information about each option.

XLINK output formats summarizes the output formats available from XLINK.

XLIB Librarian

XLIB Librarian introduces the XLIB Librarian, which is designed to allow you to create and maintain relocatable libraries of routines.

XLIB command summary gives a summary of the XLIB commands.

XLIB command reference then gives complete reference information about each XLIB command.

Diagnostics

Assembler diagnostics provides a list of error messages specific to the AT90S Assembler.

XLINK diagnostics and *XLIB diagnostics* describe the error and warning messages produced by XLINK and XLIB, together with explanations and suggested courses of action in each case.

ASSUMPTIONS

This guide assumes that you already have a working knowledge of the following:

- The AT90S processor.
- The AT90S Assembler language.
- Windows or MS-DOS, depending on your host system.

Note that the illustrations in this guide show the Workbench running with Windows 95, and their appearance will be slightly different if you are using a different platform.

CONVENTIONS

This guide uses the following typographical conventions:

Style	*Used for*
`computer`	Text that you type in, or that appears on the screen.
`parameter`	A label representing the actual value you should type as part of a command.
`[`*`option`*`]`	An optional part of a command.
`{a	b	c}`	Alternatives in a command.
bold	Names of menus, menu commands, buttons, and dialog boxes that appear on the screen.
reference	A cross-reference to another part of this guide, or to another guide.
	Identifies instructions specific to the versions of the IAR Systems tools for the Workbench interface.
	Identifies instructions specific to the command line versions of IAR Systems tools.

CONTENTS

INSTALLATION AND DOCUMENTATION ROUTE MAP

This chapter explains how to install and run the command line and Windows Workbench versions of the IAR products, and gives an overview of the user guides supplied with them.

Please note that some products only exist in a command line version, and that the information may differ slightly depending on the product or platform you are using.

COMMAND LINE VERSIONS

This section describes how to install and run the command line versions of the IAR Systems tools.

WHAT YOU NEED

- DOS 4.x or later. This product is also compatible with a DOS window running under Windows 95, Windows NT 3.51 or later, or Windows 3.1x.
- At least 10 Mbytes of free disk space.
- A minimum of 4 Mbytes of RAM available for the IAR applications.

INSTALLATION

1 Insert the first installation disk.

2 At the MS-DOS prompt type:

```
a:\install ↵
```

3 Follow the instructions on the screen.

When the installation is complete:

4 Make the following changes to your `autoexec.bat` file:

Add the paths to the IAR Systems executable and user interface files to the `PATH` variable; for example:

```
PATH=c:\dos;c:\utils;c:\iar\exe;c:\iar\ui;
```

Define environment variables `C_INCLUDE` and `XLINK_DFLTDIR` specifying the paths to the `inc` and `lib` directories; for example:

```
set C_INCLUDE=c:\iar\inc\
set XLINK_DFLTDIR=c:\iar\lib\
```

5 Reboot your computer for the changes to take effect.

6 Read the Read-Me file, named *`product`*`.doc`, for any information not included in the guides.

RUNNING THE TOOLS

Type the appropriate command at the MS-DOS prompt.

For more information refer to the chapter *Getting started* in the *Command Line Interface Guide*.

WINDOWS WORKBENCH VERSIONS

This section explains how to install and run the Embedded Workbench.

WHAT YOU NEED

- Windows 95, Windows NT 3.51 or later, or Windows 3.1x.
- Up to 15 Mbytes of free disk space for the Embedded Workbench.
- A minimum of 4 Mbytes of RAM for the IAR applications.

If you are using C-SPY you should install the Workbench before C-SPY.

INSTALLING FROM WINDOWS 95 OR NT 4.0

1 Insert the first installation disk.

2 Click the **Start** button in the taskbar, then click **Settings** and **Control Panel**.

3 Double-click the **Add/Remove Programs** icon in the **Control Panel** folder.

4 Click **Install**, then follow the instructions on the screen.

RUNNING FROM WINDOWS 95 OR NT 4.0

1 Click the **Start** button in the taskbar, then click **Programs** and **IAR Embedded Workbench**.

2 Click **IAR Embedded Workbench**.

INSTALLING FROM WINDOWS 3.1x OR NT 3.51

1. Insert the first installation disk.
2. Double-click the **File Manager** icon in the **Main** program group.
3. Click the **a** disk icon in the **File Manager** toolbar.
4. Double-click the **setup.exe** icon, then follow the instructions on the screen.

RUNNING FROM WINDOWS 3.1x OR NT 3.51

1. Go to the Program Manager and double-click the **IAR Embedded Workbench** icon.

RUNNING C-SPY

Either:

1. Start C-SPY in the same way as you start the Embedded Workbench (see above).

Or:

1. Choose **Debugger** from the Embedded Workbench **Project** menu.

UNIX VERSIONS

This section describes how to install and run the UNIX versions of the IAR Systems tools.

WHAT YOU NEED

- HP9000/700 workstation with HP-UX 9.x (minimum), or a Sun 4/SPARC workstation with SunOS 4.x (minimum) or Solaris 2.x (minimum).

INSTALLATION

Follow the instructions provided with the media.

RUNNING THE TOOLS

Type the appropriate command at the UNIX prompt. For more information refer to the chapter *Getting started* in the *Command Line Interface Guide*.

DOCUMENTATION ROUTE MAP

WINDOWS WORKBENCH VERSION

COMMAND LINE VERSION

QuickStart Card
To install the tools and run the Embedded Workbench.

QS

QuickStart Card
To install the tools and run the DOS or UNIX versions.

Windows Workbench Interface Guide
To get started with using the Embedded Workbench, and for Embedded Workbench reference.

Command Line Interface Guide and **Utilities Guide**
To get started with using the command line, and for information about the environment variables and utilities.

C Compiler Programming Guide
To learn about writing programs with the IAR Systems C Compiler, and for reference information about the compiler options and C language.

Assembler, Linker, and Librarian Programming Guide
To learn about using the IAR Systems assembler, linker, and librarian, and for reference information about these tools.

C-SPY User Guide, Windows Workbench Version
To learn about debugging with C-SPY for Windows, and for C-SPY reference.

C-SPY User Guide, Command Line Version
To learn about debugging with the command line version of C-SPY, and for C-SPY reference.

INTRODUCTION

The IAR Systems AT90S Assembler, and its associated tools the XLINK Linker and XLIB Librarian, are available in two versions: a command line version, and a Windows version integrated with the IAR Systems Embedded Workbench development environment.

This guide describes both versions of these tools, and provides information about running them from the Workbench or from the command line, as appropriate.

ASSEMBLER

The IAR Systems AT90S Assembler is a powerful relocating macro assembler with a versatile set of directives.

The assembler incorporates a high degree of compatibility with the microprocessor manufacturer's own assemblers, to ensure that software originally developed using them can be transferred to the IAR Systems Assembler with little or no modification.

It provides the following features:

GENERAL

- One pass assembly, for faster execution.
- Integration with the XLINK Linker and XLIB Librarian.
- Integration with other IAR Systems software.
- Self-explanatory error messages.

ASSEMBLER FEATURES

- Support for AT90S-family microprocessors.
- Up to 256 relocatable segments per module.
- 32-bit arithmetic and IEEE floating-point constants.
- 255 significant characters in symbols.
- Powerful recursive macro facilities.
- Number of symbols and program size limited only by available memory.

- Support for complex expressions with external references.
- Forward references allowed to any depth.
- Support for C language pre-processor directives and `sfr` keyword.
- Macros in Intel/Motorola style.

XLINK LINKER

The IAR Systems XLINK Linker converts one or more relocatable object files produced by the IAR Systems Assembler or C Compiler to machine code for a specified target processor. It supports a wide range of industry-standard loader formats, in addition to the IAR Systems debug format used by the C-SPY high level debugger.

XLINK supports user libraries, and will load only those modules that are actually needed by the program you are linking.

The final output produced by XLINK is an absolute, target-executable object file that can be programmed into an EPROM, down loaded to a hardware emulator, or run directly on the host using the IAR Systems C-SPY debugger.

XLINK offers the following important features:

FEATURES OF XLINK

- Unlimited number of input files.
- Searches user-defined library files and loads only those modules needed by the application.
- Symbols may be up to 255 characters long with all characters being significant. Both upper and lower case may be used.
- Global symbols can be defined at link time.
- Flexible segment commands allow full control of the locations of relocatable code and data in memory.
- Support for over 30 emulator formats.

XLIB LIBRARIAN

The IAR Systems XLIB Librarian enables you to manipulate the relocatable object files produced by the IAR Systems Assembler and C Compiler.

XLIB provides the following features:

FEATURES OF XLIB

- Support for modular programming.
- Modules can be listed, added, inserted, replaced, deleted, or renamed.
- Segments can be listed and renamed.
- Symbols can be listed and renamed.
- Modules can be changed between program and library type.
- Interactive or batch mode operation.
- A full set of library listing operations.

TUTORIAL

This tutorial illustrates how you might use the AT90S Assembler to develop a series of simple machine-code programs for the AT90S processor, and illustrates some of the assembler's most important features.

Before reading this chapter you should:

- Have installed the assembler software; see the *QuickStart Card* or the chapter *Installation and documentation route map*.
- Be familiar with the architecture and instruction set of the AT90S processor. For more information see the chapter *Assembler instructions*, and the manufacturer's data book.

It is also recommended that you complete the introductory tutorial in the *AT90S Windows Workbench Interface Guide* or *AT90S Command Line Interface Guide*, as appropriate, to familiarize yourself with the interface you are using.

RUNNING THE EXAMPLE PROGRAMS

This tutorial shows how to run the example programs using the optional C-SPY simulator.

Alternatively, you can run the examples by linking them without debugging information to give a file `aout.a90`, which can be downloaded to an emulator with debugging facilities. Use the XLINK `-F` option to specify a format other than the default, Intel extended.

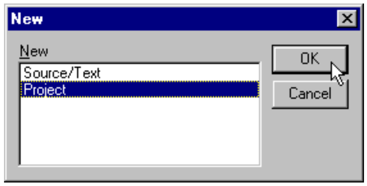
GETTING STARTED

The first step in developing an application using the assembler is to create a new project for the application files.

CREATING A NEW PROJECT

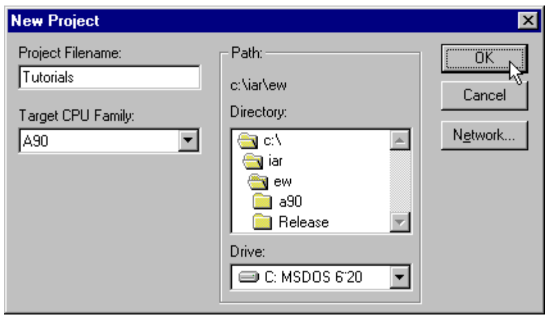
Creating a new project using the Embedded Workbench
First, run the Embedded Workbench, and create a project for the tutorial as follows.

Choose **New** from the **File** menu to display the following dialog box:



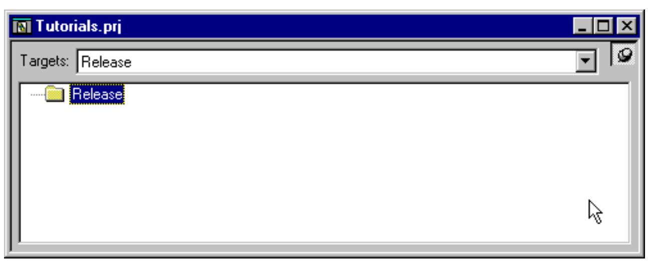
Select **Project** and choose **OK** to display the **New Project** dialog box.

Enter `Tutorials` in the **Project Filename** box, and set the **Target CPU Family** to **A90**:



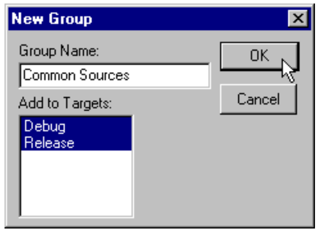
Then choose **OK** to create the new project.

The Project window will be displayed. If necessary, select **Release** from the **Targets** drop-down list box to display the **Release** target:



Next, create a group to contain the tutorial source files as follows.

Choose **New Group…** from the **Project** menu and enter the name `Common Sources`. By default both targets are selected, so the group will be added to both targets:

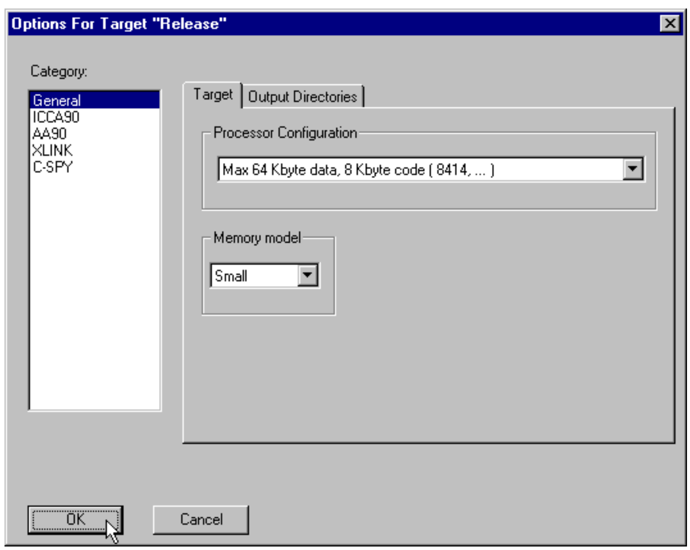


Choose **OK** to create the group. It will be displayed in the Project window.

Now set up the target options to suit the processor and memory model we have chosen.

Select the **Release** folder icon in the Project window, choose **Options…** from the Project menu, select **General** in the **Category** list, and click the **Target** tab to display the target options page.

Set the **Processor Configuration** to **Max 64 Kbyte data, 8 Kbyte code** and select the **Small** memory model.



Then choose **OK** to save the target options.

Creating a new project using the command line
It is a good idea to keep all the files for a particular project in one directory, separate from other projects and the system files.

The tutorial files are installed in the `aa90` directory. Select this directory by entering the command:

```
cd c:\iar\aa90 ↵
```

During this tutorial, you will work in this directory, so that the files you create will reside here.

CREATING A PROGRAM

The first tutorial illustrates how you write a basic assembler program, and how you then assemble, link, and run it.

WRITING A PROGRAM

The first example program is a simple count loop which counts up the registers R16 and R17 in binary-coded decimal:

```
        NAME    first
        ORG     0
        RJMP    main

        ORG     1Ch
main    CLR     R17
        CLR     R16
loop    INC     R17
        CPI     R17,10
        BRNE    loop
        CLR     R17
        INC     R16
        CPI     R16,10
        BRNE    loop
done_it JMP     done_it

        END
```

The `ORG` directive assembles the program starting at address `0`, the AT90S reset address, so the program is executed upon reset.

Writing the program using the Embedded Workbench
Run the Embedded Workbench, and choose **New** from the **File** menu to display the **New** dialog box.

Select **Source/Text** and choose **OK** to open a new text document.

Enter the program given above and save it in a file `first.s90`. The files associated with the AT90S Assembler have extensions `.s90`, `.a90`, `.d90`, and `.r90` to identify them.

Alternatively, a copy of the program is provided in the assembler files directory.

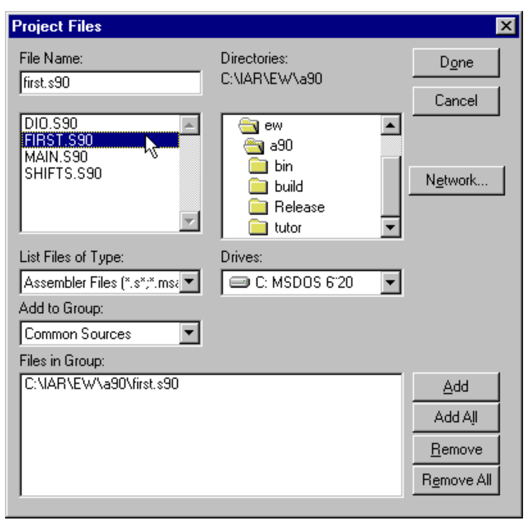
Writing the program using the command line
Enter the program using any standard text editor, such as the MS-DOS `edit` editor, and save it in a file called `first.s90`. The files associated with the AT90S Assembler have extensions `.s90`, `.a90`, `.d90`, and `.r90` to identify them. Alternatively, a copy is provided in the assembler files directory.

You now have a source file which is ready to assemble.

ASSEMBLING THE PROGRAM

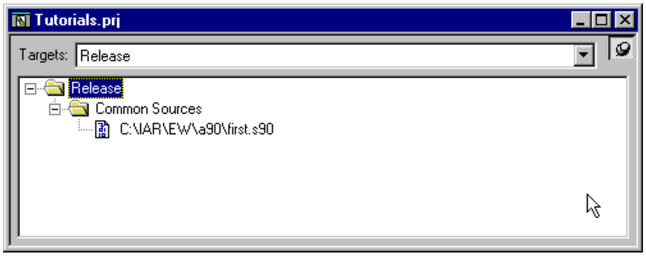
Assembling the program using the Embedded Workbench
To assemble the program first add it to the **Tutorials** project as follows.

Choose **Files...** from the **Project** menu to display the **Project Files** dialog box. Locate the file `first.s90` in the file selection list in the upper half of the dialog box, and choose **Add** to add it to the **Common Sources** group:



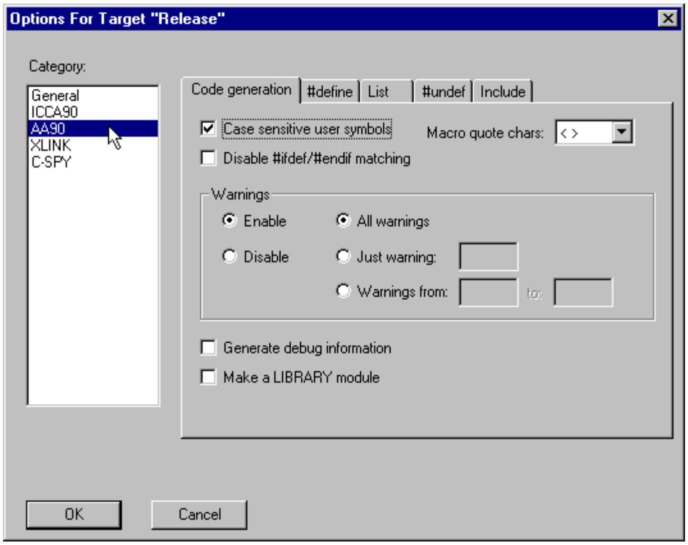
Then click **Done** to close the **Project Files** dialog box.

Click the ⊞ symbol to display the file in the Project window tree display:

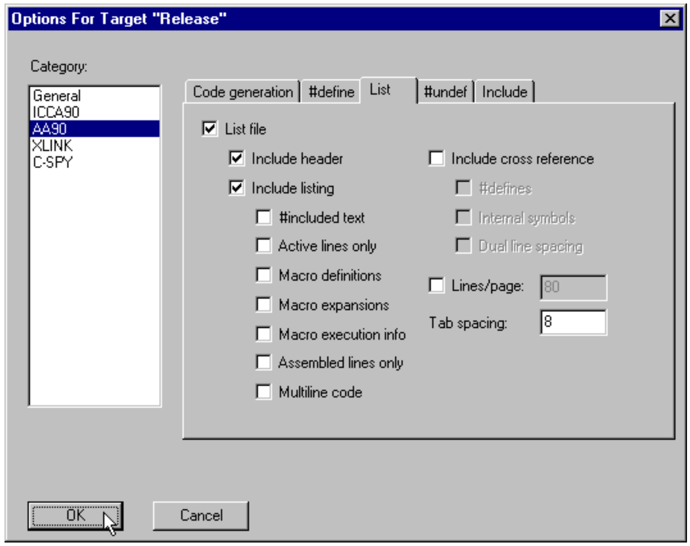


Then set up the assembler options for the project as follows.

Select the **Release** folder in the Project window. Then choose **Options...** from the **Project** menu and select **AA90** in the **Category** list to display the assembler options pages:

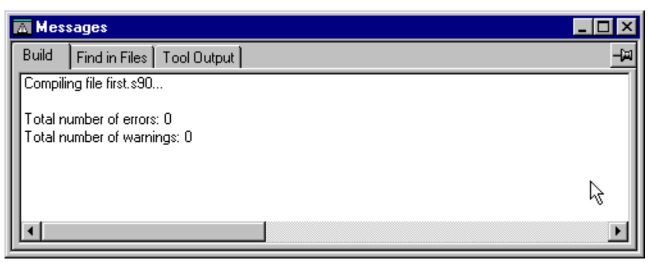


Click **List**, to display the page of list options, and select **List file** to produce an assembler list file. This will enable you to examine the code generated by the assembler:



Choose **OK** to close the **Options** dialog box.

To assemble the file select it in the Project window and choose **Compile** from the **Project** menu. The progress will be displayed in the Messages window:



The listing is created in a file `first.lst` in the folder specified in the **General** options page; by default this is `Release\list`. Open this file by choosing **Open...** from the **File** menu, and choosing `first.lst` from the appropriate folder.

Assembling the file using the command line

To assemble the file, type the following command at the prompt:

```
aa90 first -r -L ↵
```

This will send a listing to the file `first.lst`.

Viewing the listing

If you look at the listing file you will see that it contains the following (the header will be slightly different if you are using the command line):

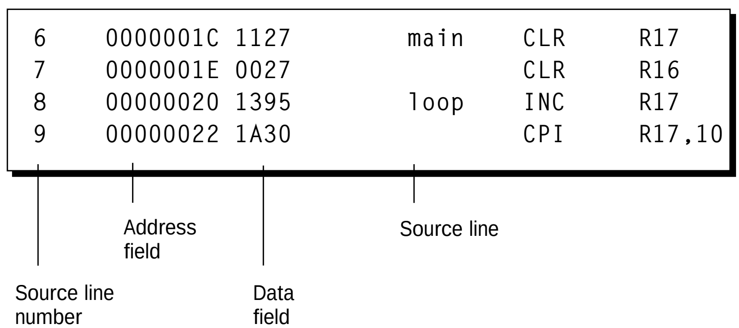
```
##############################################################################
#                                                                            #
#     IAR Systems A90 Assembler Vx.xx                                        #
#                                                                            #
#           Target option =  Relative jumps reach entire addr space          #
#           Source file   =  first.s90                                       #
#           List file     =  first.lst                                       #
#           Object file   =  first.r90                                       #
#           Command line  =  first -r -L                                     #
#                                                                            #
#                                          (c) Copyright IAR Systems 1996 #
##############################################################################

      00000000                    NAME    first
      00000000                    ORG     0
      00000000 0DC0               RJMP    main
      00000002
      0000001C                    ORG     1Ch
      0000001C 1127       main    CLR     R17
      0000001E 0027               CLR     R16
      00000020 1395       loop    INC     R17
      00000022 1A30               CPI     R17,10
      00000024 E9F7               BRNE    loop
      00000026 1127               CLR     R17
      00000028 0395               INC     R16
      0000002A 0A30               CPI     R16,10
      0000002C C9F7               BRNE    loop
      0000002E 0C941700   done_it JMP     done_it
      00000032
      00000032                    END
```

```
################################
#         CRC:7920             #
#       Errors:   0            #
#       Warnings: 0            #
#        Bytes: 24             #
################################
```

This shows the machine-code instructions generated by each of the source code statements.

Note that the CRC number depends on the date of assembly, and may vary.

The format of the listing is as follows:



Assuming that the source assembled successfully, a further file, `first.r90`, will also be created, containing the linkable object code.

If you made any errors when entering the program, these will be displayed on the screen during the assembly. If this happens, return to the editor, check carefully through the source code to locate and correct all the mistakes, resave the source file using the same name, and try assembling it again.

LINKING THE PROGRAM

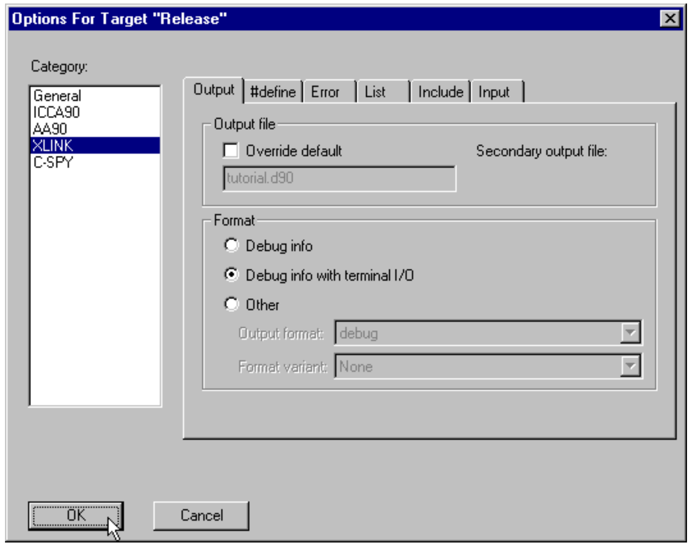
Linking the program using the Embedded Workbench

Before linking the program you need to set up the linker options for the project.

Select the **Release** folder in the Project window. Then choose **Options...** from the **Project** menu, and select **XLINK** in the **Category** list to display the linker option pages.

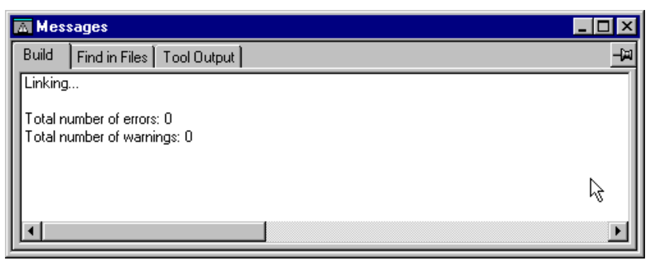
Then click **Output** to display the output options.

Check that the **Format** option is set to **Debug info with terminal I/O**, to generate a file for debugging with C-SPY.



Then choose **OK** to close the **Options** dialog box.

To link the file choose **Link** from the **Project** menu. As before, the progress during linking is shown in the Messages window.



Linking the program using the command line

To link the object file to produce code that can be executed, enter the command:

```
xlink first -ca90 -r ↵
```

The `-c` option specifies the target processor, and the `-r` option includes debugging information.

By default, the output code will be placed in a file `aout.d90`.

RUNNING THE PROGRAM

Running the program using the Embedded Workbench

To run the example program using the C-SPY debugger choose **Debugger** from the **Project** menu.

The following three warning messages will be displayed:

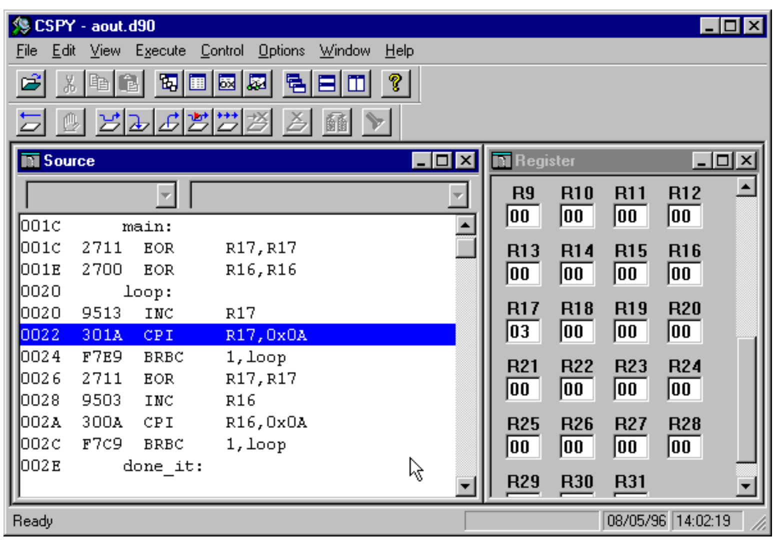
```
Only assembler level debugging available.
Exit label missing.
No break on program exit.
```

You can ignore these warnings, so click **OK** to proceed.

The C-SPY window will then be displayed.

In C-SPY open the Register window, by choosing **Register** from the **Window** menu.

Then choose **Step** from the **Execute** menu, or press F2, to step through the program and watch the R17 and R16 registers count in binary-coded decimal.



Running the program using the command line

To run the example program using the C-SPY debugger type the following command:

```
csa90 aout ↵
```

After the program has loaded enter the command `WINDOW REG ON` to display the value of the registers.

Then type `STEP`, or press F2, to step through the program and watch the registers R16 and R17 count in binary coded decimal.

USING MACROS

The second example will demonstrate the use of simple macros. It defines `outdat` which outputs an 8-bit value to port B, and `strobe` which strobes bit 7 of port A. The code to do this is quite short and may need to be executed fast, making a macro an ideal solution.

For a complete explanation of the assembler's macro features see *Macro processing directives*, page 103.

```
strobe  MACRO
        IN      R25,portA
        SBR     R25,128
        OUT     portA,R25
        CBR     R25,128
        OUT     portA,R25
        ENDM

outdat  MACRO   val
        LDI     R25,val
        OUT     portB,R25
        ENDM
```

The `strobe` macro reads port A, sets bit 7 and outputs the result. It then clears bit 7 and outputs the result again.

The `outdat` macro loads the supplied constant into R25, which is then written to port B.

The full listing of the `dio` assembler program is as follows:

```
        NAME    dio

; define the ports
        ASEG    DATA
portA   VAR     0x1B
portB   VAR     0x18

;define the macros
strobe  MACRO
        IN      R25,portA
        SBR     R25,128
        OUT     portA,R25
        CBR     R25,128
        OUT     portA,R25
        ENDM

outdat  MACRO val
        LDI     R25,val
        OUT     portB,R25
        ENDM

;Vector table
        ASEG    CODE
        ORG     0x00
        RJMP    main    ; Reset vector

;main code
        ORG     0x1C    ; Start of main code
main    outdat  23
        strobe
        outdat  40
        strobe
done    JMP     done
        END
```

Type in this listing and save it in a file `dio.s90`. Alternatively, a copy of the source is provided on the installation disk.

ASSEMBLING THE PROGRAM

Assembling the program using the Embedded Workbench

Close the **Tutorial** project, and create a new project, **Tutor2**, by choosing **New** from the **File** menu, and add the file `dio.s90` to it.

Then assemble the file as before, by selecting it in the Project window and choosing **Compile** from the **Project** menu.

Assembling the program using the command line

To assemble the source program enter the command:

```
aa90 dio -r -L -v1 ↵
```

Viewing the listing

The following output will be produced in the file `dio.lst`. In this and subsequent listings the header information is omitted for clarity:

```
   1    00000000                     NAME    dio
   2    00000000
   3    00000000             ; define the ports
   4    00000000                     ASEG    DATA
   5    0000001B             portA   VAR     0x1B
   6    00000018             portB   VAR     0x18
   7    00000000
   8    00000000             ;define the macros
  16    00000000
  21    00000000
  22    00000000             ;Vector table
  23    00000000                     ASEG    CODE
  24    00000000                     ORG     0x00
  25    00000000 0DC0                RJMP    main    ; Reset vector
  26    00000002
  27    00000002             ;main code
  28    0000001C                     ORG     0x1C    ; Start of main
                                     code
  29    0000001C             main    outdat  23
  29    0000001C             main    outdat  23
  29.1  0000001C 97E1                LDI     R25,23
  29.2  0000001E 98BB                OUT     portB,R25
  29.3  00000020                     ENDM
  30    00000020                     strobe
  30.1  00000020 9BB3                IN      R25,portA
  30.2  00000022 9068                SBR     R25,128
```

```
30.3   00000024 9BBB                 OUT      portA,R25
30.4   00000026 9F77                 CBR      R25,128
30.5   00000028 9BBB                 OUT      portA,R25
30.6   0000002A                      ENDM
31     0000002A                      outdat   40
31.1   0000002A 98E2                 LDI      R25,40
31.2   0000002C 98BB                 OUT      portB,R25
31.3   0000002E                      ENDM
32     0000002E                      strobe
32.1   0000002E 9BB3                 IN       R25,portA
32.2   00000030 9068                 SBR      R25,128
32.3   00000032 9BBB                 OUT      portA,R25
32.4   00000034 9F77                 CBR      R25,128
32.5   00000036 9BBB                 OUT      portA,R25
32.6   00000038                      ENDM
33     00000038 0C941C00     done    JMP      done
34     0000003C                      END
```

The macro-generated lines are numbered with a decimal suffix: eg 30.1, 30.2, etc.

LINKING THE PROGRAM

In order to be able to execute the program, the relocatable file produced by the assembler needs to be converted to an object code program with all the addresses resolved.

Linking the program using the Embedded Workbench
Link the file by choosing **Link** from the **Project** menu.

Linking the program using the command line
Run XLINK to produce code for debugging with the command:

```
xlink dio -ca90 -r -l dio.map ↵
```

This generates a file `aout.d90`.

RUNNING THE PROGRAM

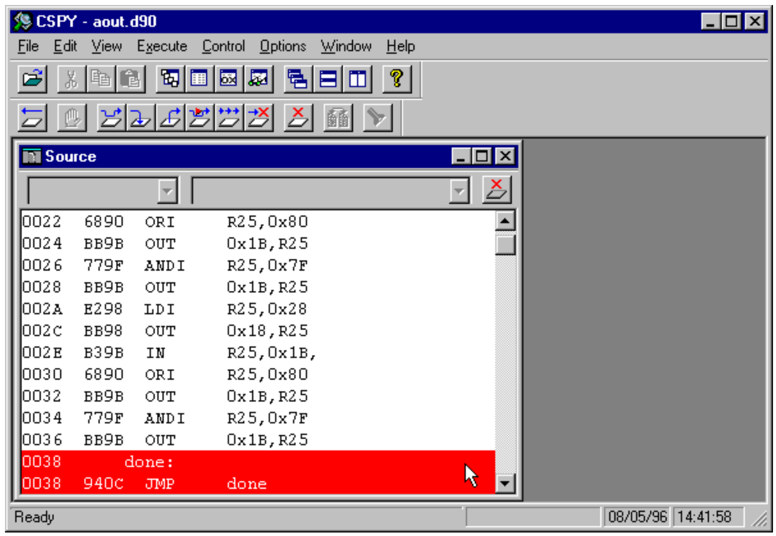
Running the program using the Embedded Workbench
To run the program using the C-SPY debugger choose **Debugger** from the **Project** menu and, as before, ignore the warning messages.

The **C-SPY** window will be displayed.

Choose **Step** from the **Execute** menu to display the source program in the Source window.

Then set a breakpoint at the instruction `JMP done` at the end of the main program in the Source window by selecting it and choosing **Toggle Breakpoint** from the **Control** menu.

The `JMP done` instruction will be highlighted to show that there is a breakpoint set there:



Open the Memory window, by choosing **Memory** from the **Window** menu, and display the contents of the locations `portA` and `portB` at `0x1B` and `0x18` respectively.

Then execute from `main` up to the breakpoint by choosing **Go** from the **Execute** menu.

You will see the effect of the program in the Memory window.

Running the program using the command line

If you have the C-SPY simulator you can run the program with the command:

```
csa90 aout -v1 ↵
```

Set C-SPY up with the following commands:

```
MEMORY SFR 0 ↵
WINDOW REG ON ↵
REG PC=0 ↵
```

These commands open Memory and Register windows, and then set the PC to address 0 which is the reset vector.

Now single step though the code using the F2 key, and notice how locations `0x1B` and `0x18` corresponding to `portA` and `portB` change.

GENERATING A FILE FOR A PROM PROGRAMMER

To generate code which can be read by a PROM programmer, link without the `-r` option to get a file `aout.a90`.

USING MODULES

The final example demonstrates how to create library modules and use the XLIB Librarian to maintain files of modules.

USING LIBRARIES

If you are working on a large project you will soon accumulate a collection of useful routines that are used by several of your programs.

To avoid the need to assemble a routine each time you need it you can store such routines as object files; ie assembled but not linked.

A collection of routines in a single object file is referred to as a library. It is recommended that you use library files to create collections of related routines, such as graphical or math libraries.

You can use the XLIB Librarian to manipulate libraries; it allows you to:

- Change modules from `PROGRAM` to `LIBRARY` type, and vice versa.
- Add or remove modules from a library file.
- Change the names of entries.
- List module names, entry names, etc.

CREATING THE MAIN PROGRAM

The main program is as follows:

```
        NAME    main

        PUBLIC  main
        EXTERN  r_shift

        RSEG    MY_CODE
main    LDI     R25,H'A
        MOV     R4,R25
        LDI     R25,5
        MOV     R5,R25
        CALL    r_shift
done_it RJMP    done_it

        END     main
```

This simply uses a routine called `r_shift` to shift the contents of register R4 to the right. The data in register R4 is set to `$A` and the `r_shift` routine is called to shift it to the right by four places as specified by the contents of register R5.

The `EXTERN` directive declares `r_shift` as an external symbol, to be resolved at link time.

Enter this program and save it as the file `main.s90` or, alternatively, copy the file provided in the assembler files directory (by default `c:\iar\aa90`).

CREATING THE LIBRARY ROUTINES

The second program is used to form a separately assembled library. This contains two library routines: the `r_shift` routine called by `main`, and the corresponding `l_shift` routine. These both operate on the contents of register R4 by repeatedly shifting it to the right or left. The number of shifts performed is controlled by decrementing register R5 to zero.

```
        MODULE  r_shift
        public  r_shift
        RSEG    MY_CODE

r_shift TST     R5
        BREQ    r_shift2
        LSR     R4
        DEC     R5
        BRNE    r_shift
r_shift2        RET
        ENDMOD

        MODULE  l_shift
        PUBLIC  l_shift

        RSEG    MY_CODE
l_shift TST     R5
        BREQ    l_shift2
        LSL     R4
        DEC     R5
        BRNE    l_shift
l_shift2        RET

        END
```

The routines are defined as library modules by the `MODULE` directives; these instruct the XLINK Linker to include them only if they are called by another module.

The `r_shift` and `l_shift` entry addresses are made public to other modules with a `PUBLIC` directive.

Save these modules in a source file called `shifts.s90` or, alternatively, copy the file provided in the assembler files directory (by default `c:\iar\aa90`).

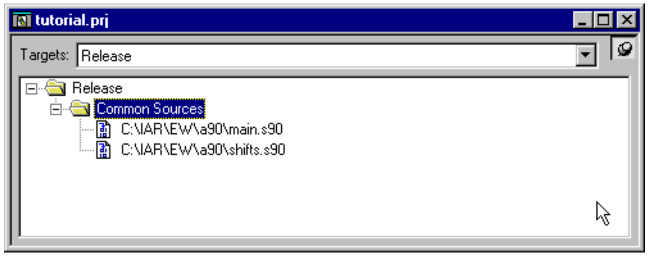
ASSEMBLING AND LINKING THE SOURCE FILES

Next you need to assemble both of the above source files.

Although it is possible to assemble both source files together, in a large project this would soon become very time-consuming. By assembling the library routines separately, changes to the main program only require reassembly of the main source file.

Assembling and linking using the Embedded Workbench

Create a project containing `main.s90` and `shifts.s90`, as described for the previous tutorials:



To assemble and link both files choose **Make** from the **Project** menu.

Assembling and linking using the command line

To assemble the main program type:

```
aa90 main -r -L ↵
```

Similarly, to assemble the library routines type:

```
aa90 shifts -r -L ↵
```

Assembling the files creates two relocatable files. You need to link these together to produce a single executable object file containing the main program and the library routine it references, with all of the cross references resolved. In this case the only reference from one section to the other is the call of the `l_shift` subroutine. The `r_shift` routine is not used at all.

To link the files in a single step enter the following at the command line (on one line):

```
xlink -ca90 main shifts -ZMY_CODE=0E -xsm -l main.map ↵
```

The following table explains the options which define the addresses for the code and data segments:

Parameter	*Description*
`-ZMY_CODE=0E`	Defines that the code segment is to be relocated to the hex address `0xE`.
`-xsm`	Requests a cross reference listing.
`-l main.map`	Directs the listing output to `main.map`.

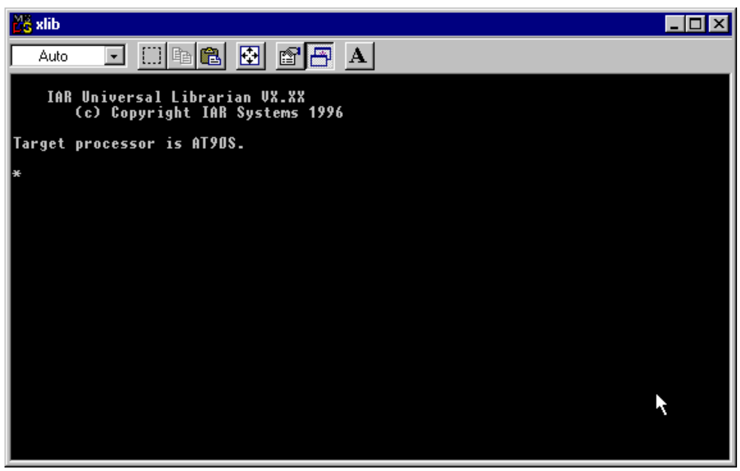
For more information about the XLINK options see the chapter *XLINK options reference*.

Viewing the listing
If you list the cross reference listing, `main.map`, you will see that the module created by XLINK includes the `main` program module and the `r_shift` library module, but not the unused `l_shift` library module.

USING THE XLIB LIBRARIAN

Once you have assembled and debugged a module intended for general use, like the `l_shift` and `r_shift` modules previously described, you can add them to a library using the XLIB Librarian.

Running the XLIB Librarian using the Embedded Workbench
Run the XLIB Librarian by choosing **Librarian** from the **Project** menu. The XLIB window will be displayed.



You can now enter XLIB commands at the * prompt.

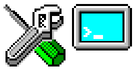
Running the XLIB Librarian using the command line
Start the XLIB Librarian by typing:

```
XLIB ↵
```

XLIB runs in an interactive mode, and displays a * prompt for you to enter your command.

The first thing you need to do within XLIB is define the CPU you are using:

`DEFINE-CPU a90` ↵



Giving XLIB commands

Extract the modules you want from `shifts.r90` into a library called `math.r90`. To do this enter the command:

`FETCH-MODULES` ↵

This prompts for the following arguments:

Prompt	*What you type*
Source file	`shifts` ↵
Destination file	`math` ↵
Start module	↵ (uses the default, which is the first in the file).
End module	↵ (uses the default, which is the last in the file).

This creates the file `math.r90` which contains the code for the `l_shift` and `r_shift` routines.

You can confirm this by typing:

`LIST-MODULES` ↵

This prompts for the following arguments:

Prompt	*What you type*
Object file	`math`
List file	↵ (to use the screen).
Start module	↵ (to start from the first module).
End module	↵ (to end at the last module).

Finally, leave the librarian by typing:

`EXIT` ↵

You could use the same procedure to add further modules to the `math` library at any time.

ASSEMBLER OPTIONS SUMMARY

This chapter gives an alphabetical summary of the assembler options, and explains how to set the options from the Embedded Workbench or the command line.

The options are divided into the following sections, corresponding to the pages in the **AA90** and **General** options in the Embedded Workbench:

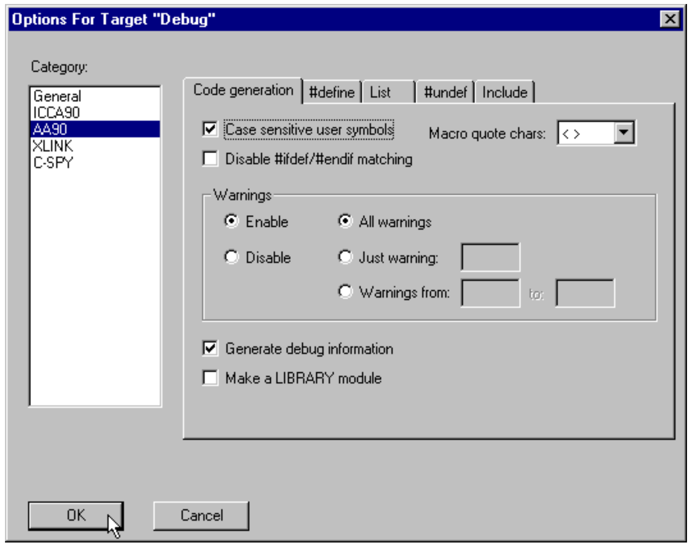
Code generation	#undef
#define	Include
List	Target

For full reference about each option refer to the following chapter, *Assembler options reference*. The *Command line* section, page 48, provides information about the options which are only available in the command line version.

SETTING ASSEMBLER OPTIONS

Setting assembler options in the Embedded Workbench

To set assembler options in the Embedded Workbench choose **Options…** from the **Project** menu, and select **AA90** in the **Category** list to display the assembler options pages:



Then click the tab corresponding to the category of options you want to view or change.

Setting assembler options from the command line

To set assembler options from the command line, you include them on the command line, after the `aa90` command. For example, when assembling the source `first`, to generate a listing to the default listing filename (`first.lst`):

```
aa90 first -L ↵
```

Some options accept a filename, included after the option letter with a separating space. For example, to generate a listing to the file `list.lst`:

```
aa90 first -l list.lst ↵
```

Some other options accept a string that is not a filename. This is included after the option letter, but without a space. For example, to generate a listing to the default filename but in the subdirectory list:

```
aa90 first -Llist ↵
```

OPTIONS SUMMARY

The following is a summary of all the assembler options. For a full description of any option, see under the option's category name in the next chapter, *Assembler options reference*.

Option	*Description*	*Section*
`-B`	Macro execution info.	List
`-b`	Make a LIBRARY module.	Code generation
`-c{DMEAO}`	Conditional list.	List
`-D`*`symb`*`[=`*`xx`*`]`	Define symbol.	#define
`-d`	Disable `#ifdef/#endif` matching.	Code generation
`-E`*`number`*	Max number of errors.	Command line
`-f` *`filename`*	Extend the command line.	Command line
`-G`	Open standard input as source.	Command line
`-I`*`prefix`*	Include paths.	Include
`-i`	Included text.	List
`-l` *`filename`*	List to named file.	List
`-L[`*`prefix`*`]`	List to prefixed source name.	List
`-M`*`ab`*	Macro quote chars.	Code generation
`-m`*`n`*	Memory model.	Target
`-N`	No header.	List
`-O`*`prefix`*	Set object filename prefix.	Command line
`-o` *`filename`*	Set object filename.	Command line
`-p`*`lines`*	Lines/page.	List
`-r`	Generate debug information.	Code generation
`-S`	Set silent operation.	Command line
`-s{+|-}`	Case sensitive user symbols.	Code generation
`-T`	Active lines only.	List
`-t`*`n`*	Tab spacing.	List
`-U`*`symb`*	Undefine symbol.	#undef

Option	*Description*	*Section*
`-v`*n*	Processor configuration.	Target
`-w[`*string*`]`	Warnings.	Code generation
`-x{DI2}`	Cross reference.	List

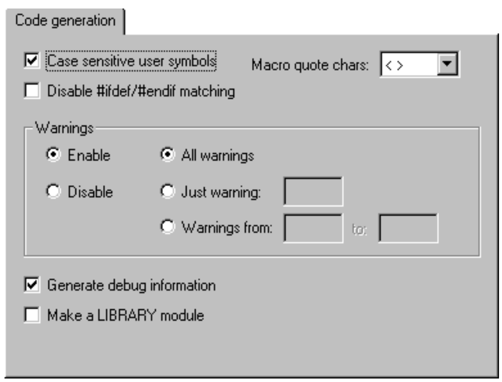
ASSEMBLER OPTIONS REFERENCE

This chapter gives detailed information on each of the AT90S Assembler options, divided into functional categories.

CODE GENERATION

These options control the assembler's code generation.

Embedded Workbench



Command line

`-s{+|-}`	Case sensitive user symbols.
`-d`	Disable `#ifdef`/`#endif` matching.
`-M`*`ab`*	Macro quote chars.
`-w[`*`string`*`]`	Warnings.
`-r`	Generate debug information.
`-b`	Make a LIBRARY module.

CASE SENSITIVE USER SYMBOLS (-s)

Syntax: `-s{+|-}`

Sets whether the assembler is sensitive to the case of user symbols:

Option	*Command line*
Case sensitive user symbols	`-s+`
Case insensitive user symbols	`-s-`

By default, case sensitivity is on. This means that, for example, `LABEL` and `label` refer to different symbols. You can choose **Case insensitive user symbols** (`-s-`) to turn case sensitivity off, in which case `LABEL` and `label` will refer to the same symbol.

DISABLE #IFDEF/#ENDIF MATCHING (-d)

Syntax: `-d`

Allows unmatched `#ifdef` … `#endif` statements to be used without causing an error.

The checks for `#ifdef` … `#endif` matching are performed for each module, and a `#endif` outside modules will therefore normally generate an error message. Use this option to turn checking off.

This allows you to write constructs such as:

```
#ifdef Version1
    MODULE M1
    NOP
    ENDMOD
#endif
    MODULE M2
    .
    .
    .
    etc
```

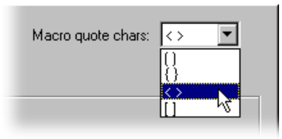
MACRO QUOTE CHARS (-M)

Syntax: `-M`*`ab`*

Sets the characters used for the left and right quotes of each macro argument to `a` and `b` respectively.

By default, the characters are < and >. The **Macro quote chars** (`-M`) option allows you to change the quote characters to suit an alternative convention or simply to allow a macro argument to contain < or > themselves.

You can select one of four types of brackets from the drop-down list as the macro quote characters:



For example, using the option:

```
-M[]
```

in the source you would write, for example:

```
print [>]
```

to call a macro print with > as the argument.

DISABLE WARNINGS (-w)

Syntax: `-w[`*`string`*`]`

Disables warnings.

By default, the assembler displays a warning message when it finds an element of the source which is legal, but probably due to a programming error (see *Assembler diagnostics* for details). The **Disable warnings** (`-w`) option with no range disables all warnings. The **Disable warnings** (`-w`) option with a range performs the following:

Range	*Effect*
`+`	Enables all warnings.
`-`	Disables all warnings.
`+`*`n`*	Enables just warning *n*.
`-`*`n`*	Disables just warning *n*.
`+`*`m-n`*	Enables warnings *m* to *n*.
`-`*`m-n`*	Disables warnings *m* to *n*.

For example, to disable just warning 0 (unreferenced label), you might use:

```
aa90 prog -w-0 ↵
```

or to disable warnings 0 to 8:

```
aa90 prog -w-0-8 ↵
```

Only one **Disable warnings** (`-w`) option may be used on the command line.

GENERATE DEBUG INFORMATION (-r)

Syntax: `-r`

Enables the inclusion of information that allows a debugger (such as C-SPY) to be used on the program.

By default, the assembler does not generate debug information, to reduce the size and link time of the object file. You must use the **Generate debug information** (`-r`) option if you want to use a debugger with the program.

MAKE A LIBRARY MODULE (-b)

Syntax: `-b`

Causes the object file to be a library module rather than a program module.

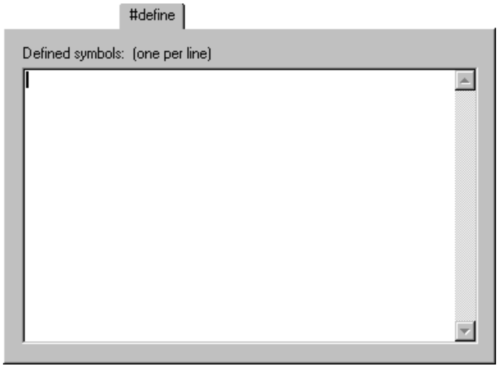
By default, the assembler produces a program module ready to be linked with XLIB. You use the **Make a LIBRARY module** (`-b`) option if you want it to make a library module for use with XLIB.

If the `NAME` directive is used in the source (to specify the name of the program module), the **Make a LIBRARY module** (`-b`) option is ignored, that is the assembler produces a program module regardless.

#define

This option allows you to define symbols.

Embedded Workbench



Command line

`-Dsymb[=xx]` Define symbol.

DEFINE SYMBOL (-D)

Syntax: `-D`*`symb`*`[=`*`xx`*`]`

Defines a symbol with the name *symb* and the value *xx*. If no value is specified, 1 is used.

The **Define symbol** (`-D`) option allows a value or choice that would otherwise have to be specified in the source file to be specified more conveniently on the command line. For example, you could arrange your source to produce either the test or production version of your program dependent on whether the symbol `testver` was defined. To do this you would use include sections such as:

```
#ifdef  testver
...     ; additional code lines for test version only
#endif
```

Then, you would select the version required in the command line as follows:

```
production version:     aa90 prog
test version:           aa90 prog -Dtestver
```

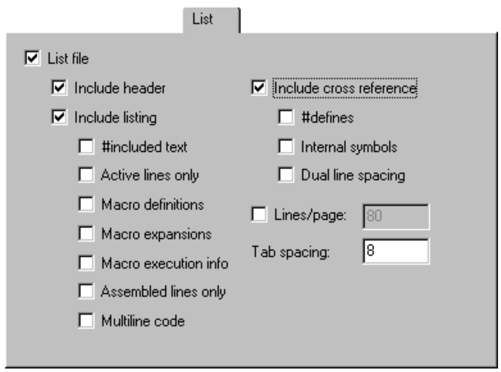
Alternatively, your source might use a variable that you need to change often. You would leave the variable undefined in the source, and use `-D` to specify the value on the command line; for example:

```
aa90 prog -Dframerate=3 ↵
```

LIST

The **List** options are used to cause the assembler to generate a listing, to select the contents of the listing, and to generate other listing-type output.

Embedded Workbench



Command line

`-l` *`filename`*	List to named file.
`-L[`*`prefix`*`]`	List to prefixed source name.
`-N`	No header.
`-i`	#included text.
`-T`	Active lines only.
`-c{DMEAO}`	Conditional list.
`-B`	Macro execution info.
`-x{DI2}`	Cross reference.
`-p`*`lines`*	Lines/page.
`-t`*`n`*	Tab spacing.

LIST FILE

Causes the assembler to generate a listing and send it to the file `sourcename.lst`.

When **List file** is selected the following list options become available:

Option	*Description*
Include header	Includes a header in the listing.
Include listing	Includes the body of the listing.

Selecting **Include listing** makes the following options available:

Option	*Description*
#included text	Includes `#include` files in the listing.
Active lines only	Includes only active lines in the listing.
Macro definitions	Includes macro definitions in the listing.
Macro expansions	Includes macro expansions in the listing.
Macro execution info	Prints macro execution information on every call of a macro.
Assembled lines only	Lists only assembled lines.
Multiline code	Lists the code generated by directives on several lines if necessary.

List to named file (-l)
Syntax: `-l filename`

Causes the assembler to generate a listing and send it to the named file. If no extension is specified, `.lst` is used. Note that you must include a space before the filename.

By default, the assembler does not generate a listing. The `-l` option turns on listing, and directs it to a specific file. To just turn on listing to the default filename, use the `-L` option instead.

List to prefixed source name (-L)

Syntax: `-L[prefix]`

Causes the assembler to generate a listing and send it to the file *prefixsourcename*.lst. Note that you must not include a space before the prefix.

By default, the assembler does not generate a listing. To simply generate a listing, you use the `-L` option without a prefix. The listing is sent to the file with the same name as the source, but extension `.lst`.

The `-L` option lets you specify a prefix, for example to direct the list file to a subdirectory:

```
aa90 prog -Llist\ ↵
```

This sends the object to `list\prog.lst` rather than the default `prog.lst`.

`-L` may not be used at the same time as `-l`.

NO HEADER (-N)

Syntax: `-N`

Disables the header normally printed in the listing.

#INCLUDED TEXT (-i)

Syntax: `-i`

Includes `#include` files in the listing.

By default, the assembler does not list `#include` file lines since these are often from standard files that would waste space in the listing. The **#included text** (`-i`) option allows you to list `#include` files should you so require.

ACTIVE LINES ONLY (-T)

Syntax: `-T`

Includes only active lines, for example not those in false `#if` blocks. By default, all lines are listed.

This option is useful for reducing the size of listings by eliminating lines that do not generate or affect code.

CONDITIONAL LIST (-c)

Syntax: `-c{DMEAO}`

Sets one or more of the following:

Option	*Command line*
Disable listing	`D`
Macro definitions	`M`
No macro expansions	`E`
Assembled lines only	`A`
Multiline code	`O`

MACRO EXECUTION INFO (-B)

Syntax: `-B`

Causes the assembler to print macro execution information to the standard output stream on every call of a macro. The information consists of:

- The name of the macro.
- The definition of the macro.
- The arguments to the macro.
- The expanded text of the macro.

CROSS-REFERENCE (-x)

Syntax: `-x{DI2}`

Causes the assembler to generate a cross-reference list at the end of the listing. See the chapter *Assembler file formats* for details.

The following options are available:

Option	*Command line*
#defines	`D`
Internal symbols	`I`
Dual line spacing	`2`

LINES/PAGE (-p)

Syntax: `-plines`

Sets the number of lines per page to *lines*, which must be in the range 10 to 150.

TAB SPACING (-t)

Syntax: `-tn`

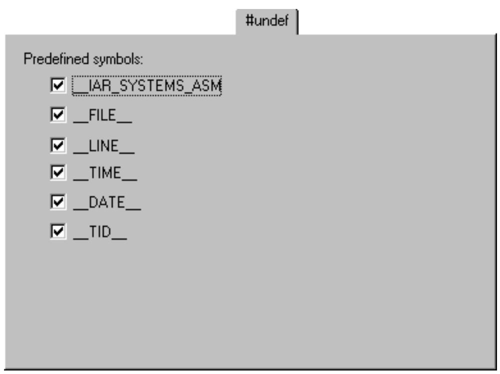
Sets the number of character positions per tab stop to *n*, which must be in the range 2 to 9.

By default, the assembler sets eight character positions per tab stop.

#undef

The **#undef** option allows you to undefine the predefined symbols.

Embedded Workbench



Command line

`-Usymb`	Undefine symbol.

UNDEFINE SYMBOL (-U)

Syntax: `-Usymb`

Undefines the symbol *symb*.

By default, the assembler provides certain pre-defined symbols; see *Pre-defined symbols*, page 55. The **Undefine symbol** (`-U`) option allows you to undefine such a pre-defined symbol to make its name available for your own use through a subsequent **Define symbol** (`-D`) option or source definition.

To undefine a symbol, deselect it in the **Predefined symbols** list.

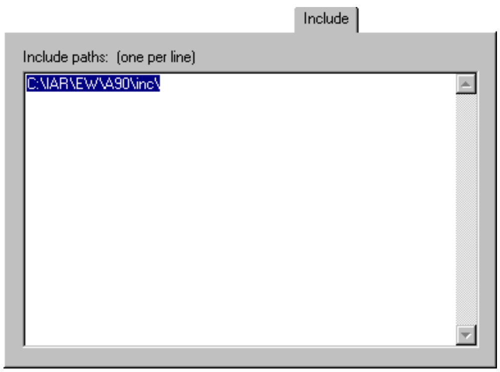
To use the name of the predefined symbol `__TIME__` for your own purposes, you could undefine it with:

```
aa90 prog -U __TIME__ ↵
```

INCLUDE

The **Include** option allows you to define the include path for the assembler.

Embedded Workbench



Command line

`-I`*`prefix`*	Include paths.

INCLUDE PATHS (-I)

Syntax: `-I`*`prefix`*

Adds the `#include` file search prefix *`prefix`*.

By default, the assembler searches for `#include` files only in the current working directory. The **Include paths** (`-I`) option allows you to give the assembler the names of directories which it will also search if it fails to find the file in the current working directory.

For example, using the options:

```
-Ic:\global\ -Ic:\thisproj\headers\
```

and then writing:

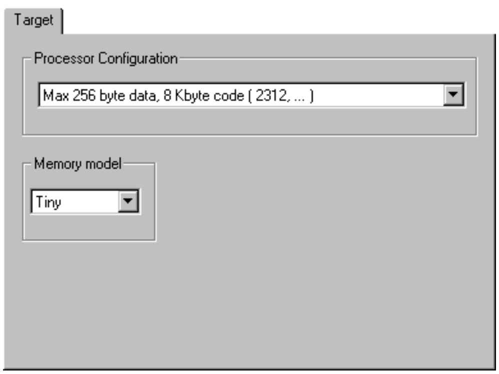
```
#include "asmlib.hdr" ↵
```

in the source, will make the assembler search first for file `asmlib.hdr`, then for file `c:\global\asmlib.hdr`, and finally for file `c:\thisproj\headers\asmlib.hdr`.

TARGET

The **Target** options specify the processor and memory model for the assembler and C compiler.

Embedded Workbench



Command line

`-v`*n*	Processor configuration.
`-m`*n*	Memory model.

PROCESSOR CONFIGURATION (-v)

Syntax: `-v`*n*

Selects the processor configuration from one of:

Option	*Command line*
Max 256 byte data, 8 Kbyte code	`-v0`
Max 64 Kbyte data, 8 Kbyte code	`-v1`
Max 256 bytes data, 128 Kbytes code	`-v2`
Max 64 Kbytes data, 128 Kbytes code	`-v3`

Versions `-v4` to `-v6` are for future expansion.

If no **Chip option** (`-v`) option is specified, the assembler uses `-v0` by default.

MEMORY MODEL (-m)

Syntax: `-m`*n*

Selects the memory model from the following:

Option	*Command line*
Tiny	`-mt`
Small	`-ms`
Large*	`-ml`

* Note that this option is included for future expansion.

COMMAND LINE

The following additional options are available from the command line.

`-E`*number*	Max number of errors.
`-f` *filename*	Extend the command line.
`-G`	Open standard input as source.
`-O`*prefix*	Set object filename prefix.
`-o` *filename*	Set object filename.
`-S`	Set silent operation.

MAX NUMBER OF ERRORS (-E)

Syntax: `-E`*number*

Sets the maximum number of errors the assembler reports.

By default, the maximum number is 100. The **Max number of errors** (`-E`) option allows you to decrease or increase this number, for example, to see more errors in a single assembly.

EXTEND THE COMMAND LINE (-f)

Syntax: `-f` *filename*

Extends the command line with text read from the file *filename*`.xcl`. Note that there must be a space between the option itself and the filename.

The `-f` option is particularly useful where there are a large number of options which are more-conveniently placed in a file than on the command line itself. For example, to run the assembler with further options taken from the file `asmopt.xcl`, you might use:

```
aa90 prog -f asmopt ↵
```

OPEN STANDARD INPUT AS SOURCE (-G)

Syntax: `-G`

Causes the assembler to read the source from the standard input stream, rather than a specified source file.

When `-G` is used, no source filename may be specified.

SET OBJECT FILENAME PREFIX (-O)

Syntax: `-O`*prefix*

Set the prefix to be used on the filename of the object. Note that you must not include a space before the prefix.

By default the prefix is null, so the object filename corresponds to the source filename (unless `-o` is used). The `-O` option lets you specify a prefix, for example to direct the object file to a subdirectory:

```
aa90 prog -Oobj\
```

This sends the object to `obj\prog.r90` rather than the default `prog.r90`.

`-O` may not be used at the same time as `-o`.

SET OBJECT FILENAME (-o)

Syntax: `-o` *filename*

Sets the filename to be used for the object. Note that you must include a space before the filename. If no extension is specified, `.r90` is used.

By default the assembler uses the source filename with the extension changed to `.r90`. The `-o` option lets you use an alternative filename for the object.

For example, the following command puts the object to the file `obj.r90` instead of the default `prog.r90`:

```
aa90 prog -o obj
```

Note that you must include a space between the option itself and the filename.

`-o` may not be used at the same time as `-O`.

SET SILENT OPERATION (-S)

Syntax: `-S`

Causes the assembler to operate without sending any messages to the standard output stream.

By default, the assembler sends various inessential messages to the terminal via the standard output stream. You can use the `-S` option to prevent this, reducing the amount of screen clutter. The assembler sends error and warning messages to the error output stream, so they appear on the terminal regardless.

ASSEMBLER FILE FORMATS

This chapter describes the source format for the AT90S Assembler, and the format of assembler listings.

SOURCE FORMAT

The format of an assembler source line is as follows:

`[`*label* `[:]]` *operation* `[`*operands*`] [;` *comment*`]`

where the components are as follows:

label	A label, which is assigned the value and type of the current location counter (PLC). The `:`(colon) is optional if the label starts in the first column.
operation	An assembler instruction or directive. This must not start in the first column.
operands	One or two operands, separated by commas.
comment	A comment, preceded by a `;` (semi-colon).

The fields can be separated by spaces or tabs.

A source line may not exceed 255 characters.

Tab characters (ASCII 09H), are expanded according to the most common practice; ie to columns 8, 16, 24 etc.

A * in the first column indicates a comment line.

EXPRESSIONS AND OPERATORS

Expressions can consist of operands and operators.

The assembler will accept a wide range of expressions, including both arithmetic and logical operations. All operators use 32-bit two's complement integers, and range checking is only performed when a value is used to generate code.

Expressions are evaluated from left to right, unless this order is overridden by the priority of operators.

The valid operands in an expression are:

- User-defined symbols and labels.
- Constants, excluding floating point constants.
- The location counter (PLC) symbol, `$`.

These are described in greater detail in the following sections.

The valid operators are described in the chapters *Assembler operator summary*, and *Assembler operator reference*.

TRUE AND FALSE

In expressions a zero value is considered FALSE, and a non-zero value is considered TRUE.

Conditional expressions return the value `0` for FALSE and `1` for TRUE.

USING SYMBOLS IN RELOCATABLE EXPRESSIONS

Expressions that include symbols in relocatable segments cannot be resolved at assembly time, because they depend on where the segments are located by XLINK.

Such expressions are evaluated and resolved at link time, by XLINK. There are no restrictions on the expression; any operator can be used on symbols from any segment, or any combination of segments.

For example, a program could define the segments `DATA` and `CODE` as follows:

```
        NAME    prog1
        EXTERN  third
        RSEG    DATA
first   DB      5
second  DB      3
        ENDMOD
        MODULE  prog2
        RSEG    CODE
start   …
```

Then in segment `CODE` the following instructions are legal:

```
        LDI     R27,first
        LDI     R27,first+1
```

```
LDI     R27,1+first
LDI     R27,(first/second)*third
```

SYMBOLS

User-defined symbols can be up to 255 characters long, and all characters are significant.

Symbols must begin with a letter, a–z or A–Z, ? (question mark), @ (at), or _ (underline). Symbols can include the digits 0–9 and $ (dollar). For user-defined symbols case is significant. For built-in symbols like instructions, registers, operators, and directives case is insignificant.

LABELS

Symbols used for memory locations are referred to as labels.

Location counter

The location counter is called `$`. For example:

```
RJMP          $       ; Loop forever
```

INTEGER CONSTANTS

Since all IAR Systems Assemblers use 32-bit two's complement internal arithmetic, integers have a (signed) range from -2147483648 to 2147483647.

Constants are written as a sequence of digits with an optional **-** (minus) sign in front to indicate a negative number.

Commas and decimal points are not permitted.

The following number bases are supported:

Hexadecimal

Hexadecimal numbers can be written in any of the following formats:

Format	*Example*	*Value*
`0x`*hex-digits*	`0x43`	67 in decimal.
`H'`*hex-digits*	`H'43`	67 in decimal.
hex-digits`H`	`43H`	67 in decimal*.

* Note that if the first digit is `A–F`, a leading zero must be included; for example, `0AH`.

Octal

Octal numbers can be written as follows:

Format	*Example*	*Value*
`'\`*`octal-digits`*`'`	`'\10'`	8 in decimal.
`Q'`*`octal-digits`*	`Q'10`	8 in decimal.
`octal-digits``Q`	`10Q`	8 in decimal.

Decimal

Decimal numbers can be written as follows:

Format	*Example*	*Value*
`digits`	`123`	123 in decimal.
`D'`*`digits`*	`D'123`	123 in decimal.

Binary

Binary numbers can be written as follows:

Format	*Example*	*Value*
`B'`*`binary-digits`*	`B'10`	2 in decimal.
`binary-digits``B`	`10B`	2 in decimal.

ASCII CHARACTER CONSTANTS

ASCII constants can consist of between zero and four characters enclosed in single quotes. Only printable characters and spaces may be used in ASCII strings.

If the quote character itself is to be accessed, two consecutive quotes must be used:

Format	*Value*
`'ABCD'`	`ABCD` (four characters).
`"ABCD"`	`ABCD'\0'` (five characters, the last ASCII null).
`'A''B'`	`A'B`
`'A'''`	`A'`
`''''` (4 quotes)	`'`

Format	*Value*
`''` (2 quotes)	Empty string (value = 0).
`""`	Empty string (an ASCII null character).
`\'`	`'`
`\\`	`\`

PRE-DEFINED SYMBOLS

The AT90S Assembler defines a set of symbols for use in assembler source files. The symbols provide information about the current assembly, allowing you to test them in pre-processor directives or include them in the assembled code.

Symbol	*Value*
`__DATE__`	Current date in `Mmm dd yyy` format.
`__FILE__`	Current source filename.
`__IAR_SYSTEMS_ASM`	IAR assembler identifier.
`__LINE__`	Current source line number.
`__TID__`	Target identity, consisting of two bytes. The high byte is the target identity, which is `90` for the AT90S. The low byte is the processor option *16. The possible values are therefore as follows:

Processor option		*Value*
`-v0`	AT90S2312	0x5A00
`-v1`	AT90S8414	0x5A10
`-v2`		0x5A20
`-v3`		0x5A30
`-v4`		0x5A40
`-v5`		0x5A50
`-v6`		0x5A60

`__TIME__`	Current time in `hh:mm:ss` format.

Including symbol values in code

To include a symbol value in the code, you use the symbol in one of the data-definition directives.

For example, to include the time and date of assembly as a string for display by the program:

```
timdat  DB      __TIME__,",",__DATE__,0 ; time and date
        ...
        LD      WA,timdat       ; load address of string
        CALL    printstring     ; routine to print string
```

Testing symbols for conditional assembly

To test a symbol at assembly-time, you use one of the conditional assembly directives.

For example, in a source file written for use on any one of the AT90S family members, you might want to assemble appropriate code for a specific processor. You could do this using the `__TID__` symbol as follows:

```
#define TARGET ((__TID__ & 0x0F0)>>4)
#if (TARGET==1)
.
.
.
#else
.
.
.
#endif
```

REGISTER SYMBOLS

Definitions of the symbols for registers, including standard SFRs, are supplied in the following files:

File	*Processor*
io2312.h	AT90S2312
io8414.h	AT90S8414

LISTING FORMAT

The format of the AT90S Assembler listing is as follows:

Header · Assembler listing · Macro generated lines · CRC

```
################################################################################
#                                                                              #
#     IAR Systems A90 Assembler Vx.xx                                          #
#                                                                              #
#           Target option =  Relative jumps reach entire addr space           #
#           Source file   =  play.s90                                          #
#           List file     =  play.lst                                          #
#           Object file   =  play.r90                                          #
#           Command line  =  play -r -L                                        #
#                                                                              #
#                                      (c) Copyright IAR Systems 1996         #
################################################################################

     1    00000000                      NAME    play
     2    00000000
     3    00000000                      LSTXRF+
     4    00000018              portb   VAR     0x18
     5    00000000                      RSEG    DATA
     6    00000000              buffer  DS      256
     7    00000200
    19    00000000                      RSEG    CODE
    20    00000000                      play
    20.1  00000000                      LOCAL   loop
    20.2  00000000 ....                 LDI     R27,HWRD(buffer)
    20.3  00000002 ....                 LDI     R26,LWRD(buffer)
    20.4  00000004 9FEF                 LDI     R25,255
    20.5  00000006 0D90         loop    LD      R0,X+
    20.6  00000008 08BA                 OUT     portb,R0
    20.7  0000000A 9A95                 DEC     R25
    20.8  0000000C E1F7                 BRNE    loop
    20.9  0000000E                      ENDM
    21    0000000E                      END

Segment     Type        Mode
--------------------------------
CODE        UNTYPED     REL
DATA        UNTYPED     REL

Label       Mode        Type                    Segment     Value/Offset
---------------------------------------------------------------------------
_args       ABS         CONST PUB LOCAL UNTYP.  ASEG        0
buffer      REL         CONST PUB UNTYP.        DATA        0
loop        REL         CONST PUB LOCAL UNTYP.  CODE        6
portb       ABS         VAR UNTYP.              ASEG        18

##############################
#          CRC:86EA          #
#        Errors:   0         #
#        Warnings: 0         #
#         Bytes: 14          #
##############################
```

The header, with assembly parameters, is only output on listings directed to files other than the terminal.

Assembly list information is put into four fields:

```
20.5  00000006 0D90        loop   LD     R0,X+
20.6  00000008 08BA               OUT    portb,R0
20.7  0000000A 9A95               DEC    R25
20.8  0000000C E1F7               BRNE   loop
20.9  0000000E                    ENDM
21    0000000E                    END
```

Address field
Source line
Source line number
Data field

Source line number
The line number in the source file.

Lines generated by macros will, if listed, have `.` (full stop) in the source line number field.

Address and data fields
These are always listed in hexadecimal notation.

Source line
Lists the source file line.

SYMBOL AND CROSS REFERENCE TABLE

If the `LSTXRF+` directive has been included, or the `-x` command line option has been specified, the following symbol and cross reference table is produced:

Segments

```
Segment     Type       Mode
-------------------------------
CODE        UNTYPED    REL
DATA        UNTYPED    REL
```

Symbols

```
Label       Mode       Type                    Segment    Value/Offset
----------------------------------------------------------------------
_args       ABS        CONST PUB LOCAL UNTYP.  ASEG       0
buffer      REL        CONST PUB UNTYP.        DATA       0
loop        REL        CONST PUB LOCAL UNTYP.  CODE       6
portb       ABS        VAR UNTYP.              ASEG       18
```

The following information is provided for each symbol in the table:

Information	*Description*
Label	The label's user-defined name.
Mode	ABS (Absolute), or REL (Relative).
Type	The label's type.
Segment	The name of the segment this label is defined relative to.
Value/Offset	The value (address) of the label within the current module, relative to the beginning of the current segment.

OUTPUT FORMATS

The relocatable and absolute output is in the same format for all assemblers, because object code is always meant to be processed by the IAR Systems XLINK Linker.

The output from XLINK, however, is in absolute formats normally compatible with the chip vendor's debugger programs (monitors), as well as with PROM programmers and stand-alone emulators from independent sources.

ASSEMBLER OPERATOR SUMMARY

This chapter summarizes the assembler operators, classified according to their precedence. A full alphabetical reference list of operators is given in the next chapter, *Assembler operator reference*.

PRECEDENCE OF OPERATORS

Each operator has a precedence number assigned to it which determines the order in which the operator and its operands are evaluated. The precedence numbers range from 1 (the highest precedence, ie first evaluated) to 7 (the lowest precedence, ie last evaluated).

The following rules determine how expressions are evaluated:

- The highest precedence (lowest number) operators are evaluated first, then the next highest precedence operators, and so on until the lowest precedence operators are evaluated.
- Operators of equal precedence are evaluated from left to right in the expression.
- Parentheses `(` and `)` can be used to group operators and operands and to control the order in which the expressions are evaluated. For example, the following expression evaluates to 1:

  ```
  7/(1+(2*3))
  ```

The following tables give a summary of the operators, in order of priority. Synonyms, where available, are shown in brackets after the operator name:

UNARY OPERATORS – 1

`+`	Unary plus.
`-`	Unary minus.
`NOT (!)`	Logical NOT.
`LOW`	Low byte.
`HIGH`	High byte.
`BYTE2`	Second byte.
`BYTE3`	Third byte.
`LWRD`	Low word.
`HWRD`	High word.
`DATE`	Current date/time.
`SFB`	Segment begin.
`SFE`	Segment end.
`SIZEOF`	Segment size.
`BITNOT (~)`	Bitwise NOT.

MULTIPLICATIVE ARITHMETIC OPERATORS – 2

`*`	Multiplication.
`/`	Division.
`MOD (%)`	Modulo.

ADDITIVE ARITHMETIC OPERATORS – 3

`+`	Addition.
`-`	Subtraction.

SHIFT OPERATORS – 4

`SHR (>>)`	Logical shift right.
`SHL (<<)`	Logical shift left.

AND OPERATORS – 5

`AND (&&)` Logical AND.

`BITAND (&)` Bitwise AND.

OR OPERATORS – 6

`OR (||)` Logical OR.

`XOR` Logical exclusive OR.

`BITOR (|)` Bitwise OR.

`BITXOR (^)` Bitwise exclusive OR.

COMPARISON OPERATORS – 7

`EQ (=, ==)` Equal.

`NE (<>, !=)` Not equal.

`GT (>)` Greater than.

`LT (<)` Less than.

`UGT` Unsigned greater than.

`ULT` Unsigned less than.

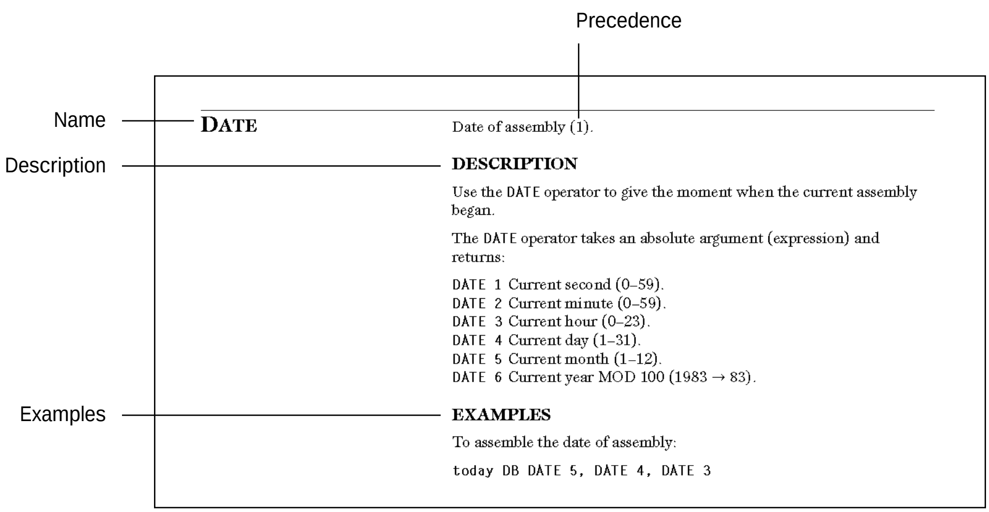
`GE (>=)` Greater than or equal.

`LE (<=)` Less than or equal.

ASSEMBLER OPERATOR REFERENCE

This section gives an alphabetical list of the assembler operators with a full description of each one.

The format of each operator description is as follows:



NAME

The operator name, and where appropriate, any synonyms for the operator, and the operator precedence.

The operator name is followed by a description of the operator.

DESCRIPTION

A detailed description covering the operator's most general use.

EXAMPLES

Examples, illustrating typical applications of the operator and clarifying any special cases.

*****

Multiplication (2).

DESCRIPTION

`*` produces the product of its two operands. The operands are taken as signed 32-bit integers and the result is also a signed 32-bit integer.

EXAMPLES

```
2*2 → 4
-2*2 → -4
```

+

Unary plus (1).

DESCRIPTION

Unary plus operator.

EXAMPLES

```
+3 → 3
3*+2 → 6
```

+

Addition (3).

DESCRIPTION

The + addition operator produces the sum of the two operands which surround it. The operands are taken as signed 32-bit integers and the result is also a signed 32-bit integer.

EXAMPLES

```
92+19 → 111
-2+2 → 0
-2+-2 → -4
```

–

Unary minus (1).

DESCRIPTION

The unary minus operator performs arithmetic negation on its operand.

The operand is interpreted as a 32-bit signed integer and the result of the operator is the two's complement negation of that integer.

–

Subtraction (3).

DESCRIPTION

The subtraction operator produces the difference when the right operand is taken away from the left operand. The operands are taken as signed 32-bit integers and the result is also signed 32-bit integer.

EXAMPLES

```
92-19 → 73
-2-2 → -4
-2--2 → 0
```

/

Division (2).

DESCRIPTION

/ produces the integer quotient of the left operand divided by the right operator. The operands are taken as signed 32-bit integers and the result is also a signed 32-bit integer.

EXAMPLES

```
8/2 → 4
-12/3 → -4
```

AND (&&)

Logical AND (5).

DESCRIPTION

Use `AND` to perform logical AND between its two integer operands. If both operands are non-zero the result is 1; otherwise it is zero.

EXAMPLES

```
1010B AND 0011B → 1
1010B AND 0101B → 1
1010B AND 0000B → 0
```

BITAND (&)

Bitwise AND (5).

DESCRIPTION

Use `BITAND` to perform bitwise AND between the integer operands.

EXAMPLES

```
1010B BITAND 0011B → 0010B
1010B BITAND 0101B → 0000B
1010B BITAND 0000B → 0000B
```

BITNOT (~)

Bitwise NOT (1).

DESCRIPTION

Use `BITNOT` to perform bitwise NOT on its operand.

EXAMPLES

```
BITNOT 1010B → 11111111111111111111111111110101B
```

BITOR (|)

Bitwise OR (6).

DESCRIPTION

Use `BITOR` to perform bitwise OR on its operands.

EXAMPLES

```
1010B BITOR 0101B → 1111B
1010B BITOR 0000B → 1010B
```

BITXOR (^)

Bitwise exclusive OR (6).

DESCRIPTION

Use `BITXOR` to perform bitwise XOR on its operands.

EXAMPLES

```
1010B BITXOR 0101B → 1111B
1010B BITXOR 0011B → 1001B
```

BYTE2

Second byte (1).

DESCRIPTION

`BYTE2` takes a single operand, which is interpreted as an unsigned, 32-bit integer value. The result is the middle-low byte (bits 15 to 8) of the operand.

EXAMPLES

```
BYTE2 0x12345678 → 0x56
```

BYTE3

Third byte (1).

DESCRIPTION

BYTE3 takes a single operand, which is interpreted as an unsigned, 32-bit integer value. The result is the middle-high byte (bits 23 to 16) of the operand.

EXAMPLES

```
BYTE3 0x12345678 → 0x34
```

DATE

Current date/time.

DESCRIPTION

Use the DATE operator to give the moment when the current assembly began.

The DATE operator takes an absolute argument (expression) and returns:

DATE 1	Current second (0–59).
DATE 2	Current minute (0–59).
DATE 3	Current hour (0–23).
DATE 4	Current day (1–31).
DATE 5	Current month (1–12).
DATE 6	Current year MOD 100 (1983 → 83).

EXAMPLES

To assemble the date of assembly:

```
today DB DATE 5, DATE 4, DATE 3
```

EQ (=, ==)

Equal (7).

DESCRIPTION

EQ evaluates to 1 (true) if its two operands are identical in value, or to 0 (false) if its two operands are not identical in value.

EXAMPLES

```
1 EQ 2 → 0
2 EQ 2 → 1
'ABC' EQ 'ABCD' → 0
```

GE (>=)

Greater than or equal (7).

DESCRIPTION

GE evaluates to 1 (true) if the left operand is equal to or has a higher numeric value than the right operand.

EXAMPLES

```
1 GE 2 → 0
2 GE 1 → 1
1 GE 1 → 0
```

GT (>)

Greater than (7).

DESCRIPTION

GT evaluates to 1 (true) if the left operand has a higher numeric value than the right operand.

EXAMPLES

```
-1 GT 1 → 0
2 GT 1 → 1
1 GT 1 → 0
```

HIGH

Second byte (1).

DESCRIPTION

`HIGH` takes a single operand to its right which is interpreted as an unsigned, 16-bit integer value. The result is the unsigned 8-bit integer value of the higher order byte of the operand.

EXAMPLES

```
HIGH 1234ABCDh → ABh
```

HWRD

High word (1).

DESCRIPTION

`HWRD` takes a single operand, which is interpreted as an unsigned, 32-bit integer value. The result is the high word (bits 31 to 16) of the operand.

EXAMPLES

```
HWRD 0x12345678 → 0x1234
```

LE (<=)

Less than or equal (7).

DESCRIPTION

`LE` evaluates to 1 (true) if the left operand has a lower or equal numeric value to the right operand.

EXAMPLES

```
1 LE 2 → 1
2 LE 1 → 0
1 LE 1 → 1
```

LOW

Low byte (1).

DESCRIPTION

`LOW` takes a single operand, which is interpreted as an unsigned, 32-bit integer value. The result is the unsigned, 8-bit integer value of the lower order byte of the operand.

EXAMPLES

```
LOW 1234ABCDh → CDh
```

LT (<)

Less than (7).

DESCRIPTION

`LT` evaluates to 1 (true) if the left operand has a lower numeric value than the right operand.

EXAMPLES

```
-1 LT 2 → 1
2 LT 1 → 0
2 LT 2 → 0
```

LWRD

Low word (1).

DESCRIPTION

`LWRD` takes a single operand, which is interpreted as an unsigned, 32-bit integer value. The result is the low word (bits 15 to 0) of the operand.

EXAMPLES

```
LWRD 0x12345678 → 0x5678
```

MOD (%)

Modulo (2).

DESCRIPTION

`MOD` produces the remainder from the integer division of the left operand by the right operand. The operands are taken as signed, 32-bit integers and the result is also a signed, 32-bit integer.

`X MOD Y` is equivalent to `X-Y*(X/Y)` using integer division.

EXAMPLES

```
2 MOD 2 → 0
12 MOD 7 → 5
3 MOD 2 → 1
```

NE (<>, !=)

Not equal (7).

DESCRIPTION

`NE` evaluates to 0 (false) if its two operands are identical in value or to 1 (true) if its two operands are not identical in value.

EXAMPLES

```
1 NE 2 → 1
2 NE 2 → 0
'A' NE 'B' → 1
```

NOT (!)

Logical NOT (1).

DESCRIPTION

Use `NOT` to negate a logical argument.

EXAMPLES

```
NOT 0101B → 0
NOT 0000B → 1
```

OR (||)

Logical OR (6).

DESCRIPTION

Use OR to perform a logical OR between two integer operands.

EXAMPLES

```
1010B OR 0000B → 1
0000B OR 0000B → 0
```

SFB

Segment begin (1).

SYNTAX

SFB(*segment* [{+ | -} *offset*])

PARAMETERS

segment	The name of a relocatable segment, which must be defined before SFB is used.
offset	An optional offset from the start address. The parentheses are optional if *offset* is omitted.

DESCRIPTION

SFB accepts a single operand to its right. The operand must be the name of a relocatable segment. The operator evaluates to the absolute address of the first byte of that segment. This evaluation takes place at linking time.

EXAMPLES

```
        NAME  demo
        RSEG  CODE
start   DW   SFB(CODE)
```

Even if the above code is linked with many other modules, start will still be set to the address of the first byte of the segment.

SFE

Segment end (1).

SYNTAX

`SFE (`*`segment`*` [{+ | -} `*`offset`*`])`

PARAMETERS

segment — The name of a relocatable segment, which must be defined before SFE is used.

offset — An optional offset from the start address. The parentheses are optional if *offset* is omitted.

DESCRIPTION

SFE accepts a single operand to its right. The operand must be the name of a relocatable segment. The operator evaluates to the segment start address plus the segment size. This evaluation takes place at linking time.

EXAMPLES

```
      NAME  demo
      RSEG  CODE
end   DW   SFE(CODE)
```

Even if the above code is linked with many other modules, end will still be set to the address of the last byte of the segment.

SHL (<<)

Logical shift left (4).

DESCRIPTION

Use SHL to shift the left operand to the left. The number of bits to shift is specified by the right operand, interpreted as an integer value between 0 and 32.

EXAMPLES

```
00011100B SHL 3 → 11100000B
0000011111111111B SHL 5 → 1111111111100000B
14 SHL 1 → 28
```

SHR (>>)

Logical shift right (4).

DESCRIPTION

Use `SHR` to shift the left operand to the right. The number of bits to shift is specified by the right operand, interpreted as an integer value between 0 and 32.

EXAMPLES

```
01110000B SHR 3 → 00001110B
1111111111111111B SHR 20 → 0
14 SHR 1 → 7
```

SIZEOF

Segment size (1).

SYNTAX

`SIZEOF` *`segment`*

PARAMETERS

`segment` The name of a relocatable segment, which must be defined before `SIZEOF` is used.

DESCRIPTION

`SIZEOF` generates `SFE-SFB` for its argument, which should be the name of a relocatable segment; ie it calculates the size in bytes of a segment. This is done when modules are linked together.

EXAMPLES

```
      NAME   demo
      RSEG   CODE
size  DW    SIZEOF CODE
```

sets `size` to the size of segment `CODE`.

UGT

Unsigned greater than (7).

DESCRIPTION

`UGT` evaluates to 1 (true) if the left operand has a larger absolute value than the right operand.

EXAMPLES

```
2 UGT 1 → 1
-1 UGT 1 → 1
```

ULT

Unsigned less than (7).

DESCRIPTION

`ULT` evaluates to 1 (true) if the left operand has a smaller absolute value than the right operand.

EXAMPLES

```
1 ULT 2 → 1
-1 ULT 2 → 0
```

XOR

Logical exclusive OR (6).

DESCRIPTION

Use `XOR` to perform logical XOR on its two operands.

EXAMPLES

```
0101B XOR 1010B → 0
0101B XOR 0000B → 1
```

ASSEMBLER DIRECTIVES SUMMARY

This chapter gives an alphabetical summary of the assembler directives.

The directives are divided into the following sections:

Module control	Macro processing
Symbol control	Listing control
Segment control	C-style preprocessor
Value assignment	Data definition or allocation
Conditional assembly	Assembler control

For a full description of any directive, see under the directive's category name in the next chapter, *Assembler directives reference*.

DIRECTIVES SUMMARY

The following table gives a summary of all the assembler directives.

Option	*Description*	*Section*
`#define`	Assigns a value to a label.	C-style preprocessor.
`#elif`	Introduces a new condition in an `#if`…`#endif` block.	C-style preprocessor.
`#else`	Assembles instructions if a condition is false.	C-style preprocessor.
`#endif`	Ends a `#if`, `#ifdef`, or `#ifndef` block.	C-style preprocessor.
`#error`	Generates an error.	C-style preprocessor.
`#if`	Assembles instructions if a condition is true.	C-style preprocessor.
`#ifdef`	Assembles instructions if a symbol is defined.	C-style preprocessor.
`#ifndef`	Assembles instructions if a symbol is undefined.	C-style preprocessor.
`#include`	Includes a file.	C-style preprocessor.

Option	*Description*	*Section*
#undef	Undefines a label.	C-style preprocessor.
$	Includes a file.	Assembler control.
/*comment*/	C-style comment delimiter.	Assembler control.
//	C++ style comment delimiter.	Assembler control.
=	Assigns a permanent value local to a module.	Value assignment.
ALIAS	Assigns a permanent value local to a module.	Value assignment.
ALIGN	Aligns the program counter by inserting zero-filled bytes.	Segment control.
ASEG	Begins an absolute segment.	Segment control.
ASSIGN	Assigns a temporary value.	Value assignment.
CASEOFF	Disables case sensitivity.	Assembler control.
CASEON	Enables case sensitivity.	Assembler control.
COL	Sets the number of columns per page.	Listing control.
COMMON	Begins a common segment.	Segment control.
DB	Generates 8-bit byte constants.	Data definition or allocation.
DD	Generates 32-bit double word constants.	Data definition or allocation.
DEFINE	Defines a file-wide value.	Value assignment.
DP	Generates 24-bit double word constants.	Data definition or allocation.
DS	Allocates space for 8-bit bytes.	Data definition or allocation.
DW	Generates 16-bit word constants.	Data definition or allocation.
ELSE	Assembles instructions if a condition is false.	Conditional assembly.

Option	*Description*	*Section*
ELSEIF	Specifies a new condition in an IF…ENDIF block.	Conditional assembly.
END	Terminates the assembly of the last module in a file.	Module control.
ENDIF	Ends an IF block.	Conditional assembly.
ENDM	Ends a macro definition.	Macro processing.
ENDMOD	Terminates the assembly of the current module.	Module control.
ENDR	Ends a repeat structure.	Macro processing.
EQU	Assigns a permanent value local to a module.	Value assignment.
EVEN	Aligns the program counter to an even address.	Segment control.
EXITM	Exits prematurely from a macro.	Macro processing.
EXPORT	Exports symbols to other modules.	Symbol control.
EXTERN	Imports an external symbol.	Symbol control.
IF	Assembles instructions if a condition is true.	Conditional assembly.
IMPORT	Imports an external symbol.	Symbol control.
LIBRARY	Begins a library module.	Module control.
LIMIT	Checks a value against limits.	Value assignment.
LOCAL	Creates symbols local to a macro.	Macro processing.
LSTCND	Controls conditional assembly listing.	Listing control.
LSTCOD	Controls multi-line code listing.	Listing control.
LSTEXP	Controls the listing of macro generated lines.	Listing control.

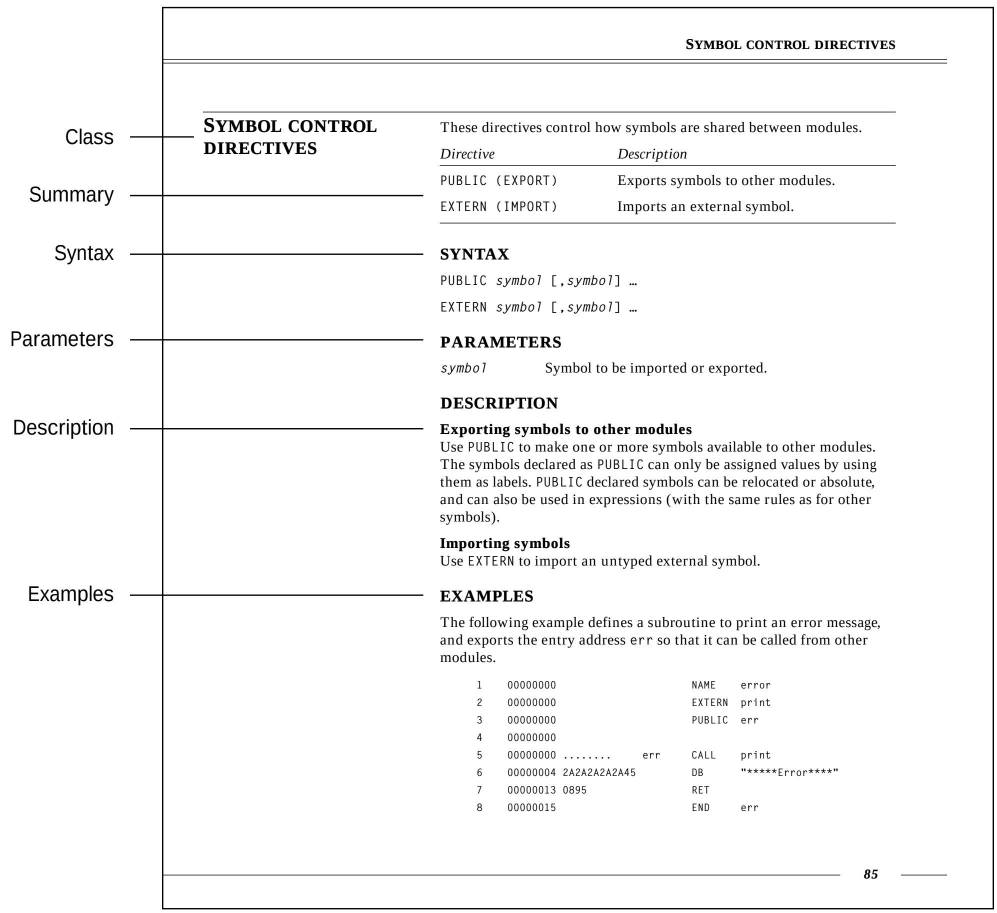
Option	*Description*	*Section*
LSTMAC	Controls the listing of macro definitions.	Listing control.
LSTOUT	Controls assembly listing output.	Listing control.
LSTPAG	Controls the formatting of output into pages.	Listing control.
LSTREP	Controls the listing of lines generated by repeat directives.	Listing control.
LSTXRF	Generates a cross reference table.	Listing control.
MACRO	Defines a macro.	Macro processing.
MODULE	Begins a library module.	Module control.
NAME	Begins a program module.	Module control.
ORG	Sets the location counter.	Segment control.
PAGE	Generates a new page.	Listing control.
PAGSIZ	Sets the number of lines per page.	Listing control.
PROGRAM	Begins a program module.	Module control.
PUBLIC	Exports symbols to other modules.	Symbol control.
RADIX	Sets the default base.	Assembler control.
REPT	Assembles instructions a specified number of times.	Macro processing.
REPTC	Repeats and substitutes characters.	Macro processing.
REPTI	Repeats and substitutes strings.	Macro processing.
RSEG	Begins a relocatable segment.	Segment control.
sfrb	Creates byte-access SFR labels.	Value assignment.
SFRTYPE	Specifies SFR attributes.	Value assignment.

Option	*Description*	*Section*
`sfrw`	Creates word-access SFR labels.	Value assignment.
`STACK`	Begins a stack segment.	Segment control.
`VAR`	Assigns a temporary value.	Value assignment.

ASSEMBLER DIRECTIVES REFERENCE

This chapter gives a list of the AT90S directives, classified according to their function, with a full description of their operation, and the options available for each one.

The format of each section is as follows:



SYMBOL CONTROL DIRECTIVES

SYMBOL CONTROL DIRECTIVES

These directives control how symbols are shared between modules.

Directive	*Description*
`PUBLIC (EXPORT)`	Exports symbols to other modules.
`EXTERN (IMPORT)`	Imports an external symbol.

SYNTAX

`PUBLIC` *`symbol`* `[,`*`symbol`*`] …`

`EXTERN` *`symbol`* `[,`*`symbol`*`] …`

PARAMETERS

`symbol` Symbol to be imported or exported.

DESCRIPTION

Exporting symbols to other modules
Use `PUBLIC` to make one or more symbols available to other modules. The symbols declared as `PUBLIC` can only be assigned values by using them as labels. `PUBLIC` declared symbols can be relocated or absolute, and can also be used in expressions (with the same rules as for other symbols).

Importing symbols
Use `EXTERN` to import an untyped external symbol.

EXAMPLES

The following example defines a subroutine to print an error message, and exports the entry address `err` so that it can be called from other modules.

```
00000000                        NAME    error
00000000                        EXTERN  print
00000000                        PUBLIC  err
00000000
00000000 ........     err       CALL    print
00000004 2A2A2A2A2A45           DB      "*****Error****"
00000013 0895                   RET
00000015                        END     err
```

85

CLASS

The class of directives.

SUMMARY

The class is followed by a summary of the class, and a description of each directive in the class.

SYNTAX

A full syntax definition of each directive.

PARAMETERS

Details of each parameter in the syntax definitions.

DESCRIPTION

A detailed description covering each directive's most general use. This includes information about what the directives are useful for, and a discussion of any special conditions and common pitfalls.

EXAMPLES

Examples, illustrating typical applications of the directives and clarifying any special cases.

SYNTAX CONVENTIONS

In the syntax definitions the following conventions are used:

Parameters, representing what you would type, are shown in italics. So, for example, in:

ORG *expr*

expr represents an arbitrary expression.

Optional parameters are shown in square brackets. So, for example, in:

END [*expr*]

the *expr* parameter is optional.

An ellipsis indicates that the previous item can be repeated an arbitrary number of times. For example:

`LOCAL` *`symbol`* `[,`*`symbol`*`] …`

indicates that `LOCAL` can be followed by one or more symbols, separated by commas.

Alternatives are enclosed in { and } brackets, separated by a vertical bar. For example:

```
LSTOUT{+ | -}
```

indicates that the directive must be followed by either + or -.

LABELS AND COMMENTS

Where a directive must be preceded by a label, this is indicated in the syntax, as in:

`label` `VAR` *`expr`*

All other directives can be preceded by an optional label, which will assume the value and type of the current location counter (PLC), and for clarity this is not included in each syntax definition.

In addition, unless explicitly specified, all directives can be followed by a comment, preceded by ; (semi-colon).

PARAMETERS

The following table shows the correct form of the most commonly-used types of parameter:

Parameter	*What it consists of*
`symbol`	An assembler symbol.
`label`	A symbolic label.
`expr`	An expression; see *Expressions and operators*, page 51.

MODULE CONTROL DIRECTIVES

Module control directives are used to mark the beginning and end of source program modules, and to assign names and types to them.

Directive	*Description*
`NAME (PROGRAM)`	Begins a program module.
`MODULE (LIBRARY)`	Begins a library module.
`ENDMOD`	Terminates the assembly of the current module.
`END`	Terminates the assembly of the last module in a file.

SYNTAX

`NAME` *`symbol`* `[(`*`expr`*`)]`

`MODULE` *`symbol`* `[(`*`expr`*`)]`

`ENDMOD [`*`label`*`]`

`END [`*`label`*`]`

PARAMETERS

`symbol`	Name assigned to module, used by XLIB when referencing the module.
`expr`	Optional expression (0–255) used by the IAR C Compiler.
`label`	An expression or label which can be resolved at assembly time. It is output in the object code as a program entry address.

DESCRIPTION

Beginning a program module

Use `NAME` to begin a program module, and assign a name for future reference by XLINK and XLIB.

Program modules are unconditionally linked by XLINK, even if they are not referenced by other modules.

Beginning a library module
Use `MODULE` to create libraries containing lots of small modules (like run time systems for high level languages), where each module also often represent a single routine. With the multi-module facility you can significantly reduce the number of source and object files needed.

Library modules are only copied into the linked code if a public symbol in the module is referenced by other modules.

Terminating a module
Use `ENDMOD` to define the end of a module.

Terminating the last module
Use `END` to indicate the end of the source file. Any lines after the `END` directive are ignored.

Program entries must be either relocatable or absolute (no externals allowed), and will show up in XLINK load maps, as well as in some of the hexadecimal absolute output formats.

The following rules apply to multi-module assemblies:

- At the beginning of a new module all user symbols are deleted, except for those created by `DEFINE`, `#define`, or `MACRO`, the location counters are cleared, and the mode is set to absolute.
- List control directives remain in effect throughout the assembly.

Note that `END` must always be used in the *last* module, and that there must not be any source lines (except for comments and list control directives) between an `ENDMOD` and a `MODULE` directive.

If the `NAME` or `MODULE` directive is missing, the module will be assigned the name of the source file and the attribute `program`.

EXAMPLES

The following example defines three modules:

```
MODULE
.
. Module #1
.
ENDMOD
MODULE
.
. Module #2
```

```
.
ENDMOD
MODULE
.
. Last module
.
END
```

SYMBOL CONTROL DIRECTIVES

These directives control how symbols are shared between modules.

Directive	*Description*
`PUBLIC (EXPORT)`	Exports symbols to other modules.
`EXTERN (IMPORT)`	Imports an external symbol.

SYNTAX

`PUBLIC` *`symbol`* `[,`*`symbol`*`] …`

`EXTERN` *`symbol`* `[,`*`symbol`*`] …`

PARAMETERS

`symbol`	Symbol to be imported or exported.

DESCRIPTION

Exporting symbols to other modules

Use `PUBLIC` to make one or more symbols available to other modules. The symbols declared as `PUBLIC` can only be assigned values by using them as labels. `PUBLIC` declared symbols can be relocated or absolute, and can also be used in expressions (with the same rules as for other symbols).

The `PUBLIC` directive always exports full 32-bit values, which makes it feasible to use global 32-bit constants also in assemblers for 8 and 16-bit processors. With the `LOW`, `HIGH`, `BYTE2`, and `BYTE3` operators any part of such a constant can be loaded in a 8 or 16-bit register or word.

There are no restrictions on the number of `PUBLIC` declared symbols in a module.

Importing symbols
Use EXTERN to import an untyped external symbol.

EXAMPLES

The following example defines a subroutine to print an error message, and exports the entry address err so that it can be called from other modules.

Since the message is enclosed in double quotes, the string will be followed by a zero byte.

It defines print as an external routine; the address will be resolved at link time.

```
1    00000000                         NAME    error
2    00000000                         EXTERN  print
3    00000000                         PUBLIC  err
4    00000000
5    00000000 ........     err        CALL    print
6    00000004 2A2A2A2A2A45            DB      "*****Error****"
7    00000013 0895                    RET
8    00000015                         END     err
```

SEGMENT CONTROL DIRECTIVES

The segment directives control how code and data are generated.

Directive	*Description*
ASEG	Begins an absolute segment.
RSEG	Begins a relocatable segment.
STACK	Begins a stack segment.
COMMON	Begins a common segment.
ORG	Sets the location counter.
ALIGN	Aligns the program counter by inserting zero-filled bytes.
EVEN	Aligns the program counter to an even address.

SYNTAX

ASEG [*start* [(*align*)]]

RSEG *segment* [:*type*] [(*align*)]

STACK *segment* [:*type*] [(*align*)]

COMMON *segment* [:*type*] [(*align*)]

ORG *expr*

ALIGN [*align*]

EVEN

PARAMETERS

start	A start address which has the same effect as using an ORG directive at the beginning of the absolute segment.
segment	The name of the segment.
type	The memory type; one of:
	UNTYPED (the default), CODE, or DATA.
	In addition, the following types are provided for compatibility with the IAR C Compilers:
	XDATA, IDATA, BIT, REGISTER, and CONST.
expr	Address to set location counter to.
align	Power of two to which the address should be aligned, in the range 0 to 30.

DESCRIPTION

Beginning an absolute segment

Use ASEG to set the absolute mode of assembly, which is the default at the beginning of a module.

If the parameter is omitted, the start address of the first segment is 0, and subsequent segments continue after the last address of the previous segment.

Beginning a relocatable segment

Use RSEG to set the current mode of the assembly to relocatable assembly mode. The assembler maintains separate location counters (initially set to zero) for all segments, which makes it possible to switch segments and mode anytime without the need to save the current segment location counter.

Up to 256 unique, relocatable segments may be defined in a single module.

Beginning a stack segment

Use STACK to allocate code or data allocated from high to low addresses (vs. the RSEG directive which causes low-to-high allocation).

Note that the contents of the segment are not generated in reverse order.

Beginning a common segment

Use COMMON to place data in memory at the same location as COMMON segments from other modules that have the same name. In other words, all COMMON segments of the same name will start at the same location in memory and overlay each other.

Obviously, the COMMON segment type should not be used for overlaid executable code. A typical application would be where you desire to have a number of different routines share a reusable, common area of memory for data.

It can be practical to have the interrupt vector table in a COMMON segment, thereby allowing access from several routines.

The final size of the COMMON segment is determined by the size of largest occurrence of this segment. The location in memory is determined by the XLINK -Z command; see *Segment control*, page 156.

Specifying the *align* parameter in any of the above directives is equivalent to including an ALIGN directive with the same value.

Setting the location counter

Use ORG to set the location counter of the current segment to the value of an expression. The optional label will assume the value and type of the new location counter.

The result of the expression must be of the same type as the current segment, that is, it is not valid to use ORG 10 during RSEG, since the expression is absolute; instead use ORG $+10. The expression must not contain any forward or external references.

All location counters are set to zero at the beginning of an assembly module.

Aligning a segment

Use `ALIGN` to align the program counter to a specified address boundary. The expression gives the power of two to which the program counter should be aligned. The `EVEN` directive aligns the program counter to an even address (which is equivalent to `ALIGN 1`).

EXAMPLES

Beginning an absolute segment

The following example assembles interrupt routine entry addresses in the appropriate AT90S interrupt vectors using an absolute segment:

```
        EXTERN  reset,IRQ0,IRQ1,TIM1CAPT

        ASEG
        ORG     0h
vec0    DW      TIM1CAPT 0
vec1    DW      TIM1CAPT 1
vec2    DW      TIM1CAPT 2
vec3    DW      TIM1CAPT .. etc

        ORG     15h
reset

        END
```

Beginning a relocatable segment

In the following example the data following the first `RSEG` directive is placed in a relocatable segment called `table`; the `ORG` directive is used to create a gap of six bytes in the table.

The code following the second `RSEG` directive is placed in a relocatable segment called `code`:

```
        EXTERN  divrtn,mulrtn

        RSEG    table
        DW      divrtn,mulrtn

        ORG     $+6
        DW      subrtn
```

```
        RSEG    code
subrtn  MOV     R16,R17
        SUBI    R16,20
        END
```

Beginning a stack segment

The following example defines two 100-byte stacks in a relocatable segment called `rpnstack`:

```
        STACK   rpnstack
parms   DS      100
opers   DS      100

        END
```

The data is allocated from high to low addresses.

Beginning a common segment

The following example defines two common segments containing variables:

```
        NAME    common1
        COMMON  data
count   DD      1
        ENDMOD

        NAME    common2
        COMMON  data
up      DB      1
        ORG     $+2
down    DB      1
        END
```

Because the common segments have the same name, `data`, the variables `up` and `down` refer to the same locations in memory as the first and last bytes of the 4-byte variable `count`.

Aligning a segment

This example starts a relocatable segment, moves to an even address and adds some data. It then aligns to a 64-byte boundary before creating a 64-byte table.

```
        RSEG    data    ; Start a relocatable data
                        segment

        EVEN            ; Ensure it is on an even
                        boundary
target  DW      1       ; target and best will be on an
                        even boundary
best    DW      1
        ALIGN   6       ; Now align to a 64 byte
                        boundary
results DS      64      ; And create a 64 byte table
        END
```

VALUE ASSIGNMENT DIRECTIVES

These directives are used to assign values to symbols.

Directive	*Description*
`VAR (ASSIGN)`	Assigns a temporary value.
`EQU (ALIAS,=)`	Assigns a permanent value local to a module.
`DEFINE`	Defines a file-wide value.
`LIMIT`	Checks a value against limits.
`sfrb`	Creates byte-access SFR labels.
`sfrw`	Creates word-access SFR labels.
`SFRTYPE`	Specifies SFR attributes.

SYNTAX

label VAR *expr*

label EQU *expr*

label = *expr*

label DEFINE *expr*

```
LIMIT label,min,max,message
[const] sfrb register = value
[const] sfrw register = value
[const] SFRTYPE register attribute [,attribute] = value
```

PARAMETERS

label	Symbol to be defined.
expr	Value assigned to symbol.
register	The special function register.
attribute	One or more of the following:
	`READ` — You can read from this SFR.
	`WRITE` — You can write to this SFR.
	`BYTE` — The SFR must be accessed as a byte.
	`WORD` — The SFR must be accessed as a word.
value	The SFR port address.
min, *max*	The minimum and maximum values allowed for *label*.
message	A text message that will be printed when the symbol is out of range.

DESCRIPTION

Defining a temporary value

Use `VAR` to define a symbol which may be redefined, such as for use with macro variables. Symbols defined with `VAR` cannot be declared `PUBLIC`.

Defining a permanent local value

Use `EQU` or = to assign a value to a symbol.

Use `EQU` to create a local symbol that denotes a number or offset.

The symbol is only valid in the module in which it was defined, but can be made available to other modules with a `PUBLIC` directive.

To import symbols from other modules use `EXTERN`.

Defining a permanent global value

Use `DEFINE` to define symbols that should be known to all modules in the source file.

A symbol which has been given a value with `DEFINE` can be made available to modules in files with the `PUBLIC` directive.

Symbols defined with `DEFINE` cannot be redefined.

Defining special function registers

Use `sfrb` to create special function register labels with attributes `READ`, `WRITE`, and `BYTE` turned on. Use `sfrw` to create special function register labels with attributes `READ`, `WRITE`, or `WORD` turned on. Use `SFRTYPE` to create special function register labels with specified attributes.

Prefix the directive with `const` to disable the `WRITE` attribute assigned to the SFR. You will then get an error/warning when trying to write to the SFR.

Checking symbol values

Use `LIMIT` to check that symbols lie within a specified range. If the symbol is assigned a value outside the range an error message will be printed.

min, *max*	The minimum and maximum values allowed for *label*.
message	A text message that will be printed when the symbol is out of range.

The check will occur as soon as the value is resolved, which will be during linking if the expression contains external references. The *min* and *max* expressions cannot involve references to forward or external labels, ie they must be resolved when encountered.

EXAMPLES

Redefining a symbol

The following example uses `SET` to redefine the symbol `cons` in a `REPT` loop to generate a table of the first 8 powers of 3:

```
        NAME    table
cons    VAR     1
buildit MACRO   times
        DW      cons
```

```
cons    VAR     cons * 3
        IF      times > 1
        buildit times - 1
        ENDIF
        ENDM
main    buildit 4
        END
```

It generates the following code:

```
  1   00000000                      NAME    table
  2   00000001              cons    VAR     1
 10   00000000              main    buildit 4
 10   00000000              main    buildit 4
 10.1  00000000 0100                DW      cons
 10.2  00000003             cons    VAR     cons * 3
 10.3  00000002                     IF      4 > 1
 10.4  00000002                     buildit 4 - 1
 10.5  00000002 0300                DW      cons
 10.6  00000009             cons    VAR     cons * 3
 10.7  00000004                     IF      4 - 1 > 1
 10.8  00000004                     buildit 4 - 1 - 1
 10.9  00000004 0900                DW      cons
 10.10 0000001B             cons    VAR     cons * 3
 10.11 00000006                     IF      4 - 1 - 1 > 1
 10.12 00000006                     buildit 4 - 1 - 1 - 1
 10.13 00000006 1B00                DW      cons
 10.14 00000051             cons    VAR     cons * 3
 10.15 00000008                     IF      4 - 1 - 1 - 1 > 1
 10.16 00000008                     buildit 4 - 1 - 1 - 1 - 1
 10.17 00000008                     ENDIF
 10.18 00000008                     ENDM
 10.19 00000008                     ENDIF
 10.20 00000008                     ENDM
 10.21 00000008                     ENDIF
 10.22 00000008                     ENDM
 10.23 00000008                     ENDIF
 10.24 00000008                     ENDM
 11    00000008                     END
```

Using local and global symbols

In the following example the symbol `value` defined in module `add1` is local to that module; a distinct symbol of the same name is defined in module `add2`. The `DEFINE` symbol is used to declare `locn` for use anywhere in the file:

```
        NAME    add1
locn    DEFINE  020h
value   EQU     77
        CLR     R27
        LDI     R26,locn
        LD      R16,X
        LDI     R17,value
        ADD     R16,R17
        RET
        ENDMOD

        NAME    add2
value   EQU     88
        CLR     R27
        LDI     R26,locn
        LD      R16,X
        LDI     R17,value
        ADD     R16,R17
        RET
        END
```

The symbol `locn` defined in module `add1` is also available to module `add2`.

Using special function registers

In this example a number of sfr variables are declared with a variety of access capabilities.

```
sfrb portd                = 0x12   /* byte read/write
                                   access */
sfrw ocr1                 = 0x2A   /* word read/write
                                   access */
const sfrb pind           = 0x10   /*byte read only access
                                   */
SFRTYPE portb write, byte = 0x18   /* byte write only
                                   access */
```

Using the LIMIT directive

The following example sets the value of a variable called `speed` and then checks it (at assembly time) to see if it is in the range 10 to 30. This might be useful if `speed` was often changed at compile time, but values outside a defined range would cause undesirable behaviour.

```
speed   VAR     23
LIMIT   speed,10,30,"fred out of range"
```

CONDITIONAL ASSEMBLY DIRECTIVES

These directives provide logical control over the selective assembly of source code.

Directive	*Description*
`IF`	Assembles instructions if a condition is true.
`ELSE`	Assembles instructions if a condition is false.
`ELSEIF`	Specifies a new condition in an `IF`…`ENDIF` block.
`ENDIF`	Ends an `IF` block.

SYNTAX

`IF` *`condition`*

`ELSE`

`ELSEIF` *`condition`*

`ENDIF`

PARAMETERS

condition One of the following:

An absolute expression	The expression must not contain forward or external references, and any non-zero value is considered as true.
string1=string2	The condition is true if *string1* and *string2* have the same length and contents.
string1<>string2	The condition is true of *string1* and *string2* have different length or contents.

DESCRIPTION

Use the `IF` … `ELSE` … `ENDIF` directives to control the assembly process at assembly time. If the condition following the `IF` directive is not true, the subsequent instructions will not generate any code (ie it will not be assembled or syntax checked) until an `ELSE` or `ENDIF` directive is found.

Use `ELSEIF` to introduce a new condition after an `IF` directive.

Conditional assembler directives may be used anywhere in an assembly, but have their greatest use in conjunction with macro processing.

All assembler directives (except for `END`), and file inclusion, may be disabled by the conditional directives. Each `IF`*xx* directive must be terminated by an `ENDIF` directive. The `ELSE` directive is optional, and if used, it must be inside a `IF` … `ENDIF` block.

`IF` … `ENDIF` and `IF` … `ELSE` … `ENDIF` blocks may be nested to any level.

EXAMPLES

The following macro subtracts a constant from the register ‘r’.

```
sub     MACRO   r,c
        IF      c=1
        DEC     r
        ELSE
        SUBI    r,c
```

```
        ENDIF
        ENDM
```

If the argument to the macro is 2 it generates an `SUBI` instruction to save instruction cycles; otherwise it generates a `DEC` instruction.

It could be tested with the following program:

```
main    LDI     R16,17
        sub     R16,2
        LDI     R17,22
        sub     R17,1
        RET

        END
```

MACRO PROCESSING DIRECTIVES

These directives allow user macros to be defined.

Directive	*Description*
`MACRO`	Defines a macro.
`ENDM`	Ends a macro definition.
`EXITM`	Exits prematurely from a macro.
`LOCAL`	Creates symbols local to a macro.
`REPT`	Assembles instructions a specified number of times.
`REPTC`	Repeats and substitutes characters.
`REPTI`	Repeats and substitutes strings.
`ENDR`	Ends a repeat structure.

SYNTAX

name `MACRO [`*argument*`] …`

`ENDM`

`EXITM`

`LOCAL` *symbol* `[,`*symbol*`] …`

`REPT` *expr*

`REPTC` *`formal,actual`*

`REPTI` *`formal,actual`* `[,`*`actual`*`] …`

`ENDR`

PARAMETERS

name	The name of the macro.
argument	A symbolic argument name.
symbol	Symbol to be local to the macro.
expr	An expression.
formal	Argument into which each character of *actual* (`REPTC`) or each *actual* (`REPTI`) is substituted.
actual	String to be substituted.

DESCRIPTION

A macro is a user-defined symbol that represents a block of one or more assembler source lines. Once you have defined a macro you can use it in your program just like an assembler directive or assembler mnemonic.

When the assembler encounters a macro, it looks up the macro's definition, and inserts the lines that the macro represents as if they were included in the source file at that position.

Although macros effectively perform simple text substitution, you can control what they substitute by supplying parameters to them.

Defining a macro

You define a macro with the statement:

`macroname` `MACRO [`*`arg`*`] [`*`arg`*`] …`

Here *`macroname`* is the name you are going to use for the macro, and `arg` is an argument for values you want to pass to the macro when it is expanded.

For example, you could define a macro `ERROR` as follows:

```
errmac  MACRO   text
        CALL    abort
        DB      text,0
        ENDM
```

This uses a parameter `text` to set up an error message for a routine `abort`. You would call the macro with a statement such as:

```
        errmac   'Disk not ready'
```

This will be expanded by the assembler to:

```
        CALL     abort
        DB       'Disk not ready',0
```

If you omit a list of one or more arguments, the arguments you supply when calling the macro are called `\1` to `\9` and `\A` to `\Z`.

The previous example could therefore be written as follows:

```
errmac  MACRO
        CALL     abort
        DB       \1,0
        ENDM
```

Use the `EXITM` directive to generate a premature exit from a macro.

`EXITM` is not allowed inside `REPT` … `ENDR`, `REPTC` … `ENDR`, or `REPTI` … `ENDR`.

Use `LOCAL` to create symbols local to a macro. The `LOCAL` directive must be used before the symbol is used.

Each time a macro is expanded new instances of local symbols are created by the `LOCAL` directive, so it is legal to use local symbols in recursive macros.

It is illegal to *redefine* a macro.

Passing special characters

Macro arguments that include commas or white space can be forced to be interpreted as one argument by using the matching quote characters `<` and `>` in the macro call.

For example:

```
macld   MACRO   op
        LDI     op
        ENDM
```

It could be called using:

```
macld   <R16, 1>
END
```

You can redefine the macro quote characters with the `-M` command line option; see *Macro quote chars (-M)*, page 36.

How macros are processed

There are three distinct phases in the macro process:

- Scanning and saving of macro definitions is performed by the assembler. The text between `MACRO` and `ENDM` is saved but not syntax checked. Include file references `$file` are recorded and will be included during macro *expansion*.
- A macro call forces the assembler to invoke the macro processor (expander) which switches (if not already in a macro) the assembler input stream from a source file to the output from the macro expander (which takes its input from the requested macro definition).

  The macro expander has no knowledge of assembler symbols since it only deals with text substitutions at source level. Before a line from the called macro definition is handed over to the assembler, the expander scans the line for all occurrences of symbolic macro arguments, and replaces them with their expansion arguments.
- The expanded line is then processed as any other assembler source line. The input stream to the assembler will continue to be the output from the macro processor, until all lines of the current macro definition have been read.

Repeating statements

Use the `REPT` **...** `ENDR` structure to assemble the same block of instructions a number of times. If *`expr`* evaluates to 0 nothing will be generated.

Use `REPTC` to assemble a block of instructions once for each character in a string. If the string contains a comma it should be enclosed in quotation marks.

Use `REPTI` to assemble a block of instructions once for each string in a series of strings. Strings containing commas should be enclosed in quotation marks.

EXAMPLES

This section gives examples of the different ways in which macros can make assembler programming easier.

Coding in-line for efficiency

In time-critical code it is often desirable to code routines in-line to avoid the overhead of a subroutine call and return. Macros provide a convenient way of doing this.

For example, the following subroutine outputs bytes from a buffer to a port:

```
        NAME    play

portb   VAR     0x18
        RSEG    DATA
buffer  DS      256

        RSEG    CODE
play    LDI     R27,HIGH(buffer)
        LDI     R26,LOW(buffer)
        LDI     R25,255
loop    LD      R0,X+
        OUT     portb,R0
        DEC     R25
        BRNE    loop
        RET
        END
```

The main program calls this routine as follows:

```
doplay  CALL    play
```

For efficiency we can recode this as the following macro:

```
        NAME    play

portb   VAR     0x18
        RSEG    DATA
buffer  DS      256

play    MACRO
        LOCAL   loop
        LDI     R27,HIGH(buffer)
```

```
        LDI     R26,LOW(buffer)
        LDI     R25,255
loop    LD      R0,X+
        OUT     portb,R0
        DEC     R25
        BRNE    loop
        ENDM

        RSEG    CODE
        play
        END
```

Note the use of the `LOCAL` directive to make the label `loop` local to the macro; otherwise an error will be generated if the macro is used twice, as the `loop` label will already exist.

To use in-line code the main program is then simply altered to:

```
doplay  play
```

Using REPTC and REPTI

The following example assembles a series of calls to a subroutine `plot` to plot each character in a string:

```
        NAME    reptc

        EXTERN  plotc
banner  REPTC   chr,"Welcome"
        LDI     R16,'chr'
        CALL    plotc
        ENDR

        END
```

This produces the following code:

```
1    00000000                        NAME    reptc
2    00000000
3    00000000                        EXTERN  plotc
4    00000000                banner  REPTC   chr,"Welcome"
5    00000000                        LDI     R16,'chr'
6    00000000                        CALL    plotc
7    00000000                        ENDR
7.1  00000000 07E5                   LDI     R16,'W'
7.2  00000002 ........               CALL    plotc
```

```
7.3  00000006 05E6                  LDI     R16,'e'
7.4  00000008 ........              CALL    plotc
7.5  0000000C 0CE6                  LDI     R16,'l'
7.6  0000000E ........              CALL    plotc
7.7  00000012 03E6                  LDI     R16,'c'
7.8  00000014 ........              CALL    plotc
7.9  00000018 0FE6                  LDI     R16,'o'
7.10 0000001A ........              CALL    plotc
7.11 0000001E 0DE6                  LDI     R16,'m'
7.12 00000020 ........              CALL    plotc
7.13 00000024 05E6                  LDI     R16,'e'
7.14 00000026 ........              CALL    plotc
8    0000002A
9    0000002A                       END
```

The following example uses `REPTI` to clear a number of memory locations:

```
          NAME    repti

          EXTERN  base,count,init

banner    REPTI   adds,base,count,init
          LDI     R30,LOW(adds)
          LDI     R31,HIGH(adds)
          LDI     R16,0
          STD     Z+0,R16
          ENDR

          END
```

This produces the following code:

```
1     00000000                      NAME    repti
2     00000000
3     00000000                      EXTERN  base,count,init
4     00000000
5     00000000              banner  REPTI   adds,base,count,init
6     00000000                      LDI     R30,LOW(adds)
7     00000000                      LDI     R31,HIGH(adds)
8     00000000                      LDI     R16,0
9     00000000                      STD     Z+0,R16
10    00000000                      ENDR
10.1  00000000 ....                 LDI     R30,LOW(base)
```

```
10.2  00000002 ....             LDI     R31,HIGH(base)
10.3  00000004 00E0             LDI     R16,0
10.4  00000006 0083             STD     Z+0,R16
10.5  00000008 ....             LDI     R30,LOW(count)
10.6  0000000A ....             LDI     R31,HIGH(count)
10.7  0000000C 00E0             LDI     R16,0
10.8  0000000E 0083             STD     Z+0,R16
10.9  00000010 ....             LDI     R30,LOW(init)
10.10 00000012 ....             LDI     R31,HIGH(init)
10.11 00000014 00E0             LDI     R16,0
10.12 00000016 0083             STD     Z+0,R16
11    00000018
12    00000018                  END
```

LISTING CONTROL DIRECTIVES

These directives provide control over the assembler listing.

Directive	*Description*
`LSTCND`	Controls conditional assembly listing.
`LSTCOD`	Controls multi-line code listing.
`LSTEXP`	Controls the listing of macro generated lines.
`LSTMAC`	Controls the listing of macro definitions.
`LSTOUT`	Controls assembly listing output.
`LSTPAG`	Controls the formatting of output into pages.
`LSTREP`	Controls the listing of lines generated by repeat directives.
`LSTXRF`	Generates a cross reference table.
`PAGSIZ`	Sets the number of lines per page.
`COL`	Sets the number of columns per page.
`PAGE`	Generates a new page.

The following directives are provided for backward compatibility only, and are ignored:

`LSTFOR`, `LSTWID`, `TITL`, `STITL`, `PTITL`, and `PSTITL`.

SYNTAX

```
LSTCND{+ | -}

LSTCOD{+ | -}

LSTEXP{+ | -}

LSTMAC{+ | -}

LSTOUT{+ | -}

LSTPAG{+ | -}

LSTREP{+ | -}

LSTXRF{+ | -}

COL columns

PAGSIZ lines

PAGE
```

PARAMETERS

columns	An absolute expression in the range 80 to 132, default 132.
lines	An absolute expression in the range 10 to 150.

DESCRIPTION

Turning the listing on or off

Use `LSTOUT-` to disable all list output except for error messages. This overrides all other list control directives.

The default is `LSTOUT+`, which lists the output (if a list file was specified).

Listing conditional code and strings

Use `LSTCND+` to force the assembler to list source code only for the parts of the assembly that are not disabled by previous conditional `IF` statements, `ELSE`, or `END`.

The default setting is `LSTCND-`, which lists all source lines.

Use `LSTCOD-` to restrict the listing of output code to just the first line of code for a source line.

The default setting is LSTCOD+, which lists more than one line of code for a source line, if needed; ie long ASCII strings will produce several lines of output. Code generation is *not* affected.

Controlling the listing of macros
Use LSTEXP- to disable the listing of macro generated lines. The default is LSTEXP+, which lists all macro generated lines.

Use LSTMAC+ to list macro definitions. The default is LSTMAC-, which disables the listing of macro definitions.

Controlling the listing of generated lines
Use LSTREP- to turn off the listing of lines generated by REPT, REPTC, and REPTI directives.

The default is LSTREP+, which lists the generated lines.

Generating a cross reference table
Use LSTXRF+ to generate a cross reference table at the end of the assembly list for the current module. The table shows values and line numbers, and the type of the symbol.

The default is LSTXRF-, which does not give a cross reference table.

Formatting listed output
Use COL to set the number of columns per page of the assembly list. The default number of columns is 132.

Use PAGSIZ to set the number of printed lines per page of the assembly list. The default number of lines per page is 44.

Use LSTPAG+ to format the assembly output list into pages.

The default is LSTPAG-, which gives a continuous listing.

Use PAGE to generate a new page in the assembly listing if paging is active.

EXAMPLES

Turning the listing on or off
To disable the listing of a debugged section of program:

```
LSTOUT-
; Debugged section

LSTOUT+
; Not yet debugged
```

Listing conditional code and strings

The following example shows how LSTCND+ hides a call to a subroutine that is disabled by an IF directive:

```
        NAME    lstcndtst
        EXTERN  print

        RSEG    prom
debug   VAR     0
begin   IF      debug
        CALL    print
        ENDIF

        LSTCND+
begin2  IF      debug
        CALL    print
        ENDIF
        END
```

This will generate the following listing:

```
 1    00000000                        NAME    lstcndtst
 2    00000000                        EXTERN  print
 3    00000000
 4    00000000                        RSEG    prom
 5    00000000                debug   VAR     0
 6    00000000                begin   IF      debug
 7    00000000                        CALL    print
 8    00000000                        ENDIF
 9    00000000
10    00000000                        LSTCND+
11    00000000                begin2  IF      debug
13    00000000                        ENDIF
14    00000000                        END
```

The following example shows the effect of LSTCOD+ on the code generated by a DB directive:

```
 1    00000000                        NAME    lstcodtst
 2    00000000 01000A006400           DW      1,10,100,100,10000
 3    0000000A
 4    0000000A                        LSTCOD+
 5    0000000A 01000A006400           DW      1,10,100,1000,10000
               E8031027
 6    00000014                        END
```

Controlling the listing of macros

The following example shows the effect of `LSTMAC` and `LSTEXP`:

```
dec2    MACRO   arg
        DEC     arg
        DEC     arg
        ENDM

        LSTMAC-

inc2    MACRO   arg
        INC     arg
        INC     arg
        ENDM

begin   dec2    R16

        LSTEXP-
        inc2    R17
        RET

        END     begin
```

This will produce the following output:

```
     5    00000000
     6    00000000                        LSTMAC-
     7    00000000
    12    00000000
    13    00000000              begin     dec2    R16
    13    00000000              begin     dec2    R16
    13.1  00000000 0A95                   DEC     R16
    13.2  00000002 0A95                   DEC     R16
    13.3  00000004                        ENDM
    14    00000004
    15    00000004                        LSTEXP-
    16    00000004                        inc2    R17
    17    00000008 0895                   RET
    18    0000000A
    19    0000000A                        END     begin
```

Formatting listed output

The following example formats the output into pages of 66 lines each with 80 columns. The LSTPAG directive organizes the listing into pages, starting each module on a new page. The PAGE directive inserts additional page breaks.

```
PAGSIZ 66  ; Page size
COL 80
LSTPAG+
…
ENDMOD
MODULE
…
PAGE
…
```

C-STYLE PREPROCESSOR DIRECTIVES

The following C-language preprocessor directives are available:

Directive	*Description*
#define	Assigns a value to a label.
#undef	Undefines a label.
#if	Assembles instructions if a condition is true.
#ifdef	Assembles instructions if a symbol is defined.
#ifndef	Assembles instructions if a symbol is undefined.
#elif	Introduces a new condition in an #if…#endif block.
#else	Assembles instructions if a condition is false.
#endif	Ends a #if, #ifdef, or #ifndef block.
#include	Includes a file.
#error	Generates an error.

SYNTAX

#define *label text*

#undef *label*

#if *condition*

```
#ifdef label
#ifndef label
#elif condition
#else
#endif
#include {"filename" | <filename>}
#error "message"
```

PARAMETERS

label	Symbol to be defined, undefined, or tested.	
text	Value to be assigned.	
condition	One of the following:	
	An absolute expression	The expression must not contain forward or external references, and any non-zero value is considered as true.
	string1=string2	The condition is true if *string1* and *string2* have the same length and contents.
	string1<>string2	The condition is true if *string1* and *string2* have different length or contents.
filename	Name of file to be included.	
message	Text to be displayed.	

DESCRIPTION

Defining and undefining labels

Use `#define` to define a temporary label.

```
#define label value
```

is similar to:

label `VAR` *value*

Use `#undef` to undefine a label; the effect is as if it had not been defined.

Conditional directives

Use the `#if` … `#else` … `#endif` directives to control the assembly process at assembly time. If the condition following the `#if` directive is not true, the subsequent instructions will not generate any code (ie it will not be assembled or syntax checked) until a `#endif` or `#else` directive is found.

All assembler directives (except for `END`), and file inclusion, may be disabled by the conditional directives. Each `#if` directive must be terminated by a `#endif` directive. The `#else` directive is optional, and if used, it must be inside a `#if` … `#endif` block.

Use `#elif` to introduce a new condition after a `#if` directive.

`#if` … `#elif` … `#else` … `#endif` blocks may be nested to any level.

Use `#ifdef` to assemble instructions up to the next `#else` or `#endif` directive only if a symbol is defined.

Use `#ifndef` to assemble instructions up to the next `#else` or `#endif` directive only if a symbol is undefined.

Including source files

Use `#include` to insert the contents of a file into the source file at a specified point.

Displaying errors

Use `#error` to force the assembler to generate an error, such as in a user-defined test.

EXAMPLES

Using conditional directives

The following example defines the labels tweek and adjust. If adjust is defined then register 16 is decremented by an amount that depends on adjust, in this case 30.

```
#define tweek 1
#define adjust  3

#ifdef  tweek
#if     adjust=1
        SUBI    R16,4
#elif   adjust=2
        SUBI    R16,20
#elif   adjust=3
        SUBI    R16,30
#endif
#endif  /* ifdef tweek*/
```

Including a source file

The following example uses `#include` to include a file defining macros into the source file. For example, the following macros could be defined in `macros.s90`:

```
xch     MACRO   a,b
        PUSH    a
        MOV     a,b
        POP     b
        ENDM
```

The macro definitions can then be included, using `#include`, as in the following example.

```
        NAME    include

;Standard macro definitions
#include "macros.s90"

; Program
main    xch     R16,R17
        RET
        END     main
```

DATA DEFINITION OR ALLOCATION DIRECTIVES

These directives define temporary values or reserve memory.

Directive	*Description*
`DS`	Allocates space for 8-bit bytes.
`DB`	Generates 8-bit byte constants.
`DW`	Generates 16-bit word constants.
`DP`	Generates 24-bit double word constants.
`DD`	Generates 32-bit double word constants.

SYNTAX

`DS` *expr*

`DB` *expr*[,*expr*]

`DW` *expr*[,*expr*]

`DP` *expr*[,*expr*]

`DD` *expr*[,*expr*]

PARAMETERS

expr	A valid absolute, relocatable, or external expression, or an ASCII string. ASCII strings will be zero filled to a multiple of the size. Double-quoted strings will be zero-terminated.

DESCRIPTION

Use `DS` to allocate space. The memory contents are not initialized in any way.

Use `DB`, `DW`, `DP`, and `DD` to initialize and reserve memory space.

EXAMPLES

The following example generates a lookup table of addresses to routines:

```
        NAME    table

table   DW      addsubr,subsubr,clrsubr
```

```
addsubr ADD     R16,R17
        RET

subsubr SUB     R16,R17
        RET

clrsubr CLR     R16
        RET

        END
```

Defining strings

To define a string:

```
mymess  DB 'Please enter your name'
```

To define a string which includes a trailing zero:

```
myCstr  DB "This is a string."
```

To include a single quote in a string, enter it twice; for example:

```
errmess DB 'Don''t understand!'
```

Reserving space

To reserve space for `0xA` bytes:

```
table   DS      0xA
```

ASSEMBLER CONTROL DIRECTIVES

These directives provide control over the operation of the assembler.

Directive	*Description*
`$`	Includes a file.
`/*comment*/`	C-style comment delimiter.
`RADIX`	Sets the default base.
`CASEON`	Enables case sensitivity.
`CASEOFF`	Disables case sensitivity.
`//`	C++ style comment delimiter.

SYNTAX

`$`*`filename`*

`/*`*`comment`*`*/`

`RADIX` *`expr`*

`CASEON`

`CASEOFF`

`//`

PARAMETERS

filename	Name of file to be included. The `$` character must be the first character on the line.
comment	Comment ignored by the assembler.
expr	Default base; default 10 (decimal).

DESCRIPTION

Use `$` to insert the contents of a file into the source file at a specified point.

Use `/*` … `*/` to comment sections of the assembler listing.

Use `RADIX` to set the default base for use in conversion of constants from ASCII source to the internal binary format.

To reset the base from 16 to 10 *`expr`* must be written in hexadecimal. For example:

```
RADIX 0x0A
```

Controlling case sensitivity

Use `CASEON` or `CASEOFF` to turn on or off case sensitivity for user-defined symbols. By default case sensitivity is off.

When `CASEOFF` is active all symbols are stored in upper case, and all symbols used by XLINK should be written in upper case in the XLINK definition file.

EXAMPLES

Including a source file

The following example uses `$` to include a file defining macros into the source file. For example, the following macros could be defined in `macros.s90`:

```
xch     MACRO   a,b
        PUSH    a
        MOV     a,b
        POP     b
        ENDM
```

The macro definitions can be included with a `$` directive, as in:

```
        NAME    include

;Standard macro definitions
$macros.s90

; Program
main    xch     R16,R17
        RET
        END     main
```

Defining comments

The following example shows how `/* ... */` can be used for a multi-line comment:

```
/*
Program to read serial input.
Version 2: 19.6.94
Author: mjp
*/
```

Changing the base

To set the default base to 16:

```
     RADIX D'16
     LD    A,12
```

The immediate argument will then be interpreted as `H'12`.

Controlling case sensitivity

By default `CASEOFF` is active, so in the following example `label` and `LABEL` are identical:

```
label   NOP     ;stored as "LABEL"
        JMP     LABEL
```

However, the following will generate a duplicate label error:

```
label   NOP
LABEL   NOP     ;Error: "LABEL" already defined
        END
```

ASSEMBLER INSTRUCTIONS

This chapter lists the mnemonics of the AT90S processor.

CPU INSTRUCTION MNEMONICS

The following symbols are used in the list of instruction mnemonics:

Symbol	*What it means*
`b`	A bit in a register in the range 0 to 7.
`s`	A bit in the status register in the range 0 to 255.
`k`	Any address.
`k64`	Any constant in the range -64 to +63.
`k255`	Any constant in the range 0 to 255.
`k4096`	Any constant in the range -4094 to +4096.
`k64K`	Any constant in the range 0 to 65535.
`k4M`	Any constant in the range 0 to 4194303.
`p`	A port number in the range 0 to 63.
`p32`	A port number in the range 0 to 31.
`q`	An offset in the range 0 to 63.
`r16`	Any of R16 to R31.
`r32`	Any of R0 to R31.
`rdl`	R24, R26, R28, or R30.
`X`	R27:R26.
`Y`	R29:R28.
`Z`	R31:R30.

ARITHMETIC AND LOGIC INSTRUCTIONS

	First argument	*Second argument*
ADD, ADC, SUB, SBC AND, OR, EOR, MUL[1]	r32	r32

[1] MUL is not available with all processors, but it is accepted by the assembler regardless of the processor option.

SUBI, SBCI, ANDI ORI, SBR, CBR	r16	k255
COM, NEG, INC DEC, TST, CLR	r32	
SER	r16	
ADIW, SBIW	rdl	k64

BRANCH INSTRUCTIONS

	First argument	*Second argument*
JMP	k4M	
CALL	k	
RJMP, RCALL	k4096	
BRCC, BRCS, BREQ BRGE, BRSH, BRID BRIE, BRLO, BRLT BRMI, BRNE, BRHC BRHS, BRPL, BRTC BRTS, BRVC, BRVS	k64	
CPI	r16	k255
BRBC, BRBS	s	k64
CPSE, CP, CPC	r32	r32
SBRC, SBRS	r32	b

	First argument	*Second argument*
SBIC, SBIS	p32	b
IJMP, ICALL, RET, RETI	-	

DATA TRANSFER INSTRUCTIONS

	First argument	*Second argument*
MOV	r32	r32
LDI	r32	k255
LD	r32	X
	r32	X+
	r32	-X
	r32	Y
	r32	Y+
	r32	-Y
	r32	Z
	r32	Z+
	r32	-Z
LDD	r32	Y+q
	r32	Z+q
LDS[2]	r32	k64K

[2] Not available with processor options -v0 or -v2.

ST	X	r32
	X+	r32
	-X	r32
	Y	r32
	Y+	r32
	-Y	r32
	Z	r32
	Z+	r32
	-Z	r32
STD	Y+q	r32
	z+q	r32

	First argument	*Second argument*
STS[3]	r32	k64K

[3] Not available with processor options -v0 or -v2.

	First argument	*Second argument*
LPM	None	
IN, OUT	r32	p
PUSH, POP	r32	
CBI, SBI	p32	b

BIT AND BIT-TEST INSTRUCTIONS

	First argument	*Second argument*
LSL, LSR, ROL ROR, ASR, SWAP	r32	
BST, BLD	r32	b
CLC, CLIM, CLN CLH, CLS, CLT CLV, CLZ, SEC SEI, SEN, SEH SES, SET, SEV, SEZ	None	
BSET, BCLR	s	

MISCELLANEOUS

	First argument	*Second argument*
NOP, SLEEP, WDR	None	

XLINK LINKER

This chapter describes the IAR Systems XLINK Linker, and gives examples of how it can be used.

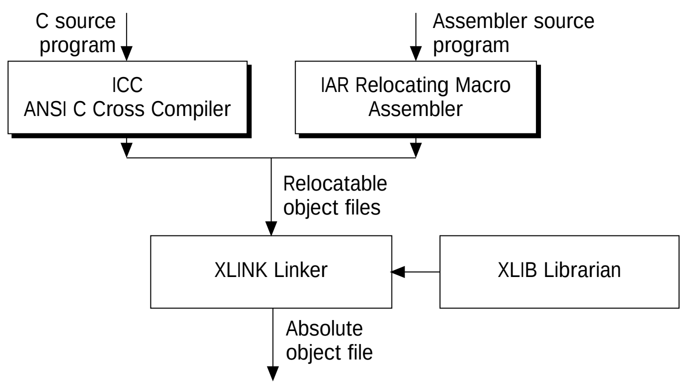
Note that some of the options described in the following chapters may not be available for all assemblers.

INTRODUCTION

The XLINK Linker is a powerful, flexible software tool for use in the development of embedded-controller applications. XLINK reads one or more relocatable object files produced by the IAR Systems Assembler or C Compiler and produces absolute, machine-code programs as output.

It is equally well-suited for linking small, single-file, absolute assembler programs as it is for linking large, relocatable, multi-module, C or mixed C and assembler programs.

The following diagram illustrates the linking process:



OBJECT FORMAT

The object files produced by the IAR Systems Assembler and C Compiler use a proprietary format called UBROF, which stands for Universal Binary Relocatable Object Format. An application can be made up of any number of UBROF relocatable files, in any combination of assembler and C.

XLINK FUNCTIONS

XLINK performs three distinct functions when you link a program:

- It loads modules containing executable code or data from the input file(s).
- It locates each segment of code or data at a user-specified address.
- It links the various modules together by resolving all global (ie non-local, program-wide) symbols that could not be resolved by the assembler or compiler.
- It loads modules needed by the program from user-defined libraries.

LIBRARIES

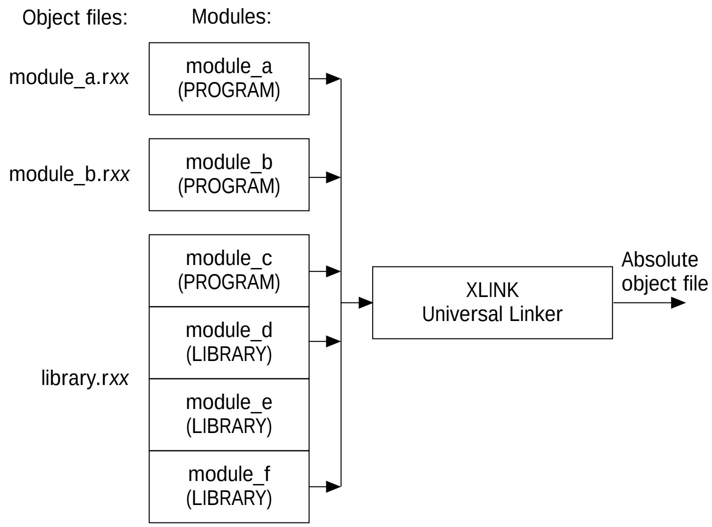
When XLINK reads a library file (which can contain multiple C or assembler modules) it will only load those modules which are actually needed by the program you are linking. This avoids having to load all the modules in a library file when you only need one routine. The XLIB Librarian is used to manage these library files.

OUTPUT FORMAT

The final output produced by XLINK is an absolute, executable object file that can be put into an EPROM, downloaded to a hardware emulator, or executed on the PC using the IAR Systems C-SPY debugger.

INPUT FILES AND MODULES

The following diagram shows how XLINK processes input files and load modules for a typical assembler or C program:



The main program has been assembled from two source files, `module_a.s`*xx* and `module_b.s`*xx*, to produce two relocatable files. Each of these files consists of a single module `module_a` and `module_b`. By default, the assembler assigns the `PROGRAM` attribute to both `module_a` and `module_b`. This means that they will always be loaded and linked whenever the files they are contained in are processed by XLINK; ie the filenames are given as arguments.

The code and data from a single C source file ends up as a single module in the file produced by the compiler. In other words, there is a one to one relationship between C source files and C modules. By default, the compiler gives this module the same name as the original C source file. Libraries of multiple C modules can only be created using XLIB.

Assembler programs can be constructed so that a single source file contains multiple modules, each of which can be a program module or a library module.

LIBRARIES

In the previous diagram, the file `library.rxx` consists of multiple modules, each of which could have been produced by the assembler or the C compiler.

The module `module_c`, which has the `PROGRAM` attribute will *always* be loaded whenever the `library.rxx` file is listed among the input files for the linker. In the run-time libraries, the startup module `cstartup` (which is a required module in all C programs) has the `PROGRAM` attribute so that it will always get included when you link a C project.

The other modules in the `library.rxx` file have the `LIBRARY` attribute. Library modules are only loaded if they contain an entry (a function, variable, or other symbol declared as `PUBLIC`) that is referenced in some way by another module that is loaded. This way, XLINK only gets the modules from the library file that it needs to build the program, and no more. For example, if the entries in `module_e` are not referenced by any loaded module, `module_e` will not be loaded.

This works as follows:

If `module_a` makes a reference to an external symbol, XLINK will search the other input files for a module containing that symbol as a `PUBLIC` entry; ie a module where the entry itself is located. If it finds the symbol declared as `PUBLIC` in `module_c`, it will then load that module (if it has not already been loaded). This procedure is iterative, so if `module_c` makes a reference to an external the same thing happens.

It is important to understand that a library file is just like any other relocatable object file. There is really no distinct type of file called a library (modules have a `LIBRARY` or `PROGRAM` attribute). What makes a file a library is what it contains and how it is used. Put simply, a library is a `.rxx` file that contains a group of related, often-used modules, most of which have a `LIBRARY` attribute so that they can be loaded on a demand-only basis.

CREATING LIBRARIES

You can create your own libraries, or add to existing libraries, using C or assembler modules. The C compiler `-b` option can be used to force a C module to have a `LIBRARY` attribute instead of the default `PROGRAM` attribute. In assembler programs, the `MODULE` directive is used to give a module the `LIBRARY` attribute, and the `NAME` directive is used to give a module the `PROGRAM` attribute.

The XLIB Librarian is used to create and manage libraries. Among other tasks, it can be used to alter the attribute (`PROGRAM/LIBRARY`) of any other module after it has been compiled or assembled.

SEGMENT LOCATION

Once XLINK has identified the modules to be loaded for a program, one of its most important functions is to assign load addresses to the various code and data segments that are being used by the program.

In assembly language programs the programmer is responsible for declaring and naming relocatable segments and determining how they are used. In C programs the compiler creates and uses a set of pre-defined code and data segments, and you have only limited control over segment naming and usage.

LISTING FORMAT

The default XLINK listing format is shown below:

Header

```
################################################################################
#                                                                              #
#      IAR Universal Linker Vx.xx                                              #
#                                                                              #
#         Target CPU    =  xxxxx                                               #
#         List file     =  c:\iar\ew\program\release\list\aout.map             #
#         Output file 1 =  c:\iar\ew\program\release\exe\aout.hex              #
#         Output format =  debug                                               #
#         Command line  =  -o C:\IAR\EW\PROGRAM\Release\exe\aout.hex           #
#                          -rt -f C:\IAR\EW\PROGRAM\ICCxxx\Lnk_kbs.xcl         #
#                          -l C:\IAR\EW\PROGRAM\Release\list\aout.map          #
#                          -x -Ic:\Program Files\iar\ew\program\iccxxx\        #
#                          C:\IAR\EW\PROGRAM\Release\obj\tutor1.rxx            #
#                                                                              #
#                                              (c) Copyright IAR Systems 1996 #
################################################################################
```

Cross reference

```
                ****************************************
                *                                      *
                *           CROSS REFERENCE            *
                *                                      *
                ****************************************

       Program entry at : 00002080  Relocatable, from module : CSTARTUP
```

Module map

```
                ****************************************
                *                                      *
                *             MODULE MAP               *
                *                                      *
                ****************************************

  DEFINED ABSOLUTE ENTRIES
  PROGRAM MODULE, NAME : ?ABS_ENTRY_MOD
          ABSOLUTE ENTRIES        ADDRESS          REF BY MODULE
           ==============         =======          =============
           SET_CCB3                0000FFFF        CSTARTUP
           SET_CCB2                0000FFFF        CSTARTUP
           SET_CCB1                000027FE        CSTARTUP
           SET_CCB0                000020FF        CSTARTUP

    *************************************************************************

  FILE NAME : c:\program files\iar\ew\program\release\obj\tutor1.rxx
  PROGRAM MODULE, NAME : tutor1

  SEGMENTS IN THE MODULE
  ======================
CODE
  Relative segment, address : 0000210C - 00002141
           ENTRIES                ADDRESS          REF BY MODULE
           do_foreground_process   0000210C        Not referred to
               calls direct
           main                    00002120        CSTARTUP
               calls direct
           LOCALS                 ADDRESS
           ?0001                   00002133
           ?0000                   0000213F
    -------------------------------------------------------------------------
CONST
  Relative segment, address : 00002146 - 00002146
           ENTRIES                ADDRESS          REF BY MODULE
           con_char                00002146        Not referred to
    -------------------------------------------------------------------------
WRKSEG
  Common segment, address : 00000024 - 00000043
```

Segment list

```
                ****************************************
                *                                      *
                *        SEGMENTS IN DUMP ORDER        *
                *                                      *
                ****************************************

 SEGMENT              START ADDRESS    END ADDRESS  TYPE  ORG  P/N  ALIGN
 =======              =============    ===========  ====  ===  ===  =====
GLOBREG                  0000001C   -   00000023     rel  stc  pos    2
WRKSEG                   00000024   -   00000043     com  flt  pos    2
IDATA0                         Not in use            rel  flt  pos    1
```

It consists of the following sections:

HEADER

Shows the command line, and options selected for the XLINK command:

Target CPU type
Output file or device name for the listing
Absolute output filename
Output file format
Full list of options

```
################################################################################
#                                                                              #
#      IAR Universal Linker Vx.xx                                              #
#                                                                              #
#           Target CPU    =  xxxxx                                             #
#           List file     =  ncr.map                                           #
#           Output file 1 =  aout.dxx                                          #
#           Output format =  debug                                             #
#           Command line  =  -cxxxxx -rt -x -l ncr.map ncr                     #
#                                                                              #
#                                           (c) Copyright IAR Systems 1996 #
################################################################################
```

The full list of options shows the options specified on the command line. Options in command files specified with the `-f` option are also shown, in brackets.

CROSS REFERENCE

The cross reference consists of the entry list, module map and/or the segment map. It includes the program entry point, used in some output formats for hardware emulator support; see the assembler `END` directive in *Module control directives*, page 88.

Segment list (-xs)

The segment list gives the segments in the order in which they were linked:

List of segments

```
 SEGMENT             START ADDRESS     END ADDRESS   TYPE  ORG  P/N  ALIGN
 =======            =============    ===========   ====  ===  ===  =====
GLOBREG                  0000001C   -   00000023     rel  stc  pos    2
WRKSEG                   00000024   -   00000043     com  flt  pos    2
IDATA0                         Not in use            rel  flt  pos    1
```

Segment name
Segment load address range
Segment type
Allocation direction
Origin
Segment alignment

This lists the start and end address for each segment, and the following parameters:

Parameter	*Description*
TYPE	The type of segment:
	rel Relative.
	stc Stack.
	bnk Banked.
	com Common.
	dse Defined but not used.
ORG	The origin; the type of segment start address:
	stc Absolute, for ASEG segments.
	flt Floating, for RSEG, COMMON, or STACK segments.
P/N	Positive/Negative; how the segment is allocated:
	pos Upwards, for ASEG, RSEG, or COMMON segments.
	neg Downwards, for STACK segments.
ALIGN	The segment is aligned to the next 2^ALIGN address boundary.

Module listing (-xm)

The module map consists of a subsection for each module that was loaded as part of the program. Each subsection shows the following information:

Input file containing the module

Module type (PROGRAM/LIBRARY) and name

List of segments

Segment name

List of public symbols

List of local symbols

Segment name

```
  FILE NAME : c:\program files\iar\ew\program\release\obj\tutor1.rxx
  PROGRAM MODULE, NAME : tutor1

  SEGMENTS IN THE MODULE
  ======================
CODE
  Relative segment, address : 0000210C - 00002141
           ENTRIES                 ADDRESS          REF BY MODULE
           do_foreground_process    0000210C        Not referred to
               calls direct
           main                     00002120        CSTARTUP
               calls direct
           LOCALS                  ADDRESS
           ?0001                    00002133
           ?0000                    0000213F
    -------------------------------------------------------------------
CONST
  Relative segment, address : 00002146 - 00002146
           ENTRIES                 ADDRESS          REF BY MODULE
           con_char                 00002146        Not referred to
    -------------------------------------------------------------------
WRKSEG
  Common segment, address : 00000024 - 00000043
```

For each segment the module map also lists locals and entries.

Symbol listing (-xe)

Shows the entry name and address for each module and filename.

Module name

List of symbols

```
  DEFINED ABSOLUTE ENTRIES
  PROGRAM MODULE, NAME : ?ABS_ENTRY_MOD
          ABSOLUTE ENTRIES        ADDRESS          REF BY MODULE
           ==============         =======          ============
           SET_CCB3                0000FFFF        CSTARTUP
           SET_CCB2                0000FFFF        CSTARTUP
           SET_CCB1                000027FE        CSTARTUP
           SET_CCB0                000020FF        CSTARTUP
```

Symbol

Value

XLINK OPTIONS SUMMARY

XLINK options allow you to control the operation of XLINK from the command line.

The options are divided into the following sections, corresponding to the pages in the **XLINK** options in the Embedded Workbench version:

Output	List
#define	Include
Error	

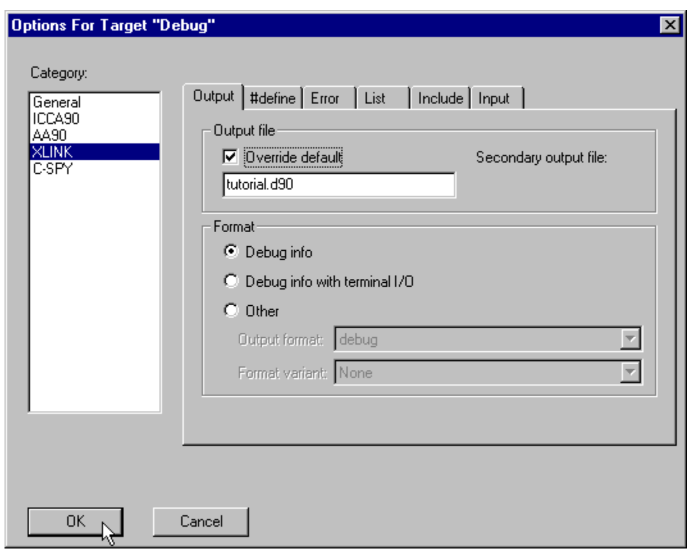
The *Command line* and *Segment control* sections provide information about additional options which are only available in the command line version, or in an XCL command file.

For full reference about each option refer to the following chapter, *XLINK options reference*.

SETTING XLINK OPTIONS

Setting XLINK options in the Embedded Workbench

To set XLINK options in the Embedded Workbench choose **Options...** from the **Project** menu, and select **XLINK** in the **Category** list to display the XLINK options pages:



Then click the tab corresponding to the category of options you want to view or change.

Setting XLINK options from the command line

To set options from the command line, either:

- Specify the options on the command line, after the `xlink` command.
- Specify the options in an XCL command file, and include this on the command line with `-f` *`file`* command.
- Specify the options in the `XLINK_ENVPAR` environment variable; see the *AT90S Command Line Interface Guide*.

SUMMARY OF OPTIONS

The following is a summary of all the XLINK options. For a full description of any option, see under the option's category name in the next chapter, *XLINK options reference*.

Option	*Description*	*Section*
`-!`	Comment delimeter.	Command line
`-A` *`file,…`*	Load as PROGRAM.	Input
`-B`	Always generate output.	Error
`-b`*`bank_def`*	Define banked segments.	Segment control
`-C` *`file, …`*	Conditionally load input files.	Command line
`-c`*`cpu`*	Processor type.	Command line
`-D`*`symbol=value`*	Define symbol.	#define
`-d`	Disable code generation.	Command line
`-E` *`file,…`*	Inherent, no object code.	Input
`-e`*`new=old`*`[,`*`old`*`] …`	Rename external symbols.	Command line
`-F`*`format`*	Output format.	Output
`-f` *`file`*	XCL filename.	Include
`-G`	No global type checking.	Error
`-I`*`pathname`*	Include paths.	Include

Option	*Description*	*Section*
-l*file*	Generate linker listing.	List
-m	Use less host memory.	Command line
-n	Ignore local symbols.	Command line
-o *file*	Output file.	Output
-p*lines*	Lines/page.	List
-R	Disable range check.	Error
-r	Debug info.	Output
-rt	Debug info with terminal I/O.	Output
-S	Silent operation.	Command line
-t	Temporary file.	Command line
-w	Disable warnings.	Error
-x[*sem*]	Cross reference.	List
-Y[*char*]	Format variant.	Output
-Z*seg_def*	Define segments.	Segment control
-z	Segment overlap warnings.	Error

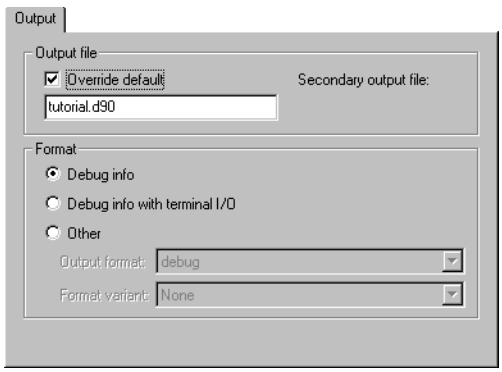
XLINK OPTIONS REFERENCE

This section gives details of the XLINK options classified according to their function.

OUTPUT

The output options are used to specify the output format and the level of debugging information.

Embedded Workbench



Command line

`-o` *`file`*	Output file.
`-r`	Debug info.
`-rt`	Debug info with terminal I/O.
`-F`*`format`*	Output format.
`-Y[`*`char`*`]`	Format variant.

OUTPUT FILE (-o)

Syntax: `-o` *`file`*

Use **Output file** (`-o`) to specify the name of the XLINK output file. If a name is not specified the linker will use the name `aout.hex`. If a name is supplied without a file type, the default file type for the selected output format (**Output format** (`-F`) option) will be used.

If a format is selected that generates two output files, the user-specified file type (`.a90`) will only affect the primary output file (first format).

DEBUG INFO (-r)

Syntax: `-r`

Use **Debug info** (`-r`) to output a file in DEBUG (AUBROF) format, with a `.d90` extension, to be used with the C-SPY debugger, or emulators which support the IAR Systems DEBUG format.

Specifying **Debug info** (`-r`) overrides any **Output format** (`-F`) option.

DEBUG INFO WITH TERMINAL I/O (-rt)

Syntax: `-rt`

Use **Debug info with terminal I/O** (`-rt`) to use the output file with the C-SPY debugger and emulate terminal I/O.

OUTPUT FORMAT (-F)

Syntax: `-F`*`format`*

Use **Output format** (`-F`) to select the output format.

The environment variable `XLINK_FORMAT` can be set to install an alternate default format on your system; see *XLINK_FORMAT* in the *AT90S Command Line Interface Guide*.

The parameter should be one of the supported XLINK output formats; for details of the formats see the chapter *XLINK output formats*.

If not specified, the default `INTEL-EXTENDED` format will be used.

Note that specifying the **Output format** (`-F`) option as `DEBUG` does not include C-SPY debug support. Use the **Debug info** (`-r`) option instead.

FORMAT VARIANT (-Y)

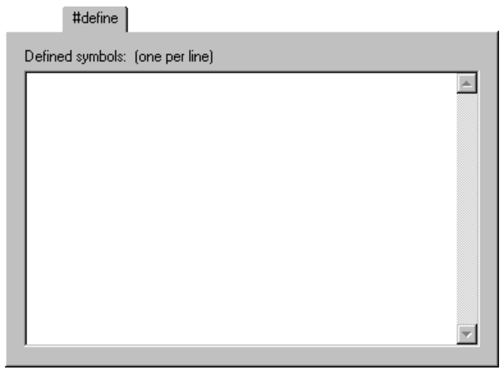
Syntax: `-Y[`*`char`*`]`

Use **Format variant** (`-Y`) to select enhancements available for some output formats. For more information see the chapter *XLINK output formats*.

#define

The **#define** option allows you to define symbols.

Embedded Workbench



Command line

`-D`*`symbol`*`=`*`value`* Define symbol.

DEFINE SYMBOL (-D)

Syntax: `-D`*`symbol`*`=`*`value`*

where *`symbol`* is any external (`EXTERN`) symbol in the program that is not defined elsewhere, and *`value`* the value to be assigned to *`symbol`*.

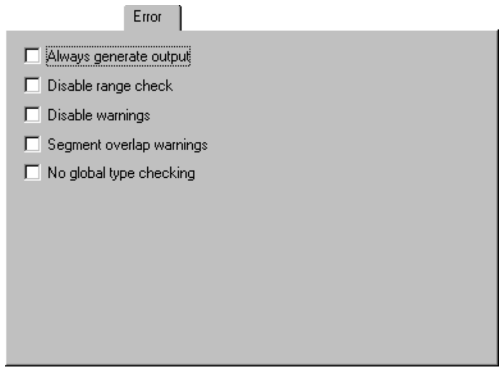
Use **Define symbol** (`-D`) to define absolute symbols at link time. This is especially useful for configuration purposes. Any number of symbols can be defined using the XCL file mode of XLINK operation. The symbol(s) defined in this manner will belong to a special module generated by the linker called `?ABS_ENTRY_MOD`.

XLINK will display an error message if you attempt to redefine an existing symbol.

ERROR

The **Error** options determine the error and warning messages generated by the XLINK Linker.

Embedded Workbench



Command line

`-B`	Always generate output.
`-R`	Disable range check.
`-w`	Disable warnings.
`-z`	Segment overlap warnings.
`-G`	No global type checking.

ALWAYS GENERATE OUTPUT (-B)

Syntax: `-B`

Use **Always generate output** (`-B`) to generate an output file even if a non-fatal error was encountered during the linking process, such as a missing global entry or a duplicate declaration. Normally, XLINK will not generate an output file if an error is encountered. Note that XLINK always aborts on fatal errors, even with `-B`.

The **Always generate output** (`-B`) option allows missing entries to be patched in later in the absolute output image.

DISABLE RANGE CHECK (-R)

Syntax: `-R`

Use **Disable range check** (`-R`) to disable the address range check.

If an address is relocated out of the target CPU's address range (code, external data, or internal data address) an error message is generated. This usually indicates an error in an assembly language module or in the XLINK segment definition list (`-Z` command).

DISABLE WARNINGS (-w)

Syntax: `-w`

Use **Disable warnings** (`-w`) to suppress all warning messages. They will, however, still be counted and shown in the linker's final statistics.

SEGMENT OVERLAP WARNINGS (-z)

Syntax: `-z`

Use **Segment overlap warnings** (`-z`) to reduce segment overlap errors to warnings, making it possible to produce cross-reference maps, etc.

NO GLOBAL TYPE CHECKING (-G)

Syntax: `-G`

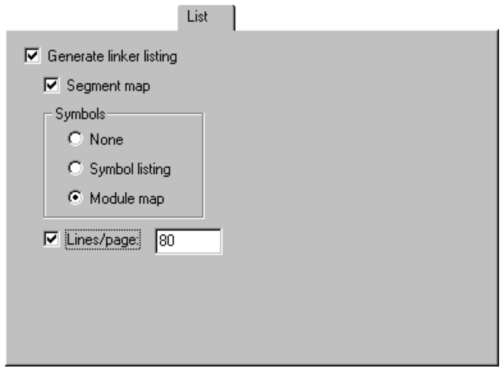
Use **No global type checking** (`-G`) to disable type checking at link time. While a well-written program should not need this option, there may be occasions where it is helpful.

By default, XLINK performs link-time type checking between modules by comparing the external references to an entry with the `PUBLIC` entry (if the information exists in the object modules involved). A warning is printed if there are mismatches; otherwise the linker will continue and not abort.

LIST

The **List** options determine the generation of an XLINK cross-reference listing.

Embedded Workbench



Command line

`-l`*`file`*	Generate linker listing.
`-x[`*`sem`*`]`	Cross reference.
`-p`*`lines`*	Lines/page.

GENERATE LINKER LISTING (-l)

Syntax: `-l`*`file`*

Use **Generate linker listing** (`-l`) to generate a linker listing.

The name of the file or device to which a listing is directed. If an extension is not specified, `.lst` is used by default. However, an extension of `.map` is recommended to avoid confusing linker list files with assembler or compiler list files.

CROSS REFERENCE (-x)

Syntax: `-x[`*sem*`]`

Use **Cross reference** (`-x`) to include a segment map in the XLINK listing file.

The following options are available:

Option	*Command line*	*Description*
Segment map	`s`	A list of all the segments in dump order.
Symbol listing	`e`	An abbreviated list of every entry (global symbol) in every module. This entry map is useful for quickly finding the address of a routine or data element.
Module map	`m`	A list of all segments, local symbols, and entries (public symbols) for every module in the program.

When the `-x` option is specified without any of the optional parameters, a default cross-reference listing will be generated which is equivalent to `-xms`. This includes:

- A header section with basic program information.
- A module load map with symbol cross-reference.
- A segment load map in dump order.

LINES/PAGE (-p)

Syntax: `-p`*lines*

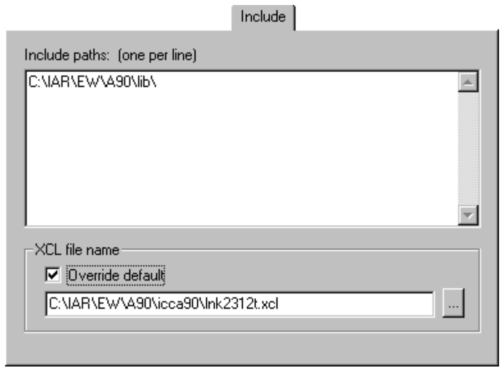
Sets the number of lines per page for the XLINK listings to *lines*, which must be in the range 10 to 150.

The environment variable `XLINK_PAGE` can be set to install a default page length on your system; see *XLINK_PAGE* in the *AT90S Command Line Interface Guide*.

INCLUDE

The **Include** option allows you to set the include path for linker command files, and specify the linker command file.

Embedded Workbench



Command line

`-I`*`pathname`*	Include paths.
`-f` *`file`*	XCL filename.

INCLUDE PATHS (-I)

Syntax: `-I`*`pathname`*

Specifies the pathname to be searched for linker command files.

By default, XLINK searches for linker command files only in the current working directory. The **Include paths** (`-I`) option allows you to specify the names of the directories which it will also search if it fails to find the file in the current working directory.

This is equivalent to the `XLINK_DFLTDIR` command line option; see the *AT90S Command Line Interface Guide*.

XCL FILENAME (-f)

Syntax: `-f` *`file`*

Use `-f` to extend the XLINK command line by reading arguments from a command file, just as if they were typed in on the command line. If not specified an extension of `.xcl` is assumed.

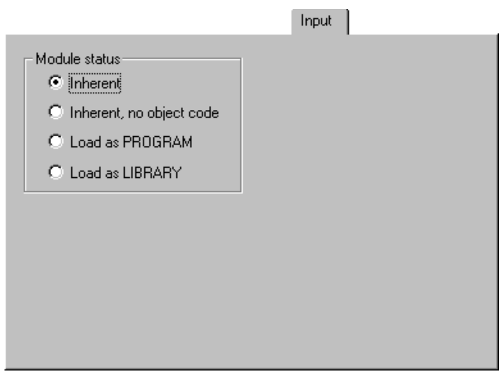
Arguments are entered into the XCL file with a text editor using the same syntax as on the command line. However, in addition to spaces and tabs, the end-of-line CR is also treated as a valid delimiter between arguments. A command line may be extended by the \↵ sequence.

A default XCL file is selected automatically for the **General Target** memory model and processor configuration selected. You can override this by selecting **Override default**, and then specifying an alternative file.

INPUT

The **Input** options define the status of input modules.

Embedded Workbench



Command line

`file,…`	Inherent.
`-E file,…`	Inherent, no object code.
`-A file,…`	Load as PROGRAM.
`-C file,…`	Load as LIBRARY.

INHERENT

Syntax: `file,…`

Use **Inherent** to link files normally, and generate output code.

INHERENT, NO OBJECT CODE (-E)

Syntax: `-E` *`file`*`,…`

Use **Inherent, no object code** (`-E`) to empty load specified input files; they will be processed normally in all regards by the linker but output code will not be generated for these files.

One potential use for this feature is in creating separate output files for programming multiple EPROMs. This is done by empty loading all input files except the ones you want to appear in the output file.

In the following example a project consists of four files, `file1` to `file4`, but we only want object code generated for `file4` to be put into an EPROM:

```
-E file1,file2,file3
file4
-o project.hex
```

To read object files from `v:\general\lib` and `c:\project\lib`:

```
-Iv:\general\lib;c:\project\lib
```

LOAD AS PROGRAM (-A)

Syntax: `-A` *`file`*`,…`

Use **Load as PROGRAM** (`-A`) to temporarily force all of the modules within the specified input files to be loaded as if they were all program modules, even if some of the modules have the `LIBRARY` attribute.

This option is particularly suited for testing library modules before they are installed in a library file, since the `-A` option will override an existing library module with the same entries. In other words, XLINK will load the module from the *input file* specified in the `-A` argument instead of one with an entry with the same name in a library module.

For example, to load the user-written library module `putchar.r03` instead of the standard one in the `CLIB` library:

```
-! these lines are in an XCL file … -!
-A putchar
CLIB
```

This assumes that the putchar file contains the same global entry as one of the modules in `CLIB`.

LOAD AS LIBRARY (-C)

Syntax: `-C file,…`

Use `-C` to temporarily cause all of the modules within the specified input files to be treated as if they were all library modules, even if some of the modules have the `PROGRAM` attribute. This means that the modules in the input files will be loaded only if they contain an entry that is referenced by another loaded module.

For example, to load the user-defined `CSTARTUP` module from the file `cstartup` instead of the program module of the same name in `CLIB`:

```
-! these lines are in an XCL file -!
cstartup
-C CLIB
```

This allows you to test the `CSTARTUP` module before installing it in the library.

COMMAND LINE

The following additional options can be set from the command line or in XCL files:

`-!` *`comment`* `-!`	Comment delimiter.
`-C` *`file`*`, …`	Conditionally load input files.
`-ca90`	Processor type.
`-d`	Disable code generation.
`-e`*`new`*`=`*`old`*`[,`*`old`*`] …`	Rename external symbols.
`-m`	Use less host memory.
`-n`	Ignore local symbols.
`-S`	Silent operation.
`-t`	Temporary file.

The C compiler includes default XCL files for each chip option and memory model.

COMMENT DELIMITER (-!)

Syntax: `-!` *`comment`* `-!`

Use `-!` to bracket off comments in an XLINK `.xcl` file. Unless the `-!` is at the beginning of a line, it must be preceded by a space or tab.

For example, to load the user-written library module `putchar.r90` instead of the standard one in the `CLIB` library:

```
-! these lines are in an XCL file … -!
-A putchar
CLIB
```

This assumes that the `putchar` file contains the same global entry as one of the modules in `CLIB`.

CONDITIONALLY LOAD INPUT FILES (-C)

Syntax: `-C` *`file`*`, …`

Use `-C` to temporarily cause all of the modules within the specified input files to be treated as if they were all library modules, even if some of the modules have the `PROGRAM` attribute. This means that the modules in the input files will be loaded only if they contain an entry that is referenced by another loaded module.

For example, to load the user-defined `CSTARTUP` module from the file `cstartup` instead of the program module of the same name in `CLIB`:

```
-! these lines are in an XCL file -!
cstartup
-C CLIB
```

This allows you to test the `CSTARTUP` module before installing it in the library.

PROCESSOR TYPE (-c)

Syntax: `-ca90`

Use `-c` to set the CPU type to AT90S.

The environment variable `XLINK_CPU` can be set to install a default for the `-c` option so that it does not have to be specified on the command line; see *XLINK_CPU* in the *AT90S Command Line Interface Guide*.

DISABLE CODE GENERATION (-d)

Syntax: `-d`

Use `-d` to disable the generation of output code from XLINK. This option is useful for the trial linking of programs; eg checking for syntax errors, missing symbol definitions, etc. XLINK will run slightly faster for larger programs when this option is used.

RENAME EXTERNAL SYMBOLS (-e)

Syntax: `-e`*`new`*`=`*`old`* `[,`*`old`*`] …`

Use `-e` to configure a program at link time by redirecting a function call from one function to another.

This can also be used for creating stub functions; ie when a system is not yet complete, undefined function calls can be directed to a dummy routine until the real function has been written.

USE LESS HOST MEMORY (-m)

Syntax: `-m`

Use `-m` to reduce the amount of host system memory needed by using file pointers to all segments and modules, instead of reading all input files into RAM. If XLINK runs out of host memory during a link, this option will often help. However, XLINK will run more slowly if the `-m` option is used.

The `-m` option is equivalent to:

```
set XLINK_MEMORY=0
```

See *XLINK_MEMORY* in the *AT90S Command Line Interface Guide*.

IGNORE LOCAL SYMBOLS (-n)

Syntax: `-n`

Use `-n` to ignore all local (non-public) symbols in the input modules. This option speeds up the linking process and can also reduce the amount of host memory needed to complete a link. If `-n` is used, locals will not appear in the listing cross-reference and will not be passed on to the output file.

Note that local symbols are only included in files if they were compiled or assembled with the appropriate option to specify this.

SILENT OPERATION (-S)

Syntax: `-S`

Use `-S` to turn off the XLINK sign-on message and final statistics report so that nothing appears on your screen while it runs. However, it does not disable error and warning messages or the listing output.

TEMPORARY FILE (-t)

Syntax: `-t`

Use `-t` to force XLINK to use a temporary file, with the default name `xlink.tmp` in the current directory, to store a large part of the linker symbol tables. This can significantly reduce the amount of host system memory needed to link a program with a large number of symbols; eg more than 1500. In some cases, it may be necessary to use this option to complete a link process.

Note that the `-t` option can significantly increase the time it takes to link a program. The `-m` file-bound processing option will also be enabled automatically when `-t` is used.

The environment variable `XLINK_TFILE` can be set to an alternate filename (with drive and directory path) to use for the temporary file; see *XLINK_TFILE* in the *AT90S Command Line Interface Guide*.

SEGMENT CONTROL

These options control the allocation of segments.

`-b`*`bank_def`*	Define banked segments.
`-Z`*`seg_def`*	Define segments.

DEFINE BANKED SEGMENTS (-b)

Syntax: `-b [`*`addrtype`*`] [(`*`type`*`)]`
`segments``=`*`first`*`,`*`length`*`,`*`increment`*

where the parameters are as follows:

addrtype	The type of load addresses used when dumping the code: `omitted` — Logical addresses with bank number. `#` — Linear physical addresses. `@` — 64180-type physical addresses.
type	Specifies the memory type for all segments in *segments* or *bankedsegments*, if applicable for the target processor. If omitted it defaults to `UNTYPED`.
segments	The list of banked segments to be linked. The delimiter between segments in the list determines how they are packed: `:` (colon) — The next segment will be placed in a new bank. `,` (comma) — The next segment will be placed in the same bank as the previous one.
first	The start address of the first segment in the banked segment list. This is a 32-bit value: the high-order 16 bits represent the starting bank number while the low-order 16 bits represent the start address for the banks in the logical address area.
length	The length of each bank, in bytes. This is a 16-bit value.
increment	The incremental factor between banks, ie the number that will be added to *first* to get to the next bank. This is a 32-bit value: the high-order 16 bits are the bank increment, and the low-order 16 bits are the increment from the start address in the logical address area.

Use `-b` to allocate banked segments for a program that is designed for bank-switched operation. It also enables the banking mode of linker operation.

There can be more than one `-b` definition.

For example, to specify that the three code segments `BSEG1`, `BSEG2`, and `BSEG3` should be linked into banks starting at 8000, each with a length of 4000, with an increment between banks of 10000:

```
-b(CODE)BSEG1,BSEG2,BSEG3=8000,4000,10000
```

DEFINE SEGMENTS (-Z)

Syntax: `-Z [(`*type*`)]` *segments* `[=|#] [`*start*`-`*end*`,] …` `[`*address*`]`

where the parameters are as follows:

type — Specifies the memory type for all segments in *segments* or *bankedsegments*, if applicable for the target processor. If omitted it defaults to `UNTYPED`.

segments — A list of one or more segments to be linked, separated by commas.

The segments are allocated in memory in the same order as they are listed. Appending +*nnnn* to a segment name increases the amount of memory that XLINK will allocate for that segment by *nnnn* bytes.

= or # — Specifies how segments are allocated.

- = — Allocates the segments so they begin at the start of the specified range (upwards allocation).
- # — Allocates the segments so they finish at the end of the specified range (downwards allocation).

If an allocation operator (and range) is not specified, the segments will be allocated upwards from the last segment that was linked, or from address 0 if no segments have been linked.

start, *end* — Addresses defining a range within which the listed *segments* should be placed.

address — Start address for placing any remaining segments to be allocated.

Use `-Z` to specify how and where segments will be allocated in the memory map.

If the linker finds a segment in an input file that is not defined either with `-Z` or `-b` (banked definition command), a warning will be displayed by the linker. However, the segment will still be allocated as if it were listed in the last segment definition; ie at the next available address.

There can be more than one `-Z` definition.

Additional related topics and optional forms for `-Z` are described below.

Allocation segment types

The following table lists the different types of segments that can be processed by XLINK:

Segment type	*Description*
`STACK`	Allocated from high to low addresses by default. The aligned segment size is subtracted from the load address before allocation, and successive segments are placed below the preceding segment.
`RELATIVE` `COMMON`	Allocated from low to high addresses by default.

If stack segments are mixed with relative or common segments in a segment definition, the linker will produce a warning message but will allocate the segments according to the default allocation set by the first segment in the segment list.

Common segments have a size equal to the largest declaration found for the particular segment. That is, if module `A` declares a common segment `COMSEG` with size 4, while module `B` declares this segment with size 5, the latter size will be allocated for the segment.

Be careful not to overlay common segments containing code or initializers.

Relative and stack segments have a size equal to the sum of the different (aligned) declarations.

Memory types of segments

The optional *type* parameter is used to assign a type to all of the segments in the list. The *type* parameter affects how XLINK processes the segment overlaps. Additionally, it generates information in some of the output formats that are used by some hardware emulators and by C-SPY.

Segment type	*Description*
`BIT`	Bit memory.*
`CODE`	Code memory.
`DATA`	Data memory.
`FAR`	Data in `FAR` memory. XLINK will not check access to it, and a part of a segment straddling a 64 Kbyte boundary will be moved upwards to start at the boundary.
`FARC`, `FARCONST`	Constant in `FAR` memory (behaves as above).
`FARCODE`	Code in `FAR` memory.
`HUGE`	Data in `HUGE` memory. No straddling problems.
`HUGEC`, `HUGECONST`	Constant in `HUGE` memory.
`HUGECODE`	Code in `HUGE` memory.
`NEAR`	Data in `NEAR` memory. Accessed using 16-bit addressing, this segment can be located anywhere in the 32-bit address space.
`NEARC`, `NEARCONST`	Constant in `NEAR` memory.
`NPAGE`	Absolute-addressed data memory.
`UNTYPED`	Default type.
`ZPAGE`	Zero-page data memory.

* The address of a `BIT` segment is specified in bits, not in bytes. `BIT` memory is allocated first.

Range errors

If the ranges specified in the `-Z` command are too short, it will cause either error 24 `Segment` *`segment`* `overlaps segment` *`segment`*, if any segment overlaps another, or error 26 `Segment` *`segment`* `is too long`, if the ranges are too small.

By default, XLINK checks to be sure that the various segments that have been defined (by the `-Z` command and absolute segments) do not overlap in memory.

Examples

To locate `SEGA` at address 0, followed immediately by `SEGB`:

```
-Z(CODE)SEGA,SEGB=0
```

To allocate `SEGA` downwards from `1000H`, followed by `SEGB` below it:

```
-Z(CODE)SEGA,SEGB#1000
```

To allocate specific areas of memory to `SEGA` and `SEGB`:

```
-Z(CODE)SEGA,SEGB=100-200,400-700,1000
```

In this example `SEGA` will be placed between address 100 and 200, if it fits in that amount of space. If it does not, XLINK will try the range 400–700. If none of these ranges are large enough to hold `SEGA`, it will start at 1000.

`SEGB` will be placed, according to the same rules, after segment `SEGA`. If `SEGA` fits the 100–200 range then XLINK will try to put `SEGB` there as well (following `SEGA`). Otherwise, `SEGB` will go into the 400 to 700 range if it is not too large, or else it will start at 1000.

```
-Z(NEAR) SEGA,SEGB=19000-1FFFF
```

Segments `SEGA` and `SEGB` will be dumped at addresses `19000` to `1FFFF` but the default 16-bit addressing mode will be used to access the data (ie `9000` to `FFFF`).

XLINK OUTPUT FORMATS

This chapter gives a summary of the XLINK output formats.

SINGLE OUTPUT FILE

The following formats result in the generation of a single output file:

Format	*Type*	*Extension*	*Address type*
AOMF8051†	binary	from CPU	N
AOMFH8†	binary	from CPU	NL
AOMF8096†	binary	from CPU	N
ASHLING	binary	none	N
ASHLING-6301†	binary	from CPU	N
ASHLING-64180†	binary	from CPU	NS
ASHLING-6801†	binary	from CPU	N
ASHLING-8080†	binary	from CPU	NS
ASHLING-8085†	binary	from CPU	NS
ASHLING-Z80†	binary	from CPU	NS
DEBUG†	binary	.dbg	NL
EXTENDED-TEKHEX†	ASCII	from CPU	NLPS
HP-CODE	binary	.x	NLPS
HP-SYMB	binary	.l	NLPS
INTEL-STANDARD	ASCII	from CPU	N
INTEL-EXTENDED	ASCII	from CPU	NLPS
MILLENIUM (Tektronix)	ASCII	from CPU	N
MOTOROLA	ASCII	from CPU	NLPS
MPDS-CODE	binary	.tsk	N
MPDS-SYMB	binary	.sym	NLPS
MSD	ASCII	.sym	N

Format	*Type*	*Extension*	*Address type*
`NEC-SYMBOLIC†`	ASCII	`.sym`	N
`NEC2-SYMBOLIC†`	ASCII	`.sym`	N
`NEC78K-SYMBOLIC†`	ASCII	`.sym`	N
`PENTICA-A`	ASCII	`.sym`	NLPS
`PENTICA-B`	ASCII	`.sym`	NLPS
`PENTICA-C`	ASCII	`.sym`	NLPS
`PENTICA-D`	ASCII	`.sym`	NLPS
`RCA`	ASCII	from CPU	N
`SYMBOLIC`	ASCII	from CPU	NLPS
`SYSROF†`	binary	`.abs`	NLPS
`TEKTRONIX (Millenium)`	ASCII	`.hex`	N
`TI7000 (TMS7000)`	ASCII	from CPU	N
`TYPED`	ASCII	from CPU	NLPS
`ZAX`	ASCII	from CPU	NLPS

† format depends on the typing of the segments; ie the *`type`* field specified in the XLINK `-Z` option is important.

Address type

The address type is one of the following:

N = Non-banked address.

L = Banked logical address.

P = Banked physical address.

S = Banked 64180 physical address.

TWO OUTPUT FILES

The following formats result in the generation of two output files:

Format	*Code format*	*Exten.*	*Symbolic format*	*Exten.*
DEBUG-MOTOROLA	DEBUG	.a*xx*	MOTOROLA	.obj
DEBUG-INTEL-STD	DEBUG	.a*xx*	INTEL-STD	.hex
DEBUG-INTEL-EXT	DEBUG	.a*xx*	INTEL-EXT	.hex
HP	HP-CODE	.x	HP-SYMB	.l
MPDS	MPDS-CODE	.tsk	MPDS-SYMB	.sym
MPDS-I	INTEL-STANDARD	.hex	MPDS-SYMB	.sym
MPDS-M	MOTOROLA	.s19	MPDS-SYMB	.sym
MSD-I	INTEL-STANDARD	.hex	MSD	.sym
MSD-M	MOTOROLA	.hex	MSD	.sym
MSD-T	MILLENIUM	.hex	MSD	.sym
NEC	INTEL-STANDARD	.hex	NEC-SYMB	.sym
NEC2	INTEL-STANDARD	.hex	NEC2-SYMB	.sym
PENTICA-AI	INTEL-STANDARD	.obj	PENTICA-A	.sym
PENTICA-AM	MOTOROLA	.obj	PENTICA-A	.sym
PENTICA-BI	INTEL-STANDARD	.obj	PENTICA-B	.sym
PENTICA-BM	MOTOROLA	.obj	PENTICA-B	.sym
PENTICA-CI	INTEL-STANDARD	.obj	PENTICA-C	.sym
PENTICA-CM	MOTOROLA	.obj	PENTICA-C	.sym
PENTICA-DI	INTEL-STANDARD	.obj	PENTICA-D	.sym
PENTICA-DM	MOTOROLA	.obj	PENTICA-D	.sym
ZAX-I	INTEL-STANDARD	.hex	ZAX	.sym
ZAX-M	MOTOROLA	.hex	ZAX	.sym

OUTPUT FORMAT VARIANTS

The following enhancements can be selected for the specified output formats, using the **Format variant** (-Y) option:

Output format	*Option*	*Description*
PENTICA-A,B,C,D	Y0	Symbols as modules:symbolname.
and MPDS-SYMB	Y1	Labels and lines as *module:symbolname*.
	Y2	Lines as *module:symbolname*.
AOMF8051	Y0	Extra type of information for Hitex.
INTEL-STANDARD	Y0	End only with :00000001FF.
	Y1	End with PGMENTRY, else :0000001FF.
MPDS-CODE	Y0	Fill with 0xFF instead.
DEBUG, -r	Y#	Old UBROF version.
INTEL-EXTENDED	Y0	Segmented variant.
	Y1	32-bit linear variant.

Refer to the file XLINK.DOC for additional options that are available.

XLIB LIBRARIAN

This chapter describes the XLIB Librarian, which is designed to allow you to create and maintain relocatable libraries of routines.

INTRODUCTION

Like the XLINK Linker, the XLIB Librarian uses the UBROF standard object format (Universal Binary Relocatable Object Format) to allow it to support a wide range of 32-bit byte-oriented processors (applies to almost all current major microprocessors).

LIBRARIES

A library is a single file that contains a number of relocatable object modules, each of which can be loaded independently from other modules in the file as it is needed.

Normally, the modules in a library file all have the `LIBRARY` attribute, which means that they will only be loaded by the linker if they are actually needed in the program. This is referred to as demand loading of modules.

On the other hand, a module with the `PROGRAM` attribute is *always* loaded when the file in which it is contained is processed by the linker.

A library file is no different from any other relocatable object file produced by the assembler or C compiler, except that it includes a number of modules of the `LIBRARY` type.

USING LIBRARIES WITH C PROGRAMS

All C programs make use of libraries, and the IAR Systems C Compilers are supplied with a number of standard library files.

Most C programmers will use the XLIB Librarian at some point, for one of the following reasons:

- To replace or modify a module in one of the standard libraries. For example, the librarian can be used to replace the distribution versions of the `CSTARTUP` and/or `putchar` modules with ones that you have customized.

- To add C or assembler modules to the standard library file so they will always be available whenever a C program is linked.
- To create custom library files that can be linked into their programs, as needed, along with the standard C library.

USING LIBRARIES WITH ASSEMBLER PROGRAMS

If you are only using assembler there is no need to use libraries. However, libraries provide the following advantages, especially when writing medium- and large-sized assembler applications:

- They allow you to combine utility modules used in more than one project into a simple library file. This simplifies the linking process by eliminating the need to include a list of input files for all the modules you need. Only the library module(s) needed for the program will be included in the output file.
- They simplify program maintenance by allowing multiple modules to be placed in a single assembler source file. Each of the modules can be loaded independently as a library module.
- They reduce the number of object files that make up an application, maintenance, and documentation.

You can create your assembly language library files using one of two basic methods:

- A library file can be created by assembling a single assembler source file which contains multiple library-type modules. The resulting library file can then be modified using XLIB.
- A library file can be produced by using the XLIB Librarian to merge any number of existing modules together to form a user-created library.

The `NAME` and `MODULE` assembler directives are used to declare modules as being of `PROGRAM` or `LIBRARY` type, respectively.

XLIB COMMAND SUMMARY

This chapter summarizes the librarian commands, classified according to their function.

A full alphabetical reference list of commands is given in the next chapter.

LIBRARY LISTING COMMANDS

`LIST-ALL-SYMBOLS`	Lists every symbol in modules.
`LIST-CRC`	Lists CRC values of modules.
`LIST-DATE-STAMPS`	Lists dates of modules.
`LIST-ENTRIES`	Lists `PUBLIC` symbols in modules.
`LIST-EXTERNALS`	Lists `EXTERN` symbols in modules.
`LIST-MODULES`	Lists modules.
`LIST-OBJECT-CODE`	Lists low-level relocatable code.
`LIST-SEGMENTS`	Lists segments in modules.

LIBRARY EDITING COMMANDS

`DELETE-MODULES`	Removes modules from a library.
`FETCH-MODULES`	Adds modules to a library.
`INSERT-MODULES`	Moves modules in a library.
`MAKE-LIBRARY`	Changes a module to library type.
`MAKE-PROGRAM`	Changes a module to program type.
`RENAME-ENTRY`	Renames `PUBLIC` symbols.
`RENAME-EXTERNAL`	Renames `EXTERN` symbols.
`RENAME-GLOBAL`	Renames `EXTERN` and `PUBLIC` symbols.
`RENAME-MODULE`	Renames one or more modules.

`RENAME-SEGMENT`	Renames one or more segments.
`REPLACE-MODULES`	Updates executable code.

MISCELLANEOUS LIBRARY COMMANDS

`COMPACT-FILE`	Shrinks library file size.
`DEFINE-CPU`	Specifies CPU type.
`DIRECTORY`	Displays available object files.
`DISPLAY-OPTIONS`	Displays XLIB options.
`ECHO-INPUT`	Command file diagnostic tool.
`EXIT`	Returns to operating system.
`HELP`	Displays help information.
`ON-ERROR-EXIT`	Quits on a batch error.
`QUIT`	Returns to operating system.
`REMARK`	Comment in command file.

XLIB COMMAND REFERENCE

This chapter gives a full syntactic and functional description of all librarian commands.

The individual words of an identifier can be abbreviated to the limit of ambiguity. For example, `LIST-MODULES` can be abbreviated to `L-M`.

When running XLIB you can press ↵ at any time to prompt for information, or display a list of the possible options.

PARAMETERS

The following parameters are common to many of the XLIB commands.

Parameter	*What it means*	
objectfile	File containing object modules.	
start, *end*	The first and last modules to be processed, in one of the following forms:	
	n	The *n*th module.
	$	The last module.
	name	Module *name*.
	name+*n*	The module *n* modules after *name*.
	$-*n*	The module *n* modules before the last.
listfile	File to which a listing will be sent.	
source	A file from which modules will be read.	
destination	The file to which modules will be sent.	

MODULE EXPRESSIONS

In most of the XLIB commands you can or must specify a source module (like *oldname* in `RENAME-MODULE`), or a range of modules (*startmodule*, *endmodule*).

Internally in all XLIB operations modules are numbered upwards from one. Modules may be referred to by the actual name of the module, by the name plus or minus a relative expression, or by an absolute number. The latter is very useful when a module name is very long, unknown, or contains unusual characters (like space or comma). Below is a list of the available variations on module expressions:

Name	*Description*
`3`	The third module.
`$`	The last module.
name`+4`	The module 4 modules after *name*.
name`-12`	The module 12 modules before *name*.
`$-2`	The module 2 modules before the last module.

The command `LIST-MOD FILE,,$-2` will thus list the three last modules in `FILE` on the terminal.

LIST FORMAT

The `LIST` commands give a list of symbols, where each symbol has one of the following prefixes:

Prefix	*Description*
nn`.Pgm`	A program module with relative number *nn*.
nn`.Lib`	A library module with relative number *nn*.
`Ext`	An external in the current module.
`Ent`	An entry in the current module.
`Loc`	A local in the current module.
`Rel`	A standard segment in the current module.
`Stk`	A stack segment in the current module.
`Com`	A common segment in the current module.

COMPACT-FILE

Shrinks library file size.

SYNTAX

`COMPACT-FILE` *`objectfile`*

DESCRIPTION

Use `COMPACT-FILE` to concatenate short, absolute records into longer records of variable length. This will decrease the size of a library file by about 5%, to give library files which take up less time during the loader/linker process.

EXAMPLES

The following command compacts the file `maxmin.`*`rxx`*:

```
COMPACT-FILE maxmin ↵
```

This displays:

```
20 byte(s) deleted
```

DEFINE-CPU

Specifies CPU type.

SYNTAX

`DEFINE-CPU` *`cpu`*

PARAMETERS

`cpu`	The target processor.

DESCRIPTION

This command must be issued before any operations on object files can be done.

EXAMPLES

The following command defines the CPU as IAR2000:

```
DEF-CPU IAR2000 ↵
```

DELETE-MODULES

Removes modules from a library.

SYNTAX

`DELETE-MODULES` *`objectfile start end`*

DESCRIPTION

Use `DELETE-MODULES` to delete the specified modules.

EXAMPLES

The following command deletes module 2 from the file `math.`*`rxx`*:

```
DEL-MOD math 2 2 ↵
```

DIRECTORY

Displays available object files.

SYNTAX

`DIRECTORY [`*`specifier`*`]`

DESCRIPTION

Use `DIRECTORY` to display on the terminal all files of the type that applies to the target processor. If no *`specifier`* is given, the current directory is listed.

EXAMPLES

The following command lists object files in the current directory:

```
DIR ↵
```

It displays:

```
general     770
math        502
maxmin      375
```

DISPLAY-OPTIONS

Displays XLIB options.

SYNTAX

`DISPLAY-OPTIONS [`*`listfile`*`]`

DESCRIPTION

Use `DISPLAY-OPTIONS` to list on the *`listfile`* the names of all the CPUs which are recognized by this version of XLIB. The default file types of object files for the different CPUs are also listed. After that a list of all UBROF tags is output.

EXAMPLES

To list the options to the file `opts.lst`:

```
DISPLAY-OPTIONS opts ↵
```

ECHO-INPUT

Command file diagnostic tool.

SYNTAX

```
ECHO-INPUT
```

DESCRIPTION

`ECHO-INPUT` is useful when debugging command files in batch mode because it makes all command input visible on the terminal. In the interactive mode it has no effect.

EXAMPLES

In a batch file

```
ECHO-INPUT
```

echoes all subsequent XLIB commands.

EXIT

Returns to operating system.

SYNTAX

`EXIT`

DESCRIPTION

Use `EXIT` to exit from XLIB after an interactive session.

EXAMPLES

To exit from XLIB:

`EXIT` ↵

FETCH-MODULES

Adds modules to a library.

SYNTAX

`FETCH-MODULES` *`source destination`* `[`*`start`*`] [`*`end`*`]`

DESCRIPTION

Use `FETCH-MODULES` to append the specified modules to the *`destination`* file. If *`destination`* already exists, it must be empty or contain valid object modules; otherwise it will be created.

EXAMPLES

The following command copies module `mean` from `math.`*`rxx`* to `general.`*`rxx`*:

`FETCH-MOD math general mean` ↵

HELP

Displays help information.

SYNTAX

`HELP [`*`command`*`] [`*`listfile`*`]`

PARAMETERS

command Command for which help is displayed.

DESCRIPTION

If the `HELP` command is given with no parameters, a list of the available commands will be displayed on the terminal. If a parameter is specified, all commands which match the parameter will be displayed with a brief explanation of their syntax and function. A * matches all commands. `HELP` output can be directed to any file.

EXAMPLES

For example, the command:

```
HELP LIST-MOD ↵
```

displays:

```
LIST-MODULES <Object file> [<List file>] [<Start module>]
[<End module>]
    List the module names from [<Start module>] to
    [<End module>].
```

INSERT-MODULES

Moves modules in a library.

SYNTAX

```
INSERT-MODULES objectfile start end {BEFORE | AFTER} dest
```

DESCRIPTION

Use `INSERT-MODULES` to move the specified modules before or after the *dest*.

EXAMPLES

The following command moves the module `mean` before module `min` in the file `math.`*rxx*:

```
INSERT-MOD math mean mean BEFORE min ↵
```

LIST-ALL-SYMBOLS

Lists every symbol in modules.

SYNTAX

`LIST-ALL-SYMBOLS` *objectfile* [*listfile*] [*start*] [*end*]

DESCRIPTION

Use `LIST-ALL-SYMBOLS` to list all symbols (module names, segments, externals, entries, and locals) for the specified modules in the *objectfile*. They are listed to the *listfile*.

Each symbol is identified with a prefix; see *List format*, page 172.

EXAMPLES

The following command lists all the symbols in `math.`*rxx*:

`LIST-ALL-SYMBOLS math` ↵

This displays:

```
1.  Lib  max
      Rel   CODE
      Ent   max
      Loc   A
      Loc   B
      Loc   C
      Loc   ncarry
2.  Lib  mean
      Rel   DATA
      Rel   CODE
      Ext   max
      Loc   A
      Loc   B
      Loc   C
      Loc   main
      Loc   start
3.  Lib  min
      Rel   CODE
      Ent   min
      Loc   carry
```

LIST-CRC

Lists CRC values of modules.

SYNTAX

`LIST-CRC` *`objectfile`* `[`*`listfile`*`] [`*`start`*`] [`*`end`*`]`

DESCRIPTION

Use `LIST-CRC` to list the module names and their associated CRCs for the specified modules.

Each symbol is identified with a prefix; see *List format*, page 172.

EXAMPLES

The following command lists the CRCs for all modules in `math.`*`rxx`*:

```
LIST-CRC math ↵
```

This displays:

```
EC41        1.  Lib  max
ED72        2.  Lib  mean
9A73        3.  Lib  min
```

LIST-DATE-STAMPS

Lists dates of modules.

SYNTAX

`LIST-DATE-STAMPS` *`objectfile`* `[`*`listfile`*`] [`*`start`*`] [`*`end`*`]`

DESCRIPTION

Use `LIST-DATE-STAMPS` to list the module names and their associated generation dates for the specified modules.

Each symbol is identified with a prefix; see *List format*, page 172.

EXAMPLES

The following command lists the date stamps for all the modules in `math.`*`rxx`*:

```
LIST-DATE-STAMPS math ↵
```

This displays:

```
09/Jan/96        1.  Lib  max
09/Jan/96        2.  Lib  mean
09/Jan/96        3.  Lib  min
```

LIST-ENTRIES

Lists `PUBLIC` symbols in modules.

SYNTAX

`LIST-ENTRIES` *`objectfile`* `[`*`listfile`*`] [`*`start`*`] [`*`end`*`]`

DESCRIPTION

Use `LIST-ENTRIES` to list the names and associated entries for the specified modules.

Each symbol is identified with a prefix; see *List format*, page 172.

EXAMPLES

The following command lists the entries for all the modules in `math.`*`rxx`*:

```
LIST-ENTRIES math ↵
```

This displays:

```
1.  Lib  max
      Ent   max
2.  Lib  mean
3.  Lib  min
      Ent   min
```

LIST-EXTERNALS

Lists `EXTERN` symbols in modules.

SYNTAX

`LIST-EXTERNALS` *`objectfile`* `[`*`listfile`*`] [`*`start`*`] [`*`end`*`]`

DESCRIPTION

Use `LIST-EXTERNALS` to list the module names and associated externals for the specified modules.

Each symbol is identified with a prefix; see *List format*, page 172.

EXAMPLES

The following command lists the externals for all the modules in `math.r`*xx*:

```
LIST-EXT math ↵
```

This displays:

```
1.  Lib  max
2.  Lib  mean
      Ext   max
3.  Lib  min
```

LIST-MODULES

Lists modules.

SYNTAX

`LIST-MODULES` *objectfile* [*listfile*] [*start*] [*end*]

DESCRIPTION

Use `LIST-MODULES` to list the module names for the specified modules.

Each symbol is identified with a prefix; see *List format*, page 172.

EXAMPLES

The following command lists all the modules in `math.r`*xx*:

```
LIST-MOD math ↵
```

It produces the following output:

```
1.  Lib  max
2.  Lib  min
3.  Lib  mean
```

LIST-OBJECT-CODE

Lists low-level relocatable code.

SYNTAX

`LIST-OBJECT-CODE` *`objectfile`* `[`*`listfile`*`]`

DESCRIPTION

Use `LIST-OBJECT-CODE` to list the contents of the *`objectfile`* on the *`listfile`* in an ASCII format.

Each symbol is identified with a prefix; see *List format*, page 172.

EXAMPLES

The following command lists the object code of `math.`*`rxx`* to `object.lst`:

```
LIST-OBJECT-CODE math object ↵
```

LIST-SEGMENTS

Lists segments in modules.

SYNTAX

`LIST-SEGMENTS` *`objectfile`* `[`*`listfile`*`] [`*`start`*`] [`*`end`*`]`

DESCRIPTION

Use `LIST-SEGMENTS` to list the module names and associated segments for the specified modules.

Each symbol is identified with a prefix; see *List format*, page 172.

EXAMPLES

The following command lists the segments in module `mean` in the file `math.`*`rxx`*:

```
LIST-SEG math,,mean mean ↵
```

Note the use of two commas to skip the *`listfile`* parameter.

This produces the following output:

```
2.  Lib  mean
      Rel   DATA
      Rel   CODE
```

MAKE-LIBRARY

Changes a module to library type.

SYNTAX

MAKE-LIBRARY *objectfile* [*start*] [*end*]

DESCRIPTION

Use MAKE-LIBRARY to change the module header attributes to conditionally loaded for the specified modules.

EXAMPLES

The following command converts all the modules in main.*rxx* to library modules:

```
MAKE-LIB main ↵
```

MAKE-PROGRAM

Changes a module to program type.

SYNTAX

MAKE-PROGRAM *objectfile* [*start*] [*end*]

DESCRIPTION

Use MAKE-PROGRAM to change the module header attributes to unconditionally loaded for the specified modules.

EXAMPLES

The following command converts module start in main.*rxx* into a program module:

```
MAKE-PROG main start ↵
```

ON-ERROR-EXIT

Quits on a batch error.

SYNTAX

`ON-ERROR-EXIT`

DESCRIPTION

Use `ON-ERROR-EXIT` to make the librarian abort if an error is found. Most suited for use in batch mode.

EXAMPLES

The following batch file aborts if the `FETCH-MODULES` command fails:

```
ON-ERROR-EXIT
FETCH-MODULES math new
```

QUIT

Returns to operating system.

SYNTAX

`QUIT`

DESCRIPTION

Use `QUIT` to exit and return to the operating system.

EXAMPLES

To quit from XLIB:

`QUIT` ↵

REMARK

Comment in command file.

SYNTAX

`REMARK` *`text`*

DESCRIPTION

Use REMARK to include a comment.

EXAMPLES

The following example illustrates the use of a comment in an XLIB command file:

```
REM Now compact file
COMPACT-FILE math
```

RENAME-ENTRY

Renames PUBLIC symbols.

SYNTAX

RENAME-ENTRY *objectfile old new* [*start*] [*end*]

DESCRIPTION

Use RENAME-ENTRY to rename all occurrences of an entry from *old* to *new* in the specified modules.

EXAMPLES

The following command renames the entry for modules 2 to 4 in math.*rxx* from mean to average:

```
RENAME-ENTRY math mean average 2 4 ↵
```

RENAME-EXTERNAL

Renames EXTERN symbols.

SYNTAX

RENAME-EXTERNAL *objectfile old new* [*start*] [*end*]

DESCRIPTION

Use RENAME-EXTERNAL to rename all occurrences of an external from *old* to *new* in the specified modules.

EXAMPLES

The following command renames all external symbols in `math.`*`rxx`* from `error` to `err`:

```
RENAME-EXT math error err ↵
```

RENAME-GLOBAL

Renames `EXTERN` and `PUBLIC` symbols.

SYNTAX

`RENAME-GLOBAL` *`objectfile old new`* `[`*`start`*`] [`*`end`*`]`

DESCRIPTION

Use `RENAME-GLOBAL` to rename all occurrences of an external or entry from *`old`* to *`new`* in the specified modules.

EXAMPLES

The following command renames all occurrences of `mean` to `average` in `math.`*`rxx`*:

```
RENAME-GLOBAL math mean average ↵
```

RENAME-MODULE

Renames one or more modules.

SYNTAX

`RENAME-MODULE` *`objectfile old new`*

DESCRIPTION

Use `RENAME-MODULE` to rename a module. Note that if there is more than one module with name *`old`*, only the first encountered is changed.

EXAMPLES

The following example renames the module `average` to `mean` in the file `math.`*`rxx`*:

```
RENAME-MOD math average mean ↵
```

RENAME-SEGMENT

Renames one or more segments.

SYNTAX

`RENAME-SEGMENT` *objectfile old new* [*start*] [*end*]

DESCRIPTION

Use `RENAME-SEGMENT` to rename all occurrences of a segment from name *old* to *new* in the specified modules.

EXAMPLES

The following example renames all `CODE` segments to `ROM` in the file `math.`*rxx*:

```
RENAME-SEG math CODE ROM ↵
```

REPLACE-MODULES

Updates executable code.

SYNTAX

`REPLACE-MODULES` *source destination*

DESCRIPTION

Use `REPLACE-MODULES` to replace modules with the same name from *source* to *destination*. All replacements are logged on the terminal. The main application for this command is to update large run-time libraries etc.

EXAMPLES

The following example replaces modules in `math.`*rxx* with modules from `newmath.`*rxx*:

```
REPLACE-MOD math newmath ↵
```

This displays:

```
Replacing module 'max'
Replacing module 'mean'
Replacing module 'min'
```

Assembler diagnostics

This chapter lists the errors and warnings for the AT90S Assembler. For details of the XLINK Linker and XLIB Librarian error messages see the chapters *XLINK diagnostics*, and *XLIB diagnostics*.

Introduction

Error messages are printed on the terminal, as well as on the optional list file.

All errors are issued as complete, self-explanatory messages. For example:

```
        ADS    B,C
-----------^
"testfile.s90",4  Error[40]: bad instruction
```

The error message consists of the erroneous source line, with a pointer to the faulty spot, followed by the diagnostic and source line number. If include files are used, error messages will be preceded by the source line number and name of *current* file:

```
        ADS    B,C
-----------^
"subfile.h",4  Error[40]: bad instruction
```

The error messages produced by the assembler fall into six categories:

- Command line error messages.
- Assembly warning messages.
- Assembly error messages.
- Assembly fatal error messages.
- Memory overflow messages.
- Assembler internal error messages.

COMMAND LINE ERROR MESSAGES

Command line errors occur when the assembler is invoked with bad parameters. The most common situation is when a file cannot be opened, or with duplicate, mis-spelled, or missing command line switches. The messages are self-explanatory.

ASSEMBLY ERROR MESSAGES

Assembly error messages are produced when the assembler has found a construct which violates the language rules. These are listed in the section *Error messages*, page 191.

ASSEMBLY WARNING MESSAGES

Assembly warning messages are produced when the assembler has found a construct which probably is due to a programming error or omission. These are listed in the section *Warning messages*, page 199.

ASSEMBLY FATAL ERROR MESSAGES

Assembly fatal error messages are produced when the assembler has found a user error so severe that further processing is not considered meaningful. After the diagnostic message has been issued the assembly is immediately terminated. The fatal error messages are identified as ‘Fatal’ in the error messages list.

MEMORY OVERFLOW MESSAGES

The assembler is a memory-based program that in the case of a system with a small primary memory or in the case of very large source files may run out of memory. This is identified by the special message:

```
* * * ASSEMBLER OUT OF MEMORY * * *
```

`Dynamic memory used:` *`nnnnnn`* `bytes`

If such a situation occurs the solution is either to add system memory or to split source files into smaller modules. However, with 1 Mbyte RAM the assembler capacity should be sufficient for all reasonably sized source files.

ASSEMBLER INTERNAL ERROR MESSAGES

During assembly a number of internal consistency checks are performed and if any of these checks fail the assembler will terminate after giving a short description of the problem. Such errors should normally not occur and should be reported to the IAR Systems technical support group. Please include all possible information about the problem and, preferably, a disk containing a copy of the program that generated the internal error.

ERROR MESSAGES

GENERAL

The following table lists the general error messages:

No	*Error message*	*Suggestion*
0	`Invalid syntax`	The assembler could not decode the expression.
1	`Too deep #include nesting (max. is 10)`	Fatal. Assembler limit for nesting of `#include` files exceeded. Recursive `#include` could be the reason.
2	`Failed to open #include file 'name'`	Fatal. Could not open a `#include` file. File does not exist in specified directories. Check `-I` prefixes.
3	`Invalid #include file name`	Fatal. `#include` file name must be written `<file>` or `"file"`.
4	`Unexpected end of file encountered`	Fatal. End of file encountered within a conditional assembly, the repeat directive or during macro expansion. Probable cause is a missing end of conditional assembly etc.
5	`Too long source line (max. is 512 characters) truncated`	Source line length exceeds assembler limit.
6	`Bad constant`	Character that is not a legal digit was encountered.

No	*Error message*	*Suggestion*
7	`Hexadecimal constant without digits`	Prefix `0x` or `0X` of hexadecimal constant found without following hexadecimal digits.
8	`Invalid floating point constant`	Too large or invalid syntax of floating-point constant.
9	`Too many errors encountered (>100).`	
10	`Space or tab expected`	
11	`Too deep block nesting (max is 50)`	Preprocessor directives are nested too deep.
12	`String too long (max is 509)`	Assembler string length limit exceeded.
13	`Missing delimiter in literal or character constant`	No closing delimiter `'` or `"` was found in character or literal constant.
14	`Missing #endif`	A `#if`, `#ifdef`, or `#ifndef` was found but had no matching `#endif`.
15	`Invalid character encountered: <char>; ignored`	
16	`Identifier expected`	A name of a label or symbol was expected.
17	`')' expected`	
18	`No such pre-processor command: <command>`	`#` was followed by an unknown identifier.
19	`Unexpected token found in pre-processor line`	The pre-processor line was not empty after the argument part was read.
20	`Argument to #define too long (max is <max>)`	

No	*Error message*	*Suggestion*
21	`Too many formal parameters for #define (max is 127)`	
22	`Macro parameter <parameter> redefined`	A `#define` symbol's formal parameter was repeated.
23	`',' or ')' expected`	
24	`Unmatched #else, #endif or #elif`	Fatal. Missing `#if`, `#ifdef`, or `#ifndef`.
25	`#error <error>.`	Printout via the `#error` directive.
26	`'(' expected`	
27	`Too many active macro parameters (max is 256)`	Fatal. Pre-processor limit exceeded.
28	`Too many nested parameterized macros (max is <max>)`	Fatal. Pre-processor limit exceeded.
29	`Too deep macro nesting (max is 100)`	Fatal. Pre-processor limit exceeded.
30	`Actual macro parameter too long (max is 512)`	A single macro (in `#define`) argument may not exceed the length of a source line.
31	`Macro <macro> called with too many parameters`	The number of parameters used was more than the number in the macro declaration.
32	`Macro <macro> called with too few parameters`	The number of parameters used was less than the number in the macro declaration (`#define`).
33	`too many MACRO arguments`	The number of assembler macros exceeds 32.
34	`may not be redefined`	Assembler macros may not be redefined.
35	`no name on macro`	Assembler macro definition without a label was encountered.

No	*Error message*	*Suggestion*
36	`Illegal formal parameter in macro`	A parameter that was not an identifier was found.
37	`ENDM or EXITM not in macro`	`ENDM` directive or `EXITM` directive encountered while not inside macro.
38	`'>' expected but found end-of-line`	A < was found but no matching >.
39	`END before start of module`	End-of-module directive has no matching `MODULE` directive.
40	`bad instruction`	The mnemonic/directive does not exist.
41	`bad label`	Labels must begin with `A-Z`, `a-z`, `_`, or `?`. The succeeding characters must be `A-Z`, `a-z`, `0-9`, `_`, or `?`. Labels cannot have the same name as a predefined symbol.
42	`duplicate label`	The label has already appeared in the label field or been declared as `EXTERN`.
43	`illegal effective address`	The addressing mode (operands) is not allowed for this mnemonic.
44	`',' expected`	A comma was expected but not found.
45	`name duplicated`	The name of `RSEG`, `STACK`, or `COMMON` segments is already used but for something else.
46	`segment type expected`	In `RSEG`, `STACK`, or `COMMON` directive `:` was found but the segment type that should follow was not valid.
47	`segment name expected`	The `RSEG`, `STACK`, and `COMMON` directives need a name.

No	*Error message*	*Suggestion*
48	`value out of range '<range>'`	The value exceeds its limits.
49	`alignment already set`	`RSEG`, `STACK`, and `COMMON` segment do not allow alignment to be set more than once. Use `ALIGN`, `EVEN`, or `ODD` instead.
50	`undefined symbol: <symbol>`	The symbol did not appear in label field nor in an `EXTERN` or `sfr` declaration.
51	`Can't be both PUBLIC and EXTERN`	Symbols can be declared as either `PUBLIC` or `EXTERN`.
52	`EXTERN not allowed`	Reference to `EXTERN` symbols is not allowed in this context.
53	`expression must be absolute`	The expression cannot involve relocatable or external symbols.
54	`expression can not be forward`	The assembler must be able to solve the expression the first time this expression is encountered.
55	`illegal size`	The maximum size for expressions is 32 bits.
56	`too many digits`	The value exceeds the size of the destination.
57	`unbalanced conditional assembly directives`	Missing conditional assembly `IF` or `ENDIF`.
58	`ELSE without IF`	Missing conditional assembly `IF`.
59	`ENDIF without IF`	Missing conditional assembly `IF`.
60	`unbalanced structured assembly directives`	Missing structured assembly `IF` or `ENDIF`.
61	`'+' or '-' expected`	Plus or minus sign missing.
62	`Illegal operation on extern or public symbol`	An illegal operation has been used on a public or external symbol; eg `SET`.

No	*Error message*	*Suggestion*
63	`Illegal operation on non-constant label`	It is not allowed to make a non-constant symbol `PUBLIC` or `EXTERN`.
64	`Extern or unsolved expression`	The expression must be solved at assembly time, ie not include external references.
65	`'=' expected`	Equals sign was missing.
66	`Segment too long (max is <max>)`	The length of `ASEG`, `RSEG`, `STACK`, or `COMMON` segments is larger than the addressable length.
67	`Public did not appear in label field`	A symbol was declared `PUBLIC` but no label with the same name was found in the source file.
68	`End of block-repeat without start`	The repeat directive `REPT` was not found although the `ENDR` directive was.
69	`Segment must be relocatable`	The operation is not allowed on `ASEG`.
70	`Limit exceeded: <error text>, value is: <value> (decimal)`	The value exceeded the limits set with the `LIMIT` directive. The `error text` is set by the user in the `LIMIT` directive.
71	`Symbol '<symbol>' has already been declared EXTERN`	An attempt to redeclare an `EXTERN` as `EXTERN` was made.
72	`Symbol '<symbol>' has already been declared PUBLIC`	An attempt to redeclare a `PUBLIC` as `PUBLIC` was made.
73	`End-of-module missing`	A `PROGRAM` or `MODULE` directive was encountered before `ENDMOD` was found.
74	`Expression must yield non-negative result`	The expression was evaluated to a negative number, whereas a positive number was required.

No	Error message	Suggestion
75	`Repeat directive unbalanced`	This error is caused by a `REPT` directive without a matching `ENDR`, or a an `ENDR` directive without a matching `REPT`.
76	`End of repeat directive is missing`	A `REPT` directive without a closing `ENDR` was encountered.
77	`LOCALs not allowed in this context, (<symbol>)`	Local symbols must be declared within macro definitions.
78	`End of macro expected`	An assembler macro is being defined but there was no end-of-macro.
79	`End of repeat expected`	One of the repeat directives is active, but there was no end-of-repeat found.
80	`End of conditional assembly expected`	Conditional assembly is active but there was no end of `if`.
81	`End of structured assembly expected`	One of the directives for structured assembly is active but has no matching `END`.
82	`Misplaced end of structured assembly`	A directive that terminates one of the structured assembly directives was found but no matching `START` directive is active.
83	`Error in SFR attribute definition`	The `SFRTYPE` directive was used with unknown attributes.

AT90S-SPECIFIC ERROR MESSAGES

The following table lists the AT90S-specific error messages:

No	Error message	Suggestion
400	`Absolute operand is not possible here`	
401	`Accessing SFR incorrectly, check read/write flags`	

No	Error message	Suggestion
402	Accessing SFR using incorrect size	
403	Number out of range. Valid range is -128 (-0x80) to 255 (0xFF).	
404	Bit-number out of range. Valid range is 0 to 7 (0x07).	
405	Address can't be negative.	
406	Register not valid. Use register R16 – R31 here	
407	Register not valid. Use register Y or Z	
408	Port address out of range. Valid range is 0 to 63 (0x3F).	
409	Register displacement out of range. Valid range is 0 to 63 (0x3F).	
410	Address out of range. Valid range is 0 to 8388606 (0x7FFFFE).	
411	Address must be even.	
412	PC offset out of range. Valid range is -128 (-0x80) to 126 (0x7E).	
413	PC offset must be even.	
414	Address out of range. Valid range is 0 to 8190 (0x1FFE).	

No	*Error message*	*Suggestion*
415	`PC offset out of range. Valid range is -4096 (-0x1000) to 4094 (0x0FFE).`	
416	`Port address out of range. Valid range is 0 to 31 (0x1F).`	
417	`Number out of range. Valid range is -32 (-0x20) to 63 (0x3F).`	
418	`Register not valid. Use any of register R24, R26, R28 and R30 here.`	

WARNING MESSAGES

GENERAL

The following table lists the general warning messages:

No	*Warning message*	*Suggestion*
0	`Unreferenced label`	The label was not used as an operand nor was it declared public.
1	`Nested comment`	A C comment was nested.
2	`Unknown escape sequence`	A backslash (\) found in a character constant or string literal was followed by an unknown escape character.
3	`Non-printable character`	A non-printable character was found in a literal or character constant.
4	`Macro or define expected`	
5	`Floating point value out-of-range`	Floating point value is too large to be represented by the floating point system of the target.

No	*Warning message*	*Suggestion*
6	`Floating point division by zero`	
7	`Wrong usage of string operator ('#' or '##'); ignored.`	The current implementation restricts use of the # and ## operators to the token field of parameterized macros. In addition, the # operator must precede a formal parameter.
8	`Macro parameter(s) not used`	
9	`Macro redefined`	
10	`Unknown macro`	
11	`Empty macro argument`	
12	`Recursive macro`	
13	`Redefinition of Special Function Register`	The `SFR` has already been defined.
14	`Division by zero`	Division by 0 in constant expression.
15	`Constant truncated`	The constant was longer than the size of the destination.
16	`Suspicious sfr expression`	A Special Function Register `SFR` is used in an expression, and the assembler cannot check access rights.
17	`Empty module '<module name>', module skipped`	An empty module was created by using `END` directly after `ENDMOD` or `MODULE`, followed by `ENDMOD` with no statements in between.
18	`End of program while in include file`	The program ended while a file was being included.
19	`Symbol '<symb>' duplicated`	

No	*Warning message*	*Suggestion*
20	`Bit symbol cannot be used as operand`	A symbol was declared using the `bit` directive, but since the bit address is not calculated the symbol should not be used.

AT90S-SPECIFIC WARNING MESSAGES

The following table lists the AT90S-specific warning messages:

No	*Warning message*	*Suggestion*
400	`SFR neither defined as READ nor WRITE`	
401	`More than one SFR size attribute defined, using default (byte)`	
402	`No SFR size attribute defined, using default (byte)`	

XLINK DIAGNOSTICS

This chapter describes the errors and warnings produced by the XLINK Linker.

INTRODUCTION

The error messages produced by the XLINK Linker fall into five categories:

- Linker warning messages.
- Linker error messages.
- Linker fatal error messages.
- Memory overflow message.
- Linker internal error messages.

XLINK WARNING MESSAGES

XLINK warning messages will appear when the linker detects something that may be wrong. The code generated may still be correct.

XLINK ERROR MESSAGES

XLINK error messages are produced when the linker detects something wrong. The linking process will not be aborted but the code produced may be faulty.

XLINK FATAL ERRORS

XLINK fatal error messages abort the linking process. They occur when continued linking is useless, ie the fault is irrecoverable.

MEMORY OVERFLOW MESSAGE

XLINK is a memory-based linker. If run on a system with a small main memory or if very large source files are being used, XLINK may run out of memory. This is recognized by the following message:

```
* * * LINKER OUT OF MEMORY * * *
```

`Dynamic memory used:` *`nnnnnn`* `bytes`

If this occurs, the solution is either to add system memory, or to enable file bound processing with the `-m` option. The `-t` option can also be used to save memory.

XLINK INTERNAL ERRORS

During linking, a number of internal consistency checks are performed. If any of these checks fail, the linker will terminate after giving a short description of the problem. These errors will not normally occur, but if they do please report them to the IAR Systems technical support group. Please include all possible information about the problem and also a disk with the program that generated the error.

ERROR MESSAGES

If you get a message that indicates a corrupt object file, reassemble or recompile the faulty file since an interrupted assembly or compilation may produce an invalid object file.

The following table lists the XLINK error messages:

No	*Error message*	*Suggestion*
0	`Format chosen cannot support banking`	Format unable to support banking.
1	`Corrupt file. Unexpected end of file in module` *`module`* `(`*`file`*`) encountered`	Linker aborts immediately. Recompile or reassemble, or check the compatibility between the linker and C compiler.
2	`Too many errors encountered (>100)`	Linker aborts immediately.

No	*Error message*	*Suggestion*
3	`Corrupt file. Checksum failed in module` *`module`* `(`*`file`*`). Linker checksum is linkcheck, module checksum is modcheck`	Linker aborts immediately. Recompile or reassemble.
4	`Corrupt file. Zero length identifier encountered in module` *`module`* `(`*`file`*`)`	Linker aborts immediately. Recompile or reassemble.
5	`Address type for CPU incorrect. Error encountered in module` *`module`* `(`*`file`*`)`	Linker aborts immediately. Check that you are using the right files and libraries.
6	`Program module` *`module`* `declared twice, redeclaration in file` *`file`*`. Ignoring second module`	XLINK will not produce code unless the `-B` option (forced dump) is used.
7	`Corrupt file. Unexpected UBROF – format end of file encountered in module` *`module`* `(`*`file`*`)`	Linker aborts immediately. Recompile or reassemble.
8	`Corrupt file. Unknown or misplaced tag encountered in module` *`module`* `(`*`file`*`). Tag` *`tag`*	Linker aborts immediately. Recompile or reassemble.
9	`Corrupt file. Module` *`module`* `start unexpected in file` *`file`*	Linker aborts immediately. Recompile or reassemble.
10	`Corrupt file. Segment no.` *`segno`* `declared twice in module` *`module`* `(`*`file`*`)`	Linker aborts immediately. Recompile or reassemble.
11	`Corrupt file. External no.` *`ext no`* `declared twice in module` *`module`* `(`*`file`*`)`	Linker aborts immediately. Recompile or reassemble.

No	*Error message*	*Suggestion*
12	`Unable to open file` *`file`*	Linker aborts immediately. If you are using the command line check the environment variable `XLINK_DFLTDIR`.
13	`Corrupt file. Error tag encountered in module` *`module`* `(`*`file`*`)`	A UBROF error tag was encountered. Linker aborts immediately. Recompile or reassemble.
14	`Corrupt file. Local` *`local`* `defined twice in module` *`module`* `(`*`file`*`)`	Linker aborts immediately. Recompile or reassemble.
15	`Faulty bank definition -bbank def`	Incorrect syntax. Linker aborts immediately.
16	`Segment` *`segment`* `is too long for segment definition`	The segment defined does not fit into the memory area reserved for it. Linker aborts immediately.
17	`Segment` *`segment`* `is defined twice in segment definition -Zsegdef`	Linker aborts immediately.
18	`Range error in module` *`module`* `(`*`file`*`), segment` *`segment`* `at address address. Value` *`value`*`, in tag` *`tag`*`, is out of bounds`	The address is out of the CPU address range. Locate the cause of the problem using the information given in the error message.
	The check can be suppressed by the `-R` option.	
19	`Corrupt file. Undefined segment referenced in module` *`module`* `(`*`file`*`)`	Linker aborts immediately. Recompile or reassemble.
20	`Undefined external referenced in module` *`module`* `(`*`file`*`)`	Linker aborts immediately. Recompile or reassemble.
21	`Segment` *`segment`* `in module` *`module`* `does not fit bank`	The segment is too long. Linker aborts immediately.

No	*Error message*	*Suggestion*
22	`Paragraph no. is not applicable for the wanted CPU. Tag encountered in module` *module* (*file*)	Linker aborts immediately. Delete the paragraph no. declaration in the `.xcl` file.
23	`Corrupt file. T_REL_FI_8 or T_EXT_FI_8 is corrupt in module` *module* (*file*)	The tag `T_REL_FI_8` or `T_EXT_FI_8` is faulty. Linker aborts immediately. Recompile or reassemble.
24	`Segment` *segment* `overlaps segment` *segment*	The segments overlap each other; ie both have code on the same address.
25	`Corrupt file. Unable to find module` *module* (*file*)	A module is missing. Linker aborts immediately.
26	`Segment` *segment* `is too long`	This error should never occur unless the program is extremely large. Linker aborts immediately.
27	`Entry` *entry* `in module` *module* (*file*) `redefined in module` *module* (*file*)	There are two or more entries with the same name. Linker aborts immediately.
28	`File` *file* `is too long`	The program is too large. Split the file. Linker aborts immediately.
29	`No object file specified in command-line`	There is nothing to link. Linker aborts immediately.
30	`Option -`*option* `also requires the -`*option* `option`	Linker aborts immediately.
31	`Option -`*option* `cannot be combined with the -`*option* `option`	Linker aborts immediately.
32	`Option -`*option* `cannot be combined with the -`*option* `option and the -`*option* `option`	Linker aborts immediately.

No	*Error message*	*Suggestion*
33	`Faulty value` *`val`* `(in command line or in XLINK_PAGE), (range is 10-150)`	Faulty page setting. Linker aborts immediately.
34	`Filename too long`	The filename is more than 255 characters long. Linker aborts immediately.
35	`Unknown flag` *`flag`* `in cross reference option` *`option`*	Linker aborts immediately.
36	`Option` *`op`* `does not exist`	Linker aborts immediately.
37	`- not succeeded by character`	The - marks the beginning of an option, and must be followed by a character. Linker aborts immediately.
38	`Option` *`option`* `multiply defined`	Linker aborts immediately.
39	`Illegal character specified in option` *`op`*	Linker aborts immediately.
40	`Argument expected after option` *`op`*	This option must be succeeded by an argument. Linker aborts immediately.
41	`Unexpected '-' in option` *`op`*	Linker aborts immediately.
42	`Faulty symbol definition -D`*`symbol`* `definition`	Incorrect syntax. Linker aborts immediately.
43	`Symbol in` *`symbol`* `definition too long`	The symbol name is more than 255 characters. Linker aborts immediately.
44	`Faulty value` *`val`* `(in command line or in XLINK_COLUMNS), (range 80-300)`	Faulty column setting. Linker aborts immediately.

No	*Error message*	*Suggestion*
45	`Unknown CPU` *`CPU`* `encountered in command line (or in XLINK_CPU)`	Linker aborts immediately. Check the argument to `-c` is valid. If you are using the command line you can get a list of CPUs by typing `xlink` ↵.
46	`Undefined external` *`external`* `referred in module (`*`file`*`)`	Entry to external is missing.
47	`Unknown format` *`format`* `encountered in command line or XLINK_FORMAT`	Linker aborts immediately.
48	`Faulty segment definition -Zsegdef`	Incorrect syntax. Linker aborts immediately.
49	`Segment name in segment definition too long`	255 characters long. Linker aborts immediately.
50	`Paragraph no. not allowed for this CPU, encountered in option` *`option`*	Linker aborts immediately. Do not use paragraph no. in declarations.
51	`Hexadecimal or decimal value expected in option` *`option`*	Linker aborts immediately.
52	`Overflow on value in option` *`option`*	Linker aborts immediately.
53	`Parameter exceeded 255 characters in extended command line file` *`file`*	Linker aborts immediately.
54	`Extended command line file` *`file`* `is empty`	Linker aborts immediately.
55	`Extended command line variable XLINK_ENVPAR is empty`	Linker aborts immediately.
56	`Overlapping ranges in segment definition` *`segment def`*	Linker aborts immediately.

No	*Error message*	*Suggestion*
57	`No CPU defined`	No CPU defined, either in the command line or in `XLINK_CPU`. Linker aborts immediately.
58	`No format defined`	No format defined, either in the command line or in `XLINK_FORMAT`. Linker aborts immediately.
59	`Revision no. for file is incompatible with XLINK revision no.`	Linker aborts immediately. If this error occurs after recompilation or reassembly, the wrong version of XLINK is being used. Check with your supplier.
60	`Segment` *`segment`* `defined in bank definition and segment definition.`	Linker aborts immediately.
61	`Symbol in bank definition is too long`	Linker aborts immediately.
62	`File` *`file`* `multiply defined in command line`	Linker aborts immediately.
63	`Trying to pop an empty stack in module` *`module`* `(`*`file`*`)`	Linker aborts immediately. Recompile or reassemble.
64	`Module` *`module`* `(`*`file`*`) has not the same debug type as the other modules`	Linker aborts immediately.
65	`Faulty replacement definition -r`*`replacement`* `definition`	Incorrect syntax. Linker aborts immediately.
66	`Function with F-index` *`index`* `has not been defined before indirect reference in module` *`module`* `(`*`file`*`)`	Indirect call to an undefined in module. Probably caused by an omitted function declaration.

No	*Error message*	*Suggestion*
67	`Function` *`name`* `has same F-index as function-`*`name`*`, defined in module` *`module`* `(`*`file`*`)`	Probably a corrupt file. Recompile file.
68	`External function` *`name`* `in module` *`module`* `(`*`file`*`) has no global definition`	If no other errors have been encountered, this error is generated by an assembly language call from C where the required declaration using the `$DEFFN` assembly language support directive is missing. The declaration is necessary to inform the linker of the memory requirements of the function.
69	`Indirect or recursive function` *`name`* `in module` *`module`* `(`*`file`*`) has parameters or auto variables in nondefault memory`	The recursively or indirectly called function *`name`* is using extended language memory specifiers (`bit`, `data`, `idata`, etc) to point to non-default memory, which is not allowed. Function parameters to indirectly called functions must be in the default memory area for the memory model in use, and for recursive functions, both local variables and parameters must be in default memory.
70	`Module` *`module`* `(`*`file`*`) has not the same memory as previously linked modules`	Only modules compiled under the same memory model may be linked together.
71	`Segment` *`name`* `is incorrectly defined (in a bank definition, has wrong segment type or mixed segment types)`	This is usually due to misuse of a predefined segment; see the explanation of *`name`* in the *AT90S C Compiler Programming Guide*. It may be caused by changing the predefined linker control file.

No	Error message	Suggestion
72	`Segment` *`name`* `must be defined in a -Z definition`	This is either an omission of a segment in the linker (usually a segment needed by the C system control) file or a spelling error (segment names are case sensitive).
73	`Label ?ARG_MOVE not found (recursive function need it)`	In the library there should be a module containing this label. If it has been removed it must be restored.
74	`There was an error when writing to file` *`file`*	Either the linker or your host system is corrupt, or the two are incompatible.
75	`SFR address in module` *`module`* `(`*`file`*`), segment` *`segment`* `at address` *`address`*`, value` *`value`* `is out of bounds`	An `SFR` has been defined to a bad address. Change the definition.
76	`Absolute segments overlap in module` *`module`*	The linker has found two or more absolute segments in *`module`* overlapping each other.
77	`Absolute segments in module` *`module`* `(`*`file`*`) overlaps absolute segment in module` *`module`* `(`*`file`*`)`	The linker has found two or more absolute segments in *`module`* `(`*`file`*`)` and *`module`* `(`*`file`*`)` overlapping each other.
78	`Absolute segment in module` *`module`* `(`*`file`*`) overlaps segment` *`segment`*	The linker has found an absolute segment in *`module`* `(`*`file`*`)` overlapping a relocatable segment.
79	`Faulty allocation definition -a`*`definition`*	The linker has discovered an error in an overlay control definition.
80	`Symbol in allocation definition (-a) too long`	A symbol in the `-a` command is too long.

No	*Error message*	*Suggestion*
81	`Unknown flag in extended format option -Y`	Check flags.
82	`Conflict in segment 'name'. Mixing overlayable and not overlayable segment parts.`	These errors only occur with the 8051 and converted PL/M code.
83	`The overlayable segment 'name' may not be banked.`	These errors only occur with the 8051 and converted PL/M code.
84	`The overlayable segment 'name' must be of relative type.`	These errors only occur with the 8051 and converted PL/M code.

WARNING MESSAGES

The following table lists the linker warning messages:

No	*Warning message*	*Suggestion*
0	`Too many warnings`	Too many warnings encountered.
1	`Error tag encountered in module` *`module`* `(`*`file`*`)`	A UBROF error tag was encountered when loading file *`file`*. This indicates a corrupt file and will generate an error in the linking phase.
2	`Symbol` *`symbol`* `is redefined in command-line`	A symbol has been redefined.
3	`Type conflict. Segment` *`segment`*`, in module` *`module`*`, is incompatible with earlier segment(s) of the same name`	Segments of the same name should have the same type.

No	*Warning message*	*Suggestion*
4	`Close/open conflict. Segment` *`segment`*`, in module` *`module`*`, is incompatible with earlier segment of the same name`	Segments of the same name should be either open or closed.
5	`Segment` *`segment`* `cannot be combined with previous segment`	The segments will not be combined.
6	`Type conflict for external/entry` *`entry`*`, in module` *`module`*`, against external/entry in module` *`module`*	Entries and their corresponding externals should have the same type.
7	`Module` *`module`* `declared twice, once as program and once as library. Redeclared in file` *`file`*`, ignoring library module`	The program module is linked.
8	`Segment` *`segment`* `undefined in segment or bank definition`	Undefined segment exists. All segments should be defined in either the segment or the bank definition.
9	`Ignoring redeclared program entry`	Only the program entry found first is chosen.
10	`No modules to link`	The linker has no modules to link.
11	`Module` *`module`* `declared twice as library. Redeclared in file` *`file`*`, ignoring second module`	The module found first is linked.
12	`Using SFB in banked segment` *`segment`* `in module` *`module`* `(`*`file`*`)`	The `SFB` assembler directive may not work in a banked segment.

No	*Warning message*	*Suggestion*
13	`Using SFE in banked segment` *`segment`* `in module` *`module`* `(`*`file`*`)`	The `SFE` assembler directive may not work in a banked segment.
14	`Entry` *`entry`* `duplicated. Module` *`module`* `(`*`file`*`) loaded, module` *`module`* `(`*`file`*`) discarded`	Duplicated entries exist in conditionally loaded modules; ie library modules or conditionally loaded program modules (with the `-C` option).
15	`Predefined type sizing mismatch between modules` *`module`* `(`*`file`*`) and` *`module`* `(`*`file`*`)`	The modules have been compiled with different options for predefined types, such as different sizes of basic C types (eg `integer`, `double`).
16	`Function` *`name`* `in module` *`module`* `(`*`file`*`) is called from two function trees (with roots` *`name1`* `and` *`name2`*`)`	The probable cause is that an interrupt function calls another function that also could be executed by a foreground program, and this could lead to execution errors.
17	`Segment` *`name`* `is too large or placed at wrong address`	This error occurs if a given segment overruns the available address space in the named memory area. To find out the extent of the overrun do a dummy link, moving the start address of the named segment to the lowest address, and look at the linker map file. Then relink with the correct address specification.
18	`Segment` *`segment`* `overlaps segment` *`segment`*	The linker has found two relocatable segments overlapping each other. Check the `-Z` option parameters.

No	*Warning message*	*Suggestion*
19	`Absolute segments overlaps in module` *`module`* `(`*`file`*`)`	The linker has found two or more absolute segments in module *`module`* overlapping each other.
20	`Absolute segment in module` *`module`* `(`*`file`*`) overlaps absolute segment in module` *`module`* `(`*`file`*`)`	The linker has found two or more absolute segments in module *`module`* `(`*`file`*`)` and module *`module`* `(`*`file`*`)` overlapping each other. Change the `ORG` directives.
21	`Absolute segment in module` *`module`* `(`*`file`*`) overlaps segment` *`segment`*	The linker has found an absolute segment in module *`module`* `(`*`file`*`)` overlapping a relocatable segment. Change either the `ORG` directive or the `-Z` relocation command.
22	`Interrupt function` *`name`* `in module` *`module`* `(`*`file`*`) is called from other functions`	Interrupt functions may not be called.

XLIB DIAGNOSTICS

This chapter lists the messages produced by the XLIB Librarian.

XLIB MESSAGES

The following table lists the XLIB messages. Commands flagged as erroneous never alter object files.

No	*Error message*	*Suggestion*
1	`Bad object file, EOF encountered`	Bad or empty object file, which could be the result of an aborted assembly or compilation.
2	`Unexpected EOF in batch file`	The last command in a command file must be `EXIT`.
3	`Unable to open file` *`file`*	Could not open the command file or, if `ON-ERROR-EXIT` has been specified, this message is issued on any failure to open a file.
4	`Variable length record out of bounds`	Bad object module, could be the result of an aborted assembly.
5	`Missing or non-default parameter`	A parameter was missing in the direct mode.
6	`No such CPU`	A list with the possible choices is displayed when this error is found.
7	`CPU undefined`	`DEFINE-CPU` must be issued before object file operations can begin. A list with the possible choices is displayed when this error is found.
8	`Ambiguous CPU type`	A list with the possible choices is displayed when this error is found.
9	`No such command`	Use the `HELP` command.

No	*Error message*	*Suggestion*
10	`Ambiguous command`	Use the `HELP` command.
11	`Invalid parameter(s)`	Too many parameters or a misspelled parameter.
12	`Module out of sequence`	Bad object module, could be the result of an aborted assembly.
13	`Incompatible object, consult distributor!`	Bad object module, could be the result of an aborted assembly, or that the assembler/compiler revision used is incompatible with the version of XLIB used.
14	`Unknown tag: hh`	Bad object module, could be the result of an aborted assembly.
15	`Too many errors`	More than 32 errors will make XLIB abort.
16	`Assembly/compilation error?`	The `T_ERROR` tag was found. Edit and re-assemble/re-compile your program.
17	`Bad CRC, hhhh expected`	Bad object module; could be the result of an aborted assembly.
18	`Can't find module: xxxxx`	Check the available modules with `LIST-MOD` *`file`*.
19	`Module expression out of range`	Module expression is less than one or greater than `$`.
20	`Bad syntax in module expression: xxxxx`	The syntax is invalid.
21	`Illegal insert sequence`	The specified *`destination`* in the `INSERT-MODULES` command must not be within the *`start-end`* sequence.
22	`<End module> found before <Start module>!`	Source module range must be from low to high order.
23	`Before or after!`	Bad `BEFORE/AFTER` specifier in the `INSERT-MODULES` command.

No	*Error message*	*Suggestion*
24	`Corrupt file, error occurred in` *`tag`*	A fault is detected in the object file *`tag`*. Reassembly or recompilation may help. Otherwise contact your supplier.
25	*`File`* `is write protected`	The file *`file`* is write protected and cannot be written to.
26	`Non-matching replacement module` *`name`* `found in source file`	In the source file, a module name with no corresponding entry in the destination file was found.

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SYMBOLS