Lattice C 5.5

the C Compiler for your Atari ST/STE/TT Computer

Addendum

User Manual

Requires:

- ✓ Atari 520ST upwards
  (1M+ memory required)
- ✓ Disk drive
  (2 floppies or hard disk advised)
- ✓ Mouse

HiSoft
High Quality Software

Lattice C 5.5 for the Atari ST/STE/TT

By HiSoft and Lattice, Inc.

Program:
designed and programmed by HiSoft and Lattice, Inc.

Manual:
written by Alex Kiernan and David Nutkins.

HiSoft
High Quality Software

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The Editor

The editor supplied with Lattice C is fully integrated with the system which means that you can develop programs in an intuitive and interactive manner, creating and editing your programs in the same environment as running and debugging your finished masterpiece.

Moreover, those of you with strong preferences for your own editor can dispense with the HiSoft editor and use your own favourite package along with the TTP version of Lattice C; although you will lose the benefits of interactive development.

The editor for Lattice C is a multi-window screen editor which allows you to enter and edit text and save and load from disk, as you would expect. It also lets you print some or all of your text, search and replace text patterns and use any of your computer's desk-accessories. It is GEM-based, which means it uses all the user-friendly features of GEM programs that you have become familiar with such as windows, menus and mice. However, if you're a die-hard used to the hostile world of computers before the advent of WIMPs, you'll be pleased to know you can do practically everything you'll want to do from the keyboard without having to touch a mouse.

The editor is 'RAM-based', which means that the file you are editing stays in memory for the whole time, so you don't have to wait while your disk grinds away loading different sections of the file as you edit. As the ST/TT range of computers have so much memory, the size limitations often found in older computer editors do not exist with Lattice C. As all editing operations, including things like searching, are RAM-based they act extremely quickly.

When you have typed in your programs it is not much use if you are unable to save them to disk, so the editor has a comprehensive range of save and load options, allowing you to save all or part of the text and to load other files into the middle of the current one, for example.

To get things to happen in the editor, there are various methods available to you. Features may be accessed in one or more of the following ways:

- Using a single key, such as a Function or cursor key;
- Clicking on a menu item, such as Save;
- Using a menu shortcut, by pressing the Alternate key (subsequently referred to as Alt) in conjunction with another, such as Alt-F for *Find*;
- Using the Control key (subsequently referred to as Ctrl) in conjunction with another, such as Ctrl-A for *cursor word left*;
- Clicking on the screen, such as in a scroll bar.

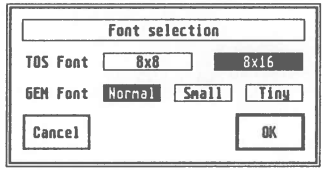
The menu shortcuts have been chosen to be, hopefully, easy to remember.

A word about pop-up menus and dialogs

The editor makes extensive use of dialog boxes and pop-up menus, so it is worth recalling how to use them, particularly for entering text. The editor's dialog boxes contain buttons, radio buttons, and editable text.

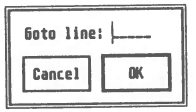
Exit buttons may be clicked on with the mouse and cause the dialog box to go away. Usually there is a default button, shown by having a wider border than the others. Pressing Return on the keyboard is equivalent to clicking on the default button. Where there are non-default buttons, the editor allows these to be selected from the keyboard using the sequence Alt-first letter of the button name; obviously where several buttons have the same first letter only one may be selected!

Radio buttons are groups of buttons of which only one may be selected at a time - clicking on one automatically de-selects all the others.



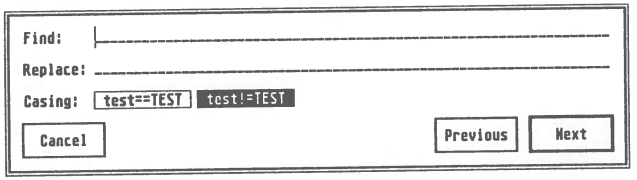
A dialog with buttons (OK, Cancel) and radio buttons (Normal, Small etc.)

Editable text is shown with a dotted line, and a vertical bar marks the cursor position.



Editable text

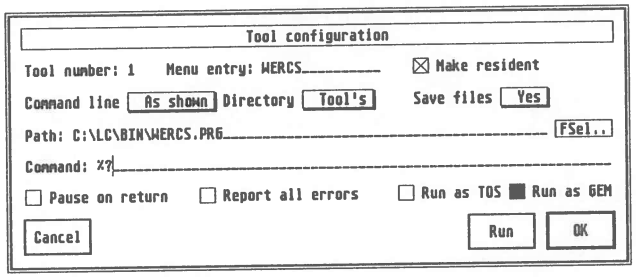
Characters may be typed in and corrected using the Backspace, Delete and cursor keys. You can clear the whole edit field by pressing the Esc key. If there is more than one editable text field in a dialog box, you can move between them using the Tab key or the ↓ and ↑ keys or by clicking near them with the mouse.



More than one editable text field

Some dialog boxes allow only a limited range of characters to be typed into them - for example the Goto... dialog box only allows numeric characters (digits) to be entered.

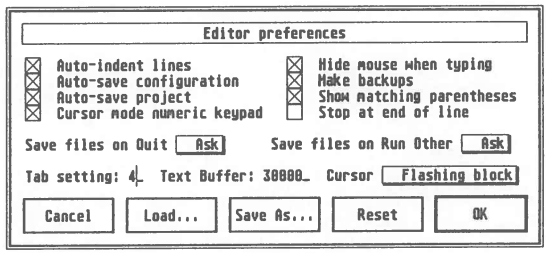
As well as the conventional GEM user interface facilities, the editor also uses some extensions. To illustrate these, consider the dialog box shown below:



The Tool Configuration dialog box

Configuring the editor

Selecting Preferences... from the Options menu will produce a dialog box like this:



The editor preferences box

This box allows you to set up the editor as you would like to use it; you can then save your customisation to disk so that the editor will always behave the same way. Here are the different settings that you can change.

Auto-indent lines

Selecting this option sets auto-indent mode. When active, an indent is added to the start of each new line created when you press Return. The contents of the indent of the new line is taken from the white space (i.e. tabs and/or spaces) at the start of the previous line. This allows you to lay out your program neatly, by simply pressing Return.

Auto-save configuration

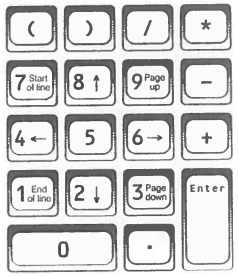
When this option is selected, the current preferences will automatically be saved when you exit the editor. So when you load the editor again, the preferences will be just the same as when you last used it.

Auto-save project

When this option is selected, the current project will automatically be saved when you exit the editor. So when you load the editor again, the project (including the compiler's options) will be just the same as when you last used it.

Cursor Mode Numeric pad

The Cursor Mode Numeric Pad option allows the use of the numeric keypad in an IBM-PC-like way allowing single key presses for cursor functions, and defaults to Cursor pad mode. The keypad works as shown in diagram below:



When this option is not selected the keyboard reverts to returning the digits etc.

Hide mouse when typing

Selecting Hide mouse when typing causes the mouse pointer to disappear when you start entering text with the keyboard. As soon as you move the mouse, or use a command that displays a dialog box, the mouse will re-appear. This option may be disabled if you prefer to always see the mouse on the screen.

Make Backups

Selecting this option causes the editor to make a backup (with the extension .BAK) when saving files.

Show matching parentheses

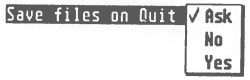
This facility lets you check that your parentheses match. With this option enables, when you press) the cursor will quickly move to any matching (character and then back to the current position, thus you can ensure that you have closed the correct number of brackets in a complex expression. If you find this cursor movement distracting then disable the option.

Stop at End of Line

When this option is selected, if you press cursor left at the beginning of a line or cursor right at the end of line, the cursor does not move. Disabling this option, causes the cursor to move to the previous line if you press cursor left at the beginning, and to the next line if you press cursor right at the end.

The best way to find out which you prefer is to try using each setting.

Save files on Quit



By default the editor will prompt you, if you are about to quit without having saved all the files, you have changed.

The saving of these files can be made automatic by selecting Yes or disabled by selecting No (but don't blame us if you forget to save your files!).

Save files on run other

This enables you to choose whether files are saved before using the Run Other and Run with Shell commands, in the same way as that for Save files on Quit.

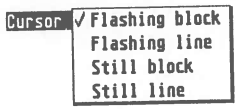
Tab setting

By default, the tab setting is 4, but this may be changed to any value from 2 to 16.

Text Buffer

By default the text buffer size is 10000 bytes, but this can be changed from 4000 to 999000 bytes. This determines the largest file size that can be loaded and edited. This amount of memory is allocated for each window in use. Care should be taken to leave sufficient room in memory for compilations - pressing the Help key displays free system memory, and for compilations this should always be at least 100k bytes. Changing the editor workspace size will cause any text you are currently editing to be lost, so a confirmation is required if it has not been saved.

Cursor



By default the editor cursor is a flashing block, but this can be changed as required.

Load...

This button lets you load a settings file. The editor settings are normally stored in a file called HISOFTED.INF in the current directory, but the editor will 'look down' both the AES and GEMDOS paths. If you want to use more than one set of preferences, then you can explicitly load a settings file.

Saving preferences

To save the settings file you can either choose Save as... from the Preferences box or choose Save preferences from the Options menu.

This latter command, on the Options menu, saves the current editor, compilation and Tools menu preferences under the name HISOFTED.INF. If you want to call your settings file a different name you should use Save as... in the Preferences... box, as described below.

When the editor is loaded, it looks for the HISOFTED.INF configuration file firstly in the current directory (which is the folder where you double-clicked on the data file), then using the system path. Saving the editor preferences this way will put the .INF file in the same place it was loaded from or, if it was not found, it will be placed in the current directory path.

In addition to saving the editor configuration the current program buffer size, from within the compilation options dialog box, is also saved.

Use Save as... from the Preferences box to save a settings file with a name other than HISOFTED.INF; an extension of .INF is still usual.

With this option you can save a number of different settings files under different names; however the editor always loads the settings file called HISOFTED.INF when it starts up so that, if you want to make a particular settings file the default, you will need to re-name it to HISOFTED.INF.

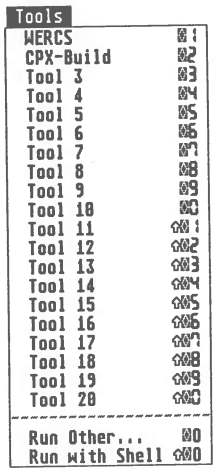
Reset

Clicking on this box causes the settings to be reset to their default values; useful if you have made a complete mess of your options.

Running other programs

There are three ways that you can execute other programs from within the editor; Run Other..., Run with Shell... and by a selection from the Tools menu. These different methods will now be described.

Tools Menu



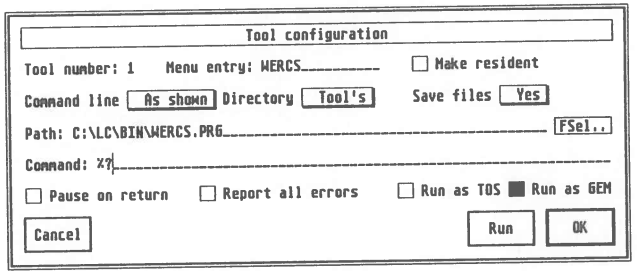
The Tools menu lets you run programs of your choice from within the editor using a single keystroke or click of the mouse.

The configuration can be saved in the preferences file, ensuring that the same facilities can be used again, the next time that you run the editor.

The preferences file that we supply is already set up to run the tools supplied with Lattice C.

Before you can use this facility you will need to configure each tool so that the editor can find the appropriate file. To configure a tool, hold down the Ctrl key and select the appropriate menu item or press Ctrl-Alt and the appropriate key *on the numeric keypad*.

This will produce a dialog box like this:



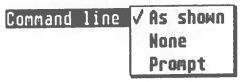
If you just want to use the default settings, you need only change the Path item so that the file can be found; either amend this item or click on FSel and use the file selector to select the appropriate file.

Once you have made the required changes you should press Return (or click on OK) to make your changes permanent; alternatively pressing Cancel will ignore any changes you have made. The other options in this box are:

Menu entry

The name typed in this field gives the name of the tool as placed on the Tools menu. Hence in the above example the name WERCS appears on the menu.

Command line



These options configure the way the command line is obtained for a program which is about to be run.

If None is selected then a program will be run as a plain GEM or TOS program with no command line. If Prompt has been selected you will be prompted for a command line in the same way as occurs when using Run Other.

Finally As shown allows the command line on the line below to be used. This command line is specified in the same way as that used by Run with Shell and may have the same meta-characters in it, as in the example above.

Directory

This sets up which directory will be the current one when the tool is run. Current will leave the directory as that of the editor itself.

Tool's switches to the directory of the tool being run, whereas Top window switches to where the file in the current window is stored on disk.

Save Files

This option changes which files will be saved before running the tool. If you select No then no files will be saved, selecting Yes (the default) will save *all* files (not just the current window), whilst Ask... will prompt you using the Save/Leave dialog described under Quitting Lattice C.

Path

This option specifies which program is actually to be run. If you give a full pathname, or select one by clicking on the FSel.. button then that specific file is run. If you just use a name then this will be treated as if you had used it as an argument to the Run with Shell command described above.

Pause on return

This option controls whether the editor pauses after running the tool. Typically you will select this when running a TOS program but disable it when running a GEM program.

Report all errors

This option allows you to specify which errors the editor will bring to your attention when returning. If this option is not selected then you will only be alerted to negative return codes from programs, i.e. those normally indicating GEMDOS errors. Selecting it will also force positive program error returns to be flagged.

Run as TOS & Run as GEM

These buttons select how the program is run, either as a GEM program or as a TOS program; note that the same warnings about GEM/TOS mode made under Run with GEM apply here also.

Make Resident

If this item is selected then when the editor next loads it will attempt to load this tool into memory and make it resident, i.e. merely execute the tool from memory rather than load it from disk each time. This is particularly useful with substantial programs like WERCS.

As well as the obvious disadvantage of permanently tying up your memory, not all programs can be made resident. In general your own Lattice C programs can be made resident if compiled using the Resident startup option.

We do not recommend running third party programs in this way. They may crash immediately, or the second time they are run or may simple not quite work correctly possibly destroying your valuable files in the process.

Running Tools

Running a configured tool is simple, just select the appropriate menu item or press Alt and the appropriate key *on the numeric keypad* and the program will be run using the settings described above.

Run Other...

This command, on the Tools menu (also reached by Alt-0), lets you run other programs from within the editor, then return to it when they finish.

When you select Run Other... you will first be warned if you have not saved your source code (unless you have modified the setting of the Save files on Run Other option in Preferences). Then the GEM File Selector will appear, from which you should select the program you wish to run. If it is a .TOS or .TTP program you will be prompted for a command line, and then the screen will be initialised suitably.

This is the command to use for 'one-off' execution of a program within the editor. If you are likely to want to run the same program a number of times, then use the facilities of the Tools menu. If you would prefer to specify the program to run via a command line, rather than using the File Selector then use the Run with Shell command described below.

If you include the character sequence `%.` (i.e. per cent followed by full stop) in the command line (remember, you are prompted for a command line) these characters will be replaced by the full name of the file that you are currently editing. To pass the name without its extension, use `%?`.

If you need a true `%` to be passed type `%%`.

Run with Shell...

This command also lets you run other programs from within the editor, then return to it when they finish. The keyboard shortcut for this command is Shift-Alt-0.

It differs from Run Other in that you enter the file to run as a command line. If the editor finds that the `_shell_p` vector has been set up then this will be called to execute the command. This works well with the Craft, PKS and Gulam shells as the shell can be used to run batch files and expand file wildcards etc.

If the `_shell_p` vector has not been set up then the editor will look for the file to run using the PATH environment variable, which can be set using the Environment command from the Options menu.

The same expansion of the current filename as used by Run Other can be used by this command. If you wish to use the same command more than once you will probably save time by using the Tools menu.

Setting the Path

The editor maintains a number of directory paths to make the operation of the integrated environment natural and seamless.

Paths are routes to files. Normally you keep all files of a similar type or usage in one folder or you may have a number of related folders all within one outer folder. For example you probably have an LC folder containing the Lattice C program, its tools and its libraries.

In order that a program that uses these files can find them without having to ask the user for help, both the ST/TT operating system and the Lattice C editor maintain a number of directory paths, some of which you can alter.

Here is a summary of the paths used by the integrated environment, how they are set and what uses them:

Current directory - this is a path that is set up (initially) by the program which ran the current program. For example, for the Lattice C editor this path will have been set up by the Desktop, assuming of course you ran Lattice C from the Desktop. However, since the editor allows this to be changed (via the Change Directory command on the File menu), it is normally reset to whatever was last stored in the HISOFTED.INF file, to save you having to change it every time you run the editor.

Most of the disk-related functions within the editor will search this path first.

GEMDOS path - this path is that contained in the PATH environment variable. It is used by shells (e.g. Craft, PKS Shell, Gulam) to locate programs to run. It is specified as a list of , or ; separated folder names, each of which specify a folder which should be searched when trying to locate a file.

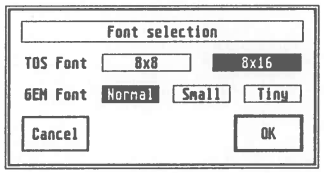
Within the editor it is used by Run with Shell, to locate the named program, and initially when attempting to find the LC1.LC file. Other tools, like WERCS, may use it for locating subsidiary files, such as WERCS.RSC and WERCS.INF.

AES path - this is the path used by the AES when the user calls one of the AES routines which search for a file (`shel_find` and `rsrc_load`). Internally the format of this variable is identical to the GEMDOS path (in fact it *is* the GEMDOS PATH for the AES program!), although the AES provides no way of altering it and merely sets it to `A:\` for a floppy based machine or `C:\` for a hard disk machine.

Miscellaneous Commands

Fonts...

The Fonts command is used to select different GEM or TOS fonts for use in the editor; it can be selected either by clicking on Fonts... from the Options menu, or by pressing Ctrl-G. It displays a dialog box like this:



The GEM Font is the font that will be used by the editor to display text. In ST high resolution and the TT resolutions, there are three fonts available as above. Changing to Small will double the number of line displayed on the screen. With the Tiny font the characters are only 6 pixels by 6 pixels wide but this does mean that even in ST high resolution, there are over 100 characters per line and 54 lines!

In ST medium resolution, there are only two fonts; Normal and Small. Small is 6 by 6 pixels and thus the characters are difficult to read but this does give an extra 7 lines of text and over 100 characters per line.

TOS font is used by non-GEM programs. In TT medium resolution, using 8x8 will give 60 lines instead of 30.

You should be aware that any change of font that you make here will also be effective outside the editor, after you leave it.

ASCII Table...

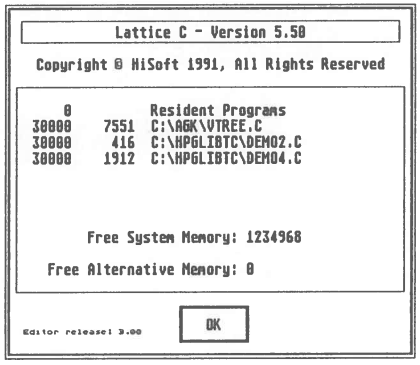
To be found on the Edit menu, this displays a pop-up dialog box at the current mouse position, showing all the ASCII characters:

You may click on an individual character and it will be added to the text that you are editing at the current cursor position. You can bring up this display from the keyboard using Shift-Insert. This short cut can also be used in the editor's dialog boxes.

Note that the characters that would confuse the editor are 'greyed out' and may not be selected. Remember that characters other than those in the standard 7 bit ASCII set are not necessarily the same on other computers.

About Lattice C

It you select About Lattice C... from the Desk menu, a dialog box will appear giving various details about Lattice C, including its version number. You will also be told the amount of free memory that is available to you and how much is used by the resident programs including the text in the open windows.



Pressing Return or clicking on OK will return you to the editor.

Help Screen

The key equivalents for the commands not found in menus can be seen by pressing the Help key, or Alt-H. A dialog box will appear showing the cursor and function keys, as well as the free memory left for the system.

Desk Accessories

If your system has any desk accessories, you will find them in the Desk menu. If they use their own window, as Control Panel does, you will find that you can control which window is at the front by clicking on the one you require.

For example, if you have selected the Control Panel it will appear in the middle of the screen, on top of the editor window. You can then move it around and, if you wish it to lie 'behind' the editor window, you can do it by clicking on an editor window, which brings the editor window to the front; you can then re-size it so you can see some part of the control panel's window behind it. When you want to bring the control panel back to the front just click on it and the editor window will go behind. The editor's cursor only flashes and the menus only work when an editor window is at the front.

Automatic Launching

You may configure Lattice C to be loaded automatically whenever a source file is double-clicked from the Desktop, using the *Install Application* option.

To do this you first have to decide on the extension you are going to use for your files, which we recommend to be .C for C files. Having done this, go to the Desktop, and click once on LC5.PRG to highlight it. Next click on Install Application from the `Options` menu and a dialog box will appear. You should set the Document Type to be `C` (or whatever you require), and leave the GEM radio button selected. Finally click on the OK button (if you press `Return` it will be taken as `Cancel`).

Having done this, you will return to the Desktop. To test the installation, double-click on a file with the chosen extension which must be on the same disk and in the same folder as Lattice C and the Desktop will load Lattice C, which will in turn load in the file of your choice ready for editing or compilation.

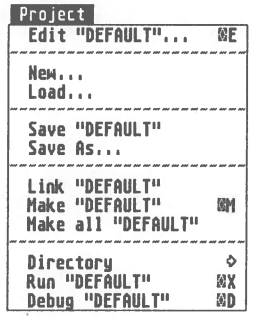
Note: To make the configuration permanent, you have to use the Save Desktop option.

Compiling Programs

Having produced your C program and saved it to disk using the editor you can then compile it. Normally this is a two stage process; first the compiler turns the C source file into an object file and then the linker links this object (together with any other object and/or libraries required) to produce an executable program.

Because most larger programs consist of more than one C source file, the integrated compiler provides a *Project manager* to aid in the maintenance of larger projects. For small, single file projects, the project manager is still employed using a *default* project.

The Project menu



The Project menu allows the entire structure of an application to be set up and managed from within the integrated compiler.

A project file (.PRJ) contains a list of all the files (and which files they include) and options which are required to rebuild an application.

Associated with each project is a project directory, the directory in which the project file is located. This directory is used as the current directory for both compiling an running the program, thus ensuring that subsidiary files (such as resource files) can be easily located.

New...

The New... option is used to create a new project, and presents a file selector to allow you select the project directory, and the name of the project file. Note that you should decide on a name for your project at this time to ensure that output file names are chosen appropriately.

Load...

The Load... option reloads a previously saved project. On loading the project the current in-memory project definition is completely replaced by the new one, together with all its options.

Save "..."

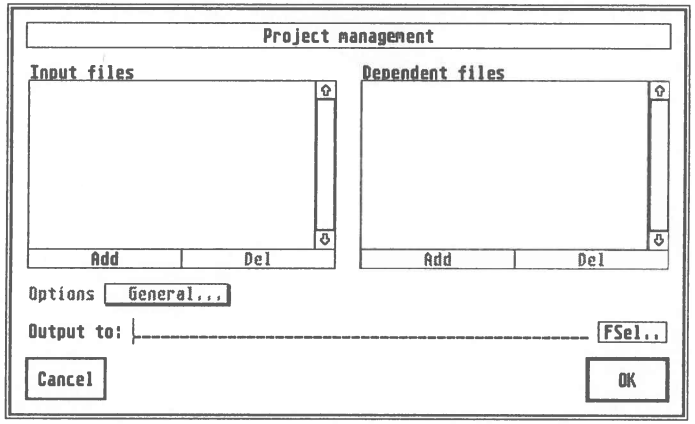
This saves the current project under the name originally given to the project.

Save As ...

Save As... is used to save the current project under a new name; this may be useful if you are editing an old project to create a new project.

Edit "..."...

The Edit... item is the central part of the project interface. It allows the files which form part of a project to be set up, and the final output file to be set. The following large dialog box is used:



The main part of the Project management dialog consists of two list boxes. The left hand one is used to enter the source files which make up the project; the files may be added, deleted or changed in the normal list box manner. In addition it is possible to change the 'build order' of the files (i.e. the order in which they are built & then linked) by clicking on an entry and dragging it to a new position.

Within a project any number of input files may be specified in the Input files list; the extension of the file is used to decide how the project manager will process it:

Extension	Action
C None	Compile named file
S	Assemble named file
LIB	Include named library file when linking
LNK	Include file as WITH file during linking
O Other	Include named object file when linking
PRJ	Make sub-project substituting target name in source file list

For each source file (.C/.S) within a project dependent files may be specified; these are the files which are *included* by the main source file. To specify dependent files for a particular source file, selecting the source file will activate the Dependent files list box allowing any number of dependents to be entered.

In addition to allowing dependent files a source file may have specific options set. Note that this is only required where a particular source file should have specific options, normally the options for the whole project should be set via the normal options menu. To set a set of file specific options first select the file and then select the appropriate options box which you wish to change via the Options popup menu.

The output filename may be specified in the Output to line or via a file selector after clicking on FSel. The extension of the output file name is used by the project manager to decide what sort of object file is to be built:

Extension	Action
LIB	Pass input files to librarian
O	Pass input files to linker for pre-linking (PRELINK keyword)
Other	Pass input files to linker and any other automatic files (startup stubs, math libraries, gem libraries & C libraries) for linking into an executable.

Note that the project manager recognises any non .LIB or .O extension as a normal executable file. It is often easiest to give the output file no extension and instead allow one to be invented based upon the setting of the *Executable options - Application type* setting.

Make "..."

Make "..." is used to start the process of rebuilding a project. The project manager examines the time and dates of all the input source files with respect to their object files and rebuilds only those that have changed.

Note that you *must* ensure that the real time clock in your machine is set; *if you do not the project manager will not function correctly.*

Make all "..."

Make all "..." is used to unconditionally rebuild a project. This can be useful if you have changed a global option which would affect the 'code model' and so all source files need rebuilding. This is obviously much slower than the Make "..." option!

Link "..."

Link "..." is used to unconditionally rebuild the output file; note that all the input files must be available, the project manager will not attempt to build any of them. Link "..." is useful in situations where you have simply changed one of the linker options (e.g. *Linker options - Add exported symbols*) and want the project manager to build a new output file.

Note that the name Link "..." is something of a misnomer; if the output file is a library (*output*.lib) then the librarian would be run instead!

Run "..."

Run "..." runs the output file for the current project. Note that the output file must be executable in order to select this option; if the output file ends in `.O` or `.LIB` you will not be able to run it directly.

Debug "..."

Debug "..." passes the output file for the current project to the debugger. The options to the debugger may be set using the *Options - Debugger...* option.

Note that the output file must be executable in order to select this option; if the output file ends in `.O` or `.LIB` you will not be able to run it directly.

Directory

Directory is used to select which directory is current when a program is run.

Because many GEM programs have difficulty finding subsidiary files when run from remote directories the default setting of *Directory - Project* ensures that the current directory is that of the project. For TOS or more robust GEM programs the *Directory - Current* is useful to ensure that a program will function correctly when run from a remote directory.

Problems

When issuing a Run command from the editor the machine may seem to 'hang up' and not run the program. This occurs if the mouse is in the menu bar area of the screen and can be corrected by moving the mouse. Similarly when a program has finished running, the machine may not return to the editor. Again, moving the mouse will cure the problem. This is due to a feature of GEM beyond our control.

Compilation Errors

When the compiler detects an error or something that may be an error (a warning) it generates a message; these errors are remembered, and can be recalled from the editor.

When you return to be editor you can use Alt-J to move to the next error with the error message displayed in the status line. If you have a large number of errors the editor may not be able to remember them all. Alt-J goes to the next error regardless of the position of the cursor; it will switch windows if required. To go to a previous error use Ctrl-J. The editor takes account of any insertions or deletions automatically so that unless one error (like a mistake in a definition) has caused multiple errors you should only need to compile once.

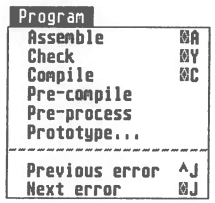
There's also the Shift-Alt-J command which finds the next error after the cursor in the current window. It is the appropriate one to use if you have got a number of include files and want to fix all the errors in one file before going on to the next one. You can also use it to find the first error in a file by typing Alt-T (to go to the top) and then Shift-Alt-J.

Occasionally the compiler will spot errors somewhat later than you might expect. This is usually because the text up to the point it has read is allowed in a certain context. If you have missed something out at the end of a line, then the error may be detected at the beginning of the next line.

On occasions the compiler will generate more than one error message as a result of a single error in your program; do not be put off by this. If you get confused, just re-compile.

Incidentally, if you start a compilation of a large program you can break out and returned to the editor using the key combination Left-Right-Shift when using the integrated compiler.

The Program menu



The Program menu provides facilities for compiling single source files in a 'one-shot' manner. Although this menu allows compilation and assembly of source files, normally you will not use these functions, preferring instead the facilities of the Project menu.

Assemble

The Assemble option is used to assemble the current window, using the global project options (described below). Since an assembly language source file will normally be part of a much larger project it is normally easier to place the description of the file within a project for later reuse.

Check

The Check option, checks the syntax of the source text that is currently being edited without producing any output file. If the compiler is already loaded then this lets you check your program quickly.

Compile

The Compile option is used to compile the current window, using the global project options (described below). Since many C source files will be part of a much larger project it is normally easier to place the description of the file within a project for later reuse.

Pre-compile

The Pre-Compile option is used to generate a pre-compiled header file suitable for inclusion in the Compiler options - Advanced (Precompiled headers) dialog. The current source window is processed together with the global project options (described below) to produce a symbol file *source*.sym.

Note that any files mentioned in the Compiler options - Advanced (Precompiled headers) dialog *will* be loaded as part of the precompilation process and so must be available (i.e. if you are rebuilding an existing pre-compiled header you should remove its declaration from the Precompiled headers list).

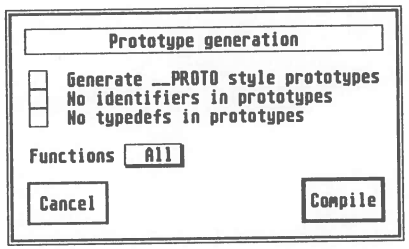
Pre-process

The Pre-process option is used to force the compiler to write the results of preprocessing the current source file into the output file *source*.p.

Prototype...

The Prototype... option is to invoke the compilers prototype generation option on the current window, using the global project options (described below), building a prototype file *source*.i.

This option produces a dialog allowing the options for the prototype generation to be set:



Generate __PROTO style prototypes -pp

This option forces the compiler to generate prototypes 'protected' by an `__PROTO` macro. Normally on re-reading the prototype file the prototypes will be used, however if the symbol `__NOPROTO` is pre-defined by the user then the prototypes will be ignored. This can be useful to allow portability of source files to older K&R compilers.

No identifiers in prototypes -pi

No identifiers in prototypes (`-pi`) suppresses the compilers generation of formal names for the prototypes. Since these names are not required in the prototypes removing them can save both space and compilation time later.

No typedefs in prototypes -pt

No typedefs in prototypes (`-pt`) suppresses the compilers use of `typedef` names within prototypes. In many cases this is desirable as the `typedef` may not be 'visible' to the prototype file and so any unknown types would cause the compiler to issue an error.

Functions

The *Functions* option allows the user to configure how prototyping deals with `static` functions.

There are three possible options:

All -pr

Causes the compiler to generate a prototype file containing prototypes for all functions defined in the source file.

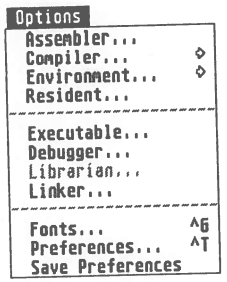
External -pe

Eliminates prototypes for all static functions. Only those functions available externally will have prototypes generated for them.

Static -ps

Generates prototypes only for static functions. Only those functions defined with the static function will be output.

The Options menu



The Options menu provides the main place from which options for both the compiler and editor are set.

The items on this menu relating to the compiler are described in this section; the other options are described elsewhere.

Environment...

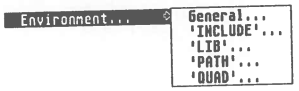
The Environment... option allows the environment variables used by the tools which are run (and other parts of the Lattice C system as described above) to be altered.

The 'environment variables' are an array of strings which GEMDOS creates for every program which it runs. This array of strings contains 'variables' of the form *`name=value`* which the program may interrogate to obtain information about the 'environment' in which it is running (hence the name). Some typical environment variables are: `PATH` - specify the directories in which a program should look, `INCLUDE` - specify the directories in which a compiler should look for include files, `EDITOR` - the users preferred text editor which an application should run.

Normally a parent program creates a new environment for the child program; if this is not done explicitly then the child 'inherits' a copy of the parent's environment. Hence every program has its own, unique, copy of the environment.

For programs started normally from the Desktop, only a single environment variable is available, `PATH`.

Lattice C and the environment



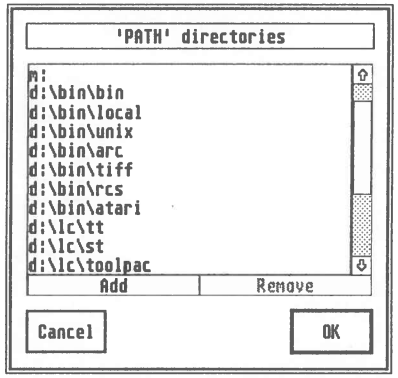
Several environment variables are used by the compiler to locate files it may need.

These are `INCLUDE`, `LIB`, `PATH` and `QUAD`.

PATH — Executable path

This variable defines a sequence of directory prefixes where a program (e.g. the editor!) should search for an executable file (e.g. when trying to run LC1, LC2, GO etc.).

On selecting the `Environment-'PATH'` option, the following dialog appears (although without all the entries!):



This shows a list of all the directory prefixes specified in the PATH variable. The entries in this list dialog may be manipulated in the manner described in the section *A word about pop-up menus and dialog*.

When a new entry is added, or an existing one edited (by double-clicking), a file selector is presented to allow the entry of a path.

INCLUDE — Include path

The INCLUDE variable is similar to the PATH variable except that it is used by the compiler to locate include files referenced by your program.

Manipulating this variable is done in an identical manner to that described for the PATH variable.

LIB — Library path

The LIB variable is similar to the PATH variable except that it is used by the linker to locate input and library files referenced by the editor.

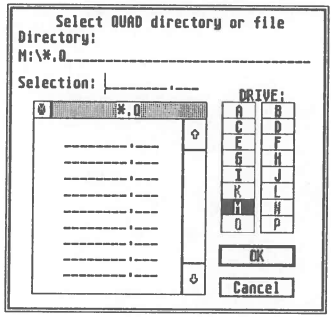
Manipulating this variable is done in an identical manner to that described for the PATH variable.

Note that just because a library file is in the library directory does not mean that the file will be linked in, you must tell the compiler to link it!

QUAD — Quad file

The QUAD environment variable specifies the default intermediate (QUAD) *file name* used by the compiler. If the filename has a trailing backslash (\) then the compiler assumes that this is the name of a directory such that it may form a filename by concatenating the source file name to it.

On selecting the `Environment-'QUAD'` option, a standard file selector appears to allow you to select a quad file name, or path. To select a specific name, enter it in the file selector, or to set a directory, leave the filename portion blank:



If you have a RAM disk installed you can greatly increase compiler performance if you use this as the quad temporary directory.

General...

Because the Lattice C editor provides a full visual shell, in order that other programs which may be run from it (e.g. the Tools, etc.), full support is available for arbitrary environment variables (i.e. other than PATH, INCLUDE, LIB and QUAD).

There are several new error/warning messages:

register __fpX requires -f8 switch on LC1

A function of the form:

```
__asm fn(register __fp0 double);
```

has been defined/used without the `-f8` flag having been specified.

146 (W) long case value in short switch

The compiler has detected a switch value whose range exceeds the range of the switch type. The compilation will continue using the truncated value.

148 (W) use of incomplete struct/union/enum tag <name>

The named struct/union/enum tag had been used without a corresponding in scope definition. This warning is normally disabled, or enabled in ANSI mode.

149 (W) undefined struct/union/enum tag in prototype scope

An undefined `struct/union/enum` tag has been encountered within a prototype. Because a prototype forms its own scope it is thus impossible to have any type (within the translation unit) which is compatible with it.

This warning is normally only issued for `enums` when in non-ANSI mode, or for all types in ANSI mode. This is because the compiler uses the ANSI cross-translation-unit model (member name and type equivalence) for structure equivalence when in non-ANSI mode, rather than exact type equivalence in ANSI mode.

151 (W) use of ANSI flexible keyword ordering

The compiler has detected a use of flexible keyword ordering in declarations, as permitted by ANSI. Note that use of such orderings is generally confusing and less portable to older compilers. This message is disabled by default in ANSI mode (`-ca`).

152 (W) cannot define function via typedef name

An attempt is being made to define a function via a `typedef` name. In default mode this is accepted with this warning; in ANSI mode (`-ca`) it constitutes an error.

153 (W) use of string constant concatenation

The compiler has detected a use of ANSI string concatenation. This warning is normally disabled.

159 (W) use of unary minus on unsigned value

The compiler has detected a unary minus on an unsigned expression; often this will not indicate an error, although it can be useful for tracking down unexpected effects.

161 (W) no prototype at definition of public function

At the definition of a public function (i.e. non-`static`) there was no in scope prototype. This may indicate a prototype missing from a global header file. This warning is normally disabled.

162 (W) non-ANSI use of ellipsis punctuator

The compiler has detected a non-ANSI usage of the ellipsis punctuator, typically this will indicate that C++ syntax was used,. i.e.

```
void fn(const char *s …);
```

This warning is promoted to an error in ANSI mode.

166 unbalanced comment

The end of file was reached whilst a closing comment was still outstanding. Note that this error is a refinement of the previously all encompassing error, unexpected end of file.

167 (W) nested comment detected

This warning is issued whenever the compiler detects an apparent use of comment nesting. Note that this may indicate a portability problem to compilers which do not allow the user to dictate whether comments nest or not. This warning is normally disabled.

170 (W) C++-style comment detected

The compiler has detcted a usage of the C++ `//` style commenting. This warning is normally disabled and an error in ANSI mode.

171 (W) **implicit cast of integral argument**

The argument to a function, or function return value, has been implicitly cast from one integer type to another; note that this may only occur if there is an in-scope prototype. This is a refinement of warning 88, argument type incorrect, and is disabled by default.

Pre-processor symbols

This is a current list of pre-processor symbols which the compiler predefines:

Optional definitions

Name	Option
_ANSI	-ca
_BASEREL	-b1
_DEBUG	-d1..-d5
LPTR	without -w
_M881	-f8
_MDOUBL	-fd
_MLATTICE	-fl
_MMIXED	-fm
_MSINGLE	-fs
__PLAIN_CHAR_UNSIGNED	-cu
_PCREL	-r1
_REGARGS	-rr
_SHORTINT	-w
SPTR	-w
_UNSIGNEDCHAR	-cu

Static definitions

These definitions are always made by the compiler, regardless of the options, unless overriden using the *#undef symbols* (-u) option.

Name	Value	Meaning
ATARI	1	Host Machine
LATTICE	1	Compiler Name
LATTICE_50	1	Compiler Version
LATTICE_550	1	Current compiler release
M68000	1	Processor type

Permanent definitions

Name	Value	Meaning
__DATE__	"date"	Date on which compilation was started
__FILE__	"name"	Name of main file which is being compiled
__LINE__	n	Current line which is being translated
__REVISION__	50	Current minor version number.
__STDC__	1	ANSI operation mode
__TIME__	"time"	Time at which compilation was started
__VERSION__	5	Current major version number.

Changes to the run-time model

There are a number of changes to the run time model which will require most programs to be fully recompiled, whilst those with assembly language portions may need rewriting. This section attempts to cover those points which may cause problems within assembler portions.

We strongly recommend that *all* applications are recompiled in their entirety.

Register passing mode

In registerised parameter passing mode (`-rr` or `__regargs`) changes have been made to the way parameters are passed. In true 68882 mode (`-f8`), `FP0` and `FP1` are used to pass the first two double parameters to the function in emulation mode (`-f1`) if the first parameter in a function is of type double then registers `D0/D1` are used to pass the parameter (strictly if no integer parameters precede them that would have used `D0/D1`). Note that this change alone means that *any* code using real maths and `-rr` *must* be recompiled.

__saveds and stack checks

Functions which are declared `__saveds` now automatically disable stack checking on a per-function basis. Note that this *cannot* apply to functions called by the `__saveds` function.

A2 as a register variable

The compiler now makes register A2 available as a register variable, giving 3 pointer type register variables: A2, A3 & A5. If this register is not preserved across calls then your program is almost certain to crash; previously the compiler rarely relied on A2 across a subroutine call.

__asm functions

Functions declared `__asm` are now always _ prefixed at link time. This means that `@` is reserved for `__regargs`. This also means that it is no longer legal to write:

```
__asm __stdargs fn(…);
```

Note that for functions declared `__asm` it is quite legal to omit a register specification for a parameter; any such parameters will be passed on the stack in the normal way. Such usages elicit a harmless warning however.

Signed and sized bit fields

Changes to bitfields now mean that in default short integer mode (`-w`) a bitfield is now shorter than in the pre-5.50 releases If you have used bitfields at all you should consider a *complete* recompile.

LC.TTP

With the release of Lattice C 5.50 the functionality of the integrated compiler has been greatly improved, however for those die-hard command line or dedicated editor users, the capabilities of the command line compiler driver have also been extended.

New LC.TTP driver options

`-+` list the options passed to each phase of the compiler; prior to starting compilation the LC.TTP lists the options which it is going to pass to each phase of the compiler.

`-E` automatically invoke $EDITOR on error. When this option is used, the `-j` option is automatically turned on (to generate an error file) and the editor given by the EDITOR environment variable started with the command line:

```
$EDITOR [options] <error-file> <source-file>
```

the options part of this command line may be set by appending an '=' to the `-E` option, together with any options required. For example, MicroEMACS (*not* supplied) allows the startup file error.cmd (supplied on Disk 3) to be automatically run when passed the `-e` option, hence setting up your environment variables as:

```
EDITOR=c:\bin\ue.ttp     ; or whatever
LC_OPT=-E=-e
```

would automatically invoke MicroEMACS when errors are reported, together with a script loaded to parse the errors.

Note that the `-E` option will normally delete the errors file after any editor has been successfully called.

`-g=` specify listing file name. By default any listing file is sent to the source file name, but with the extension .LST. This option allows this to be changed if required.

-j generate error file. By default any listing file is sent to quad file directory, but with the extension .ERR, this may be changed by specifying the option as `-j=filename`.

-L When this option is present, lc invokes the linker if all compilations are successful. The first source file name is used as the name of the executable and map files produced by the linker. Any other files that were compiled are supplied to the linker as secondary object files. The Lattice C startup routine is included as the first object module, with an appropriate standard library file (lc.lib) searched last.

Additional Lattice libraries and linker options may be specified by immediately following the `-L` option with one or more of the following letters:

a This invokes the ADDSYM option of the linker. It causes HiSoft extended debugging information for all routines to be output in the executable file.

b This invokes the BATCH option of the linker. It forces batch mode linking.

c This invokes the NOCASE option of the linker. It forces case-insensitive linking.

f This invokes the MAP option of the linker. It causes a map file to be generated with the `.MAP` file extension.

g This letter specifies that the GEM AES and VDI library lcg.lib is to be searched before the standard run-time support library. When this option is specified the default extension for the output file becomes `.PRG` rather than `.TTP`.

h This letter directs the linker to output the hunk portion of the map. This is the default map if no other map options are specified.

i This letter directs the linker to ignore errors during linking; it is equivalent to the IGNORE linker keyword.

l This letter directs the linker to include library information in the map file.

m This letter specifies that the Lattice IEEE maths library lcm.lib is to be searched before the standard run-time support library.

n This invokes the NODEBUG option of the linker. It causes all debugging information to be stripped from the final executable.

q This invokes the QUIET option of the linker. It causes no messages to be output by the linker if a link is successful.

s This letter directs the linker to produce a symbol listing in the map file.

v This invokes the VERBOSE option of the linker. It causes the linker to display statistical messages as it is processing the object files and libraries.

x This directs the linker to include cross reference information in the map file.

For example, `-Lm` will search lcm.lib before lc.lib, and `-Lvg` will search lcg.lib and lc.lib, and display messages regarding the current linker status. Note that the standard libraries are always searched last.

If you want to search other libraries, you must list those libraries after the option letters, and use plus signs as separators. For example, `-L+myfuncs.lib` searches `myfuncs.lib` before the standard Lattice library, while `-Lm+myfuncs.lib+\george\myfuncs.lib` searches the libraries `myfuncs.lib`, `\george\myfuncs.lib`, `lcm.lib` and `lc.lib`. Note that the special libraries are searched before the Lattice libraries.

The `-L` option creates a file in the current directory named *xxx*`.lnk`, where *xxx* is the name of the first source file to be compiled (i.e., the same name that is used for the executable and map files). This `.LNK` file serves as input to the linker, and it is not deleted at the end of the procedure. This allows you to easily re-link if, during your testing, you find a need to change and re-compile only one module. To do this, simply execute CLink in the following way:

```
clink WITH xxx.lnk
```

where *xxx*.lnk is the name of the .LNK file previously produced by the lc command.

At the end of the -L options, if an '=' is present then the remaining part of the -L option specifies the output file name.

-o The exact meaning of -o has changed such that it is now the name of the compilation output file, i.e. if pre-processing or precompiling (processes which do not require LC2) then the output filename is now specified by -o, rather than -q as in pre 5.50 releases.

-N no compile, link named files only. This is useful to allow linking of all files on the command line with no compilation taking place what-so-ever.

-S This option specifies the stack size for any or all compiler phases. Because the compiler uses some recursive algorithms, very complex expressions may cause it to run out of stack space. If this happens, you can increase the stack beyond its 16K default size in the following way:

-S=n Specifies the stack size for phase 1, phase 2, and the optimiser.

-S1=n Specifies the stack size for phase 1.

-S2=n Specifies the stack size for phase 2.

-S0=n Specifies the stack size for the optimiser.

The value n in the preceding list is the number of bytes in the stack. For example, you can specify 16 kilobytes as 16384, 16k or 16K.

-tx use .CPX startup stub

-tx=y use .CPX startup stub, specifying file y as the CPX header to be prepended to the executable.

-Y syntax check only (-y to lc1.ttp).

-z2 generate DRI format object code

The LC_OPT variable can have the form LC_OPT="FILE". In this instance lc.ttp reads the options from the named file.

New compiler options

In addition to the new LC.TTP driver options there are many additional compiler options. All of these are listed in the Integrated compiler section under their relative subsection. The format of these entries is as follows:

Assume best case aliasing **-Oalias**

The *Assume best case aliasing* option is enabled via the command line option -Oalias, the emboldening of the entire option indicates that the text should be typed literally.

Pre-processor expansion buffer: *size* **-z***size*

The *Pre-processor expansion buffer* option is enabled via the command line option -z*size*, the non-bold size part indicates that the user preference is entered here (e.g. -z10000).

Ignore symbol casing **NOCASE**

This is a linker option (indicated by the lack of a preceding minus); there is no way of passing these directly from LC.TTP to CLink, however many of these options have -L equivalents (-Lc in this instance). The full linker commands may either be passed on the command line to CLink, or via a WITH file.

Linker

To better support new Atari machines (e.g. the TT), several new options have been added to the linker, in addition to greatly improved speed for those with plenty of memory.

The new (or modified options are):

ADDSYM	Replace symbol table with table built from exported symbols.
BUFSIZE size	If `size` > 0 set input *and* output buffer size to `size` bytes, if `size` < 0 set output buffer size to `-size` bytes. By default the linker now buffers the whole of input source files for as long as possible, this often means that no re-reading is necessary for the second pass, although it may run out of memory as a result. If this happens, try setting an buffer size of 1024 to try and release more memory. If you have plenty of memory you may like to increase the output buffer from the default of 4K, by specifying an output buffer size of say -32K.
DRISYM	Force symbols placed in the executable to be of standard format. Note that this option is only effective when generating an executable file.
NOCASE	Ignore casing of symbols whilst resolving externals
NOFASTLOAD	This disables the setting of the 'fast load' bit in the program header of an executable program. This means that the whole of the TPA will be zeroed rather than just the BSS section. Note that this option is only effective when generating an executable file.
PREFIX file	This specifies a file which is to be prepended to the output file; this is particularly useful for building control panel extensions. Note that this option is only effective when generating an executable file.

TPASIZE n	Sets the size of TPA required for loading into alternative RAM. This value sets the minimum amount of alternative RAM, in Kbytes, which must be free for a program which has the TTLOAD bit set. The minimum value is 128, the maximum 2048 (2Mb). Note that this option automatically enables the TTLOAD option. Note that this option is only effective when generating an executable file.
TTLOAD	This sets the load into alternative RAM bit in the program header of an executable program. Note that this option is only effective when generating an executable file.
TTMALLOC	This sets the malloc-from alternative RAM bit in the program header of an executable program. Note that this option is only effective when generating an executable file.

The XADDSYM option has been removed, the default is now extended format symbols, also the way in which symbols are generated has changed... Within a linkable file both the assembler and compiler generate a HUNK_SYMBOL section (this contains the values for all debugging symbols), when any of the relevant debug options are enabled.

The semantics of the ADDSYM option have also therefore changed... If present this option causes the contents of all HUNK_SYMBOL sections to be discarded and the executable symbol table built from the exported symbols. This has the advantage that library names then appear in the symbol table, howver any non-global symbols disappear.

CLINKWITH; the CLink environment variable

The environment variable CLINKWITH, if available, is takèn by CLink to be the name of a WITH file whose contents is to be searched *before* any of the other files mentioned on the command line. This allows a template WITH file to be generated with the standard startup and library files mentioned in the CLINKWITH file, whilst the additional files are specified on the command line. The format of the CLINKWITH variable should be:

```
CLINKWITH=c:\lattice\default.lnk
```


Note that if you are running on a TT you usually want the load bits set to run in TT RAM etc., but CLink defaults to TTLOAD etc. off, for compatability. If a CLINKWITH file is specified and includes the lines:

```
TTLOAD
TTMALLOC
```

programs will automatically be linked to go into TT RAM.

ASM
The Assembler

The Lattice Macro Assembler supports the development of assembly language modules for use with C programs. Because the Lattice C Compiler generally produces very good machine code you seldom have to resort to assembly language programming. However, some intimate relations between hardware and software are best achieved in the assembly language environment. Also, assembly language is sometimes necessary when you want to get the best combination of code size and speed.

The assembler handles the complete set of Motorola 680x0 instruction mnemonics as well as an extensive set of assembler directives and a powerful macro facility. It can, therefore, be used to develop complete systems in assembly language. Nonetheless, it is provided primarily to supplement the C compiler and has not really been designed for large assembly language projects. For such tasks a full assembler package, such as DevpacST should be used giving more power for the assembly language programmer.

Basic concepts

The assembler reads a source file and produces an object file in the Lattice object file format, along with an optional listing of the source and assembled code. The source file is assumed to have a `.S` extension and the object file is produced with a `.O` extension.

Source format

Each assembly language source line has the following format:

```
label     operation  operands      comment
```

White space (i.e. spaces and tabs) can appear before any field and must appear between the `operation` and `operand`.

The four fields of the source line are described below:

Label

The `label` field is optional. If it is present and is preceded by white space, it must be followed immediately by a colon. That is how the assembler determines that the field is a label and not an operation. If there is no white space before the label, then the colon may be omitted.

A label can normally be up to 63 characters long and can contain letters, digits, underscores, periods, at symbols (`@`) and dollar signs. It cannot start with a digit, and the case of letters *is* significant. For example, labels `XYZ`, `xYZ`, and `XyZ` are distinct.

Local labels are supported using the Motorola standard syntax of a decimal number followed by a dollar character. They may be used between two non-local labels and need only have unique names within that scope. Note that unlike GenST, starting a label with a period *does not* signify a local label.

Operation

The `operation` field contains the name of an instruction, assembly directive, or macro. This field may not begin a line; if no label is present, then the line must begin with white space. If a label is present but is not followed by a colon, then white space must separate the label and operation fields.

The case of this field is *not* significant. That is, operation `MOVE` is the same as `move`, this applies equally to macros.

Operands

The `operands` field contains zero or more expressions, depending on the particular operation. For some operations, the `operands` field is optional or never used. Expressions are composed of constants, variables, and operators.

A *constant* is a decimal, hexadecimal, octal, or binary number. The default number base is decimal, and the other bases are indicated by a prefix:

Number representations

Number	Representation	Example
Decimal	a string of decimal digits	`1234`
Hexadecimal	$ followed by a string of hex digits	`$89AB`
Octal	@ followed by a string of octal digits	`@743`
Binary	% followed by zeros and ones	`%10110111`
ASCII Literal	Up to 4 ASCII characters within quotes	`"AC9T"`

A *variable* is a label name or a name defined via an assembler directive. The special variable, * (asterisk) can be used to signify the current program counter.

An *operator* is one of the following:

Order	Operator	Meaning
1	-	Unary minus
	~	Bitwise NOT
2	<<	Left shift
	>>	Right shift
3	&	Bitwise AND
	!	Bitwise OR
4	*	Multiply
	/	Divide
	%	Modulo
5	==	Equal to
	!=	Not equal to
	<	Less than
	<=	Less than or equal to
	>	Greater than
	>=	Greater than or equal to
	+	Add
	-	Subtract
6	^	Bitwise Exclusive OR

The Order column indicates the order in which operators are processed. Operators of the same precedence are processed from left to right. For example, in the expression

```
ABC+DEF*-PDQ
```

the negation of PDQ is performed first, followed by the multiplication and then the addition, although this can be overridden by the use of parentheses as in,

```
(ABC+DEF)*-PDQ
```

Each expression represents a 32-bit value. An *absolute expression* is one that contains only constants (literal or equated), while a *relocatable expression* contains symbols whose value is determined during linking.

Comment

This field is any text appearing after an operation, associated operands and white space. A comment may also be specified after a label or on a blank line when prefixed with a semi-colon or asterisk.

Addressing modes

The addressing modes supported by the Lattice assembler are as follows:

Mode	Example
Dn	add.w d1,d0
An	addq.w #1,a1
(An)	add.w (a1),d0
(An)+	add.w (a1)+,d0
-(An)	add.w -(a1),d0
d16(An)	add.w 10(a1),d0
d8(An,Xn)	add.w 10(a1,a2.l),d0
bd(An,Xn)	add.w $10000(a1,a2.l),d0
([bd,An],Xn,od)	add.w ([10,a1],a2.l,20),d0
([bd,An,Xn],od)	add.w ([10,a1,a2.l],20),d0
(xxx).W	add.w (100).w,d0
(xxx).L	add.l (100).l,d0
#<data>	add.l #100,d0
d16(pc)	add.w 10(pc),d0
d8(pc,Xn)	add.w 10(pc,a2.l),d0
bd(pc,Xn)	add.w $10000(pc,a2.l)
([bd,pc],Xn,od)	add.w ([10,pc],a2.l,20),d0
([bd,pc,Xn],od)	add.w ([10,pc,a2.l],20),d0

where:

d8	8 bit number
d16	16 bit number
bd	32 bit byte displacement
od	32 bit outer displacement
An	Address register (a0-a7)
Dn	Data register (d0-d7)
Xn	Index register (d0-d7/a0-a7)

Note that all the operands of the 68020 addressing modes are optional.

Data for the 68881 floating point instructions may be specified using floating point notation, i.e.

```
…#2.1
…#2.1E+10
```

will be converted into the proper floating point formats according to the type of instruction. For example, in the following instruction:

```
fmove.s    #2.1,fp1
```

The 2.1 would be in single precision. Other sizes allowed are:

```
fmove.d    #2.1,fp1      ; double precision
fmove.x    #2.1,fp1      ; extended precision
```

Note that the packed data format is not converted for you. Also if you want to specify the bit pattern by hand you may use the following formats:

```
fmove.s    #$12345678,fp1                  ; 32 bit
fmove.d    #$123456781234568,fp1           ; 64 bit
fmove.x    #$123456781234567812345678,fp1  ; 96 bit
```

You can also specify the constants in octal (i.e. @123456712) or binary (i.e. %0110110100110101).

Using the assembler from the command line

The assembler can be run via the following command:

```
asm [>listfile] [options] filename
```

Optional fields are enclosed in brackets, and all fields are described below:

>listfile

Causes the listing and error message output of the assembler to be directed to the specified file.

options

Assembler options are specified as a minus sign followed by a single letter; in some cases, additional text may be appended. The letter may be in either upper or lower case. Each option must be specified separately, with a separate minus and letter. The options are:

`-d` This option has two uses. It activates the debugging mode (in the same way as the compiler `-dl` option) or it defines symbols. When used to define symbols it may be used in the following ways.

`-dsymbol`

Causes `symbol` to be defined as if your source file had the statement:

```
symbol      EQU         1
```

`-dsymbol=value`

Causes `symbol` to be defined as if your source file had the statement:

```
symbol      EQU         value
```


`-ipfx` Specifies that `INCLUDE` files are to be searched for by prefixing the filename with the string `pfx`, unless the filename in the `INCLUDE` statement is already prefixed by a drive or directory specifier. Up to 16 different -i strings may be specified in the same command. No intervening blanks are permitted in the string following the -i. Note that if a directory name is to be specified as a prefix, a trailing backslash *must* be supplied.

When an unprefixed `INCLUDE` filename is encountered, the current directory is searched first; then file names are constructed and searched for, using prefixes specified in -i options, in the same left-to-right order as they were supplied on the command line.

`-lopt` Causes a listing of the source file to be written to the standard output. The listing displays the appropriate program counter and code information alongside the assembly source. One or more of the following characters may be appended to the `-l` option, with the following effects:

- `i` List the source for text from `INCLUDE` files as well as the original source file.
- `m` List additional data generated for source lines which cannot be accommodated alongside the original source line (i.e. allows multiple listing lines for each source line).
- `x` List the expansion text for macros.

`-m` This option controls whether warnings are generated when code for the relevant processor is encountered. The `-m` must be immediately followed by one of the letters from the following list:

- `0` Used for 68000 target. Provides warning if you attempt to use 68010/020/030/040/332 only instructions. This is the default case.
- `1` Used for 68010 target. Provides warning if you attempt to use 68000/020/030/040/332 only instructions.
- `2` Used for 68020 target. Provides warning if you attempt to use 68000/010/030/040/332 only instructions.

3 Used for 68030 target. Provides warning if you attempt to use 68000/010/020/040/332 only instructions.

4 Used for 68010 target. Provides warning if you attempt to use 68000/010/020/030/332 only instructions.

32 Used for 68332 target. Provides warning if you attempt to use 68000/010/020/030/040 only instructions.

8 Used for 68881/68882 target.

9 Used for 68851 target.

`-nsig` Sets the significance of symbols to `sig` characters. If no size is specified, this option defaults to using 8 character significance.

`-opfx` Specifies that the output filename (the .O file). If a directory name is specified the output name is formed by prefixing the input filename (the .S file which is being assembled) with `pfx`. Any drive or directory prefixes originally attached to the input filename are discarded before the new prefix is added. No intervening blanks are permitted in the string following the `-o`. Note that if a directory name is to be specified as a prefix, a trailing backslash *must* be supplied.

`-u` This option automatically prefixes all external references with an underline (_). If references to C labels have already been prefixed with an underline, the option is not needed.

`-w` This option works like the option `-dSHORTINT`.

filename

Specifies the name of the source file to be assembled. This is the nly required field on the command line. If the name does not have an extension `.S` is assumed. The object file will have the same name as the source file, except that the source file extension is replaced with `.O`.

For example, the following command causes the assembly language source file modn.s to be assembled, producing the object file modn.o. A listing of the source file, along with any error messages generated, will be written to the file modn.lst.

```
asm >modn.lst -l modn
```

Assembler directives

The assembler handles all the instructions of all members of the M68000 family as detailed in the 'Motorola M68000 family programmers reference manual'. Assembler directives are instructions to the assembler rather than instructions to be translated directly into object code. Note that although the `IDNT`, `PAGE`, `SPC` and `TTL` directives are recognised, they are not supported and do not cause errors to be generated in order to provide compatibility with other assemblers. Also, as with instruction mnemonics, directives cannot begin in the first character of the source line.

COMM symbol,size

The `COMM` directive creates a 'common' block identified by `symbol` and of the given `size`. Space for a common block is allocated at link time and, in the absence of an external definition, is the size of the largest block encountered by the linker.

CNOP offset,alignment

This directive aligns the program counter using the given byte alignment and offset. For example,

```
cnop        1,4
```

aligns the program counter one byte past the next long-word boundary relative to the start of the current section. Note that

```
cnop        0,2
```

is equivalent to the `EVEN` directive found in other assemblers and will ensure that the following data is aligned on an even address (i.e. a word boundary). This is normally only necessary when 68000 instructions follow byte-aligned data as the `DC` and `DS` directives word-align automatically.

CSECT name[,type,alignment,reltype,relsize]

Defines a program control section. Some form of section *must* be defined before any data can be generated. All parameters are optional except `name` and have the following functions:

`name`	is the control section name, note that this is case sensitive.
`type`	may be CODE (or 0) for instructions, DATA (or 1) for initialised data, or BSS (or 2) for uninitialised data sections; the default value is 0.
`align`	specifies the alignment requirements of the control section as a power of 2; this parameter is currently ignored and all sections are longword aligned.
`reltype`	specifies the relocation type, which determines the default addressing mode to be used for all symbol references and definitions from within the control section. The default value is 0.
`relsize`	specifies the size, in bytes, of the relocation data for the section; the default value is 4.

Legal `reltype` and `relsize` combinations for relocation information on the 68000 are summarised in the following table:

reltype	relsize	Description
0	4	Absolute long addressing (default)
0	2	Absolute short addressing
1	2	PC-relative offset (PC)
2	2	Address-register-relative offset (A4)

A discussion of the use of `CSECT` directives which are compatible with the `-b` and `-r` options of the C compiler appears later.

[label] DC.B expression[,expression] ...
[label] DC.W expression[,expression] ...
[label] DC.L expression[,expression] ...

These directives define constants in memory. They may have one or more operands, separated by commas. The constants and any associated label will be aligned on a word boundary for DC.W and DC.L. You may also specify string expressions for DC.B within single or double quotes.

Be very careful about spaces in DC directives, as a space is the delimiter before a comment. For example, the line:

```
dc.b        1,2,3 ,4
```

will only generate 3 bytes - the `,4` will be taken as a comment.

[label] DS.B expression
[label] DS.W expression
[label] DS.L expression

These directives reserve uninitialised memory locations. Any label specified is set to the start of the area, which will lie on a word boundary for the `DS.W` and `DS.L` directives. If used within a BSS section, the reserved space is simply added to the section size and no object code is generated.

For example, each of these lines will reserve 8 bytes of space in different ways:

```
ds.b 8
ds.w 4
ds.l 2
```

END

Signifies the end of program source.

ENDM

Terminates a macro definition. Must be used after a `MACRO` directive.

label EQU expression

This directive permanently assigns the value and type of a given label to be equivalent to the expression. If there is an error or forward reference in the expression, the assignment will not be made.

IDNT string

Currently ignored, provided for compatibility only.

INCBIN filename

Includes a binary file, verbatim, in the output file. Suggested uses include graphics data and ASCII files. You may specify a drive specifier and directory for `INCBIN`, otherwise it will default to searching the current directory.

INCLUDE filename

This directive will take source code from a file on disk and assemble it exactly as though it were present in the text. The directive must be followed by a filename in normal GEMDOS format. If a drive specifier or directory is included, the entire filename must be surrounded by quotes, e.g.

```
include    "b:\constants\header.s"
```

In the absence of a drive specifier, the filename is taken to be relative to the current directory and any include directories specified on the command line are also searched.

Include directives may be nested up to 16 levels and if any error occurs when trying to open the file or read it, assembly will be aborted with a fatal error.

LIST

Turns on the assembly listing. All subsequent lines will be listed until an `END` directive is reached, the end of the text is reached, or a `NOLIST` directive is encountered.

[label] MACRO

This starts a macro definition causing all following lines to be copied into a macro buffer until a matching `MEXIT` directive is encountered. The presence of a label determines whether Motorola-style macros are to be used. Refer to the macro definition section for a more detailed explanation.

MEXIT

This can be used as part of a `MACRO` definition to stop the current macro expansion prematurely, usually as a result of a conditional. `EXITM` is accepted as a synonym for `MEXIT`.

NARG

This is not a directive but a reserved symbol. Its value is the number of parameters passed to the current macro. Note that `\#` may be used as a synonym for NARG.

NOLIST

Switches the assembly listing off.

OFFSET [expression]

The OFFSET directive switches code generation to a special dummy section for the generation of absolute labels. The optional expression sets the value for the first label, otherwise zero is used. No bytes are written to the disk and the only directive allowed is DS. This can be used to generate labels which represent offsets into a data structure. For example,

```
        offset    10
next    ds.l      1
title   ds.b      32
```

will assign the value of 10 to the label `next` and 14 to `title` (i.e. 1 longword after next). To return to ordinary code generation, use the `CSECT` or `SECTION` directive.

OPSYN name,opcode

Can be used to create a synonym of any valid label name for any opcode, directive or macro. Some examples of synonym definition and usage are:

```
        opsyn     banana,move
        opsyn     is,equ
        opsyn     .dcb,dc.b

        banana.l  d0,d1
label   is        42
        .dcb      1,2,3,4
```

The last example shows how this feature can be used to create pseudo-directives which provide compatibility with other ST assemblers in a way that is not possible with standard macro definitions.

PAGE

Currently ignored, provided for compatibility only.

RORG expression

This directive changes the program counter to the specified number of bytes from the start of the current section. Note that the value specified *must be less than* the current PC.

SECTION name[,type]

Define a program section. There are no restrictions on name and the optional type may be one of the following (in upper or lower case):

CODE	code section (instructions)
DATA	data section (initialised data)
BSS	BSS section (uninitialised data)

The default type is CODE. Note that the SECTION directive is a subset of the CSECT directive which is explained in greater detail elsewhere.

label SET expression

This is similar to EQU, but the assignment is only temporary and can be changed with a subsequent SET directive. Forward references cannot be used in the expression.

TTL string

Currently ignored, provided for compatibility only.

XDEF symbol[,symbol...]

Defined symbols may be exported using XDEF; the symbol type (relocatable or absolute) will also be exported.

XREF symbol[,symbol...]

This defines labels to be imported from other programs or modules. If any of the labels specified are already defined an error will occur, although importing a label more than once is accepted. Note that the symbol will inherit the relocation type of the control section in which it appears.

Conditional assembly

Conditional assembly allows the programmer to write a comprehensive source program that can cover many conditions. At the start of the conditional block there must be one of the many IF directives and at the end of each block there must be a corresponding ENDC directive.

IF expression
IFEQ expression
IFNE expression
IFGT expression
IFGE expression
IFLT expression
IFLE expression

These directives evaluate the expression, compare it with zero and then conditionally assemble depending on the result. The conditions correspond exactly to the 68000 condition codes with the exception of the IF directive, which is identical to IFNE.

IFD label
IFND label

These directives allow control depending on whether a label is defined or not. With IFD, assembly is switched on if the label is defined, whereas with IFND assembly is switched on if the label is *not* defined.

IFC 'string1','string2'
IFNC 'string1','string2'

Primarily for use within macros, these directives perform a case-sensitive comparison of two strings, both of which must be enclosed within quotes. IFC will only assemble the block if the strings match exactly, whereas IFNC does *not* assemble if the strings match.

ELSE

Toggles conditional assembly on or off. If the preceding conditional block was assembled, ELSE will cause assembly to stop until a matching ENDC is encountered, and vice-versa. ELSEIF is accepted as a synonym for the ELSE directive.

ENDC

This directive terminates the current level of conditional assembly. If there are more ENDCs than IFs, an error will be reported.

Macro definition

Asm supports two styles of macro definition. Motorola standard macros are defined via the following sequence:

```
name    MACRO
        ...
        ENDM
```

The definition must begin with the macro name followed by the directive MACRO. This is followed by the lines that comprise the macro itself, terminated by the ENDM directive. The MEXIT directive may also be used within the macro to terminate the macro early. Using this method of definition, macro parameters are referenced by a backslash and a number, for example

```
        move.w      \2,(a0)
```

which would substitute the second macro parameter for \2. Alternatively, you may wish to use the second form of macro definition which is more flexible although non-standard:

```
        MACRO
        name        [arglist]
        ...
        ENDM
```

With this system the MACRO directive must appear first, followed by a line showing a model of how the macro will be called. The arglist is a comma-separated list of argument strings which provide macro parameter names and default values in the following format:

```
        arg[=default]
```

where arg is an identifier which can be used within the macro to refer to the corresponding argument text in the macro invocation and default is a string that will be associated with arg when that argument is not provided by a particular macro invocation. Note that default must be enclosed in single or double quotes if it contains any white space characters.

Both formats of macro definition support the NARG reserved word - and its alternative syntax of \# - which will be substituted with the number of macro arguments. Also, quoted strings may be passed as macro parameters.

In order to define labels within a macro you should use the special symbol \@. This causes the assembler to generate a unique number each time the macro is used, preventing multiple definitions of the same label.

The following example illustrates macro definition using the second style:

```
        MACRO
        MINWORD     source=#100,dest
        cmp.w       source,dest
        blt.b       min\@
        move.w      source,dest
min\@
        ENDM
```

The macro name is MINWORD and it could be invoked in the following way:

```
        MINWORD     ,d2
        rts
```

resulting in the instructions,

```
        cmp.w       #100,d2
        blt.b       min.0
        move.w      #100,d2
min.0
        rts
```

Note that the default value of #100 was substituted because the first parameter was omitted and that \@ was replaced by .0 (calling the macro a second time would use .1 etc.).

Pre-defined macros and synonyms

To aid in porting code from other assemblers there are a number of pre-defined macros and opcode synonyms which reflect common usage under other assemblers:

```
BSS     MACRO
        CSECT       udata,2
        ENDM
```

```
DATA    MACRO
        CSECT   data,1
        ENDM

EVEN    MACRO
        CNOP    0,2
        ENDM

TEXT    MACRO
        CSECT   TEXT,0
        ENDM

        OPSYN   ELSEIF,ELSE

        OPSYN   EXITM,MEXIT
```

Interfacing C with assembly language

The aim of this section is to discuss the conventions which a program must follow when interfacing to C. Attention is given to features of the Lattice assembler, Asm, which assist in writing such code and some of the pitfalls which can occur. Full examples of both C calling an assembly language routine and assembly calling a C function are given towards the end of the section.

The following list covers the main points which you should bear in mind when writing assembly code for use with C. Each of these is covered in greater detail with examples later in the section.

- Separate control sections containing definitions or external references should be defined for code, initialised data and uninitialised data (BSS) via the `CSECT` or `SECTION` directives.
- Code references (including function calls) may use PC-relative addressing or branch instructions if the function is within a 32K range, otherwise you should use absolute addressing (i.e. a JSR instruction).
- Data references for `near` data should use register A4 as a base pointer whereas `far` data must use absolute addressing.
- Near data must be defined in the named section `__MERGED`.
- Standard argument passing functions are prefixed by an underscore (_) and use values pushed onto the stack.
- Register passing functions have a prefix of `@` and place *some* arguments in registers with the remainder on the stack.

- The `__asm` specifier can be used to determine which register each function argument is passed in, with certain limitations.
- The size of type `int` may vary between word and long. Also, type `char` may be signed or unsigned depending upon compiler options.
- Return values appear in D0 with D1 also being used for `double` values. Note that the condition codes after a function call *cannot* be relied upon.
- A function may only corrupt registers D0-D1/A0-A1, all others *must* be preserved, including 68881 floating point registers (except for FP0/FP1) if used.

Control sections

In order for an assembly language program to link correctly with C object files you must use named control sections. The Lattice assembler provides this facility through the `SECTION` and `CSECT` directives. The latter of these provides more powerful options concerning automatic conversion of addressing modes, although in many cases you can simply use `SECTION`. A summary of both options can be found in the assembly directives section.

Programs should be divided into *code* (assembly language instructions and routines), *data* (initialised data and constants) and *BSS* (uninitialised data) sections. Each of these is described in greater detail below.

Code sections

All assembly language instructions should appear within code sections. The two simplest form of directives you can use to specify a code section are:

```
SECTION     name
CSECT       name
```

where `name` is the control section name. The compiler uses the default section name of `text` for all code generation although you may wish to use different names to identify program modules.

Any functions defined within a code section can be called from the same module with a branch or jump to subroutine instruction which you may wish to make PC-relative. However, in order to make a function visible to other modules when the program is linked you must define it as an external definition, for example,

```
XDEF        newtable
```

would make the function `newtable` callable from any other module. You should take into account that the C compiler automatically prefixes all external references with an underscore character _. The `XREF` directive may be used to access an external reference which is defined in another module.

The `CSECT` directive may also be used to specify additional information about the control section; its general format is:

```
CSECT       name,type,align,reltype,relsize
```

Only the `name` parameter must be present; it specifies the name of the control section. The `type` parameter describes the type of section; code, data or BSS (the values 0, 1 and 2 may also be used). The `align` parameter specifies the alignment requirements of the control section. The last two parameters, `reltype` and `relsize`, specify the type and size of relocation information associated with symbols declared within the control section.

For example, the section directives described previously are equivalent to:

```
CSECT       name,code,4,0,4
```

which is interpreted as a named code section, aligned on a longword boundary, defaulting to absolute longword addressing for symbols. The final two parameters can be used in code sections to automatically convert absolute long addressing to PC-relative for more compact code, as in

```
CSECT       text,0,,1,2
XREF        _function
JSR         _function
```

Note that we have used the number `0` rather than `code` and the alignment parameter has been omitted as all sections are longword aligned. The `JSR` instruction will actually be assembled as

```
JSR         _function(PC)
```


because we have specified a relocation type of PC-relative. To override this you may move the `XREF` out of the PC-relative section. It is also possible to use several code sections with different relocation types, the assembler will only use PC-relative addressing for symbols declared in the correct sections.

The advantage of using `CSECT` to provide PC-relative instructions is that changing a single `CSECT` directive gives you the ability to transform all external references. This provides you with an equivalent mechanism to that provided by the `-r` option on `lc`.

To call a C function from an assembly language module, you must always include an `XREF` declaration for the function. Before calling the function (via `JSR` or `BSR`), you must supply any expected arguments in the proper order either on the stack or in registers, depending upon the style of parameter passing employed by the function. After control returns from the called function, the stack pointer must be adjusted to account for any pushed arguments.

```
XREF        _cfunc

MOVE.L      D0,-(A7)        ;push argument
MOVE.L      D1,-(A7)
JSR         _cfunc          ;call function
ADDQ.W      #8,A7           ;restore stack pointer
```

This code fragment illustrates stack parameter passing, more details can be found in the relevant section. Remember to prefix function names with an underscore _ or @ symbol accordingly.

Data sections

There are two types of control sections in which program data can be held; *data* and *BSS* sections (described later). The first of these is for initialised data and constants and may be defined with either of the following directives,

```
SECTION     name,data
CSECT       name,data
```

where name is the control section name. The compiler uses two names for data sections; data for far data (this is accessed with absolute long addressing) and __MERGED (the program's near data, accessed as a base-relative offset from register A4). Examples of instructions used to access each type of data are

```
        move.w      fardata,d0
        move.w      neardata(a4),d1
```

When defining global data in assembly which is accessed by a C program you must declare the symbol as an external with an XDEF directive. The C source must also include an extern declaration of the correct type. For example, this assembly program *defines* a global variable:

```
        CSECT       asmdata,data
        XDEF        _entrynum

_entrynum DC.W      15
        END
```

Note that data is always prefixed with an underscore. This can be done automatically via the -u option. The corresponding C code to declare the variable is as follows,

```
extern unsigned short far entrynum;
```

The Lattice assembler provides a way of specifying a near data section, i.e. where all the data lies within a 32K range which is accessed off A4. All absolute longword references to symbols declared within such a control section will automatically be converted to the address-register-relative addressing mode. This is done through the CSECT directive:

```
        CSECT       __MERGED,data,,2,2
```

where the case of the section name *is* important. In practice, this gives you a direct equivalent to the -b option of lc, allowing you to change the arrangement and thus the access mode for any data by simply placing it in an appropriate control section. Consider the following code:

```
        SECTION     text
        move.w      globl,d0
        move.l      _otherdata,d1
        rts

        CSECT       __MERGED,1,,2,2
        XREF        _otherdata
globl   DC.W        42
```

The move instructions will actually be assembled as

```
        move.w      global(a4),d0
        move.l      _otherdata(a4),d1
```

because the symbols were declared in a near data section.

BSS and offset sections

The second form of data section is the *BSS* or uninitialised data section. It behaves in exactly the same way as a regular data section except that the only directive allowed is the DS directive. By placing all data which you require to be initialised to zero in the BSS section you can save considerable file space because no data is actually written, the *size* of the section is merely remembered.

The directives to start a BSS section are identical to data sections in every respect other than the section type. The special section name of __MERGED is also recognised for near data in a similar way to that described previously.

Although visibly very similar to a BSS section, an *offset* section describes merely the layout of data and not actually a specific instance of it. The primary use of the OFFSET directive is to provide a simple way to declare offsets into data structures. For example, here is a structure described in C:

```
struct NameNode {
   struct NameNode *next;
   struct NameNode *prev;
   int uses;
   unsigned char name[16];
};
```

In order to use this structure from an assembly language program, we must use numerical offsets into the structure. To aid readability and maintainability we wish to use symbols which refer to each element. The following description provides just that:

```
        OFFSET
nn_next DS.L        1
nn_prev DS.L        1
        IFD         SHORTINT
nn_uses DS.W        1
```

```
            ELSE
nn_uses     DS.L        1
            ENDC
nn_name     DS.B        16
sizeof_nn   DS.B        0
```

This does not generate any code, simply offset values. The symbols `nn_next`, `nn_prev` and `nn_uses` will be set to the absolute values of 0, 4 and 8 respectively. The prefix of `nn_` has been added to avoid possible name clashes with other symbols and the dummy entry `sizeof_nn` provides a convenient way of referring to the size of the entire structure.

A conditional block has been used around the integer field because the length of an integer may vary between word and longword. Using this method, re-assembling the source with the `-w` flag for short integers will automatically generate the correct offsets. Some code which accesses this structure might look like the following:

```
        lea         firstnode(a4),a0
        subq.w      #1,nn_uses(a0)
        move.l      nn_next(a0),a0
        rts
```

Function Entry Rules

There are several rules which the compiler enforces to provide a mechanism for calling functions. These rules must also be followed by assembly programmers wishing to interface with C.

Regardless of how the function was called, register A7 (the stack pointer) always points to a return address. Register A4 points into a program's near data to allow base-relative addressing as discussed in the previous section.

Depending upon the style of parameter passing employed by a particular function, parameters may either be found on the stack, in registers or a combination of both. Arguments are always passed by value. An explanation of the three methods of parameter passing follows.

Standard arguments

This is the default method of parameter passing where all function arguments are placed on the stack immediately before the return address. The `__stdargs` keyword may also be used in a function prototype or definition to force stack parameters. Note that functions which take a variable number of parameters *always* use standard argument passing.

Register A7 is the stack pointer which points to the 4-byte return address followed by the arguments in left-to-right order. Arguments can then be accessed as an offset from the stack pointer. The exact location of the parameters on the stack depends on the argument types and the current flags. Considering the default long integer mode, for the function call:

```
char ccc;
double ddd;
int iii;
func(ccc,ddd,iii);
```

The compiler generates code to extend each of the parameters to the size of an `int` if it is smaller and then push the arguments onto the stack in *reverse* order. For example,

```
        move.l      d0,-(sp)
        movem.l     d2-d3,-(sp)
        ext.w       d1
        ext.l       d1
        move.l      d1,-(sp)
```

This results in a stack organised in the following way:

Location	Size	Contents
(A7)	4	Return address
4(A7)	4	Argument `ccc`
8(A7)	8	Argument `ddd`
16(A7)	4	Argument `iii`

By comparison, in default short integer mode (option `-w`) the compiler would generate code to push the arguments `ccc`, `ddd`, and `iii` onto the stack using *two* bytes, eight bytes and *two* bytes, respectively:

```
        move.w      d0,-(sp)
        movem.l     d2-d3,-(sp)
```

```
ext.w     d1
move.w    d1,-(sp)
```

Location	Size	Contents
(A7)	4	Return address
4(A7)	2	Argument ccc
6(A7)	8	Argument ddd
14(A7)	2	Argument iii

Note that due to the widening of `char` types to the size of an `int`, the actual parameter is in the *low byte* of the `int` although the full integer value may be used. Also remember that `char` may be `signed` (the default) or `unsigned` depending upon compiler options.

If a structure or union is passed by value to a function, then the contents of the aggregate are copied onto the stack with the last element pushed first. In effect you receive a complete copy of the aggregate on the stack followed by a single byte for alignment if necessary.

Stack space occupied by function arguments may be used by the function as temporary workspace once the values are no longer needed.

Register arguments

If a function is explicitly declared `__regargs` or is called from a module compiled with the `-rr` option, some arguments are passed in registers instead of on the stack. Note that functions which accept a variable number of parameters always use the previous style of parameter passing.

With register parameters, the first two pointer arguments will appear in `A0` and `A1`, and the first two integral arguments will be in `D0/D1` and widened to an `int` if necessary as previously described.

When not generating inline floating point code (`-f8`) a double pair will be passed in `D0/D1` if both are available, or any combination of float and integral parameter may be passed in `D0/D1`. When inline FPU code *is* being generated then `FP0/FP1` are used to pass real parameters.

Structures and unions along with any parameters not placed in registers are passed via the stack in the usual way.

Obviously, the function needs to know whether it is being called with some arguments in registers or with all arguments on the stack. The compiler helps make this distinction by placing the character `@` in front of function names that are called with register arguments, replacing the underscore that the compiler normally supplies as a function prefix.

The __asm keyword

Providing much greater control over register passing, the `__asm` keyword allows you to specify exactly which registers parameters are to be passed in. It can be used in both function definitions and declarations:

```
int __asm mymax(register __d0 int,register __d1 int);

int __asm myfun( i,p )
   register __d0 int i;
   register __a1 char *p;
```

In order for the register specifier sequence to be used, you must have the `__asm` keyword specified on the function. If you do use the `__asm` keyword, you *must* specify a register for each parameter and not re-use the same register for any two parameters. If you need to pass some parameters on the stack then you should use the `__regargs` keyword instead. Note that currently the compiler is restricted to returning only basic types like `long`, `double`, etc.

In order to permit the most flexibility in register passing, the compiler does not limit what registers may be passed. However this can lead to situations in which it is impossible to generate code that works in the presence of aliased variables. To ensure that such situations are not encountered, you should avoid utilising registers that would normally be assigned as register variables and instead only use the registers:

```
__d0      __a0      __fp0
__d1      __a1      __fp1
__d2                __fp2
```

The best advice is to be careful when using this feature and if you are uncomfortable with it, use the `-rr` option of `lc1` (or `__regargs`).

Another mechanism which may be used to achieve similar effect to `__asm` is the `#pragma inline` statement described in detail elsewhere in this manual. When no instruction stream is present, this will generate a function call which may use any register or the stack for parameters and may use any register for the return value.

Function exit rules

Function return values are passed back in one or more registers, depending on the data type declared for the function. The conventions are:

Return Data	Bits	Asm Syntax	Meaning
`char`	8	`D0.B`	Low byte of D0
`short`	16	`D0.W`	Low word of D0
`long`	32	`D0.L`	All of D0
`float`	32	`D0.L`	All of D0
`double`	64	`D0.L, D1.L`	High bits in D0
`pointer`	32	`D0.L`	All of D0

Note that the above table does not mention `int`. An assembly language function should return its value as a `short`, if in default short integer mode (`-w`) or as a `long` if not in that mode, i.e. `D0.W` or `D0.L`.

If inline floating point is being used (`-f8`) then register `FP0` is used for floating point returns, viz:

Return Data	Bits	Asm Syntax	Meaning
`float`	96	`FP0`	All of FP0
`double`	96	`FP0`	All of FP0

If the function returns a structure or union, it must define a static work area (i.e. not on the stack) to temporarily hold the returned object. Then the function must return in D0 a pointer to this temporary copy, and the calling function will immediately move the data to the appropriate place. This approach implies that functions returning structures or unions are not re-entrant, although they are serially re-usable. Such functions *can* be recursive if designed very carefully with this in mind.

The registers D2 through D7 and A2 through A6 must be saved if they are used by the function, similarly if a 68881 maths co-processor is present (only possible on 68020 or 68030 systems) and any of the floating point registers FP2 through FP7 is used, they must also be saved.

After setting up the return value, a function exits with the `RTS` instruction. Note that the calling function removes the arguments from the stack.

Calling assembly from C

To illustrate how the rules governing C functions affect an assembly language routine we have chosen a short example which can be implemented either as C calling assembly, or assembly callingCC (the C and assembly object modules must be linked with the startup code and appropriate libraries). It illustrates many of the points made previously and can be used as a basis for your own function calls.

The function returns a hash value calculated by adding together the ASCII codes of each character in the supplied string up to a specified length. This value is then divided by the number held in the global variable `maxhash` and the remainder (or modulo) is returned.

The calling program simply defines and initialises the variable `maxhash` and calls the hash function with a sample string. Implemented in C, this is as follows:

```
unsigned short maxhash;    /* definition */
/* declaration (prototype) */
unsigned int
hash(unsigned int length, const char *string);

void
main(void)
{
   unsigned int result;

   maxhash = 101;
   result = hash(4,"Banana");
}
```

The hash function coded in assembly language for default addressing modes, parameter passing and types:

```
            CSECT       text,code       control section
            XDEF        _hash,@hash     declarations
            XREF        _maxhash        imported global

_hash                                   ; stdargs entry point
            movem.l     4(sp),d0/a0     get the parameters
@hash                                   ; regargs entry point
            move.l      d2,-(sp)        preserve register
            moveq       #0,d2
            bra.s       1$
2$          move.b      (a0)+,d1
            ext.w       d1
            ext.l       d1
            add.l       d1,d2
1$          subq.l      #1,d0
            bcc.s       2$
            divu        _maxhash(a4),d2
            clr.w       d2              make result 32-bit
            swap        d2              get remainder
            move.l      d2,d0           return value in D0
            move.l      (sp)+,d2        restore register
            rts

            END
```

Any labels available to the C program are prefixed by an underscore character _ or @. Note that for this function, it is easy to provide an entry point for register parameter calling by simply bypassing the code which loads arguments from the stack into registers for use by the body of the function. If you are using register parameters as default, you may leave out this code entirely.

The global variable is accessed as a base-relative offset from A4 because we are using default near data. The function must also save D2 on the stack because it is used as a temporary register and must be restored.

Compiling the program with default short integers, unsigned characters and far data does not change the C source although it causes many changes to the assembly language. The function must now be changed to:

```
_hash
            move.w      4(sp),d0        length is now a word
            move.l      6(sp),a0        changing stack offsets
@hash
            move.l      d2,-(sp)
            moveq       #0,d1           can't sign extend char
            moveq       #0,d2
            bra.s       1$

2$          move.b      (a0)+,d1
            add.l       d1,d2
1$          dbra        d0,2$           optimised loop

            divu        _maxhash,d2
            swap        d2              don't clear high word

            move.w      d2,d0
            move.l      (sp)+,d2
            rts
```

Note that the parameters now have different offsets on the stack, characters can no longer be sign extended and global data must be accessed using absolute long addressing.

It becomes apparent that changes in compiler options such as `-b` or `-r` can dramatically alter the appearance of assembly code. The Lattice compiler provides some ways of insulating the programmer from these factors, as illustrated in the next section.

Calling C from assembly

This time, we will write the same program but as a C function called from assembly language. In order to provide the greatest flexibility whilst preserving code clarity, we will make use of the CSECT directive. This is the calling program for register arguments only:

```
            CSECT       text,code,,1,2
            XDEF        @main           PC-relative
            XREF        @hash

@main                                   ; regargs version
            move.w      #101,maxhash
            moveq       #4,d0
            lea         string,a0
            jsr         @hash           returns D0
            rts

            CSECT       __MERGED,data,,2,2
```

```
string    DC.B      'Radish'      data access off A4

          CSECT     __MERGED,bss,,2,2
          XDEF      maxhash
maxhash   DS.W      1
          END
```

Firstly, you may notice that there are no longer underscores before external labels. This is because the assembler can be called with the `-u` option which automatically prefixes an underscore to all externally visible labels whilst being overridden by the presence of an `@` symbol.

The relocation type and size parameters of the `CSECT` directive have been used in order to provide automatic `PC` and `A4` base-relative addressing modes for the relevant sections. This has the effect of automatically converting the references to `string` and `hash` to:

```
          lea       string(a4),a0
          jsr       hash(pc)
```

Simply changing the relocation type allows the assembler to automatically generate the correct addressing modes. This corresponds directly to the C compiler options. To override the default addressing mode you may simply specify another, or for external symbols, provide an `XREF` in an appropriate control section. In our example, moving the reference to `@hash` outside the PC-relative section forces absolute long addressing for all references to that symbol.

Specifying the special section name of `__MERGED` causes the linker to include the section contents within the program's near data segment allowing base-relative addressing via `A4`.

Now the hash function written in C:

```
/* declaration */
extern unsigned short maxhash;

unsigned int __regargs
hash(unsigned int length, const char *string)
{
   unsigned long total = 0;

   while (length--)
      total += *string++;

   return total % maxhash;
}
```

The `__regargs` keyword is present to force the compiler to use register passing for this function. Remember to link with the startup code and libraries for register parameters since we are using `@main` rather than `_main`.

Asm error messages

1 invalid opcode

An unrecognised opcode name was encountered; this is often caused by a mis-typed instruction.

2 unrecognized opcode

An operation was encountered which was not recognised as a valid opcode, synonym or macro.

3 data generation must occur in reloc section

A data generation operation other than DS appeared in an OFFSET section.

4 invalid operands for this opcode

This error can be caused by invalid addressing modes, data size, macro parameters etc.

5 (W) label ignored <label>

The label before a directive, such as a conditional, is not a recognised syntax and has been ignored.

6 must occur inside section

A data generation directive was used outside a control section.

7 invalid symbol

A symbol containing an illegal character or characters was declared.

8 public symbol not defined <name>

The program source contained an XDEF directive of a symbol which was not defined in the program.

9 cannot define absolute public symbol

10 external symbol redefined <name>

11 invalid expression

An OFFSET or IF directive contained an invalid expression. This error can also be caused by an expression containing a divide or modulo by zero.

12 missing label

An EQU or SET directive was encountered with no corresponding label.

13 duplicate label <label>

More than one definition of the same label was encountered.

14 not inside scope of IF directive

An ELSE directive was found which did not lie within a conditional control block.

15 invalid origin

An assembly directive causing incorrect data alignment or origin was found.

16 constant size not same as relocation size

A reference to a relative symbol conflicts with the byte size of relocation information for the current control section.

17 invalid string

A define constant or condition directive contained an invalid string.

18 (W) extraneous data on input line

A valid source line was followed by invalid text, which was ignored. This can be caused by providing too many parameters for an assembler directive.

19 duplicate section name

A section name was re-used illegally. This error can also be caused by an invalid OPSYN directive.

20 ELSE/ENDIF not found

An unterminated IFcc directive was encountered.

21 label offset different in pass 2

A phasing error caused by different code being generated on the first and second pass.

22 macro argument too large

A macro invocation was encountered with an argument string which was too long.

23 missing macro definition

The definition of a macro could not be found.

24 illegal macro definition

The syntax of a macro definition was incorrect.

25 duplicate macro definition

A macro was defined more than once.

26 invalid control section parameter

A CSECT directive with invalid parameters was encountered.

27 **invalid file name**

The filename specified for an INCBIN or INCLUDE directive was not valid.

28 **maximum include file nesting exceeded**

The INCLUDE directive has nested files too deeply. This is caused by included files referencing other files to a number of levels.

29 **file not found**

The file specified by an INCLUDE directive could not be found.

30 **invalid repeat count**

31 **macro substitution line overflow**

The substitution of macro arguments caused the line to overflow.

32 **immediate data out of range**

An arithmetic or logical operation was specified with an out of range immediate value.

33 **invalid effective address for opcode**

An attempt is being made to use an addressing mode not supported by the current instruction.

34 **invalid instruction size**

An attempt is being made to use an instruction size not supported by the current instruction.

35 **target out of range**

A reference to a label which is out of range has been encountered.

36 **value out of range for addressing mode**

An out of range value was used in an addressing mode.

37 **input line buffer overflow**

A source line has exceeded the maximum length.

38 **long branch to XDEF not supported by linker**

The Lattice linkable object file format does not support branches to external labels using a long-word offset.

39 **macro buffer overflow**

A macro definition was too long.

40 **ENDM/MEXIT not inside macro definition**

An ENDM or MEXIT assembly directive was encountered outside a macro definition.

41 **target not in current section**

42 (W) **END directive assumed**

This warning notifies you that there was no explicit END directive in the source file being assembled.

43 **invalid relocation type/size combination**

The specified relocation type and relocation data size specified in a CSECT directive are not available.

44 **unknown segment type**

The type specifier for a SECTION or CSECT directive was other than CODE, DATA or BSS.

45 **numeric value out of range**

A value in an expression overflowed the allowable range.

46 **opcode generated for <processor>**

An opcode only permitted for the indicated processors was generated.

47 **unrecognized expression**

48 **syntax error**

49 **invalid operation for relocatable data**

50 **undefined symbol**

51 **invalid opcode parameter reference**

52 **location counter not defined**

DERCS
The Resource Decompiler

Introduction

DERCS is utility for turning a resource file created using WERCS into a set of initialised data structures (`OBJECT`, `BITBLK`, `ICONBLK` etc.) which may subsequently be compiled to give a resource file embedded in a program.

This is advantageous when creating desk accessories (since desk accessories should not call `rsrc_load()`) and *essential* for writing control panel extensions (CPXs).

DERCS supports generation of both C and assembly langauge. Unfortunately the initialisation support available from other languages is not sufficiently rich to allow the representation of general resource files and so if a language of anything other than C is selected DERCS will generate an assembly language file.

Running DERCS

DERCS is run using a command line of the form:

```
dercs [-options] filename [filename]
```

The options are denoted by a - sign then a character *before* the filename. The options recognised are:

`-a` don't generate ANSI style function definitions. Normally DERCS generates any functions which it requires using the ANSI prototype syntax, viz:

```
void rsrc_init(void);
```

specifying this option causes it to use the old K&R syntax for function definitions. Obviously this flag has no effect for assembly language.

`-cx` specify casing is to be peformed according to *x* rather than the value set in the .HRD file; the values used for *x* are identical to those used by WERCS:

0	mixed
1	upper
2	lower

`-dx` specify *x* as name of the section data is to be placed in. This option allows you to configure the name of the section which DERCS generates when outputting the data section information for assembly language. If none is specified it defaults to DATA. Note that Lattice C ASM users may like to change this to '`__MERGED,data`'. Obviously this flag has no effect for C.

`-f` Suppress output of tree fixup code. Normally DERCS generates a function which you may call which 'fixes up' the resource trees in your file (i.e. the conversion from character to pixel co-ordinates). Specifying this options suppresses this behaviour. You can use this option if you want to fix up trees yourself, or if you are using more than one resource file.

`-h` write only a header file. This option writes only a header file in the desired langauge. Note that with careful use of the `-l` option this allows the generation of resource file constants for more than one language (e.g. in a mixed assembler/C project).

`-lx` use language specified by language number *x*; the values used for *x* are identical to those used by WERCS:

1	C
2	Pascal
4	Modula-2
8	FORTRAN
16	Assembler
32	BASIC

Note that for DERCS values 2 through 32 *all* generate assembly language.

`-px` use *x* as the prefix for automatically generated names. When DERCS is generating some of the more complex AES object structures it has to generate its own names for items which are unnamed in the resource file. If you are merging two or more DERCS'd resource files then this option can be used to ensure that no naming clashes occur.

`-v` suppress output of `section` directives or `include` directives. This means that DERCS will not output any of the 'padding' which it normally generates.

`-xic` generate pre-fixed resource file. This option is designed for building CPXs and fixes up all characters based on an 8x16 character. If *ic* is supplied, this should be the name of a free image in the resource file which is to be extracted into a .ICN file ready to be passed to CPREFIX.

The file specified first on the command line is then decompiled into either a C source file (if C was selected as the language in WERCS), or into assembler otherwise.

An optional second file name may be supplied to indicate a name for the output file.

Programming with DERCS

Programming using a resource file passed through DERCS is not dissimilar to using an ordinary resource file, the main difference is that `rsrc_gaddr()` is never used. Instead, DERCS builds all of the necessary resource information into a C file with the extension .C. This file also contains a special resource intialisation routine `rsrc_init()` (this routine actually performs the normal character to pixel coordinate transformations made by `rsrc_load()`).

Consider the following fragment written without DERCS:

```
#include <aes.h>
#include "resource.h"

int main(void)
{
   OBJECT *myobj;

   appl_init();
   rsrc_load("resource.rsc");
```

```
    rsrc_gaddr(TREE, MYOBJ. &myobj);
    objc_draw(myobj, ROOT, …);
    …
    rsrc_free();
    appl_exit();
}
```

Now assume that the command:

```
dercs resource.rsc
```

had been issued, generating the files resource.c and resource.h, then the same program could be written with DERCS:

```
#include <aes.h>
#include "resource.h"
#include "resource.c"

int main(void)
{
   appl_init();
   rsrc_init();
   objc_draw(MYOBJ, ROOT, …);
   …
   appl_exit();
}
```

Note that the `rsrc_load()` call has been replaced by `rsrc_init()`, and that the `rsrc_gaddr()` and `rsrc_free()` have disappeared altogether!

The object `MYOBJ` (which was what you named your object in resource.rsc) which is normally declared as a `#define` constant by WERCS is replaced by an `OBJECT` definition by DERCS, hence the address of the object (which `rsrc_gaddr()` would have obtained) is found simply by naming the object.

CPXBUILD
CPX .HDR Utility

Introduction

CPXBUILD is used to build the .HDR files used as arguments to the linker `PREFIX` option which specify the parameters for a CPX.

Running CPXBUILD

CPXBUILD is run using a command line of the form:

```
cpxbuild [-options] filename
```

The options are denoted by a - sign then a character *before* the filename. The options recognised are:

`-b` set boot-init flag; the boot initialisation flag of the CPX is set indicating that the CPX should be called during XControl's initialisation.

`-ccol` set title colour; the colour of the title is set to *`col`*. The colour numbers used are those used by the AES.

`-did` set CPX-id; the CPX id is set to *`id`*. If *`id`* has the special format `'cpid'` then the specifed alphanumeric *`cpid`* is used as the long-word CPX id.

`-fval` set flags absolutely; the header flags are set to the absolute value *`val`*; this option is provided to support any future additions which Atari may make to XControl during the lifetime of a CPXBUILD release.

`-iicn` specify an icon file; *`icn`* specifies a .ICN file which is to be used as the CPX's icon. The .ICN file is generated using DERCS' `-xic` option.

`-ntxt` set icon text; the descriptive text attached to the icon is set to *`txt`*.

`-pcol` set icon colour; set icon colour; the colour of the title is set to *`col`*. The colour numbers used are those used by the AES.

`-r` set resident flag; the resident flag of the CPX is set indicating that the CPX should be made resident at the time of XControl's startup.

`-s` set set-only flag; the set-only flag for the CPX is set; this indicates that the CPX performs all its work at boot time and need never be called again.

`-ttxt` set title text; the title text for the CPX is set to *`txt`*.

`-v` force CPXBUILD to print sign-on and version numbers. Normally CPXBUILD runs silently; this option causes more information to be generated.

`-vvsn` set CPX version; the CPX version number is set to *`vsn`*. Typically this will have the format *`major.minor`*.

The *`filename`* given on the CPXBUILD command line indicates the name of the .HDR file which should be built. Note that the .HDR is *not* automatically supplied; you must specifiy it if required.

Appendix A
Project file syntax

A project file is the file used by the integrated compiler to control the management of multi-module programs. These project (.PRJ) files are in an ASCII format and are compatible with those used by the German Pure-C™ and PKS-Edit™. The syntax may be described by the following grammar:

project:
(***** | *filename*) { *options* } = { *module* [(*dependents*)] }

options:
.L [*linker-options*]
.C [*compiler-options*]
.S [*assembler-options*]
.A [*librarian-options*]

module:
c-source-file [*compiler-options*]
assembler-source-file [*assembler-options*]
linker-file | *with-file* | *project-file*

c-source-file:
***** | *filename* | *filename***.C**

assembler-source-file:
*filename***.S**

linker-file:
*filename***.O** | *filename***.LIB**

with-file:
*filename***.LNK**

project-file:
*filename***.PRJ**

dependents:
filename [**,** *dependents*]