

Free Pascal
Programmers' manual

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About this document

This is the programmer's manual for Free Pascal.

It describes some of the peculiarities of the Free Pascal compiler, and provides a glimpse of how the compiler generates its code, and how you can change the generated code. It will not, however, provide a detailed account of the inner workings of the compiler, nor will it describe how to use the compiler (described in the [Users guide](#)). It also will not describe the inner workings of the Run-Time Library (RTL). The best way to learn about the way the RTL is implemented is from the sources themselves.

The things described here are useful when things need to be done that require greater flexibility than the standard Pascal language constructs (described in the [Reference guide](#)).

Since the compiler is continuously under development, this document may get out of date. Wherever possible, the information in this manual will be updated. If you find something which isn't correct, or you think something is missing, feel free to contact me¹.

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Chapter 1

Compiler directives

Free Pascal supports compiler directives in the source file. They are not the same as Turbo Pascal directives, although some are supported for compatibility. There is a distinction between local and global directives; local directives take effect from the moment they are encountered, global directives have an effect on all of the compiled code.

Many switches have a long form also. If they do, then the name of the long form is given also. For long switches, the + or - character to switch the option on or off, may be replaced by ON or OFF keywords.

Thus `{ $I+ }` is equivalent to `{ $IOCHECKS ON }` or `{ $IOCHECKS + }` and `{ $C- }` is equivalent to `{ $ASSERTIONS OFF }` or `{ $ASSERTIONS - }`

The long forms of the switches are the same as their Delphi counterparts.

1.1 Local directives

Local directives can occur more than once in a unit or program, If they have a command-line counterpart, the command-line argument is restored as the default for each compiled file. The local directives influence the compiler's behaviour from the moment they're encountered until the moment another switch annihilates their behaviour, or the end of the current unit or program is reached.

\$A or \$ALIGN : Align Data

This switch is recognized for Turbo Pascal Compatibility, but is not yet implemented. The alignment of data will be different in any case.

\$ASMMODE : Assembler mode (Intel 80x86 only)

The `{ $ASMMODE XXX }` directive informs the compiler what kind of assembler it can expect in an asm block. The XXX should be replaced by one of the following:

att Indicates that asm blocks contain AT&T syntax assembler.

intel Indicates that asm blocks contain Intel syntax assembler.

direct Tells the compiler that asm blocks should be copied directly to the assembler file.

These switches are local, and retain their value to the end of the unit that is compiled, unless they are replaced by another directive of the same type. The command-line switch that corresponds to this switch is `-R`.

The default assembler reader is the AT&T reader.

\$B or \$BOOLEVAL : Complete boolean evaluation

This switch is understood by the Free Pascal compiler, but is ignored. The compiler always uses shortcut evaluation, i.e. the evaluation of a boolean expression is stopped once the result of the total expression is known with certainty.

So, in the following example, the function `Bofu`, which has a boolean result, will never get called.

```
If False and Bofu then
    ...
```

This has as a consequence that any additional actions that are done by `Bofu` are not executed.

\$C or \$ASSERTIONS : Assertion support

The `{ $ASSERTION }` switch determines if assert statements are compiled into the binary or not. If the switch is on, the statement

```
Assert (BooleanExpression,AssertMessage) ;
```

Will be compiled in the binary. If `BooleanExpression` evaluates to `False`, the RTL will check if the `AssertErrorProc` is set. If it is set, it will be called with as parameters the `AssertMessage` message, the name of the file, the `LineNumber` and the address. If it is not set, a runtime error 227 is generated.

The `AssertErrorProc` is defined as

```
Type
    TAssertErrorProc=procedure(const msg:string;lineno,erroraddr:longint);
Var
    AssertErrorProc = TAssertErrorProc;
```

This can be used mainly for debugging purposes. The `system` unit sets the `AssertErrorProc` to a handler that displays a message on `stderr` and simply exits. The `sysutils` unit catches the run-time error 227 and raises an `EAssertionFailed` exception.

\$DEFINE : Define a symbol

The directive

```
{ $DEFINE name }
```

defines the symbol name. This symbol remains defined until the end of the current module (i.e. unit or program), or until a `$UNDEF name` directive is encountered.

If name is already defined, this has no effect. Name is case insensitive.

The symbols that are defined in a unit, are not saved in the unit file, so they are also not exported from a unit.

\$ELSE : Switch conditional compilation

The `{ $ELSE }` switches between compiling and ignoring the source text delimited by the preceding `{ $IFxxx }` and following `{ $ENDIF }`. Any text after the `ELSE` keyword but before the brace is ignored:

```
{ $ELSE some ignored text }
```

is the same as

```
{ $ELSE }
```

This is useful for indication what switch is meant.

\$ENDIF : End conditional compilation

The `{ $ENDIF }` directive ends the conditional compilation initiated by the last `{ $IFxxx }` directive. Any text after the `ENDIF` keyword but before the closing brace is ignored:

```
{ $ENDIF some ignored text }
```

is the same as

```
{ $ENDIF }
```

This is useful for indication what switch is meant to be ended.

\$ERROR : Generate error message

The following code

```
{ $ERROR This code is erroneous ! }
```

will display an error message when the compiler encounters it, and increase the error count of the compiler. The compiler will continue to compile, but no code will be emitted.

\$F : Far or near functions

This directive is recognized for compatibility with Turbo Pascal. Under the 32-bit and 64-bit programming models, the concept of near and far calls have no meaning, hence the directive is ignored. A warning is printed to the screen, as a reminder.

As an example, the following piece of code:

```
{ $F+ }

Procedure TestProc;

begin
  Writeln ( 'Hello From TestProc' );
end;

begin
  testProc
end.
```

Generates the following compiler output:

```
malpertuus: >pp -vw testf
Compiler: ppc386
Units are searched in: /home/michael;/usr/bin;/usr/lib/ppc/0.9.1/linuxunits
Target OS: Linux
Compiling testf.pp
testf.pp(1) Warning: illegal compiler switch
7739 kB free
Calling assembler...
Assembled...
Calling linker...
12 lines compiled,
  1.000000000000000E+0000
```

One can see that the verbosity level was set to display warnings.

When declaring a function as `Far` (this has the same effect as setting it between `{ $F+ }` ... `{ $F- }` directives), the compiler also generates a warning:

```
testf.pp(3) Warning: FAR ignored
```

The same story is true for procedures declared as `Near`. The warning displayed in that case is:

```
testf.pp(3) Warning: NEAR ignored
```

`$FATAL` : Generate fatal error message

The following code

```
{ $FATAL This code is erroneous ! }
```

will display an error message when the compiler encounters it, and the compiler will immediately stop the compilation process.

This is mainly useful in conjunction with `{ $IFDEF }` or `{ $IFOPT }` statements.

`$GOTO` : Support `Goto` and `Label`

If `{ $GOTO ON }` is specified, the compiler will support `Goto` statements and `Label` declarations. By default, `$GOTO OFF` is assumed. This directive corresponds to the `-Sg` command-line option.

As an example, the following code can be compiled:

```
{ $GOTO ON }

label Theend;

begin
  If ParamCount=0 then
    GoTo TheEnd;
  Writeln ( 'You specified command-line options' );
TheEnd:
end.
```

Remark: When compiling assembler code using the inline assembler readers, any labels used in the assembler code must be declared, and the `{ $GOTO ON }` directive should be used.

\$H or \$LONGSTRINGS : Use AnsiStrings

If `{ $LONGSTRINGS ON }` is specified, the keyword `String` (no length specifier) will be treated as `AnsiString`, and the compiler will treat the corresponding variable as an ansistring, and will generate corresponding code.

By default, the use of ansistrings is off, corresponding to `{ $H- }`. The `system` unit is compiled without ansistrings, all its functions accept shortstring arguments. The same is true for all RTL units, except the `sysutils` unit, which is compiled with ansistrings.

\$HINT : Generate hint message

If the generation of hints is turned on, through the `-vh` command-line option or the `{ $HINTS ON }` directive, then

```
{ $Hint This code should be optimized }
```

will display a hint message when the compiler encounters it.

By default, no hints are generated.

\$HINTS : Emit hints

`{ $HINTS ON }` switches the generation of hints on. `{ $HINTS OFF }` switches the generation of hints off. Contrary to the command-line option `-vh` this is a local switch, this is useful for checking parts of the code.

\$IF : Start conditional compilation

The directive `{ $IF expr }` will continue the compilation if the boolean expression `expr` evaluates to `true`. If the compilation evaluates to false, then the source is skipped to the first `{ $ELSE }` or `{ $ENDIF }` directive.

The compiler must be able to evaluate the expression at parse time. This means that variables or constants that are defined in the source cannot be used. Macros and symbols may be used, however.

More information on this can be found in the section about conditionals.

\$IFDEF Name : Start conditional compilation

If the symbol `Name` is not defined then the `{ $IFDEF name }` will skip the compilation of the text that follows it to the first `{ $ELSE }` or `{ $ENDIF }` directive. If `Name` is defined, then compilation continues as if the directive wasn't there.

\$IFNDEF : Start conditional compilation

If the symbol `Name` is defined then the `{ $IFNDEF name }` will skip the compilation of the text that follows it to the first `{ $ELSE }` or `{ $ENDIF }` directive. If it is not defined, then compilation continues as if the directive wasn't there.

\$IFOPT : Start conditional compilation

The `{ $IFOPT switch }` will compile the text that follows it if the switch `switch` is currently in the specified state. If it isn't in the specified state, then compilation continues after the corresponding

{`$ELSE`} or {`$ENDIF`} directive.

As an example:

```
{$IFOPT M+}  
  Writeln ('Compiled with type information');  
{$ENDIF}
```

Will compile the `writeln` statement if generation of type information is on.

Remark: The {`$IFOPT`} directive accepts only short options, i.e. {`$IFOPT TYPEINFO`} will not be accepted.

`$INFO` : Generate info message

If the generation of info is turned on, through the `-vi` command-line option, then

```
{$INFO This was coded on a rainy day by Bugs Bunny}
```

will display an info message when the compiler encounters it.

This is useful in conjunction with the {`$IFDEF`} directive, to show information about which part of the code is being compiled.

`$INLINE` : Allow inline code.

The {`$INLINE ON`} directive tells the compiler that the `Inline` procedure modifier should be allowed. Procedures that are declared inline are copied to the places where they are called. This has the effect that there is no actual procedure call, the code of the procedure is just copied to where the procedure is needed, this results in faster execution speed if the function or procedure is used a lot.

By default, `Inline` procedures are not allowed. This directive must be specified to use inlined code. The directive is equivalent to the command-line switch `-Si`. For more information on inline routines, consult the [Reference guide](#).

`$I` or `$IOCHECKS` : Input/Output checking

The {`$I-`} or {`$IOCHECKS OFF`} directive tells the compiler not to generate input/output checking code in the program. By default, the compiler does not generate this code, it must be switched on using the `-Ci` command-line switch.

When compiling using the `-Ci` compiler switch, the Free Pascal compiler inserts input/output checking code after every input/output call in the code. If an error occurred during input or output, then a run-time error will be generated. Use this switch to avoid this behaviour.

To check if something went wrong, the `IOResult` function can be used to see if everything went without problems.

Conversely, {`$I+`} will turn error-checking back on, until another directive is encountered which turns it off again.

The most common use for this switch is to check if the opening of a file went without problems, as in the following piece of code:

```
assign (f, 'file.txt');  
{$I-}  
rewrite (f);
```

```
{ $I+ }  
if IOResult<>0 then  
  begin  
    Writeln ( 'Error opening file: "file.txt"' );  
    exit  
  end;
```

See the `IOResult` function explanation in [Reference guide](#) for a detailed description of the possible errors that can occur when using input/output checking.

\$I or \$INCLUDE : Include file

The `{ $I filename }` or `{ $INCLUDE filename }` directive tells the compiler to read further statements from the file `filename`. The statements read there will be inserted as if they occurred in the current file.

The compiler will append the `.pp` extension to the file if no extension is given. Do not put the filename between quotes, as they will be regarded as part of the file's name.

Include files can be nested, but not infinitely deep. The number of files is restricted to the number of file descriptors available to the Free Pascal compiler.

Contrary to Turbo Pascal, include files can cross blocks. I.e. a block can start in one file (with a `Begin` keyword) and can end in another (with a `End` keyword). The smallest entity in an include file must be a token, i.e. an identifier, keyword or operator.

The compiler will look for the file to include in the following places:

1. It will look in the path specified in the include file name.
2. It will look in the directory where the current source file is.
3. it will look in all directories specified in the include file search path.

Directories can be added to the include file search path with the `-I` command-line option.

\$I or \$INCLUDE : Include compiler info

In this form:

```
{ $INCLUDE %xxx% }
```

where `xxx` is one of `TIME`, `DATE`, `FPCVERSION` or `FPCTARGET`, will generate a macro with the value of these things. If `xxx` is none of the above, then it is assumed to be the value of an environment variable. Its value will be fetched, and inserted in the code as if it were a string.

For example, the following program

```
Program InfoDemo;  
  
Const User = { $I %USER% };  
  
begin  
  Write ( 'This program was compiled at ', { $I %TIME% } );  
  Writeln ( ' on ', { $I %DATE% } );  
  Writeln ( 'By ', User );
```

```
Writeln ('Compiler version: ',{$I %FPCVERSION%});  
Writeln ('Target CPU: ',{$I %FPCTARGET%});  
end.
```

Creates the following output:

```
This program was compiled at 17:40:18 on 1998/09/09  
By michael  
Compiler version: 0.99.7  
Target CPU: i386
```

`$I386_XXX` : Specify assembler format (Intel 80x86 only)

This switch selects the assembler reader. `{$I386_XXX}` has the same effect as `{$ASMMODE XXX}`, section [1.1](#), page [12](#)

This switch is deprecated, the `{$ASMMODE XXX}` directive should be used instead.

`$L` or `$LINK` : Link object file

The `{$L filename}` or `{$LINK filename}` directive tells the compiler that the file `filename` should be linked to the program. This cannot be used for libraries, see section [1.1](#), page [19](#) for that.

The compiler will look for this file in the following way:

1. It will look in the path specified in the object file name.
2. It will look in the directory where the current source file is.
3. it will look in all directories specified in the object file search path.

Directories can be added to the object file search path with the `-F○` option.

On LINUX systems and on operating systems with case-sensitive filesystems (such as UNIX systems), the name is case sensitive, and must be typed exactly as it appears on your system.

Remark: Take care that the object file you're linking is in a format the linker understands. Which format this is, depends on the platform you're on. Typing `ld` or `ld -help` on the command line gives a list of formats `ld` knows about.

Other files and options can be passed to the linker using the `-k` command-line option. More than one of these options can be used, and they will be passed to the linker, in the order that they were specified on the command line, just before the names of the object files that must be linked.

`$LINKLIB` : Link to a library

The `{$LINKLIB name}` will link to a library `name`. This has the effect of passing `-lname` to the linker.

As an example, consider the following unit:

```
unit getlen;  
  
interface  
{$LINKLIB c}
```

```
function strlen (P : pchar) : longint;cdecl;

implementation

function strlen (P : pchar) : longint;cdecl;external;

end.
```

If one would issue the command

```
ppc386 foo.pp
```

where foo.pp has the above unit in its uses clause, then the compiler would link the program to the c library, by passing the linker the -lc option.

The same effect could be obtained by removing the linklib directive in the above unit, and specify -k-lc on the command-line:

```
ppc386 -k-lc foo.pp
```

\$M or \$TYPEINFO : Generate type info

For classes that are compiled in the {\$M+} or {\$TYPEINFO ON} state, the compiler will generate Run-Time Type Information (RTTI). All descendent objects of an object that was compiled in the {\$M+} state will get RTTI information too, as well as any published classes. By default, no Run-Time Type Information is generated. The TPersistent object that is present in the FCL (Free Component Library) is generated in the {\$M+} state. The generation of RTTI allows programmers to stream objects, and to access published properties of objects, without knowing the actual class of the object.

The run-time type information is accessible through the TypInfo unit, which is part of the Free Pascal Run-Time Library.

Remark: The streaming system implemented by Free Pascal requires that all streamable components be descendent from TPersistent.

\$MACRO : Allow use of macros.

In the {\$MACRO ON} state, the compiler allows to use C-style (although not as elaborate) macros. Macros provide a means for simple text substitution. More information on using macros can be found in the section 2.3, page 37 section. This directive is equivalent to the command-line switch -Sm.

By default, macros are not allowed.

\$MAXFPUREGISTERS : Maximum number of FPU registers for variables (Intel 80x86 only)

The {\$MAXFPUREGISTERS XXX} directive tells the compiler how much floating point variables can be kept in the floating point processor registers. This switch is ignored unless the -Or (use register variables) optimization is used.

This is quite tricky because the Intel FPU stack is limited to 8 entries. The compiler uses a heuristic algorithm to determine how much variables should be put onto the stack: in leaf procedures it is limited to 3 and in non leaf procedures to 1. But in case of a deep call tree or, even worse, a recursive procedure this can still lead to a FPU stack overflow, so the user can tell the compiler how much (floating point) variables should be kept in registers.

The directive accepts the following arguments:

N where N is the maximum number of FPU registers to use. Currently this can be in the range 0 to 7.

Normal restores the heuristic and standard behavior.

Default restores the heuristic and standard behaviour.

Remark: This directive is valid until the end of the current procedure.

\$MESSAGE : Generate info message

If the generation of info is turned on, through the `-vi` command-line option, then

```
{ $MESSAGE This was coded on a rainy day by Bugs Bunny }
```

will display an info message when the compiler encounters it. The effect is the same as the `{ $INFO }` directive.

\$MMX : Intel MMX support (Intel 80x86 only)

Free Pascal supports optimization for the **MMX** Intel processor (see also chapter 5).

This optimizes certain code parts for the **MMX** Intel processor, thus greatly improving speed. The speed is noticed mostly when moving large amounts of data. Things that change are

- Data with a size that is a multiple of 8 bytes is moved using the `movq` assembler instruction, which moves 8 bytes at a time

Remark: MMX support is NOT emulated on non-MMX systems, i.e. if the processor doesn't have the MMX extensions, the MMX optimizations cannot be used.

When **MMX** support is on, it is not allowed to do floating point arithmetic. It is allowed to move floating point data, but no arithmetic can be done. If floating point math must be done anyway, first **MMX** support must be switched off and the FPU must be cleared using the `emms` function of the `cpu` unit.

The following example will make this more clear:

```
Program MMXDemo;

uses mmx;

var
  d1 : double;
  a : array[0..10000] of double;
  i : longint;

begin
  d1:=1.0;
  { $mmx+ }
  { floating point data is used, but we do _no_ arithmetic }
  for i:=0 to 10000 do
    a[i]:=d2; { this is done with 64 bit moves }
```

```
{ $mmx- }  
    emms;    { clear fpu }  
    { now we can do floating point arithmetic }  
    ...  
end.
```

See, however, the chapter on MMX (5) for more information on this topic.

\$NOTE : Generate note message

If the generation of notes is turned on, through the `-vn` command-line option or the `{ $NOTES ON }` directive, then

```
{ $NOTE Ask Santa Claus to look at this code }
```

will display a note message when the compiler encounters it.

\$NOTES : Emit notes

`{ $NOTES ON }` switches the generation of notes on. `{ $NOTES OFF }` switches the generation of notes off. Contrary to the command-line option `-vn` this is a local switch, this is useful for checking parts of the code.

By default, `{ $NOTES }` is off.

\$OUTPUT_FORMAT : Specify the output format

`{ $OUTPUT_FORMAT format }` has the same functionality as the `-A` command-line option: it tells the compiler what kind of object file must be generated. You can specify this switch only *before* the `Program` or `Unit` clause in your source file. The different kinds of formats are shown in table (1.1).

The default output format depends on the platform the compiler was compiled on.

Table 1.1: Formats generated by the x86 compiler

Switch value	Generated format
AS	AT&T assembler file.
AS_AOUT	Go32v1 assembler file.
ASW	AT&T Win32 assembler file.
COFF	Go32v2 COFF object file.
MASM	Masm assembler file.
NASM	Nasm assembler file.
NASMCOFF	Nasm assembler file (COFF format).
NASMELF	Nasm assembler file (ELF format).
PECOFF	PECOFF object file (Win32).
TASM	Tasm assembler file.

\$P or \$OPENSTRINGS : Use open strings

If this switch is on, all function or procedure parameters of type `string` are considered to be open string parameters; this parameter only has effect for short strings, not for `ansistrings`.

When using openstrings, the declared type of the string can be different from the type of string that is actually passed, even for strings that are passed by reference. The declared size of the string passed can be examined with the `High(P)` call.

Default the use of openstrings is off.

\$PACKENUM : Minimum enumeration type size

This directive tells the compiler the minimum number of bytes it should use when storing enumerated types. It is of the following form:

```
{ $PACKENUM xxx}  
{ $MINENUMSIZE xxx}
```

Where the form with `$MINENUMSIZE` is for Delphi compatibility. `xxx` can be one of 1, 2 or 4, or `NORMAL` or `DEFAULT`.

As an alternative form one can use `{ $Z1}`, `{ $Z2}` `{ $Z4}`. Contrary to Delphi, the default is `({ $Z4})`.

So the following code

```
{ $PACKENUM 1}  
Type  
  Days = (monday, tuesday, wednesday, thursday, friday,  
          saturday, sunday);
```

will use 1 byte to store a variable of type `Days`, whereas it normally would use 4 bytes. The above code is equivalent to

```
{ $Z1}  
Type  
  Days = (monday, tuesday, wednesday, thursday, friday,  
          saturday, sunday);
```

\$PACKRECORDS : Alignment of record elements

This directive controls the byte alignment of the elements in a record, object or class type definition.

It is of the following form:

```
{ $PACKRECORDS n}
```

Where `n` is one of 1, 2, 4, 16, `C`, `NORMAL` or `DEFAULT`. This means that the elements of a record that have size greater than `n` will be aligned on `n` byte boundaries. Elements with size less than or equal to `n` will be aligned to a natural boundary, i.e. to a power of two that is equal to or larger than the element's size. The type `C` is used to specify alignment as by the GNU CC compiler. It should be used only when making import units for C routines.

The default alignment (which can be selected with `DEFAULT`) is 2, contrary to Turbo Pascal, where it is 1.

More information on this and an example program can be found in the reference guide, in the section about record types.

\$Q \$OVERFLOWCHECKS: Overflow checking

The `{ $Q+ }` or `{ $OVERFLOWCHECKS ON }` directive turns on integer overflow checking. This means that the compiler inserts code to check for overflow when doing computations with integers. When an overflow occurs, the run-time library will print a message `Overflow at xxx`, and exit the program with exit code 215.

Remark: Overflow checking behaviour is not the same as in Turbo Pascal since all arithmetic operations are done via 32-bit or 64-bit values. Furthermore, the `Inc ()` and `Dec` standard system procedures *are* checked for overflow in Free Pascal, while in Turbo Pascal they are not.

Using the `{ $Q- }` switch switches off the overflow checking code generation.

The generation of overflow checking code can also be controlled using the `-Co` command line compiler option (see [Users guide](#)).

\$R or \$RANGECHECKS : Range checking

By default, the compiler doesn't generate code to check the ranges of array indices, enumeration types, subrange types, etc. Specifying the `{ $R+ }` switch tells the computer to generate code to check these indices. If, at run-time, an index or enumeration type is specified that is out of the declared range of the compiler, then a run-time error is generated, and the program exits with exit code 201. This can happen when doing a typecast (implicit or explicit) on an enumeration type or subrange type.

The `{ $RANGECHECKS OFF }` switch tells the compiler not to generate range checking code. This may result in faulty program behaviour, but no run-time errors will be generated.

Remark: The standard functions `val` and `Read` will also check ranges when the call is compiled in `{ $R+ }` mode.

\$SATURATION : Saturation operations (Intel 80x86 only)

This works only on the intel compiler, and MMX support must be on (`{ $MMX + }`) for this to have any effect. See the section on saturation support (section 5.2, page 48) for more information on the effect of this directive.

\$SMARTLINK : Use smartlinking

A unit that is compiled in the `{ $SMARTLINK ON }` state will be compiled in such a way that it can be used for smartlinking. This means that the unit is chopped in logical pieces: each procedure is put in it's own object file, and all object files are put together in a big archive. When using such a unit, only the pieces of code that you really need or call, will be linked in your program, thus reducing the size of your executable substantially.

Beware: using smartlinked units slows down the compilation process, because a separate object file must be created for each procedure. If you have units with many functions and procedures, this can be a time consuming process, even more so if you use an external assembler (the assembler is called to assemble each procedure or function code block separately).

The smartlinking directive should be specified *before* the unit declaration part:

```
{ $SMARTLINK ON }
```

```
Unit MyUnit;
```

```
Interface
```

...

This directive is equivalent to the `-Cx` command-line switch.

\$STATIC : Allow use of static keyword.

If you specify the `{ $STATIC ON }` directive, then `Static` methods are allowed for objects. `Static` objects methods do not require a `Self` variable. They are equivalent to `Class` methods for classes. By default, `Static` methods are not allowed. Class methods are always allowed.

By default, the address operator returns an untyped pointer.

This directive is equivalent to the `-St` command-line option.

\$STOP : Generate fatal error message

The following code

```
{ $STOP This code is erroneous ! }
```

will display an error message when the compiler encounters it. The compiler will immediately stop the compilation process.

It has the same effect as the `{ $FATAL }` directive.

\$T or \$TYPEDADDRESS : Typed address operator (@)

In the `{ $T+ }` or `{ $TYPEDADDRESS ON }` state the `@` operator, when applied to a variable, returns a result of type `^T`, if the type of the variable is `T`. In the `{ $T- }` state, the result is always an untyped pointer, which is assignment compatible with all other pointer types.

\$UNDEF : Undefine a symbol

The directive

```
{ $UNDEF name }
```

un-defines the symbol `name` if it was previously defined. Name is case insensitive.

\$V or \$VARSTRINGCHECKS : Var-string checking

When in the `+` or `ON` state, the compiler checks that strings passed as parameters are of the same, identical, string type as the declared parameters of the procedure.

\$WAIT : Wait for enter key press

If the compiler encounters a

```
{ $WAIT }
```

directive, it will resume compiling only after the user has pressed the enter key. If the generation of info messages is turned on, then the compiler will display the following message:

Press <return> to continue

before waiting for a keypress.

Remark: This may interfere with automatic compilation processes. It should be used for debugging purposes only.

\$WARNING : Generate warning message

If the generation of warnings is turned on, through the `-vw` command-line option or the `{ $WARNINGS ON }` directive, then

```
{ $WARNING This is dubious code }
```

will display a warning message when the compiler encounters it.

\$WARNINGS : Emit warnings

`{ $WARNINGS ON }` switches the generation of warnings on. `{ $WARNINGS OFF }` switches the generation of warnings off. Contrary to the command-line option `-vw` this is a local switch, this is useful for checking parts of your code.

By default, no warnings are emitted.

\$X or \$EXTENDED SYNTAX : Extended syntax

Extended syntax allows you to drop the result of a function. This means that you can use a function call as if it were a procedure. Standard this feature is on. You can switch it off using the `{ $X- }` or `{ $EXTENDED SYNTAX OFF }` directive.

The following, for instance, will not compile:

```
function Func (var Arg : sometype) : longint;
begin
...           { declaration of Func }
end;

...

{ $X- }
Func (A);
```

The reason this construct is supported is that you may wish to call a function for certain side-effects it has, but you don't need the function result. In this case you don't need to assign the function result, saving you an extra variable.

The command-line compiler switch `-Sal` has the same effect as the `{ $X+ }` directive.

By default, extended syntax is assumed.

1.2 Global directives

Global directives affect the whole of the compilation process. That is why they also have a command-line counterpart. The command-line counterpart is given for each of the directives.

\$APPTYPE : Specify type of application (Win32 and AmigaOS only)

The {`$APPTYPE XXX`} accepts one argument that can have two possible values: `GUI` or `CONSOLE`. It is used to tell the WINDOWS Operating system if an application is a console application or a graphical application. By default, a program compiled by Free Pascal is a console application. Running it will display a console window. Specifying the {`$APPTYPE GUI`} directive will mark the application as a graphical application; no console window will be opened when the application is run. If run from the command-line, the command prompt will be returned immediately after the application was started.

Care should be taken when compiling GUI applications; the `Input` and `Output` files are not available in a GUI application, and attempting to read from or write to them will result in a run-time error.

It is possible to determine the application type of a WINDOWS or AMIGA application at runtime. The `IsConsole` constant, declared in the `Win32` and `Amiga` system units as

```
Const
  IsConsole : Boolean
```

contains `True` if the application is a console application, `False` if the application is a GUI application.

\$D or \$DEBUGINFO : Debugging symbols

When this switch is on, the compiler inserts GNU debugging information in the executable. The effect of this switch is the same as the command-line switch `-g`.

By default, insertion of debugging information is off.

\$DESCRIPTION : Application description

This switch is recognised for compatibility only, but is ignored completely by the compiler. At a later stage, this switch may be activated.

\$E : Emulation of coprocessor

This directive controls the emulation of the coprocessor. There is no command-line counterpart for this directive.

Intel 80x86 version

When this switch is enabled, all floating point instructions which are not supported by standard coprocessor emulators will give out a warning.

The compiler itself doesn't do the emulation of the coprocessor.

To use coprocessor emulation under DOS go32v2 you must use the `emu387` unit, which contains correct initialization code for the emulator.

Under LINUX and most UNIX'es, the kernel takes care of the coprocessor support.

Motorola 680x0 version

When the switch is on, no floating point opcodes are emitted by the code generator. Instead, internal run-time library routines are called to do the necessary calculations. In this case all real types are

mapped to the single IEEE floating point type.

Remark: By default, emulation is on. It is possible to intermix emulation code with real floating point opcodes, as long as the only type used is single or real.

Under LINUX and most UNIX'es, the kernel takes care of the coprocessor support.

\$G : Generate 80286 code

This option is recognised for Turbo Pascal compatibility, but is ignored, since the compiler works only on 32-bit and 64-bit processors.

\$INCLUDEPATH : Specify include path.

This option serves to specify the include path, where the compiler looks for include files. { \$INCLUDEPATH XXX } will add XXX to the include path. XXX can contain one or more paths, separated by semi-colons or colons.

For example:

```
{ $INCLUDEPATH ../inc;../i386 }  
  
{ $I strings.inc }
```

will add the directories ../inc and ../i386 to the include path of the compiler. The compiler will look for the file strings.inc in both these directories, and will include the first found file. This directive is equivalent to the -Fi command-line switch.

Caution is in order when using this directive: If you distribute files, the places of the files may not be the same as on your machine; moreover, the directory structure may be different. In general it would be fair to say that you should avoid using *absolute* paths, instead use *relative* paths, as in the example above. Only use this directive if you are certain of the places where the files reside. If you are not sure, it is better practice to use makefiles and makefile variables.

\$L or \$LOCALSYMBOLS : Local symbol information

This switch (not to be confused with the { \$L file } file linking directive) is recognised for Turbo Pascal compatibility, but is ignored. Generation of symbol information is controlled by the \$D switch.

\$LIBRARYPATH : Specify library path.

This option serves to specify the library path, where the linker looks for static or dynamic libraries. { \$LIBRARYPATH XXX } will add XXX to the library path. XXX can contain one or more paths, separated by semi-colons or colons.

For example:

```
{ $LIBRARYPATH /usr/X11/lib;/usr/local/lib }  
  
{ $LINKLIB X11 }
```

will add the directories /usr/X11/lib and /usr/local/lib to the linker library path. The linker will look for the library libX11.so in both these directories, and use the first found file. This directive is equivalent to the -Fl command-line switch.

Caution is in order when using this directive: If you distribute files, the places of the libraries may not be the same as on your machine; moreover, the directory structure may be different. In general it would be fair to say that you should avoid using this directive. If you are not sure, it is better practice to use makefiles and makefile variables.

\$M or \$MEMORY : Memory sizes

This switch can be used to set the heap and stacksize. It's format is as follows:

```
{ $M StackSize, HeapSize }
```

where `StackSize` and `HeapSize` should be two integer values, greater than 1024. The first number sets the size of the stack, and the second the size of the heap. (Stack setting is ignored under LINUX, NETBSD and FREEBSD). The two numbers can be set on the command line using the `-Ch` and `-Cs` switches.

\$MODE : Set compiler compatibility mode

The `{ $MODE }` sets the compatibility mode of the compiler. This is equivalent to setting one of the command-line options `-So`, `-Sd`, `-Sp` or `-S2`. it has the following arguments:

Default Default mode. This reverts back to the mode that was set on the command-line.

Delphi Delphi compatibility mode. All object-pascal extensions are enabled. This is the same as the command-line option `-Sd`.

TP Turbo pascal compatibility mode. Object pascal extensions are disabled, except ansistrings, which remain valid. This is the same as the command-line option `-So`.

FPC FPC mode. This is the default, if no command-line switch is supplied.

OBJFPC Object pascal mode. This is the same as the `-S2` command-line option.

GPC GNU pascal mode. This is the same as the `-Sp` command-line option.

For an exact description of each of these modes, see appendix [D](#), on page [112](#).

\$N : Numeric processing

This switch is recognised for Turbo Pascal compatibility, but is otherwise ignored, since the compiler always uses the coprocessor for floating point mathematics.

\$O : Overlay code generation

This switch is recognised for Turbo Pascal compatibility, but is otherwise ignored.

\$OBJECTPATH : Specify object path.

This option serves to specify the object path, where the compiler looks for object files. `{ $OBJECTPATH XXX }` will add XXX to the object path. XXX can contain one or more paths, separated by semi-colons or colons.

For example:

```
{ $OBJECTPATH ../inc;../i386 }
```

```
{ $L strings.o }
```

will add the directories `../inc` and `../i386` to the object path of the compiler. The compiler will look for the file `strings.o` in both these directories, and will link the first found file in the program. This directive is equivalent to the `-Fo` command-line switch.

Caution is in order when using this directive: If you distribute files, the places of the files may not be the same as on your machine; moreover, the directory structure may be different. In general it would be fair to say that you should avoid using *absolute* paths, instead use *relative* paths, as in the example above. Only use this directive if you are certain of the places where the files reside. If you are not sure, it is better practice to use makefiles and makefile variables.

\$s : Stack checking

The `{ $S+ }` directive tells the compiler to generate stack checking code. This generates code to check if a stack overflow occurred, i.e. to see whether the stack has grown beyond its maximally allowed size. If the stack grows beyond the maximum size, then a run-time error is generated, and the program will exit with exit code 202.

Specifying `{ $S- }` will turn generation of stack-checking code off.

The command-line compiler switch `-Ct` has the same effect as the `{ $S+ }` directive.

By default, no stack checking is performed.

\$UNITPATH : Specify unit path.

This option serves to specify the unit path, where the compiler looks for unit files. `{ $UNITPATH XXX }` will add XXX to the unit path. XXX can contain one or more paths, separated by semi-colons or colons.

For example:

```
{ $UNITPATH ../units;../i386/units }
```

```
Uses strings;
```

will add the directories `../units` and `../i386/units` to the unit path of the compiler. The compiler will look for the file `strings.ppu` in both these directories, and will link the first found file in the program. This directive is equivalent to the `-Fu` command-line switch.

Caution is in order when using this directive: If you distribute files, the places of the files may not be the same as on your machine; moreover, the directory structure may be different. In general it would be fair to say that you should avoid using *absolute* paths, instead use *relative* paths, as in the example above. Only use this directive if you are certain of the places where the files reside. If you are not sure, it is better practice to use makefiles and makefile variables.

\$W or \$STACKFRAMES : Generate stackframes

The `{ $W }` switch directive controls the generation of stackframes. In the on state, the compiler will generate a stackframe for every procedure or function.

In the off state, the compiler will omit the generation of a stackframe if the following conditions are satisfied:

- The procedure has no parameters.
- The procedure has no local variables.
- If the procedure is not an `assembler` procedure, it must not have a `asm . . . end;` block.
- it is not a constructor or destructor.

If these conditions are satisfied, the stack frame will be omitted.

\$Y or \$REFERENCEINFO : Insert Browser information

This switch controls the generation of browser information. It is recognized for compatibility with Turbo Pascal and Delphi only, as Browser information generation is not yet fully supported.

Chapter 2

Using conditionals, messages and macros

The Free Pascal compiler supports conditionals as in normal Turbo Pascal. It does, however, more than that. It allows you to make macros which can be used in your code, and it allows you to define messages or errors which will be displayed when compiling.

2.1 Conditionals

The rules for using conditional symbols are the same as under Turbo Pascal. Defining a symbol goes as follows:

```
{ $define Symbol }
```

From this point on in your code, the compiler knows the symbol `Symbol`. Symbols are, like the Pascal language, case insensitive.

You can also define a symbol on the command line. the `-dSymbol` option defines the symbol `Symbol`. You can specify as many symbols on the command line as you want.

Undefined an existing symbol is done in a similar way:

```
{ $undef Symbol }
```

If the symbol didn't exist yet, this doesn't do anything. If the symbol existed previously, the symbol will be erased, and will not be recognized any more in the code following the `{ $undef \dots }` statement.

You can also undefine symbols from the command line with the `-u` command-line switch.

To compile code conditionally, depending on whether a symbol is defined or not, you can enclose the code in a `{ $ifdef Symbol } ... { $endif }` pair. For instance the following code will never be compiled:

```
{ $undef MySymbol }  
{ $ifdef Mysymbol }  
    DoSomething;  
    ...  
{ $endif }
```

Similarly, you can enclose your code in a `{$ifndef Symbol} ... {$endif}` pair. Then the code between the pair will only be compiled when the used symbol doesn't exist. For example, in the following example, the call to the `DoSomething` will always be compiled:

```
{ $undef MySymbol }
{ $ifndef Mysymbol }
    DoSomething;
    ...
{ $endif }
```

You can combine the two alternatives in one structure, namely as follows

```
{ $ifdef Mysymbol }
    DoSomething;
{ $else }
    DoSomethingElse
{ $endif }
```

In this example, if `MySymbol` exists, then the call to `DoSomething` will be compiled. If it doesn't exist, the call to `DoSomethingElse` is compiled.

Except for the Turbo Pascal constructs the Free Pascal compiler also supports a stronger conditional compile mechanism: The `{ $if }` construct.

The prototype of this construct is as follows:

```
{ $if expr }
    CompileTheseLines;
{ $else }
    BetterCompileTheseLines;
{ $endif }
```

In this directive `expr` is a Pascal expression which is evaluated using strings, unless both parts of a comparison can be evaluated as numbers, in which case they are evaluated using numbers¹. If the complete expression evaluates to `'0'`, then it is considered false and rejected. Otherwise it is considered true and accepted. This may have unexpected consequences:

```
{ $if 0 }
```

will evaluate to `False` and be rejected, while

```
{ $if 00 }
```

will evaluate to `True`.

You can use any Pascal operator to construct your expression: `=`, `<>`, `>`, `<`, `>=`, `<=`, `AND`, `NOT`, `OR` and you can use round brackets to change the precedence of the operators.

The following example shows you many of the possibilities:

```
{ $ifdef fpc }

var
    y : longint;
{ $else fpc }
```

¹Otherwise `{ $if 8>54 }` would evaluate to `True`

```
var
    z : longint;
{$endif fpc}

var
    x : longint;

begin

    {$if (fpc_version=0) and (fpc_release>6) and (fpc_patch>4)}
    {$info At least this is version 0.9.5}
    {$else}
    {$fatal Problem with version check}
    {$endif}

    {$define x:=1234}
    {$if x=1234}
    {$info x=1234}
    {$else}
    {$fatal x should be 1234}
    {$endif}

    {$if 12asdf and 12asdf}
    {$info $if 12asdf and 12asdf is ok}
    {$else}
    {$fatal $if 12asdf and 12asdf rejected}
    {$endif}

    {$if 0 or 1}
    {$info $if 0 or 1 is ok}
    {$else}
    {$fatal $if 0 or 1 rejected}
    {$endif}

    {$if 0}
    {$fatal $if 0 accepted}
    {$else}
    {$info $if 0 is ok}
    {$endif}

    {$if 12=12}
    {$info $if 12=12 is ok}
    {$else}
    {$fatal $if 12=12 rejected}
    {$endif}

    {$if 12<>312}
    {$info $if 12<>312 is ok}
    {$else}
    {$fatal $if 12<>312 rejected}
    {$endif}
```

```
{ $if 12<=312}
{ $info $if 12<=312 is ok}
{ $else}
{ $fatal $if 12<=312 rejected}
{ $endif}

{ $if 12<312}
{ $info $if 12<312 is ok}
{ $else}
{ $fatal $if 12<312 rejected}
{ $endif}

{ $if a12=a12}
{ $info $if a12=a12 is ok}
{ $else}
{ $fatal $if a12=a12 rejected}
{ $endif}

{ $if a12<=z312}
{ $info $if a12<=z312 is ok}
{ $else}
{ $fatal $if a12<=z312 rejected}
{ $endif}

{ $if a12<z312}
{ $info $if a12<z312 is ok}
{ $else}
{ $fatal $if a12<z312 rejected}
{ $endif}

{ $if not(0)}
{ $info $if not(0) is OK}
{ $else}
{ $fatal $if not(0) rejected}
{ $endif}

{ $info *****}
{ $info * Now have to follow at least 2 error messages: *}
{ $info *****}

{ $if not(0)}
{ $endif}

{ $if not(<)}
{ $endif}

end.
```

As you can see from the example, this construct isn't useful when used with normal symbols, only if you use macros, which are explained in section 2.3, page 37. They can be very useful. When trying this example, you must switch on macro support, with the `-Sm` command-line switch.

Predefined symbols

The Free Pascal compiler defines some symbols before starting to compile your program or unit. You can use these symbols to differentiate between different versions of the compiler, and between different compilers. To get all the possible defines when starting compilation, see [appendix G](#)

Remark: Symbols, even when they're defined in the interface part of a unit, are not available outside that unit.

2.2 Messages

Free Pascal lets you define normal, warning and error messages in your code. Messages can be used to display useful information, such as copyright notices, a list of symbols that your code reacts on etc.

Warnings can be used if you think some part of your code is still buggy, or if you think that a certain combination of symbols isn't useful.

Error messages can be useful if you need a certain symbol to be defined, to warn that a certain variable isn't defined, or when the compiler version isn't suitable for your code.

The compiler treats these messages as if they were generated by the compiler. This means that if you haven't turned on warning messages, the warning will not be displayed. Errors are always displayed, and the compiler stops if 50 errors have occurred. After a fatal error, the compiler stops at once.

For messages, the syntax is as follows:

```
{ $Message Message text }
```

or

```
{ $Info Message text }
```

For notes:

```
{ $Note Message text }
```

For warnings:

```
{ $Warning Warning Message text }
```

For errors:

```
{ $Error Error Message text }
```

Lastly, for fatal errors:

```
{ $Fatal Error Message text }
```

or

```
{ $Stop Error Message text }
```

The difference between `$Error` and `$FatalError` or `$Stop` messages is that when the compiler encounters an error, it still continues to compile. With a fatal error, the compiler stops.

Remark: You cannot use the `'`' character in your message, since this will be treated as the closing brace of the message.

As an example, the following piece of code will generate an error when the symbol `RequiredVar` isn't defined:

```
{ $ifndef RequiredVar }
{ $Error Requiredvar isn't defined ! }
{ $endif }
```

But the compiler will continue to compile. It will not, however, generate a unit file or a program (since an error occurred).

2.3 Macros

Macros are very much like symbols in their syntax, the difference is that macros have a value whereas a symbol simply is defined or is not defined. If you want macro support, you need to specify the `-Sm` command-line switch, otherwise your macro will be regarded as a symbol.

Defining a macro in your program is done in the same way as defining a symbol; in a `{ $define }` preprocessor statement²:

```
{ $define ident:=expr }
```

If the compiler encounters `ident` in the rest of the source file, it will be replaced immediately by `expr`. This replacement works recursive, meaning that when the compiler expanded one of your macros, it will look at the resulting expression again to see if another replacement can be made. You need to be careful with this, because an infinite loop can occur in this manner.

Here are two examples which illustrate the use of macros:

```
{ $define sum:=a:=a+b; }
...
sum          { will be expanded to 'a:=a+b;'
              remark the absence of the semicolon }
...
{ $define b:=100 }
sum          { Will be expanded recursively to a:=a+100; }
...
```

The previous example could go wrong:

```
{ $define sum:=a:=a+b; }
...
sum          { will be expanded to 'a:=a+b;'
              remark the absence of the semicolon }
...
{ $define b=sum } { DON'T do this !!! }
sum          { Will be infinitely recursively expanded \dots }
...
```

On my system, the last example results in a heap error, causing the compiler to exit with a run-time error 203.

Remark: Macros defined in the interface part of a unit are not available outside that unit! They can just be used as a notational convenience, or in conditional compiles.

By default the compiler predefines three macros, containing the version number, the release number and the patch number. They are listed in table (2.1).

Remark: Don't forget that macros support isn't on by default. You need to compile with the `-Sm` command-line switch.

²In compiler versions older than 0.9.8, the assignment operator for a macros wasn't `:=` but `=`

Table 2.1: Predefined macros

Symbol	Contains
FPC_VERSION	The version number of the compiler.
FPC_RELEASE	The release number of the compiler.
FPC_PATCH	The patch number of the compiler.

Chapter 3

Using Assembly language

Free Pascal supports inserting assembler statements in your code. The mechanism for this is the same as under Turbo Pascal. There are, however some substantial differences, as will be explained in the following sections.

3.1 Intel 80x86 Inline assembler

Intel syntax

Free Pascal supports Intel syntax for the Intel family of Ix86 processors in its `asm` blocks.

The Intel syntax in your `asm` block is converted to AT&T syntax by the compiler, after which it is inserted in the compiled source. The supported assembler constructs are a subset of the normal assembly syntax. In what follows we specify what constructs are not supported in Free Pascal, but which exist in Turbo Pascal:

- The `TBYTE` qualifier is not supported.
- The `&` identifier override is not supported.
- The `HIGH` operator is not supported.
- The `LOW` operator is not supported.
- The `OFFSET` and `SEG` operators are not supported. Use `LEA` and the various `Lxx` instructions instead.
- Expressions with constant strings are not allowed.
- Access to record fields via parenthesis is not allowed
- Typecasts with normal pascal types are not allowed, only recognized assembler typecasts are allowed. Example:

```
mov al, byte ptr MyWord      -- allowed,  
mov al, byte(MyWord)        -- allowed,  
mov al, shortint(MyWord)    -- not allowed.
```

- Pascal type typecasts on constants are not allowed. Example:

```
const s= 10; const t = 32767;
```


in Turbo Pascal:

```
mov al, byte(s)           -- useless typecast.
mov al, byte(t)           -- syntax error!
```

In this parser, either of those cases will give out a syntax error.

- Constant references expressions with constants only are not allowed (in all cases they do not work in protected mode, under LINUX i386). Examples:

```
mov al,byte ptr ['c']     -- not allowed.
mov al,byte ptr [100h]    -- not allowed.
```

(This is due to the limitation of Turbo Assembler).

- Brackets within brackets are not allowed
- Expressions with segment overrides fully in brackets are presently not supported, but they can easily be implemented in BuildReference if requested. Example:

```
mov al,[ds:bx]           -- not allowed
```

use instead:

```
mov al,ds:[bx]
```

- Possible allowed indexing are as follows:

- Sreg:[REG+REG*SCALING+/-disp]
- SReg:[REG+/-disp]
- SReg:[REG]
- SReg:[REG+REG+/-disp]
- SReg:[REG+REG*SCALING]

Where Sreg is optional and specifies the segment override. *Notes:*

1. The order of terms is important contrary to Turbo Pascal.
2. The Scaling value must be a value, and not an identifier to a symbol. Examples:

```
const myscale = 1;
...
mov al,byte ptr [esi+ebx*myscale] -- not allowed.
use:
mov al, byte ptr [esi+ebx*1]
```

- Possible variable identifier syntax is as follows: (Id = Variable or typed constant identifier.)

1. ID
2. [ID]
3. [ID+expr]
4. ID[expr]

Possible fields are as follow:

1. ID.subfield.subfield ...

2. [ref].ID.subfield.subfield ...

3. [ref].typename.subfield ...

- Local labels: Contrary to Turbo Pascal, local labels, must at least contain one character after the local symbol indicator. Example:

```
@:                -- not allowed
```

use instead, for example:

```
@1:               -- allowed
```

- Contrary to Turbo Pascal local references cannot be used as references, only as displacements. Example:

```
lds si,@mylabel   -- not allowed
```

- Contrary to Turbo Pascal, SEGCS, SEGDS, SEGES and SEGSS segment overrides are presently not supported. (This is a planned addition though).
- Contrary to Turbo Pascal where memory size specifiers can be practically anywhere, the Free Pascal Intel inline assembler requires memory size specifiers to be outside the brackets. Example:

```
mov al,[byte ptr myvar]    -- not allowed.
```

use:

```
mov al,byte ptr [myvar]    -- allowed.
```

- Base and Index registers must be 32-bit registers. (limitation of the GNU Assembler).
- XLAT is equivalent to XLATB.
- Only Single and Double FPU opcodes are supported.
- Floating point opcodes are currently not supported (except those which involve only floating point registers).

The Intel inline assembler supports the following macros:

@Result represents the function result return value.

Self represents the object method pointer in methods.

AT&T Syntax

Free Pascal uses the GNU `as` assembler to generate its object files for the Intel `Ix86` processors. Since the GNU assembler uses AT&T assembly syntax, the code you write should use the same syntax. The differences between AT&T and Intel syntax as used in Turbo Pascal are summarized in the following:

- The opcode names include the size of the operand. In general, one can say that the AT&T opcode name is the Intel opcode name, suffixed with a 'l', 'w' or 'b' for, respectively, longint (32 bit), word (16 bit) and byte (8 bit) memory or register references. As an example, the Intel construct `'mov al bl'` is equivalent to the AT&T style `'movb %bl,%al'` instruction.

- AT&T immediate operands are designated with '\$', while Intel syntax doesn't use a prefix for immediate operands. Thus the Intel construct 'mov ax, 2' becomes 'movb \$2, %al' in AT&T syntax.
- AT&T register names are preceded by a '%' sign. They are undelimited in Intel syntax.
- AT&T indicates absolute jump/call operands with '*', Intel syntax doesn't delimit these addresses.
- The order of the source and destination operands are switched. AT&T syntax uses 'Source, Dest', while Intel syntax features 'Dest, Source'. Thus the Intel construct 'add eax, 4' transforms to 'addl \$4, %eax' in the AT&T dialect.
- Immediate long jumps are prefixed with the 'l' prefix. Thus the Intel 'call/jmp section:offset' is transformed to 'lcall/ljmp \$section,\$offset'. Similarly the far return is 'lret', instead of the Intel 'ret far'.
- Memory references are specified differently in AT&T and Intel assembly. The Intel indirect memory reference

Section:[Base + Index*Scale + Offs]

is written in AT&T syntax as:

Section:Offs(Base, Index, Scale)

Where Base and Index are optional 32-bit base and index registers, and Scale is used to multiply Index. It can take the values 1,2,4 and 8. The Section is used to specify an optional section register for the memory operand.

More information about the AT&T syntax can be found in the `as` manual, although the following differences with normal AT&T assembly must be taken into account:

- Only the following directives are presently supported:
 - .byte**
 - .word**
 - .long**
 - .ascii**
 - .asciz**
 - .globl**
- The following directives are recognized but are not supported:

.align
.lcomm

Eventually they will be supported.

- Directives are case sensitive, other identifiers are not case sensitive.
- Contrary to GAS local labels/symbols *must* start with `.L`
- The not operator '!' is not supported.
- String expressions in operands are not supported.
- CBTW,CWTL,CWTD and CLTD are not supported, use the normal intel equivalents instead.

- Constant expressions which represent memory references are not allowed even though constant immediate value expressions are supported. Examples:

```
const myid = 10;
...
movl $myid,%eax      -- allowed
movl myid(%esi),%eax  -- not allowed.
```

- When the `.globl` directive is found, the symbol following it is made public and is immediately emitted. Therefore label names with this name will be ignored.
- Only Single and Double FPU opcodes are supported.

The AT&T inline assembler supports the following macros:

`__RESULT` represents the function result return value.

`__SELF` represents the object method pointer in methods.

`__OLDEBP` represents the old base pointer in recursive routines.

3.2 Motorola 680x0 Inline assembler

The inline assembler reader for the Motorola 680x0 family of processors, uses the Motorola Assembler syntax (q.v). A few differences do exist:

- Local labels start with the `@` character, such as

```
@MyLabel:
```

- The `XDEF` directive in an assembler block will make the symbol available publicly with the specified name (this name is case sensitive)
- The `DB`, `DW`, `DD` directives can only be used to declare constants which will be stored in the code segment.
- The `Align` directive is not supported.
- Arithmetic operations on constant expression use the same operands as the intel version (e.g : `AND`, `XOR` ...)
- Segment directives are not supported
- Only 68000 opcodes are currently supported

The inline assembler supports the following macros:

`@Result` represents the function result return value.

`Self` represents the object method pointer in methods.

3.3 Signaling changed registers

When the compiler uses variables, it sometimes stores them, or the result of some calculations, in the processor registers. If you insert assembler code in your program that modifies the processor registers, then this may interfere with the compiler's idea about the registers. To avoid this problem, Free Pascal allows you to tell the compiler which registers have changed. The compiler will then avoid using these registers. Telling the compiler which registers have changed is done by specifying a set of register names behind an assembly block, as follows:

```
asm
    . . .
end [ 'R1' , . . . , 'Rn' ] ;
```

Here R1 to Rn are the names of the registers you modify in your assembly code.

As an example:

```
asm
movl BP,%eax
movl 4(%eax),%eax
movl %eax,__RESULT
end [ 'EAX' ] ;
```

This example tells the compiler that the EAX register was modified.

Chapter 4

Generated code

The Free Pascal compiler relies on the assembler to make object files. It generates just the assembly language file. In the following two sections, we discuss what is generated when you compile a unit or a program.

4.1 Units

When you compile a unit, the Free Pascal compiler generates 2 files:

1. A unit description file.
2. An assembly language file.

The assembly language file contains the actual source code for the statements in your unit, and the necessary memory allocations for any variables you use in your unit. This file is converted by the assembler to an object file (with extension `.o`) which can then be linked to other units and your program, to form an executable.

By default, the assembly file is removed after it has been compiled. Only in the case of the `-s` command-line option, the assembly file will be left on disk, so the assembler can be called later. You can disable the erasing of the assembler file with the `-a` switch.

The unit file contains all the information the compiler needs to use the unit:

1. Other used units, both in interface and implementation.
2. Types and variables from the interface section of the unit.
3. Function declarations from the interface section of the unit.
4. Some debugging information, when compiled with debugging.

The detailed contents and structure of this file are described in the first appendix. You can examine a unit description file using the `ppudump` program, which shows the contents of the file.

If you want to distribute a unit without source code, you must provide both the unit description file and the object file.

You can also provide a C header file to go with the object file. In that case, your unit can be used by someone who wishes to write his programs in C. However, you must make this header file yourself since the Free Pascal compiler doesn't make one for you.

4.2 Programs

When you compile a program, the compiler produces again 2 files:

1. An assembly language file containing the statements of your program, and memory allocations for all used variables.
2. A linker response file. This file contains a list of object files the linker must link together.

The link response file is, by default, removed from the disk. Only when you specify the `-s` command-line option or when linking fails, then the file is left on the disk. It is named `link.res`.

The assembly language file is converted to an object file by the assembler, and then linked together with the rest of the units and a program header, to form your final program.

The program header file is a small assembly program which provides the entry point for the program. This is where the execution of your program starts, so it depends on the operating system, because operating systems pass parameters to executables in wildly different ways.

It's name is `prt0.o`, and the source file resides in `prt0.as` or some variant of this name. It usually resided where the system unit source for your system resides. It's main function is to save the environment and command-line arguments and set up the stack. Then it calls the main program.

Chapter 5

Intel MMX support

5.1 What is it about?

Free Pascal supports the new MMX (Multi-Media extensions) instructions of Intel processors. The idea of MMX is to process multiple data with one instruction, for example the processor can add simultaneously 4 words. To implement this efficiently, the Pascal language needs to be extended. So Free Pascal allows to add for example two `array[0..3] of word`, if MMX support is switched on. The operation is done by the MMX unit and allows people without assembler knowledge to take advantage of the MMX extensions.

Here is an example:

```
uses
    MMX;    { include some predefined data types }

const
    { tmmxword = array[0..3] of word; , declared by unit MMX }
    w1 : tmmxword = (111,123,432,4356);
    w2 : tmmxword = (4213,63456,756,4);

var
    w3 : tmmxword;
    l : longint;

begin
    if is_mmx_cpu then { is_mmx_cpu is exported from unit mmx }
    begin
        {$mmx+}    { turn mmx on }
        w3:=w1+w2;
        {$mmx-}
    end
    else
    begin
        for i:=0 to 3 do
            w3[i]:=w1[i]+w2[i];
        end;
    end.
end.
```


5.2 Saturation support

One important point of MMX is the support of saturated operations. If a operation would cause an overflow, the value stays at the highest or lowest possible value for the data type: If you use byte values you get normally $250+12=6$. This is very annoying when doing color manipulations or changing audio samples, when you have to do a word add and check if the value is greater than 255. The solution is saturation: $250+12$ gives 255. Saturated operations are supported by the MMX unit. If you want to use them, you have simple turn the switch saturation on: `$saturation+`

Here is an example:

```
Program SaturationDemo;
{
  example for saturation, scales data (for example audio)
  with 1.5 with rounding to negative infinity
}
uses mmx;

var
  audio1 : tmmxword;
  i: smallint;

const
  helpdata1 : tmmxword = ($c000,$c000,$c000,$c000);
  helpdata2 : tmmxword = ($8000,$8000,$8000,$8000);

begin
  { audio1 contains four 16 bit audio samples }
  {$mmx+}
  { convert it to $8000 is defined as zero, multiply data with 0.75 }
  audio1:=(audio1+helpdata2)*(helpdata1);
  {$saturation+}
  { avoid overflows (all values>$7fff becomes $ffff) }
  audio1:=(audio1+helpdata2)-helpdata2;
  {$saturation-}
  { now mupltily with 2 and change to integer }
  for i:=0 to 3 do
    audio1[i] := audio1[i] shl 1;
  audio1:=audio1-helpdata2;
  {$mmx-}
end.
```

5.3 Restrictions of MMX support

In the beginning of 1997 the MMX instructions were introduced in the Pentium processors, so multitasking systems wouldn't save the newly introduced MMX registers. To work around that problem, Intel mapped the MMX registers to the FPU register.

The consequence is that you can't mix MMX and floating point operations. After using MMX operations and before using floating point operations, you have to call the routine `EMMS` of the MMX unit. This routine restores the FPU registers.

Careful: The compiler doesn't warn if you mix floating point and MMX operations, so be careful.

The MMX instructions are optimized for multi media (what else?). So it isn't possible to perform

each operation, some operations give a type mismatch, see section 5.4 for the supported MMX operations

An important restriction is that MMX operations aren't range or overflow checked, even when you turn range and overflow checking on. This is due to the nature of MMX operations.

The MMX unit must always be used when doing MMX operations because the exit code of this unit clears the MMX unit. If it wouldn't do that, other program will crash. A consequence of this is that you can't use MMX operations in the exit code of your units or programs, since they would interfere with the exit code of the MMX unit. The compiler can't check this, so you are responsible for this!

5.4 Supported MMX operations

The following operations are supported in the compiler when MMX extensions are enabled:

- addition (+)
- subtraction (-)
- multiplication(*)
- logical exclusive or (xor)
- logical and (and)
- logical or (or)
- sign change (-)

5.5 Optimizing MMX support

Here are some helpful hints to get optimal performance:

- The EMMS call takes a lot of time, so try to separate floating point and MMX operations.
- Use MMX only in low level routines because the compiler saves all used MMX registers when calling a subroutine.
- The NOT-operator isn't supported natively by MMX, so the compiler has to generate a workaround and this operation is inefficient.
- Simple assignments of floating point numbers don't access floating point registers, so you need no call to the EMMS procedure. Only when doing arithmetic, you need to call the EMMS procedure.

Chapter 6

Code issues

This chapter gives detailed information on the generated code by Free Pascal. It can be useful to write external object files which will be linked to Free Pascal created code blocks.

6.1 Register Conventions

The compiler has different register conventions, depending on the target processor used; some of the registers have specific uses during the code generation. The following section describes the generic names of the registers on a platform per platform basis. It also indicates what registers are used as scratch registers, and which can be freely used in assembler blocks.

accumulator register

The accumulator register is at least a 32-bit integer hardware register, and is used to return results of function calls which return integral values.

accumulator 64-bit register

The accumulator 64-bit register is used in 32-bit environments and is defined as the group of registers which will be used when returning 64-bit integral results in function calls. This is a register pair.

float result register

This register is used for returning floating point values from functions.

self register

The self register contains a pointer to the actual object or class. This register gives access to the data of the object or class, and the VMT pointer of that object or class.

frame pointer register

The frame pointer register is used to access parameters in subroutines, as well as to access local variables. References to the pushed parameters and local variables are constructed using the frame

pointer. ¹.

stack pointer register

The stack pointer is used to give the address of the stack area, where the local variables and parameters to subroutines are stored.

scratch registers

Scratch registers are those which can be used in assembler blocks, or in external object files without requiring any saving before usage.

Processor mapping of registers

This indicates what registers are used for what purposes on each of the processors supported by Free Pascal. It also indicates which registers can be used as scratch registers.

Intel 80x86 version

Table 6.1: Intel 80x86 Register table

Generic register name	CPU Register name
accumulator	EAX
accumulator (64-bit) high / low	EDX:EAX
float result	FP(0)
self	ESI
frame pointer	EBP
stack pointer	ESP
scratch regs.	N/A

Motorola 680x0 version

Table 6.2: Motorola 680x0 Register table

Generic register name	CPU Register name
accumulator	D0
accumulator (64-bit) high / low	D0:D1
float result	FP0 ²
self	A5
frame pointer	A6
stack pointer	A7
scratch regs.	D0, D1, A0, A1, FP0, FP1

¹The frame pointer is not available on all platforms

²On simulated FPU's the result is returned in D0

6.2 Name mangling

Contrary to most C compilers and assemblers, all labels generated to pascal variables and routines have mangled names³. This is done so that the compiler can do stronger type checking when parsing the pascal code. It also permits function and procedure overloading.

Mangled names for data blocks

The rules for mangled names for variables and typed constants are as follows:

- All variable names are converted to upper case
- Variables in the main program or private to a unit have an `_` prepended to their names
- Typed constants in the main program have an `TC__` prepended to their names
- Public variables in a unit have their unit name prepended to them : `U_UNITNAME_`
- Public and private typed constants in a unit have their unit name prepended to them : `TC__UNITNAME$$`

Currently, in Free Pascal v1.0, if you declare a variable in unit name `tunit`, with the name `_a`, and you declare the same variable with name `a` in unit name `tunit_`, you will get the same mangled name. This is a limitation of the compiler which will be fixed in release v1.1.

Examples

```
unit testvars;

interface

const
  publictypedconst : integer = 0;
var
  publicvar : integer;

implementation
const
  privatetypedconst : integer = 1;
var
  privatevar : integer;

end.
```

Will give the following assembler output under GNU as :

```
.file "testvars.pas"

.text

.data
```

³This can be avoided by using the `alias` or `cdecl` modifiers

```
# [6] publictypedconst : integer = 0;
.globl TC__TESTVARS$$_PUBLICTYPEDCONST
TC__TESTVARS$$_PUBLICTYPEDCONST:
.short 0
# [12] privatetypedconst : integer = 1;
TC__TESTVARS$$_PRIVATETYPEDCONST:
.short 1

.bss
# [8] publicvar : integer;
.comm U_TESTVARS_PUBLICVAR,2
# [14] privatevar : integer;
.lcomm _PRIVATEVAR,2
```

Mangled names for code blocks

The rules for mangled names for routines are as follows:

- All routine names are converted to upper case.
- Routines in a unit have their unit name prepended to them : `_UNITNAME$$_`
- All Routines in the main program have a `_` prepended to them.
- All parameters in a routine are mangled using the type of the parameter (in uppercase) prepended by the `$` character. This is done in left to right order for each parameter of the routine.
- Objects and classes use special mangling : The class type or object type is given in the mangled name; The mangled name is as follows: `__$$_TYPEDECL_$$` optionally preceded by mangled name of the unit and finishing with the method name.

The following constructs

```
unit testman;

interface
type
  myobject = object
    constructor init;
    procedure mymethod;
  end;

implementation

  constructor myobject.init;
  begin
  end;

  procedure myobject.mymethod;
  begin
  end;

  function myfunc: pointer;
  begin
```

```
end;

procedure myprocedure(var x: integer; y: longint; z : pchar);
begin
end;

end.
```

will result in the following assembler file for the Intel 80x86 target:

```
.file "testman.pas"

.text
.balign 16
.globl _TESTMAN$$$_MYOBJECT$$$_INIT
_TESTMAN$$$_MYOBJECT$$$_INIT:
pushl %ebp
movl %esp,%ebp
subl $4,%esp
movl $0,%edi
call FPC_HELP_CONSTRUCTOR
jz .L5
jmp .L7
.L5:
movl 12(%ebp),%esi
movl $0,%edi
call FPC_HELP_FAIL
.L7:
movl %esi,%eax
testl %esi,%esi
leave
ret $8
.balign 16
.globl _TESTMAN$$$_MYOBJECT$$$_MYMETHOD
_TESTMAN$$$_MYOBJECT$$$_MYMETHOD:
pushl %ebp
movl %esp,%ebp
leave
ret $4
.balign 16
_TESTMAN$$$_MYFUNC:
pushl %ebp
movl %esp,%ebp
subl $4,%esp
movl -4(%ebp),%eax
leave
ret
.balign 16
_TESTMAN$$$_MYPROCEDURE$INTEGER$LONGINT$PCHAR:
pushl %ebp
movl %esp,%ebp
leave
ret $12
```

Modifying the mangled names

To make the symbols externally accessible, it is possible to give nicknames to mangled names, or to change the mangled name directly. Two modifiers can be used:

cdecl: A function that has a `cdecl` modifier, will be used with C calling conventions, that is, the caller clears the stack. Also the mangled name will be the name *exactly* as it is declared. `cdecl` is part of the function declaration, and hence must be present both in the interface and implementation section of a unit.

alias: The `alias` modifier can be used to assign a second assembler label to your function. This label has the same name as the alias name you declared. This doesn't modify the calling conventions of the function. In other words, the `alias` modifier allows you to specify another name (a nickname) for your function or procedure.

The prototype for an aliased function or procedure is as follows:

```
Procedure AliasedProc; alias : 'AliasName';
```

The procedure `AliasedProc` will also be known as `AliasName`. Take care, the name you specify is case sensitive (as C is).

Furthermore, the `exports` section of a library is also used to declare the names that will be exported by the shared library. The names in the `exports` section are case-sensitive (while the actual declaration of the routine is not). For more information on the creating shared libraries, chapter 11, page 94.

6.3 Calling mechanism

Procedures and Functions are called with their parameters on the stack. Contrary to Turbo Pascal, *all* parameters are pushed on the stack, and they are pushed *right to left*, instead of left to right for Turbo Pascal. This is especially important if you have some assembly subroutines in Turbo Pascal which you would like to translate to Free Pascal.

Function results are returned in the accumulator, if they fit in the register. Methods calls (from either objects or classes) have an additional invisible parameter which is `self`. This parameter is the leftmost parameter within a method call (it is therefore the last parameter passed to the method).

When the procedure or function exits, it clears the stack.

Other calling methods are available for linking with external object files and libraries, these are summarized in table (6.3). The first column lists the modifier you specify for a procedure declaration. The second one lists the order the parameters are pushed on the stack. The third column specifies who is responsible for cleaning the stack: the caller or the called function. The alignment column indicates the alignment of the parameters sent to the stack area. Finally, the fifth column indicates if any registers are saved in the entry code of the subroutine.

More about this can be found in chapter 7, page 59 on linking. Information on GCC registers saved, GCC stack alignment and general stack alignment on an operating system basis can be found in Appendix H. The `register` modifier is currently not supported, and maps to the default calling convention.

Furthermore, the `saveregisters` modifier can be used with any of the calling mechanism specifiers. When `saveregisters` is used, all registers will be saved on entry to the routine, and will be restored upon exit. Of course, if the routine is a function, and it normally returns its return value in a register, that register will not be saved. Also, if the `self` register is used, it will also neither be saved nor restored.

Table 6.3: Calling mechanisms in Free Pascal

Modifier	Pushing order	Stack cleaned by	alignment	registers saved
<none>	Right-to-left	Function	default	None
cdecl	Right-to-left	Caller	GCC alignment	GCC registers
interrupt	Right-to-left	Function	default	all registers
pascal	Left-to-right	Function	default	None
safecall	Right-to-left	Function	default	GCC registers
stdcall	Right-to-left	Function	GCC alignment	GCC registers
popstack	Right-to-left	Caller	default	None
register	Left-to-right	Caller	default	None

6.4 Nested procedure and functions

When a routine is declared within the scope of a procedure or function, it is said to be nested. In this case, an additional invisible parameter is passed to the nested routine. This additional parameter is the frame pointer address of the calling routine. This permits the nested routine to access the local variables and parameters of the calling routine.

The resulting stack frame after the entry code of a simple nested procedure has been executed is shown in table (6.4).

Table 6.4: Stack frame when calling a nested procedure (32-bit processors)

Offset from frame pointer	What is stored
+x	parameters
+8	Frame pointer of parent routine
+4	Return address
+0	Saved frame pointer

6.5 Constructor and Destructor calls

When using objects that need virtual methods, the compiler uses two help procedures that are in the run-time library. They are called `FPC_HELP_DESTRUCTOR` and `FPC_HELP_CONSTRUCTOR`. They are used to allocate the necessary memory if needed, and to insert the Virtual Method Table (VMT) pointer in the newly allocated object.

When the compiler encounters a call to an object's constructor, it sets up the stack frame for the call, and inserts a call to the `FPC_HELP_CONSTRUCTOR` procedure before issuing the call to the real constructor. The helper procedure allocates the needed memory (if needed) and inserts the VMT pointer in the object. After that, the real constructor is called.

A call to `FPC_HELP_DESTRUCTOR` is inserted in every destructor declaration, just before the destructor's exit sequence, it deallocates the memory allocated in the constructor.

6.6 Entry and exit code

Each Pascal procedure and function begins and ends with standard epilogue and prologue code.

Intel 80x86 standard routine prologue / epilogue

Standard entry code for procedures and functions is as follows on the 80x86 architecture:

```
pushl    %ebp
movl     %esp,%ebp
```

The generated exit sequence for procedure and functions looks as follows:

```
leave
ret     $xx
```

Where `xx` is the total size of the pushed parameters.

To have more information on function return values take a look at [section 6.1](#), page 50.

Motorola 680x0 standard routine prologue / epilogue

Standard entry code for procedures and functions is as follows on the 680x0 architecture:

```
move.l   a6,-(sp)
move.l   sp,a6
```

The generated exit sequence for procedure and functions looks as follows:

```
unlk     a6
move.l   (sp)+,a0      ; Get return address
add.l    #xx,sp        ; Remove allocated stack
move.l   a0,-(sp)      ; Put back return address on top of the stack
```

Where `xx` is the total size of the pushed parameters.

To have more information on function return values take a look at [section 6.1](#), page 50.

6.7 Parameter passing

When a function or procedure is called, then the following is done by the compiler:

1. If there are any parameters to be passed to the procedure, they are pushed from right to left on the stack.
2. If a function is called that returns a variable of type `String`, `Set`, `Record`, `Object` or `Array`, then an address to store the function result in, is pushed on the stack.
3. If the called procedure or function is an object method, then the pointer to `self` is pushed on the stack.
4. If the procedure or function is nested in another function or procedure, then the frame pointer of the parent procedure is pushed on the stack.
5. The return address is pushed on the stack (This is done automatically by the instruction which calls the subroutine).

The resulting stack frame upon entering looks as in table ([6.5](#)).

Table 6.5: Stack frame when calling a procedure (32-bit model)

Offset	What is stored	Optional?
+x	parameters	Yes
+12	function result	Yes
+8	self	Yes
+4	Return address	No
+0	Frame pointer of parent procedure	Yes

Parameter alignment

Each parameter passed to a routine is guaranteed to decrement the stack pointer by a certain minimum amount. This behavior varies from one operating system to another. For example, passing a byte as a value parameter to a routine could either decrement the stack pointer by 1, 2, 4 or even 8 bytes depending on the target operating system and processor. The minimal default stack pointer decrement value is given in [Appendix H](#).

For example, on `FREEBSD`, all parameters passed to a routine guarantee a minimal stack decrease of four bytes per parameter, even if the parameter actually takes less than 4 bytes to store on the stack (such as passing a byte value parameter to the stack).

Processor limitations

Certain processors have limitations on the size of the parameters which can be passed to routine. This is shown in [table \(6.6\)](#).

Table 6.6: Maximum parameter sizes for processors

Processor	Limit (in Bytes)
Intel 80x86	64K
Motorola 680x0	32K

Chapter 7

Linking issues

When you only use Pascal code, and Pascal units, then you will not see much of the part that the linker plays in creating your executable. The linker is only called when you compile a program. When compiling units, the linker isn't invoked.

However, there are times that linking to C libraries, or to external object files created by other compilers may be necessary. The Free Pascal compiler can generate calls to a C function, and can generate functions that can be called from C (exported functions).

7.1 Using external code and variables

In general, there are 3 things you must do to use a function that resides in an external library or object file:

1. You must make a pascal declaration of the function or procedure you want to use.
2. You must declare the correct calling convention to use.
3. You must tell the compiler where the function resides, i.e. in what object file or what library, so the compiler can link the necessary code in.

The same holds for variables. To access a variable that resides in an external object file, you must declare it, and tell the compiler where to find it. The following sections attempt to explain how to do this.

Declaring external functions or procedures

The first step in using external code blocks is declaring the function you want to use. Free Pascal supports Delphi syntax, i.e. you must use the `external` directive. The `external` directive replaces, in effect, the code block of the function.

The `external` directive doesn't specify a calling convention; it just tells the compiler that the code for a procedure or function resides in an external code block. A calling convention modifier should be declared if the external code blocks does not have the same calling conventions as Free Pascal. For more information on the calling conventions section [6.3](#), page [55](#).

There exist four variants of the `external` directive:

1. A simple external declaration:

```
Procedure ProcName (Args : TProcArgs); external;
```

The `external` directive tells the compiler that the function resides in an external block of code. You can use this together with the `{ $L }` or `{ $LinkLib }` directives to link to a function or procedure in a library or external object file. Object files are looked for in the object search path (set by `-Fo`) and libraries are searched for in the linker path (set by `-Fl`).

2. You can give the `external` directive a library name as an argument:

```
Procedure ProcName (Args : TProcArgs); external 'Name';
```

This tells the compiler that the procedure resides in a library with name `'Name'`. This method is equivalent to the following:

```
Procedure ProcName (Args : TProcArgs); external;  
{ $LinkLib 'Name' }
```

3. The `external` can also be used with two arguments:

```
Procedure ProcName (Args : TProcArgs); external 'Name'  
name 'OtherProcName';
```

This has the same meaning as the previous declaration, only the compiler will use the name `'OtherProcName'` when linking to the library. This can be used to give different names to procedures and functions in an external library. The name of the routine is case-sensitive and should match exactly the name of the routine in the object file.

This method is equivalent to the following code:

```
Procedure OtherProcName (Args : TProcArgs); external;  
{ $LinkLib 'Name' }
```

```
Procedure ProcName (Args : TProcArgs);
```

```
begin  
  OtherProcName (Args);  
end;
```

4. Lastly, under WINDOWS and OS/2, there is a fourth possibility to specify an external function: In .DLL files, functions also have a unique number (their index). It is possible to refer to these functions using their index:

```
Procedure ProcName (Args : TProcArgs); external 'Name' Index SomeIndex;
```

This tells the compiler that the procedure `ProcName` resides in a dynamic link library, with index `SomeIndex`.

Remark: Note that this is ONLY available under WINDOWS and OS/2.

Declaring external variables

Some libraries or code blocks have variables which they export. You can access these variables much in the same way as external functions. To access an external variable, you declare it as follows:

```
Var  
  MyVar : MyType; external name 'varname';
```

The effect of this declaration is twofold:

1. No space is allocated for this variable.
2. The name of the variable used in the assembler code is `varname`. This is a case sensitive name, so you must be careful.

The variable will be accessible with it's declared name, i.e. `MyVar` in this case.

A second possibility is the declaration:

```
Var
  varname : MyType; cvar; external;
```

The effect of this declaration is twofold as in the previous case:

1. The `external` modifier ensures that no space is allocated for this variable.
2. The `cvar` modifier tells the compiler that the name of the variable used in the assembler code is exactly as specified in the declaration. This is a case sensitive name, so you must be careful.

The first possibility allows you to change the name of the external variable for internal use.

As an example, let's look at the following C file (in `extvar.c`):

```
/*
Declare a variable, allocate storage
*/
int extvar = 12;
```

And the following program (in `extdemo.pp`):

```
Program ExtDemo;

{$L extvar.o}

Var { Case sensitive declaration !! }
  extvar : longint; cvar;external;
  I : longint; external name 'extvar';
begin
  { Extvar can be used case insensitive !! }
  Writeln ('Variable ''extvar'' has value: ',ExtVar);
  Writeln ('Variable ''I''      has value: ',i);
end.
```

Compiling the C file, and the pascal program:

```
gcc -c -o extvar.o extvar.c
ppc386 -Sv extdemo
```

Will produce a program `extdemo` which will print

```
Variable 'extvar' has value: 12
Variable 'I'      has value: 12
```

on your screen.

Declaring the calling convention modifier

To make sure that all parameters are correctly passed to the external routines, you should declare it with the correct calling convention modifier. When linking with code blocks compiled with standard C compilers (such as GCC), the `cdecl` modifier should be used so as to indicate that the external routine uses C type calling conventions. For more information on the supported calling conventions, section 6.3, page 55.

As might be expected, external variable declarations do not require any calling convention modifier.

Declaring the external object code

Linking to an object file

Having declared the external function or variable that resides in an object file, you can use it as if it was defined in your own program or unit. To produce an executable, you must still link the object file in. This can be done with the `{$L file.o}` directive.

This will cause the linker to link in the object file `file.o`. On most systems, this filename is case sensitive. The object file is first searched in the current directory, and then the directories specified by the `-Fo` command line.

You cannot specify libraries in this way, it is for object files only.

Here we present an example. Consider that you have some assembly routine which uses the C calling convention that calculates the *nth* Fibonacci number:

```
.text
    .align 4
.globl Fibonacci
    .type Fibonacci,@function
Fibonacci:
    pushl %ebp
    movl %esp,%ebp
    movl 8(%ebp),%edx
    xorl %ecx,%ecx
    xorl %eax,%eax
    movl $1,%ebx
    incl %edx
loop:
    decl %edx
    je endloop
    movl %ecx,%eax
    addl %ebx,%eax
    movl %ebx,%ecx
    movl %eax,%ebx
    jmp loop
endloop:
    movl %ebp,%esp
    popl %ebp
    ret
```

Then you can call this function with the following Pascal Program:

```
Program FibonacciDemo;

var i : longint;
```

```
Function Fibonacci (L : longint):longint;cdecl;external;  
  
{ $L fib.o }  
  
begin  
  For I:=1 to 40 do  
    writeln ('Fib(',i,') : ',Fibonacci (i));  
end.
```

With just two commands, this can be made into a program:

```
as -o fib.o fib.s  
ppc386 fibo.pp
```

This example supposes that you have your assembler routine in `fib.s`, and your Pascal program in `fibo.pp`.

Linking to a library

To link your program to a library, the procedure depends on how you declared the external procedure. In case you used the following syntax to declare your procedure:

```
Procedure ProcName (Args : TProcArgs); external 'Name';
```

You don't need to take additional steps to link your file in, the compiler will do all that is needed for you. On WINDOWS it will link to `name.dll`, on LINUX and most UNIX'es your program will be linked to library `libname`, which can be a static or dynamic library.

In case you used

```
Procedure ProcName (Args : TProcArgs); external;
```

You still need to explicitly link to the library. This can be done in 2 ways:

1. You can tell the compiler in the source file what library to link to using the `{ $LinkLib 'Name' }` directive:

```
{ $LinkLib 'gpm' }
```

This will link to the `gpm` library. On UNIX systems (such as LINUX), you must not specify the extension or `'lib'` prefix of the library. The compiler takes care of that. On other systems (such as WINDOWS, you need to specify the full name.

2. You can also tell the compiler on the command-line to link in a library: The `-k` option can be used for that. For example

```
ppc386 -k'-lgpm' myprog.pp
```

Is equivalent to the above method, and tells the linker to link to the `gpm` library.

As an example; consider the following program:


```
program printlength;

{$linklib c} { Case sensitive }

{ Declaration for the standard C function strlen }
Function strlen (P : pchar) : longint; cdecl;external;

begin
  Writeln (strlen('Programming is easy !'));
end.
```

This program can be compiled with:

```
ppc386 prlen.pp
```

Supposing, of course, that the program source resides in `prlen.pp`.

To use functions in C that have a variable number of arguments, you must compile your unit or program in `objfpc` mode or `Delphi` mode, and use the `Array of const` argument, as in the following example:

```
program testaocc;

{$mode objfpc}

Const
  P : Pchar
    = 'example';
  F : Pchar
    = 'This %s uses printf to print numbers (%d) and strings.'#10;

procedure printf(fm: pchar;args: array of const);cdecl;external 'c';

begin
  printf(F,[P,123]);
end.
```

The output of this program looks like this:

This example uses `printf` to print numbers (123) and strings.

7.2 Making libraries

Free Pascal supports making shared or static libraries in a straightforward and easy manner. If you want to make static libraries for other Free Pascal programmers, you just need to provide a command line switch. To make shared libraries, refer to the chapter [11](#), page [94](#). If you want C programmers to be able to use your code as well, you will need to adapt your code a little. This process is described first.

Exporting functions

When exporting functions from a library, there are 2 things you must take in account:

1. Calling conventions.
2. Naming scheme.

The calling conventions are controlled by the modifiers `cdecl`, `stdcall`, `pascal`, `safecall`, `stdcall` and `register`. See section 6.3, page 55 for more information on the different kinds of calling scheme.

The naming conventions can be controlled by 2 modifiers in the case of static libraries:

- `cdecl`
- `alias`

For more information on how these different modifiers change the name mangling of the routine section 6.2, page 52.

Remark: If you use in your unit functions that are in other units, or system functions, then the C program will need to link in the object files from these units too.

Exporting variables

Similarly as when you export functions, you can export variables. When exporting variables, one should only consider the names of the variables. To declare a variable that should be used by a C program, one declares it with the `cvar` modifier:

```
Var MyVar : MyTpe; cvar;
```

This will tell the compiler that the assembler name of the variable (the one which is used by C programs) should be exactly as specified in the declaration, i.e., case sensitive.

It is not allowed to declare multiple variables as `cvar` in one statement, i.e. the following code will produce an error:

```
var Z1,Z2 : longint;cvar;
```

Compiling libraries

Once you have your (adapted) code, with exported and other functions, you can compile your unit, and tell the compiler to make it into a library. The compiler will simply compile your unit, and perform the necessary steps to transform it into a `static` or `shared` (dynamic) library.

You can do this as follows, for a dynamic library:

```
ppc386 -CD myunit
```

On UNIX systems, such as LINUX, this will leave you with a file `libmyunit.so`. On WINDOWS and OS/2, this will leave you with `myunit.dll`. An easier way to create shared libraries is to use the `library` keyword. For more information on creating shared libraries, chapter 11, page 94.

If you want a static library, you can do

```
ppc386 -CS myunit
```

This will leave you with `libmyunit.a` and a file `myunit.ppu`. The `myunit.ppu` is the unit file needed by the Free Pascal compiler.

The resulting files are then libraries. To make static libraries, you need the `ranlib` or `ar` program on your system. It is standard on most UNIX systems, and is provided with the `gcc` compiler under DOS. For the dos distribution, a copy of `ar` is included in the file `gnuutils.zip`.

BEWARE: This command doesn't include anything but the current unit in the library. Other units are left out, so if you use code from other units, you must deploy them together with your library.

Unit searching strategy

When you compile a unit, the compiler will by default always look for unit files.

To be able to differentiate between units that have been compiled as static or dynamic libraries, there are 2 switches:

-XD: This will define the symbol `FPC_LINK_DYNAMIC`

-XS: This will define the symbol `FPC_LINK_STATIC`

Definition of one symbol will automatically undefine the other.

These two switches can be used in conjunction with the configuration file `fpc.cfg`. The existence of one of these symbols can be used to decide which unit search path to set. For example, on LINUX:

```
# Set unit paths

#ifdef FPC_LINK_STATIC
-Up/usr/lib/fpc/linuxunits/staticunits
#endif
#ifdef FPC_LINK_DYNAMIC
-Up/usr/lib/fpc/linuxunits/sharedunits
#endif
```

With such a configuration file, the compiler will look for it's units in different directories, depending on whether `-XD` or `-XS` is used.

7.3 Using smart linking

You can compile your units using smart linking. When you use smartlinking, the compiler creates a series of code blocks that are as small as possible, i.e. a code block will contain only the code for one procedure or function.

When you compile a program that uses a smart-linked unit, the compiler will only link in the code that you actually need, and will leave out all other code. This will result in a smaller binary, which is loaded in memory faster, thus speeding up execution.

To enable smartlinking, one can give the `smartlink` option on the command line: `-Cx`, or one can put the `{SMARTLINK ON}` directive in the unit file:

```
Unit Testunit

{SMARTLINK ON}
Interface
...
```

Smartlinking will slow down the compilation process, especially for large units.

When a unit `foo.pp` is smartlinked, the name of the codefile is changed to `libfoo.a`.

Technically speaking, the compiler makes small assembler files for each procedure and function in the unit, as well as for all global defined variables (whether they're in the interface section or not). It then assembles all these small files, and uses `ar` to collect the resulting object files in one archive.

Smartlinking and the creation of shared (or dynamic) libraries are mutually exclusive, that is, if you turn on smartlinking, then the creation of shared libraries is turned off. The creation of static libraries is still possible. The reason for this is that it has little sense in making a smartlinked dynamical library. The whole shared library is loaded into memory anyway by the dynamic linker (or the operating system), so there would be no gain in size by making it smartlinked.

Chapter 8

Memory issues

8.1 The memory model.

The Free Pascal compiler issues 32-bit or 64-bit code. This has several consequences:

- You need a 32-bit or 64-bit processor to run the generated code. The compiler functions on a 286 when you compile it using Turbo Pascal, but the generated programs cannot be assembled or executed.
- You don't need to bother with segment selectors. Memory can be addressed using a single 32-bit (on 32-bit processors) or 64-bit (on 64-bit processors with 64-bit addressing) pointer. The amount of memory is limited only by the available amount of (virtual) memory on your machine.
- The structures you define are unlimited in size. Arrays can be as long as you want. You can request memory blocks from any size.

The fact that 16-bit code is no longer used, means that some of the older Turbo Pascal constructs and functions are obsolete. The following is a list of functions which shouldn't be used anymore:

Seg() : Returned the segment of a memory address. Since segments have no more meaning, zero is returned in the Free Pascal run-time library implementation of `Seg`.

Ofs() : Returned the offset of a memory address. Since segments have no more meaning, the complete address is returned in the Free Pascal implementation of this function. This has as a consequence that the return type is `longint` or `int64` instead of `Word`.

Cseg(), Dseg() : Returned, respectively, the code and data segments of your program. This returns zero in the Free Pascal implementation of the system unit, since both code and data are in the same memory space.

Ptr : Accepted a segment and offset from an address, and would return a pointer to this address. This has been changed in the run-time library, it now simply returns the offset.

memw and mem : These arrays gave access to the DOS memory. Free Pascal supports them on the go32v2 platform, they are mapped into DOS memory space. You need the `go32` unit for this. On other platforms, they are *not* supported

You shouldn't use these functions, since they are very non-portable, they're specific to DOS and the 80x86 processor. The Free Pascal compiler is designed to be portable to other platforms, so you should keep your code as portable as possible, and not system specific. That is, unless you're writing some driver units, of course.

8.2 Data formats

This section gives information on the storage space occupied by the different possible types in Free Pascal. Information on internal alignment will also be given.

integer types

The storage size of the default integer types are given in [Reference guide](#). In the case of user defined-types, the storage space occupied depends on the bounds of the type:

- If both bounds are within range -128..127, the variable is stored as a shortint (signed 8-bit quantity).
- If both bounds are within the range 0..255, the variable is stored as a byte (unsigned 8-bit quantity).
- If both bounds are within the range -32768..32767, the variable is stored as a smallint (signed 16-bit quantity).
- If both bounds are within the range 0..65535, the variable is stored as a word (unsigned 16-bit quantity).
- If both bounds are within the range 0..4294967295, the variable is stored as a cardinal (unsigned 32-bit quantity).
- Otherwise the variable is stored as a longint (signed 32-bit quantity).

char types

A char, or a subrange of the char type is stored as a byte.

boolean types

The boolean type is stored as a byte and can take a value of true or false.

A ByteBool is stored as a byte, a WordBool type is stored as a word, and a longbool is stored as a longint.

enumeration types

By default all enumerations are stored as a cardinal (4 bytes), which is equivalent to specifying the `{ $Z4 }`, `{ $PACKENUM 4 }` or `{ $PACKENUM DEFAULT }` switches.

This default behavior can be changed by compiler switches, and by the compiler mode.

In the `tp` compiler mode, or while the `{ $Z1 }` or `{ $PACKENUM 1 }` switches are in effect, the storage space used is shown in table (8.1).

When the `{ $Z2 }` or `{ $PACKENUM 2 }` switches are in effect, the value is stored on 2 bytes (word), if the enumeration has less or equal then 65535 elements, otherwise, the enumeration value is stored as a 4 byte value (cardinal).

Table 8.1: Enumeration storage for `tp` mode

# Of Elements in Enum.	Storage space used
0..255	byte (1 byte)
256..65535	word (2 bytes)
> 65535	cardinal (4 bytes)

Table 8.2: Processor mapping of real type

Processor	Real type mapping
Intel 80x86	double
Motorola 680x0 (with {\$E-} switch)	double
Motorola 680x0 (with {\$E+} switch)	single

floating point types

Floating point type sizes and mapping vary from one processor to another. Except for the Intel 80x86 architecture, the extended type maps to the IEEE double type.

Floating point types have a storage binary format divided into three distinct fields : the mantissa, the exponent and the sign bit which stores the sign of the floating point value.

single

The single type occupies 4 bytes of storage space, and its memory structure is the same as the IEEE-754 single type.

The memory format of the single format looks like what is shown in figure (8.1).

double

The double type occupies 8 bytes of storage space, and its memory structure is the same as the IEEE-754 double type.

The memory format of the double format looks like like what is shown in figure (8.2).

On processors which do not support co-processor operations (and which have the `{ $\$$ E-}` switch), the `double` type does not exist.

Figure 8.1: The single format

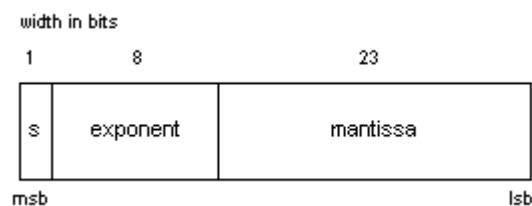
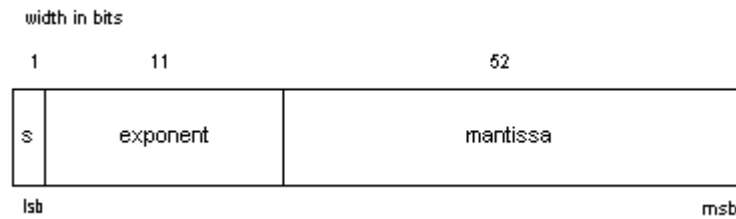


Figure 8.2: The double format

**extended**

For Intel 80x86 processors, the `extended` type has takes up 10 bytes of memory space. For more information on the extended type consult the Intel Programmer's reference.

For all other processors which support floating point operations, the `extended` type is a nickname for the `double` type. It has the same format and size as the `double` type. On processors which do not support co-processor operations (and which have the `{E-}` switch), the `extended` type does not exist.

comp

For Intel 80x86 processors, the `comp` type contains a 63-bit integral value, and a sign bit (in the MSB position). The `comp` type takes up 8 bytes of storage space.

On other processors, the `comp` type is not supported.

real

Contrary to Turbo Pascal, where the `real` type had a special internal format, under Free Pascal the `real` type simply maps to one of the other real types. It maps to the `double` type on processors which support floating point operations, while it maps to the `single` type on processors which do not support floating point operations in hardware. See table (8.2) for more information on this.

pointer types

A `pointer` type is stored as a cardinal (unsigned 32-bit value) on 32-bit processors, and is stored as a 64-bit unsigned value¹ on 64-bit processors.

string types**ansistring types**

The `ansistring` is a dynamically allocated string which has no length limitation. When the string is no longer being referenced (its reference count reaches zero), its memory is automatically freed.

If the `ansistring` is a constant, then its reference count will be equal to -1, indicating that it should never be freed. The structure in memory for an `ansistring` is shown in table (8.3).

¹this is actually the `qword` type, which is not supported in Free Pascal v1.0

Table 8.3: AnsiString memory structure (32-bit model)

Offset	Contains
-12	Longint with maximum string size.
-8	Longint with actual string size.
-4	Longint with reference count.
0	Actual array of <code>char</code> , null-terminated.

shortstring types

A shortstring occupies as many bytes as its maximum length plus one. The first byte contains the current dynamic length of the string. The following bytes contain the actual characters (of type `char`) of the string. The maximum size of a short string is the length byte followed by 255 characters.

widestring types

The widestring (composed of unicode characters) is not supported in Free Pascal v1.0.

set types

A set is stored as an array of bits, where each bit indicates if the element is in the set or excluded from the set. The maximum number of elements in a set is 256.

If a set has less than 32 elements, it is coded as an unsigned 32-bit value. Otherwise it is coded as a 8 element array of 32-bit unsigned values (cardinal) (hence a size of 256 bytes).

The cardinal number of a specific element `E` is given by :

```
CardinalNumber = (E div 32);
```

and the bit number within that 32-bit value is given by:

```
BitNumber = (E mod 32);
```

array types

An array is stored as a contiguous sequence of variables of the components of the array. The components with the lowest indexes are stored first in memory. No alignment is done between each element of the array. A multi-dimensional array is stored with the rightmost dimension increasing first.

record types

Each field of a record are stored in a contiguous sequence of variables, where the first field is stored at the lowest address in memory. In case of variant fields in a record, each variant starts at the same address in memory. Fields of record are usually aligned, unless the `packed` directive is specified when declaring the record type. For more information on field alignment, consult section [8](#), page [76](#).

object types

Objects are stored in memory just as ordinary records with an extra field: a pointer to the Virtual Method Table (VMT). This field is stored first, and all fields in the object are stored in the order

they are declared (with possible alignment of field addresses, unless the object was declared as being packed).

This field is initialized by the call to the object's `Constructor` method. If the `new` operator was used to call the constructor, the data fields of the object will be stored in heap memory, otherwise they will directly be stored in the data section of the final executable.

If an object doesn't have virtual methods, no pointer to a VMT is inserted.

The memory allocated looks as in table (8.4).

Table 8.4: Object memory layout (32-bit model)

Offset	What
+0	Pointer to VMT (optional).
+4	Data. All fields in the order they've been declared.
...	

The Virtual Method Table (VMT) for each object type consists of 2 check fields (containing the size of the data), a pointer to the object's ancestor's VMT (`Nil` if there is no ancestor), and then the pointers to all virtual methods. The VMT layout is illustrated in table (8.5). The VMT is constructed by the compiler.

Table 8.5: Object Virtual Method Table memory layout (32-bit model)

Offset	What
+0	Size of object type data
+4	Minus the size of object type data. Enables determining of valid VMT pointers.
+8	Pointer to ancestor VMT, <code>Nil</code> if no ancestor available.
+12	Pointers to the virtual methods.
...	

class types

Just like objects, classes are stored in memory just as ordinary records with an extra field: a pointer to the Virtual Method Table (VMT). This field is stored first, and all fields in the class are stored in the order they are declared.

Contrary to objects, all data fields of a class are always stored in heap memory.

The memory allocated looks as in table (8.6).

Table 8.6: Class memory layout (32-bit model)

Offset	What
+0	Pointer to VMT.
+4	Data. All fields in the order they've been declared.
...	

The Virtual Method Table (VMT) of each class consists of several fields, which are used for runtime type information. The VMT layout is illustrated in table (8.7). The VMT is constructed by the compiler.

Table 8.7: Class Virtual Method Table memory layout (32-bit model)

Offset	What
+0	Size of object type data
+4	Minus the size of object type data. Enables determining of valid VMT pointers.
+8	Pointer to ancestor VMT, Nil if no ancestor available.
+12	Pointer to the class name (stored as a <code>shortstring</code>).
+16	Pointer to the dynamic method table (using <code>message</code> with integers).
+20	Pointer to the method definition table.
+24	Pointer to the field definition table.
+28	Pointer to type information table.
+32	Pointer to instance initialization table.
+36	Reserved.
+40	Pointer to the interface table.
+44	Pointer to the dynamic method table (using <code>message</code> with strings).
+48	Pointer to the <code>Destroy</code> destructor.
+52	Pointer to the <code>NewInstance</code> method.
+56	Pointer to the <code>FreeInstance</code> method.
+60	Pointer to the <code>SafeCallException</code> method.
+64	Pointer to the <code>DefaultHandler</code> method.
+68	Pointer to the <code>AfterConstruction</code> method.
+72	Pointer to the <code>BeforeDestruction</code> method.
+76	Pointer to the <code>DefaultHandlerStr</code> method.
+80	Pointers to other virtual methods.
...	

file types

File types are represented as records. Typed files and untyped files are represented as a fixed record:

```

filerec = packed record
  handle      : longint;
  mode        : longint;
  recsize     : longint;
  _private    : array[1..32] of byte;
  userdata    : array[1..16] of byte;
  name        : array[0..255] of char;
End;
```

Text files are described using the following record:

```

TextBuf = array[0..255] of char;
textrec = packed record
  handle      : longint;
  mode        : longint;
  bufsize     : longint;
  _private    : longint;
  bufpos      : longint;
  bufend      : longint;
  bufptr      : ^textbuf;
  openfunc    : pointer;
  inoutfunc   : pointer;
```

```

flushfunc : pointer;
closefunc : pointer;
userdata  : array[1..16] of byte;
name      : array[0..255] of char;
buffer    : textbuf;
End;
```

handle The handle field returns the file handle (if the file is opened), as returned by the operating system.

mode The mode field can take one of several values. When it is `fmclosed`, then the file is closed, and the handle field is invalid. When the value is equal to `fminput`, it indicates that the file is opened for read only access. `fmoutput` indicates write only access, and the `fminout` indicates read-write access to the file.

name The name field is a null terminated character string representing the name of the file.

userdata The userdata field is never used by Free Pascal, and can be used for special purposes by software developers.

procedural types

A procedural type to a normal procedure or function is stored as a generic pointer, which stores the address of the entry point of the routine.

In the case of a method procedural type, the storage consists of two pointers, the first being a pointer to the entry point of the method, and the second one being a pointer to `self` (the object instance).

8.3 Data alignment

Typed constants and variable alignment

All static data (variables and typed constants) which are greater than a byte are usually aligned on a power of two boundary. This alignment applies only to the start address of the variables, and not the alignment of fields within structures or objects for example. For more information on structured alignment, section 8, page 76. The alignment is similar across the different target processors. ²

Table 8.8: Data alignment

Data size (bytes)	Alignment (small size)	Alignment (fast)
1	1	1
2-3	2	2
4-7	2	4
8+	2	4

The alignment columns indicates the address alignment of the variable, i.e the start address of the variable will be aligned on that boundary. The small size alignment is valid when the code generated should be optimized for size (`-Og` compiler option) and not speed, otherwise and by default, the fast alignment is used to align the data.

²The Intel 80x86 version does not align data in the case of constant strings, constant sets, constant floating point values and global variables. This will be fixed in the version 1.1 release.

Structured types alignment

By default all elements in a structure are aligned to a 2 byte boundary, unless the `$PACKRECORDS` directive or `packed` modifier is used to align the data in another way. For example a record or object having a 1 byte element, will have its size rounded up to 2, so the size of the structure will actually be 2 bytes.

8.4 The heap

The heap is used to store all dynamic variables, and to store class instances. The interface to the heap is the same as in Turbo Pascal, although the effects are maybe not the same. On top of that, the Free Pascal run-time library has some extra possibilities, not available in Turbo Pascal. These extra possibilities are explained in the next subsections.

Heap allocation strategy

The heap is a memory structure which is organized as a stack. The heap bottom is stored in the variable `HeapOrg`. Initially the heap pointer (`HeapPtr`) points to the bottom of the heap. When a variable is allocated on the heap, `HeapPtr` is incremented by the size of the allocated memory block. This has the effect of stacking dynamic variables on top of each other.

Each time a block is allocated, its size is normalized to have a granularity of 16 bytes.

When `Dispose` or `FreeMem` is called to dispose of a memory block which is not on the top of the heap, the heap becomes fragmented. The deallocation routines also add the freed blocks to the `freelist` which is actually a linked list of free blocks. Furthermore, if the deallocated block was less then 8K in size, the free list cache is also updated.

The free list cache is actually a cache of free heap blocks which have specific lengths (the adjusted block size divided by 16 gives the index into the free list cache table). It is faster to access then searching through the entire `freelist`.

The format of an entry in the `freelist` is as follows:

```
PFreeRecord = ^TFreeRecord;
TFreeRecord = record
    Size : longint;
    Next : PFreeRecord;
    Prev : PFreeRecord;
end;
```

The `Next` field points to the next free block, while the `Prev` field points to the previous free block.

The algorithm for allocating memory is as follows:

1. The size of the block to allocate is adjusted to a 16 byte granularity.
2. The cached free list is searched to find a free block of the specified size or bigger size, if so it is allocated and the routine exits.
3. The `freelist` is searched to find a free block of the specified size or of bigger size, if so it is allocated and the routine exits.
4. If not found in the `freelist` the heap is grown to allocate the specified memory, and the routine exits.

5. If the heap cannot be grown internally anymore and if `heaperror` is set accordingly, it calls the heap error handler. If there is no heap error handler installed, the runtime library generates a runtime error 203.

The HeapError variable

The heap error permits developers to install a heap error hook which is called each time an allocation cannot be completed by the default heap manager. `HeapError` is a pointer that points to a function with the following prototype:

```
function HeapFunc(size : longint): integer;
```

The `size` parameter indicates the size of the block which could not be allocated. Depending on the success, the error handler routine should return a value which indicates what the default heap manager should do thereafter (cf. table (8.9)).

Table 8.9: Heap error result

Value returned	Memory manager action
0	Generates a runtime error 203
1	<code>GetMem</code> , <code>ReallocMem</code> and <code>New</code> returns <code>nil</code>
2	Try allocating the memory block once again

The heap grows

By default, `HeapError` points to the `GrowHeap` function, which tries to increase the heap.

The `GrowHeap` function issues a system call to try to increase the size of the memory available to your program. It first tries to increase memory in a 256Kb chunk if the size to allocate is less than 256Kb, or 1024K otherwise. If this fails, it tries to increase the heap by the amount you requested from the heap.

If the call to `GrowHeap` was successful, then the needed memory will be allocated.

If the call to `GrowHeap` fails, the value returned depends on the value of the `ReturnNilIfGrowHeapFails` global variable. This is summarized in table (8.10).

Table 8.10: `ReturnNilIfGrowHeapFails` value

<code>ReturnNilIfGrowHeapFails</code> value	Default memory manager action
FALSE	(The default) Runtime error 203 generated
TRUE	<code>GetMem</code> , <code>ReallocMem</code> and <code>New</code> returns <code>nil</code>

`ReturnNilIfGrowHeapFails` can be set to change the behavior of the default memory manager error handler.

Debugging the heap

Free Pascal provides a unit that allows you to trace allocation and deallocation of heap memory: `heaptrc`.

If you specify the `-gh` switch on the command-line, or if you include `heaptrc` as the first unit in your `uses` clause, the memory manager will trace what is allocated and deallocated, and on exit of your program, a summary will be sent to standard output.

More information on using the `heaptrc` mechanism can be found in the [Users guide](#) and [Unit reference](#).

Writing your own memory manager

Free Pascal allows you to write and use your own memory manager. The standard functions `GetMem`, `FreeMem`, `ReallocMem` and `MaxAvail` use a special record in the `system` unit to do the actual memory management. The `system` unit initializes this record with the `system` unit's own memory manager, but you can read and set this record using the `GetMemoryManager` and `SetMemoryManager` calls:

```
procedure GetMemoryManager(var MemMgr: TMemoryManager);
procedure SetMemoryManager(const MemMgr: TMemoryManager);
```

the `TMemoryManager` record is defined as follows:

```
TMemoryManager = record
  Getmem      : Function(Size:Longint):Pointer;
  Freemem     : Function(var p:pointer):Longint;
  FreememSize : Function(var p:pointer;Size:Longint):Longint;
  AllocMem    : Function(Size:longint):Pointer;
  ReAllocMem  : Function(var p:pointer;Size:longint):Pointer;
  MemSize     : function(p:pointer):Longint;
  MemAvail    : Function:Longint;
  MaxAvail    : Function:Longint;
  HeapSize    : Function:Longint;
end;
```

As you can see, the elements of this record are procedural variables. The `system` unit does nothing but call these various variables when you allocate or deallocate memory.

Each of these functions corresponds to the corresponding call in the `system` unit. We'll describe each one of them:

Getmem This function allocates a new block on the heap. The block should be `Size` bytes long. The return value is a pointer to the newly allocated block.

Freemem should release a previously allocated block. The pointer `P` points to a previously allocated block. The Memory manager should implement a mechanism to determine what the size of the memory block is ³ The return value is optional, and can be used to return the size of the freed memory.

FreememSize This function should release the memory pointed to by `P`. The argument `Size` is the expected size of the memory block pointed to by `P`. This should be disregarded, but can be used to check the behaviour of the program.

AllocMem Is the same as `getmem`, only the allocated memory should be filled with zeroes before the call returns.

ReAllocMem Should allocate a memory block `Size` bytes large, and should fill it with the contents of the memory block pointed to by `P`, truncating this to the new size of needed. After that, the

³By storing it's size at a negative offset for instance.

memory pointed to by P may be deallocated. The return value is a pointer to the new memory block.

MemSize should return the total amount of memory available for allocation. This function may return zero if the memory manager does not allow to determine this information.

MaxAvail should return the size of the largest block of memory that is still available for allocation. This function may return zero if the memory manager does not allow to determine this information.

HeapSize should return the total size of the heap. This may be zero if the memory manager does not allow to determine this information.

To implement your own memory manager, it is sufficient to construct such a record and to issue a call to `SetMemoryManager`.

To avoid conflicts with the system memory manager, setting the memory manager should happen as soon as possible in the initialization of your program, i.e. before any call to `getmem` is processed.

This means in practice that the unit implementing the memory manager should be the first in the `uses` clause of your program or library, since it will then be initialized before all other units (except of the `system` unit)

This also means that it is not possible to use the `heaptrc` unit in combination with a custom memory manager, since the `heaptrc` unit uses the system memory manager to do all its allocation. Putting the `heaptrc` unit after the unit implementing the memory manager would overwrite the memory manager record installed by the custom memory manager, and vice versa.

The following unit shows a straightforward implementation of a custom memory manager using the memory manager of the C library. It is distributed as a package with Free Pascal.

```
unit cmem;

{$mode objfpc}

interface

Function Malloc (Size : Longint) : Pointer; cdecl;
  external 'c' name 'malloc';
Procedure Free (P : pointer); cdecl; external 'c' name 'free';
Procedure FreeMem (P : Pointer); cdecl; external 'c' name 'free';
function ReAlloc (P : Pointer; Size : longint) : pointer; cdecl;
  external 'c' name 'realloc';
Function CAlloc (unitSize, UnitCount : Longint) : pointer; cdecl;
  external 'c' name 'calloc';

implementation

Function CGetMem (Size : Longint) : Pointer;

begin
  result:=Malloc(Size);
end;

Function CFreeMem (Var P : pointer) : Longint;

begin
  Free(P);
```



```
    Result:=0;
end;

Function CFreeMemSize(var p:pointer;Size:Longint):Longint;

begin
    Result:=CFreeMem(P);
end;

Function CAllocMem(Size : Longint) : Pointer;

begin
    Result:=calloc(Size,1);
end;

Function CReAllocMem (var p:pointer;Size:longint):Pointer;

begin
    Result:=realloc(p,size);
end;

Function CMemSize (p:pointer): Longint;

begin
    Result:=0;
end;

Function CMemAvail : Longint;

begin
    Result:=0;
end;

Function CMaxAvail: Longint;

begin
    Result:=0;
end;

Function CHeapSize : Longint;

begin
    Result:=0;
end;

Const
    CMemoryManager : TMemoryManager =
    (
        GetMem : CGetmem;
        FreeMem : CFreeMem;
        FreememSize : CFreememSize;
        AllocMem : CAllocMem;
        ReallocMem : CReAllocMem;
```

```
    MemSize : CMemSize;
    MemAvail : CMemAvail;
    MaxAvail : MaxAvail;
    HeapSize : CHeapSize;
);

Var
    OldMemoryManager : TMemoryManager;

Initialization
    GetMemoryManager (OldMemoryManager);
    SetMemoryManager (CmemoryManager);

Finalization
    SetMemoryManager (OldMemoryManager);
end.
```

8.5 Using DOS memory under the Go32 extender

Because Free Pascal for DOS is a 32 bit compiler, and uses a DOS extender, accessing DOS memory isn't trivial. What follows is an attempt to an explanation of how to access and use DOS or real mode memory⁴.

In *Protected Mode*, memory is accessed through *Selectors* and *Offsets*. You can think of Selectors as the protected mode equivalents of segments.

In Free Pascal, a pointer is an offset into the DS selector, which points to the Data of your program.

To access the (real mode) DOS memory, somehow you need a selector that points to the DOS memory. The `go32` unit provides you with such a selector: The `DosMemSelector` variable, as it is conveniently called.

You can also allocate memory in DOS's memory space, using the `global_dos_alloc` function of the `go32` unit. This function will allocate memory in a place where DOS sees it.

As an example, here is a function that returns memory in real mode DOS and returns a selector:offset pair for it.

```
procedure dosalloc(var selector : word;
                  var segment : word;
                  size : longint);

var result : longint;

begin
    result := global_dos_alloc(size);
    selector := word(result);
    segment := word(result shr 16);
end;
```

(You need to free this memory using the `global_dos_free` function.)

You can access any place in memory using a selector. You can get a selector using the `allocate_ldt_descriptor` function, and then let this selector point to the physical memory you want using the `set_segment_base_address` function, and set its length using `set_segment_limit` function. You can manipulate the memory

⁴Thanks for the explanation to Thomas Schatzl (E-mail: tom_at_work@geocities.com)

pointed to by the selector using the functions of the GO32 unit. For instance with the `seg_fillchar` function. After using the selector, you must free it again using the `free_ldt_selector` function.

More information on all this can be found in the [Unit reference](#), the chapter on the `go32` unit.

Chapter 9

Resource strings

9.1 Introduction

Resource strings primarily exist to make internationalization of applications easier, by introducing a language construct that provides a uniform way of handling constant strings.

Most applications communicate with the user through some messages on the graphical screen or console. Storing these messages in special constants allows to store them in a uniform way in separate files, which can be used for translation. A programmers interface exists to manipulate the actual values of the constant strings at runtime, and a utility tool comes with the Free Pascal compiler to convert the resource string files to whatever format is wanted by the programmer. Both these things are discussed in the following sections.

9.2 The resource string file

When a unit is compiled that contains a `resourcestring` section, the compiler does 2 things:

1. It generates a table that contains the value of the strings as it is declared in the sources.
2. It generates a *resource string file* that contains the names of all strings, together with their declared values.

This approach has 2 advantages: first of all, the value of the string is always present in the program. If the programmer doesn't care to translate the strings, the default values are always present in the binary. This also avoids having to provide a file containing the strings. Secondly, having all strings together in a compiler generated file ensures that all strings are together (you can have multiple `resourcestring` sections in 1 unit or program) and having this file in a fixed format, allows the programmer to choose his way of internationalization.

For each unit that is compiled and that contains a `resourcestring` section, the compiler generates a file that has the name of the unit, and an extension `.rst`. The format of this file is as follows:

1. An empty line.
2. A line starting with a hash sign (#) and the hash value of the string, preceded by the text `hash value =`.
3. A third line, containing the name of the resource string in the format `unitname.constantname`, all lowercase, followed by an equal sign, and the string value, in a format equal to the pascal

representation of this string. The line may be continued on the next line, in that case it reads as a pascal string expression with a plus sign in it.

4. Another empty line.

If the unit contains no `resourcestring` section, no file is generated.

For example, the following unit:

```
unit rsdemo;

{$mode delphi}
{$H+}

interface

resourcestring

    First = 'First';
    Second = 'A Second very long string that should cover more than 1 line';

implementation

end.
```

Will result in the following resource string file:

```
# hash value = 5048740
rsdemo.first='First'

# hash value = 171989989
rsdemo.second='A Second very long string that should cover more than 1 li'+
'ne'
```

The hash value is calculated with the function `Hash`. It is present in the `objpas` unit. The value is the same value that the GNU `gettext` mechanism uses. It is in no way unique, and can only be used to speed up searches.

The `rstconv` utility that comes with the Free Pascal compiler allows to manipulate these resource string files. At the moment, it can only be used to make a `.po` file that can be fed to the GNU `msgfmt` program. If someone wishes to have another format (Win32 resource files spring to mind), one can enhance the `rstconv` program so it can generate other types of files as well. GNU `gettext` was chosen because it is available on all platforms, and is already widely used in the `Unix` and free software community. Since the Free Pascal team doesn't want to restrict the use of resource strings, the `.rst` format was chosen to provide a neutral method, not restricted to any tool.

If you use resource strings in your units, and you want people to be able to translate the strings, you must provide the resource string file. Currently, there is no way to extract them from the unit file, though this is in principle possible. It is not required to do this, the program can be compiled without it, but then the translation of the strings isn't possible.

9.3 Updating the string tables

Having compiled a program with resourcestrings is not enough to internationalize your program. At run-time, the program must initialize the string tables with the correct values for the language that the user selected. By default no such initialization is performed. All strings are initialized with their declared values.

The `objpas` unit provides the mechanism to correctly initialize the string tables. There is no need to include this unit in a `uses` clause, since it is automatically loaded when a program or unit is compiled in Delphi or `objfpc` mode. Since this is required to use resource strings, the unit is always loaded when needed.

The resource strings are stored in tables, one per unit, and one for the program, if it contains a `resourcestring` section as well. Each `resourcestring` is stored with its name, hash value, default value, and the current value, all as `AnsiStrings`.

The `objpas` unit offers methods to retrieve the number of `resourcestring` tables, the number of strings per table, and the above information for each string. It also offers a method to set the current value of the strings.

Here are the declarations of all the functions:

```
Function ResourceStringTableCount : Longint;
Function ResourceStringCount(TableIndex : longint) : longint;
Function GetStringResourceStringName(TableIndex,
                                     StringIndex : Longint) : Ansistring;
Function GetStringResourceStringHash(TableIndex,
                                     StringIndex : Longint) : Longint;
Function GetStringResourceStringDefaultValue(TableIndex,
                                             StringIndex : Longint) : AnsiString;
Function GetStringResourceStringCurrentValue(TableIndex,
                                             StringIndex : Longint) : AnsiString;
Function SetResourceStringValue(TableIndex,
                               StringIndex : longint;
                               Value : Ansistring) : Boolean;
Procedure SetResourceStrings (SetFunction : TResourceIterator);
```

Two other function exist, for convenience only:

```
Function Hash(S : AnsiString) : longint;
Procedure ResetResourceTables;
```

Here is a short explanation of what each function does. A more detailed explanation of the functions can be found in the [Reference guide](#).

ResourceStringTableCount returns the number of resource string tables in the program.

ResourceStringCount returns the number of resource string entries in a given table (tables are denoted by a zero-based index).

GetStringResourceStringName returns the name of a resource string in a resource table. This is the name of the unit, a dot (.) and the name of the string constant, all in lowercase. The strings are denoted by index, also zero-based.

GetStringResourceStringHash returns the hash value of a resource string, as calculated by the compiler with the `Hash` function.

GetStringResourceStringDefaultValue returns the default value of a resource string, i.e. the value that appears in the resource string declaration, and that is stored in the binary.

GetResourceStringCurrentValue returns the current value of a resource string, i.e. the value set by the initialization (the default value), or the value set by some previous internationalization routine.

SetResourceStringValue sets the current value of a resource string. This function must be called to initialize all strings.

SetResourceStrings giving this function a callback will cause the callback to be called for all resource strings, one by one, and set the value of the string to the return value of the callback.

Two other functions exist, for convenience only:

Hash can be used to calculate the hash value of a string. The hash value stored in the tables is the result of this function, applied on the default value. That value is calculated at compile time by the compiler.

ResetResourceTables will reset all the resource strings to their default values. It is called by the initialization code of the objpas unit.

Given some Translate function, the following code would initialize all resource strings:

```
Var I,J : Longint;  
    S : AnsiString;  
  
begin  
  For I:=0 to ResourceStringTableCount-1 do  
    For J:=0 to ResourceStringCount(i)-1 do  
      begin  
        S:=Translate(GetResourceStringDefaultValue(I,J));  
        SetResourceStringValue(I,J,S);  
      end;  
    end;  
end;
```

Other methods are of course possible, and the Translate function can be implemented in a variety of ways.

9.4 GNU gettext

The unit **gettext** provides a way to internationalize an application with the GNU **gettext** utilities. This unit is supplied with the Free Component Library (FCL). it can be used as follows:

for a given application, the following steps must be followed:

1. Collect all resource string files and concatenate them together.
2. Invoke the **rstconv** program with the file resulting out of step 1, resulting in a single **.po** file containing all resource strings of the program.
3. Translate the **.po** file of step 2 in all required languages.
4. Run the **msgfmt** formatting program on all the **.po** files, resulting in a set of **.mo** files, which can be distributed with your application.
5. Call the **gettext** unit's **TranslateResourceStrings** method, giving it a template for the location of the **.mo** files, e.g. as in

```
TranslateResourceStrings( 'intl/retest.%s.mo' );
```

the `%s` specifier will be replaced by the contents of the `LANG` environment variable. This call should happen at program startup.

An example program exists in the FCL sources, in the `fcl/tests` directory.

9.5 Caveat

In principle it is possible to translate all resource strings at any time in a running program. However, this change is not communicated to other strings; its change is noticed only when a constant string is being used.

Consider the following example:

```
Const
  help = 'With a little help of a programmer.';

Var
  A : AnsiString;

begin
  { lots of code }

  A:=Help;

  { Again some code }

  TranslateStrings;

  { More code }
```

After the call to `TranslateStrings`, the value of `A` will remain unchanged. This means that the assignment `A:=Help` must be executed again in order for the change to become visible. This is important, especially for GUI programs which have e.g. a menu. In order for the change in resource strings to become visible, the new values must be reloaded by program code into the menus ...

Chapter 10

Optimizations

10.1 Non processor specific

The following sections describe the general optimizations done by the compiler, they are not processor specific. Some of these require some compiler switch override while others are done automatically (those which require a switch will be noted as such).

Constant folding

In Free Pascal, if the operand(s) of an operator are constants, they will be evaluated at compile time.

Example

```
x := 1+2+3+6+5 ;
```

will generate the same code as

```
x := 17 ;
```

Furthermore, if an array index is a constant, the offset will be evaluated at compile time. This means that accessing `MyData[5]` is as efficient as accessing a normal variable.

Finally, calling `Chr`, `Hi`, `Lo`, `Ord`, `Pred`, or `Succ` functions with constant parameters generates no run-time library calls, instead, the values are evaluated at compile time.

Constant merging

Using the same constant string, floating point value or constant set two or more times generates only one copy of that constant.

Short cut evaluation

Evaluation of boolean expression stops as soon as the result is known, which makes code execute faster than if all boolean operands were evaluated.

Constant set inlining

Using the `in` operator is always more efficient than using the equivalent `<>`, `=`, `<=`, `>=`, `<` and `>` operators. This is because range comparisons can be done more easily with `in` than with normal

comparison operators.

Small sets

Sets which contain less than 33 elements can be directly encoded using a 32-bit value, therefore no run-time library calls to evaluate operands on these sets are required; they are directly encoded by the code generator.

Range checking

Assignments of constants to variables are range checked at compile time, which removes the need of the generation of runtime range checking code.

And instead of modulo

When the second operand of a `mod` on an unsigned value is a constant power of 2, an `and` instruction is used instead of an integer division. This generates more efficient code.

Shifts instead of multiply or divide

When one of the operands in a multiplication is a power of two, they are encoded using arithmetic shift instructions, which generates more efficient code.

Similarly, if the divisor in a `div` operation is a power of two, it is encoded using arithmetic shift instructions.

The same is true when accessing array indexes which are powers of two, the address is calculated using arithmetic shifts instead of the multiply instruction.

Automatic alignment

By default all variables larger than a byte are guaranteed to be aligned at least on a word boundary.

Alignment on the stack and in the data section is processor dependant.

Smart linking

This feature removes all unreferenced code in the final executable file, making the executable file much smaller.

Smart linking is switched on with the `-Cx` command-line switch, or using the `{ $SMARTLINK ON }` global directive.

Inline routines

The following runtime library routines are coded directly into the final executable: `Lo`, `Hi`, `High`, `Sizeof`, `TypeOf`, `Length`, `Pred`, `Succ`, `Inc`, `Dec` and `Assigned`.

Stack frame omission

Under specific conditions, the stack frame (entry and exit code for the routine, see section [6.3](#), page 55) will be omitted, and the variable will directly be accessed via the stack pointer.

Conditions for omission of the stack frame:

- The function has no parameters nor local variables.
- Routine is declared with the `assembler` modifier.
- Routine is not a class.

Register variables

When using the `-Or` switch, local variables or parameters which are used very often will be moved to registers for faster access.

10.2 Processor specific

This lists the low-level optimizations performed, on a processor per processor basis.

Intel 80x86 specific

Here follows a listing of the optimizing techniques used in the compiler:

1. When optimizing for a specific Processor (`-Op1`, `-Op2`, `-Op3`, the following is done:
 - In case statements, a check is done whether a jump table or a sequence of conditional jumps should be used for optimal performance.
 - Determines a number of strategies when doing peephole optimization, e.g.: `movzbl (%ebp), %eax` will be changed into `xorl %eax,%eax; movb (%ebp),%al` for Pentium and PentiumMMX.
2. When optimizing for speed (`-OG`, the default) or size (`-Og`), a choice is made between using shorter instructions (for size) such as `enter $4`, or longer instructions `subl $4,%esp` for speed. When smaller size is requested, data is aligned to minimal boundaries. When speed is requested, data is aligned on most efficient boundaries as much as possible.
3. Fast optimizations (`-O1`): activate the peephole optimizer
4. Slower optimizations (`-O2`): also activate the common subexpression elimination (formerly called the "reloading optimizer")
5. Uncertain optimizations (`-Ou`): With this switch, the common subexpression elimination algorithm can be forced into making uncertain optimizations.

Although you can enable uncertain optimizations in most cases, for people who do not understand the following technical explanation, it might be the safest to leave them off.

Remark: If uncertain optimizations are enabled, the CSE algorithm assumes that

- If something is written to a local/global register or a procedure/function parameter, this value doesn't overwrite the value to which a pointer points.
- If something is written to memory pointed to by a pointer variable, this value doesn't overwrite the value of a local/global variable or a procedure/function parameter.

The practical upshot of this is that you cannot use the uncertain optimizations if you both write and read local or global variables directly and through pointers (this includes `Var` parameters, as those are pointers too).

The following example will produce bad code when you switch on uncertain optimizations:

```
Var temp: Longint;

Procedure Foo(Var Bar: Longint);
Begin
  If (Bar = temp)
    Then
      Begin
        Inc(Bar);
        If (Bar <> temp) then Writeln('bug!')
      End
    End;
End;

Begin
  Foo(Temp);
End.
```

The reason it produces bad code is because you access the global variable Temp both through its name Temp and through a pointer, in this case using the Bar variable parameter, which is nothing but a pointer to Temp in the above code.

On the other hand, you can use the uncertain optimizations if you access global/local variables or parameters through pointers, and *only* access them through this pointer¹.

For example:

```
Type TMyRec = Record
      a, b: Longint;
    End;
PMyRec = ^TMyRec;

TMyRecArray = Array [1..100000] of TMyRec;
PMyRecArray = ^TMyRecArray;

Var MyRecArrayPtr: PMyRecArray;
    MyRecPtr: PMyRec;
    Counter: Longint;

Begin
  New(MyRecArrayPtr);
  For Counter := 1 to 100000 Do
    Begin
      MyRecPtr := @MyRecArrayPtr^[Counter];
      MyRecPtr^.a := Counter;
      MyRecPtr^.b := Counter div 2;
    End;
  End.
```

Will produce correct code, because the global variable MyRecArrayPtr is not accessed directly, but only through a pointer (MyRecPtr in this case).

In conclusion, one could say that you can use uncertain optimizations *only* when you know what you're doing.

¹ You can use multiple pointers to point to the same variable as well, that doesn't matter.

Motorola 680x0 specific

Using the `-O2` switch does several optimizations in the code produced, the most notable being:

- Sign extension from byte to long will use `EXTB`
- Returning of functions will use `RTD`
- Range checking will generate no run-time calls
- Multiplication will use the long `MULS` instruction, no runtime library call will be generated
- Division will use the long `DIVS` instruction, no runtime library call will be generated

10.3 Optimization switches

This is where the various optimizing switches and their actions are described, grouped per switch.

-On: with $n = 1..3$: these switches activate the optimizer. A higher level automatically includes all lower levels.

- Level 1 (`-O1`) activates the peephole optimizer (common instruction sequences are replaced by faster equivalents).
- Level 2 (`-O2`) enables the assembler data flow analyzer, which allows the common subexpression elimination procedure to remove unnecessary reloads of registers with values they already contain.
- Level 3 (`-O3`) enables uncertain optimizations. For more info, see `-Ou`.

-OG: This causes the code generator (and optimizer, IF activated), to favor faster, but code-wise larger, instruction sequences (such as `"subl $4, %esp"`) instead of slower, smaller instructions (`"enter $4"`). This is the default setting.

-Og: This one is exactly the reverse of `-OG`, and as such these switches are mutually exclusive: enabling one will disable the other.

-Or: This setting causes the code generator to check which variables are used most, so it can keep those in a register.

-Opn: with $n = 1..3$: Setting the target processor does NOT activate the optimizer. It merely influences the code generator and, if activated, the optimizer:

- During the code generation process, this setting is used to decide whether a jump table or a sequence of successive jumps provides the best performance in a case statement.
- The peephole optimizer takes a number of decisions based on this setting, for example it translates certain complex instructions, such as

```
movzbl (mem), %eax|  
to a combination of simpler instructions  
  
xorl %eax, %eax  
movb (mem), %al  
for the Pentium.
```

-Ou: This enables uncertain optimizations. You cannot use these always, however. The previous section explains when they can be used, and when they cannot be used.

10.4 Tips to get faster code

Here, some general tips for getting better code are presented. They mainly concern coding style.

- Find a better algorithm. No matter how much you and the compiler tweak the code, a quicksort will (almost) always outperform a bubble sort, for example.
- Use variables of the native size of the processor you're writing for. This is currently 32-bit or 64-bit for Free Pascal, so you are best to use `longint` and `cardinal` variables.
- Turn on the optimizer.
- Write your `if/then/else` statements so that the code in the "then"-part gets executed most of the time (improves the rate of successful jump prediction).
- Profile your code (see the `-pg` switch) to find out where the bottlenecks are. If you want, you can rewrite those parts in assembler. You can take the code generated by the compiler as a starting point. When given the `-a` command-line switch, the compiler will not erase the assembler file at the end of the assembly process, so you can study the assembler file.

10.5 Tips to get smaller code

Here are some tips given to get the smallest code possible.

- Find a better algorithm.
- Use the `-Og` compiler switch.
- Regroup global static variables in the same module which have the same size together to minimize the number of alignment directives (which increases the `.bss` and `.data` sections unnecessarily). Internally this is due to the fact that all static data is written to in the assembler file, in the order they are declared in the pascal source code.
- Do not use the `cdecl` modifier, as this generates about 1 additional instruction after each subroutine call.
- Use the smartlinking options for all your units (including the `system` unit).
- Do not use `ansistring`s and exception support, as these require a lot of code overhead.
- Turn off range checking and stack-checking.

Chapter 11

Programming shared libraries

11.1 Introduction

Free Pascal supports the creation of shared libraries on several operating systems. The following table (table (11.1)) indicates which operating systems support the creation of shared libraries.

Table 11.1: Shared library support

Operating systems	Library extension	Library prefix
linux	.so	lib
windows	.dll	<none>
BeOS	.so	lib
FreeBSD	.so	lib
NetBSD	.so	lib

The library prefix column indicates how the names of the libraries are resolved and created. For example, under LINUX, the library name will always have the `lib` prefix when it is created. So if you create a library called `mylib`, under LINUX, this will result in the `libmylib.so`. Furthermore, when importing routines from shared libraries, it is not necessary to give the library prefix or the filename extension.

In the following sections we discuss how to create a library, and how to use these libraries in programs.

11.2 Creating a library

Creation of libraries is supported in any mode of the Free Pascal compiler, but it may be that the arguments or return values differ if the library is compiled in 2 different modes. E.g. if your function expects an `Integer` argument, then the library will expect different integer sizes if you compile it in Delphi mode or in TP mode.

A library can be created just as a program, only it uses the `library` keyword, and it has an `exports` section. The following listing demonstrates a simple library:

Listing: progex/subs.pp

```
{  
  Example library
```

```
}  
library subs;  
  
function SubStr(CString: PChar;FromPos,ToPos: Longint): PChar;  
    cdecl; export;  
  
var  
    Length: Integer;  
  
begin  
    Length := StrLen(CString);  
    SubStr := CString + Length;  
    if (FromPos > 0) and (ToPos >= FromPos) then  
        begin  
            if Length >= FromPos then  
                SubStr := CString + FromPos - 1;  
            if Length > ToPos then  
                CString[ToPos] := #0;  
            end;  
        end;  
  
exports  
    SubStr;  
  
end.
```

The function `SubStr` does not have to be declared in the library file itself. It can also be declared in the interface section of a unit that is used by the library.

Compilation of this source will result in the creation of a library called `libsubs.so` on UNIX systems, or `subs.dll` on WINDOWS or OS/2. The compiler will take care of any additional linking that is required to create a shared library.

The library exports one function: `SubStr`. The case is important. The case as it appears in the `exports` clause is used to export the function.

If you want your library to be called from programs compiled with other compilers, it is important to specify the correct calling convention for the exported functions. Since the generated programs by other compilers do not know about the Free Pascal calling conventions, your functions would be called incorrectly, resulting in a corrupted stack.

On WINDOWS, most libraries use the `stdcall` convention, so it may be better to use that one if your library is to be used on WINDOWS systems. On most UNIX systems, the C calling convention is used, therefore the `cdecl` modifier should be used in that case.

11.3 Using a library in a pascal program

In order to use a function that resides in a library, it is sufficient to declare the function as it exists in the library as an `external` function, with correct arguments and return type. The calling convention used by the function should be declared correctly as well. The compiler will then link the library as specified in the `external` statement to your program¹.

For example, to use the library as defined above from a pascal program, you can use the following pascal program:

Listing: progex/psubs.pp

¹If you omit the library name in the `external` modifier, then you can still tell the compiler to link to that library using the `{ $Linklib }` directive.

```
program testsubs;  
  
function SubStr(const CString: PChar; FromPos, ToPos: longint): PChar;  
    cdecl; external 'subs';  
  
var  
    s: PChar;  
    FromPos, ToPos: Integer;  
begin  
    s := 'Test';  
    FromPos := 2;  
    ToPos := 3;  
    WriteLn(SubStr(s, FromPos, ToPos));  
end.
```

As is shown in the example, you must declare the function as `external`. Here also, it is necessary to specify the correct calling convention (it should always match the convention as used by the function in the library), and to use the correct casing for your declaration. Also notice, that the library importing did not specify the filename extension, nor was the `lib` prefix added.

This program can be compiled without any additional command-switches, and should run just like that, provided the library is placed where the system can find it. For example, on LINUX, this is `/usr/lib` or any directory listed in the `/etc/ld.so.conf` file. On WINDOWS, this can be the program directory, the WINDOWS system directory, or any directory mentioned in the `PATH`.

Using the library in this way links the library to your program at compile time. This means that

1. The library must be present on the system where the program is compiled.
2. The library must be present on the system where the program is executed.
3. Both libraries must be exactly the same.

Or it may simply be that you don't know the name of the function to be called, you just know the arguments it expects.

It is therefore also possible to load the library at run-time, store the function address in a procedural variable, and use this procedural variable to access the function in the library.

The following example demonstrates this technique:

Listing: progex/plsubs.pp

```
program testsubs;  
  
Type  
    TSubStrFunc =  
        function (const CString: PChar; FromPos, ToPos: longint): PChar; cdecl;  
  
Function dlopen(name: pchar; mode: longint): pointer; cdecl; external 'dl';  
Function dlsym(lib: pointer; name: pchar): pointer; cdecl; external 'dl';  
Function dlclose(lib: pointer): longint; cdecl; external 'dl';  
  
var  
    s: PChar;  
    FromPos, ToPos: Integer;  
    lib: pointer;  
    SubStr: TSubStrFunc;  
  
begin
```

```
s := 'Test';
FromPos := 2;
ToPos := 3;
lib:=dlopen('libsubs.so',1);
Pointer(SubStr):=dlsym(lib,'SubStr');
WriteLn(SubStr(s, FromPos, ToPos));
dlclose(lib);
end.
```

As in the case of compile-time linking, the crucial thing in this listing is the declaration of the `TSubStrFunc` type. It should match the declaration of the function you're trying to use. Failure to specify a correct definition will result in a faulty stack or, worse still, may cause your program to crash with an access violation.

11.4 Using a pascal library from a C program

Remark: The examples in this section assume a LINUX system; similar commands as the ones below exist for other operating systems, though.

You can also call a Free Pascal generated library from a C program:

Listing: progex/ctest.c

```
#include <string.h>

extern char* SubStr(const char*, int, int);

int main()
{
    char *s;
    int FromPos, ToPos;

    s = strdup("Test");
    FromPos = 2;
    ToPos = 3;
    printf("Result from SubStr: '%s'\n", SubStr(s, FromPos, ToPos));
    return 0;
}
```

To compile this example, the following command can be used:

```
gcc -o ctest ctest.c -lsubs
```

provided the code is in `ctest.c`.

The library can also be loaded dynamically from C, as shown in the following example:

Listing: progex/ctest2.c

```
#include <dlfcn.h>
#include <string.h>

int main()
{
    void *lib;
    char *s;
    int FromPos, ToPos;
    char* (*SubStr)(const char*, int, int);
```

```
lib = dlopen("./libsubs.so", RTLD_LAZY);
SubStr = dlsym(lib, "SUBSTR");

s = strdup("Test");
FromPos = 2;
ToPos = 3;
printf("Result from SubStr: '%s'\n", (*SubStr)(s, FromPos, ToPos));
dlclose(lib);
return 0;
}
```

This can be compiled using the following command:

```
gcc -o ctest2 ctest2.c -ldl
```

The `-ldl` tells gcc that the program needs the `libdl.so` library to load dynamical libraries.

Chapter 12

Using Windows resources

12.1 The resource directive \$R

Under WINDOWS, you can include resources in your executable or library using the `{ $R filename }` directive. These resources can then be accessed through the standard WINDOWS API calls.

When the compiler encounters a resource directive, it just creates an entry in the unit `.ppu` file; it doesn't link the resource. Only when it creates a library or executable, it looks for all the resource files for which it encountered a directive, and tries to link them in.

The default extension for resource files is `.res`. When the filename has as the first character an asterisk (`*`), the compiler will replace the asterisk with the name of the current unit, library or program.

Remark: This means that the asterisk may only be used after a `unit`, `library` or `program` clause.

12.2 Creating resources

The Free Pascal compiler itself doesn't create any resource files; it just compiles them into the executable. To create resource files, you can use some GUI tools as the Borland resource workshop; but it is also possible to use a WINDOWS resource compiler like GNU `windres`. `windres` comes with the GNU binutils, but the Free Pascal distribution also contains a version which you can use.

The usage of `windres` is straightforward; it reads an input file describing the resources to create and outputs a resource file.

A typical invocation of `windres` would be

```
windres -i mystrings.rc -o mystrings.res
```

this will read the `mystrings.rc` file and output a `mystrings.res` resource file.

A complete overview of the `windres` tools is outside the scope of this document, but here are some things you can use it for:

stringtables that contain lists of strings.

bitmaps which are read from an external file.

icons which are also read from an external file.

Version information which can be viewed with the WINDOWS explorer.

Menus Can be designed as resources and used in your GUI applications.

Arbitrary data Can be included as resources and read with the windows API calls.

Some of these will be described below.

12.3 Using string tables.

String tables can be used to store and retrieve large collections of strings in your application.

A string table looks as follows:

```
STRINGTABLE { 1, "hello World !"
               2, "hello world again !"
               3, "last hello world !" }
```

You can compile this (we assume the file is called `tests.rc`) as follows:

```
windres -i tests.rc -o tests.res
```

And this is the way to retrieve the strings from your program:

```
program tests;
```

```
{ $mode objfpc }
```

```
Uses Windows;
```

```
{ $R *.res }
```

```
Function LoadResourceString (Index : longint): Shortstring;
```

```
begin
```

```
    SetLength(Result, LoadString(FindResource(0, Nil, RT_STRING), Index, @Result[1], SizeOf(Result)))
end;
```

```
Var
```

```
    I: longint;
```

```
begin
```

```
    For i:=1 to 3 do
```

```
        Writeln (Loadresourcestring(I));
```

```
end.
```

The call to `FindResource` searches for the stringtable in the compiled-in resources. The `LoadString` function then reads the string with index `i` out of the table, and puts it in a buffer, which can then be used. Both calls are in the `windows` unit.

12.4 Inserting version information

The win32 API allows to store version information in your binaries. This information can be made visible with the WINDOWS Explorer, by right-clicking on the executable or library, and selecting the 'Properties' menu. In the tab 'Version' the version information will be displayed.

Here is how to insert version information in your binary:

```
1 VERSIONINFO
FILEVERSION 4, 0, 3, 17
PRODUCTVERSION 3, 0, 0, 0
FILEFLAGSMASK 0
FILEOS 0x40000
FILETYPE 1
{
    BLOCK "StringFileInfo"
    {
        BLOCK "040904E4"
        {
            VALUE "CompanyName", "Free Pascal"
            VALUE "FileDescription", "Free Pascal version information extractor"
            VALUE "FileVersion", "1.0"
            VALUE "InternalName", "Showver"
            VALUE "LegalCopyright", "GNU Public License"
            VALUE "OriginalFilename", "showver.pp"
            VALUE "ProductName", "Free Pascal"
            VALUE "ProductVersion", "1.0"
        }
    }
}
```

As you can see, you can insert various kinds of information in the version info block. The keyword `VERSIONINFO` marks the beginning of the version information resource block. The keywords `FILEVERSION`, `PRODUCTVERSION` give the actual file version, while the block `StringFileInfo` gives other information that is displayed in the explorer.

The Free Component Library comes with a unit (`fileinfo`) that allows to extract and view version information in a straightforward and easy manner; the demo program that comes with it (`showver`) shows version information for an arbitrary executable or DLL.

12.5 Inserting an application icon

When WINDOWS shows an executable in the Explorer, it looks for an icon in the executable to show in front of the filename, the application icon.

Inserting an application icon is very easy and can be done as follows

```
AppIcon ICON "filename.ico"
```

This will read the file `filename.ico` and insert it in the resource file.

12.6 Using a pascal preprocessor

Sometimes you want to use symbolic names in your resource file, and use the same names in your program to access the resources. To accomplish this, there exists a preprocessor for `windres` that understands pascal syntax: `fprcp`. This preprocessor is shipped with the Free Pascal distribution.

The idea is that the preprocessor reads a pascal unit that has some symbolic constants defined in it, and replaces symbolic names in the resource file by the values of the constants in the unit:

As an example: consider the following unit:

```
unit myunit;  
  
interface  
  
Const  
    First  = 1;  
    Second = 2;  
    Third  = 3;  
  
Implementation  
end.
```

And the following resource file:

```
#include "myunit.pp"  
  
STRINGTABLE { First, "hello World !"  
             Second, "hello world again !"  
             Third, "last hello world !" }
```

if you invoke windres with the `-preprocessor` option:

```
windres --preprocessor fprcp -i myunit.rc -o myunit.res
```

Then the preprocessor will replace the symbolic names 'first', 'second' and 'third' with their actual values.

In your program, you can then refer to the strings by their symbolic names (the constants) instead of using a numeric index.

Appendix A

Anatomy of a unit file

A.1 Basics

As described in chapter 4, page 45, unit description files (hereafter called PPU files for short), are used to determine if the unit code must be recompiled or not. In other words, the PPU files act as mini-makefiles, which is used to check dependencies of the different code modules, as well as verify if the modules are up to date or not. Furthermore, it contains all public symbols defined for a module.

The general format of the ppu file format is shown in figure (A.1).

To read or write the ppuf file, the ppu unit `ppu.pas` can be used, which has an object called `tppuf` which holds all routines that deal with ppuf handling. While describing the layout of a ppuf, the methods which can be used for it are presented as well.

A unit file consists of basically five or six parts:

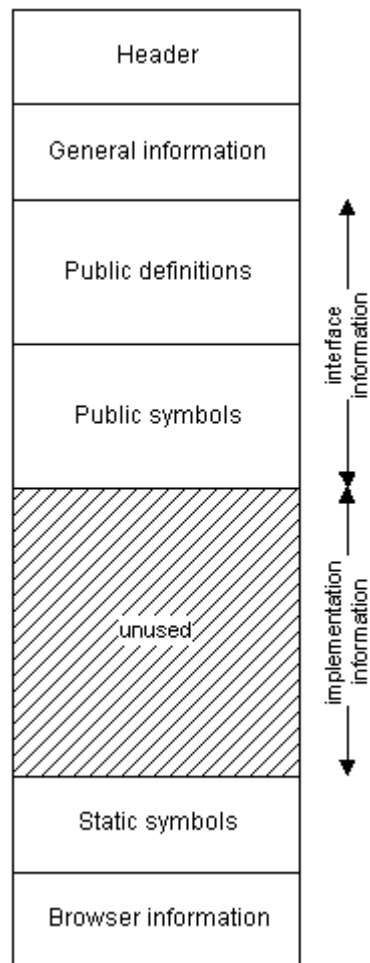
1. A unit header.
2. A general information part (wrongly named interface section in the code)
3. A definition part. Contains all type and procedure definitions.
4. A symbol part. Contains all symbol names and references to their definitions.
5. A browser part. Contains all references from this unit to other units and inside this unit. Only available when the `uf_has_browser` flag is set in the unit flags
6. A file implementation part (currently unused).

A.2 reading ppuf files

We will first create an object `ppuf` which will be used below. We are opening unit `test.ppu` as an example.

```
var
  ppuf : tppuf;
begin
  { Initialize object }
  ppuf:=new(tppuf,init('test.ppu'));
  { open the unit and read the header, returns false when it fails }
```


Figure A.1: The PPU file format



```

if not ppufile.openfile then
    error('error opening unit test.ppu');

{ here we can read the unit }

{ close unit }
ppufile.closefile;
{ release object }
dispose(ppufile,done);
end;

```

Note: When a function fails (for example not enough bytes left in an entry) it sets the `ppufile.error` variable.

A.3 The Header

The header consists of a record (`tppuheader`) containing several pieces of information for recompilation. This is shown in table (A.1). The header is always stored in little-endian format.

Table A.1: PPU Header

offset	size (bytes)	description
00h	3	Magic : 'PPU' in ASCII
03h	3	PPU File format version (e.g : '021' in ASCII)
06h	2	Compiler version used to compile this module (major,minor)
08h	2	Code module target processor
0Ah	2	Code module target operating system
0Ch	4	Flags for PPU file
10h	4	Size of PPU file (without header)
14h	4	CRC-32 of the entire PPU file
18h	4	CRC-32 of partial data of PPU file (public data mostly)
1Ch	8	Reserved

The header is already read by the `ppufile.openfile` command. You can access all fields using `ppufile.header` which holds the current header record.

Table A.2: PPU CPU Field values

value	description
0	unknown
1	Intel 80x86 or compatible
2	Motorola 680x0 or compatible
3	Alpha AXP or compatible
4	PowerPC or compatible

Some of the possible flags in the header, are described in table (A.3). Not all the flags are described, for more information, read the source code of `ppu.pas`.

Table A.3: PPU Header Flag values

Symbolic bit flag name	Description
uf_init	Module has an initialization (either Delphi or TP style) section.
uf_finalize	Module has a finalization section.
uf_big_endian	All the data stored in the chunks is in big-endian format.
uf_has_browser	Unit contains symbol browser information.
uf_smart_linked	The code module has been smartlinked.
uf_static_linked	The code is statically linked.
uf_has_resources	Unit has resource section.

A.4 The sections

Apart from the header section, all the data in the PPU file is separated into data blocks, which permit easily adding additional data blocks, without compromising backward compatibility. This is similar to both Electronic Arts IFF chunk format and Microsoft's RIFF chunk format.

Each 'chunk' (`tppuentry`) has the following format, and can be nested:

Table A.4: chunk data format

offset	size (bytes)	description
00h	1	Block type (nested (2) or main (1))
01h	1	Block identifier
02h	4	Size of this data block
06h+	<variable>	Data for this block

Each main section chunk must end with an end chunk. Nested chunks are used for record, class or object fields.

To read an entry you can simply call `ppufile.readentry:byte`, it returns the `tppuentry.nr` field, which holds the type of the entry. A common way how this works is (example is for the symbols):

```
repeat
  b:=ppufile.readentry;
  case b of
    ib<etc> : begin
      end;
  ibendsyms : break;
  end;
until false;
```

The possible entry types are found in `ppu.pas`, but a short description of the most common ones are shown in table (A.5).

Then you can parse each entry type yourself. `ppufile.readentry` will take care of skipping unread bytes in the entry and reads the next entry correctly! A special function is `skipuntilentry(untilb:byte):boolean;` which will read the ppufile until it finds entry `untilb` in the main entries.

Parsing an entry can be done with `ppufile.getxxx` functions. The available functions are:

```
procedure ppufile.getdata(var b:len:longint);
```

Table A.5: Possible PPU Entry types

Symbolic name	Location	Description
ibmodulename	General	Name of this unit.
ibsourcefiles	General	Name of source files.
ibusedmacros	General	Name and state of macros used.
ibloadunit	General	Modules used by this units.
inlinkunitofiles	General	Object files associated with this unit.
iblinkunitstaticlibs	General	Static libraries associated with this unit.
iblinkunitsharedlibs	General	Shared libraries associated with this unit.
ibendinterface	General	End of General information section.
ibstartdefs	Interface	Start of definitions.
ibenddefs	Interface	End of definitions.
ibstartsyms	Interface	Start of symbol data.
ibendsyms	Interface	End of symbol data.
ibendimplementation	Implementation	End of implementation data.
ibendbrowser	Browser	End of browser section.
ibend	General	End of Unit file.

```
function getbyte:byte;  
function getword:word;  
function getlongint:longint;  
function getreal:ppureal;  
function getstring:string;
```

To check if you're at the end of an entry you can use the following function:

```
function EndOfEntry:boolean;
```

notes:

1. `ppureal` is the best real that exists for the cpu where the unit is created for. Currently it is extended for i386 and single for m68k.
2. the `ibobjectdef` and `ibrecorddef` have stored a definition and symbol section for themselves. So you'll need a recursive call. See `ppudump.pp` for a correct implementation.

A complete list of entries and what their fields contain can be found in `ppudump.pp`.

A.5 Creating ppufiles

Creating a new ppufile works almost the same as reading one. First you need to init the object and call create:

```
ppufile:=new(pppufile,init('output.ppu'));  
ppufile.createfile;
```

After that you can simply write all needed entries. You'll have to take care that you write at least the basic entries for the sections:

```
ibendinterface
ibenddefs
ibendsyms
ibendbrowser (only when you've set uf_has_browser!)
ibendimplementation
ibend
```

Writing an entry is a little different than reading it. You need to first put everything in the entry with `ppufile.putxxx`:

```
procedure putdata(var b:len:longint);
procedure putbyte(b:byte);
procedure putword(w:word);
procedure putlongint(l:longint);
procedure putreal(d:ppureal);
procedure putstring(s:string);
```

After putting all the things in the entry you need to call `ppufile.writeentry(ibnr:byte)` where `ibnr` is the entry number you're writing.

At the end of the file you need to call `ppufile.writeheader` to write the new header to the file. This takes automatically care of the new size of the `ppufile`. When that is also done you can call `ppufile.closefile` and dispose the object.

Extra functions/variables available for writing are:

```
ppufile.NewHeader;
ppufile.NewEntry;
```

This will give you a clean header or entry. Normally this is called automatically in `ppufile.writeentry`, so there should be no need to call these methods.

```
ppufile.flush;
```

to flush the current buffers to the disk

```
ppufile.do_crc:boolean;
```

set to false if you don't want that the crc is updated, this is necessary if you write for example the browser data.

Appendix B

Compiler and RTL source tree structure

B.1 The compiler source tree

All compiler source files are in several directories, normally the non-processor specific parts are in `source/compiler`. Subdirectories are present for each of the supported processors and target operating systems.

For more informations about the structure of the compiler have a look at the Compiler Manual which contains also some informations about compiler internals.

The `compiler` directory also contains a subdirectory `utils`, which contains mainly the utilities for creation and maintainance of the message files.

B.2 The RTL source tree

The RTL source tree is divided in many subdirectories, but is very structured and easy to understand. It mainly consists of three parts:

1. A OS-dependent directory. This contains the files that are different for each operating system. When compiling the RTL, you should do it here. The following directories exist:
 - `atari` for the ATARI.
 - `amiga` for the AMIGA.
 - `beos` for BEOS. It has one subdirectory for each of the supported processors.
 - `freebsd` for the FREEBSD platform.
 - `go32v1` For DOS, using the GO32v1 extender. Not maintained any more.
 - `go32v2` For DOS, using the GO32v2 extender.
 - `linux` for LINUX platforms. It has one subdirectory for each of the supported processors.
 - `netbsd` for NETBSD platforms. It has one subdirectory for each of the supported processors.
 - `palms` for the PALMOS Dragonball processor based platform.
 - `os2` for OS/2.

- `sunos` for the SOLARIS platform. It has one subdirectory for each of the supported processors.
 - `qnx` for the QNX REALTIME PLATFORM.
 - `win32` for Win32 platforms.
 - `posix` for posix interfaces (used for easier porting).
 - `unix` for unix common interfaces (used for easier porting).
2. A processor dependent directory. This contains files that are system independent, but processor dependent. It contains mostly optimized routines for a specific processor. The following directories exist:
 - `i386` for the Intel 80x86 series of processors.
 - `m68k` for the Motorola 680x0 series of processors.
 3. An OS-independent and Processor independent directory: `inc`. This contains complete units, and include files containing interface parts of units as well as generic versions of processor specific routines.

Appendix C

Compiler limits

Although many of the restrictions imposed by the MS-DOS system are removed by use of an extender, or use of another operating system, there still are some limitations to the compiler:

1. Procedure or Function definitions can be nested to a level of 32.
2. Maximally 255 units can be used in a program when using the real-mode compiler (i.e. a binary that was compiled by Borland Pascal). When using the 32-bit compiler, the limit is set to 1024. You can change this by redefining the `maxunits` constant in the `files.pas` compiler source file.

Appendix D

Compiler modes

Here we list the exact effect of the different compiler modes. They can be set with the `$Mode` switch, or by command line switches.

D.1 FPC mode

This mode is selected by the `$MODE FPC` switch. On the command-line, this means that you use none of the other compatibility mode switches. It is the default mode of the compiler. This means essentially:

1. You must use the address operator to assign procedural variables.
2. A forward declaration must be repeated exactly the same by the implementation of a function/procedure. In particular, you can not omit the parameters when implementing the function or procedure.
3. Overloading of functions is allowed.
4. Nested comments are allowed.
5. The `Objpas` unit is NOT loaded.
6. You can use the `cvar` type.
7. `PChars` are converted to strings automatically.

D.2 TP mode

This mode is selected by the `$MODE TP` switch. On the command-line, this mode is selected by the `-So` switch.

1. Enumeration sizes default to a storage size of 1 byte if there are less than 257 elements.
2. You cannot use the address operator to assign procedural variables.
3. A forward declaration must not be repeated exactly the same by the implementation of a function/procedure. In particular, you can omit the parameters when implementing the function or procedure.

4. Overloading of functions is not allowed.
5. The Objpas unit is NOT loaded.
6. Nested comments are not allowed.
7. You can not use the cvar type.

D.3 Delphi mode

This mode is selected by the `$MODE DELPHI` switch. On the command-line, this mode is selected by the `-Sd` switch.

1. You can not use the address operator to assign procedural variables.
2. A forward declaration must not be repeated exactly the same by the implementation of a function/procedure. In particular, you not omit the parameters when implementing the function or procedure.
3. Overloading of functions is not allowed.
4. Nested comments are not allowed.
5. The Objpas unit is loaded right after the `system` unit. One of the consequences of this is that the type `Integer` is redefined as `Longint`.

D.4 GPC mode

This mode is selected by the `$MODE GPC` switch. On the command-line, this mode is selected by the `-Sp` switch.

1. You must use the address operator to assign procedural variables.
2. A forward declaration must not be repeated exactly the same by the implementation of a function/procedure. In particular, you can omit the parameters when implementing the function or procedure.
3. Overloading of functions is not allowed.
4. The Objpas unit is NOT loaded.
5. Nested comments are not allowed.
6. You can not use the cvar type.

D.5 OBJFPC mode

This mode is selected by the `$MODE OBJFPC` switch. On the command-line, this mode is selected by the `-S2` switch.

1. You must use the address operator to assign procedural variables.
2. A forward declaration must be repeated exactly the same by the implementation of a function/procedure. In particular, you can not omit the parameters when implementing the function or procedure.

3. Overloading of functions is allowed.
4. Nested comments are allowed.
5. The Objpas unit is loaded right after the **system** unit. One of the consequences of this is that the type `Integer` is redefined as `Longint`.
6. You can use the `cvar` type.
7. `PChars` are converted to strings automatically.

Appendix E

Using fpcmake

E.1 Introduction

Free Pascal comes with a special makefile tool, **fpcmake**, which can be used to construct a **Makefile** for use with GNU **make**. All sources from the Free Pascal team are compiled with this system.

fpcmake uses a file **Makefile.fpc** and constructs a file **Makefile** from it, based on the settings in **Makefile.fpc**.

The following sections explain what settings can be set in **Makefile.fpc**, what variables are set by **fpcmake**, what variables it expects to be set, and what targets it defines. After that, some settings in the resulting **Makefile** are explained.

E.2 Functionality

fpcmake generates a makefile, suitable for GNU **make**, which can be used to

1. Compile units and programs, fit for testing or for final distribution.
2. Compile example units and programs separately.
3. Install compiled units and programs in standard locations.
4. Make archives for distribution of the generated programs and units.
5. Clean up after compilation and tests.

fpcmake knows how the Free Pascal compiler operates, which command line options it uses, how it searches for files and so on; It uses this knowledge to construct sensible command-lines.

Specifically, it constructs the following targets in the final makefile:

all Makes all units and programs.

debug Makes all units and programs with debug info included.

smart Makes all units and programs in smartlinked version.

examples Makes all example units and programs.

shared Makes all units and programs in shared library version (currently disabled)

install Installs all units and programs.

sourceinstall Installs the sources to the Free Pascal source tree.

exampleinstall Installs any example programs and units.

distinstall Installs all units and programs, as well as example units and programs.

zipinstall Makes an archive of the programs and units which can be used to install them on another location, i.e. it makes an archive that can be used to distribute the units and programs.

zipsourceinstall Makes an archive of the program and unit sources which can be used to distribute the sources.

zipexampleinstall Makes an archive of the example programs and units which can be used to install them on another location, i.e. it makes an archive that can be used to distribute the example units and programs.

zipdistinstall Makes an archive of both the normal as well as the example programs and units. This archive can be used to install them on another location, i.e. it makes an archive that can be used to distribute.

clean Cleans all files that are produced by a compilation.

distclean Cleans all files that are produced by a compilation, as well as any archives, examples or files left by examples.

cleanall Same as clean.

info Produces some information on the screen about used programs, file and directory locations, where things will go when installing and so on.

Each of these targets can be highly configured, or even totally overridden by the configuration file `Makefile.fpc`

E.3 Usage

`fpcmake` reads a `Makefile.fpc` and converts it to a `Makefile` suitable for reading by GNU `make` to compile your projects. It is similar in functionality to GNU `configure` or `lmake` for making X projects.

`fpcmake` accepts filenames of makefile description files as its command-line arguments. For each of these files it will create a `Makefile` in the same directory where the file is located, overwriting any existing file with that name.

If no options are given, it just attempts to read the file `Makefile.fpc` in the current directory and tries to construct a `Makefile` from it if the `-m` option is given. Any previously existing `Makefile` will be erased.

if the `-p` option is given, instead of a `Makefile`, a `Package.fpc` is generated. A `Package.fpc` file describes the package and its dependencies on other packages.

Additionally, the following command-line options are recognized:

-p A `Package.fpc` file is generated.

-w A `Makefile` is generated.

-T targets Support only specified target systems. `Targets` is a comma-separated list of targets. Only rule for the specified targets will be written.

- v** Be more verbose.
- q** be quiet.
- h** Writes a small help message to the screen.

E.4 Format of the configuration file

This section describes the rules that can be present in the file that is fed to `fpcmake`.

The file `Makefile.fpc` is a plain ASCII file that contains a number of pre-defined sections as in a WINDOWS .ini-file, or a Samba configuration file.

They look more or less as follows:

```
[package]
name=mysql
version=1.0.5

[target]
units=mysql_com mysql_version mysql
examples=testdb

[require]
libc=y

[install]
fpcpackage=y

[default]
fpkdir=../..
```

The following sections are recognized (in alphabetical order):

clean

Specifies rules for cleaning the directory of units and programs. The following entries are recognized:

units names of all units that should be removed when cleaning. Don't specify extensions, the make-file will append these by itself.

files names of files that should be removed. Specify full filenames.

compiler

In this section values for various compiler options can be specified, such as the location of several directories and search paths.

The following general keywords are recognised:

options The value of this key will be passed on to the compiler as options.

version If a specific or minimum compiler version is needed to compile the units or programs, then this version should be specified here.

The following keys can be used to control the location of the various directories used by the compiler:

unitdir A colon-separated list of directories that must be added to the unit search path of the compiler.

librarydir A colon-separated list of directories that must be added to the library search path of the compiler.

objectdir A colon-separated list of directories that must be added to the object file search path of the compiler.

targetdir Specifies the directory where the compiled programs should go.

sourcedir A space separated list of directories where sources can reside. This will be used for the `vpath` setting of GNU `make`.

unittargetdir Specifies the directory where the compiled units should go.

includedir A colon-separated list of directories that must be added to the include file search path of the compiler.

sourcedir

Default

The `default` section contains some default settings. The following keywords are recognized:

cpu Specifies the default target processor for which the `Makefile` should compile the units and programs. By default this is determined from the default compiler processor.

dir Specifies any subdirectories that make should also descend in and make the specified target there as well.

fpcdir Specifies the directory where all the Free Pascal source trees reside. Below this directory the `Makefile` expects to find the `rtl`, `fcl` and `packages` directory trees.

rule Specifies the default rule to execute. `fpcmake` will make sure that this rule is executed if `make` is executed without arguments, i.e., without an explicit target.

target Specifies the default operating system target for which the `Makefile` should compile the units and programs. By default this is determined from the default compiler target.

Dist

The `Dist` section controls the generation of a distribution package. A distribution package is a set of archive files (zip files or tar files on unix systems) that can be used to distribute the package.

The following keys can be placed in this section:

destdir Specifies the directory where the generated zip files should be placed.

zipname Name of the archive file to be created. If no `zipname` is specified, this defaults to the package name.

ziptarget This is the target that should be executed before the archive file is made. This defaults to `install`.

Install

Contains instructions for installation of the compiler units and programs. The following keywords are recognized:

basedir The directory that is used as the base directory for the installation of units. Default this is `prefix` appended with `/lib/fpc/FPC_VERSION` for LINUX or simply the `prefix` on other platforms.

datadir Directory where data files will be installed, i.e. the files specified with the `Files` keyword.

fpcpackage A boolean key. If this key is specified and equals `y`, the files will be installed as a fpc package under the Free Pascal units directory, i.e. under a separate directory. The directory will be named with the name specified in the `package` section.

files extra data files to be installed in the directory specified with the `datadir` key.

prefix is the directory below which all installs are done. This corresponds to the `-prefix` argument to GNU `configure`. It is used for the installation of programs and units. By default, this is `/usr` on LINUX, and `/pp` on all other platforms.

units extra units that should be installed, and which are not part of the unit targets. The units in the `units` target will be installed automatically.

Units will be installed in the subdirectory `units/$(OS_TARGET)` of the `dirbase` entry.

Package

If a package (i.e. a collection of units that work together) is being compiled, then this section is used to keep package information. The following information can be stored:

name The name of the package. When installing it under the package directory, this name will be used to create a directory (unless it is overridden by one of the installation options)

version The version of this package.

main If the package is part of another package, this key can be specified to indicate which package it is part of.

Prerules

Anything that is in this section will be inserted as-is in the makefile *before* the makefile target rules that are generated by `fpcmake`. This means that any variables that are normally defined by `fpcmake` rules should not be used in this section.

Requires

This section is used to indicate dependency on external packages (i.e units) or tools. The following keywords can be used:

fpcmake Minimal version of `fpcmake` that this `makefile.fpc` needs.

packages Other packages that should be compiled before this package can be compiled. Note that this will also add all packages these packages depend on to the dependencies of this package. By default, the Free Pascal Run-Time Library is added to this list.

libc a boolean value that indicates whether this package needs the C library.

nortl a boolean that prevents the addition of the Free Pascal Run-Time Library to the required packages.

unitdir These directories will be added to the units search path of the compiler.

packagedir List of package directories. The packages in these directories will be made as well before making the current package.

tools A list of executables of extra tools that are required. The full path to these tools will be defined in the makefile as a variable with the same name as the tool name, only in uppercase. For example, the following definition:

```
tools=upx
```

will lead to the definition of a variable with the name `UPX` which will contain the full path to the `upx` executable.

Rules

In this section dependency rules for the units and any other needed targets can be inserted. It will be included at the end of the generated makefile. Targets or 'default rules' that are defined by `fpcmake` can be inserted here; if they are not present, then `fpcmake` will generate a rule that will call the generic `fpc_` version. For a list of standard targets that will be defined by `fpcmake`, see section [E.2](#), page [115](#).

For example, it is possible to define a target `all`:. If it is not defined, then `fpcmake` will generate one which simply calls `fpc_all`:

```
all: fpc_all
```

The `fpc_all` rule will make all targets as defined in the `Target` section.

Target

This is the most important section of the `makefile.fpc` file. Here the files are defined which should be compiled when the 'all' target is executed.

The following keywords can be used there:

dirs A space separated list of directories where make should also be run.

examplesdirs A space separated list of directories with example programs. The examples target will descend in this list of directories as well.

examples A space separated list of example programs that need to be compiled when the user asks to compile the examples. Do not specify an extension, the extension will be appended.

loaders A space separated list of names of assembler files that must be assembled. Don't specify the extension, the extension will be appended.

programs A space separated list of program names that need to be compiled. Do not specify an extension, the extension will be appended.

rsts a list of `rst` files that needs to be converted to `.po` files for use with GNU `gettext` and internationalization routines.

units A space separated list of unit names that need to be compiled. Do not specify an extension, just the name of the unit as it would appear un a `uses` clause is sufficient.

E.5 Programs needed to use the generated makefile

At least the following programs are needed by the generated Makefile to function correctly:

cp a copy program.

date a program that prints the date.

install a program to install files.

make the make program, obviously.

pwd a program that prints the current working directory.

rm a program to delete files.

zip the zip archiver program. (on dos/windows/OS2 systems only)

tar the tar archiver program (on Unix systems only).

These are standard programs on LINUX systems, with the possible exception of **make**. For DOS or WINDOWS NT, they can be found in the file **makeutil.zip** on the Free Pascal FTP site.

The following programs are optionally needed if you use some special targets. Which ones you need are controlled by the settings in the **tools** section.

cmp a DOS and WINDOWS NT file comparer.

diff a file comparer.

ppdep the ppdep dependency lister. Distributed with Free Pascal.

ppufiles the ppufiles unit file dependency lister. Distributed with Free Pascal.

ppumove the Free Pascal unit mover.

sed the sed program.

upx the UPX executable packer.

All of these can also be found on the Free Pascal FTP site for DOS and WINDOWS NT. **ppdep**, **ppufiles** and **ppumove** are distributed with the Free Pascal compiler.

E.6 Variables that affect the generated makefile

The makefile generated by **fpcmake** contains a lot of variables. Some of them are set in the makefile itself, others can be set and are taken into account when set.

These variables can be split in two groups:

- Directory variables.
- Compiler command-line variables.

Each group will be discussed separately.

Directory variables

The first set of variables controls the directories that are recognised in the makefile. They should not be set in the `Makefile.fpc` file, but can be specified on the commandline.

INCDIR this is a list of directories, separated by spaces, that will be added as include directories to the compiler command-line. Each directory in the list is prepended with `-I` and added to the compiler options.

UNITDIR this is a list of directories, separated by spaces, that will be added as unit search directories to the compiler command-line. Each directory in the list is prepended with `-Fu` and added to the compiler options.

LIBDIR is a list of library paths, separated by spaces. Each directory in the list is prepended with `-Fl` and added to the compiler options.

OBJDIR is a list of object file directories, separated by spaces, that is added to the object files path, i.e. Each directory in the list is prepended with `-Fo`.

Compiler command-line variables

The following variable can be set on the `make` command-line, they will be recognised and integrated in the compiler command-line options.:

CREATESMART If this variable is defined, it tells the compiler to create smartlinked units. Adds `-CX` to the command-line options.

DEBUG If defined, this will cause the compiler to include debug information in the generated units and programs. It adds `-gl` to the compiler command-line, and will define the `DEBUG` define.

LINKSMART Defining this variable tells the compiler to use smartlinking. It adds `-XX` to the compiler command-line options.

OPT Any options that you want to pass to the compiler. The contents of `OPT` is simply added to the compiler command-line.

OPTDEF Are optional defines, added to the command-line of the compiler. They get `-d` prepended to them.

OPTIMIZE if this variable is defined, this will add `-OG2p3` to the command-line options.

RELEASE if this variable is defined, this will add the `-xs -OG2p3 -n` options to the command-line options, and will define the `RELEASE` define.

STRIP if this variable is defined, this will add the `-xs` option to the command-line options.

VERBOSE if this variable is defined, then `-vnrwi` will be added to the command-line options.

E.7 Variables set by fpcmake

The makefile generated by `fpcmake` contains a lot of makefile variables. `fpcmake` will write all of the keys in the `makefile.fpc` as makefile variables in the form `SECTION_KEYNAME`. This means that the following section:

```
[package]
name=mysql
version=1.0.5
```

will result in the following variable definitions:

```
override PACKAGE_NAME=mysql
override PACKAGE_VERSION=1.0.5
```

Most targets and rules are constructed using these variables. They will be listed below, together with other variables that are defined by `fpcmake`.

The following sets of variables are defined:

- Directory variables.
- Program names.
- File extensions.
- Target files.

Each of these sets is discussed in the subsequent:

Directory variables

The following compiler directories are defined by the makefile:

BASEDIR is set to the current directory if the `pwd` command is available. If not, it is set to `'.'`.

COMPILER_INCDIR is a space-separated list of library paths. Each directory in the list is prepended with `-F1` and added to the compiler options. Set by the `incdir` keyword in the `Compiler` section.

COMPILER_LIBDIR is a space-separated list of library paths. Each directory in the list is prepended with `-F1` and added to the compiler options. Set by the `libdir` keyword in the `Compiler` section.

COMPILER_OBJDIR is a list of object file directories, separated by spaces. Each directory in the list is prepended with `-Fo` and added to the compiler options. Set by the `objdir` keyword in the `Compiler` section.

COMPILER_TARGETDIR This directory is added as the output directory of the compiler, where all units and executables are written, i.e. it gets `-FE` prepended. It is set by the `targetdir` keyword in the `Compiler` section.

COMPILER_TARGETUNITDIR If set, this directory is added as the output directory of the compiler, where all units and executables are written, i.e. it gets `-FU` prepended. It is set by the `targetdir` keyword in the `Dirs` section.

COMPILER_UNITDIR is a list of unit directories, separated by spaces. Each directory in the list is prepended with `-Fu` and is added to the compiler options. Set by the `unitdir` keyword in the `Compiler` section.

GCCLIBDIR (LINUX only) is set to the directory where `libgcc.a` is. If `needgcclib` is set to `True` in the `Libs` section, then this directory is added to the compiler commandline with `-F1`.

OTHERLIBDIR is a space-separated list of library paths. Each directory in the list is prepended with `-F1` and added to the compiler options. If it is not defined on linux, then the contents of the `/etc/ld.so.conf` file is added.

The following directories are used for installs:

INSTALL_BASEDIR is the base for all directories where units are installed. By default, On LINUX, this is set to `$(INSTALL_PREFIX)/lib/fpc/$(RELEASEVER)`. On other systems, it is set to `$(PREFIXINSTALLDIR)`. You can also set it with the `basedir` variable in the `Install` section.

INSTALL_BINDIR is set to `$(INSTALL_BASEDIR)/bin` on LINUX, and `$(INSTALL_BASEDIR)/bin/$(OS_TARGET)` on other systems. This is the place where binaries are installed.

INSTALL_DATADIR The directory where data files are installed. Set by the `Data` key in the `Install` section.

INSTALL_LIBDIR is set to `$(INSTALL_PREFIX)/lib` on LINUX, and `$(INSTALL_UNITDIR)` on other systems.

INSTALL_PREFIX is set to `/usr/local` on LINUX, `/pp` on DOS or WINDOWS NT. Set by the `prefix` keyword in the `Install` section.

INSTALL_UNITDIR is where units will be installed. This is set to `$(INSTALL_BASEDIR)/units/$(OS_TARGET)`. If the units are compiled as a package, `$(PACKAGE_NAME)` is added to the directory.

Target variables

The second set of variables controls the targets that are constructed by the makefile. They are created by `fpcmake`, so you can use them in your rules, but you shouldn't assign values to them yourself.

TARGET_DIRS This is the list of directories that make will descend into when compiling. Set by the `Dirs` key in the `Target` section?

TARGET_EXAMPLES The list of examples programs that must be compiled. Set by the `examples` key in the `Target` section.

TARGET_EXAMPLEDIRS the list of directories that make will descend into when compiling examples. Set by the `exampledirs` key in the `Target` section.

TARGET_LOADERS is a list of space-separated names that identify loaders to be compiled. This is mainly used in the compiler's RTL sources. It is set by the `loaders` keyword in the `Targets` section.

TARGET_PROGRAMS This is a list of executable names that will be compiled. the makefile appends `$(EXEEXT)` to these names. It is set by the `programs` keyword in the `Target` section.

TARGET_UNITS This is a list of unit names that will be compiled. The makefile appends `$(PPUEXT)` to each of these names to form the unit file name. The sourcename is formed by adding `$(PASEXT)`. It is set by the `units` keyword in the `Target` section.

ZIPNAME is the name of the archive that will be created by the makefile. It is set by the `zipname` keyword in the `Zip` section.

ZIPTARGET is the target that is built before the archive is made. this target is built first. If successful, the zip archive will be made. It is set by the `ziptarget` keyword in the `Zip` section.

Compiler command-line variables

The following variables control the compiler command-line:

CPU_SOURCE the target CPU type is added as a define to the compiler command line. This is determined by the Makefile itself.

CPU_TARGET the target CPU type is added as a define to the compiler command line. This is determined by the Makefile itself.

OS_SOURCE What platform the makefile is used on. Detected automatically.

OS_TARGET What platform will be compiled for. Added to the compiler command-line with a `-T` prepended.

Program names

The following variables are program names, used in makefile targets.

AS The assembler. Default set to `as`.

COPY a file copy program. Default set to `cp -fp`.

COPYTREE a directory tree copy program. Default set to `cp -frp`.

CMP a program to compare files. Default set to `cmp`.

DEL a file removal program. Default set to `rm -f`.

DELTREE a directory removal program. Default set to `rm -rf`.

DATE a program to display the date.

DIFF a program to produce diff files.

ECHO an echo program.

FPC the Free Pascal compiler executable. Default set to `ppc386.exe`

INSTALL a program to install files. Default set to `install -m 644` on LINUX.

INSTALLEXE a program to install executable files. Default set to `install -m 755` on LINUX.

LD The linker. Default set to `ld`.

LDCONFIG (LINUX only) the program used to update the loader cache.

MKDIR a program to create directories if they don't exist yet. Default set to `install -m 755 -d`

MOVE a file move program. Default set to `mv -f`

PP the Free Pascal compiler executable. Default set to `ppc386.exe`

PPAS the name of the shell script created by the compiler if the `-s` option is specified. This command will be executed after compilation, if the `-s` option was detected among the options.

PPUMOVE the program to move units into one big unit library.

PWD the `pwd` program.

SED a stream-line editor program. Default set to `sed`.

UPX an executable packer to compress your executables into self-extracting compressed executables.

ZIPPROG a zip program to compress files. zip targets are made with this program

File extensions

The following variables denote extensions of files. These variables include the `.` (dot) of the extension. They are appended to object names.

ASMEXT is the extension of assembler files produced by the compiler.

LOADEREXT is the extension of the assembler files that make up the executable startup code.

OEXT is the extension of the object files that the compiler creates.

PACKAGESUFFIX is a suffix that is appended to package names in zip targets. This serves so packages can be made for different OSes.

PPLEXT is the extension of shared library unit files.

PPUEXT is the extension of default units.

RSTEXT is the extension of the `.rst` resource string files.

SHAREDLIBEXT is the extension of shared libraries.

SMARTEXT is the extension of smartlinked unit assembler files.

STATICLIBEXT is the extension of static libraries.

Target files

The following variables are defined to make targets and rules easier:

COMPILER is the complete compiler commandline, with all options added, after all Makefile variables have been examined.

DATESTR contains the date.

UNITPPUFILES a list of unit files that will be made. This is just the list of unit objects, with the correct unit extension appended.

E.8 Rules and targets created by fpcmake

The `makefile.fpc` defines a series of targets, which can be called by your own targets. They have names that resemble default names (such as `'all'`, `'clean'`), only they have `fpc_` prepended.

Pattern rules

The makefile makes the following pattern rules:

units how to make a pascal unit from a pascal source file.

executables how to make an executable from a pascal source file.

object file how to make an object file from an assembler file.

Build rules

The following build targets are defined:

fpc_all target that builds all units and executables as well as loaders. If `DEFAULTUNITS` is defined, executables are excluded from the targets.

fpc_debug the same as `fpc_all`, only with debug information included.

fpc_exes target to make all executables in `EXEOBJECTS`.

fpc_loaders target to make all files in `LOADEROBJECTS`.

fpc_packages target to make all packages that are needed to make the files.

fpc_shared target that makes all units as dynamic libraries.

fpc_smart target that makes all units as smartlinked units.

fpc_units target to make all units in `UNITOBJECTS`.

Cleaning rules

The following cleaning targets are defined:

fpc_clean cleans all files that result when `fpc_all` was made.

fpc_distclean is the same as both previous target commands, but also deletes all object, unit and assembler files that are present.

archiving rules

The following archiving targets are defined:

fpc_zipdistinstall Target to make a distribution install of the package.

fpc_zipinstall Target to make an install zip of the compiled units of the package.

fpc_zipexampleinstall Target to make a zip of the example files.

fpc_zipsourceinstall Target to make a zip of the source files.

The zip is made using the `ZIPEXE` program. Under `LINUX`, a `.tar.gz` file is created.

Installation rules

fpc_distinstall target which calls the `install` and `exampleinstall` targets.

fpc_install target to install the units.

fpc_sourceinstall target to install the sources (in case a distribution is made)

fpc_exampleinstall target to install the examples. (in case a distribution is made)

Informative rules

There is only one target which produces information about the used variables, rules and targets: `fpc_info`.

The following information about the makefile is presented:

- general configuration information: the location of the makefile, the compiler version, target OS, CPU.
- the directories, used by the compiler.
- all directories where files will be installed.
- all objects that will be made.
- all defined tools.

Appendix F

Compiling the compiler

F.1 Introduction

The Free Pascal team releases at intervals a completely prepared package, with compiler and units all ready to use, the so-called releases. After a release, work on the compiler continues, bugs are fixed and features are added. The Free Pascal team doesn't make a new release whenever they change something in the compiler, instead the sources are available for anyone to use and compile. Compiled versions of RTL and compiler are also made daily, and put on the web.

There are, nevertheless, circumstances when the compiler must be recompiled manually. When changes are made to compiler code, or when the compiler is downloaded through CVS.

There are essentially 2 ways of recompiling the compiler: by hand, or using the makefiles. Each of these methods will be discussed.

F.2 Before starting

To compile the compiler easily, it is best to keep the following directory structure (a base directory of `/pp/src` is supposed, but that may be different):

```
/pp/src/Makefile
      /makefile.fpc
      /rtl/linux
          /inc
          /i386
          /...
      /compiler
```

When the makefiles should be used, the above directory tree must be used.

The compiler and rtl source are zipped in such a way that when both are unzipped in the same directory (`/pp/src` in the above) the above directory tree results.

There are 2 ways to start compiling the compiler and RTL. Both ways must be used, depending on the situation. Usually, the RTL must be compiled first, before compiling the compiler, after which the compiler is compiled using the current compiler. In some special cases the compiler must be compiled first, with a previously compiled RTL.

How to decide which should be compiled first? In general, the answer is that the RTL should be compiled first. There are 2 exceptions to this rule:

1. The first case is when some of the internal routines in the RTL have changed, or if new internal routines appeared. Since the OLD compiler doesn't know about these changed internal routines, it will emit function calls that are based on the old compiled RTL, and hence are not correct. Either the result will not link, or the binary will give errors.
2. The second case is when something is added to the RTL that the compiler needs to know about (a new default assembler mechanism, for example).

How to know if one of these things has occurred? There is no way to know, except by mailing the Free Pascal team. When the compiler cannot be recompiled when first compiling the RTL, then try the other way.

F.3 Compiling using make

When compiling with `make` it is necessary to have the above directory structure. Compiling the compiler is achieved with the target `cycle`.

Under normal circumstances, recompiling the compiler is limited to the following instructions (assuming you start in directory `/pp/src`):

```
cd compiler
make cycle
```

This will work only if the `makefile` is installed correctly and if the needed tools are present in the `PATH`. Which tools must be installed can be found in [appendix E](#).

The above instructions will do the following:

1. Using the current compiler, the RTL is compiled in the correct directory, which is determined by the OS. e.g. under `LINUX`, the RTL is compiled in directory `rtl/linux`.
2. The compiler is compiled using the newly compiled RTL. If successful, the newly compiled compiler executable is copied to a temporary executable.
3. Using the temporary executable from the previous step, the RTL is re-compiled.
4. Using the temporary executable and the newly compiled RTL from the last step, the compiler is compiled again.

The last two steps are repeated 3 times, until three passes have been made or until the generated compiler binary is equal to the binary it was compiled with. This process ensures that the compiler binary is correct.

Compiling for another target: When compiling the compiler for another target, it is necessary to specify the `OS_TARGET` makefile variable. It can be set to the following values: `win32`, `go32v2`, `os2` and `linux`. As an example, cross-compilation for the `go32v2` target from the `win32` target is chosen:

```
cd compiler
make cycle OS_TARGET=go32v2
```

This will compile the `go32v2` RTL, and compile a `go32v2` compiler.

When compiling a new compiler and the compiler should be compiled using an existing compiled RTL, the `all` target must be used, and another RTL directory than the default (which is the `../rtl/${OS_TARGET}` directory) must be indicated. For instance, assuming that the compiled RTL units are in `/pp/rtl`, typing

```
cd compiler
make clean
make all UNITDIR=/pp/rtl
```

should use the RTL from the `/pp/rtl` directory.

This will then compile the compiler using the RTL units in `/pp/rtl`. After this has been done, the 'make cycle' can be used, starting with this compiler:

```
make cycle PP=./ppc386
```

This will do the `make cycle` from above, but will start with the compiler that was generated by the `make all` instruction.

In all cases, many options can be passed to `make` to influence the compile process. In general, the makefiles add any needed compiler options to the command-line, so that the RTL and compiler can be compiled. Additional options (e.g. optimization options) can be specified by passing them in `OPT`.

F.4 Compiling by hand

Compiling by hand is difficult and tedious, but can be done. The compilation of RTL and compiler will be treated separately.

Compiling the RTL

To recompile the RTL, so a new compiler can be built, at least the following units must be built, in the order specified:

loaders the program stubs, that are the startup code for each pascal program. These files have the `.as` extension, because they are written in assembler. They must be assembled with the GNU `as` assembler. These stubs are in the OS-dependent directory, except for `LINUX`, where they are in a processor dependent subdirectory of the `LINUX` directory (`i386` or `m68k`).

system the `system` unit. This unit is named differently on different systems:

- Only on `GO32v2`, it's called `system`.
- For `LINUX` it's called `syslinux`.
- For `WINDOWS NT` it's called `syswin32`.
- For `OS/2` it's called `sysos2`

This unit resides in the OS-dependent subdirectories of the RTL.

strings The `strings` unit. This unit resides in the `inc` subdirectory of the RTL.

dos The `dos` unit. It resides in the OS-dependent subdirectory of the RTL. Possibly other units will be compiled as a consequence of trying to compile this unit (e.g. on `LINUX`, the `linux` unit will be compiled, on `go32`, the `go32` unit will be compiled).

objects the `objects` unit. It resides in the `inc` subdirectory of the RTL.

To compile these units on a `i386`, the following statements will do:

```
ppc386 -Tlinux -b- -Fi../inc -Fi../i386 -FE. -di386 -Us -Sg syslinux.pp
ppc386 -Tlinux -b- -Fi../inc -Fi../i386 -FE. -di386 ../inc/strings.pp
ppc386 -Tlinux -b- -Fi../inc -Fi../i386 -FE. -di386 dos.pp
ppc386 -Tlinux -b- -Fi../inc -Fi../i386 -FE. -di386 ../inc/objects.pp
```

These are the minimum command-line options, needed to compile the RTL.

For another processor, the `i386` should be changed into the appropriate processor. For another operating system (target) the `syslinux` should be changed in the appropriate system unit file, and the target OS setting (`-T`) must be set accordingly.

Depending on the target OS there are other units that can be compiled, but which are not strictly needed to recompile the compiler. The following units are available for all platforms:

objpas Needed for Delphi mode. Needs `-S2` as an option. Resides in the `objpas` subdirectory.

sysutils many utility functions, like in Delphi. Resides in the `objpas` directory, and needs `-S2` to compile.

typinfo functions to access RTTI information, like Delphi. Resides in the `objpas` directory.

math math functions like in Delphi. Resides in the `objpas` directory.

mmx extensions for MMX class Intel processors. Resides in in the `i386` directory.

getopts a GNU compatible getopts unit. resides in the `inc` directory.

heaptrc to debug the heap. resides in the `inc` directory.

Compiling the compiler

Compiling the compiler can be done with one statement. It's always best to remove all units from the compiler directory first, so something like

```
rm *.ppu *.o
```

on LINUX, and on DOS

```
del *.ppu
del *.o
```

After this, the compiler can be compiled with the following command-line:

```
ppc386 -Tlinux -Fu../rtl/linux -di386 -dGDB pp.pas
```

So, the minimum options are:

1. The target OS. Can be skipped when compiling for the same target as the compiler which is being used.
2. A path to an RTL. Can be skipped if a correct `fpc.cfg` configuration is on the system. If the compiler should be compiled with the RTL that was compiled first, this should be `../rtl/OS` (replace the OS with the appropriate operating system subdirectory of the RTL).
3. A define with the processor for which the compiler is compiled for. Required.
4. `-dGDB` is not strictly needed, but is better to add since otherwise compiling with debug information will not be possible.

5. `-Sg` is needed, some parts of the compiler use `goto` statements (to be specific: the scanner).

So the absolute minimal command line is

```
ppc386 -di386 -Sg pp.pas
```

Some other command-line options can be used, but the above are the minimum. A list of recognised options can be found in table (F.1).

Table F.1: Possible defines when compiling FPC

Define	does what
USE_RHIDE	Generates errors and warnings in a format recognized by <code>rhide</code> .
TP	Needed to compile the compiler with Turbo or Borland Pascal.
Delphi	Needed to compile the compiler with Delphi from Borland.
GDB	Support of the GNU Debugger.
I386	Generate a compiler for the Intel i386+ processor family.
M68K	Generate a compiler for the M68000 processor family.
USEOVERLAY	Compiles a TP version which uses overlays.
EXTDEBUG	Some extra debug code is executed.
SUPPORT_MMX	only i386: enables the compiler switch <code>MMX</code> which allows the compiler to generate <code>MMX</code> instructions.
EXTERN_MSG	Don't compile the <code>msgfiles</code> in the compiler, always use external messagefiles (default for TP).
NOAG386INT	no Intel Assembler output.
NOAG386NSM	no NASM output.
NOAG386BIN	leaves out the binary writer.

This list may be subject to change, the source file `pp.pas` always contains an up-to-date list.

Appendix G

Compiler defines during compilation

This appendix describes the possible defines when compiling programs using Free Pascal. A brief explanation of the define, and when it is used is also given.

Table G.1: Possible defines when compiling using FPC

Define	description
FPC_LINK_DYNAMIC	Defined when the output will be linked dynamically. This is defined when using the -XD compiler switch.
FPC_LINK_STATIC	Defined when the output will be linked statically. This is the default mode.
FPC_LINK_SHARED	Defined when the output will be smartlinked. This is defined when using the -XX compiler switch.
FPC_PROFILE	Defined when profiling code is added to program. This is defined when using the -pg compiler switch.
FPC	Always defined for Free Pascal.
VER1	Always defined for Free Pascal version 1.x.x.
VER1_0	Always defined for Free Pascal version 1.0.x.
ENDIAN_LITTLE	Defined when the Free Pascal target is a little-endian processor (80x86, Alpha, ARM).
ENDIAN_BIG	Defined when the Free Pascal target is a big-endian processor (680x0, PowerPC, SPARC, MIPS).
FPC_DELPHI	Free Pascal is in Delphi mode, either using compiler switch -Sd or using the \$MODE DELPHI directive.
FPC_OBJFPC	Free Pascal is in Delphi mode, either using compiler switch -S2 or using the \$MODE OBJFPC directive.
FPC_TP	Free Pascal is in Turbo Pascal mode, either using compiler switch -So or using the \$MODE TP directive.
FPC_GPC	Free Pascal is in GNU Pascal mode, either using compiler switch -Sp or using the \$MODE GPC directive.

Remark: The ENDIAN_LITTLE and ENDIAN_BIG defines were added starting from Free Pascal version 1.0.5.

Remark: The UNIX define was added starting from Free Pascal version 1.0.5.

Table G.2: Possible CPU defines when compiling using FPC

Define	When defined?
CPU86	Free Pascal target is an Intel 80x86 or compatible.
CPU87	Free Pascal target is an Intel 80x86 or compatible.
CPU386	Free Pascal target is an Intel 80x86 or compatible.
CPU68k	Free Pascal target is a Motorola 680x0 or compatible.
CPU68	Free Pascal target is a Motorola 680x0 or compatible.
CPUSPARC	Free Pascal target is a SPARC v7 or compatible.
CPUALPHA	Free Pascal target is an Alpha AXP or compatible.
CPUPOWERPC	Free Pascal target is a 32-bit PowerPC or compatible.

Table G.3: Possible defines when compiling using target OS

Target operating system	Defines
linux	LINUX, UNIX
freebsd	FREEBSD, BSD, LINUX, UNIX
netbsd	NETBSD, BSD, LINUX, UNIX
sunos	SUNOS, SOLARIS, UNIX
go32v2	GO32V2, DPMI
os2	OS2
Windows 32-bit	WIN32
Classic Amiga	AMIGA
Atari TOS	ATARI
Classic Macintosh	MAC
PalmOS	PALMOS
BeOS	BEOS, UNIX
QNX RTP	QNX, UNIX

Appendix H

Operating system specific behavior

This appendix describes some special behaviors which vary from operating system to operating system. This is described in table (H.1). The GCC saved registers indicates what registers are saved when certain declaration modifiers are used.

Table H.1: Operating system specific behavior

Operating systems	Min. param. stack align	GCC saved registers
Amiga	2	D2..D7,A2..A5
Atari	2	D2..D7,A2..A5
BeOS-x86	4	ESI, EDI, EBX
DOS	2	ESI, EDI, EBX
FreeBSD	4	ESI, EDI, EBX
linux-m68k		D2..D7,A2..A5
linux-x86	4	ESI, EDI, EBX
MacOS-68k		D2..D7,A2..A5
NetBSD-x86		ESI, EDI, EBX
NetBSD-m68k		D2..D7,A2..A5
OS/2	4	ESI, EDI, EBX
PalmOS	2	D2..D7,A2..A5
QNX-x86		ESI, EDI, EBX
Solaris-x86	4	ESI, EDI, EBX
Win32	4	ESI, EDI, EBX