Pascal implementation

The P5 Compiler

Scott A. Franco

1 Overview of Pascal-P5

This section contains background material on Pascal-P5. If you want to get started using Pascal-P5 now, skip to 2 “Using Pascal-P5”

1.1 Introduction

The Pascal-P series compilers were the original proving compilers for the language Pascal. Created in 1973, Pascal-P was part of a “porting kit” designed to enable the quick implementation of a Pascal language compiler on new machines. It was released by Niklaus Wirth’s students at ETH in Zurich.

The implementation and description of the language Pascal in terms of itself and in terms of a “pseudo machine” were important factors in the propagation of the language Pascal. From the early version of Pascal-P came the CDC 6000 full compiler at Zurich, several independent compilers including an IBM-360 compiler and a PDP-11 compiler, and the UCSD “byte code” interpreter.

The original article for the Pascal-P compiler is at:

http://www.standardpascal.org/The_Pascal_P_Compiler_implementation_notes.pdf

In the name “Pascal-P” the “P” stood for “portable”, and this was what Pascal-P was designed to do. It also stood for an example and reference implementation of Pascal, although Wirth later issued a paper, together with Tony Hoare for the “Axiomatic definition of Pascal”, which was also aimed at exactly specifying the semantics of Pascal.

As the importance of Pascal-P grew, the authors adopted a version number system and working methodology for the system. A new, cleaner and more portable version of the system was created in 1974 with the name Pascal-P2, and left the multiple early versions of the system as termed Pascal-P1.

From the Pascal-P2 revision of the compiler comes many of the original Pascal compilers, including UCSD. In 1976, Wirth’s group made one last series of improvements and termed the results Pascal-P3 and Pascal-P4. Pascal-P3 was a redesigned compiler, but used the same pseudo machine instruction set as Pascal-P2, and thus could be bootstrapped from an existing Pascal-P2 implementation. Pascal-P4 featured a new pseudo instruction set, and thus was a fully redesigned compiler.

Version	Year	Exists	Comments
Pascal-P1	1973	No	first version of Pascal-P compiler. Several different versions.
Pascal-P2	1974	Yes	Unified version of Pascal-P.
Pascal-P3	1976	No	New version Pascal-P backwards compatible with old Pascal-P2 pint.pas
Pascal-P4	1976	Yes	New improved Pascal-P.
Pascal-P5	2009	Yes	ISO 7185 compliant Pascal-P.
Pascal-P6	2020	Yes	Extended version of Pascal-P (Pascaline).

Pascal-P was always an incomplete implementation of the Pascal language (a subset), and was designed to be so. After it was created, the ISO 7185 standard for Pascal was issued, and today Pascal-P4 exists and is still usable with minor changes to bring it into ISO 7185 compliance (as a Pascal source, not in the language it compiles).

Pascal-P4 has it's legacy problem of being a subset compiler of the full language. Further, it is only usable for programs that avoid its weaknesses, such as string storage. Keep in mind that Pascal-P was never designed to be a general purpose system, but rather to compile itself on a new machine – and then rapidly be improved to become a full compiler.

Thus in 2008 I set out to improve the Pascal-P4 code to accept the full language Pascal as stated by the ISO 7185 language standard. The name of the result was obvious: Pascal-P5[1].

And so, 35 years after the original Pascal-P compiler was created, a new version of the series exists.

The Pascal-P compiler series (and it's companion Pascal-S) have been extensively documented in the literature. The book "Pascal implementation: The P4 compiler" by Steve Pemberton and Martin Daniels stands out as a running code commentary on the level of "lion's commentary on Unix". It is just that good. It is also available free on line at:

http://homepages.cwi.nl/~steven/pascal/book/.

Accordingly, for the Pascal-P5 document, I have not attempted to recapitulate the entire Pascal-P4 part of the compiler in this document. I see this document as an incremental explaination of the improvements to Pascal-P4 needed to arrive at Pascal-P5. I could not have completed the Pascal-P5 project without Steve's work. It was Steve's book that convinced me that Pascal-P4 was worth preservation and modernization.

1.2 Why a P5 compiler?

It actually makes more sense to ask "why a Pascal-P4 compiler" than "why a Pascal-P5 compiler". Pascal-P4 was not a full Pascal at all, but rather a subsetted version of the language with several features removed. The omissions and changes were (from the Pascal-P4 web page at http://www.standardpascal.com/p4.html):

- Procedure/function parameters.
- Interprocedural gotos (goto must terminate in the same procedure/function).
- Only files of type "text" can be used, and then only the ones that are predefined by Pascal-P4, which are "input", "output", and two special files defined so that Pascal-P4 can compile itself.
- "mark" and "release" instead of "dispose".
- Curly bracket comments {} are not implemented.
- The predeclared identifiers maxint, text, round, page, dispose, and the functions they represent, are not present.
- The procedures reset, rewrite, pack and unpack are not implemented (they are recognized as valid predefined procedures, but give an 'unimplemented' error on use).
- Undiscriminated variant records.
- Output of boolean types.
- Output of reals in "fixed" format.
- Set constructors using subranges ('0'..'9').

[1] An ISO 7185 version of Pascal-P4 named Pascal-P5 was also proposed in PUG news #15 page 100 attributed to Arthur Sale.

There were several other issues with the Pascal-P4 compiler beyond simply the language it implemented. Pascal-P4 made no attempt to economize on its storage of strings. This meant that each string constant, no matter how long it was, would be stored in a fixed length in the pseudo-machine code. Although the internal string length in the interpreter was a settable constant, an implementor using Pascal-P4 would always be operating between the mutually exclusive goals of having enough string characters to represent usable strings and having the total string storage use too much space.

Every variable in the Pascal-P4 interpreter is given the same space. A character or a boolean used the same space as a floating point value, and an array of characters would be as costly as an array of floating point numbers.

Pascal-P4 itself got around these limitations by using strings and string constants sparingly. This goes to the idea that Pascal-P4 (and the Pascal-P series) was primarily designed to compile itself, and was never designed as a real, working compiler.

When Kenneth Bowles received Pascal-P2 and wanted to use it as an interpreter in and of itself, not as just a stepping stone to a native compiler, his team extensively reworked it to use a byte orientation, and implemented string storage efficiency.

The exact reasons why Pascal-P4 is as it is, of course, belong to it's original authors. It is fair to say that Pascal-P was designed to be a lightweight porting kit for Pascal. The two main concerns were:

- Limiting the required memory for the run of the self compilation.
- Limiting the complexity of the self compilation.

For the first, obviously the Zurich crew was not particularly limited by memory. The CDC 6000 series computers they had access to were state of the art for their day, and after Pascal-P was produced, they extended it to a full native compiler for the CDC 6000 (see http://www.standardpascal.com/CDC6000pascal.html). This implies that a full language version of Pascal-P4 could have been completed. They may have wished to lessen the load on other implementers of the language outside of Zurich.

The second reason is far more concrete. Even a complex program such as a compiler may not use the entire language, simply because the need did not arise. It was, and is, standard practice to implement a subset of a full language for the first compiler version and improve it later.

Finally, it is important to understand that the designers of Pascal-P never intended it to be used as a implementation for it's own sake. A Pascal implementation that simulated, not executed, its output code was interesting to Wirth, but that resulted in the Pascal-S project, a one piece compiler/interpreter program that has also been said to have originated with the Pascal-P project (although you will find little in common between the source code for the two).

Thus, it would never have occurred to the original designers to make Pascal-P an efficient and full implementation of Pascal. It was simply a bridge to better things.

There is certainly less reason to keep Pascal-P as a language subset compiler today. Computers are drowning in memory, and virtual memory operating systems are the rule, not the exception. Further, there are several advantages to having even a compiler porting kit such as P4 process the full language:

- To serve as an example implementation of the language.
- To reduce the total work needed to convert a bootstrapped Pascal-P to the full language.
- To serve as a full language stand-alone interpreter.

Accordingly, such a compiler was created, the "Model implementation of Standard Pascal" [Welsh and Hay] with the advent of the ISO 7185 standard in 1982. This is a very good and complete implementation of Pascal which I can recommend reading. However, it has two significant drawbacks to it's use:

- It was never freely distributed, and the rights to it were closely held.
- It had nothing in common with the Pascal-P project.

Because or in spite of this, the "model implementation" is virtually unobtainable and unknown today. It can only be found in it's increasingly rare book form.

The advantages of having a new version of Pascal-P4 that both processes the full language, and also embodies an efficient interpreter in its own right are:

- It is a fairly reasonable increment in complexity of the original code.
- It starts from an existing and well understood code base.
- The main part of it is already well documented.

The number of lines in the source for Pascal-P4 vs. Pascal-P5 bear this out:

	P4	P5
pcom.pas	4119	6626
pint.pas	1099	3181

177 of the increased line count for the compiler front end, pcom.pas, are due to the error message printing routine that could be removed without ill effect (arriving at the same, numeric only error messages as the original Pascal-P4).

The most radical changes were done in the interpreter, but this still remains a low percentage of the total, since the interpreter is not where the majority of the code in was in Pascal-P.

I have tried to stay within the original style of the code, although at times more than one style is evident in the source (due to the multiple original authors). I have, for example, refrained from reformatting or extensively adding comments to the code.

I admit this was difficult. I don't care for the "compressed" nature of the formatting, nor the general lack of comments. For Pascal style, I both prefer and recommend the style of Henry Ledgard in "Pascal with style: Programming Proverbs". I note that Niklaus Wirth's general style is to present the comments separately from the program code, and thus having this document cover the additions required to the code suits me.

Many people give me suggestions for features to add to Pascal-P5, which I think is great, and certainly you can do that for yourself, as many have. It is true that Pascal-P5 is not really appropriate for a full implementation on a target processor. Indeed all of the practical implementations of the Pascal-P family have included extensions.

1.3 The organization of the Pascal-P compiler

Pascal-P does not feature a machine independent front end. The sizes and characteristics of machine level objects in the interpreter also appear in the front end. The front end uses these sizes to form the layout of things such as local block frames, parameter lists and records.

This is one reason that Pascal-P has been criticized for being a less than ideal basis on which to build a full, machine independent compiler system. If the front end were to be fully machine independent, it would mean a great deal of change to the whole compiler system, and the intermediate would certainly change, since it is currently stated in machine dependent form, using fixed offsets and other machine dependent embedded numbers.

In practice, it is not much trouble to create a set of front and back end modules for any machine. The machine dependent figures are isolated to equates in the top of the program, and these simply need to be changed in both compiler and interpreter equally.

1.4 Pascal-P5 as a practical compiler

Is Pascal-P5 a useable compiler for real applications? I would assert that it is not. The reason is the way it processes files. All of the files it uses must be declared specifically via the program header. For Pascal-P5 to process files from a user program, it must map these files into header files defined by Pascal-P5 itself.

The most obvious files for any program are the **input** and **output** files. Even though Pascal-P5 itself uses these files, both to input the target program, and to output listings and error messages,these are useable by the target program simply because they are separated positionally in the output.

Pascal-P5 defines two more files, **prd** and **prr**. These files are used for reading only and writing only, respectively. Pascal-P5 uses **prd** to input and output the program code for the target. Although these files can be used by the target, again, the input and output is mixed with Pascal-P5's use of the files, and must be done positionally. In fact, this is the technique used to accomplish a self compile and run, where the target program is the Pascal-P5 system itself.

Pascal-P5 could map the header files to arbitrary files, but this would have to be done by non-standard code, since there is no method specified in either the original (J&W) standard, nor in ISO 7185, of mapping header files to external files. It is left as "implementation specific".

All of this matches the original purpose of Pascal-P5, which was simply to serve as a compiler porting platform. It also serves as a demonstration compiler. To make it a practical compiler, it would have to be extended, at least to operate on runtime specified files. The CDC 6000 compiler is effectively a Pascal-P compiler that was extended to be a practical use compiler.

The other way to achieve a practical use Pascal-P5 would be to specify implementation specific characteristics in it, such as external file connections. This would involve creating a Pascal-P5 that is no longer strictly ISO 7185, since it would need to specify how the external file connections are done.

I do think this is valuable. However, I also believe that instead of adding extentions valid for only one implementation of Pascal, it makes more sense to organize the extentions as a whole. This is what the Pascal-P6 project is about, so this work is deferred to Pascal-P6.

1.5 Pascal-P5 as a model compiler

The definition of a model compiler is as an example of how to carry out the actual execution of of the language pascal. Unfortunately, this is one area where the "model implementation of Pascal" [Welsh&Hay] is ahead of Pascal-P5. The problem is that most of the I/O formatting is simply passed on to the underlying compiler, meaning that things like the exact format of input numbers, and the exact format produced by output of numbers, is left to whatever the implementation that Pascal-P5 is run on does.

The way to get around this is to be fairly pedantic about processing input and output, for example reading and parsing a complete input number, with sign, even if the underlying implementation is capable of doing that.

This wasn't done in Pascal-P5, probally to keep the compiler/interpreter simple. It should be done to enhance the Pascal-P implementation's status as a model compiler. Although it can be done as an enhanced version of Pascal-P5.

1.6 Moving on to Pascal-P6

Pascal-P6 was designed to be completely compatible with Pascal-P5. It will take any source code that Pascal-P5 will, and the source code for Pascal-P6 will compile under Pascal-P5. The capabilities of the P6 compiler/interpreter are considerably greater, and you may want to consider using that system instead. The major reason for staying with the Pascal-P5 is that it is oriented only to the ISO 7185 Pascal language, and thus is a smaller compiler.

Pascal-P6 will directly compile programs from Pascal-P5 without any options given that:

- None of the new Pascaline keywords are used.
- Any use of the character '\' in strings are doubled ('\\') due to character escape support in Pascaline.

Alternately, the ISO 7185 standard option can be used with the program (s+).

For more information see the Pascal-P6 documentation.

2 Using Pascal-P5

2.1 Configuring Pascal-P5

Pascal-P5 has a simple configuration script to set up the binary, script files and compiler in use for the system, that uses the proper defaults for your system[2]:

[Windows]

```
> setpath
> configure
> make
```

[Linux/Mac]

```
$ ./setpath
$ ./configure
$ make
```

You can avoid "setpath" by placing the ./bin directory on your path.

The configure script attempts to automatically determine the environment you are running under, choose the correct compiler, bit width of your computer, etc. You can override this by using the options for configure:

[2] The configure system and general file/directory layout is deliberately modeled after GNU standards for the same.

Option	Meaning
--gpc	Selects the GPC compiler.
--ip_pascal	Selects the IP Pascal compiler.
--32	Selects 32 bit mode.
--64	Selects 64 bit mode.
--help	Prints a help menu.

The configure script will take the preconfigured versions of the Pascal-P5 binaries, the script files and other files and install them for the specified compiler. The Pascal-P5 system is configured by default for GPC Pascal running on windows, and can be left as such if desired.

Note that if you have more than one acceptable compiler resident, the configure script will choose the first one found in the order IP Pascal, then GPC Pascal.

2.2 Compiling and running Pascal programs with Pascal-P5

To simply compile a run a program, use the Pascal-P5 batch file:

```
C:\> p5 hello
```

When a pascal program is run this way, it gets it's input from the terminal (you), and prints its results there. The p5 script accommodates the compiler that was used to build the system, and therefore you don’t need to know the exact command format of the executable.

The rules for ISO 7185 Pascal are simple, and you can find a complete overview of the language in the file:

```
iso7185rules.html
```

In the ./doc directory.

You will find the complete standard for the language in the files:

```
iso7185.html     html format
iso7185.pdf      pdf format
```

In the ./doc directory.

If you were expecting Pascal-P5 to look like UCSD Pascal or Borland Pascal, please note you took a wrong turn somewhere. Pascal-P5 is the original Pascal language. The "Pascal" languages processed by UCSD and Borland were heavily modified, and very incompatible variants that that were brought out years after the original.

All files in Pascal-P5 are anonymous (as in “no filename”), and only last the length of the program run. The exceptions to this are the **prd** and **prr** files, which are used by the Pascal-P5 compiler to compile and run itself. You can use them, but you really have to know what you are doing. If you need to read from a file or write to a file use redirection:

```
C:\> p5 test < myinputfile > myoutputfile
```

You will find you can get a lot of tasks done this way.

Note:

Pascal-P5, as was Pascal-P4, was designed to be a Pascal compiler porting tool and model implementation ***first***, and not really as a practical day to day compiler. If you want a compiler/interpreter for that use, you want the Pascal-P6 compiler, which contains things like file access extentions and a lot more.

2.3 Compiler options

Pascal-P5 uses a "compiler comment" to indicate options to the compiler, of the form:

(*$option+/-,...*)

This option can appear anywhere a normal comment can. The first character of the comment MUST be "$". This is followed by any number if option switches separated by ",". If the option end with "+", it means to turn it on. If the option ends with "-", it means turn it off.

Example:

(*$l-*)

Turns the listing of the source code OFF.

The following options are available:

Option	Meaning	Default
t+/-	Print/don't print internal tables after each routine is compiled.	OFF
l+/-	List/don't list the source program during compilation.	ON
d+/-	Add extra code to check array bounds, subranges, etc.	ON
c+/-	Output/don't output intermediate code.	ON
v+/-	Invokes validity checks for tagfield assignments, etc.	ON
r+/-	Checks for unreferenced identifiers.	ON
u+/-	Invokes checks on Undiscriminated variants by forcing the tagfield to exist, and managing assignments to it. Note that this option must appear at the top of the program to have any effect.	ON
x+/-	Dump lexical. Prints all tolkens when they appear.	OFF
z+/-	Dump recycling tracker counts. Shows a report of how many entries were recycled of each kind.	OFF
b+/-	Print goto labels. Prints out all goto labels that appeared in the program, along with their parameters.	OFF
y+/-	Dump the display. Performs a complete diagnostic dump of the display at program end.	OFF
i+/-	Check for VAR block violations. Checks for things like changing tag values with an outstanding VAR reference. Note this is an expensive check.	OFF
o+/-	Arithmetic overflow checks. Checks for things like maxint+1.	ON
e+/-	List intermediate instructions after assembly.	OFF
g+/-	Dump intermediate label definitions.	OFF
a+/-	Dump runtime storage layout.	OFF
f+/-	Trace system routine executions.	OFF

m+/-	Trace intermediate instruction executions.	OFF
j+/-	Do postmortem (after failed execution) dump.	OFF
h+/-	Add source line sets to executed intermediate code (larger intermediate code, but better diagnostics).	ON
k+/-	Trace source line executions. Outputs the number of each source line executed.	OFF
w+/-	Dump heap space. Dumps a report on heap occupation.	OFF
n+/-	Do/do not recycle heap entries. If off, heap entries are not reused.	ON
p+/-	Check free entry reuse. Checks if the heap entry referenced has been freed by dispse(). Automatically turns "n" flag off.	OFF
q+/	Check undefined accesses. Checks if the memory accessed has never been set. Note that this is an expensive check.	ON

2.4 Other operations

Within the Pascal-P5 toolset, you will find a series of scripts to perform common operations using Pascal-P5. This includes building the compiler and interpreter using an existing ISO 7185 compatible compiler, and also testing Pascal-P5.

The scripts used in Pascal-P5 are designed to be independent of what operating system you are running on. The Pascal-P5 system as been successfully run on the following systems:

- Windows
- Ubuntu linux

To enable this to work, there are two kinds of scripts available, one for DOS/Windows command shells, and another for Unix/Bash. These two script files live side by side, because the DOS/Windows scripts use a .bat extension, and Bash scripts use no extentions. Thus, when a script command is specified here, the particular type of script file is selected automatically.

The only exception to this rule is that Unix users commonly do not place the current directory in the path. This means to execute a script file in the current directory, you need to specify the current directory in front of the script. For example:

~/p5$ ./p5 hello

2.5 Reliance on Unix commands in the Pascal-P5 toolset

Most of the scripts in this package, even the DOS/Windows scripts, rely on Unix commands like cp, sed, diff, chmod and others. I needed a reasonable set of support tools that were command line callable, and these are all both standard and reasonable.

For Windows, the MinGW toolset is available:

http://www.mingw.com

Where possible, I have tried to use DOS/Windows commands. The scripts are available in both DOS/Windows and bash versions. I could have just required the use of bash, which is part of the MinGW toolkit, but my aim is not to force Windows users into a Unix environment.

Since all scripts are provided in both Windows/DOS command shell and Unix/Linux Bash shell form, Pascal-P5 can be run as well from a Bash shell provided by MinGW.

2.6 The "flip" command and line endings

Every effort was made to make the Pascal-P5 compile and evaluate system indenpendent of what system it is running on, from Windows command shell, to Linux with Bash shell. One common thing I have found is that several utilities don't appreciate seeing a line ending outside of their "native" line ending, such as CRLF for Windows, and LF for linux. Examples include "diff" (find file differences) and Bash.

Therefore many of the scripts try to remove the line ending conserations, either by ignoring such line endings, or by converting all of the required files to the particular line ending in use.

The key to this is the "flip" utility. After searching for several line ending converters, "flip" was found on the most number of systems, as well as being one of the most clear and reliable utilities (it translates in both directions, it tolerates any mode of line ending as input, will not corrupt binaries, etc.).

Unfortunately, even flip was not found on some systems. The simpliest way to fix this was to include the flip.c program with the distribution, then let you compile to form a binary on your system to replace the utility.

To make the flip utility, you run:

$ make_flip

Then flip will exist in the bin directory.

3 Building the Pascal-P5 system

3.1 The preprocessor system

Pascal-P5 uses cpp, the C preprocessor to build the system. This is run by the scripts pascpp and pascpp.bat. It is run with options to completely ignore what source language it is processing, and so is not C source dependent.

The preprocessor is used to configure several features of Pascal-P5. The define flags are:

Define	Configures
WRDSIZ16	Select 16 bit word size for target machine
WRDSIZ32	Select 32 bit word size for target machine
WRDSIZ64	Select 64 bit word size for target machine
IMM_ERR	Causes error numbers in pcom.pas to be output immediately
SELF_COMPILE	Configures the Pascal-P5 system to be able to compile itself

All of these features are configured in the Makefile created for your system by the configure script.

The effect of running cpp preprocessor against the sources is that any errors in the compile must be examined in the output file of the preprocessor. Otherwise the line numbers and errors will be incorrect, since the original source file is not the one actually being compiled. The result of the preprocessor is stored in the same file as input, but with ".mpp.pas" appended at the end. For the Pascal-P5 source files these are:

Original source file	Output of preprocessor
pcom.pas	pcom.mpp.pas
pint.pas	pint.mpp.pas

3.2 Compiling and running Pascal-P5 with an existing ISO 7185 compiler

You do not need to compile P5 unless you are using an alternative compiler or installation. The current Pascal-P5 has been compiled and run with the following compilers and operating systems:

Compiler	Installations
IP Pascal	Windows
GPC	Windows, Ubuntu, Mac OSx

First, you must have a ISO 7185 Pascal compiler available. There are several such compilers, see:

http://www.standardpascal.org/compiler.html

You will probally need to compile pcom.pas and pint.pas with the ISO 7185 Pascal compatibility mode option on for your compiler. See your documentation for details.

If you are using a compiler or version of a compiler that is not tested to ISO 7185 standards, you will want to make sure that it is ISO 7185 compliant. See "Testing Pascal-P5" section 8 for details on how to test an existing compiler to ISO 7185 standards.

To compile pcom and pint, the components of the Pascal-P5 compiler, use the make utility:

Command	Meaning
make	Make both pcom and pint.
make pcom	Make pcom.
make pint	Make pint.
make clean	Remove all product files (usually to insure a clean remake).
make pcom_immerr	Make pcom with immediate error reporting (used for debug purposes).
make spew	Make the “spew” utility.
make help	Print a help menu of what make can do.

To run the other programs and batch files, you should modify the following files to work with your compiler:

p5[.bat] The single program compile and run batch file.

Compile[.bat] To compile a file with all inputs and outputs specified.

Run[.bat] To run (interpret) the intermediate file with all inputs and outputs specified.

The reason you need to change these files is because pcom.pas uses the header file "prr" to output intermediate code, and pint.pas uses "prd" for input and "prd" for output. You need to find out how to connect these files in the program header to external named files.

For example, in IP Pascal, header files that don't bear a standard system name (like "input" and "output") are simply assigned in order from the command line. Thus, P5.bat is simply:

```
pcom %1.p5 < %1.pas
pint %1.p5 %1.out
```

Where %1 is the first parameter from the command line.

P5.bat lets the input and output from the running program go to the user terminal. Compile.bat and run.bat both specify all of the input, output, prd and prr files. The reason the second files are needed is so that the advanced automated tests can be run using batch files that aren't dependent on what compiler you are using.

If your compiler does nothing with header files at all, you will probally have to change the handling of the prd and prr files to get them connected to external files. To do this, search pcom and pint for "!!!" (three exclamation marks). This will appear in comments just before the declaration, reset and rewrite of these files.

3.3 Evaluating an existing Pascal compiler using Pascal-P5

If you plan to compile and run Pascal-P5 using your compiler, you should evaluate your compiler's ISO 7185 Pascal compliance. Of course, simply compiling pcom.pas and pint.pas is one way to achieve that. But since this package gives you the ability to fully evaluate your compiler, I would suggest you use it.

First, you need to determine if your compiler has a ISO 7185 Pascal compliance option and turn it on if needed. I say "if needed", because some compilers actually change their behavior with the option enabled, and thus it is not possible to compile and run standard Pascal programs unless the option is on (a very unfortunate property of a Pascal implementation).

Within ISO 7185 Pascal, there are two characteristics of an implementation that could cause Pascal-P5 to not compile, even if the implementation otherwise completely complies with the standard:

1. Conflict with extended keywords.
2. Character formats.

The first concerns an implementation that defines a new keyword conflicting with an identifier used in Pascal-P5. For example, if your compiler has an extended keyword "variant", this would cause pcom.pas not to compile: it uses that as an identifier. Ideally, the ISO 7185 Pascal option should turn off such extended keywords, but you may have to invoke another option to do this. Such extended keywords are allowed by the ISO 7185 Pascal standard.

The second is simply that the character set in use is not specified by the ISO 7185 Pascal standard. This is rarely an issue now, because virtually all implementations are based on either ISO 8859-1 (or ASCII), or are based on a character set that contains ISO 8859-1 as a base standard (both ISO 8859 and Unicode do this).

It is also possible that an implementation may define special character formats. For example, the commonly implemented character force sequences are a special format:

```
'this is a string\n'
```

This is valid, since ISO 7185 Pascal does not specify the exact format of strings.

Fortunately, Pascal-P5 does not contain nor need force sequences, so this will not cause problems.

Besides compiling pcom.pas and pint.pas, I strongly recommend you run and check at least ISO7185pat.pas. This is a fairly comprehensive test of ISO 7185 Pascal compliance.

If you wish to run the entire compliance test on your compiler, you simply need to change or create a version of compile.bat and run.bat for your implementation that operate with your compiler. Then you can run the regression test ***without*** the self compile features (**cpcoms** and **cpints**).

Finally, building Pascal-P5, and then running it through a full regression is itself a good final test of ISO 7185 compliance. It does not substitute for direct testing of your compiler. Pascal-P5 could well run correctly even if your compiler is not fully ISO 7185 Pascal compliant!

For further details concerning the ISO 7185 tests, see 8 "Testing Pascal-P5”.

3.4 Notes on using existing compilers

When using an existing ISO 7185 compatible compiler, the configure script will install all the files needed to work with that particular compiler. Thus these hosts will work without any modification.

3.4.1 GPC

GPC (GNU Pascal Compiler) is used in the following version:

```
GNU Pascal version 20070904, based on gcc-4.1.3 20080704 (prerelease)
(Ubuntu 2.1-4.1.2-27ubuntu2).
Copyright (C) 1987-2006 Free Software Foundation, Inc.
```

I have had several difficulties with other versions of GPC, which give errors on standard ISO 7185 source, or crash, or other difficulties. The GPC developers announced they were halting development on GPC in the gpc mailing list. Please see their web page:

http://www.gnu-pascal.de

For any further information.

The main difficulty with GPC vis-a-vie Pascal-P5 is that testing of the GPC compiler for ISO 7185 compatability was not regularly done on GPC releases. Thus, otherwise working GPC releases were not able to compile and run standard ISO 7185 source code.

Because of this, I can only recommend the above version of GPC be used, which compiles and runs Pascal-P5 error free.

In addition, please be aware that I have not run the GPC compiler, including the above version, through a current ISO 7185 compliance test such as appears here. My only concern is that GPC be able to complile and run Pascal-P5, and that the resulting Pascal-P5 runs the compliance tests. I leave it for others to run full compliance for GPC itself..

3.4.1.1 GPC for mingw and windows

Mingw (Minimal GNU for Windows) is a different port of the GNU catalog for windows that runs directly on windows. That is, each binary is statically linked with its support library, and it is designed to work with windows directly. There are other packages capable of running GPC on Windows (Cygwin), but MinGW is by far the best and has the fewest issues.

MinGW is a package that uses Windows MSVCRT.DLL, a C library that emulates most C library calls and even goes a long way towards emulating Unix/Linux calls. The MinGW project uses that to port a number of GNU utilities, starting with the GCC toolset, and uses that to port a number of other Unix/Linux command line tools to Windows.

MinGW does not come natively with GPC installed (or much else). I recommend you also pick up the MSYS package for minGW, which is a series of GNU programs that are compiled to run in the windows environment using MinGW.

The MinGW project can be found at:

http://www.mingw.org

I recommend you go through a complete install of the MinGW system before installing GPC.

A prebuilt package of 32 bit GPC for Windows/MinGW can be found here:

https://sourceforge.net/projects/pascalp5/files/gpc-20070904-with-gcc.i386-pc-mingw32.tar.gz

Download and install that.

This is from the GPC page at:

http://www.gnu-pascal.de/binary/mingw32/

But sometimes things get moved around.

After installation, I recommend that you place the bin directory under the gpc home directory in your command line path.

To reiterate the steps that follow:

$ configure --gpc	Configure for GPC compiler.
$ make	Build the Pascal-P5 binaries.
$ regress	Run the regression suites to check the Pascal-P5 compiler.

3.4.1.2 GPC for Linux

A prebuilt package of 64 bit GPC for linux can be found here:

https://sourceforge.net/projects/pascal-p5/files/gpc-20070904-141.1.x86_64.rpm

Download and install that.

Now add the following line to your startup file, usually .bash_aliases:

```
LIBRARY_PATH="/usr/lib/x86_64-linux-gnu:/usr/lib/gcc/x86_64-linux-
gnu/7:/usr/lib/x86_64-linux-gnu"
export LIBRARY_PATH
```

This was done with gcc version 7 in mind. You will need to substitute the current version for the "7" above for other versions.

I recommend you match the GPC bit width to the version of Linux you are using. In this case, it is a 64 bit compiler for 64 bit Linux. It is possible to set up a cross compile, but that is more (perhaps much more) difficult.

Run the usual:

```
. setpath
./configure
make
```

4 Files in the Pascal-P5 package

Note: for script files, both a DOS/Windows (X.bat) and bash script (X) are provided. Their function is identical, one is for use with the DOS/Windows command shell, the other for bash shell.

configure configure.bat	Sets the current compiler to use to create P5 binaries.
INSTALL	Installation instructions
LICENSE	License information for Pascal-P5
Makefile	The make file to run builds on Pascal-P5. This is customized for a particular host compiler.
NEWS	Contains various information about the current release.

README	Brief introduction to the project, it points to this document now.
regress_report.txt	Contains the last full test series done on Pascal-P5. See the section on "testing".
setpath	
setpath.bat	Adds the "bin" directory to the current path. Used to quickly run procedures in P5 directory.
TODO	Contain a list of "to do" items in Pascal-P5.

4.1 Directory: basic

Basic.cmp	Basic interpreter test output compare file
Basic.inp	Basic interpreter test input file (contains "lunar lander" program and test input.
Basic.pas	Contains Basic-P5 source.

4.1.1 Directory: basic/prog

*.bas	Contains a series of Basic programs collected for Basic-P5. From the web site http://www.classicbasicgames.org/

4.2 Directory: bin

chgver.bat chgvers.bat	Scripts to change the compiler version numbers on all compare files.
chkfiles chkfiles.bat	Scripts to perform an md5sum check on all files used in testing.
compile compile.bat	Batch mode compile for Pascal-P5. It takes all input and output from supplied files, and is used by all of the other testing scripts below. You will need to change this to fit your particular Pascal implementation. *** You will need to change this to fit your particular Pascal system *** It uses input and output from the terminal, so is a good way to run arbitrary programs.
cpcoms cpcoms.bat	Self compile, run and check the pcom.pas file. This batch file compiles com.pas, then runs it on the interpreter and self compiles it, and checks the intermediate files match.
cpints cpints.bat	Self compile, run and check the pint.pas file. This batch file compiles pint.pas and iso7185pat.pas, then runs pint on itself and then runs iso7185pat.pas, and checks the result file.
diffnole	

diffnole.bat	Runs a diff, but ignoring line endings (DOS/Windows vs. Unix). Also ignores version numbers in compiler output.
doseol doseol.bat	Fixes the line endings on text files to match the DOS/Windows convention, CRLF.
fixeol fixeol.bat	Arranges the line endings on bash scripts to be Unix, and those of the DOS/Windows scripts to be DOS/Windows line endings. This is required because the editors on the respective systems insert their own line endings according to system, and this can cause problems when they are run on a different system.
make_flip make_flip.bat	A script to compile deoln and ueoln and create a flip script for Unix. This is used to replace the “flip” program if required.
p5 p5.bat	A batch file that compiles and runs a single Pascal program. You will need to change this to fit your particular Pascal implementation. It uses input and output from the terminal, so it is a good way to run arbitrary programs. *** You will need to change this to fit your particular Pascal system *** It uses input and output from the terminal, so is a good way to run arbitrary programs.
pascpp pascpp.bat	A script to run the cpp preprocessor. It takes the input .pas source, runs the preprocessor on it with options that make it language neutral (otherwise it would try to recognize C language constructs), and gives the output source .mpp.pas.
pcom pcom.exe pcom16.exe pcom32.exe pcom64.exe	The IP Pascal compiled pcom binary for Windows/Unix. See comments in 2.2 “Compiling and running Pascal programs with Pascal-P5” for how to use this. All of the supplied batch files are customized for this version. Note that not all of these files may exist.
pint pint.exe pint16.exe pint32.exe pint64.exe	The IP Pascal compiled pint binary for Windows. See comments in 2.2 “Compiling and running Pascal programs with Pascal-P5” for how to use this. All of the supplied batch files are customized for this version. Note that not all of these files may exist.
regress	

regress.bat	The regression test simply runs all of the possible tests through Pascal-P5. It is usually run after a new compile of Pascal-P5, or any changes made to Pascal-P5.
repo_ready repo_ready.bat	A script file that brings the Pascal-P5 repository to a standard state for commits.
rpcoms.bat	A script to compile a given file using the interpreted version of pcom.pas. Used to find errors in the compiler.
run run.bat	Batch mode run for Pascal-P5. It takes all input and output from supplied files, and is used by all of the other testing scripts below. You will need to change this to fit your particular Pascal implementation. *** You will need to change this to fit your particular Pascal system *** It uses input and output from the terminal, so is a good way to run arbitrary programs.
runprt runprt.bat	Runs the Pascal rejection test. See 8.4.
testp2 testp2.bat	Runs a compile and check on Pascal-P2, the second version of Pascal-P.
testp4 testp4.bat	Runs a compile and check on Pascal-P4, the fourth version of Pascal-P.
testpascals testpascals.bat	Runs a compile and check on pascals.pas, the Pascal subset interpreter created by Niklaus Wirth.
testprog testprog.bat	An automated testing batch file. Runs a given program with the input file, delivering an output file, then compares to a reference file. Testprog is used to test the following program files for p5: hello, roman, match, startrek, basics and iso7185pat.
unixeol unixeol.bat	Fixes the line endings on text files to match the Unix convention, LF.
zipp5 zipp5.bat	Creates a zipfile for the entire p5 project. This is used to create the releases available on the p5 web site.

4.3 Directory: c_support

c_support/flip.c	C program to replace the local version of “flip”, the Unix line ending fixup tool. It is provided in source form here because not all Unix installations have it

(for example MAC OS X didn't have it). This allows you to compile it yourself for your target system.

4.4 Directory: doc

basic.docx	Contains documentation for Basic-P5.
iso7185rules.html	A description of the ISO 7185 Pascal language.
the_p5_compiler.docx	This document, in Word 2010.

The_Programming_Language_Pascal_1973.pdf

Niklaus Wirth's description of the Pascal language, the last version to come from ETH. This is the equivalent of the "Report", from "Pascal user's manual and report [Jensen and Wirth].

4.5 Directory: mac_X86

A placeholder for Mac OS X specific files.

4.6 Directory: gpc

This directory contains scripts specifically modified for GPC.

compile compile.bat	The GPC specific version of the compile script.
Makefile	The GPC specific version of the make input file for P5 builds.
p5 p5.bat	The GPC specific version of the p5 script.
run run.bat	The GPC specific version of the run script.

4.7 Directory: gpc/linux_X86

pcom pint	Contains binaries compiled by GPC for Linux/Ubuntu

4.8 Directory: gpc/standard_tests

iso7185pat.cmp	Contains the compare file for iso7185pat for gpc.
iso7185pats.cmp	Contains the compare file for iso7185pats for gpc.

4.9 Directory: gpc/windows_X86

pcom.exe pint.exe	Contains binaries compiled by GPC for Windows.

4.10 Directory: ip_pascal

This directory contains scripts specifically modified for IP Pascal.

compile compile.bat	The IP Pascal specific version of the compile script.
Makefile	The IP Pascal specific version of the make input file for P5 builds.
cpcom cpcom.bat	The IP Pascal specific version of the compile compiler script.
cpint cpint.bat	The IP Pascal specific version of the compile interpreter script.
p5 p5.bat	The IP Pascal specific version of the p5 script.
run.bat run	The IP Pascal specific version of the run script.

4.11 Directory: ip_pascal/standard_tests

iso7185pat.cmp	Contains the compare file for iso7185pat for IP Pascal.
iso7185pats.cmp	Contains the compare file for iso7185pats for IP Pascal.

4.12 Directory: ip_pascal/windows_X86

pcom.exe pint.exe	Contains binaries compiled by IP Pascal for Windows

4.13 Subdirectory: sample_programs

Note that each test program as a .pas, a .inp (batch input, which could be empty) and output compare file .cmp. See 8.1.1 for more information.

basics.inp basics.cmp basics.pas	A tiny basic interpreter in Pascal.
drystone.cmp drystone.inp drystone.pas	File set for drystone benchmark.
fbench.com fbench.inp fbench.pas	Another benchmark program.
hello.inp hello.cmp hello.pas	The standard "hello, world" program.
match.cmp match.inp match.pas	A game, place "match" a number game.
match.bas	The basic version of the match game. This is the same program that appears in match.inp.

pascals.cmp pascals.inp pascals.pas	Niklaus Wirth's Pascal-s subset interpreter.
prime.cmp prime.inp prime.pas	A Pascal benchmark program.
qsort.cmp qsort.inp qsort.pas	A Pascal benchmark program.
roman.inp roman.cmp roman.pas	Prints roman numerals. From Niklaus Wirth's "User Manual and Report".
startrek.inp startrek.cmp startrek.pas	Startrek game.

4.14 Directory: source

source/pcom.pas	The compiler source in Pascal.
source/pint.pas	The interpreter source in Pascal.

4.15 Directory: standard_tests

iso7185pat.cmp	Contains the output from the PAT file with the IP Pascal compiled P5 executables above.
iso7185pat.inp	The input file for the Pascal acceptance test.
iso7185pat.pas	The Pascal Acceptance Test. This is a single Pascal source that tests how well a given Pascal implementation obeys ISO 7185 Pascal. It can be used on Pascal-P5 or any other Pascal implementation.
iso7185pats.cmp	Contains the output from the PAT file resulting from the cpints run. This is slightly different than the normal run.
iso7185prt.bat	Compiles the Pascal rejection tests.
iso7185prtXXXX.cmp	Comparision file for pascal rejection test. XXXX is a four digit number. See the rejection tests text for information.
Iso7185prtXXXX.inp	Contains the input file for the Pascal rejection test XXXX.
Iso7185prtXXXX.pas	Contains the source file for the Pascal rejection test XXXX.

5 Differences between Pascal-P4 and Pascal-P5

Pascal-P5 functionality is not covered completely by this document, but rather documentation about what differs from Pascal-P4 to Pascal-P5.This has the advantages of being terse, being an increment to

Pascal-P4, and highlighting the additions to Pascal-P4 necessary to bring Pascal-P4 to a state of being a full language compiler.

The reference manual for Pascal-P4 is the book “Pascal implementation: The P4 compiler” by Steve Pemberton and Martin Daniels, and the description of the changes from Pascal-P4 to Pascal-P5 assumes you are reading that:

http://homepages.cwi.nl/~steven/pascal/book/.

5.1 Viewing changes

The difference set between Pascal-P4 sources and Pascal-P5 sources, as available on http://www.sourceforge.net, were used in this text. This can be done with a standard Unix “diff” command, however, I recommend an advanced visual difference such as WinMerge or similar be used. This type of source difference analyzer is simply better suited to deal with a complex set of changes such as I will present here.

Note that the Pascal-P4 used to perform the comparision is the one I made minor modifications to in order to allow compilation and run under ISO 7185 rules. The modifications from Pemberton’s source to do this were detailed in the Pascal-P4 documentation on sourceforge.net.

5.2 Notes about change descriptions

For references in the code, I have used a different typeface, as in:

reference

This means you will find the symbol in the code.

I don’t comment on simple formatting changes. While as I said earlier I attempt to limit formatting changes, I did make them occasionally where they might make the source more clear.

I have not used line numbers in the description. Instead, I have described the code from top to bottom and pointed out landmarks, such as “in the types section”, “in procedure x”, etc. I think this works better than line numbers, which are obsolete whenever changes are made to the source.

As with all Pascal sources, the case of the identifiers is not to be taken literally. If an identifier appeared at the start of a sentence in this text, I capitalized it.

5.3 Changes to the parser

5.3.1 Thematic changes

Most of the changes to Pascal-P4 involved single features that need to be added or changed in the compiler. However, there were a few things that needed to be generally changed in the system.

5.3.1.1 Variable strings

First, the allocation of strings was changed from the fixed strings used in P4, to a type of dynamic string that can take any length. The method used for this appears in the Pascal FAQ:

http://www.standardpascal.com/pascalfaq.html#Q. Can variable length strings be used in stand

Basically, a string becomes a series of linked short arrays whose length is referred to as a “quanta” of string characters. In the release compiler that is 10 characters. The string itself is a pointer to a list of records containing quantas and pointers to the next quanta record.

The string itself is a space padded string, just as the prevous strings in Pascal-P4 were. The constant record contains the length of the string, and the value of the string simply changes to a list of string quanta instead of the string itself.

There are a series of routines that deal with the quanta based string form, such as finding the padded length, writing them to the output, interchange between quanta based and fixed length string forms, and comparisions.

The string quanta representation is used both for the internal storage of strings, and for symbols in the compiler. This solves the ISO 7185 need to keep symbol characters significant no matter how many characters appear.

5.3.1.2 Recycling based on dispose

Aother major change within the compiler is the removal of the use of **mark** and **release** procedures and replacement with ISO 7185 **dispose**. The **mark** and **release** system consisted of saving the heap address in a variable, then using that to reset the heap pointer later to “cut” heap so that all variables allocated between the **mark** and the **release** are simply lost. It is a very dirty and machine dependent operation that rightly was not included in the standard. It was used because it takes all the work out of tracking and returning dynamic variables to free storage.

With **mark**/**release** gone, the principle requirement is to accomplish “tear downs” of all of the dynamic structures when a block left scope. There are several routines that help with recycling, and there are a series of counters that track the entry of new variables in the heap, and the exit of previous variables from the heap. These were used to “prove out” the new storage management system. If the counters are not zero at the end of any run, there is a storage leak somewhere.

5.3.1.3 Files

Files had to be extensively reworked in Pascal-P5. In Pascal-P4 files were limited to text types. However, the upgrade of files to any type had far reaching consequences. In Pascal-P4, the handling of the file buffer was just passed on to the host. With any possible component type, file buffers must be managed just as formal variables.

Also, Pascal-P4 only allowed the four predefined **files**, **input**, **output**, **prr** and **prd** to be accessed. In Pascal-P4 files were recognized by their address on the stack. This does not work when an arbitrary number of files can appear in the program.

In Pascal-P5, a file is defined as a logical number of 1 byte length, followed by a buffer variable for the file, that matches the component type of the file. The result is that when the address of the file is known, both the logical id of the file, and the buffer variable for it can be accessed.

The logical file number is used to index into a logical file table in the interpreter that associates a non-zero file with one of 255 actual files. The initialized state of 0 for a file id indicates that the file was never opened, and this is used as a flag to allocate a file table entry for it.

The runtime association of a logical file id to a real file means that file types themselves don’t need to be converted to and from a byte format in the pseudo machine.

5.3.1.4 Byte oriented pseudo-machine

The original Pascal-P4 pseudo-machine was based on having a single word for all instructions and operands that was formed around the native word size of the machine. This was a very good and efficient plan for the original CDC 6000 computer series, and it is not a bad plan for todays machines, either. However, having instructions and operands that are quantitized in bytes is a better match for todays machines, and results in better utilization of memory.

Thus, the Pascal-P5 pseudo-machine features both instructions and operands packed along byte boundaries. Each instruction is a number from 0 to 255 and fits in a single byte. The P and Q operands of the Pascal-P4 machine are optional by instruction and P occupies one byte, while Q (which is commonly used for immediate integers and addresses) occupies the basic word length of the machine.

The result is an instruction set that only takes as many bytes as the particular instruction requires, and data in memory that occupies its inherent size. Bytes for characters and boolean, words for addresses and integers, reals on their required length, and sets on their required length (typically 32 bytes or 256 bits, one for each possible character in a byte).

The Pascal-P5 machine does ***not*** feature addresses and integers sized for their length. If an integer immediate is 3, it does not get only one byte of storage, it gets a full word. This is a common optimization in such implementations of a byte machine as JVM or UCSD that enable programs to be packed in less space. I tried a sample implementation of packing immediate integer operands in their native byte size, and the result was code for the compiler itself (always a good benchmark) that occupied about %10 less space, but complicated pint quite a bit. I didn't think that this fit Pascal-P5's goal of being the simplest possible implementation of the full Pascal language so I took it back out. It ***is*** a good optimization, especially if all of the possible compressions are used together to result in a reduced code and data requirement. However, I decided it belonged to a later version of Pascal-P.

5.3.1.5 Byte integer storage

One of the unfortunate side effects of having one single size of integer is that, even though that scheme can implement all of ISO 7185 Pascal, it prevents Pascal-P5 from compiling itself. This is because the byte machine storage idea would be unable to store individual bytes, being always extended to full integer, and thus the coercion of types into byte storage would not work.

The fix for this was to introduce a series of byte operators into the intermediate, and have the compiler recognize that the storage for a subrange based type can be reduced to bytes, not full integers.

5.3.1.6 Redesign of the stack machine layout

In Pascal-P4, the stack grows upwards and the heap grows downwards. This is pretty much the opposite of actual processor designs today, and I knew that it would have to be flipped if Pascal-P were to ever generate real machine code. Of course, its up for debate as to if this was necessary in Pascal-P5, since Pascal-P won't get (real machine) code generation until Pascal-P6. The argument for this arrangement is it makes Pascal-P5 a lot easier to understand for today's compiler students as well as easing the transistion to a full compiler.

One of the big advantages of the old arrangement was that globals, during the compile phase, aren't treated any different than locals, and they are "allocated" first on the stack, then they can be accessed in the back end by a fixed global base offset. In the new arrangement globals must be treated specially, and they grow up, whereas locals grow down. Since the back end (pint) treats all globals specially in any case, the changes for this are mostly confined to the front end (pcom).

5.3.2 Reading the source code

5.3.2.1 Preprocessor and preprocessor definitions

The source has the preprocessor cpp run on it. This is a standard Unix/Linux tool, and appears under windows care of MinGW and other porting environments. I use it with the options:

-P -nostdinc -traditional-cpp

Which tell cpp to turn off line marker generation, do not search for header files, and do not depend on the C language. These options are sufficient to allow cpp to work with an alternate language, in this case

Pascal. See the man page for cpp. Note line marker generation can actually be left on for some compilers (such as GPC), in which case it will show you accurate correspondence of errors to line numbers.

cpp is only used to process the following constructs:

#define To define cpp macros.

#include To include external files.

#ifdef/#endif To configure the source.

5.3.2.2 Input file

The header file **input** is changed to **prd**. As detailed elsewhere, the compiler has 4 files built in that it knows how to handle, and the rest (files created at program run) are assigned to temporary files. The predefined files are:

File name	Meaning
Input	Console input
Output	Console output
Prd	External file input
Prr	External file output

The compiler uses **prd** to input the source file. In Pascal-P2 and Pascal-P4, the input file is used for this, which would require the input source be redirected to the console input. This can be done (typically in a batch file), but it makes far more sense to input from the **prd** file, which gets connected to an external file. In the case of **pcom.pas**, this means the standard input file is not used, but in the case of **pint.pas**, it is passed through to the running program.

Thus it is a global change, **input** becomes **prd**.

5.3.2.3 Exit label

The addition of an exit label, **99**, allows immediate exit from the compiler for fatal errors. This is a "Wirthisim", and I am sure he meant **99** to mean "the last label in the program", implying he thought that less than 100 labels were all a typical program should need or want.

There is only one direct error exit in the program, which I added for a compiler fault. All other (Pascal-P4) errors let the parser continue (including, strangely, the compiler fault errors 400 and 500).

5.3.2.4 The machine parameter block

Pascal-P5 starts with the machine parameter block in the constants section. For the most part, this is simple rearrangement of the existing constants to highlight which constants control the characteristics of the target machine. Pascal-P4 had such a machine parameter list, I collected it into one place, and put it in an include file. Both the front end (pcom.pas) and backend (pint.pas) reference the same MPB file, and it can be changed for target characteristics, chiefly word size.

You might say that the characteristics of a pseudo machine don't vary, and are not important. However, Pascal-P is designed to target real machines as well, and very much treats its pseudo machine as a real machine with real sizes.

The good news is that, since the time of the original Pascal-P compiler in 1973, processors are much more regular in construction than before. In fact, a few simple rules unite today's processors:

- They are byte oriented. Addresses denominate bytes, and a byte can be picked up from anywhere. Often, even bigger operands can be fetched at byte addresses, even unaligned ones[3].
- The word sizes are based on multiples of bytes that are even powers of two, thus 8, 16, 32, 64, etc.
- Operands are most efficient when aligned according to their size. Thus a 32 bit word is most efficient aligned to 4 bytes.

Because of this, there are only three MPBs required for all existing CPUs, and that will likely suffice for decades. Thus there are three include files containing them:

Word size (bits)	file
16	mpb16.inc
32	mpb32.inc
64	mpb64.inc

A given host machine can compile for any word size at or below it's native word size. Thus a 32 bit machine (like 80386) can compile for 32 or 16 bits, and a 64 bit machine (like AMD64) can compile for 64, 32 and 16 bit.

Since Pascal-P5 cannot produce binary images of the machine code, compiling "under" the bit size for the host machine only serves to check if a given program can fit within the target machine. 16 bit is special in that it does not have sufficient space to self compile, that is, both pcom.pas and pint.pas overflow the target machine.

Note that endian mode is not a part of Pascal-P5's MPB. The reason for this is that, again, since it does not export binary images, the code is identical regardless of endian mode.

5.3.2.4.1 Contents of the MPB

The MPB contains most of the Pascal-P4 parameters **intsize** though **ordminchar**. Added are **intdig**, the number of decimal digits in an integer, and **inthex**, the number of hex digits in an integer. This is only for diagnostics, since ISO 7185 Pascal does not have hex I/O.). Note that sizes for integer, real and others now have a size in bytes instead of the Pascal-P4 "unit" size, reflecting the byte machine implementation. **adrsize** is the size of an address, **filesize**, the sizeof a file, and **fileidsize**, the sizeof a logical file number (which are interchangeable). **strglgth** has been moved out of the MPB. **maxsize** is the largest type that can be put on the stack (usually a set). **maxint** was removed, meaning that the size of some items comes from the host compiler. This was done because **maxint** is used both to specify things only within the parser, as well as machine specific parameters. Probably a better way would be to have a separate **maxint** just for the target. **heapal** is the alignment of the heap. **gbsal** is the alignment of the global variables area, **maxresult** is the size of the largest type that can be returned from a function (usually real). **maxexp** gives the maximum exponent of a real, and is used for error checking. Finally, **nilval** is the value of pointers that do not point to anything.

nilval is an interesting constant, and represents the value assigned to pointers that do not point anywhere. You would expect it to be zero, but this means that variables that were cleared to zero, and not specifically assigned a nil value, are also effectively nil. Having nil be a non-zero value adds the ability for Pascal-P5 to check for uninitalized pointers (unfortunately one of the few types where uninitialized checking is easy).

[3] In the years before 2000, it was common to leave off the BAU or Byte Access Unit to save on silicon space. However, this was unpopular and the space is no longer an issue.

Files are a new kind of object, but are just logical table indexes of one byte. The stack parameters get a new **maxsize**, which gives the largest size element possible on the stack (that of set). **Heapal** sets the alignment for the machine, but is unused in the parser. This is an example of "standardizing" the machine specific parameter block. **gbsal** gives the globals area alignment and is used to set the space between code and globals. **Maxresult** sets the size of the largest result a function can return, and this is needed now on machines where there is a difference between that and other types, say, integer. **marksize** was covered above.

begincode is copied from the backend, and it sets the location of program code after the startup preamble.

In Pascal-P4 the size of the stack mark, as well as the offsets of it's fields, are magic numbers. In the Pascal-P5 MPB, they are explicit. **marksize** gives the total size of the mark. **marfv** gives the offset of the function return value. marksl gives the static link. **markdl** gives the dynamic link. **markep** gives the (previous) maximum frame size. **marksb** gives the stack bottom for overflow checking. **market** gives the (current) maximum frame size. **markwb** gives the "with" stack base count, and is used to "cut" the with stack on interprocedure gotos. Finally, **markra** is the return address for the current procedure/function.

Of these, **market** and **markwb** are added since Pascal-P4. **market** or "current ep" is used to reset the ep when an interprocedural goto is executed. markwb is similar, but used to reset the current "with stack", which will be discussed later. It is used to track "with" record pointer bases for error checking.

And oddity of the MPB system is that it is carried intact by both the front end (pcom.pas) and back end (pint.pas). Thus it has constants that may not be used. This is handled in the main block by faking a reference to them to suppress errors, as you will see.

5.3.2.5 Other constants

displimit, **maxlevel** and **strglgth** (string length) were moved out of the MPB, since they are not machine specific. l**caftermarkstack** (line counter after mark stack) is moved out and equated using a new MPB parameter, **marksize**. I needed to represent the size of a mark in the interpreter, and carrying the parser oriented **lcaftermarkstack** name down didn't seem appropriate. So **lcaftermarkstack** lives, but simply as an equation to the machine parameter **marksize**. It is also now negative, because the stack grows down, and not up.

maxlevel was increased to follow the increased ability of pint to handle nested procedures. This also required a change to **displimit**. **displimit** must be greater than **maxlevel** by definition, since there are more levels used than procedure or function levels at any given time, because records add a scoping level outside of procedures and functions.

strglgth (string length) is an interesting constant. It used to be the absolute determinant of string lengths in the parser, but the parser now has the ability to represent any length string via string quanta. It still does that job, but all strings no longer are simply sized as arrays of characters with **strglgth** length. Instead, the buffers used to read strings in are still such arrays, then the string quanta system is used to store them. Thus, **strglgth** being a large value, the size of a maximum input line, no longer wastes space in the parser.

You will find the constant 250 several places as the effective limit of an input line. This is a "Scottisism", that is an old habit of rounding off 256 for the length of a line buffer[4]. The curious thing is that nowhere in the parser is there an input line buffer (although there is a string buffer)! Thus, 250 simply stands for

[4] Actually, the convention comes from an old basic I once used. Old habits die hard.

the maximum size of runs of characters we allow in the input (this could be removed entirely by making all string buffers variable length).

maxstack got changed to **maxsize** for reasons that are lost in time. **filebuffer** was used to set the number of active files in the compiler, which was 4 (**input**, **output**, **prd**, **prr**). It was used to reserve the first 4 locations in the globals for files, but now these files are allocated differently.

digmax was converted from an integer variable to a constant. It was treated as a constant in Pascal-P4, set but never modified. In Pascal-P5, since reals are stored as variable length strings, it is the size of the maximum length of digits we expect in the source, and thus is 250 for the same reasons as **strglgth**.

After that, there are a series of manifest constants. This was simply my annoyance with the magic numbers used to create the tables in the parser. **maxsp**, **maxins**, **maxids**, **maxstd**, **maxres**, **reslen**, **prtlin**, **varmax**, **intdeff**, **reldeff**, **chrdeff** and **boldeff** are all examples of such constants, and explained in the comments. In this case, the magic numbers are simply moved a short distance from the variables section for the program block to the constants section, but it reflects my habit of wanting to see all key adjustments to a program up high in the constants section.

varsqt is a new constant and represents the size of a string quanta (discussed previously). Changing this constant up or down will effectively change the amount of string space wasted in “last block breakage” for strings. If a string occupies 41 characters, and **varsqt** is 10, then 9 characters are wasted in the last quanta of the string. Changing this value lower means less padding waste, but increases the overhead due to the need for multiple quanta and pointers. Changing it higher increases padding waste, and decreases the total pointer overhead.

The version numbers **majorver**, **minorver** and **experiment** come from the fact that Pascal-P5 now signs on. I think of the major number as being a release number, that is, counting the number of times that a major change was released to users. The minor number is simply marks a series of changes. The convention is that when a release is made, the version number is incremented after, so the version number of the source always is the next version than the release, meaning that any changes in the source apply to the next version. To make is clear that builds directly from source are not the same as releases, the **experiment** flag, if true, adds an “.x” to the end of the version in the sign on. Thus, this flag is only turned off when building a new release, then immediately turned back on again.

5.3.2.6 Types

marktype is a vestige of the **mark**/**release** system and is commented out. When I started changing P4 to P5 I tried to preserve the original compiler and changes via commenting things out, but this rapidly became unmanageable. This is a leftover.

For **symbol**, the list of reserved symbols, range was added for ‘..’ because this is handled as a formal symbol. Formerly, it was handled by equating it to colon, because 1:4 (for example) was a valid subrange in the old Pascal language. **forwardsy** was removed because forward is not a reserved word in ISO 7185. **nilsy** was added because **nil** is a reserved symbol in ISO 7185.

For **chtp** or character types, **chlcmt** was added because we added “{“ as an opening to the new style of comments {}.

strvs is the declaration of a single quanta for a variable length string, and **strvsp** is a pointer to such an entry.

strvsp is then used to replace a fixed length string **sval** in the record **constant**, and fixed length string **name** in **identifier**. Note that in constant, the string length is held in **slgth**, and in **identifier**, the string is a right padded identifier whose length is inherent. This is, again, why **strvs** does not need a length as part of its structure.

constant gets refactored to use **strvsp** for real strings, as does the string **strg** entry for same. **constant** also gets a next pointer so that we can form lists of constants.

valu, used at various points, had a tagfield intval that was never referenced. The new code requires it is set appropriately.

In **addrrange**, we change the range of addresses to include negative numbers. This is required to enable stack offsets, which are negative. The stack in Pascal-P4 grew upwards. In Pascal-P5, it grows downwards.

In the record **structure**, I added a next **structure** pointer **next**, which is used to form lists for the new total recycling system. In general, you see these new recycling links added only when there was not already a linked list system of representation that could be followed to complete the recycling teardown. Fortunately, most structures already had such a list representation.

Also in **structure**, the boolean **packing** was added to mark the packed/unpacked status of structures. This was needed for ISO 7185 compliance.

Again in **structure**, the boolean **matchpack** indicates to the type compare routine **comptypes** if packing status matters. This is because set constants appearing in the code assume the packing status of the other operand in expressions, and thus are disabled for packing checks.

Again in **structure**, a field was added just to records as **recyc** that contains a list of structures appearing in the field list for a record. This was needed to keep track of such entries for the new recycling system.

Finally in **structure**, we added a pointer to **variant**, **caslst** to hold a list of variant cases.

The original alpha, which signified “a standard identifier string” in P4, was replaced with two fixed string types more appropriate to each use of the type. **Idstr** is used for external filenames and general identifiers. **restr** is used for reserved words.

nmstr is a new declaration for a string buffer that contains the characters making up a real. It is used by insymbol. **P4** and **P5** both treat reals (but not integers) as just the string of characters that make up the number. This is how **Pascal-P** keeps from imposing any of the characteristics of its underlying real type on the input number. The convertion to a binary type is left entirely to **pint**.

csstr is also new, and it is the buffer type used to store constant strings while they are being parsed.

The first change to **identifier** is the removal of the **packed** keyword. **identifier** is referenced in several places by a **var** reference, and this is an ISO 7185 violation.

Identifier had **name** changed to accept variable length identifiers as described (out of order) above.

Identifier also gets the boolean flag **keep** which is used to keep parameter ids out of the recycling system when a block is torn down. This is necessary because parameter lists need to stay around even after the block the procedure or function defined is sent back to recycling.

identifier gets a flag, **refer**, that indicates the identifier has been referred to in the program. This suppresses an error due to unreferenced ids.

Identifier contains a series of variants for the type of object it names. The **vars** variant gets a flag that indicates if the variable threat, that indicates if the variable is threatened. Look at the ISO 7185 standard for more information on that, but it means any kind of assignment, pass as **var** parameter, use as a **for** variable, etc. Anything that would change the variable. **vars** also gets **forcnt**, which is incremented on use in a **for** statement, and decremented at the end, and thus tracks nested use of **for** statements on that variable. This is used to check threats to **for** loop variables.

In **identifier**, field gets quite a few new fields. **varnt** indicates if the field is in a variant, and makes it easy to check if the variant is active (without searching). It links to the variant the field belongs to. **varlb** links the tagfield that controls the variant (see the diagram on page 45 of "Pascal implementation").

tagfield flags if the field itself is a tagfield. **taglvl** gives the nesting level of a tagfield in variants, which is used to enable assignment checks. varsaddr and varssize are used to store offsets for tagfields to enable fast assignment validity checks.

proc and **func** mark both procedures and procedure or function parameters. These then need a frame offset address as **pfaddr**, just as **vars** do.

pflist is needed because when we tear down a procedure or function block and recycle the entries, the parameter list for a procedure or function is removed from the general storage system. So the **keep** flag above saves the list, and **pflist** is used to keep that list around so that we can check for parameter list congruence.

asgn indicates if a function result has been assigned, for checks.

The **attr** structure is used to track in process (stacked) result types. It gets several new fields which are basically copied from types that get picked up during operations.This includes **packing** and **packcom** for packed status, **tagfield** for if it is a tagfield, **taglvl** for variant nesting level, and **vartagoff** and **varssize** for the characteristics of the tagfield controlling an enclosing variant.

testp and the **testpointer** record was eliminated because type comparisions no longer recursively examine types for structural equivalence. This is one of the few areas where the ISO 7185 standard actually simplified the code.

The **labl** record gets quite a few more fields to cover the requirements on goto labels that they not reference deeper nested structures, and to allow intraprocedural gotos. The algorithim is outlined in "A model implementation of standard Pascal" [Welsh & Hay].

The **vlevel** field saves the procedure nesting level at the point the label is defined. It is used to output the difference between the nesting level at the time of a goto and its target in order to adjust the stack frame.

The **slevel** field saves the statement nesting level at the point the label is defined. It is used to check for references to deeper nested statements, and to flag inactive statement blocks.

ipcref is used to flag if the label was targeted by an intraprocedural goto, and can produce an error if the label is nested at greater than level one in the defining statement of the label.

minlvl tracks the minimum statement level of all the referencing gotos for a label. It is used to flag an error if a goto references a deeper nested label.

bact flags if the containing statement block for a label is active. If the label is in a block that is no longer active, this flag is reset. This is how Pascal-P5 checks for gotos between statement levels where the goto is at the same or greater statement nesting, but in a different statement block. This algorithim will be covered later.

The **refer** flag allows checks of if the label was referenced.

Finally, the type declaration for case statement tracking entries was moved from the **casestatement** procedure to the global types section. This was mainly done so that the recycling routines **getcas** and **putcas** procedures could be global, and thus is perhaps a questionable change. I suspect that it was a matter of wanting to see the recycling control routines lined up in the same section.

5.3.2.7 Global Variables

The ISO 7185 required declaration of prr as text type is bracked by special comments that an external sed script uses to change the file pcom.pas to pcomm.pas in order to accomplish a self compile. The sed script changes:

{elide} to {

And

{noelide} to }

And thus converts:

{elide}prr: text;{noelide}

To

{prr: text;}

Commenting the statement out for self compile[5].

The reason why this needs to be done is because of the way program parameters are classified in **ISO 7185**. If the parameter is "known", that is, a compiler defined parameter of the program such as **input** or **output**, then it automatically possesses the compiler defined type, which is usually text. If the parameter is not predefined, then it's type must be made clear via a definition in the global variables.

prr is "unknown" when pcom is compiled by another compiler. However, to Pascal-**P5**, **prr** is "known", and so should not appear in a global variable definition.

Fortunately, there are few of these sorts of changes required for the self compile. I have marked them in comments with "!!!" to make them easy to find[6].

The variable **id**, used to contain the last identifier seen by the scanner, is changed from the general alpha type used in Pascal-P4 to the more specific **idstr** in Pascal-P5. Note that this results in a fairly large buffer for identifiers at the global level, but whenever id is copied into a specific symbol, it is changed to our variable length format.

kk gets a constant define **maxids** for its maximum value, part of the "magic number" elimination drive. This is perhaps a good place to mention that Pascal-P relies far too much on global variables.

[5] Pascal-P5 uses SED scripts to perform such macro processing. In Pascal-P6, I used the full C macro processing facility, which simplified it quite a bit. This may be backported.
[6] A left-over from when the change was done manually.

gc adds to **lc** and **ic**, and it tracks the globals locations. In Pascal-P5, globals count up whereas locals count down, so are tracked by a different counter.

prterr is no longer needed, due to changes in the way forward references are done. **chkvar** is a new option that enables things like tagfield assignments and active variant checks.

chkref enables reference checking, giving errors for unreferenced ids. **chkudtc** and **chkudtf** both enable checks for Undiscriminated unions, that is, tagfields that are not allocated as fields. It is split into “first” and “final” flags because it would case problems if the setting is not consistent, so we let the user change **chkudtc** but copy that to the real flag, **chkudtf**, on program block start.

option is a new feature that allows each letter, a-z, represent an option. This allows the user to set an option that only means something to the backend (pint.pas), and the front end does not define it. We accomplish this by outputting the setting of all the options to intermediate via a special instruction.

Note that the options are set redundantly. That is, ‘r’ (for example) enables reference checks, and this sets both ‘r’ in the option array as well, as the **chkref** flag.

outputptr and **inppptr** are identifier pointers that are set to the entries for the **input** and **output** predefined files. These pointers are used to gain access to the actual definition of the files in Pascal-**P5** when they are used as defaults in statements like read and write. In Pascal-**P4**, they were simply referred to by their fixed offset addresses in the program stack frame.

stalvl was added to keep track of statement nesting. Each statement, **if**, **while**, **with**, etc., adds a level. If the statement nests like a begin, the statement level also increases. This is used to track goto labels.

globtestp was removed as described above.

display, which is an array of records that keeps track of the block nesting levels of the program, is central to the new recycling system. In fact most of the tedious process of tearing down and recycling all of the entries in a nested block can be done by reference to the display record. In accordance with this, two new fields were added to the display to keep a list of things that were not explicitly tracked in Pascal-**P4**. **fconst** was added to track constant entries, and **fstruct** was added to structure entries. Both of these entry types, **constant** and **structure**, received next list links in Pascal-**P5**, and so form a linear list attached to a display record.

The display also keeps a copy of packing, packcom, and ptrref from the variable reference of a with statement that created the display entry (if there is one). In this way, variable references contained in a with block can use these parameters to perform error checking.

In **errlist**, the field **nmr** range was increased from 1..400 to 1..500, reflecting the true span of error numbers in use. The error 500 was in use in Pascal-**P4**, it indicated a compiler error in the **gentypindicator** routine for an unexpected type.

Between the global variables **rw** and **pdx**, what follows are a series of magic number eliminations which were covered in the constants section. The only change not of that nature is the change in **na** from **alpha** to **restr**, which is a change from the general string type **alpha** to a more specific type **restr** for reserved word strings.

cdxs is an extension to the **cdx** table, (Pemberton&Daniels pg. 53) which is a table of stack offsets by intermediate instructions. What **cdxs** does, is, for selected instructions, break the offsets down by type of instructions.

The pseudoconstant **digmax** was moved back to the constants section, as detailed above.

The variables section finishes out with several new variables.

inputhdf and **outputhdf** are booleans that indicate if the **input** or **output** file appeared in the program header file. They are used to generate errors if the default file is used in a read or write, but does not appear in the header.

errtbl is an array of booleans, one per possible error number, that are used to track the total set of errors that occurred in the program. This is used to generate a new feature in **P5**, which is a dictionary of error number equivalences in the program. This was done in **Pascal-S**, and I decided to carry it over to Pascal-**P5**. The saving of memory no longer was warranted, and **Pascal-P** could now support the long strings required, so it was included. It is perhaps the only example in Pascal-**P5** of an improvement that was not absolutely required by the standard[7].

toterr is a counter for all of the errors in the program, and is used for a diagnostic at the end.

The recycling counters that appear next, **strcnt**, **cspcnt**, **stpcnt**, **ctpcnt**, **lbpcnt**, **filcnt**, and **cipcnt**, are incremented for each new dynamic storage record that is allocated, and decremented when these records are freed. These counters are how the new/dispose system of Pascal-P5 was validated after replacing the mark/release system of Pascal-P4. If the counters are zero after the run, the system works. If any counter is positive 1 or more, then one or more of the entries failed to be disposed of. If any counter is negative 1 or less, then one or more of the entries was disposed of multiple times.

The tracking counters can be printed by constant flag at the end of the run. They are normally not printed, but can be turned on for a health check of the dynamic storage system.

F and I are used to print the error table at the end of the program block.

5.3.2.8 Procedures and functions

For the rest of the program, here is a map of the program, procedure and function blocks from the entire program:

```
program pascalcompiler
  function stptoint
  function ctptoint
  procedure getstr
  procedure putstrs
  procedure getlab
  procedure putlab
  procedure pshcst
  procedure putcst
  procedure pshstc
  procedure putstc
  procedure ininam
  procedure putnam
  procedure putnams
  procedure putdsp
  procedure putdsps
  procedure getfil
  procedure putfil
```

[7] And it comes with the price of inflating the number of source lines in pcom.pas.

```
procedure getcas
procedure putcas
function lcase
function strequri
procedure writev
function lenpv
procedure strassvf
procedure strassvr
procedure strassvd
procedure strassvc
procedure strassfv
function strequvv
function strltnvv
function strequvf
function strltnvf
function strchr
procedure strchrass
procedure prtdsp
procedure endofline
procedure errmsg
procedure error
procedure insymbol
  procedure nextch
  procedure options
procedure enterid
procedure searchsection
procedure searchidnenm
procedure searchidne
procedure searchid
procedure getbounds
function isbyte
function basetype
function alignquot
procedure alignu
procedure alignd
function aligns
procedure printtables
  procedure marker
    procedure markstp
    procedure markctp
  procedure followstp
  procedure followctp
procedure chkrefs
procedure genlabel
procedure searchlabel
procedure newlabel
procedure prtlabels
procedure block
  procedure skip
  procedure constant
  function comptypes
```

```
function filecomponent
function string
procedure resolvep
procedure typ
  procedure simpletype
  procedure fieldlist
procedure labeldeclaration
procedure constdeclaration
procedure typedeclaration
procedure vardeclaration
procedure procdeclaration
  procedure pushlvl
  procedure parameterlist
procedure body
  procedure addlvl
  procedure sublvl
  procedure mesl
  procedure mes
  procedure mest
    function mestn
  procedure putic
  procedure gen0
  procedure gen1
  procedure gen2
  procedure gentypindicator
  procedure gen0t
  procedure gen1t
  procedure gen2t
  procedure load
  procedure store
  procedure loadaddress
  procedure genfjp
  procedure genujpxjp
  procedure genipj
  procedure gencupent
  procedure genlpa
  procedure checkbnds
  procedure putlabel
  procedure statement
    procedure selector
    procedure call
      procedure variable
      procedure getputresetrewriteprocedure
      procedure pageprocedure
      procedure readprocedure
      procedure writeprocedure
      procedure packprocedure
      procedure unpackprocedure
      procedure newdisposeprocedure
      procedure absfunction
      procedure sqrfunction
```

```
            procedure truncfunction
            procedure roundfunction
            procedure oddfunction
            procedure ordfunction
            procedure chrfunction
            procedure predsuccfunction
            procedure eofeolnfunction
            procedure callnonstandard
              procedure compparam
          procedure expression
            procedure simpleexpression
              procedure term
                procedure factor
          procedure assignment
          procedure gotostatement
          procedure compoundstatement
          procedure ifstatement
          procedure casestatement
          procedure repeatstatement
          procedure whilestatement
          procedure forstatement
          procedure withstatement
    procedure programme
    procedure stdnames
    procedure enterstdtypes
    procedure entstdnames
    procedure enterundecl
    procedure exitundecl
    procedure initscalars
    procedure initsets
    procedure inittables
      procedure reswords
      procedure symbols
      procedure rators
      procedure procmnemonics
      procedure instrmnemonics
      procedure chartypes
      procedure initdx
```

For each procedure or function that was changed, added or deleted, a new heading will appear.

Two major sections of support procedures and functions were added globally. The first covers recycling using new/dispose. The second covers string handling using our new variable string length system. A minor addition were the type changing routines.

5.3.2.9 Mark and release

mark and **release** were removed, as that functionality is replaced by **new** and **dispose** in Pascal-P5. There is no ISO 7185 functionality for **mark** or **release**, and in fact they would have to be implemented at the assembly level in any case, since they directly manipulate the stack.

These routines don't appear in the listing in Pemberton&Daniels, but do appear in the listing Pemberton gives on his web site, which makes sense, because it would compile in the book's form. In any case, those routines are no-ops, which means that the freed space in the compiler is simply thrown away and not reused.

5.3.2.10 Type change routines

pcom has the “bad” type escape routines to change stp (structure) pointers to integers and ctp (identifier) pointers to integers. This is used in the symbol and type table print routines. These routines existed in Pascal-P4, but I moved them to the top, probably to highlight them. These were, in fact, the only type changing routines in Pascal-P4 (pcom.pas or pint.pas). Its worth noting they were not in fact necessary. In Pascal-P6 I eliminated them by numbering all of the stp and ctp entries with an included field.

5.3.2.11 Recycling support routines

When allocating control records, the method followed is to introduce a pair of procedures, **get** and **put**, for each record type. This gives a central point to control the method of allocation and tracking of each type.

Some types have variants that are too complex for the simple **get** and **put** scheme. The variants would have to appear as parameters to the **get** routine. So the method followed there is to let the main code allocate the record with **new**, then provide a routine that completes the processing on the created entry.

Recycling of control records falls into two classes. The first are entries that are directly rooted in the **display**. The second are records that can be recoved as links from the first type of entries. The reason it matters here is that the **display** rooted entries have their get processing combined with a push to the list that is rooted to the display, and are termed **psh** (for “push”) procedures, because all of the lists are represented as pushdown lists. It does not indicate that stacking behavior is going on.

5.3.2.11.1 Procedure getstr

Getstr gets a single quanta, or element, of a variable length string.

5.3.2.11.2 Procedure putstrs

Putstrs recycles a list of string quantas that make up a variable length string. Variable length strings are built up one quanta at a time, but released as a set.

5.3.2.11.3 procedure getlab

Gets a single label entry.

5.3.2.11.4 procedure putlab

Releases a single label entry.

5.3.2.11.5 procedure pshcst

In the case of constants, the number of variants make it inconvienent to follow the **get**/**put** rule. Instead, pshcst is used to place a **constant** record to the **display** rooted list, then perform the tracking counts.

5.3.2.11.6 procedure putcst

Releases a **constant** record. Also releases the set of string quanta contained, if the constant is a string.

5.3.2.11.7 procedure pshstc

Pushes a structure record to the display rooted list and counts it.

5.3.2.11.8 procedure putstc

Releases a **structure** record.

5.3.2.11.9 procedure ininam

Performs processing on an **identifier** record. **Identifier** records are kept in a binary search tree rooted to the display, and have complex variant structure. So this routine simply finishes allocation processing, and thus bears an **ini** prefix.

5.3.2.11.10 procedure putnam

Releases an **identifier** record. Also releases the variable length string that keeps the **identifier** name itself. Finally, **putnam** takes care of releasing parameter lists for procedures and functions. Parameter lists are kept out of the recycling for the block that contains them because the surrounding block needs to refer to them to check the structure of passed parameters in a call. This is what the **keep** flag does.

Thus, when the procedure or function entry that contains the parameter list is recycled, it is time to recycle the parameter list as well.

5.3.2.11.11 procedure putnams

Releases an entire tree of **identifier** names. Identifier records are rooted in **display** and have a binary tree structure. Thus, this procedure tours the tree and performs a depth first pruning of the tree. It won't touch records with the keep flag on, which is a bit confusing with respect to the **putnam** comments. However, at the time of **putnams**, the identifiers that reference the parameter list are removed from the block symbol list, but kept on their associated procedure or function header list. This is a consequence of the unification of **identifier** name records and the structuring information about what the name contains.

5.3.2.11.12 procedure putdsp

putdsp is the key routine in the new P5 recycling system. **putdsp** recycles a **display** level, that is, all of the entries that are rooted to the given **display** level are sent back to free storage. In the Pascal-**P4** system, the process of removing a **display** scoping level was simply a matter of decrementing the **level** count and performing a **release** procedure to remove all outstanding entries. Putdsp starts with the use of putnams to release the binary identifier tree. This is most convient as a subroutine, because it calls itself recursively for the left and right forks that form the the tree.

Next, the label entries are disposed of, followed by the constant list.

The **structure** list is disposed of with a subroutine **putsub** that checks if the structure is a record, and frees the list of structures that comprise the record if so. It also removes the identifiers that are attached to the record. The identifiers that make up the field list of the record don't appear in the **display**. A **display** level is used to collect them when the record is defined, but the root of that tree is saved into the **fstfld** field of the record structure. The structures corresponding to the record structure fields themselves are stored in the recyc field, which is new with Pascal-**P5**.

You might think that the identical looking **recvar** field from P4 would do this job, but this field actually points to the record variant part, if it has one.

Tagfields for records are treated specially. They are allowed to be anonymous, but take an identifier entry in any case. The problem is that they don't also appear in the identifier tree, and so don't get recycled. We check for this special case and perform it here.

Because **putsub** recurses to process all fields of a record, and entire record is torn down here.

5.3.2.11.13 procedure putdsps

putdsp is called for a particular level number, but could be abused by being used to pull down display levels out of stacking order. However, this does not happen. The procedure **putdsps** is used to tear down all display levels until a given display level is reached. It might seem to make sense to only remove scoping levels one at a time, but levels are created for things like record scoping, and this is handled by saving the level at the start of the procedure or function that defines a block, then removing all levels until the block is removed, also removing any record subscoping.

5.3.2.11.14 procedure getfil
The **getfil** procedure simply gets and tracks an external file entry.

5.3.3 procedure putfil

putfil recycles and tracks an external file entry.

5.3.3.1.1 procedure getcas
getcas allocates and tracks a case statement entry.

5.3.3.1.2 procedure putcas
putcas recycles and tracks a case statement entry.

5.3.3.2 Character and string quata routines
The majority of the complexity for the new variable length string system in Pascal-P5 is enclosed in a series of routines in this section. The buffers used in Pascal-P4 to represent things such as identifiers and strings that the scanner reads in still exist, but of course are much larger. They are converted to variable string format when the buffers are copied to **identifier** records, or **constant** records. This saves us from having to modify all of the scanner code that parses and collects these values, and results in the same amount of savings in space from not having to store the buffers literally.

The string handlers are oriented around three different formats:

idstr Which gives a maximum length of string buffer in Pascal-P5.

restr Which is used for reserved words only (like procedure, var type, etc.).

strvsp Which is a variable string based on a linked list of string quanta.

Despite the name, **idstr** is used for all identifiers and string constants in buffers. **restr** is simply used to define the length of entries in the reserved word table. Strvsp is represents variable strings in their "efficient" format, which is a linked list of string quanta.

For each of the fixed **idstr** and **restr** there exist convertions to the variable length **strvsp** type. This is used to convert fixed length buffers into variable length strings in data structures for the compiler. In addition, several cross type comparision routines exist so that fixed buffers can be compared to variable string types.

It also occasionally matters as to what the right space padded length of a variable length string is. A right padded string is a string with blanks or spaces at the right side:

```
'my long string      '
```

Is a 14 character, right padded string in a 20 character stored format. This may seem odd that we use this mechanisim from old, fixed length string Pascal for variable length strings. However, the string quanta system does not exactly represent the length of strings, but the length of the string rounded up to the nearest quanta, which in the release compiler is equivalent to 10. This means that, for example, if the string to be stored is 35 characters, 4 quantas must be used, for a total space of 40 characters, with 5 characters of right padding.

Variable strings in Pascal-**P5** have no inherent method to indicate length. For identifiers and reserved words, the right padded length (the length of the string with all right hand space padding removed) is used. For constant strings, the length of the string is actually kept as a separate field, and thus is the exact length in characters.

Many of the string routines have a naming convention based on using a few letters at the end. Unfortunately, the convention was not that evenly implemented. Never the less, here are the characters used:

R Reserved

V Variable

F Fixed (usually identifier strings)

I Fixed identifiers

D Digit string

C Constant string

If the routine only takes one parameter, then only one trailing character will appear. If it takes two parameters, there will be two characters in order of the parameters. For example, **writev** takes a single variable parameter. **strassvf** takes two parameters, a destination variable string and a source fixed string. **Writev** tells you it is the standard write procedure for variable strings. **strassvf** means to assign a fixed to variable string.

5.3.3.2.1 function lcase
lcase converts upper case characters to lower case characters. It is used to establish case insensitivity, which was not present in the P4 compiler..

5.3.3.2.2 function strequri
Strequri checks if a reserved word string is equal to an identifier string, disregarding case. This is used to compare the scanner identifier buffer to various reserved word and short strings.

5.3.3.2.3 procedure writev
This procdure is used to provide write style fielded length output capability for variable length strings. It is exclusively used for diagnostics in P5.

5.3.3.2.4 function lenpv
This function finds the right padded length of a variable length string.

5.3.3.2.5 procedure strassvf
Assigns a fixed length identifier string to a variable length string. Note that string quantas are allocated as required to create the linked list that is the result.

5.3.3.2.6 procedure strassvr
As in **strassvf**, but assigns a reserved word string to a variable length string.

5.3.3.2.7 procedure strassvd
As in **strassvf**, but assigns a number string to a variable length string.

5.3.3.2.8 procedure strassvc
As in **strassvf**, but assigns a constant string to a variable length string.

5.3.3.2.9 procedure strassfv

As in **strassvf**, but assigns a variable length string to a fixed identifier.

5.3.3.2.10 function strequvv

Compares two variable length strings without regard to case. Strings are equal only if they are also equal in length.

5.3.3.2.11 function strltnvv

Compare that one variable length string is after another in character order. That is:

```
'alpha' < 'beta'
```

You will note that the length of the strings is irrelevant. Why? Consider:

```
'markalpha' < 'marker'
```

Because the first would be alphabetized before the second in a dictionary.

Note that when performing string compares using a fairly complex method (compared to compared to letting the compiler do it), we only need to define the routines for equals and less than. This is because all other compare types can be derived from these two basic types:

a > b is not (a < b) and not (a = b)

a <= b is not (b < a)

etc.

5.3.3.2.12 function strequvf

Finds a variable string equal to an identifier string. This is used to compare variable strings in data tables to fixed buffers.

5.3.3.2.13 function strltnvf

Finds a variable string less than an identifier string. Why do we need a less than for identifiers, but not for reserved words? Because identifiers are stored in binary search trees, and reserved words are found via straight linear searches.

5.3.3.2.14 Function strchr

Returns a single character from the given index in a variable string. It finds which quanta the index belongs to, and retrives the character from that quanta. If the index is beyond the end of the total string, a space is returned. This emulates a string that exists right padded in a virtual buffer of infinite length.

5.3.3.2.15 Procedure strchrass

Places a single character to the given index in a variable string. It find which quanta the index belongs to, and places the character in the quanta. If the variable string does not have sufficient quanta to represent the character at the index, then any number of quantas are automatically added and set to blanks until it is.

strchr and **strchrass** form the basis for higher level systems using the string quanta format. They could be used to extract or insert a substring, and perform most functions that could be done on fixed strings using the variable string format.

However, **strchr** and **strchrass** were created solely to handle the manipulations required on the variable strings that represent real number constants. Specifically, the ability to read and change the sign, and thus the first character of

5.3.3.2.16 procedure prtdsp

Closing out the section of added support routines in Pascal-**P5** that were not in Pascal-**P4**, **prtdsp** is a diagnostic routine that was added to debug the compiler. It prints out the contents of the display identifiers in binary tree format.

You will note that Pascal-P4 already had a fairly complex dump procedure printtables for the user. **prtdsp** is strictly a routine for debugging the compiler.

5.3.4 Modifications

For the most part, the rest of the changes to routines in the compiler are modifications to existing routines (a large exception is **errmsg** below). Thus you will note that we describe what is new or what has changed in the compiler on a routine by routine basis, and not that the routine does. The Pascal-P4 description is still valid for the vast majority of these routines.

5.3.4.1 procedure endofline

A small bug in **endofline** was fixed by setting **lastpos** to -1 instead of 0. The test **currpos** = **lastpos** is used to see if we are outputting the first error on a line in the error printout, but pos got set from **chcnt**, which starts at 0, meaning that test does not work. Instead we use -1, an impossible **chcnt** value.

endofline gets a small section of code at the end that outputs “line markers” to the intermediate code. This allows pint to tell you which source line was associated with which error in the back end. Perhaps one of the most useful modifications to Pascal-P4.

5.3.4.2 procedure errmsg

Errmsg was one of the few places I added a modification that was not strictly needed for ISO 7185 compliance. Given an error number, it outputs the equivalent error string. It is used to produce a dictionary of all errors that were seen in the run, very similar to what Pascal-S does. I found it invaluable not only because it avoids the need to go look up errors by number, but also because the errors for Pascal-P4 were nowhere exactly defined. The “Users Manual and Report” [J&W] gives a list that is very close to Pascal-P4, even though nowhere could I find a reference that states this. There were a few additional errors used in Pascal-P4 that didn’t appear in this reference, and I have added yet more for ISO 7185 specific errors.

5.3.4.3 procedure error

error begins with a mysterious commented out write statement. The reason for this is that the compiler does not actually output errors when they are entered, but records up to 10 errors in a table and outputs them during **endofline** processing. This can be quite annoying when you are debugging the compiler, because the errors are delayed until the statement causing the error is long gone. Uncommenting this write statement helps with such debugging.

Then, error records all errors that were seen in **errtbl**, which contains a true/false bit for every error number possible. If an error was seen, its bit is set true. This tells us what errors to output in the dictionary at the end.

You will note that a set is not used for **errtbl**. This is to avoid limitations on set size.

Finally, **error** tallies a total count of errors for the run that is output at the end.

5.3.4.4 procedure insymbol

Starting at the top, insymbol gets a lot less goto labels, which I consider a major blow for sanity. There was no deliberate effort to get rid of gotos in the procedure, it simply fell out of the required changes naturally. The remaining **goto** target, 1, is just used to restart the scanner from the top.

insymbol gets a few new flags, including **ferr**, which flags an error during parsing, and **iscmte**, which indicates end of comment, and a few variable string pointers. **rvalb** buffers a complete "real string" (character representation of real). **ev** holds the value of a floating point exponent.

In **insymbol** routine **options**, we add a routine **switch**, which takes a var referenced boolean option variable, parses a '+' or '-', and uses that to set both the passed option variable, as well as set the letter based **option** table. If no '+' or '-' is found, it defaults to option on. The rest of **options** is refactored to use this routine, and the number of options is expanded. Finally, if an alpha character ('a'-'z') is seen, this is set as an anonymous option for the back end.

The first change, in the body of **insymbol** proper, was to treat control characters identically to spaces. This is made easy with ASCII/ISO 8859 character encoding, because all control characters are below a space, and printing characters above. Of course this makes the routine dependent on such character sets, but since even Unicode based programs would obey the rule, I believe it can stand.

The idea of ignoring all control characters is that the user can insert things like page feeds and any other control characters into the source without the compiler caring.

insymbol uses the character type table **chartp** to classify characters, and then uses that to divide up the different sections of insymbol according to what tolken they operate on. It exclusively operates on one character at a time, which is why multiple character sequences like '>=' must be handled as a check for a follow on character for '>', and why things like '..' must be rejected within the parsing of a number. Contrast this with the common technique where the current and follow character are simply selected from a table at the start of the scanner.

5.3.4.4.1 Letter: identifiers and reserved words

In the letter section, which parses reserved words and identifiers, we have added an error for reserved words and identifiers that are too long. In Pascal-P4, identifiers obeyed the rule that only the first 8 characters were significant, which was according to the original J&W rules. In Pascal-P5, overlength identifiers generate an error, but note that this would only occur on identifiers that were longer than a reasonable line length (250 characters in the current implementation).

Insymbol then searches the reserved word table to find if an identifier is a reserved word. This code isn't changed except for the use of the **strequri** function to accommodate the new larger **id** buffer. However, it also now checks if the length of the **id** is less than or equal to the largest reserved word, in which case the entire search is unnecessary. **strequri** also is a case insensitive compare.

We also initialize the **sy** and **op** variables before the loop, and thus get rid of the need for a goto.

5.3.4.4.2 Number: integers and reals

After the first series of digits are parsed, insymbol looks for a possible follow character of '.' or 'e'. The first signifies a decimal point, the second an exponent. **Insymbol** must reject both the symbols '..' and '.)', which look like a decimal point, but are the range and alternate for ']'. The first was done in Pascal-**P4**, the second is new with ISO 7185. To do the rejection, **insymbol** takes advantage of the fact that the input file buffer can look ahead one character.

The code for this was changed from Pemberton&Daniels even in the running version of Pascal-P4, because the goto 3 would not compile under ISO 7185 rules. The old code, which is still there but commented out, handled the '..' (range) case by seeing the second '.', and equating it to ':' (colon) and continuing. To understand why that made sense, you have to know that a subrange like 1:4 (for example) used to be valid in the first versions of the Pascal language, and through Pascal-P4 it was an acceptable substitute for '..'.

Insymbol now tolerates either case for the 'e' (exponent) character in a real.

Then next change is the handling of exponent in real. The old code didn't check for overflow in exponent, even though it did for the mantissa, so it was extended to also perform this check.

Next is the processing of the mantissa. We add a push to the constants list in the **display** for real constants. You'll note that **number** stores real constants in a constant entry, but lets the caller to **insymbol** handle it if it is an integer. In both cases, the number is left as a string.

In the case of integer, the numeric string is converted to an integer. In the case of real, it is left as a string in order not to impose **pcom**'s binary format limits on the compiler. The convertion to binary real format is left to **pint**.

In Pascal-**P4**, the real constant string is directly copied to the location in **val**. However, in Pascal-**P5** that is now a variable string, which means that Pascal-**P5** can store real constants efficiently. In keeping with the general theme in Pascal-**P5**, real constants are collected instead in a buffer **rvalb**, then the real constant string is copied to its final location in val by the **styrassvd** procedure.

5.3.4.4.3 Chstrquo: Strings

Chstrquo is changed to use the pshcst to process the new constant, then the string buffer is copied to a variable string by strassvc. Unlike other variable length strings, which are inherently right padded modulo the quanta with spaces, string constants have a specific length, as represented in **val** by **slgth**.

We clear the string buffer to start, and alsoremove the trailing quote. I believe this is for debugging, since the trailing quote is not accounted for in the length. The check for zero length strings is moved down into the string processing, past the check for single character. Finally, **strassvc** is used to transfer from the string buffer to a variable length string.

5.3.4.4.4 Chperiod: '.', '..' and '.)' tolkens

Here we get to say goodbye to a very old quirk of Pascal-P where the symbol '..' (range) is treated identically to ':' (colon). This is a holdover from a day when a range was specified as x:y instead of x..y, in an old version of Pascal.

In any case, **insymbol** now treats '..' as a range, and adds the '.)' symbol (as alternate to ']').

5.3.4.4.5 Chlparen: '('and comment start

chlparen must handle '(', '(*' (comment start), and '(.' (alias for '['). The follow on character of '*', '.', or other character determines which. If it is a comment start, **insymbol** checks for a comment option embedded with '$', just after the start of the comment. For comments, **insymbol** skips forward until the end of a comment is seen, which now must include '}'. The difference is handled via a flag, **iscmte**, to compensate for the fact '}' is a single character, and '*)' is two.

5.3.4.4.6 Chlcmt: ISO 7185 comment start

cmlcmt handles the fact that in ISO 7185, '{' can also start a comment. This case is very similar to **chlparen**, except that no follow on character need be parsed.

5.3.4.4.7 Lexical dump

A diagnostic was added at the end of insymbol to print the tolken that insymbol has parsed. This is simply a large (and yes, poorly formatted) case statement for all of the symbol types. Most of the symbols evaluate to a single string, but ident, intconst, and stringconst can print the actual value of the tolken as well.

5.3.4.5 procedure enterid

enterid enters a new identifier into the binary tree structure at the top display. The first change was to change it from declaring a local buffer, and copying **fcp^.name** to it. There was no real need for this copy, **fcp** is invariant in the routine, so it looks like the original authors were trying to save the need to perform an indirect field access.

In any case, it no longer makes sense in Pascal-P5. **fcp^.name** is a variable string id, and buffering it is no longer wise. So we eliminated the local copy, and changed the compares to **strqeuvv** and **strltnvv**.

5.3.4.6 procedure searchsection

searchsection takes the global **id** string (returned by **insymbol**) and finds it in a binary tree as rooted in the parameter **fcp**. Because identifiers are variable length strings in **P5**, the compare routines **strequvf** and **strltnvf** must be used.

5.3.4.7 procedure searchidnenm

In Pascal-P4, there was only one id search routine, **searchid**, which would search for an id with a given type (selected by a set of types), and if not found, both process an error and return a "dummy" entry which had the requested type, but could be used to suppress further errors by being recognizable as undefined, one of **utypptr**, **uvarptr**, **ufldptr**, **ucstptr**, **uprcptr** or **ufctptr**. Thus **enterid** was used to enter a new id, and **searchid** used to look up a previously entered id. There was a flag, **prterr**, which was used to suppress both the error print and the return of a dummy type. In Pascal-P5, we needed more complex search functions to handle searches where we may or may not use an id if found.

searchidnenm (search id with no error or type mismatch message) performs a search using both name and a set of possible types, but produces no error if not found, and instead returns a boolean indicating if the target was found, but has a type mismatch. This is used both for forward references (pointers), and to determine if a tag field is anonymous or is a field.

When parsing the identifier **mysel**, we don't know if it is an id for the tagfield, or the type of the tagfield itself. A follow on tolken of ':' tells us that, but by then, the id is gone. So a search to find if the id is a type finds this out for us.

searchidnenm gets most of the inner workings of **searchid**. The other routines become wrappers to it.

5.3.4.8 procedure searchidne

searchidne is somewhat misnamed, since it does print an error, but does not return a dummy type. Its only used in one place, which is to look up file variables that were found in the header and see if they were declared as variables. This is required in ISO 7185 for header files that are not predefined.

5.3.4.9 procedure searchid

searchid simply had the first half of it moved to **searchidne**. It is otherwise identical.

5.3.4.10 procedure getbounds

For **getbounds**, we added integers to the objects that bounds could be found for. This is used later.

5.3.4.11 procedure isbyte

isbyte as added to determine if a structure fits in a single byte. As detailed earlier, we treat integers that can fit in a single byte specially so that Pascal-P5 can self compile.

5.3.4.12 procedure basetype

basetype is used to remove any subrange qualifiers from a type. This makes all integer based types equal even if they are subranges. Recall that subrange types are to be treated as the type they were subranged from.

5.3.4.13 procedure alignd

alignd works the same way as alignu, but aligns down instead of up. Typically used to align the stack, which grows down now.

5.3.4.14 procedure printtables

This procedure is called when the user selects the **t+** option, for "print tables" (give a compiler dump). It has a few minor changes to cover any changes in the format of table items. These are detailed by subroutines of **printtables**. In the body of printtables, a header is now output that shows what the common fields mean.

5.3.4.15 procedure followstp

folllowstp got several magic numbers changed to equates, mostly to **intdig**. It was changed to use the **writev** procedure to output real constant **min** and **max** portions of a subrange, because real constants are now variable strings. Why would a subrange be real? Well, Pascal-P has an error in simpletype of "not implemented" for subranges of real, meaning that was planned at some point. Pascal-P5 should issue a hard error for that.

5.3.4.16 procedure followctp

As for **followstp**, many immediate constants were changed, usually to **intdig**. **followctp** had to be modified to output the identifier name field as a variable string using **writev**. It also is changed to output real constants and string constants this way.

5.3.4.17 procedure chkrefs

The procedure **checkrefs** tours the tree of identifiers in a given block and outputs a warning for any that do not have their referenced flag set. This is called at the end of each block with the root of the block id tree.

5.3.4.18 procedure searchlabel

searchlabel was added to support the ISO 7185 **goto** checking requirements. It finds a matching **goto** target label whose number matches the number found by **insymbol** in the given display level. This is returned as a pointer, or **nil** if not found.

5.3.4.19 procedure newlabel

newlabel does quite a bit of the processing to allocate a new goto label. It allocates it, places the numeric value of it from the insymbol value, generates an internal number for it and sets up all of its fields.

5.3.4.20 procedure prtlabels

Printlabels simply dumps all of the labels in the current display goto label list. It was used to debug the goto label system, and you will notice that it is not called anywhere. This is because I would place a call to it where I needed a label dump in the code.

Of course, your compiler may warn that the routine is not used. You can suppress this warning, or delete the routine as desired.

5.3.4.21 procedure block (header)

block begins the real meat of the compiler. Its actual body does not begin until much later, which is one of the complaints about Pascal's nested routine ability, that it can have its preamble so far from the actual body code (an issue that **forward** partially solves). The majority of the changes to block are in its subroutines.

In the declaration, **test** has been removed and placed into the routines that actually use it, which, curiously, was not **block** itself. **Test** is used for constructs like:

```
repeat

   { parsing code }
   test := sy <> comma;
   if not test then insymbol

until test;
```

It carries the status of the next symbol over **insymbol** so that it can control the loop. This is a common paradigm that eliminates the need for **goto**s and early exit constructs in Pascal.

Test was also used for more complex syntax tests.

Unfortunately, it was not only curious to have **test** declared, but not used in block (as Pemberton mentions), but actually wrong in places. The problem was that essentially making test global to all of block caused it to fail when a subroutine used test and changed the value of its caller. The answer was to move test to the routines that actually use it.

block gets a single new definition, **stalvl**, which is a counter that keeps track of the statement nesting level. This is cleared to zero within the body of block.

5.3.4.22 procedure constant

constant was modified to use the **pshstc** or "push structure" call to set up a structure for both string and real constants. We also set the "packing" flag on strings, since in ISO 7185, strings, which are defined as:

```
packed array [1..x] of char;
```

Must be packed. It matters now when comparing types.

When negating real constants, **constant** changed the sign by changing the '+' character at the front to a '-' character, and vice versa. Recall that reals are kept in string format. This was changed to use the **strchr** and **strchrass** routines.

A similar method is used to insert a sign later in this routine.

5.3.4.23 Function equalbounds

This function was removed. It was only called by comptypes (compare two types for compatibility), but comptypes does not compare for "equivalent structures" anymore. See the comments for comptypes.

5.3.4.24 function string (forward)

5.3.4.25 function comptypes

comptypes takes to structure pointers and returns true if they are compatible types. The method to check if the types are compatible changes completely with ISO 7185. The good news is that it actually becomes simplier. The reason is that the Pascal-**P4** compiler used “structural equivalence”, meaning that these two types would be equal:

```
type a = record a: integer; b: char end;
     b = record a: integer; b: char end;
```

Because the two record types have the same structure. This is difficult to implement, and **P4** recursively decended through the tree that forms a type and successively compared each level. It also needed a system to prevent loops through the links that pointers represent. It was also a fairly ambiguous system, and things like:

```
type a = record a: integer; b: char end;
     b = record a: 0..255; b: char end;
```

Were a problem. Are the types compatible? They might be physically different. It might depend on the packed status of the types.

In the ISO 7185 system, the above types must be identical or “named aliases” of each other. The system is easier to implement, less ambiguous, and very little added programmer effort is needed to use the system.

As a result, I find it easier to describe the way **comptypes** works from scratch, it is that different.

First, the result is set to be false, or no compare, by default. The first check is if the types are identical, that is, the two structure pointers passed in point to the same structure entry. Note that a named alias of a type has an identical structure pointer (see **typedeclaration**). I slight complication of this is handled with the function basetype, which simply removes any number of subranges from the type (and subranges can nest). Thus all subranges of the same base type are compared as the same.

Second, we check if both pointers are not **nil**. Having a structure pointer be nil is how errors are recorded. Note that the undefined types returned by **searchid** are all given **nil** structure pointers in **enterundecl**. If either or both of the structure pointers are nil, the result is a type match. It does not mean they actually match, it means that further errors should be suppressed.

Third, we check if the form of both structures are identical. The form is the scalar, set, pointer, or other type of structure. If these are equal, we proceed to a case statement that handles each form of type. These are then handled by ISO 7185 rules.

power (sets): Two sets are equal if they have the same base type and packed status, or if one of them is the empty set.

arrays: The only reason that arrays compare is if they are both string types (packed array of char, with 1 as the first index), and are also the same size.

pointer: Pointers must have the same base type, or aliases or one or both must be nil.

records, **files**: Must be the same type or aliases of that type. This is handled in comptypes preamble, so is not broken out.

5.3.4.26 function filecomponent

There are a few places in the ISO 7185 standard where either a file or a structure containing a file is disallowed. Examples include return types, assignments, and even files themselves. You can't have files of files[8]. Filecomponent is a classic recursive touring routine that explores the entire tree of a type by using its linkages. The only complication of it is that records are represented by a tree of the ids representing its fields. Recall that the fields of a record are represented by pushing a display level and then storing the resulting root of the symbol tree in the record as fstfld, because a record has its own scope.

5.3.4.27 function string (body)

string accepts a structure pointer, and returns true if the type is string. **string** was forwarded ahead of comptypes, which now uses this routine. It had to be forwarded, because **string** uses **comptypes**, and so they reference each other.

In Pascal-**P4**, string simply checked if the type was an array of character. The ISO 7185 demands are greater, and now **string** checks if the array is packed, and begins with an index of 1.

There is also a problem with string constants. They get an index type pointer that is nil (in **factor**). This is because string constants can have any given index type, which would have to be created anew on each string constant encountered. Instead, the index is simply set nil, and this is recognized where necessary.

This causes the problem with string, because it now needs the index type to be an existing type. In **P4**, the index type was ignored in string. **getbounds** is used to fetch the lower bound, with the high bound discarded, and **getbounds** handles a nil type. Unfortunately, it returns 0s for the bounds, which is the wrong answer (should be 1).

So **string** checks if it has a nil index type, and sets the lower bound to 1, skipping the **getbounds** call. Now the base type of the array is compared as in P4, but the test for lower bound equals 1 is added.

5.3.4.28 Procedure resolvep

This procedure gets the code that originally was in **typedeclaration**, and what it does is to go through the pointer forward definition list **fwptr** and resolve all of the entries found there[9].

To accomplish the forward reference, the pointer entry contains the identifier name it is forwarded to. The pointer entry is removed from the **fwptr** list, then the name is copied back to the id name buffer. We save the id buffer in ids during the routine run just to make sure we don't disturb an id there. Then we use **searchidnenm**, the no error search, to find the matching name, which would have been defined. If not, we output an error, as well as a diagnostic about what name was unsatisfied (this matches Pascal-P4 code). Then we discard the name to recycling from the pointer entry.

5.3.4.29 procedure typ (header)

typ contains **simpletype** and **fieldlist**. **test** and **ispacked** are added.

5.3.4.30 procedure simpletype

In **simpletype**, structure for enumeration is pushed into the recycling system. Why isn't there one routine to do both the allocation (new) of the structure as well is push to a recyle list? Because it is allocated tagged, and that is a constant operation. It now flags the structure as not packed. When the individual constants of the enumerator are created, the are initialized with **ininam** instead of pushed this is the id version of recycle tracking, because all ids are recycled at once when the tree they belong

[8] I have to admit that I have many times considered the uses of files of files.

[9] Aside from simplifying the code and refactoring search, I'm not sure why this was functionally necessary.

to are recycled, when the display is torn down. It then checks if the resulting size can fit into a byte, and resizes the enumeration to 1 if so.

For ids, it must be either a subrange or a type id. We record the structure using pshstc. Now is a good time to deep dive into what seems to be a trivial change:

Pascal-P4:

```
begin rangetype := idtype; form := subrange;
```

Pascal-P5:

```
begin form := subrange; rangetype := idtype;
```

What happened here? form is a tagfield, and rangetype resides in the variant subrange, as selected by form. Is that variant valid before the tagfield form is set? Nope. The Pascal-P4 compiler is full of little gotchas like that. In fact, Pascal-P5 was the one that caught these. After ISO 7185 checks went in, and I tried to self compile, these sorts of errors started to crop up.

After this, we again turn off packing. Then, the check for colon is changed to range. Recall the conversation above about 1:2 being a valid subrange in old Pascal?

After this, there is no id, and we know that the type must be <const>..<constant> subrange. We create the subrange, push to recycling, and turn off packing. When the subrange is done, again check for byte sizing and modify the size of the subrange accordingly.

5.3.4.31 procedure fieldlist

fieldlist is impacted mainly because of the increased checks built into the Pascal-P5 compiler, which are complex. The checks added to the Pascal-P5 compiler mainly concern variant records. Tagfields are checked for valid assignments, accesses to variants are checked to see if the variant is active (by examining the controlling tagfield), and if the tagfield does not exist (anonymous), it can be forced to exist so that automatic checks can be done.

All of these checks are performed elsewhere. However, the data to generate such checks, including where the tagfield is, what values are valid for it, and what variants correspond to what tag values, would generate expensive and redundant searches in the checking code. Thus **fieldlist** gets a new job, which is decorating structures with pointers on where to quickly find the information needed, along with other information.

To the original fieldlist parameters we add **vartyp**, an in parameter that carries the head of the variant list, and **varlab**, an in parameter that carries the tag field controlling that variant (which could have a **nil** label if it is anonymous). Finally,an in parameter **lvl** counts the number of enclosing levels of field lists there are. The **vartyp** and **varlab** parameters are passed in as nil from the first call to **fieldlist**, meaning "no variant", but when a variant is parsed, these parameters are passed down from the tagfield and used on all the fields in the record, including an enclosed tagfield.

A **test** variable is added, as well as a **mm** flag. test was always used, but was left to use the one from the enclosing scope **typ**, which was unnessary[10]. **mm** is used as a dummy search parameter.

As per usual, the field identifier entries gathered in the first part of fieldlist are tracked using ininam. This counts the entry for recycling purposes, as well as clears common flags.

[10] As said elsewhere, I try to refrain from such "code improvements", but sometimes I can't resist.

The identifier **variant field** has several new fields that get set at this point. **varnt** gives what variant entry this field belongs to. **varlb** gives the identifier entry of the controlling tag. Admittedly it can be confusing here why we need both. **varnt** is used to access the list of case constants for variants, and **varlb** is used to address the tagfield. Continuing, we initialize tagfield to false. This field gives rapid identification if the field is a tagfield or not, and is used for various tagfield checks. Then, **taglvl** is set to the variant nesting level. This is used as a table index when we validate tagfields.

varnt and **varlb** give sufficient information to generate tagfield validity checks. When a field address is being resolved, we can stop after the record address is resolved, and before the field offset address is calculated and check the tagfield values, made easy because the tagfield will, by definition, be the first field in the record, and thus have an offset of 0.

varnt and **varlb** are a bit redundant, and perhaps could have been derived. This goes to the point that Pascal-P5, breaking with Pascal-P, does not emphasize runtime data compactness as much as previous versions.

varsaddr and **varssize** are used to carry the offset address of the variant “area” and its size. The variant area starts after the tagfield and contains all possible variants defined. Its size is the maximum size of all possible variants. This information is used to do ISO 7185 error checking in assignments as I will cover later.

Continuing in the source, **align** is changed to **alignu** to cover the fact that we now have both up and down alignments.

The second half of fieldlist is the variant record part. The tagfield structure is created, and we push it to recycling. Packing cleared (again, because we must set all variables due to increased error checking in Pascal-P5).

Here the code differs quite a bit from Pascal-P4, because it didn’t implement undiscriminated variant records. We use the new search function searchidnenm to “probe” if the identifier is the name of a tagfield or just a type. We put the potential type in lcp1. The tagfield itself is set up as in standard field above in lcp. The possible tagfield id is not entered into the symbol table yet. If ‘:’ is found, indicating a type, then we enter lcp into the symbol table, move forward to the type id, and search for a type. Otherwise, we flag an error if lcp1 doesn’t contain a type (search failed above) and set it to usclrptr, a new undefined entry pointer. If the mm flag was set on the search, we flag an “inappropriate class” error. In any case, the name of the tagfield, which was set to the type name, not the field name, is recycled and we replace the name pointer with nil. This nil value is used across the compiler to tell that the tagfield is anonymous.

From there we again change **align** to **alignu**. Then, the tagfield is allocated and located as in Pasca-P4, but if the tagfield is anonymous or has an undefined type, we don’t move the allocation base tracking value displ forward by the size of the tagfield, meaning it has no allocation (but it did get an address before; it is located, but not allocated).

After that, we remove the Pascal-P4 insymbol call and subsequent error handling. This got moved back, since we handle it right after the ‘:’ was parsed.

After the tagfield is handled, we move on to parsing variants. As usual, the new variant is pushed into the recycling system. Then, we set a new field, caslst, which keeps a list of variants that hold the constant values of that tagfield. We also clear the packing flag.

Next we set the **varsaddr** and **varssize** of the tagfield, which contains the base offset of the variant area, and the total size of the variant (the maximum of all variants). Before the variant is parsed and allocated, we align the allocation, displ, to the nearest whole word size. This just means that whatever the variant holds, we use "worst case" alignment for it, and usually a pointer is worst case. If the tagfield exists, we set **varsaddr** from the base before the variant is parsed. After the variant parse, and the calculation for maxsize is done, we set the **varssize** of the tagfield.

The **varsaddr** and **varssize** are assigned redundantly for each variant that gets parsed. Only the last variant that is parsed is relivant.

5.3.4.32 procedure typ (body)

Pointer: The new pointer structure entry gets pushed to recycling. We set the **packing** flag false as well.

We handle forward referenced pointers a bit differently than Pascal-P4. We don't search for the pointer id, but rather just put it into an identifier entry and push it onto the forward pointer list **fwptr**. This means all pointer references get handled by forward reference. This has the effect of simplifying the code in several places.

The **prterr** flag (suppress search error) is gone, and we just create an identifier entry for the pointer with the given base type as a name. This is just a dummy entry, and will be discarded when the pointer forward reference is complete. The entry is then pushed to the **fwptr** list.

Pascal-P4 had code to determine if a file type was the base type of the pointer, and rejected it as an error. Thus the original Pascal apparently considered this an error, but not ISO 7185 Pascal.

The refactor for how pointers work appears to be mainly to clean up the search code. In Pascal-P4, pointer types were forwarded and checked for undefined at the end of **typedeclaration**, and only checked for undefined at the end of vardeclaration. In pascal-P5, both simply call **resolvep** at the end, so both could both resolve forwards as well as check for undefined forwarded pointers. However, since there has to be a **typ** section to define a type for forwarding, **vardeclaration** could never actually do that. It does become interesting in Pascal-P6, because that language allows multiple out of order definition blocks.

After pointers, any **packed** attribute is parsed. In Pascal-P4 this keyword is just skipped. In Pascal-P5 we actually do something with it, so the flag **ispacked** is set or not set accordingly.

array: Array is mostly unchanged. The **arrays** structure entry is pushed to recycling. The **packed** flag is set according to **ispacked**. The call to **align** is changed to **alignu**.

record: Record throws a new display level, and we initialize the new fields **fconst**, **fstruct** and **packing**. The call to fieldlist is changed to include dummy parameters for the variant list, variant label, and variant nesting level.

After parsing the record description with **fieldlist**, the **fname** root is cleared. This prevents the recycling code from recycling the names, which are kept with the record and recycled when the record type itself is recycled. The packing for the record is set. As with **fname**, the recycler structure list **fstruct** is removed from the display and kept with the record, to be recycled when the record is. Finally, the display is send to recycling with **putdsps** (which will recycle all nested displays created by **fieldlist**), and then the record entry itself is pushed into the recycling system. The code bears a note that the operations must be done in that order.

set: Sets are mostly unchanged. The power structure entry is pushed into the recycling system. The packing flag is set by **ispacked**. The new power flag **matchpack** is set, which suppresses packed status matching in comptypes. It is only used to suppress packed matching with empty sets, for which packing has no meaning.

file: In Pascal-P4, files as a type were not implemented, although most of the file mechanisims are implemented for header files. Pascal-P5 implements files as a temporary/anonymous construct, with arbitrary base types (done by retyping everything as byte)[11].

The of tolken is parsed, then **typ** is used to parse a type. The file structure entry is created and pushed to the recycling system. It gets initialized to its base type. The file size is set to **filesize** plus the size of the base type. The packing status is set to **ispacked**.

Ok, so here comes a few tricks. The size of a file is just a byte, because all of the mechanics of the file are hidden in the back end. The "file" as an object is just a 0-255 number that is used to look up in a table of file control structures, which (at this writing) is limited to a total of 100 outstanding files. This means, technically, that lots of stuff forbidden in ISO 7185 like files of files, structures containing files, assignment of one file to another, etc., these actually could exist without issue[12].

The business about adding the size of file type (byte) and the size of the base type means that each file has the form:

0: File id.

1 – n: File buffer variable.

So each file also has space for a buffer variable associated with it.

5.3.4.33 procedure labeldeclaration

labeldeclaration got refactored quite a bit by creating the routines searchlabel and newlabel. Thus labeldeclaration is practically a new routine. After parsing an integer constant, an existing label is searched for by value. Then if found, we flag a duplicate label. After that newlabel is used to create a label.

Goto labels change quite a bit in Pascal-P5. Part of this is because gotos can cross from one procedure to another (so called "Interprocedural gotos"). The other part is because the requirements to check the validity of such gotos increases dramatically. The code to do this is scattered in different procedures and will be discussed.

5.3.4.34 procedure constdeclaration

For constant identifiers, **ininam** is used to enter into the recycle system. The assignment of the name changes from simple array to variable. Note the assignment is from fixed string (buffer) to variable. Then the **refer** flag is cleared.

5.3.4.35 procedure typedeclaration

First we use ininam to enter the identifier into the recycling system. A fixed to variable name assignment is done.

[11] For which many readers seem to feel a burning desire to implement external file name association. Knock yourself out. Also note that Pascal-P6 implements that.

[12] I personally like the idea of files of files, and this was effectively implemented in early Pascal compilers by using "segmented" files. However, even Pascal-P6 does not implement that.

After that, the main changes are to remove the forward pointer reference resolution, as well as the generation of errors for unresolved forward references. This is all left to resolvep, as covered earlier.

5.3.4.36 procedure vardeclaration

As before, **vardeclaration** gets **ininam** for recycling, variable length assignment for the name, and initializes the new flags **refer** and **threat**, and clears the for loop nesting count. When the variable is allocated, we now differentiate between global variables, indicated by a scoping level of <= 1, and > 1, which are locals. Globals allocate upwards, locals allocate downwards (since the stack now goes downwards). Globals are aligned upwards according to type, and locals are allocated downwards according to type.

Finally, the code to check undefined forward pointer references is replaced by the procedure **resolvep**.

5.3.4.37 procedure procdeclaration (header)

A lot is changed with procdeclaration. The header parameter markp is removed, since we don't use mark/release anymore. A routine is added, called pushlvl.

5.3.4.37.1 Procedure pushlvl

pushlvl systemitises the creation of a new display level. The main reason it was needed is because Pascal-P5 allows procedure/function parameters, whereas Pascal-P4 does not. Pascal-P5 needs to push a new display level for procedure/function parameters as well as regular procedure/funtions, so it made sense to put that in a routine.

The header flag **forw** indicates if the level is for a forwarded procedure/function. The parameter **lcp** gets the identifier entry for the procedure/function.

If the number of allowable display levels is exceeded, we flag an error. This is 255, meaning 255 levels of nested procedures or functions. We do this again by checking top, the current display level, against its limit, which is 300. A new display entry is pushed, and its fields initialized. If the procedure/function is forwarded, the display name root gets the parameter list for the procedure/function, otherwise nil. This only happens if the procedure/function has been forwarded, and thus does not have its parameter list. So the display needs to start with the parameters defined.

5.3.4.37.2 procedure parameterlist

Most of the changes for parameterlist are due to the implementation of procedure/function parameters. The Pascal-P4 code had an implementation for it, but it was flags as an error.

New locals **oldlev** and **oldtop** are used to save the current display settings. **lcs** is used to save the locals offset count **lc**[13]. **test** is added because the routine uses a non-local test (the one that is in block), a bad practice.

The handlers for procedure parameters and function parameters in Pascal-P4 are actually not far off Pascal-P5. I kept the comment "beware of parameter procedures" because it is too funny to take out. The error 399 is removed ("feature not implemented"). lcp gets set to nil to indicate no procedure name was found. The procedure name is sent to ininam and the recycling system. Then we allocate mp (mark pointer) and the procedure/function address under the parameters and align lc to pointer.

The name of the proc/func is assigned fixed to variable. pfaddr is set to lc. The keep flag is set on. pfaddr is the base address of the address/mp pair used to call a procedure/function parameter:

0: Address of procedure or function

[13] It's a theme that if I introduce a variable to save another, I add an 's' at the end.

4: Mark pointer for that function.

We need this pair to call a procedure/function parameter, because the called function gets the context from the caller that passed the parameter.

I removed Pascal-P4's align and comment about allocating the parameter. Then we save the display parameters, push a new display level, and parse a parameter list. The original Pascal language didn't require that a parameter list appear with procedure/function parameters. ISO 7185 does. It is used to compare the parameter list of declaration with the parameter list of the caller for congruence. This parameter list is stored in the procedure/function parameter as pflist. Then the display level is backed out, and the entries within it sent to recycling.

The processing of function parameters is very similar to procedure parameters, except the function result type is parsed, a type is searched for, and validated to be a scalar, subrange or pointer.

For **var** and value parameters, we use ininam to register the identifier with recycling, then use fixed to variable string assignment to set the name. We initialize several fields of the identifier, including **keep**, **refer** and **threat**. The **keep** flag is how we keep parameter lists out of the recycling system until the procedure/function the list belongs to falls out of scope. The old Pascal-P4 code made sure the identifiers and their type stayed in the scope they were declared in. Another way to think of the **keep** flag is as saying "this entry is tracked elsewhere, and will be recycled elsewhere as well".

After that we add an error for missing parameter idents. I admit I am mystified why that error was not detected in Pascal-P4.

Next, there was a check for if the parameter was a file as a value parameter. We extend that to include any type with a file component as required by ISO 1785.

Next we change **align** to **alignu** (for size of parameter), and change the allocation to **alignd** or "align down" because locals go downwards now. This also required changing the order from "align, then allocate" to "allocate then align".

This allocates parameters using lc or "local offset", but then we transfer allocations to the vaddr field of all entries within that type group. Since the type is the same, the aligned **lsize** is the same as well.

If we didn't see a type id, we flag an error as in Pascal-P4, but we also remove all of the keep flags so that the (erroneous) parameter list will be recycled. This again occurs if the ':' to introduce types is not seen.

Finally for **parameterlist**, there is the code that reserves cells to make local copies of value parameters. We change the **align** to **alignd** ("align down"), and reverse the order to alignment and allocation, as well as reorder the assignment of **vaddr**. When the locals grew upward, **vaddr** was set before moving **lc**, now it is set after because the locals grow downwards.

5.3.4.38 procedure procdeclaration (body)

After the procedure/function identifier is created, **ininam** is used to enter the recycle system, then fixed to variable is used to assign the name. Then we also set the asgn flag (which records if a function was assigned a result), and refer flag.

If the procedure/function is forwarded, we run a pass over the parameters to refresh lc (locals offset counter) to the correct location. Note that we don't use the size anymore because the downward direction of stack means the correct location of the "next" **lc** offset is the same as the address of the last parameter. The parameter list is contained in **pflist**, as opposed to the old Pascal-P4 convention of putting them in the next field. This appears to have been done to neaten up the code.

At the end of the “id not found” error 2, we change the lcp set from ufctptr (undefined function pointer) to a selection of undefined pointer based on if a function or procedure is being parsed.

Following, we replace the code to push a new level with **pushlvl**. Then, after calls to **parameterlist**, we place the list into the **pflist** field as discussed above.

At the test for **forwardsy**, we replace this with a test for **ident** and if the **id** is “forward”. This is the required test for ISO 7185, which does not consider **forward** to be a keyword, and it was removed from Pascal-P5 as previously discussed[14].

Next, the call to **mark** is removed as discussed.

After the procedure/function block is parsed, we check if the result was assigned to, and issue an error if not. This is suppressed if the function is undefined.

The call to **release** is removed, as discussed.

At procdeclaration end, we add a call to putdsps to complete recycling.

5.3.4.39 procedure body (header)

The procedure **body** is where most of the remaining code in Pascal-P is located. It is where all of the code generation occurs. It is also, coincidentally, the midpoint in the source.

In the locals for body, oprange gets a constant instead of a magic number. **saveid** changes to **idstr** from **alpha**. There are actually a couple of different string types based on what they are used for, and some of them have routines to translate to and from variable length strings.

gblsize complements **segsize**, and is the total size of the globals segment **pint.pas** needs to know this for where to start the heap, and similar tasks.

topmin replaces **topmax**, which just reflects which way the stack grows (downwards). The same comment applies to **lcmin** replacing **lcmax**[15].

The rest of the locals are pretty much working variables. **fp** traverses the files list. **printed** is a dummy variable.

5.3.4.40 procedure addlvl

In ISO 7185, the ability to goto any point in code is distinctly restricted. In reality, on any practical compiler, it is restricted simply because any stack activity that adds something to the stack (the statement with comes to mind), jumping into that statement is a bad idea.

Thus in Pascal-P5, we track where statements begin and end religiously. **addlvl** simply increments the statement level, and was added as a complement to **sublvl**, which has more to do.

5.3.4.41 procedure sublvl

sublvl both decrements the statement label, and as well purges the flabel list from the current display when the statement labels it contains fall out of activation. A label no longer being in active code is

[14] And I have registered my opinion on that change. In Pascal-P6/Pascaline, it is a keyword once again.

[15] It is a point of the science of refactoring: do or do you not replace variable names that no longer match their function.

flagged with the **bact** label field, which is new with Pascal-P5. We could just remove and recycle the label, but instead we keep the label entries and let them go into recycling when the display level is removed.

The minimum active statement level is tracked by **minlvl**. This is used for the **goto** verification algorithim.

5.3.4.42 procedure mesl

The Pascal-P4 tracks the level of its stack by consulting a table of stack offsets that each instruction makes to the stack. For example a push of integer substracts the size of an integer from the stack, so the table contains -4. This is the **cdx** table. In Pascal-P4 this table was fairly simple, because each item on the stack was the same size, since the runtime stack was basically a series of variant records. Thus integers, reals, even sets and other values, occupied the same stack entry. Thus the **cdx** table was a series of 1's and -1s. This does not work with the byte machine that Pascal-P5 uses, where different types occupy different numbers of bytes.Of course that's why the **cdx** table exists, and a lot of the adaption was taken care of by just entering different values in the table.

There are a couple of items that weren't taken care of by the **cdx** table. These are handled in two ways. First, various exceptions are handled by the generator code (this method has always existed, including in Pascal-P4). Second, I introduced the tabld **cdxs**, or **cdx** secondary, which expands opcodes into one entry per operand type. This means that instructions like inc, which have different stack effects for different types of operand types, can be looked up again by using the code from the **cdx** table to index the cdxs table by using the **cdx** code and the type code. There is no special indication for which **cdx** table entry is a secondary lookup, it is done entirely by context. In practice, this works quite well.

At any rate, I introduced **mesl** (meaning mes level) that uses a direct stack offset to change the current stack offset, and the old procedure mes calls that. **mesl** then is called at several points in the code where the stack tracking must be handled by exception to the cdx/cdxs system. **mesl** both changes the current stack offset represented by topnew, as well as throws an error if the stack underflows (meaning that the number of pops exceeded the number of pushes). This error, **500**, is key: if the table offsets are not correct you will see this error. The other place you will see this error is in the code for body, where the stack is checked for 0 at the end of each program, procedure or function block. That is, the stack must unwind to zero.

Of course all the stack offsets are negative.

5.3.4.43 procedure mes

As described above, the contents of **mes** got moved to **mesl**. Now, **mes** just performs the **cdx** lookup for the opcode and sends the resulting stack offset to **mesl**.

5.3.4.44 procedure mest (header)

5.3.4.45 procedure mestn

Performs the lookup of a type code from a structure entry. If the structure entry is not nil, a lookup gives separate types for each type of structure. Scalars are broken down by the type of base entry. If there is no structure entry (it is nil), then a default of integer type is selected.

The type code is one of:

Code	Type	Instruction Memnomic
1	integer	i
2	real	r

3	boolean	b
4	char	c
5	file or pointer	a (address)
6	set	s
7	record or array	m (apparently for "multiple")

5.3.4.46 procedure mest (body)

mest is the type specific version of mes. It accepts both an opcode and a structure entry. The opcode entry in **cdx** is first validated for a type code (1 to 7). There is no particular need for this, it is just extra checking[16]. Then, a lookup is performed using the cdxs table indexed by both **cdx** "second table" code and the type code, to arrive at the final lookup for a stack offset.

5.3.4.47 procedure putic

No change.

5.3.4.48 procedure gen0

No change.

All of the gen routines accept an opcode number, some number of parameters, and then generate the corresponding intermediate codes, assembly instructions for pint.pas. Thus as I added new instructions, you will find most of the processing in additions to these routines.

The processing in the gen routines can vary from simple to complex depending on the instruction code. gen0 just outputs the instruction memnonic. **gen2** handles many instructions in different ways, using 2 parameters.

The gen routines come with both 0 to 2 parameters, as well as 0 to 2 parameters with a type.

5.3.4.49 procedure gen1

First, we add a variable length string pointer to process strings. Then, we can remove the processing for the pdx table result (**pdx** is the same as the **cdx** table, but for system routines, not instructions) and replace by a **mesl** call.

For opcode 38 (lca or "load constant address") this is used to output a string. In Pascal-P4, a string was output and space padded to the full length of all strings. In Pascal-P5 the length of the string is output, followed by a single quoted string of just the left non-space characters in the string. The net difference is that we leave it up to the back end (pint.pas) to expand the string to its full right padded length. The other difference is that single quotes contained within the string are expanded to double quotes so they will be unambiguous. Pascal-P4 didn't have this issue because it knew exactly how many characters were in the string, and so just eats characters and discards the ending single quote. The net result of this is that the intermediate file looks better, and in addition we don't output ridiculous padded strings to the ultimate length of strings in the compiler (currently 250 characters).

I added the instruction 67 (cip or "call indirect procedure", for procedure/function parameters). Instruction 42 (ret) gets handled specially, And the reason for this is that most ret opcodes are typed because they are functions returning a type, but the ret for procedures is not typed. The entry in the **cdx** table is reserved for typed ret, so we avoid it and directly enter the stack offset, which is 0, since procedures have no net effect on the stack.

[16] On the other hand, its amazing how many mistakes were flagged by this error while developing the code.

5.3.4.50 procedure gen2

gen2 is the busiest gen procedure, both in Pascal-P4 and Pascal-P5. The first case just prints the opcode memnonic and the 2 parameters as numbers, to which we add 74 (lip or "load indirect procedure"), 62 (pck or "pack"), 63 (upk or "unpack"), 81 (cta or "check tag assignment"), and 82 (ivt or "invalidate tagged variant").

For cases 47, 48, 49, 52, 53, and 55, which are typed instructions that pass a type character (see mest above), we translate the type character to a type number and look up the offset in the cdxs table.

In case 51 (ldc or "load constant"), we get to see the complete opposite of the "type as letter" method, here the type is passed in as a number from 1 to 6 (of the 7 possible types). I needed to change the generation of this instruction to use the **cdxs** type system. This follows mostly the **cdxs** table for 51, namely table 6. As you no doubt have found out by now, one of the side advantages of the **cdxs** secondary lookup table system is that some of the instructions can share tables with others.

The other issue with this instruction is that the numbers don't quite follow the type convention given above (which was my convention, after all). Thus I need to describe the subcases in detail.

case 51 subcase 1 (integer) uses a standard **cdxs** lookup, but performs that in line, since there is no structure entry to use as type[17]. Subcase 2 (real) is the same, but uses a variable string write to output the real (remember reals are kept as strings in Pascal-P). Subcase 3 (boolean) is also derived from cdxs. Subcase 4 (nil pointer) simply uses the size of pointers as its offset. Subcase 6 (char) gets translated to cdxs table 6 entry 4 (char), but I also put in a check for printable characters, made easy by the character type table **chartp**. If it is not printable, it gets output as a number. pint.pas can accept character constants as either quoted single characters or numbers, so that works out, and cleans up the intermediate. Subcase 5 (set) uses **cdxs** table 6 entry 6 (set). You will note the code makes no attempt to output ranges, so constant sets could get quite long. This would need to be fixed in an installation with longer set sizes than 256 elements.

5.3.4.51 procedure gentypindicator

In this routine, a check is added to both scalar and subrange cases for byte values (determined by size of 1). They are output as type 'x'. Why not 'b' (for byte)? Because that was taken by boolean.

Also files now gets a type 'a' (address), since files are now a thing in Pascal-P5.

5.3.4.52 procedure gen0t

This routine gets one change, which is to use the typed version of **mes**, **mest**. It already had a type parameter **fsp** (the genxt routines don't consider the type, passed by a structure pointer, to be a parameter).

5.3.4.53 procedure gen1t

I added a space before the numeric parameter output **fp2**. This change gets done in a lot of places, and continues in Pascal-P6. Why? Because in a statement like writeln(x, y:10) is that if the number overflows the space provided, you get "yyyyyxxxxx", ie., no spacing at all. In the case of Pascal-P intermediate, this can be fatal, since in several places pint.pas relies on the operands of instructions to be spaces off. So restating it as writeln(x, ' ', y:9) changes it so it occupies the same space, but the leftmost space is "hard" and will never be overwritten.

The **mes** is converted to **mest** as detailed above.

[17] This whole system of types as numbers could probably use cleanup.

5.3.4.54 procedure gen2t

This routine gets the same two changes, space and **mes** to **mest** as **gen1t**.

5.3.4.55 procedure load

The first change is just formatting, which I generally try to avoid. The second is to remove subrange types on loaded expressions. This was required for byte variables. If a byte scalar is loaded, it is expanded automatically to the size of a basic stack element. Thus it looses its original size as byte.

5.3.4.56 procedure store

Unchanged.

5.3.4.57 procedure loadaddress

Also clears the packing flag on the gattr record it is loaded to.

5.3.4.58 procedure genfjp

Unchanged.

5.3.4.59 procedure genujpxjp

Unchanged.

5.3.4.60 procedure genipj

This is a new routine, and it handles interprocedural jumps, that is, jumps from one procedure to another.

5.3.4.61 procedure gencupent

gencupent stands for "generate cup (call user procedure) or enter (perform entry to procedure). Here I readily admit I created a neatness. The enter instructions used to be ent1 and ent2, which I found to be very unmemnomic. So I changed them to ents (enter stack allocate) and ente (enter and set extent of stack). They were coded by the numeric parameter fp1 as 1 or 2, and I changed the code to select 's' or 'e' at the end. Also, the stack offset is determined by the cdx table address for the ents and ente instructions, but directly by parameter for cup. The reason is that the stack essentially starts at 0 at procedure/function entry, but for cup it is determined by the number of parameters on the call. This will seem strange as **callnonstandard** passes **locpar**, the space in parameters, as a positive value, until you realize that the parameters stacked and moved the stack bottom down, and so adding **locpar** moves it back up, erasing the parameters off the stack. Since the called procedure/function removes its parameters, that is essentially what happens after the cup instruction[18].

5.3.4.62 procedure genlpa

genlpa is a new routine that generates a lpa (load procedure address) instruction.

5.3.4.63 procedure checkbnds

checkbnds is extended to also generate a bounds check on sets. It does this by using the base type to determine the subrange of the set that is to be checked within, or the total set elements that are valid for assignment. This is done by the **chks** (check set) instruction. It uses the bounds and finds if any set elements exist outside the valid range.

5.3.4.64 procedure putlabel

Unchanged.

5.3.4.65 procedure statement (header)

Unchanged (see body for further changes).

[18] I have to admit that, looking at the Pascal-P4 code, I am mystified as to how it worked, or if it did work.

5.3.4.66 procedure expression (header)

Expression gets a new header parameter, **threaten**. threaten tells expression that the object of the expression can be a threat to a variable. Its only used in factor when a variable reference is being parsed, and it is only set when passing a var reference in a procedure/function call.

5.3.4.67 procedure selector (header)

id is added, which is rather misnamed, since it holds a type (structure). It is used to help process references to a function result.

5.3.4.68 procedure schblk

This simple routine is used to find a block (program/procedure/function) in the active display stack by looking for the identifier for that block. It is used to validate that the block for a function result is active. In ISO 7185 rules a function result can be accessed either in that function itself, or any enclosed block.

5.3.4.69 procedure checkvrnt

checkvnt is used to generate a check for a field contained in a variant, as to if that variant is active or not. The check is designed to be "transparent", that is, it happens just after we have developed the address of the containing record, and leaves the stack in the same state as before (as well as the code).

checkvnt first checks if the **chkvar** flag is on, then checks if the identifier being accessed is a field, only performing the check if both are true. Then, it loads the identifier and the structure of the controlling tag field. If the structure pointer is nil, the field is not part of a variant, so we don't produce the check. Also, if the name of the tagfield is nil, this indicates an anonymous tagfield (undiscriminated union), and again we don't perform the check, since there is no tagfield to check[19].

The tagfield is then setup using the **fldaddr** and **load** used to bring it's value to the stack top. If the access mode is direct, it is processed using a field offset. If indirect it is loaded via the base address of the record already on the stack, and so it will generate a dupa or "duplicate address" so that the original field address is preserved for the field access that called for the check. In practice the indirect access will be with a 0 offset, since all variants (in Pascal-P5 at least) have the tag field as the first field.

Again because this is a transparent operation, a local, gattrs, is used to save the gattr structure and restore it after the check operation is complete[20].

5.3.4.70 procedure selector (body)

selector starts by initializing a few more fields to gattr than before, for various modes and checking. The structure of Pascal-P is such that operands get loaded into gattr and are carried along during code generation, occasionally requiring gattr be copied elsewhere[21]. One of the results of this is a lot of the new flags and controls I introduced on identifiers in Pascal-P5 have to be copied to gattr on load, and that is done in selector.

[19] There is actually a `chkudtf flag to force checking on Undiscriminated unions, and it is not complete in Pascal-P5, but did go into Pascal-P6.`

[20] Try ***that*** in C!

[21] And in fact is a pretty good example of why not to over-rely on globals.

5.3.4.71 procedure call

5.3.4.72 procedure variable

5.3.4.73 procedure getputresetrewriteprocedure

5.3.4.74 procedure pageprocedure

5.3.4.75 procedure readprocedure

5.3.4.76 procedure writeprocedure

5.3.4.77 procedure packprocedure

5.3.4.78 procedure unpackprocedure

5.3.4.79 procedure newdisposeprocedure

5.3.4.80 procedure absfunction

5.3.4.81 procedure sqrfunction

5.3.4.82 procedure truncfunction

5.3.4.83 procedure roundfunction

5.3.4.84 procedure oddfunction

5.3.4.85 procedure ordfunction

5.3.4.86 procedure chrfunction

5.3.4.87 procedure predsuccfunction

5.3.4.88 procedure eofeolnfunction

5.3.4.89 procedure callnonstandard

5.3.4.90 procedure compparam

5.3.4.91 procedure expression

5.3.4.92 procedure simpleexpression

5.3.4.93 procedure term

5.3.4.94 procedure factor

5.3.4.95 procedure assignment

5.3.4.96 procedure gotostatement

5.3.4.97 procedure compoundstatement

5.3.4.98 procedure ifstatement

5.3.4.99 procedure casestatement

5.3.4.100 procedure repeatstatement

5.3.4.101 procedure whilestatement

5.3.4.102 procedure forstatement

5.3.4.103 procedure withstatement

5.3.4.104 procedure block (body)

5.3.4.105 procedure programme

5.3.4.106 procedure entstdnames

5.3.4.107 procedure enterundecl

5.3.4.108 procedure exitundecl

5.3.4.109 procedure initscalars

5.3.4.110 procedure initsets

5.3.4.111 procedure inittables

5.3.4.112 procedure reswords

5.3.4.113 procedure symbols

5.3.4.114 procedure rators

5.3.4.115 procedure procmnemonics

5.3.4.116 procedure instrmnemonics

5.3.4.117 procedure chartypes

5.3.4.118 procedure initdx

6 Changes to the assembler/interpreter

When it comes to pint.pas, the files between Pascal-P4 and Pascal-P5 are so very different that it does not really benefit from a “list of differences” type description. In addition, pint.pas is a fairly short listing at 2958 lines. Thus I decided to write a “from scratch” description of how pint.pas works in Pascal-P5.

7 The intermediate language

The intermediate language for Pascal-P6 is in the form of an assembly language file for the abstract machine called the P-Machine. Each instruction in the intermediate specifies the semantics of operations in the language.

7.1 Format of intermediate

The intermediate has the format:

<main code>

<start code>

<further prd input>

The main section contains all of the generated code, except for a startup section:

```
mst       0
cup  0  l  3
stp
```

The main section is assembled past the startup code, then the assembly location is restarted and the startup section is assembled, placed under the main code.

After both the main code and start code sections, the contents of the prd file are not read. The interpreted code can keep reading from the prd file at this point. This means that input for the prd file as used by the interpreted program can be concatenated to the intermediate file. This feature is used for the self compile and run.

7.2 Intermediate line format

For each line in the intermediate, the first character indicates:

Character	Parameter(s)	Description
!	<arbitrary characters>	Indicates a comment, the rest of the line is discarded.
l	<number>	A label. Used to establish jump locations in the code.
q		Marks the end of the main code or startup code section.
(blank)		An intermediate instruction.
:	<number>	A source line marker.
o	<options>	Passes the settings of all options to the backend.
g	<number>	Passes the total size of globals to the back end.
v	l<label> <size> <logical variant numbers>	Passes a "logical variant table" to the backend. Size indicates the number of logical variant numbers that will appear.
f	f <number>	Number of source code errors found by pcom.

7.2.1 Comments

A comment appears as:

i<any text>

Comments are used to generate any descriptive text in the intermediate. They are also used to output a marker every 10 intermediate instructions, of where the "logical program count" or index of instructions, is currently located in the intermediate with a marker of the form:

i   n

Where n is the logical program count.

7.2.2 Source lines

A source line marker appears as:

: n [<source line>]

The number given is the source line number, 1 to N, in the source being compiled. The compiler also has an option to pass the entire source line, so that the intermediate is annotated with the original source. If the source lines are included, it appears after the line number and a space.

7.2.3 Label

Label lines are of the format:

l m.n[= val]

The first part of the label is the module to which the label belongs, which is a full name ['a'..'z', 'A'..'Z', '0'..'9']. The label number is either a numeric ['0'..'9'] or starts with with an alphanumeric label leader ['a'..'z', 'A'..'Z', '0'..'9']. If the label is numeric, it is a "near" label and only refers to the current module being compiled. If the label is alphanumeric, it is a "far" label, and can either be in the current module or an external module. If "=" follows, the instruction address of the label appears, otherwise it is set to the current instruction being processed (the pc).

The logical label number is a value from 0 to n. The value can be anything, and it is used both to define parameters as well as addresses. When used in an instruction, the assembler is capable of processing forward references to labels not yet defined in the assembly.

7.2.4 End of section

Marks the end of a startup or main code section:

q

7.2.5 Source line marker

A source line marker gives the line number currently being parsed in the compiler when the intermediate is generated. It is of the form:

:n

Where n is the source line number. This information can be used to show where errors occurred in the source.

7.2.6 Options

An option line appears with the setting of each of the options, a-z:

o a+b-c+…z+

Each option letter appears, follows by a '+' if it is set, or '-' if it is not.

7.2.7 Global size

The global size set gives the total size of the globals in the program, which (using the globals grow up scheme), the backend needs to know:

g <size>

7.2.8 Logical variant table

When processing tag field values for variant records, Pascal-P6 converts tag field values to and from “logical variant numbers”, which are sequental numbers from 1 to n that denote variants in tables. For example:

```
type
  select = 1..3;
  r = record case s: select of 1, 2: (c: char); 3: (i: integer) end;
```

The reason for this is that variants are unique, but tag values are not. More than one tag value can correpond to a given variant. Each variant record definition generates a logical variant to tag value table, and each table is a line in the intermediate. These lines are of the form:

v <label> <length> <value>[<value]…

The label gives the address of the lookup table. The length gives the number of entries in the table. The values give the equivalent logical variant values for each tagfield value. An example table and the source code that produces it is:

```
var r: record case q: s of
     1, 2: (c: char);
     3: (i: integer);
  end;

v l test.7 4 0 1 1 2
```

This table is four entries long, and translates tag field value 0 to 0 (not used), tagfield values 1 and 2 to logical variant 1, and tagfield value 3 to logical variant 2.

The table is always 0 to n. If the tagfield values only cover a subset of that range, those entries are left empty (0). The logical variants themselves are numbered 1 to n.

7.2.9 Source errors

The faults or errors line gives the number of source file errors that pcom generated when parsing the program. It is of the form:

f <errors>

Where errors gives the total number of errors encontered. The purpose of the fault line is to give pint/pgen the option to reject the intermediate if the source contains errors.

Indicates how many source errors were found in the compile:

f 42

Used to determine if the program should be run.

7.3 Intermediate instruction set

What follows is a complete listing of all instructions, parameters, and numeric equivalences in the interpreter instruction set. The following instruction endings are common and indicate the type of the operation:

i	Integer (4 bytes)
x	byte or short integer (1 byte)
r	Real (8 bytes)
s	Set (32 bytes)
b	Boolean (1 byte)
a	Address (4 bytes)
m	Memory (or memory block)
c	Character (1 byte)

Note that all boolean and character values are extended to 4 byte integers when loaded to the stack. Reals and sets are loaded as whole entities, 8 and 32 bytes respectively.

Note that there will often not be a type indicator if there is only one type operated on by the instruction.

The operation codes are from 0 to 255 or $00 to $ff, fitting in one unsigned byte. The format of the opcodes and operands is:

Op [p] [q [q1]]

The p parameter, if it is exists, is always an unsigned byte. The q parameter, if it exists, is either one or N bytes long, where N is the word size of the machine. If q1 exists, q is always N bytes long. q1 is always N bytes long. These will be refered to below as q8 and qn (8 bit and B bits). The endian nature of words will depend on the compiler used for P6.

This table shows the byte and bit length of words in Pascal-P6:

Word size N (bytes)	Bit size B
2	16
4	32
8	64

Each instruction is listed first in the form it appears in the intermediate assembly form. The second is the format the opcode will take in interpreter store. The stack contents are listed in order on the stack, so the first parameter is the top of stack, the second parameter is the second on stack, etc. Both the contents of the stack before and after the operation are listed (stack in and stack out).

This list of instructions is in alphabetical order.

Instruction	Opcode	Stack in	Stack out
abi	40	integer	integer
abr	41	real	real

Find absolute value of integer or real on top of stack.

Instruction	Opcode	Stack in	Stack out
adi	28	integer integer	integer
adr	29	real real	real

Add the top two stack integer or real values and leave result on stack.

Instruction	Opcode	Stack in	Stack out
and	43	boolean boolean	boolean

Find logical ‘and’ of the top two Booleans on stack, and replace with result.

Instruction	Opcode	Stack in	Stack out
chka low high	95 q32	address	address
chkb low high	98 q32	boolean	boolean
chkc low high	99 q32	char	char
chki low high	26 q32	integer	integer
chkx low high	199 q32	integer	integer
chks low high	97 q32		

Bounds check. The q parameter contains the address of a pair of low and high bounds values, low followed by high, each one integer in size. The bounds pair is placed in the constant area during assembly, and the address placed into the instruction.

The value on top of the stack is verified to lie in the range low..high. If not, a runtime error results. The value is left on the stack.

If the instruction was chka, the low value will contain the code:

0	Pointer is not being dereferenced
1	Pointer is being dereferenced

Pointer values are considered valid if between 0..maxaddr, where maxaddr is the maximum address in the interpreter. If the dereference code is present, it indicates a check if the pointer is nil. This instruction is only applied to dynamic variable addresses, and thus other checks are possible.

Set values are checked to see if any elements outside the elements from low..high are set. If so, a runtime error results.

Instruction	Opcode	Stack in	Stack out
chr	60	integer	character

Find character from integer. Finds the character value of an integer on stack top. At present, this is a no-op.

Instruction	Opcode	Stack in	Stack out
cip p	113	mp address	

Call indirect procedure/function. The top of stack has the address of a mp/address pair pushed by lpa. The dl of the current mark is replaced by the mp, and the address replaces the current pc. The mp/ad address is removed from stack. The size of the parameters appears as p, which shows where to find the mark.

Instruction	Opcode	Stack in	Stack out
cke	188	tagcst boolean	

Terminate active variant check, started by cks. Expects the "running boolean" value on stack top, followed by the current value of the tagfield. If the Boolean value is false, meaning that none of the constants matched the tagfield, a runtime error results.

Both the Boolean value and the tagfield value are removed from the stack.

Instruction	Opcode	Stack in	Stack out
ckla low high	190	address	address

Bounds check. This instruction is identical to the instruction chka, but indicates a pointer to a tagged record. At present this requires no special action over the normal processing of chka.

ckla an chka check if the pointer is dereferencing an allocation that has been freed. In the current implementation this check works on both tag listed and normal dynamic variables. Because this is dependent on the way the allocator is structured, ckla exists in case tag list pointers need special handling.

Instruction	Opcode	Stack in	Stack out
cks	187	tagval	tagval boolean

Start active variant check. The current value of the tag is on stack top. Pushes a false binary value onto the stack. This value is 'or'ed with all of the following variant checks.

Instruction	Opcode	Stack in	Stack out
ckvb val	179 q32	tagval Boolean	tagval boolean
ckvc val	180 q32		
ckvi val	175 q32		
ckvx val	203 q32		

Checks a tagfield for active variants. The "running Boolean" is expected at stack top, followed by the current tagfield value. The tagfield is compared to the constant val and the Boolean equality 'or'ed into the running Boolean. Both are left on stack.

Instruction	Opcode	Stack in	Stack out
csp rout	15 q8	Per call	Per call

Call system routine. The routine number rout indicates the routine to call, from 0 to 255 (or $00 to $ff). Note that the main difference between system and user procedures is that system calls have no framing information.

Instruction	Opcode	Stack in	Stack out
cta off lvl l lvt	191 q32 q32	tagaddr newtagval	tagaddr newtagval

Check tag assignment for dynamically allocated record. Expects the value to assign to the tagfield on stack top, followed by the address of the tagfield as second on stack. Dynamic records containing tagfields are allocated by a special procedure that creates a tagfield constant list with the constants that were used to allocate the record with variants. The cta instruction looks at the list to see if the given tagfield appears in that list, indicating that the tagfield is fixed and cannot be changed. If such a list entry exists and does not match the tagfield assignment, a runtime error results. The instruction contains the offset from the start of the record to the tagfield, at what nesting level the tagfield exists, and The lvt label indicates the logical variant table, used to translate the tag values to their logical variants. It uses the tagfield offset to find the start of record and look for the list, and the nesting level to find the exact tag constant, if it exists. Leaves both values on stack.

Instruction	Opcode	Stack in	Stack out
ctp	100	addr	addr

Check tagged allocated pointer. Expects a pointer allocated by new() on stack. The pointer is checked to see if it was allocated by new() with constants to select the allocated variants. If so, an error results. This instruction is used in several situations where the record addr points to will be used in whole form, that is, without being allocated with fixed variants, and therefore in less space. Examples include use as a factor, or the right side of an assignment. Leaves the address on the stack.

Instruction	Opcode	Stack in	Stack out
cup p l addr	12 p8 q32		

Call user procedure. The instruction contains the number of bytes in the parameter section, and the address of the procedure to call. The mp or mark pointer is set to the location of the stack mark record established by the mst instruction, then the return address is placed into the mark record. The specified location is then jumped to.

The assembly code represents the address as a forward referenced label. This is defined later in a label statement and back referenced by the assembler.

Instruction	Opcode	Stack in	Stack out
cvbi off size l lvt	8 q32 q32 q32	tagaddr integer	tagaddr integer
cvbx off size lvn	100 qn qn qn	tagval tagaddr	tagval tagaddr
cvbb off size lvn	100 qn qn qn	tagval tagaddr	tagval tagaddr
cvbc off size lvn	100 qn qn qn	tagval tagaddr	tagval tagaddr

Check change to tagfield in variable referenced variant. Expects a new setting for a tagfield at stack top, and the address of the tagfield below that. If the tagfield was defined, and the new tag value is different than the old tag value, the variant area controlled by the tagfield is checked if it overlaps an outstanding variable reference. If it does, an error results, since ISO 7185 specifies variants cannot be changed with an outstanding variable reference. The off instruction field constains the offset from the tagfield to the base of the variant. The size instruction field contains the size of the variant. The logical variant table contains a label of the tagfield value to logical variant lookup table for the variant record in use. The offset is applied to the address of the tagfield, and the variant is checked for variable reference. Note that the size of the variant is the maximum size of all possible subvariants. The stack is left the same way it was found.
The stack is unchanged during this operation.

Instruction	Opcode	Stack in	Stack out
decb cnt	103 q32	boolean	boolean
decc cnt	104 q32	character	character
deci cnt	57 q32	integer	integer
decx cnt	202	integer	integer

The unsigned cnt parameter is subtracted from the value at stack top.

Instruction	Opcode	Stack in	Stack out
dif	45	set set	set

Find set difference, or s1-s2. The members of the set on stack top are removed from the set that is second on the stack, and the top set on stack is removed.

Instruction	Opcode	Stack in	Stack out
dmp cnt	117 q32	value	

The unsigned cnt parameter is subtracted from the current stack pointer. The effect is to "dump" or remove the topmost cnt data from the stack.

Instruction	Opcode	Stack in	Stack out
dupa	182	address	address address
dupb	185	boolean	boolean boolean
dupc	186	character	character character
dupi	181	integer	integer integer
dupr	183	real	real real
dups	184	set	set set

Duplicate stack top. The top value on the stack is copied to a new stack top value according to type.

Instruction	Opcode	Stack in	Stack out
dvi	53	integer integer	integer
dvr	54	real real	real

Divide. The value second on stack is divided by the value first on stack. The division is done in integer or real according to type.

Instruction	Opcode	Stack in	Stack out
ente l size	173q32		

Sets the maximum extent of stack use. The size constant in the instruction gives a compiler calculated size that is the maximum extent of stack that will be used by this routine. If that overlaps the bottom of the heap, then a runtime error results. The ep or extreme stack pointer is updated, and also stored in the stack mark record for use in the ipj instruction to jump between procedures.

The assembly code represents the size as a forward referenced label. This is defined later in a label statement and back referenced by the assembler.

Instruction	Opcode	Stack in	Stack out
ents l size	13 q32		

Enter routine and allocate local variable space. The size field in the instruction contains the size of data for the routine being entered, including stack mark, parameters, and locals. The mp or mark pointer is offset by size, the area between the sp or stack pointer and the new allocation is cleared to zero and the sp set after that. The bottom of the stack field in the stack mark record is set from that, which allows the ipj instruction to find the proper setting of the stack for interprocedural jumps.

Checks if the resulting locals allocation would overrun the heap, and thus require more memory that is available. A runtime error results if not.

The assembly code represents the size as a forward referenced label. This is defined later in a label statement and back referenced by the assembler.

Instruction	Opcode	Stack in	Stack out
equa	17	address address	boolean
equb	139	boolean Boolean	boolean
equc	141	character character	boolean
equi	137	integer integer	boolean
equm size	142 q32	address address	boolean
equr	138	real real	boolean
equs	140	set set	boolean

Find equal. The top of stack and second on stack values are compared, and a Boolean result of the comparision replaces them both. The compare is done according to type. Note that types a, b, c and i are treated equally since values are normalized to 32 bit integer on stack.

Instruction	Opcode	Stack in	Stack out
fjp addr	24 q32	boolean	

Jump false. Expects a Boolean value atop the stack. If the value is false, or zero, execution continues at the instruction constant addr. Removes the boolean from stack.

Instruction	Opcode	Stack in	Stack out
flo	34	integer real	real real
flt	33	integer	real

Convert stack integer to floating point. flt converts the top of stack to floating point from integer. flo converts the second on stack to floating point, but it assumes that the top of stack is real as well.

Instruction	Opcode	Stack in	Stack out
geqb	151	boolean boolean	boolean
geqc	153	character character	boolean
geqi	149	integer integer	boolean
geqm size	154 q32	address address	boolean
geqr	150	real real	boolean
geqs	152	set set	boolean

Find greater than or equal. The top of stack and second on stack values are compared for second on stack greater than or equal to the top of stack, and a Boolean result of the comparision replaces them both. The compare is done according to type. Note that types a, b, c and i are treated equally since values are normalized to 32 bit integer on stack.

Instruction	Opcode	Stack in	Stack out
grtb	157	boolean boolean	boolean
grtc	159	character character	boolean
grti	155	integer integer	boolean
grtm size	160 q32	address address	boolean
grtr	156	real real	boolean
grts	158	set set	boolean

Find greater than. The top of stack and second on stack values are compared for second on stack greater than the top of stack, and a Boolean result of the comparision replaces them both. The compare is done according to type. Note that types a, b, c and i are treated equally since values are normalized to 32 bit integer on stack.

Instruction	Opcode	Stack in	Stack out
inca cnt	90 q32	address	address
incb cnt	93 q32	boolean	boolean
incc cnt	94 q32	character	character
inci cnt	10 q32	integer	integer
incx cnt	201	integer	integer

Increment top of stack. The unsigned constant cnt is added to the value on stack top. Note that type a is not subject to arithmetic checks, but the other types are.

Instruction	Opcode	Stack in	Stack out
inda off	85 q32	address	address
indb off	88 q32	address	boolean
indc off	89 q32	address	character
indi off	9 q32	address	integer
indx off	198 q32	address	integer
indr off	86 q32	address	real
inds off	87 q32	address	set

Load indirect to stack. Expects the address of an operand in memory on the stack top. The constant off is added to the address, then the operand fetched from memory and that replaces the address on stack top.

Instruction	Opcode	Stack in	Stack out
inn	48	value set	boolean

Set inclusion. Expects a set on stack top, and the value of a set element below that. Tests for inclusion of the value in the set, then replaces both of them with the Boolean result of that test.

Instruction	Opcode	Stack in	Stack out
int	46	set set	set

Set intersection. Finds the intersection of the two sets on the stack and replaces them both with the resulting set.

Instruction	Opcode	Stack in	Stack out
inv	189	address2	

Invalidate address. Expects an address on stack, then flags that location as undefined if undefined checking is enabled. This instruction is used to return variables to the undefined state. Removes the address from stack.

Instruction	Opcode	Stack in	Stack out
ior	44	boolean boolean	boolean

Boolean inclusive ‘or ‘. Expects to find two Boolean values on stack. Replaces them with the inclusive ‘or’ of the values.

Instruction	Opcode	Stack in	Stack out
ipj p l addr	112 p8 q32		

Interprocedure jump. The instruction contains the relative frame number p, and the address to jump to within the target procedure addr. The frames above the target procedure frame are discarded, and the target frame is loaded. Execution then proceeds at the given address addr.

The assembly code represents the address addr as a forward referenced label. This is defined later in a label statement and back referenced by the assembler.

Instruction	Opcode	Stack in	Stack out
ivti off size l lvt	192 q32 q32 q32	tagaddr integer	tagaddr integer
ivtx off size l lvt	91 q32 q32 q32	tagaddr integer	tagaddr integer
ivtb off size l lvt	92 q32 q32 q32	tagaddr boolean	tagaddr boolean
ivtc off size l lvt	96 q32 q32 q32	tagaddr char	tagaddr char

Invalidate tagged variant. Expects a new setting for a tagfield at stack top, and the address of the tagfield below that. If the tagfield was defined, and the new tag value is different than the old tag value, the variant area controlled by the tagfield is set as undefined. The off instruction field constains the offset from the tagfield to the base of the variant. The size instruction field contains the size of the variant. The offset is applied to the address of the tagfield, and the entire variant is set undefined. Note that the size of the variant is the maximum size of all possible variants. The lvt label indicates the logical variant table, used to translate the tag values to their logical variants.

The stack is unchanged during this operation.

Instruction	Opcode	Stack in	Stack out
ixa size	16 q32	address index	address

Scale array access. Expects an index value at stack top, and the address of an array below that. The size instruction field contains the size of the base element of the array. The index is multiplied by the size, then added to the address of the base of the array, then that element address replaces both the index and the base address on stack.

Note that this operation does not remove the array index offset, ie., array [1..10] does not have 1 removed here.

Instruction	Opcode	Stack in	Stack out
lao off	5 q32		address

Load address with offset. Loads the address in the stack area with offset off. This instruction is used to index globals. The address is placed on stack top.

Instruction	Opcode	Stack in	Stack out
lca len 'str'	56 q32		address

Load string address. P5 accepts any length of string between quotes, but stores the string as the given length. The string is padded as required with spaces. Accepts a "quote image" in the string.The string is placed in the constants area, and the instruction gets the address of that. Loads the string constant address off to the top of the stack.

Instruction	Opcode	Stack in	Stack out
lda p addr	4 p8 q32		address

Load local address. Expects the relative frame number of the target procedure in p, and the offset address of the local in addr. The frame is found and the address calculated as an offset from the locals there and placed on the stack.

Instruction	Opcode	Stack in	Stack out
ldcb bool	126 q8		boolean
ldcc char	127 q8		character
ldci int	123 q32		integer

Load constant. Loads a constant from within the instruction according to the type, Boolean, character or integer.

Instruction	Opcode	Stack in	Stack out
ldcn	125		nilcst

Load nil value. Loads the value of nil to the stack top.

Instruction	Opcode	Stack in	Stack out
ldcr real	124 q32		real

Load constant real. The address in the instruction gives the address of the real, which is loaded to stack top. The real given is loaded into the constants area on assembly, and the instruction contains the address of that.

Instruction	Opcode	Stack in	Stack out
ldcs (set)	7 q32		set

Load constant set. The address in the instruction gives the address of the set, which is loaded to stack top. This is used to load sets from the constant area. The set is specified as a series of values in the set between parenthsis. This set is loaded into the constant area on assembly, and the instruction contains the address of that.

Instruction	Opcode	Stack in	Stack out
ldoa off	65 q32		address
ldob off	68 q32		boolean
ldoc off	69 a32		character
ldoi off	1 q32		integer
ldox off	194 q32		integer
ldor off	66 q32		real
ldos off	67 q32		set

Load from offset. Loads a global value from the globals area. The off constant gives the offset of the variable in the stack area. The value is loaded to the top of stack according to type.

Instruction	Opcode	Stack in	Stack out
leqb	163	boolean boolean	boolean
leqc	165	character character	boolean
leqi	161	integer integer	boolean
leqm size	166 q32	address address	boolean
leqr	162	real real	boolean
leqs	164	set set	boolean

Find less than or equal. The top of stack and second on stack values are compared for second on stack less than or equal to the top of stack, and a Boolean result of the comparision replaces them both. The compare is done according to type. Note that types a, b, c and i are treated equally since values are normalized to 32 bit integer on stack.

Instruction	Opcode	Stack in	Stack out
lesb	169	boolean boolean	boolean
lesc	171	character character	boolean
lesi	167	integer integer	boolean
lesm size	172 q32	address address	boolean
lesr	168	real real	boolean
less	170	set set	boolean

Find less than. The top of stack and second on stack values are compared for second on stack less than the top of stack, and a Boolean result of the comparision replaces them both. The compare is done according to type. Note that types a, b, c and i are treated equally since values are normalized to 32 bit integer on stack.

Instruction	Opcode	Stack in	Stack out
lip p addr	120 p8 q32		mp pfaddr

load procedure function address. Expects the relative mark count p, and the address of an existing mark/function address pair in the instruction. Loads a mark/address pair for a procedure or function parameter onto the stack from a previously calculated pair in memory. Used to pass a procedure or function parameter that was passed to the current function to another procedure or function. See the cip instruction for further information.

Instruction	Opcode	Stack in	Stack out
loda p off	105		Address
lodb p off	108		boolean
lodc p off	109		character
lodi p off	0		integer
lodx p off	193		integer
lodr p off	106		real
lods p off	107		set

Load local value. Expects the display offset p and the offset address in the local procedure frame off in the instruction. The value is loaded according to type.

Instruction	Opcode	Stack in	Stack out
lpa p l addr	114 p8 q32		mp pfaddr

Load procedure address. The current mark pointer is loaded onto the stack, followed by the target procedure or function address. This puts enough information on the stack to call it with the callers environment.

The assembly code represents the address addr as a forward referenced label. This is defined later in a label statement and back referenced by the assembler.

Instruction	Opcode	Stack in	Stack out
mod	49	integer integer	integer

Find modulo. Finds the modulo of the second on stack by the top of stack. The result replaces both operands. This is always an integer operator.

Instruction	Opcode	Stack in	Stack out
mov size	55	destaddr srcaddr	

Move bytes. The instruction contains the number of bytes to move. The top of stack contains the source address, and the second on stack contains the destination address. The specified number of bytes are moved. Both addresses are removed from the stack.

Instruction	Opcode	Stack in	Stack out
mpi	51	integer integer	integer
mpr	52	real real	real

Multiply. The first and second on stack are multiplied together, and the result replaces them both.

Instruction	Opcode	Stack in	Stack out
mrkl line	174		

Mark source line. This instruction exists only within the interpreter, and is not specified in the intermediate. The instruction parameter line contains the number of the source line that was read in at this point in the intermediate generation. The interpreter can use this to provide various source level debug services.

Instruction	Opcode	Stack in	Stack out
mst p	11 p8		

Mark stack. This instruction is used before parameters are loaded in expectation of a user procedure call. The p parameter in the instruction contains the level of the calling procedure minus the level of the called procedure and is used to establish the static links in the mark. A stack mark record is placed onto the stack an the sl or static link is placed, the dl or dynamic link, and the ep or extended stack pointer.

Instruction	Opcode	Stack in	Stack out
neqa	18	address address	boolean
neqb	145	boolean Boolean	boolean
neqc	147	character character	boolean
neqi	143	integer integer	boolean
neqm size	148	address address	boolean
neqr	144	real real	boolean
neqs	146	set set	boolean

Find not equal. The top of stack and second on stack values are compared for second on stack not equal to the top of stack, and a Boolean result of the comparision replaces them both. The compare is done according to type. Note that types a, b, c and i are treated equally since values are normalized to 32 bit integer on stack.

Instruction	Opcode	Stack in	Stack out
ngi	36	integer	integer
ngr	37	real	real

Negate. The operand atop the stack is negated according to type.

Instruction	Opcode	Stack in	Stack out
not	42	boolean	boolean

Logical ‘not’. The Boolean value atop the stack is inverted.

Instruction	Opcode	Stack in	Stack out
odd	50	integer	boolean

Find odd/even. The lowest bit of the integer on stack is masked to find the even/odd status of the integer as a Boolean value.

Instruction	Opcode	Stack in	Stack out
ordb	134	boolean	integer
ordc	136	character	integer
ordi	59	integer	integer
ordx	200	integer	integer

Find ordinal value of Boolean, character or integer. This is a no-op, because P5 always converts values to 32 bit integers on load to stack.

Instruction	Opcode	Stack in	Stack out
pck sizep sizeu	63 q32 q32	uparr inx parr	

Convert unpacked array to packed array. Because P5 does not support packing, this is effectively a copy operation. The instruction contains the size of the packed array sizep and the size of the unpacked array sizeu. The stack contains the address of the packed array at top, the starting index of the unpacked array under that, and the unpacked array address as third on stack. The number of elements in the packed array are moved from the unpacked array at the starting index to the packed array. All parameters are removed from the stack.

Instruction	Opcode	Stack in	Stack out
reta	132		address
retb	131		boolean
retc	130		character
reti	128		integer
retx	204		integer
retp	14		
retr	129		real

Return from procedure or function with result. Returns from the current procedure or function. The pc, sp, ep and mp pointers are restored from the saved data in the active stack mark record. For retp or return from procedure, this is all that is done. For the others, a return value is processed according to type. The value of the result is loaded from its place in the stack mark record, and expanded to 32 bits if Boolean or character.

Instruction	Opcode	Stack in	Stack out
rgs	110	low high	set

Build range set on stack. Expects a high value on stack top, and a low value below that. A set is constructed that has all of the members from the low value to the high value in it, then that set is placed as stack top.

The range builder instruction, along with sgs or build singleton set, is used to construct complex sets by creating sets of each individual ranges of values, then adding the resulting sets together on stack.

Instruction	Opcode	Stack in	Stack out
rnd	62	real	integer

Round real value to integer. Converts the real on top of the stack to integer by rounding.

Instruction	Opcode	Stack in	Stack out
sbi	30	integer integer	integer
sbr	31	real real	real

Subtract. Subtracts the top of stack value from the second on stack value according to type.

Instruction	Opcode	Stack in	Stack out
sgs	32	integer	set

Construct singleton set. Expects a value on stack. Constructs a set with that value as the single member, then that set replaces the value on stack.

The singleton set instruction, along with rgs or range set builder, is used to construct complex sets by creating sets with individual ranges of values, then adding the resulting sets together on stack.

Instruction	Opcode	Stack in	Stack out
sqi	38	integer	integer
sqr	39	real	real

Find square of value. Expects a value on stack top, and finds the square of that value according to type. This replaces the value on stack top.

Instruction	Opcode	Stack in	Stack out
sroa off	75	address	
srob off	78	boolean	
sroc off	79	character	
sroi off	3	integer	
srox off	196	integer	
sror off	76	real	
sros off	77	set	

Store global value. The instruction contains the offset of a variable in the stack bottom, where the globals for the program exist. The variable is stored from the stack according to type, and the value removed from the stack.

Instruction	Opcode	Stack in	Stack out
stoa	80	address address	
stob	83	address boolean	
stoc	84	address character	
stoi	6	address integer	
stox	197	address byte	
stor	81	address real	
stos	82	address set	

Store value to address. Expects a value according to instruction type atop the stack, and an address below that. The value is stored to the address, and both are removed from the stack.

Instruction	Opcode	Stack in	Stack out
stp	58		

Stop. Executing this instruction causes the interpreter to exit.

Instruction	Opcode	Stack in	Stack out
stra p off	70	address	
strb p off	73	boolean	
strc p off	74	character	
stri p off	2	integer	
strx p off	195	integer	
strr p off	71	real	
strs p off	72	set	

Store local. Instruction parameter p contains the relative count of the procedure frame to access. Instruction parameter off contains the offset address within the frame. The value at stack top is stored to the local variable according to type, and the value removed from the stack.

Instruction	Opcode	Stack in	Stack out
swp size	118	value address	address value

Swap first and second stack operands. The instruction contains the size of the second value on stack. The top value is assumed to be 32 bit. The top and second values are swapped. This instruction is used primarily to chain writes together to the same file access pointer.

Instruction	Opcode	Stack in	Stack out
tjp l addr	119	boolean	

Jump true. Expects a Boolean value on stack top. If the Boolean is true, the jump is taken to address addr. The Boolean is removed from the stack.

The assembly code represents the address addr as a forward referenced label. This is defined later in a label statement and back referenced by the assembler.

Instruction	Opcode	Stack in	Stack out
trc	35	real	integer

Truncate to integer. The real on stack top is converted to integer by truncating the fractional part. The integer replaces the real on stack top.

Instruction	Opcode	Stack in	Stack out
ujc	61 q32		

Output case error. This instruction is used in case statement tables to output case value errors. See xjp for the case table format. It is designed to be the same length as ujp, which is used to build the case table. The 32 bit address in the struction is a dummy, and contains zero. Always outputs a bad case select error. Inserted into the table where the value for the case would be invalid.

Instruction	Opcode	Stack in	Stack out
ujp l addr	23		

Unconditional jump. The instruction contained address addr is jumped to.

The assembly code represents the address addr as a forward referenced label. This is defined later in a label statement and back referenced by the assembler.

Instruction	Opcode	Stack in	Stack out
uni	47	set set	set

Find set union. Expects two sets on stack. The union of the sets is found, and that replaces them both.

Instruction	Opcode	Stack in	Stack out
upk sizep sizeu	64 q32 q32	packarr upackarr sindex	

Unpack a packed array. P5 does not implement packing, so this instruction is implemented as a copy operation. Expects the size of the packed array sizep and the size of the unpacked array sizeu in the instruction. The stack contains the starting index of the unpacked array at top, followed by the address of the unpacked array, and the address of the packed array as third on stack. The entire contents of the packed array are transferred into the unpacked array, which can be larger than the packed array.

Instruction	Opcode	Stack in	Stack out
vbe	20 qn	addresss	

Variable reference block end. Ends a variable reference.

Instruction	Opcode	Stack in	Stack out
vbs len	19 qn	addresss	

Variable reference block start. Establishes a variable reference to a block. Expects a base address for the referenced block on stack. The instruction contains the length of the block. Used to enforce the rule that tag values cannot be changed in a variable referenced block. The variable reference will exist until terminated by a vbe instruction. For each vbs instruction, there must be a matching vbe instruction.

Instruction	Opcode	Stack in	Stack out
wbe	102		

With block end. This instruction terminates a with block, and the last with block is removed. See wbs for more information.

Instruction	Opcode	Stack in	Stack out
wbs	101	addr	addr

With block start. Registers the start of a with block, with a pointer address of a record allocated with new(). When a dispose() call is made, it is checked against the list of outstanding with references, and and an error is thrown if an attempt is made to dispose of a block that has an outstanding with reference. There is no specific method prescribed for saving the with reference pointers, but usually they are just stacked and searched.

Instruction	Opcode	Stack in	Stack out
xjp l addr	25 q32	index	

Table jump. Expects an address of a jump table within the instruction, and a jump table index on the stack. The jump table constists of a series of jump instructions using the ujp instruction. The index is multiplied by the length of the ujp instruction, which is 5 bytes long, and the pc set to that address. The effect is to jump via a table of entries from 0 to n. The index is removed from stack.

This instruction is used to implement the case statement.

The assembly code represents the address addr as a forward referenced label. This is defined later in a label statement and back referenced by the assembler.

7.4 System calls

The p5 interpreter partitions the execution work done in the stack machine into directly executed instructions and system calls. The system call instructions consist of I/O related calls and dynamic storage allocation. These are normally things that are handled by the runtime support system.

The difference between a function executed in an instruction and a function executed in a system call is minimal. A system call uses parameters stacked onto the interpreter operand stack in reverse just as the intermediate does.

The difference between a function executed in a user based procedure or function and a function executed in a system call is that the system call requires no framing or locals.

System calls are executed by number via the csp instruction.

The following system call descriptions show the intermediate menmomic of the call, the instruction number used as a parameter to the csp instruction, and the operands as they exist on the stack before the call. The stack operands are listed deepest first at left, to the topmost operand at the right. This is the logical call order of the routine parameters.

Each system call can be a procedure or a function. If it is a function, it leaves its result on the stack.

System Call	Number	Stack in	Stack out
atn	19	real	real

Find arctangent. Expects a real on stack. Finds the arctangent, and that replaces the stack top.

System Call	Number	Stack in	Stack out
cos	15	real	real

Find cosine. Expects a real on stack. Finds the cosine, and that replaces the stack top.

System Call	Number	Stack in	Stack out
dsl	40	addr tagcst.. tagcnt size	

Dispose of dynamic tagged record. This is a special form of dispose for a dynamically allocated record with tagged variants. The top of the stack contains the size of the record, after any fixed tag constants specified are taken into account. Below that, the number of tagfield constants that were specified exists. Below that, a list of all the constants that were used to specify the allocation. This list is from leftmost in sourcecode order and deepest in the stack to rightmost in source and topmost in stack. Following that, the address of the dynamic record.

The allocation of the record, done by the system call nwl, contains a matching list of tagfield constants allocated “behind” the allocated pointer, with the number of tag constants last in the list so that it can be found just below the pointer. These lists represent the tagfield list used to allocate the record, in the dynamic itself, and the tagfield list used to dispose of it, on stack. These lists are compared for both number and value, and a runtime error results if not equal. The total allocation, record plus taglist, is then disposed of.

System Call	Number	Stack in	Stack out
dsp	26	addr size	

Dispose of dynamic variable. The top of stack contains the variable size, and the address under that is the address of the dynamic record. The variable is deallocated. Both operands are removed from stack.

System Call	Number	Stack in	Stack out
efb	42	fileaddr	boolean

Find eof of binary file. Expects the address of a file variable on stack. The file is tested for eof() true, and the Boolean result replaces the address on stack.

System Call	Number	Stack in	Stack out
eln	7	fileaddr	boolean

Test for eoln of text file. Expects the address of a file variable on stack. The file is tested for eoln() true, and the Boolean result replaces the address on stack.

System Call	Number	Stack in	Stack out
eof	41	fileaddr	boolean

Find eof of text file. Expects the address of a file variable on stack. The file is tested for eof() true, and the Boolean result replaces the address on stack.

System Call	Number	Stack in	Stack out
exp	16	real	real

Find exponential. Expects a real on stack. Finds the exponential, and that replaces the stack top.

System Call	Number	Stack in	Stack out
fbv	43	fileaddr	fileaddr

File buffer validate text. Expects the address of a file variable on stack. Ensures the file buffer variable is loaded. If the file is a read file, or the file is in read mode, the file buffer variable is loaded by reading the file. The file address pointer is left on stack. This call is used to insure the file buffer contains data from the file, if it exists, when the file buffer variable is referenced. It is part of the “lazy I/O” file scheme.

System Call	Number	Stack in	Stack out
fvb	44	fileaddr size	fileaddr

File buffer validate binary. Expects the base element size of the file on stack, followed by the address of a file variable on stack. Ensures the file buffer variable is loaded. If the file is a read file, or the file is in read mode, the file buffer variable is loaded by reading the file. The element length tells the call how many bytes to read. The file address pointer is left on stack, but the size is purged. This call is used to insure the file buffer contains data from the file, if it exists, when the file buffer variable is referenced. It is part of the “lazy I/O” file scheme.

System Call	Number	Stack in	Stack out
gbf	35	fileaddr size	

Get file buffer binary. Expects the base element size of the file on stack, followed by the address of a file variable on stack. If the file buffer variable is indicated as full, then it is marked empty, thus discarding the data there. If it is full, new data is read over the file buffer variable. Both the file address pointer and the size are discarded from stack. This operation is part of the “lazy I/O scheme”.

System Call	Number	Stack in	Stack out
get	0	fileaddr	

Get file buffer text. Expects the address of a file variable on stack. Reads the next element of the file into the file variable buffer. The file pointer is discarded.

System Call	Number	Stack in	Stack out
log	17	real	real

Find logarithm. Expects a real on stack. Finds the logarithm, and that replaces the stack top.

System Call	Number	Stack in	Stack out
new	4	addr size	

Allocate dynamic variable. Expects the size of variable in bytes to allocate on stack top, followed by the address of the pointer variable. Space with the given size is allocated, and the address placed into the pointer variable. Both operands are removed from stack.

System Call	Number	Stack in	Stack out
nwl	39	addr tagcst.. tagcnt size	

Allocate dynamic tagged record. This is a special form of new() for a dynamically allocated record with tagged variants. The top of the stack contains the size of the record, after any fixed tag constants specified are taken into account. Below that, the number of tagfield constants that were specified exists. Below that, a list of all the logical variant numbers that were used to specify the allocation. This list is from leftmost in sourcecode order and deepest in the stack to rightmost in source and topmost in stack. Following that, the address of the pointer variable.

The space required for the tagfield constant list and length is added to the total space required, and that space is allocated. The tagfield constant list, with the following length, is copied to the start of the allocated space, and the pointer variable is set just after that. Thus the tagfield constant list exists “behind” the pointer or in “negative space”, so that it can be found and referenced for various purposes. These are:

1. To check that the tagfield constant list is equal between new() and dispose() operations.
2. To check if a tagfield used to set the total space allocated for the variable is assigned with a different value than originally used in the new() call.

The size, tagfield list and length, and the address of the pointer variable are discarded.

System Call	Number	Stack in	Stack out
pag	21	fileaddr	

Page text file. Expects the address of a file variable on stack. A page request is sent to the file, and the file address is discarded.

System Call	Number	Stack in	Stack out
pbf	36	fileaddr size	

Put file buffer binary. Expects the base element size of the file on stack, followed by the address of a file variable on stack. If the file buffer variable is empty, a runtime error results. Otherwise, the contents of the file buffer variable are written out to the file. The size and file address are discarded.

System Call	Number	Stack in	Stack out
put	1	fileaddr	

Get file buffer text. Expects the address of a file variable on stack. If the file buffer is empty, a runtime error results. Otherwise, writes the contents of the file buffer variable to the file. The file address is discarded.

System Call	Number	Stack in	Stack out
rbf	32	fileaddr varaddr len	fileaddr

Read binary file. Expects a file variable address on stack, the address to place read data above that, and the length of the base file element on stack top. If the buffer for the file is has data, then the data is read from that, otherwise the data is read from the file. The number of bytes in the element length are read.

Purges the target variable address and the element length from the stack, but leaves the file variable address. This is because a group of single reads can use the same file reference, so it is left on stack until specifically removed.

System Call	Number	Stack in	Stack out
rbr	32	fileaddr varaddr len min max	fileaddr

Read binary file with range check. Expects a file variable address on stack, the address to place read data above that, and the length of the base file element, the minimum value, and the maximum value on stack top. If the buffer for the file is has data, then the data is read from that, otherwise the data is read from the file. The number of bytes in the element length are read. The value read is checked to lie in the range min..max. If not, a value out of range results. This instruction is the same as rbf, but used when the target of a read must be verified to lie in a given subrange.

Purges the target variable address, the element length, and the min and max from the stack, but leaves the file variable address. This is because a group of single reads can use the same file reference, so it is left on stack until specifically removed.

System Call	Number	Stack in	Stack out
rcb	38	fileaddr vaddr min max	fileaddr

Read character from text file with range check. Expects the file variable address on stack, the variable address to read to above that, then the minimum value min and the maximum value max at stack top. Reads a single character from the file, verifies that it lies in the specified range, and places it to the variable. If the character value lies out of range, a runtime error results.

Purges the target variable address from the stack, but leaves the file variable address. This is because a group of single reads can use the same file reference, so it is left on stack until specifically removed.

System Call	Number	Stack in	Stack out
rdc	13	fileaddr varaddr	fileaddr

Read character from text file. Expects the file variable address on stack, and the variable address to read to above that. Reads a single character from the file to the variable.

Purges the target variable address from the stack, but leaves the file variable address. This is because a group of single reads can use the same file reference, so it is left on stack until specifically removed.

System Call	Number	Stack in	Stack out
rdi	11	fileaddr varaddr	fileaddr

Read integer from text file. Expects the file variable address on stack, and the variable address to read to above that. Reads a single integer from the file to the variable.

Purges the target variable address from the stack, but leaves the file variable address. This is because a group of single reads can use the same file reference, so it is left on stack until specifically removed.

System Call	Number	Stack in	Stack out
rdr	12	fileaddr varaddr	fileaddr

Read real from text file. Expects the file variable address on stack, and the variable address to read to above that. Reads a single real from the file to the variable.

Purges the target variable address from the stack, but leaves the file variable address. This is because a group of single reads can use the same file reference, so it is left on stack until specifically removed.

System Call	Number	Stack in	Stack out
rib	37	fileaddr vaddr min max	fileaddr

Read an integer from text file with range check. Expects the file variable address on stack, the variable address to read to above that, then the minimum value min and the maximum value max at stack top. Reads a single integer from the file, verifies that it lies in the specified range, and places it to the variable. If the character value lies out of range, a runtime error results.

Purges the target variable address from the stack, but leaves the file variable address. This is because a group of single reads can use the same file reference, so it is left on stack until specifically removed.

System Call	Number	Stack in	Stack out
rln	3	fileaddr	fileaddr

Read next line from text file. Expects the file variable address on stack. The text file is read until an eoln() or eof() is encountered.

Leaves the file variable address. This is because a group of single reads can use the same file reference, so it is left on stack until specifically removed.

System Call	Number	Stack in	Stack out
rsb	33	fileaddr	

Reset file binary. Expects the file variable address on stack. The binary file is reset(). The file variable address is purged.

System Call	Number	Stack in	Stack out
rsf	22	fileaddr	

Reset file text. Expects the file variable address on stack. The text file is reset(). The file variable address is purged.

System Call	Number	Stack in	Stack out
rwb	34	fileaddr	

Rewrite file binary. Expects the file variable address on stack. The binary file is rewritten. The file variable address is purged.

System Call	Number	Stack in	Stack out
rwf	23	fileaddr	

Rewrite file text. Expects the file variable address on stack. The text file is rewritten. The file variable address is purged.

System Call	Number	Stack in	Stack out
sin	14	real	real

Find sine. Expects a real on stack. Finds the sine, and that replaces the stack top.

System Call	Number	Stack in	Stack out
sqt	18	real	real

Find square root. Expects a real on stack. Finds the square root, and that replaces the stack top.

System Call	Number	Stack in	Stack out
wbb	31	fileaddr boolean	fileaddr

Write Boolean to binary file. Expects the file variable address on stack, and the Boolean to write to above that. Writes a single boolean to the file from the variable.

Purges the boolean from the stack, but leaves the file variable address. This is because a group of single writes can use the same file reference, so it is left on stack until specifically removed.

System Call	Number	Stack in	Stack out
wbc	30	fileaddr char	fileaddr

Write character to binary file. Expects the file variable address on stack, and the Boolean to write to above that. Writes a single character to the file from the variable.

Purges the character from the stack, but leaves the file variable address. This is because a group of single writes can use the same file reference, so it is left on stack until specifically removed.

System Call	Number	Stack in	Stack out
wbf	27	fileaddr varaddr size	fileaddr

Write binary variable to binary file. Expects the file variable address on stack, the address of the variable to write above that, and the size in bytes of the variable at stack top. Writes all the bytes of the variable to the file single boolean to the file from the variable.

Purges the size and the variable address from the stack, but leaves the file variable address. This is because a group of single writes can use the same file reference, so it is left on stack until specifically removed.

System Call	Number	Stack in	Stack out
wbi	28	fileaddr integer	fileaddr

Write integer to binary file. Expects the file variable address on stack, and an integer to write to above that. Writes a single integer to the file from the variable.

Purges the integer from the stack, but leaves the file variable address. This is because a group of single writes can use the same file reference, so it is left on stack until specifically removed.

System Call	Number	Stack in	Stack out
wbr	29	fileaddr real	fileaddr

Write a real to binary file. Expects the file variable address on stack, and a real to write to above that. Writes a single real to the file from the variable.

Purges the real from the stack, but leaves the file variable address. This is because a group of single writes can use the same file reference, so it is left on stack until specifically removed.

System Call	Number	Stack in	Stack out
wbx	28	fileaddr integer	fileaddr

Writes byte integer to binary file. Expects the file variable address on stack, and an integer to write to above that. Writes a single byte integer to the file from the variable.

Purges the integer from the stack, but leaves the file variable address. This is because a group of single writes can use the same file reference, so it is left on stack until specifically removed.

System Call	Number	Stack in	Stack out
wln	5	fileaddr	fileaddr

Write next line to text file. Expects the file variable address on stack. A new line is written to the text file.

Leaves the file variable address. This is because a group of single reads can use the same file reference, so it is left on stack until specifically removed.

System Call	Number	Stack in	Stack out
wrb	24	fileaddr boolean width	fileaddr

Write boolean to text file. Expects the file variable address on stack, a boolean to write to above that., and a field width at stack top. Writes the Boolean in the given width.

Purges the width and the boolean from the stack, but leaves the file variable address. This is because a group of single writes can use the same file reference, so it is left on stack until specifically removed.

System Call	Number	Stack in	Stack out
wrc	10	fileaddr char width	fileaddr

Write character to text file. Expects the file variable address on stack, a character to write to above that., and a field width at stack top. Writes the character in the given width.

Purges the width and the character from the stack, but leaves the file variable address. This is because a group of single writes can use the same file reference, so it is left on stack until specifically removed.

System Call	Number	Stack in	Stack out
wrf	25	fileaddr real width frac	fileaddr

Write real to text file in fixed point notation. Expects the file variable address on stack, a real to write to above that., a field width above that, and a fraction at stack top. Writes the real in the given width.

Purges the fraction, width and the real from the stack, but leaves the file variable address. This is because a group of single writes can use the same file reference, so it is left on stack until specifically removed.

System Call	Number	Stack in	Stack out
wri	8	fileaddr integer width	fileaddr

Write integer to text file. Expects the file variable address on stack, a integer to write to above that., and a field width at stack top. Writes the integer in the given width.

Purges the width and the integer from the stack, but leaves the file variable address. This is because a group of single writes can use the same file reference, so it is left on stack until specifically removed.

System Call	Number	Stack in	Stack out
wrr	9	fileaddr real width	fileaddr

Write real to text file in floating point notation. Expects the file variable address on stack, a real to write to above that., and a field width at stack top. Writes the real in the given width.

Purges the width and the real from the stack, but leaves the file variable address. This is because a group of single writes can use the same file reference, so it is left on stack until specifically removed.

System Call	Number	Stack in	Stack out
wrs	6	fileaddr saddr width len	fileaddr

Write string to text file. Expects the file variable address on stack, the address of the string to write to above that., the field width above that, and the length of the string at stack top. Writes the string in the given width.

Purges the length, width and the string address from the stack, but leaves the file variable address. This is because a group of single writes can use the same file reference, so it is left on stack until specifically removed.

8 Testing Pascal-P5

In the original implementation of Pascal and the Pascal-P porting kit, the implementation of tests on the system were largely undefined. Today, most programmers realize that any program exists as a collection of the code, documentation, and finally the tests for the program to prove it correct. If any one of these elements is missing, much as a three legged stool, the program will fall over. In reality, an “undocumented” program that is popular gets documented by its users or by third parties, such as independent book writers. Tests can be carried out ad-hoc, or essentially fall to the users (their happiness with this situation being quite another matter!).

Thus, as important to P5 as its code or documents are its tests.This was widely recognized with original Pascal, and an extensive series of tests were created with the advent of the ISO 7185 standard, as documented in “Pascal compiler validation” [Brian Wichmann & Z. J. Chechanowicz]. This was an excellent series of tests that showed close relationship to the standard. Unfortunately, like the “model compiler”, the rights to this test series, which was initially openly distributed, were closely held, and the project is essentially dead today.

Accordingly, I have created a new series of tests for P5, and now that is distributed with P5 itself, and continues to be improved. The PAT or Pascal Acceptance Test is completely automated. Further, because the original ISO 7185 validation tests were distributed in the “Pascal User’s Group” free of restrictions, I have used them to check on the completeness of the PAT. Thus, even if the original ISO 7185 validation tests cannot legally be distributed, the PAT is tracable back to these tests and is a reliable substitute for them.

8.1 Running tests

8.1.1 testprog

The main test script for testing is:

testprog <Pascal source file>

testprog.bat <Pascal source file>

testprog is a “one stop” test resource for most programs. It expects the following files to exist under the given primary filename:

program.pas The Pascal source file.

program.inp The input file for the running program.

program.cmp The reference file for the expected output.

testprog compiles and runs the target program, and checks its output against the reference file. Several files are produced during the process:

program.p5 Contains the intermediate code for the program as compiled by pcom.

Program.err Contains the output from pcom. This includes the status line indicating the number of errors. It also typically contains a listing of the program as compiled, which contains line numbers and other information. Note that if the pcom compile run produces errors, testprog will stop.

Program.lst Contains the output from the program when run. This is all output to the standard “ output” file.

Program.out This is all of the output to the “prr” special file. This is only used by P5 for special purposes, such as to output the intermediate code, and most programs will be empty.

Program.dif This is the output of the diff command between program.lst and program.cmp. It should be empy if the program produced the output expected.

Not all of the files for testprog need to have contents. For example, a program that does not do input does not need to have a program.inp file. An example of this would be the “hello” program. However, testprog expects all of the files to exist.

To determine if the test ran correctly, the output of first the program.err file should be checked for zero errors, then the resulting program.dif file is checked for zero length. All of these results are announced during the test:

```
C:\projects\PASCAL\p5_ext>testprog sample_programs\roman
Compile and run sample_programs\roman
Compile fails, examine the sample_programs\roman.err file
```

For a program that has a compile error.

```
C:\projects\PASCAL\p5_ext>testprog sample_programs\roman
Compile and run sample_programs\roman
03/18/2012  10:44 AM                76 roman.dif
```

For a program that does not match it's expected output.

If a large series of test programs are compiled and run with testprog, it may be more efficient to examine the output files to determine the result, first the program.err file, then the program.dif file. The rejection test is a good example of such a large series of files.

8.1.2 Other tests

Not all test programs work well with the testprog script. Examples are "pascals", and the self compile. For these programs a special test script is provided.

8.1.3 Regression test

All of the "positive" tests are wrapped up in a single script, "regress.bat". This script runs all of the positive tests in order of successive complexity. Whenever a change is made to P5, the regression test is run to verify that the resulting compiler is still valid.

8.2 Test types

The Pascal-P5 tests are divided into two major catagories, referred here as "positive" and "negative" tests. The positive tests are designed to test what the compiler should accept as a valid program. The negative tests are designed to test what the compiler should reject as invalid programs.

Thus, they are termed here as the "Pascal Acceptance" test, and the "Pascal rejection test". The two test types are fundamentally different. For example, all of the acceptance tests can appear in a single program, since the entire program should compile and run as a valid program. However, the Pascal rejection test cannot practically be represented as a single program because it would (or should) consist of a repeated series of errors. The compiler could conceivably recover from the each error sufficiently to encounter and properly flag the next error, but this would not be reliable, and would vary from compiler to compiler. Further, such a test would test error recovery as well as simple error detection, which are two separate issues, and should be covered by two separate tests.

8.3 The Pascal acceptance test

The Pascal acceptance test consists of program constructs that are correct for ISO 7185 Pascal. It should both compile and run under a ISO 7185 Pascal compatible compiler. The acceptance test is present in a single source file:

iso7185pat.pas

8.4 The Pascal rejection test

The Pascal rejection test is arranged as a series of short tests because each test is designed to fail. Thus, ideally only one failure point at a time is executed.

The test script, runprt, is designed so that each result is checked for if an error occurred or not, with the lack of an error being a fail. However, there are at least two characteristics of a test result that go to quality, and thus imply that the result should be hand checked at least once:

1. The indicated error may or may not be appropriate for the error that was caused (for example, indicating a missing ':' when the problem was a missing ';').
2. The error may generate many collateral errors, or even refuse to compile the remainder of the program. This includes generating recycle balance errors.

The error signature of the compile can be compared to the previous runs, but a miscompare does not automatically fail the compiler, since error handling may have changed. The typical stragey is to run a new compiler version through the PRT test, and hand-examine only the error differences. If the changes in the compiler are minor, a compare go/no go will serve as a regression test.

Here are descriptions of each of the tests.

Class 1: Syntax graph visitation. These tests are for various points on the syntax graph, typically addition or elidation of a critical symbol. These tests are not meant to be exhaustive, since there are an infinite number of possible syntax constructions. Rather, it is designed to be representative.

The syntax visitation is according to the Pascal Users's manual and Report" 4th edition, Appendix D, Syntax diagrams. The tests run in reverse, starting with "program", and working backwards. Thus, the syntax checks are performed top to bottom.

Class 2: Semantic tests. These tests are for the meaning of the program. Examples include using an undefined variable, using a type in the incorrect context, executing a case statement where there is no case matching the selector, etc.

Note that the tests are not designed to be a complete set of failure modes for the compiler, nor is that possible, since the set of possible failure modes is infinite. Instead, this test is designed to be representative", or contain a series of known failure modes that test the quality of error checking and recovery in the compiler.

Note that the semantic errors are the same as those enumerated in the ISO 7185 standard in Appendix D, offset in number by the section 1700. Not all errors in this section have equivalent test cases. It is possible for an error defined by the standard to be without expression as a program. The description of the error is as was written in the ISO 7185 standard.

The ISO 7158 listed errors are a mix of compile time and runtime errors. On some errors, either mode is possible, on others, not. For these cases, we have tried to break the test program into two sections, one that could fail at compile time, and others that do not. These are labeled with an appended A, B, C, etc.

There can be other reasons to divide a test case into two programs.

With semantic errors, there is always the posibility that the code could be changed by an agressive compiler to eliminate or nulify the test case. There is no requirement in ISO 7185 that the compiler render into code a statement that clearly has no effect in the final program, just to achieve an error result. Its really not possible to defeat this kind of optimization entirely. Printing to output is one possibility, but even then there is nothing to prevent the compiler from assuming it knows what the output will be and changing it. This is perhaps a subject for further research.

8.4.1 List of tests

8.4.1.1 Class 1: Syntatic errors

Program

iso7185prt0001	Missing semicolon after program statement
iso7185prt0002	missing "program" word-symbol
iso7185prt0003	missing program name word-symbol
iso7185prt0004	Moved
iso7185prt0005	Moved
iso7185prt0006	missing period
iso7185prt0007	Extra semicolon
iso7185prt0008	Missing header parameters
iso7185prt0009	Opening paren for program header only
iso7185prt0010	Closing paren for program header only
iso7185prt0011	Improperly terminated header list
iso7185prt0012	Consecutive semicolons

Block

iso7185prt0013	Missing number for label
iso7185prt0014	Missing semicolon after label
iso7185prt0015	Non-numeric label
iso7185prt0016	Unterminated label list
iso7185prt0017	Unstarted label list
iso7185prt0018	Missing constant
iso7185prt0019	Missing constant right side
iso7185prt0020	Missing "=" in const
iso7185prt0021	Incomplete second in const
iso7185prt0022	Missing ident in const
iso7185prt0023	Missing semicolon in const
iso7185prt0024	Reverse order between label and const
iso7185prt0025	Missing type
iso7185prt0026	Missing type right side
iso7185prt0027	Missing "=" in type
iso7185prt0028	Missing ident in type
iso7185prt0029	Incomplete second in type
iso7185prt0030	Missing semicolon in type
iso7185prt0031	Reverse order between const and type
iso7185prt0032	Missing var
iso7185prt0033	Missing var right side
iso7185prt0034	Missing var ident list prime
iso7185prt0035	Missing var ident list follow
iso7185prt0036	Missing ":" in var
iso7185prt0037	Missing ident list in var
iso7185prt0038	Incomplete second in var
iso7185prt0039	Missing semicolon in var
iso7185prt0040	Reverse order between type and var

iso7185prt0041 Missing "procedure" or "function"
iso7185prt0042 Missing ident
iso7185prt0043 Missing semicolon
iso7185prt0044 Consecutive semicolons start
iso7185prt0045 Missing block
iso7185prt0046 Missing final semicolon
iso7185prt0047 Misspelled directive
iso7185prt0048 Bad directive
iso7185prt0049 Misspelled procedure
iso7185prt0050 Misspelled function
iso7185prt0051 Bad procedure/function
iso7185prt0052 Missing ":" on return type for function
iso7185prt0053 Missing type id on return type for function
iso7185prt0054 Reverse order between var and procedure
iso7185prt0055 Reverse order between var and function
iso7185prt0056 missing begin word-symbol
iso7185prt0057 missing end word-symbol

Statement

iso7185prt0100 Missing label ident
iso7185prt0101 Missing label ":"
iso7185prt0102 Missing assignment left side
iso7185prt0103 Missing assignment ":="
iso7185prt0104 Missing procedure identifier
iso7185prt0105 Missing "begin" on statement block
iso7185prt0106 Misspelled "begin" on statement block
iso7185prt0107 Missing "end" on statement block
iso7185prt0108 Mispelled "end" on statement block
iso7185prt0109 Missing "if" on conditional
iso7185prt0110 Misspelled "if" on conditional
iso7185prt0111 Missing expression on conditional
iso7185prt0112 Missing "then" on conditional
iso7185prt0113 Misspelled "then" on conditional
iso7185prt0114 Misspelled "else" on conditional
iso7185prt0115 Missing "case" on case statement
iso7185prt0116 Misspelled "case" on case statement
iso7185prt0117 Missing expression on case statement
iso7185prt0118 Missing "of" on case statement
iso7185prt0119 Misspelled "of" on case statement
iso7185prt0120 Missing constant on case stament list
iso7185prt0121 Missing 2nd constant on case statement list
iso7185prt0122 Missing ":" before statement on case statement
iso7185prt0123 Missing ";" between statements on case statement
iso7185prt0124 Missing "end" on case statement
iso7185prt0125 Misspelled "end" on case statement
iso7185prt0126 Missing "while" on while statement
iso7185prt0127 Mispelled "while" on while statement
iso7185prt0128 Missing expression on while statement
iso7185prt0129 Missing "do" on while statement
iso7185prt0130 Missing "repeat" on repeat statement

iso7185prt0131	Misspelled "repeat" on repeat statement
iso7185prt0132	Missing "until" on repeat statement
iso7185prt0133	Misspelled "until" on repeat statement
iso7185prt0134	Missing expression on repeat statement
iso7185prt0135	Missing "for" on for statement
iso7185prt0136	Misspelled "for" on for statement
iso7185prt0137	Missing variable ident on for statement
iso7185prt0138	Misspelled variable ident on for statement
iso7185prt0139	Missing ":=" on for statement
iso7185prt0140	Missing start expression on for statement
iso7185prt0141	Missing "to"/"downto" on for statement
iso7185prt0142	Misspelled "to" on for statement
iso7185prt0143	Misspelled "downto" on for statement
iso7185prt0144	Missing end expression on for statement
iso7185prt0145	Missing "do" on for statement
iso7185prt0146	Misspelled "do" on for statement
iso7185prt0147	Missing "with" on with statement
iso7185prt0148	Misspelled "with" on with statement
iso7185prt0149	Missing first variable in with statement list
iso7185prt0150	Missing second variable in with statement list
iso7185prt0151	Missing "goto" in goto statement
iso7185prt0152	Misspelled "goto" in goto statement
iso7185prt0153	Missing unsigned integer in goto statement
iso7185prt0154	Missing 1st constant on case statement list
iso7185prt0155	Missing only variable in with statement list
iso7185prt0156	Missing ',' between case constants
iso7185prt0157	Missing ',' between variables in with statement

<u>Field list</u>

iso7185prt0200	Missing field ident
iso7185prt0201	Missing first field ident
iso7185prt0202	Missing second field ident
iso7185prt0203	Missing ':' between ident and type
iso7185prt0204	Missing type
iso7185prt0205	Missing ';' between successive fields
iso7185prt0206	Misspelled 'case' to variant
iso7185prt0207	Missing identifier for variant
iso7185prt0208	Missing type identifier with field identifier
iso7185prt0209	Missing type identifier without field identifier
iso7185prt0210	Missing 'of' on variant
iso7185prt0211	Misspelled 'of' on variant
iso7185prt0212	Missing case constant on variant
iso7185prt0213	Missing first constant on variant
iso7185prt0214	Missing second constant on variant
iso7185prt0215	Missing ':' on variant case
iso7185prt0216	Missing '(' on field list for variant
iso7185prt0217	Missing ')' on field list for variant
iso7185prt0218	Missing ';' between successive variant cases
iso7185prt0219	Attempt to define multiple variant sections
iso7185prt0220	Standard field specification in variant

iso7185prt0221 Missing ',' between first and second field idents
iso7185prt0222 Missing ',' between first and second field idents in variant

Procedure or Function Heading

iso7185prt0300 Missing 'procedure'
iso7185prt0301 Misspelled 'procedure'
iso7185prt0302 Missing procedure identifier
iso7185prt0303 Missing 'function'
iso7185prt0304 Misspelled 'function'
iso7185prt0305 Missing function identifier
iso7185prt0306 Missing type ident after ':' for function

Ordinal Type

iso7185prt0400 Missing '(' on enumeration
iso7185prt0401 Missing identifier on enumeration
iso7185prt0402 Missing 1st identifier on enumeration
iso7185prt0403 Missing 2nd identifier on enumeration
iso7185prt0404 Missing ')' on enumeration
iso7185prt0405 Missing 1st constant on subrange
iso7185prt0406 Missing '..' on subrange
iso7185prt0407 Missing 2nd constant on subrange
iso7185prt0408 Missing ',' between identifiers on enumeration

Type

iso7185prt0500 Missing type identifer after '^'
iso7185prt0501 Misspelled 'packed'
iso7185prt0502 Missing 'array'
iso7185prt0503 Missing '[' on array
iso7185prt0504 Missing index in array
iso7185prt0505 Missing first index in array
iso7185prt0506 Missing second index in array
iso7185prt0507 Missing ']' on array
iso7185prt0508 Missing index specification in array
iso7185prt0509 Missing 'of' on array
iso7185prt0510 Misspelled 'of' on array
iso7185prt0511 Missing type on array
iso7185prt0512 Missing 'file' or 'set' on file or set type
iso7185prt0513 Misspelled 'file' on file type
iso7185prt0514 Missing 'of' on file type
iso7185prt0515 Missing type on file type
iso7185prt0516 Misspelled 'set' on set type
iso7185prt0517 Missing 'of' on set type
iso7185prt0518 Missing type on set type
iso7185prt0519 Missing 'record' on field list
iso7185prt0520 Misspelled 'record' on field list
iso7185prt0521 Missing 'end' on field list
iso7185prt0522 Misspelled 'end' on field list

Formal Parameter List

iso7185prt0600	Missing parameter identifier
iso7185prt0601	Missing first parameter identifier
iso7185prt0602	Missing second parameter identifier
iso7185prt0603	Missing ',' between parameter identifiers
iso7185prt0604	Missing ':' on parameter specification
iso7185prt0605	Missing type identifier on parameter specification
iso7185prt0606	Missing parameter specification after 'var'
iso7185prt0607	Misspelled 'var'
iso7185prt0608	Missing ';' between parameter specifications

Expression

iso7185prt0700	Missing operator
iso7185prt0701	Missing first operand to '='
iso7185prt0702	Missing second operand to '='
iso7185prt0703	Missing first operand to '>'
iso7185prt0704	Missing second operand to '>'
iso7185prt0705	Missing first operand to '<'
iso7185prt0706	Missing second operand to '<'
iso7185prt0707	Missing first operand to '<>'
iso7185prt0708	Missing second operand to '<>'
iso7185prt0709	Missing first operand to '<='
iso7185prt0710	Missing second operand to '<='
iso7185prt0711	Missing first operand to '>='
iso7185prt0712	Missing second operand to '>='
iso7185prt0713	Missing second operand to 'in'
iso7185prt0714	Alternate '><'
iso7185prt0715	Alternate '=<'
iso7185prt0716	Alternate '=>'
iso7185prt0717	Missing first operand to 'in'

Actual Parameter List

iso7185prt0800	Empty list (parens only)
iso7185prt0801	Missing leading '(' in list
iso7185prt0802	Missing ',' in parameter list
iso7185prt0803	Missing first parameter in parameter list
iso7185prt0804	Missing second parameter in parameter list
iso7185prt0805	Missing ')' in list

Write Parameter List

iso7185prt0900	Empty list (parens only)
iso7185prt0901	Missing leading '(' in list
iso7185prt0902	Missing ',' in parameter list
iso7185prt0903	Missing first parameter in parameter list
iso7185prt0904	Missing second parameter in parameter list
iso7185prt0905	Field with missing value
iso7185prt0906	Fraction with missing value
iso7185prt0907	Field and fraction with missing field
iso7185prt0908	Missing ')' in list

Factor

iso7185prt1000	Missing leading '(' for subexpression
iso7185prt1001	Missing subexpression in '()'
iso7185prt1002	Misspelled 'not'
iso7185prt1003	'not' missing expression
iso7185prt1004	Missing '[' on set constant
iso7185prt1006	Missing first expression in range
iso7185prt1007	Missing second expression in range
iso7185prt1008	Missing '..' or ',' in set constant list
iso7185prt1009	Missing first expression in ',' delimited set constant list
iso7185prt1010	Missing second expression in ',' delimited set constant list

Term

iso7185prt1100	Missing first operand to '*'
iso7185prt1101	Missing second operand to '*'
iso7185prt1102	Missing first operand to '/'
iso7185prt1103	Missing second operand to '/'
iso7185prt1104	Missing first operand to 'div'
iso7185prt1105	Missing second operand to 'div'
iso7185prt1106	Missing first operand to 'mod'
iso7185prt1107	Missing second operand to 'mod'
iso7185prt1108	Missing first operand to 'and'
iso7185prt1109	Missing second operand to 'and'

Simple Expression

iso7185prt1200	'+' with missing term
iso7185prt1201	'-' with missing term
iso7185prt1203	Missing second operand to '+'
iso7185prt1205	Missing second operand to '-'
iso7185prt1206	Missing first operand to 'or'
iso7185prt1207	Missing second operand to 'or'

Unsigned Constant

iso7185prt1300	Misspelled 'nil'

Variable

iso7185prt1400	Missing variable or field identifier
iso7185prt1401	Missing '[' in index list
iso7185prt1402	Missing expression in index list
iso7185prt1403	Missing first expression in index list
iso7185prt1404	Missing second expression in index list
iso7185prt1405	Missing ',' in index list
iso7185prt1406	Missing ']' in index list
iso7185prt1407	Missing field identifier after '.'

Unsigned number

iso7185prt1500	Missing leading digit before '.'

iso7185prt1501	Missing digit after '.'
iso7185prt1502	Missing digit before and after '.'
iso7185prt1503	Mispelled 'e' in exponent
iso7185prt1504	Missing 'e' in exponent
iso7185prt1505	Missing digits in exponent
iso7185prt1506	Missing digits in exponent after '+'
iso7185prt1507	Missing digits in exponent after '-'
iso7185prt1508	Missing number before exponent

Character String

iso7185prt1600 String extends beyond eol (no end quote)

8.4.1.2 Class 2: Semantic errors

iso7185prt1701 For an indexed-variable closest-containing a single index-expression, it is an error if the value of the index-expression is not assignment-compatible with the index-type of the array-type.

iso7185prt1702 It is an error unless a variant is active for the entirety of each reference and access to each component of the variant.

iso7185prt1703 It is an error if the pointer-variable of an identified-variable denotes a nil-value.

iso7185prt1704 It is an error if the pointer-variable of an identified-variable is undefined.

iso7185prt1705 It is an error to remove from its pointer-type the identifying-value of an identified-variable when a reference to the identified-variable exists.

iso7185prt1706 It is an error to alter the value of a file-variable f when a reference to the buffer-variable f^ exists.

iso7185prt1707 It is an error if the value of each corresponding actual value parameter is not assignment compatible with the type possessed by the formal-parameter.

iso7185prt1708 For a value parameter, it is an error if the actual-parameter is an expression of a set-type whose value is not assignment-compatible with the type possessed by the formal-parameter.

iso7185prt1709 It is an error if the file mode is not Generation immediately prior to any use of put, write, writeln or page.

iso7185prt1710 It is an error if the file is undefined immediately prior to any use of put, write, writeln or page.

iso7185prt1711 It is an error if end-of-file is not true immediately prior to any use of put, write, writeln or page.

iso7185prt1712 It is an error if the buffer-variable is undefined immediately prior to any use of put.

iso7185prt1713 It is an error if the file is undefined immediately prior to any use of reset.

iso7185prt1714 It is an error if the file mode is not Inspection immediately prior to any use of get or read.

iso7185prt1715	It is an error if the file is undefined immediately prior to any use of get or read.
iso7185prt1716	It is an error if end-of-file is true immediately prior to any use of get or read.
iso7185prt1717	For read, it is an error if the value possessed by the buffer-variable is not assignmentcompatible with the variable-access.
iso7185prt1718	For write, it is an error if the value possessed by the expression is not assignment-compatible with the buffer-variable.
iso7185prt1719	For new(p,c l ,...,c n,), it is an error if a variant of a variant-part within the new variable becomes active and a different variant of the variant-part is one of the specified variants.
iso7185prt1720	For dispose(p), it is an error if the identifying-value had been created using the form new(p,c l ,...,c n).
iso7185prt1721	For dispose(p,k l ,...,k,), it is an error unless the variable had been created using the form new(p,c l ,...,c,,,) and m is equal to n.
iso7185prt1722	For dispose(p,k l ,...,k,), it is an error if the variants in the variable identified by the pointer value of p are different from those specified by the case-constants k l ,...,k,,,,.
iso7185prt1723	For dispose, it is an error if the parameter of a pointer-type has a nil-value.
iso7185prt1724	For dispose, it is an error if the parameter of a pointer-type is undefined.
iso7185prt1725	It is an error if a variable created using the second form of new is accessed by the identified variable of the variable-access of a factor, of an assignment-statement, or of an actual-parameter.
iso7185prt1726	For pack, it is an error if the parameter of ordinal-type is not assignment-compatible with the index-type of the unpacked array parameter.
iso7185prt1727	For pack, it is an error if any of the components of the unpacked array are both undefined and accessed.
iso7185prt1728	For pack, it is an error if the index-type of the unpacked array is exceeded.
iso7185prt1729	For unpack, it is an error if the parameter of ordinal-type is not assignment-compatible with the index-type of the unpacked array parameter.
iso7185prt1730	For unpack, it is an error if any of the components of the packed array are undefined.
iso7185prt1731	For unpack, it is an error if the index-type of the unpacked array is exceeded.
iso7185prt1732	Sqr(x) computes the square of x. It is an error if such a value does not exist.
iso7185prt1733	For ln(x), it is an error if x is not greater than zero.
iso7185prt1734	For sqrt(x), it is an error if x is negative.
iso7185prt1735	For trunc(x), the value of trunc(x) is such that if x is positive or zero then 0 < x-trunc(x) < 1; otherwise 1 <x-trunc(x) < 0. It is an error if such a value does not exist.

iso7185prt1736	For round(x), if x is positive or zero then round(x) is equivalent to trunc(x+0.5), otherwise round(x) is equivalent to trunc(x- 0.5). It is an error if such a value does not exist.
iso7185prt1737	For chr(x), the function returns a result of char-type that is the value whose ordinal number is equal to the value of the expression x if such a character value exists. It is an error if such a character value does not exist.
iso7185prt1738	For succ(x), the function yields a value whose ordinal number is one greater than that of x, if such a value exists. It is an error if such a value does not exist.
iso7185prt1739	For pred(x), the function yields a value whose ordinal number is one less than that of x, if such a value exists. It is an error if such a value does not exist.
iso7185prt1740	When eof(f) is activated, it is an error if f is undefined.
iso7185prt1741	When eoln(f) is activated, it is an error if f is undefined.
iso7185prt1742	When eoln(f) is activated, it is an error if eof(f) is true.
iso7185prt1743	An expression denotes a value unless a variable denoted by a variable-access contained by the expression is undefined at the time of its use, in which case that use is an error.
iso7185prt1744	A term of the form x/y is an error if y is zero.
iso7185prt1745	A term of the form i div j is an error if j is zero.
iso7185prt1746	A term of the form i mod j is an error if j is zero or negative.
iso7185prt1747	It is an error if an integer operation or function is not performed according to the mathematical rules for integer arithmetic.
iso7185prt1748	It is an error if the result of an activation of a function is undefined upon completion of the algorithm of the activation.
iso7185prt1749	For an assignment-statement, it is an error if the expression is of an ordinal-type whose value is not assignment-compatible with the type possessed by the variable or function-identifier.
iso7185prt1750	For an assignment-statement, it is an error if the expression is of a set-type whose value is not assignment-compatible with the type possessed by the variable.
iso7185prt1751	For a case-statement, it is an error if none of the case-constants is equal to the value of the case-index upon entry to the case-statement.
iso7185prt1752	For a for-statement, it is an error if the value of the initial-value is not assignment-compatible with the type possessed by the control-variable if the statement of the for-statement is executed.
iso7185prt1753	For a for-statement, it is an error if the value of the final-value is not assignment-compatible with the type possessed by the control-variable if the statement of the for-statement is executed.

iso7185prt1754	On reading an integer from a textfile, after skipping preceding spaces and end-of-lines, it is an error if the rest of the sequence does not form a signed-integer.
iso7185prt1755	On reading an integer from a textfile, it is an error if the value of the signed-integer read is not assignment-compatible with the type possessed by variable-access.
iso7185prt1756	On reading a number from a textfile, after skipping preceding spaces and end-of-lines, it is an error if the rest of the sequence does not form a signed-number.
iso7185prt1757	It is an error if the buffer-variable is undefined immediately prior to any use of read.
iso7185prt1758	On writing to a textfile, the values of TotalWidth and FracDigits are greater than or equal to one ; it is an error if either value is less than one.
iso7185prt1800	Access to dynamic variable after dispose.
iso7185prt1801	Threats to FOR statement index. Threat within the controlled statement block, assignment.
iso7185prt1802	Threats to FOR statement index. Threat within the controlled statement block, VAR param.
iso7185prt1803	Threats to FOR statement index. Threat within the controlled statement block, read or readln.
iso7185prt1804	Threats to FOR statement index. Threat within the controlled statement block, reuse of index in nested FOR loop.
iso7185prt1805	Threats to FOR statement index. Threat in same scope block, assignment..
iso7185prt1806	Threats to FOR statement index. Threat in same scope block, VAR parameter.
iso7185prt1807	Threats to FOR statement index. Threat in same scope block, read or readln.
iso7185prt1808	Validity of for loop index. Index out of current block.
iso7185prt1809	Validity of for loop index. Index not ordinal type.
iso7185prt1810	Validity of for loop index. Index is part of structured type.
iso7185prt1811	State of for loop index after loop. Test undefined value of loop index after for.
iso7185prt1820	Backwards pointer association. Indicates an error unless a pointer reference uses backwards assocation, which is incorrect.
iso7185prt1821	Double definitions. Double define with same type.
iso7185prt1822	Double definitions. Double define with different case.
iso7185prt1823	Invalid type substitutions. Use of subrange for VAR reference.
iso7185prt1824	Invalid type substitutions. Assign of real to integer.
iso7185prt1825	Invalid type substitutions. Wrong type of case label.

iso7185prt1826	Files of files. Direct specification of file of file.
iso7185prt1827	Files of files. File in substructure.
iso7185prt1828	Out of bounds array access. Simple out of bounds access, with attempt to redirect to runtime.
iso7185prt1829	Parameter number mismatch. Less parameters than specified.
iso7185prt1830	Parameter number mismatch. More parameters than specified.
iso7185prt1831	Parameter type mismatch. Wrong type of a parameter.
iso7185prt1832	Goto/label issues. Goto nested block.
iso7185prt1833	Goto/label issues. Intraprocedure Goto nested block.
iso7185prt1834	Goto/label issues. Unreferenced label.
iso7185prt1835	Goto/label issues. No label to go to.
iso7185prt1836	Goto/label issues. Label defined, but never used.
iso7185prt1837	Goto/label issues. Label used but not defined.
iso7185prt1838	Undefineds. Undefined variable.
iso7185prt1839	Write with invalid fields. Write with zero field.
iso7185prt1840	Write with invalid fields. Write with zero fraction.
iso7185prt1841	Zero length string. Write zero length string.
iso7185prt1842	Use of text procedure with non-text. Use readln with integer file.
iso7185prt1843	Variable reference to tagfield. Pass of a tagfield as a variable reference.
iso7185prt1844	Variable reference to packed variable. Passing a packed element as a variable reference.
iso7185prt1845	Goto/label issues. Label defined in outter block than use.
iso7185prt1846	Numeric overflow on constant. Integer overflow.
iso7185prt1847	Numeric overflow on constant. Overflow on exponent.
iso7185prt1848	Variable reference to packed variable. Passing a packed element as a variable reference.
iso7185prt1849	Variable reference to packed variable. Passing a packed element as a variable reference.
iso7185prt1850	Unreferenced variable. Variable without reference in program.
iso7185prt1851	Reference to undefined variant. Test if undefined variant can be detected after the variant is changed.

iso7185prt1852 Out of range for index variable. Test if out of range is checked on 'for' index variable.

8.4.1.3 Class 3: User submitted tests/encountered failures

iso7185prt1900 Elide of type. Type description completely missing.

iso7185prt1901 Constructing set from real. Check attempt to construct set from real element.

iso7185prt1902 Goto/label issues. Goto nested block.

iso7185prt1903 Goto/label issues. Goto nested block.

iso7185prt1904 If statement. The condition part of an if statement must have boolean type.

iso7185prt1905 Repeat statement. The condition of the until part of a repeat statement must have boolean type.

iso7185prt1906 While statement. The condition part of a while statement must have boolean type.

8.4.2 Running the PRT and interpreting the results

There is a single script that runs the prt:

$ runprt

The results of all of the tests are gathered and formatted into the file:

iso7185prt.lst

This file has several sections:

1. List of tests with no compile or runtime error.
2. List of differences between compiler output and “gold” standard outputs.
3. List of differences between runtime output and “gold” standard outputs.
4. Collected compiler listings and runtime output of all tests.

Each of these will be examined in turn.

8.4.2.1 List of tests with no compile or runtime error.

The purpose of the rejection test is to cause an error in the test program, either at compile time or runtime, and test its proper handling. By definition, if no error exists, the test has failed. This list gives the tests that need to be examined for why they didn’t detect an error.

8.4.2.2 List of differences between compiler output and “gold” standard outputs.

Shows the number of lines difference between the output test.err or compiler output listing, and test.ecp or “gold standard” compiler output listing, for each test program. A difference of 0 means that nothing has changed in the run.

The compiler output listing flagging an error and the run output flagging an error are mutually exclusive. If the compiler listing shows an error, the program will not be run. If if the compiler output shows an error, it is examined to see if it flagged an appropriate error for the fault, and that it didn’t generate excessive “cascade” or further errors caused by the compiler having difficulty recovering from the error.

Once the test.err file is judged satisfactory, it is copied to the test.ecp file as the “gold” standard. If the test run shows a difference between the current compile and the gold standard file, it does not necessarily mean that it is wrong. It simply means it needs to be reevaluated and perhaps copied as the new gold standard file.

8.4.2.3 List of differences between runtime output and "gold" standard outputs.

If the test file is successfully compiled, it is run and the output collected as test.lst. This is compared to the "gold" run output file test.cmp.

The run output file, if it exists, is checked to see if it indicates an appropriate error for the fault indicated in the test. If the run indicates no error, or an error that is not related to the fault, or simply crashes, that is a failure to properly handle the fault.

Once the test.lst file is judged satisfactory, it is copied to the test.cmp file as the "gold" standard. If the test run shows a difference between the current output and the gold standard file, it does not necessarily mean that it is wrong. It simply means it needs to be reevaluated and perhaps copied as the new gold standard file.

8.4.2.4 Collected compiler listings and runtime output of all tests.

The output of the compiler listing, as well as the output of the run, if that exists, for each test is concatenated and placed at the end of the listing file. This allows the complete output of each test to be examined, without having to look at the individual test.err or test.list file.

8.4.3 Overall interpretation of PRT results

The rejection test is a "quality" test. There is no absolute right and wrong. The clearest indication of failure is failure to find any error. Past that are issues that indicate the quality of the error handling in the compiler:

1. If the error is indicative of what the failure was.
2. No or few further errors resulted after the failure.
3. The compiler was able to resyncronise with the source.
4. No data was corrupted as a result of the run (dynamic space imbalance, null pointer errors or similar).

You can say that failure to achieve the above marks a poor quality compiler, but not a failing test.

8.5 Sample program tests

The sample program tests give a series of sample programs in Pascal. The idea of the sample programs tests is to prove out operation on common programs, and also to give a newly modified version of P5 a series if tests progressing from the most simple ("hello world") to more complex tests. If the new version of the compiler has serious problems, it is better to find out with simple tests rather than have it fail on a more complex, and difficult to debug, test.

Hello	Gives the standard "hello, world" minimum test.
Roman	Prints a series of roman numerals. From Jensen and Wirth's "User Manual and report".
Match	A number match game, this version from Conway, Gries and Zimmerman "A primer on Pascal".
Startrek	Plays text mode startrek. From the internet.
Basics	Runs a subset Basic interpreter. It is tested by running a recoded version of "match" above.

Pascal-S Runs a subset of ISO 7185 Pascal. From Niklaus Wirth's work at ETH. It is tested by running the "Roman" program above.

8.6 Previous Pascal-P versions test

As part of the regression tests, Pascal-P5 runs the older versions of itself, namely Pascal-P2 and Pascal-P4. These are the only versions of the compiler available. See the section "introduction" on page 8, and also the historical material on Pascal-P on the Standard Pascal website.

The run of previous versions of Pascal-P perhaps constitutes the purest form of regression test. It not only insures that P5 is compatible with previous versions, but that it can actually compile and run all of the previous code. Of course, this is possible in main because these 1970's versions were adapted to the ISO 7185 standard, but that, fortunately, was a small change.

8.6.1 Compile and run Pascal-P2

Pascal-P2 runs on Pascal-P5 virtually unmodified. It needed only the declarations of the **prd** and **prr** files removed. This is required because they are predefined in Pascal-P5. In a stand-alone use of Pascal-P2, those files are real external files and have to be declared.

P2 runs as a test a modified version of **roman.pas**. It has to be modified because of:

1. Pascal-P2 only supports upper case.
2. Pascal-P2 does not support the output file as a default parameter to **writeln**.

These changes are documented in the P2 archive on http://www.standardpascal.org.

Pascal-P2 does not have a full regression test of its own because I didn't do the work of cutting down the ISO 7185 test to the subset that Pascal-P2 implements, as I did for Pascal-P4. This is perhaps a future project.

8.6.2 Compile and run Pascal-P4

Pascal-P4 has the same modification of the **prd** and **prr** files as Pascal-P2, but otherwise runs unmodified. P4 runs as its target standardp.pas, which was a version of iso7185pat.pas that was stripped so as to fit the subset of ISO 7185 that Pascal-P4 runs. Recall that Pascal-P4 does not run any standard of Pascal at all, it is intentionally a subset.

Standard.pas was modified only in that P4 running under P5 cannot execute a for loop of the form:

```
for b := false to true do ...
```

The reason for this is non-trival. The way that P4 executes such a loop is to check that b lies in the range of boolean 0..1, and terminate if it lies outside that range. This actually makes it an illegal program if variable b is treated as boolean, since b will be incremented to 2 and thus be an out of range value.

This is actually a standard issue with Pascal in general, and the ISO 7185 standard took pains to show an equivalent form of the for loop that does not involve creating an out of range boolean. P5 also uses a form internally that fixes this, it has to in order to fully comply with the ISO 1785 standard.

So why does that work with a standalone Pascal-P4 and not with a Pascal-P4 running under Pascal-P5? Pascal-P4, as well as Pascal-P5, treat the internal data store as typeless and use type escapes in the form of undiscriminated variants in order to differentiate the different data forms. This means that the result of assigning 2 to b (or incrementing it from 1) are system and compiler dependent. Thus, the direct code generating compilers tolerate this, and P5 simply does not.

8.7 Self compile

One of the more difficult tests for Pascal-P5 (and the most time consuming) is to have Pascal-P5 compile and run itself. Actually the entire idea of Pascal-P was to compile and run itself in order to accomplish a bootstrap of the compiler. Pascal-P was never provided in a form able to directly compile itself, it needed a few modifications in order to do that. Also, self compiling a compiler that interprets its final code is different from a machine code generating compiler. Whereas it is conceptually simple to imagine the parser and intermediate code generator compling a version of itself, having the interpreter run another instance of itself on itself is like looking into a series of mirrors. The interpreter will be interpreting itself while that interpreter interprets another program, etc.

This can actually be carried out to any depth of self-interpretation, but because each interpretation level slows down the code by an order of magnitude, such nested self interpretation rapidly becomes impractical to complete. As it is, a single level of self-interpretation takes hours.

The reason to put work into a self compile of Pascal-P5 is that it is a difficult test that goes a long way to prove out the stability and capacity of the compiler, and also because it proves out a very important function of Pascal-P, that of bootstrapping itself.

8.7.1 pcom

I was able to get pcom.pas to self compile. This means to compile and run pcom.pas, then execute it in the simulator, pint. Then it is fed its own source, and compiles itself into intermediate code. Then this is compared to the same intermediate code for pcom as output by the regular compiler. Its a good self check, and in fact found a few bugs.

The Windows batch file to control a self compile and check is:

cpcoms.bat

What does it mean to self compile? For pcom, not much. Since it does not execute itself (pint does that), it is simply operating on the interpreter, and happens to be compiling a copy of itself.

8.7.1.1 Changes required

pcom won't directly compile itself the way it is written. The reason is that the "prr" file, the predefined file it uses to represent it's output file is only predefined to Pascal-P5 itself. The rules for ISO 7185 are that each file that is defined in the header which is not predefined, such as "input" or "output", must be also declared in a var statement. This makes sense, because if it is not a predefined file, the compiler must know what type of file (or even non-file) that is being accessed externally to the program.

Because the requirements are different from a predefined special compiler file to a file that is simply external, the source code must be different for a Pascal-P5 file vs. another compiler. A regular ISO 7185 Pascal compiler isn't going to have a predefined prr file.

To configure the compiler for self compile, the define SELF_COMPILE must be set in the preprocessor.

In the batch file above, this modified file is represented as pcomm.pas, or "modified" pcom.pas.

All of the source code changes from pcom.pas to pcomm.pas are automated in cpints.bat.

8.7.2 pint

pint is more interesting to self compile, since it is running (being interpreted) on a copy of itself. Unlike the pcom self compile, pint can run a copy of itself running a copy of itself, etc., to any depth. Of course, each time the interpreter runs on itself, it slows down orders of magnitude, so it does not take many levels to make it virtually impossible to run to completion. I ran a copy of pint running on itself, then interpreting a copy of iso7185pat. The result of the iso7185pat is then compared to the "gold" standard file.

As with pcom, pint will not self compile without modification. It has the same issue with predefined header files. Also, pint cannot run on itself unless its storage requirements are reduced. For example, if the "store" array, the byte array that is used to contain the program, constants and variables, is 1 megabyte in length, the copy of pint that is hosted on pint must have a 1 megabyte store minus all of the overhead associated with pint itself.

The windows batch file required to self compile pint is:

cpints.bat

As a result, these are the changes required in pint:

```
{ !!! Need to use the small size memory to self compile, otherwise, by definition,
  pint cannot fit into its own memory. }
#ifndef SELF_COMPILE
      maxstr      = 16777215;  { maximum size of addressing for program/var }
      maxtop      = 16777216;  { maximum size of addressing for program/var+1 }
      maxdef      = 2097152;   { maxstr / 8 for defined bits }
#else
      maxstr     =  2000000;   { maximum size of addressing for program/var }
      maxtop     =  2000001;   { maximum size of addressing for program/var+1 }
      maxdef      = 250000;    { maxstr /8 for defined bits }
#endif
```

pint also has to change the way it takes in input files. It cannot read the intermediate from the input file, because that is reserved for the program to be run. Instead, it reads the intermediate from the "prd" header file. The interpreted program can also use the same prd file. The solution is to "stack up" the intermediate files. The intermediate for pint itself appears first, followed by the file that is to run under that (iso7185pat). It works because the intermediate has a command that signals the end of the intermediate file, "q". The copy of pint that is reading the intermediate code for pint stops, then the interpreted copy of pint starts and reads in the other part of the file. This could, in fact, go to any depth.

All of the source code changes from pint.pas to pintm.pas are automated in cpints.bat.

Self compiled files and sizes

The resulting sizes of the self compiled files are:

pcomm.p5

Storage areas occupied

Contents	Range of storage	Net size
Program	0-114657	(114658)
Stack/Heap	114658-1987994	(1873337)
Constants	1987995-2000000	(12005)

pintm.p5

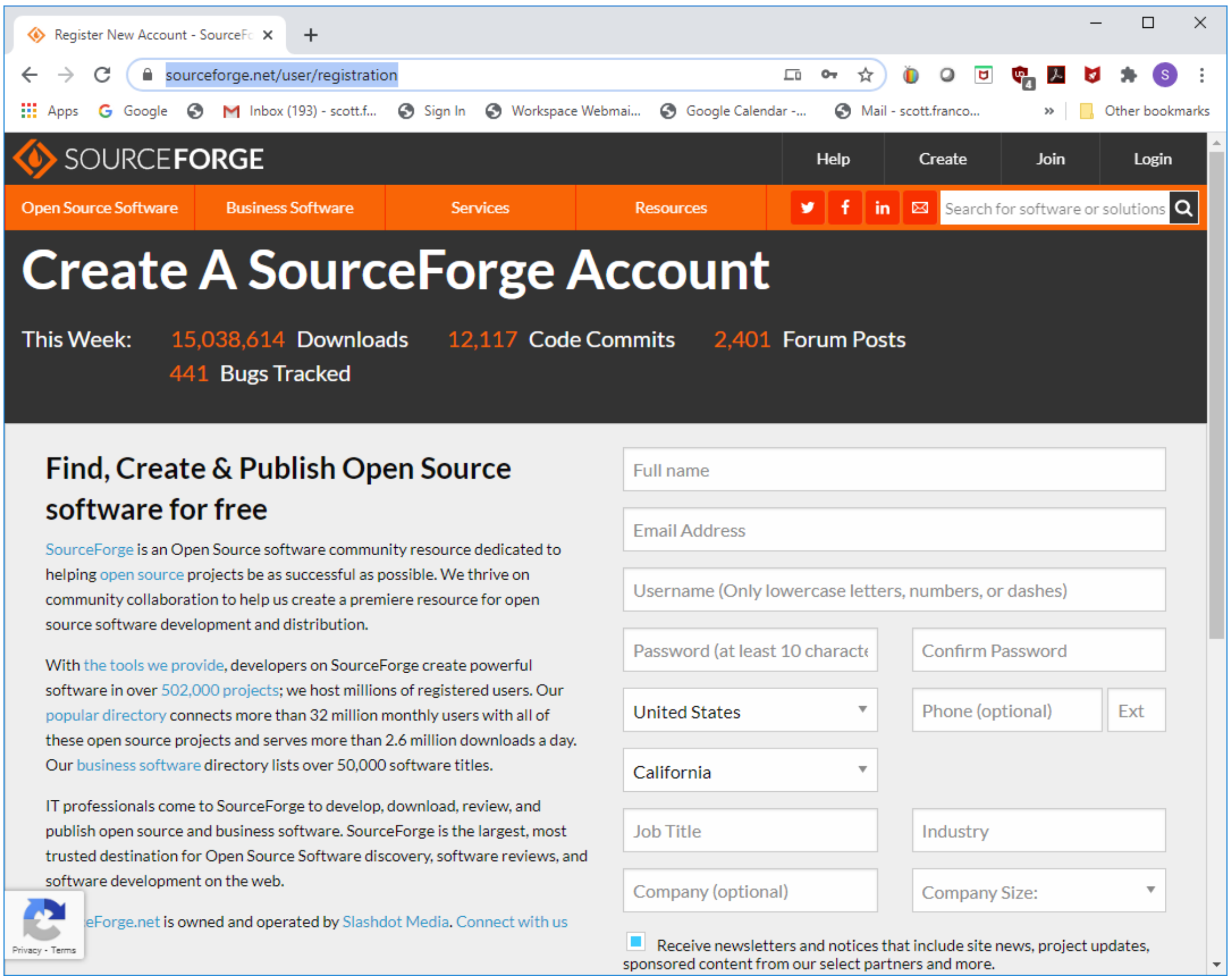
Storage areas occupied

Contents	Range of storage	Net size
Program	0- 56194	(56195)
Stack/Heap	56195-1993985	(1937791)
Constants	1993986-2000000	(6014)

9 Submtting bugs

If you think you have found an issue with Pascal-P5, I encourage you to submit a bug report. To do this, you are going to need a login to SourceForge at:

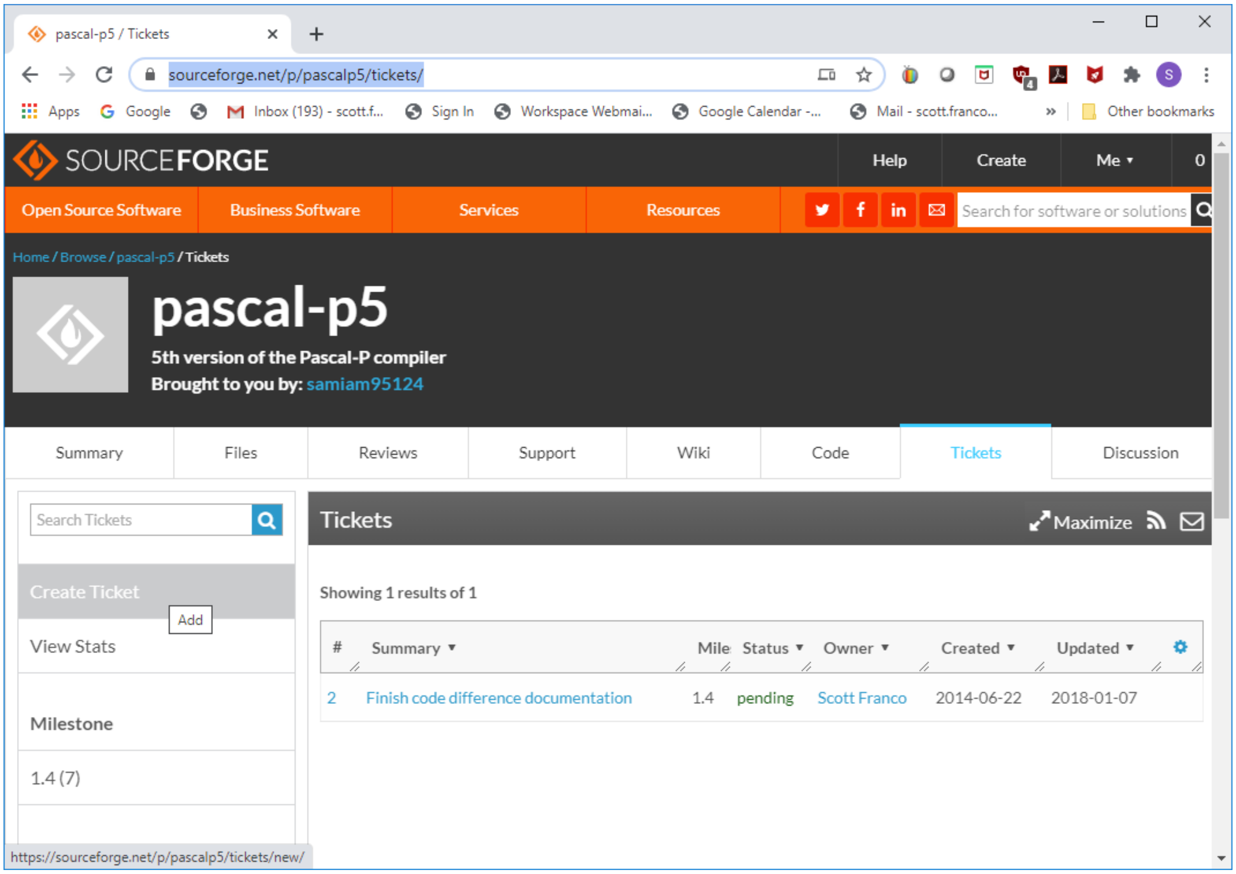
https://sourceforge.net/user/registration



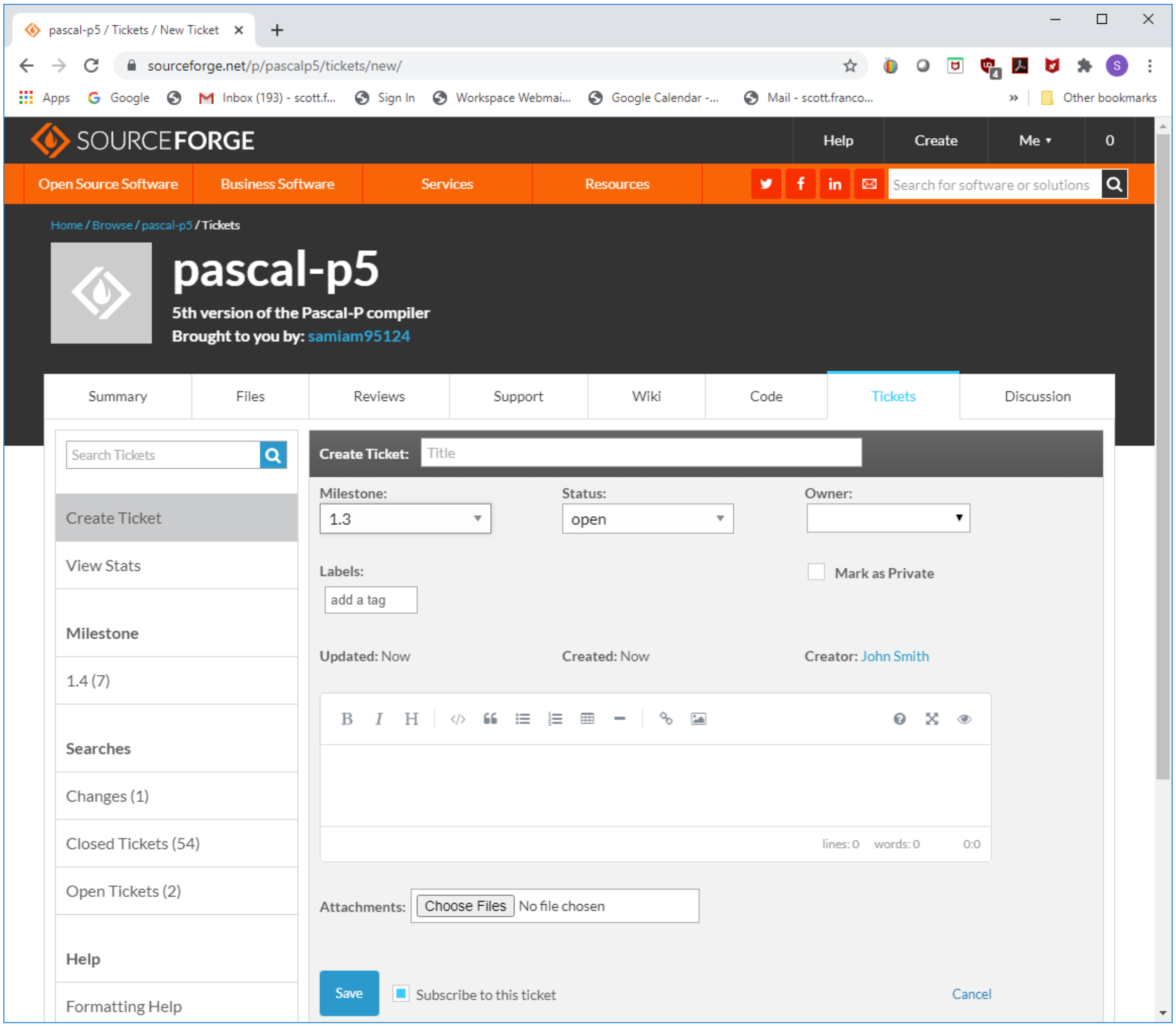
(they need people to register so that they don't get flooded with false bug submissions).

Here's a sample runthough of creating a bug report online:

https://sourceforge.net/projects/pascalp5/files/

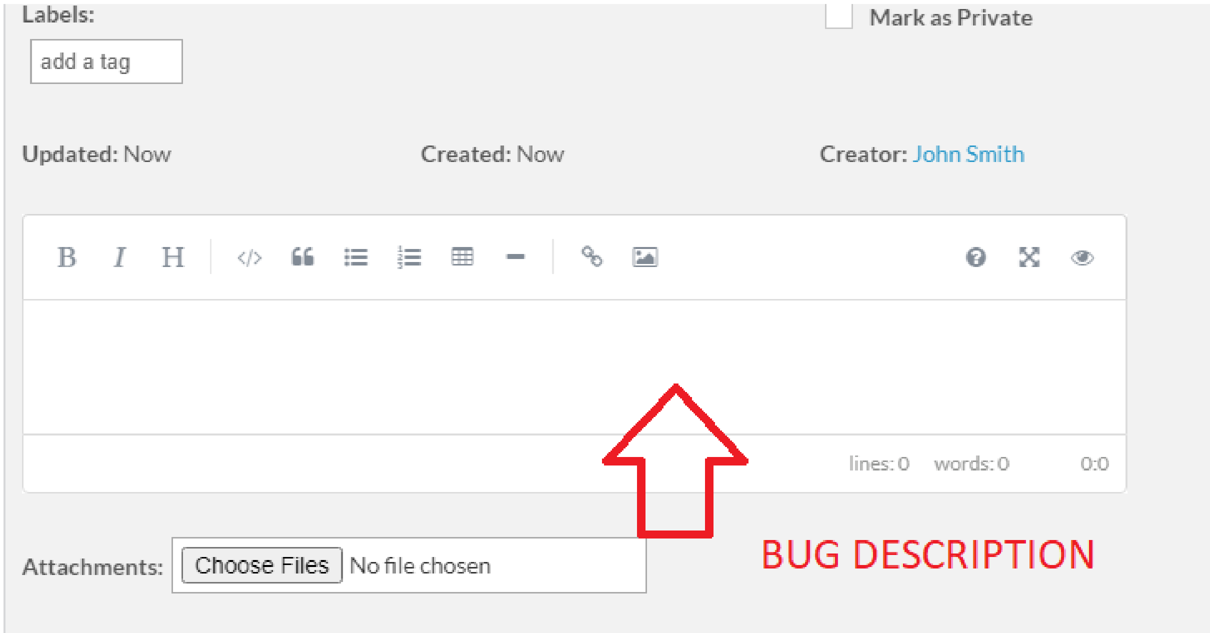


Then hit “Create Ticket”:

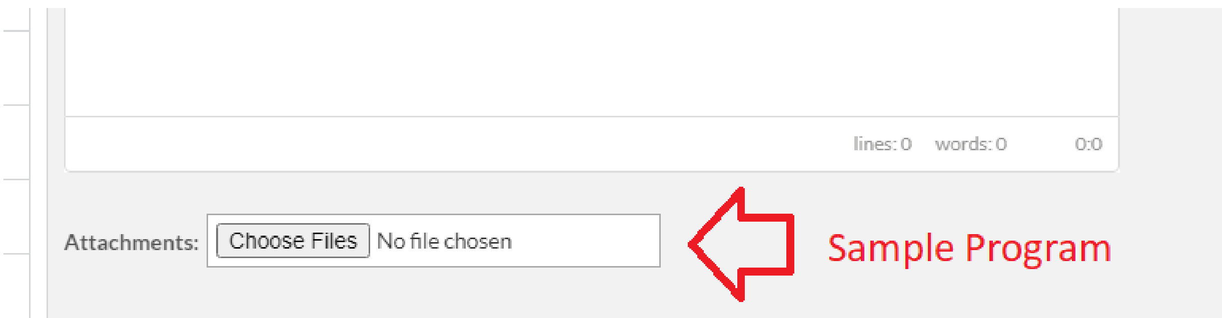


Don't worry about the boxes "Milestone", "status", "owner" and other fields. These will be filled out by us.

What we need for the bug are two things, but equally important. First, you will out the description of the issue in the center edit box:



Then, we need a sample program that demonstrates the issue:



That's it! The rest of this section is going to be about what should go into both the description and the sample program.

9.1 What constitutes a bug

Bugs submissions are very valuable to us. By submitting a proper bug report, you are not only helping yourself, but other users, and the developers. It's one of the best ways to say thank you for the freeware that is Pascal-P5.

A bug is a defect in the source code or associated files of Pascal-P5. What is not a proper subject for for a bug report?

- A feature request that does not pertain to the mission of the software (what is the mission of the software? See below).
- A complaint about the way the software works, unless it something broken, and perhaps more importantly, is stopping you from getting work done.

Remember, Pascal-P5 is designed to accomplish one thing: to be a complete and bug free compiler for ISO 7185 Level 0 Pascal. Ways to extend it to, say, add new procedures or functions may be interesting but if they don't pertain to the ISO 7185 standard, they don't belong as a bug report (see "discussion" instead).

To insure that you have a proper bug, we ask only that:

- Read the standard (http://www.standardpascal.org/standards.html). The majority of issues reported to me are actually misunderstandings about the rules of the standard.
- Read the previous bugs and make sure you are not submitting a duplicate bug.
- Make sure that you are using the latest version of the software.

9.2 The bug demonstration program

A good bug demonstration program is a short program, no more than a page or two, that demonstrates the problem. It should be a complete program, please.No snippets from other programs. It should be ready to compile asnd run as is.

If you have a large program that demonstrates the issue, the best way do proceed is to cut it down in size or just extract the relivant parts. you don't want to give us your entire program, and we don't need to see it.

There are two classes of demonstration programs:

1. The program has a error on compilation.
2. The program has an error during its run.

The methods you can use to cut down the size of the program depend on which type of error it is.

To cut down on a compilation error, here are some hints:

- Try removing all code after the error, but keep the program correct. For example if the error occurs in the middle of the program block, remove all the code under the error until the "end.".
- Try removing procedures, functions or declarations that don't seem to relate to the problem. For example, most or all of the code in procedure/functions can be removed, just leaving the skeleton. Watch for label declarations which would generate errors if the label is not found, and missing function returns. The locals for the procedure usually can then be removed. If you remove all of the code from all of the functions that are not related to the error, you can remove most of the code of a program without affecting the error.
- After removing procedure/function internals, you will find that you can then remove procedure calls, function calls, and many declarations that are no longer referenced.

Reduction is an interative process. After removing code and checking that the compilation error still exists, you may find more declarations and code to remove that are no longer referenced, then you check again. Save a copy of the "stripped" file each time, and that way you can return to the previous copy if you loose the error you were interested in finding.

For runtime errors, the procedure is similar:

- Try removing all the code that would run after the error you want to demonstrate.
- Remove the code in procedures and functions that you don't think are being executed.
- After removing code as above, try removing declarations that are no longer used.

After this, the same comments about reduction from compiler errors applies.

There are very few test cases that cannot be reduced this way, frequently to less than a page worth of code. Further, reduction of problem cases often illustrates if there was an error in the construction of the program, meaning no bug case need be filed.

10 Licensing

Pascal-P5 is derived from the original sources of the Pascal-P compiler from ETH Zurich, as created by Niklaus Wirth and his students. It was and is public domain, as acknowledged by Professor Wirth.

If there is any question as to if the BSD or public domain applies to any part of the sources, the source in question should be compared to the same source in Pascal-P4, and any code that is the same as Pascal-P4 is public domain. Any code exclusive to Pascal-P5 is covered by the BSD license.