Pascal implementation

The Pascal-P6 Compiler

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1 Introduction to Pascal-P6

To get started using Pascal-P6, skip to “3 Using Pascal-P6”.

Memory or type protected languages are a current fad, starting with Java, through C#, and now Rust. But type safe languages have been around since the beginning of computer languages.

Pascal, a language popular since it’s beginning over 50 years ago, has a common form that is not type safe, often referred to as Pascal-C. Its Pascal stripped of it’s type safety and combined with C type constructs such as type casting.

Original Pascal was a type and memory safe language, and has been since the beginning. The modern constructs of the Pascaline language extension bring the language up to the present day, giving you functionality equivalent to C, or even C++, but with complete type and memory safety.

Pascal-P6 is a compiler for an extended version of ISO 7185 Pascal known as “Pascaline”. This is a type secure language known for regularity of syntax and function. The original Pascal Language was created in the 1970s by Niklaus Wirth’s group in ETH Zurich.

The implementation package Pascal-P was created by Wirth’s group as a machine independent compiler interpreter. Pascal-P6 is the 6th edition of that compiler. Pascal-P4 was a “subset” of the original Pascal language. Pascal-P5 supported the full ISO 7185 standard Pascal language. Pascal-P6 supports the original ISO 7185 Pascal language and a set of extensions known as “Pascaline”.

The original Pascal language is well documented. The files accompanying the Pascal-P6 compiler in the doc directory are:

Filename	Contents
iso7185rules.html	Covers the ISO 7185 Pascal language in conversational form.
iso7185.html	Covers the technical details of the ISO 7185 standard.
The_programming_language_pascal_1973.pdf	The original 1973 introduction to Pascal.
pascaline.pdf	The technical details of Pascaline.

For the original Pascal language, many good references exist:

Filename	Contents	Purchase at
Pascal User Manual and Report **Kethleen Jensen & Niklaus Wirth**	The original reference manual for Pascal. Seems to be out of print, and may be hard to find or expensive.	https://www.amazon.com/Pascal-User-Manual-Report-Standard/dp/0387960481/ref=sr_1_3?crid=MJI9YDL7FFG5&keywords=pascal+user+manual+and+report&qid=1671226529&sprefix=pascal+user+manual+and+report%2Caps%2C129&sr=8-3
Standard Pascal User Reference Manual **Doug Cooper**	Covers the details of the ISO 7185 standard. Reasonably priced.	https://www.amazon.com/Standard-Pascal-User-Reference-Manual/dp/0393301214/ref=sr_1_1?crid=2O6HPEQYWSJZP&keywords=standard+pascal+user+reference+manual&qid=1671226757&sprefix=standard+pascal+user+reference+manual%2Caps%2C133&sr=8-1
A Primer on Pascal **Conway, Gries, Zimmerman**	A good basic introduction to Pascal. Appears to be out of print.	https://www.amazon.com/Primer-PASCAL-Winthrop-computer-systems/dp/0876266944/ref=sr_1_1?Adv-Srch-Books-Submit.x=0&Adv-Srch-Books-Submit.y=0&qid=1671227001&refinements=p_27%3Aconway+gries%2Cp_28%3Aa+primer+on+pascal&s=books&sr=1-1&unfiltered=1
Oh! Pascal! **Doug Cooper**	An in-depth introduction to Pascal. Appears to be out of print.	https://www.amazon.com/Oh-Pascal-Third-Doug-Cooper-dp-0393963985/dp/0393963985/ref=dp_ob_title_bk

Note that there are countless other books on Pascal. Avoid books that talk about one specific implementation, or are meant for Borland Pascal (see below).

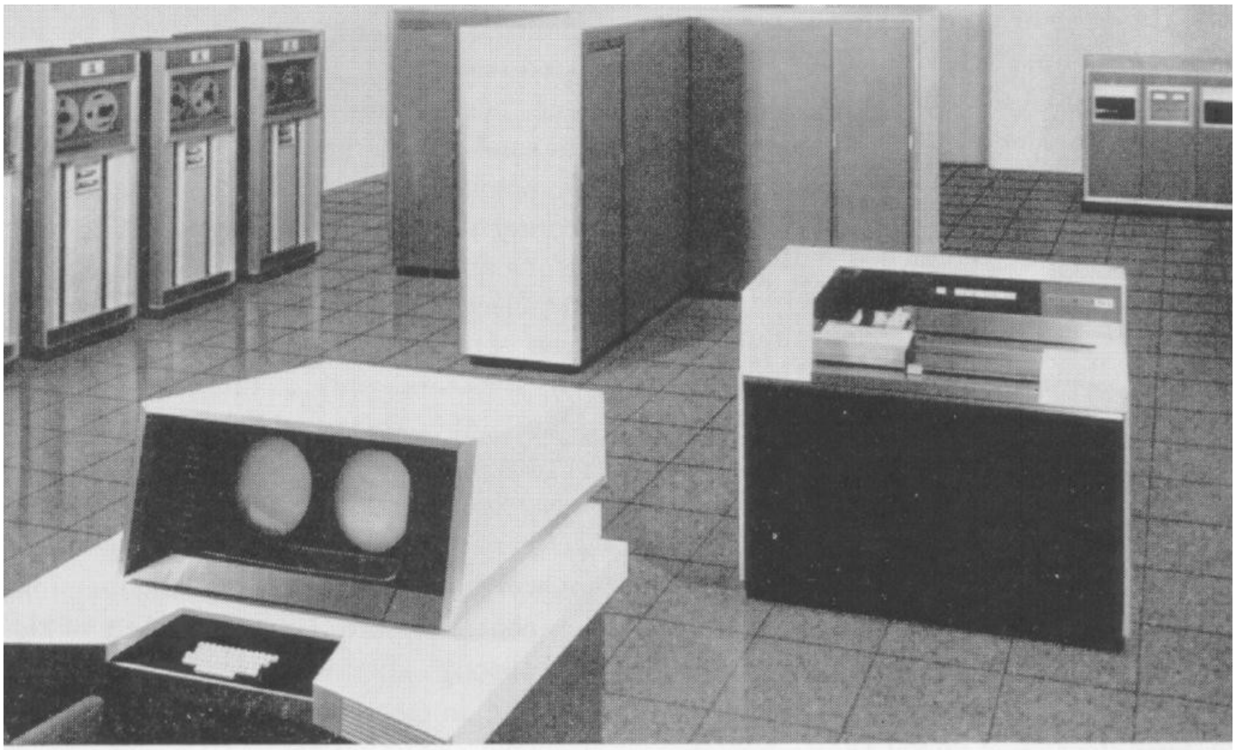
Pascal-P6 can be used as an ISO 7185 language compiler, as a Pascaline compiler, or a mixture of both. Pascaline is completely downward compatible with ISO 7185 Pascal.

Please note that Borland or “Delphi” Pascal is a distinct language from original Pascal (despite bearing the same name), created in around 1983. The two languages are not compatible. For more information on the Borland language series see their documentation.

Note that this document covers very little about the Pascal or Pascaline languages themselves. See the above documentation for information on the languages covered.

Pascal-P6 has both an interpreter and a machine code generator. See “5: Different generation and run options: pint, pmach and cmach, and pgen”.

1.1 History of Pascal-P6



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 “bytecode” interpreter.

The original article for the Pascal-P compiler is “The_Pascal_P_Compiler_implementation_notes.pdf” in the doc area of the Pascal-P6 project directory tree.

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. Niklaus 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, Niklaus 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 P2, and thus could be bootstrapped from an existing P2 implementation. P4 featured a new pseudo instruction set, and thus was a fully redesigned compiler.

Pascal-P was always an imcomplete 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 for its source (not 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.

In 2008 I set out to improve the 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.

Pascal-P5 exists as a separate project and is an interpreter only. It can form the basis for any ISO 7185 based project. The project intent was to only add the minimum code to the Pascal-P4 implementation to bring it up to ISO 7185 status. It also introduced a large suite of tests to verify compliance with the ISO 7185 Pascal standard.

The purpose of Pascal-P6 was to create a working compiler implementation from Pascal-P5. Thus Pascal-P5 serves as a working, interpretive model of ISO 7185 Pascal, and Pascal-P6 serves as an actual machine implementation of it.

The first task of the Pascal-P6 implementation was to create a series of extensions to ISO 7185 Pascal. All actual machine implementations of Pascal, including the original CDC 6600 implementation, include a series of extensions. With Pascal-P6, I wanted to introduce a series of extensions that would both bring the compiler to a usable state as practical compiler and also bring it up to the "state of the art" (at least as of 2024).

I realize that introducing a set of new features to Pascal is going to be controversial. I wanted the extensions to be more than just a laundry list of features added by a compiler implementor (as has happened with Pascal so many times in the past). Thus I collected the features implemented by Pascal-P6 as a formal language in its own right, as the language "Pascaline". There is a formal specification accompanying Pascal-P6 ("pascaline.pdf") as well as a rationale ("Pascaline_rationale.pdf"), a discussion of both the language, its features, and its implementation.

1.2 Pascal-P6 as a strict ISO 7185 compiler

Pascal-P6 can easily be used as a strict ISO 7185 Pascal compiler. Using the s+/iso7185+ option, or "strict" flag, the source language for Pascal-P6 and the ISO 7185 language are identical. It is, however, important to understand the exact meaning of the s+/iso7185+ option.

I use the term “strict” for the s+/iso7185+ option, and not “standard”, because the Pascal-P6 compiler is fully compatible with the ISO 7185 Pascal language regardless of if the flag is off or on[1]. In pascal-P6 the option has the following meanings when ON:

- All extended keywords from Pascaline are turned OFF, meaning they can be used as program identifiers.
- So called “force sequences” or “\” character special interpretations in strings is turned off, meaning the “\” character has no special meaning in strings.

Both of these are in compliance with the ISO 7185 standard. An implementation is allowed to define new keywords in ISO 7185 Pascal. Also the interpretation of characters in ISO 7185 Pascal is up to the implementation (it does not even specify ASCII).

I recommend that even if you are developing strict ISO 7185 Pascal source code that you leave the s flag OFF (the default). Why? If the flag is off, that allows you to use keywords that are reserved in Pascaline, or use the force character “\” in your source. This will cause problems later if you then decide to use Pascaline extensions. In fact, the best way to develop truly portable ISO 7185 Pascal programs is to avoid using other ISO 7185 Pascal implementations’ keywords as well. You might want to examine the keyword list for FPC (Free Pascal) as well to make sure.

The use of the force character (“\”) is trickier. If you put it in your ISO 7185 programs with the s flag OFF (s-), then you will need to specify “\\” to get just the force character. But if you then compile it on a system that does not understand force sequences, it will evaluate to “\\” (double “\”). The best method is to avoid the force character whenever possible. Fortunately, most ISO 7185 Pascal compilers today do understand force sequences.

When using Pascal-P6 as a ISO 7185 compiler, I recommend that you occasionally check your compiles by turning on the s+ switch. This will make sure that you have not inadvertently used Pascaline constructs in your source.

1.3 Pascal-P6 vs. FPC (Free pascal), Borland, or other dialects

Pascal-P6 does not accept the common dialects[2] of Borland or FPC languages[3]. There are good implementations of these dialects, both by Borland themselves and by the FPC group. My recommendation is if you want to use that source language, use the best compiler for it, namely the FPC or Borland compilers. There is no plan for a Pascal-P series compiler that is also Borland dialect compatible, and further, the type protection model of the two are diametrically opposed.

FPC recently completed implementation of an ISO 7185 compliance switch. This makes it a good backup compiler for ISO 7185 Pascal compliant applications. See the FPC web site for more details.

See also then next section for comments on source language.

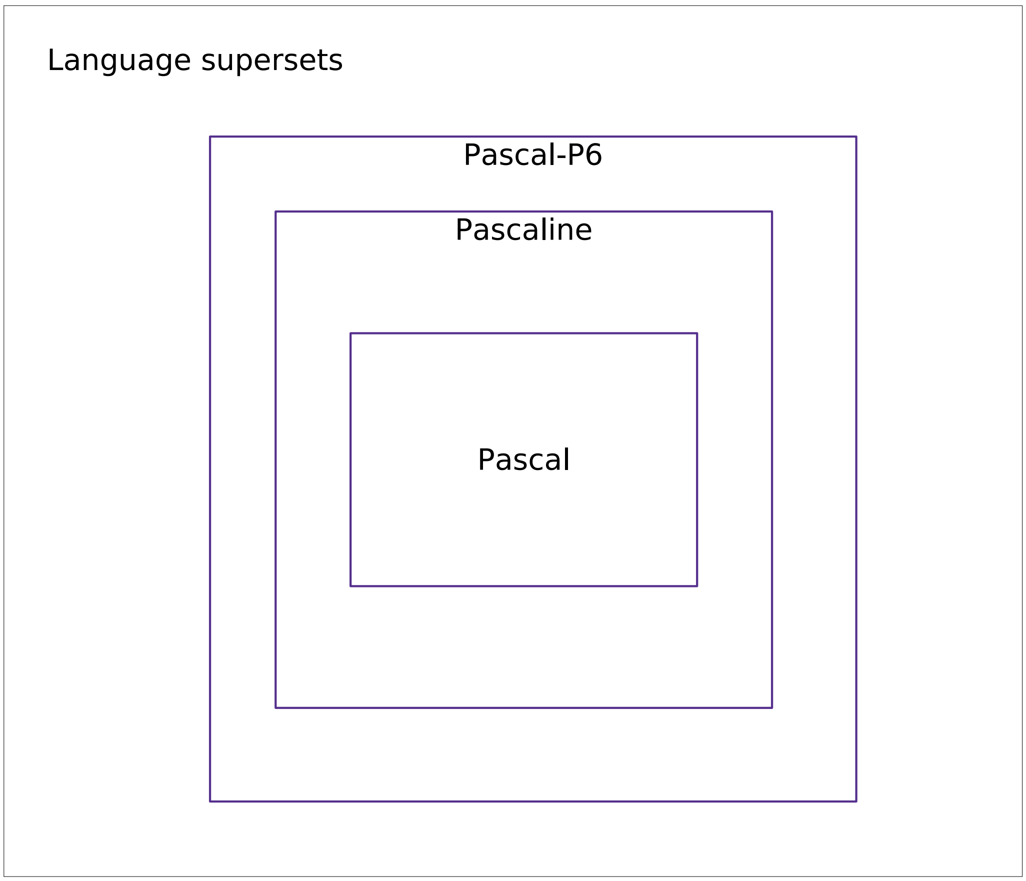
[1] Many Pascal compilers that feature an ISO 7185 standards compliance flag in fact change the source language to be incompatible with ISO 7185 if the flag is off. Pascal-P6 does not do this.
[2] The term “dialect” is the correct term for a variant of a language that is not close enough to be mutually understood between different speaking peoples or computer language implementations.
[3] Although UCSD Pascal is no longer in wide use, that language had much of its constructs copied into other dialects, including Borland, Apple Pascal and many others.

2 The Pascal-P6 source language

Pascal-P6 understands the Pascaline source language as documented in pascaline.pdf, available in the doc or documents directory of Pascal-P6 project. Pascaline is fully compatible with ISO 7185. There are, however, several things you will find only in this documentation and not the Pascaline specific documentation:

- Features of Pascaline that are not (yet) implemented in Pascal-P6.
- Local extensions in Pascal-P6 that are not also in general Pascaline.
- Concrete details of features in Pascaline specific to Pascal-P6.

These will be detailed.



Pascal is the base language for Pascal-P6. Pascaline is a superset of Pascal. Pascal-P6 accepts both, but adds a few features of its own.

2.1 Features of Pascaline NOT implemented in Pascal-P6

The following features of Pascaline are not yet implemented in Pascal-P6. The expectation is all of them will be implemented shortly. Also keep in mind that Pascal-P6 is still a project in development, and carries a version number < 1.0.

Pascaline manual section	Description
6.35	Matrix mathematics
6.36	Saturated math operators
6.37	Properties
6.39.5	Parallel modules
6.40	Channels
6.41	Classes

Please see “pascaline.pdf” in the doc file section for more details on the Pascaline language.

2.2 Pascal-P6 implementation details

At this writing, there is a 16 bit, 32 bit and a 64 bit implementation of Pascal-P6. The following characteristics exist:

Type	Size/limit 16 bits	Size/limit 32 bits	Size/limit 64 bits
integer	Maxint = 32767	maxint =2147483647	maxint = 9223372036854775807
linteger	Alias of integer	Alias of integer	Alias of integer
cardinal	Alias of integer	Alias of integer	Alias of integer
lcardinal	Alias of integer	Alias of integer	Alias of integer
set	256 elements	256 elements	256 elements
real	64 bit real	64 bit real	64 bit real
sreal	Alias of real	Alias of real	Alias of real
lreal	Alias of real	Alias of real	Alias of real

The maximum size of any input line, identifier, or string constant is 250 characters.

The base character set is ISO 8859-1, or 8 bit characters. The compiler has no reliance on any character in the range 128 to 255 and will accept any character in that range for input or output.

2.2.1 Header files

All of the Pascaline header files are implemented, **input**, **output**, **error**, **list** and **command**. **output**, **error** and **list** all go to the standard output file. As detailed in Annex C of the Pascaline standard, undefined program header parameters must be declared in a type statement. Any type of valid Pascaline file is acceptable, including complex structured types.

The filenames corresponding to the names of the header file parameters are read from the command line:

```
program print(myfile, output);
var myfile: text;
…
```

executed with a command line of:

print document.txt

Will assign file myfile to the name on disk "document.txt".

The command file reads the command line passed to the program on startup. There is only one line in the file, and eof() immediately follows eoln() in the file. When the command file is read as well as other parameters appear in the program header, then the command file will be positioned after all other header file names or entries have been read from the command line.

2.2.2 Alternative header value input

Pascal-P6 can have integer or real parameters in the header file, in addition to just files:

```
program test(myint, myreal);
var myint: integer;
    myreal: real;
```

Pascal-P6 automatically reads these values off of the command line and into the specified variables. If a they are mixed values on the header, they will be read in turn from the command line as specified in Annex C of the Pascaline standard.

2.2.3 Character escapes

Pascal-P6 implements Pascaline Annex E: character escapes in total.

2.2.4 Character sets

Pascal-P6 implements Annex D.1 "ISO 8859-1 Character Set Encodings". However, it only relies on the parts of ISO 8859 that are common to all pages in the standard. Thus, Pascal-P6 will accept, and will generate, any character in any page in the set of ISO 8859 code pages.

Note that Pascal-P6 is dependent on ISO 8859 because it can generate force control characters specific to the ISO 8859 standard.

2.2.5 Modular structure

Pascal-P6 implements modules by outputting an intermediate file for each module, then the intermediates are concatenated and loaded as a single file. The intermediate contains sufficient information for pint to understand the module structure, and it links the modules together.

In the case of pgen, each module is compiled to an assembly file, and then the modules are linked together as a stack of modules by the compiler/assembler for the target machine.

Modules in Pascal-P6 are implemented by the following method:

1. Each module calls its own initializer block, then calls the next module in the stacking order. When the module it calls returns, that module then calls the deinitializer for the module, and returns to the module that called it. Program modules only have a single initializer block. When the block is done, the program module returns.
2. Each module is stacked up on the last. The interpreter or runtime system arranges to call the first module in the stacking order, then when it returns, the entire program exits.
3. Its up to the user to stack the modules properly on the command line. If a module is called via a function or procedure, and accesses global data from that module, the program will fault with uninitialized access error. Module overrides are an exception. Each virtual function or procedure in the module is initialized to point to an error routine when the module is started, and attempts to override an uninitialized virtual vector will generate an error.
4. The program module MUST be the last module in the stacking order.

5. A process module is like a program module, but it starts a new processor thread to run its initialize block, then calls the next module in the stacking order. From the time the thread is branched off to run the process block, the main thread and the thread running the process module run in parallel.

2.2.6 Implementation of Annexes G-O

Pascal-P6 has the ability to link to and run procedures and functions from the standard Pascaline libraries. These include:

Name of module	Function
services	Provides basic operating system services, such as directory list, environment variables, etc.
strings	Operations on strings (arrays of characters).
math	Extended math operations.
sound	Access to sound system, including midi, wave input and output, etc.
terminal	Access to a text based terminal.
graphics	Access to a graphics terminal.
network	Access to networking.

At this writing, only the services module is implemented in pint.

The Pascaline libraries, originally written in Pascaline, were rewritten in C (for several reasons), and appear as the independent library called “Petit-ami”. They can be accessed by any language.

Note that not all Pascaline libraries appear in Petit-ami. For example the strings module is still written in Pascaline, and makes no sense for other languages outside of Pascaline.

2.2.6.1 Enabling externals

External linking to Petit-ami is enabled via the EXTERNALS define when compiling Pascal-P6. When this definition is active, all modules with the names in the Pascaline external module table above will be redirected to external definitions.

2.2.6.2 Using externals

The externals in Pascal-P6 are compiled with the system as object files that are linked into the system. Further, there is a block of code in pint that translates each call to the C language, in the file:

externals_<system>.inc

Where <system> is a specific compiler implementation. The existing implementations are:

File	Selected by define
externals_iso7185_pascal.inc	ISO7185_PASCAL
externals_pascaline.inc	PASCALINE

Note that the ISO 7185 file essentially selects “no externals”, since ISO 7185 Pascal does not have that capability.

Programs that use the externals will simply use or join them the same way as any other module:

```
program dir(output);

uses services;

var fp: filptr;

begin

   list('*.pas', fp);
   while fp <> nil do begin

      writeln(fp^.name);
      fp := fp^.next

   end

end.
```

To allow the program to see the definitions, the module used must have a local Pascaline file:

services.pas

The module used should not be included (as normal modules are) in the input deck (usually created for you by the Pascal-P6 script). It will not harm anything, but it will do nothing and will take up space. All the functions in the module will be redirected to the externals handling in pint.pas.

The joins statement can be equally used to access externals. The above program using this method is:

```
program dir(output);

joins services;

var fp: services.filptr;

begin

   services.list('*.pas', fp);
   while fp <> nil do begin

      writeln(fp^.name);
      fp := fp^.next

   end

end.
```

3 Using Pascal-P6

3.1 Getting Pascal-P6: Repositories for Pascal-P6

Pascal-P6 is managed using git version control system. It is stored at the following repositories:

https://github.com/samiam95124/Pascal-P6

https://sourceforge.net/projects/pascal-p6/

You can obtain Pascal-P6 from a given version of the system, or from the current tip (the collection of most current files). Versioned trees contain code that has been extensively tested, but the tip will contain the latest code. The available versions can be found at:

https://github.com/samiam95124/Pascal-P6/releases

To obtain a release, go to the above page, find an archive type you want and click on it. The archive methods are **zip** and **tar.gz**. To unpack each is approximately:

```
$ unzip Pascal-P6-X.X.zip

$ tar -xvzf Pascal-P6-X.X.tar.gz
```

To download the tip typically is:

$ git clone https://github.com/samiam95124/Pascal-P6.git

Besides the advantage of having the current code, using git to obtain a file tree also gives you source control capabilities.

Please submit any bug tickets to:

https://github.com/samiam95124/Pascal-P6/issues

3.2 Configuring Pascal-P6

Pascal-P6 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. Go to the root directory and execute:

[Windows]

```
> setpath
> configure
> make (optional)
```

[Linux/BSD/Mac]

```
$ . setpath
$ ./configure
$ make (optional)
```

You can avoid the need for **setpath** by placing the ./bin directory on your path. You will also want to set the environment variable:

```
export PASCALP6="$PWD"
```

Different scripts in the archive reference this environment variable.

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:

Option	Meaning
--iso7185	Selects the Pascal-P6 compiler (default).
--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-P6 binaries, the script files and other files and install them for the specified host compiler.

Although the directory bin will contain working copies of the binaries and scripts, there is no guarantee which version it contains. Always run the configure script to setup the particular system you are using.

The configure script loads precompiled versions of the binaries for the system into the bin/ directory. At this writing, these are for Linux/Ubuntu 64 bit systems. If you do not have the means or don't wish to rebuild the binaries, you can leave them to be the defaults and not run a make on the project.

Example configure:

```
Pascal-P6$ ./configure
Set up for iso7185
Bit length 64
Configure completed!
```

3.3 Compiling and running Pascal programs with Pascal-P6

To simply compile a run a program, you can use the **p6** batch file:

```
$ p6 hello
```

When a pascal program is run this way, it gets it's input from the terminal (you), and prints its results there. It both compiles and runs the target program.

To just compile a program, use the **compile** batch file:

```
$ compile hello
```

Then the program can be run as a binary:

```
$ ./hello
```

3.3.1 Compiling with multiple modules

The **p6** script can accept multiple modules:

```
$ p6 mylib1 mylib2 test
```

The script will compile and load each of the modules in turn, and run them as a group. The program module should always be last in the module stacking order. See “2.2.5 Modular structure”. In this case **test** is the target program, and can be run as:

```
$ ./test
```

3.3.2 Compiling on different run configurations

There are several types of run arrangements for Pascal-P6. The current options are:

Option	Meaning
--pint	Run on the pint machine.
--pmach	Run on the pmach machine.
--cmach	Run on the cmach machine.
--package	Run via the packaging option (using cmach).
--pgen	Run via binary generation (default).

Typical configurations are:

```
p6 –pint test
```

For interpretation.

```
p6 test
compile test; run test
```

For compilation to binary.

Note that a compiled binary, either –pgen or –package, results in a standalone binary that can run without need for the run script. The main purpose of the run script is for testing purposes.

3.4 The basic programs

The previous scripts operate via the basic binary programs:

pcom <source file> <intermediate file> <options>

Compiles a Pascaline source file to produce an intermediate language file.

pint <intermediate file> <output file> <options>

Either interprets the given intermediate file or converts it to a binary deck to the output.

pmach <binary deck> <output file> <options>

Loads and interprets the given binary deck.

cmach <binary deck> <output file> <options>

Loads and interprets the given binary deck. The same as pmach, but it is encoded in C.

pgen <intermediate code> <assembly file> <options>

Converts the input intermediate code into assembly code for the current host processor. This is subsequently converted to a binary by an assembler or C compiler.

3.5 Compiler options

Pascal-P6 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 ends with "+", it means to turn it ***on***. If the option ends with "-", it means turn it ***off***. If neither appear, it means to turn the option ***on***.

Example:

(*$l-*)

Turns the listing of the source code OFF.

Alternately, the options can be specified on the command line:

p6 -[-]option[+/-]

Note that for command line options, either a single '-' (hyphen) or double '–' will introduce an option. Pascal-P6 does not support true GNU/Linux single character options like -ld where each of the letters are an option. Each option is a complete word. As with compiler comment options, '+' turns the option ***on***, and '-' turns the option ***off***, and if neither appear, the default is to turn the option on.

The following options are available:

Short option	Long option	Meaning	Default
t+/-	prttables+/-	Print/don't print internal tables after each routine is compiled.	OFF
l+/-	list+/-	List/don't list the source program during compilation.	ON
d+/-	chk+/-	Add extra code to check array bounds, subranges, etc.	ON
c+/-	lstcod+/-	Output/don't output intermediate code.	ON
v+/-	chkvar+/-	Check variant records.	ON
r+/+	reference+/-	Perform reference checking.	ON
u+/-	undestag+/-	Perform undiscriminated variant checking.	ON
s+/-	iso7185+/-	Restrict input language to ISO 7185 Pascal.	OFF
x+/-	prtlex+/-	Dump lexical information during the run.	OFF
b+/-	prtlab+/-	Print goto labels used at the end of the compile.	OFF
y+/-	prtdisplay+/-	Dump display information at the end of the compile (symbols).	OFF
i+/-	varblk+/-	Check VAR block violations.	OFF
g+/-	prtlabdef+/-	Dump goto and other location labels at intermediate assembly time.	OFF
h+/-	sourceset+/-	Add source line sets to code. This tells pint where the source lines are in the code.	ON
n+/-	recycle+/-	Obey heap recycle requests. If false, no space is recycled.	ON
o+/-	chkoverflo+/-	Check for arithmetic overflow.	ON
p+/-	chkreuse+/-	Check for reuse of freed entry in heap space.	OFF
m+/-	breakheap+/-	Break returned entries in heap into occupied and free blocks.	OFF
q+/-	chkundef+/-	Check accesses to undefined memory.	ON
w+/-	debug+/-	Enter debug mode (pint only).	OFF
a+/-	debugflt+/-	Enter debugger on fault	OFF
f+/-	debugsrc+/-	Perform source level debugging.	OFF
e+/-	machdeck+/-	Output binary deck from pint instead of running the assembled results (pint only).	OFF
ee+/-	experror+/-	Output expanded error descriptions.	ON
z+/-	lineinfo+/-	Output line statistics.	ON

It is possible to cause problems in the code if the options are turned on or off arbitrarily in the middle of the program. It is recommended that you place option sets at the top of the program only unless you are sure what you are doing.

Pascal-P6 provides a lot of switches for developers to use to debug the compiler. A good rule is: if you don't know what a switch does, don't use it. Pascal-P6 is a compiler developer's compiler. This means that everything in the system is available to change, including things that make no sense for end users.

Note that a lot of the debug switches previously available in Pascal-P5 have been moved to the debug mode in Pascal-P6. See "4 Pascal-P6 debugger mode".

3.5.1 Option descriptions

List format is: short form, long form, description.

t+/- prttables+/- Print/don't print internal tables after each routine is compiled.

Prints the complete set of identifier and types declared in each block at the end of the block.

l+/- list+/- List/don't list the source program during compilation.

Enables the compiler to output a source listing.

d+/- chk+/- Add extra code to check array bounds, subranges, etc.

Enables several debug checks in the code.

c+/- lstcod+/- Output/don't output intermediate code.

Supresses the creation of the intermediate file contents. Note that the output intermediate file is always created, but it's contents will be empty.

v+/- chkvar+/- Check variant records.

Perform active variant checks. Checks if the variant in a variant record is active when accessed.

r+/+ reference+/- Perform reference checking.

Checks if identifiers used in the program have been referenced by the code.

u+/- undestag+/- Perform Undiscriminated variant checking.

Forces checking on undiscriminated variants. These are variant records where the tagfield is not allocated, meaning there is no tagfield to check before accessing a given variant. The u flag forces the tagfield to be allocated as an anonymous member of the record, and will assign it the correct value any time a write access is done within a variant. On read access to the variant, the anonymous tag field value is checked, and faulted if not correct. This option actually generates more code than just specifying the tag field exists and setting it properly. However, the overhead of this check can be simply removed by removing the option. See also the v option.

s+/- iso7185+/- Restrict input language to ISO 7185 Pascal.

Produces errors on any Pascaline level language features. Disables all Pascaline extended keywords. Removes the ability to use force sequences in strings ("\"). Note that this is ***not a ISO 7185 compliance flag***. Pascaline is completely compliant with ISO 7185 Pascal regardless of the state of the s option. It simply restricts the source language to ISO 7185 Pascal only.

x+/- prtlex+/- Dump lexical information during the run.

Outputs the lexical tolkens scanned from the input source.

b+/- prtlab+/- Print goto labels used at the end of the compile.

Prints all goto labels used in the compile. For debugging purposes.

y+/- prtdisplay+/- Dump display information at the end of the compile (symbols).

Performs a dump of all identifiers in the display at the end of the compile run. For debugging purposes.

i+/- varblk+/- Check VAR block violations.

Checks various faults caused by having a parameter VAR access outstanding. This includes changing a variant while there is an outstanding reference, or disposing a dynamic variable, etc. This is an expensive check, and thus normally set OFF. It should be enabled and used for advanced checking of a running program.

g+/- prtlabdef+/- Dump goto and other location labels at intermediate assembly time.

Dumps the interpreter label tables at the end of intermediate assembly.

h+/- sourceset+/- Add source line sets to code.

Adds source set instructions in the output byte code. These are used to produce error diagnostics indicating what source line was executing. Note that debug mode does not use these instructions for listing, only for breakpoints on given source lines.

n+/- recycle+/- Obey heap recycle requests. If false, no space is recycled.

This flag is used to turn off all recycling of dynamic variables. Any variables recycled will simply be left occupied, effectively quarantining them. This is used to debug recycle issue. Note that there are other options that fault on attempts to access variables that have previously been disposed, such as the p and m flags.

o+/- chkoverflo+/- Check for arithmetic overflow.

Enables checking for various overflow conditions.

p+/- chkreuse+/- Check for reuse of freed entry in heap space.

When variables are freed, the space returned is broken into a flagged entry that generates faults on use, followed by free space. This effectively enforces use after recycle checks but with low waste of freed blocks.

m+/- breakheap+/- Modifies the p flag to flag the remaining space as occupied.

The use of p option should check all attempts to use a previously freed block. However there are cases where, especially when mixed protection checks are enabled, that it is better not to reuse the recycled space at all. This is effectively a mixture of the n and p flags, and thus combines stoppage of recycling with flagging of reuse after dispose checks.

q+/- chkundef+/- Check accesses to undefined memory.

Checks if an undefined location is accessed in the code. The interpreter keeps a large bitmap of memory and checks read/write accesses. Note that some undefined checks such as pointer undefined cannot be turned off. Note also that this check is only performed in the interpreter.

w+/- debug+/- Enter debug mode (pint only).

Causes pint to enter debug mode before starting the program. See also “Pascal-P6 debugger mode”.

a+/- debugflt+/- Enter debugger on fault

Enters debug mode if any fault occurs. See also the w option.

f+/- debugsrc+/- Perform source level debugging.

Loads the source code file(s) for the current code, and cross indexes the source code lines. Debug mode then changes to source mode. See also “Pascal-P6 debugger mode”.

e+/- machdeck+/- Output binary deck from pint instead of running the assembled results.

Changes the way pint works. After the intermediate is assembled to byte code into the internal store, the entire byte code program is output in a hex file format. Then pint stops without running the resulting program. This flag is used to prepare binaries for pmach or cmach. Note that the output file, which normally contains output from the running program, now will contain the hex encoded binary, and thus should be treated differently.

3.6 Errors

3.6.1 Source errors

Source errors are output as follows:

```
     1       -48 program test(output);
     2       -48
     3       -48 begin x
     4         7
     5         7    writeln('hello, world')
     5    ****              ^104,59
     5    ****  104 Identifier not declared
     5    ****   59 Error in variable
     6         7
     7         7 end.
     7    ****     ^51
     7    ****   51 ':=' expected

Errors in program: 3

Error numbers in listing:
-------------------------
 51   1 ':=' expected
 59   1 Error in variable
104   1 Identifier not declared
```

The caret (‘^’) character indicates where in the line the error occurred. The error numbers are an expanded set of the original errors from the ETH compiler. pcom outputs an optional list of the error equivalents for error numbers.

At the end of the compiler run, a list of errors by number, the number of occurrences of each error, and the error text is output.

3.6.2 Interpreter errors

When the program is run by pint, the errors appear as:

```
     1       -48 program test(output);
     2       -48
```

```
     3      -48 begin
     4        7
     5        7    writeln('The number is: ', 10/0)
     6       21
     7       21 end.

Errors in program: 0
P6 Pascal interpreter vs. 0.1.x

Assembling/loading program
Running program

The number is:
*** Runtime error [5]: Zero divide
```

The source line number of the error text is given, followed by the error description.

3.7 Runtime errors

When a binary executable is run, the errors appear as:

```
Compiling test...
P6 Pascal compiler vs. 0.2.x
Pascal-P6 complies with the requirements of Pascaline version 0.4
and the following annexes: A,B,C,E.


     1       -8 program test(output);
     2       -8
     3       -8 begin
     4        5
     5        5    writeln(1/0)
     6       14
     7       14 end.

Errors in program: 0
P6 Pascal AMD64/gcc 64 bit code generator vs. 0.2.x

Generating program

Program generation complete
Running with pgen
/usr/bin/ld: /tmp/ccsmxSEo.o: in function `resetfn':
/home/samiam/projects/pascal/pascal-p6/source/AMD64/gcc/
psystem.c:1846: warning: the use of `tmpnam' is dangerous, better use
`mkstemp'

*** Runtime error: test:5:Zero divide
```

The module name where the error occurred and the line number of the error is given.

3.8 Other operations

Within the Pascal-P6 toolset, you will find a series of scripts to perform common operations using Pascal-P6. This includes building the compiler and interpreter using an existing ISO 7185 compatible compiler, and also testing Pascal-P6.

The scripts used in Pascal-P6 are designed to be independent of what operating system you are running on. The Pascal-P6 system as been successfully run on the following systems[4]:

- Windows
- Ubuntu linux
- Mac OS X

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 extensions. Thus, when a script command is specified here, the particular type of script file is selected automatically.

3.9 Reliance on Unix commands in the Pascal-P6 toolset

Most of the scripts in this package, even the DOS/Windows scripts, rely on Unix commands like cp, sed, diff, chmod and others.

For Windows, the Mingw toolset is available:

http://www.mingw.org/

Mingw uses GNU programs that are compiled as native Windows .exe files without special .dll files

The scripts in Pascal-P6 are available in both DOS/Windows and bash versions. It is also possible to just use the bash shell that is provided with Mingw.

Using the Mingw toolkit, it is possible to use the bash scripts by simply executing bash under Windows.

Alternately, you can use the WSL or “Windows Subsystem for Linux”.

3.10 The “flip” command and line endings

Every effort was made to make the Pascal-P6 compile and evaluate system independent of what system it is running on, from Windows command shell, to Linux with Bash shell. One common problem 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 considerations, 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. “flip” is available on most systems. Unfortunately, even flip is not found on some systems. Thus Pascal-P6 includes the flip.c program with the distribution, and you can compile to form a binary on your system to replace the utility.

To make the flip utility, you run:

$ make_flip

[4]At the present time, the Windows and Mac OS X support is not functioning.

Then flip will exist in the root directory.

4 Pascal-P6 debugger mode

Debug mode in Pascal-P6 gives you the ability to step through, set break points, dump variable values and other facilities to enable debugging of issues with Pascaline code, both at the machine level and also at source level.

It is possible to debug Pascal-P6 programs at the target machine code level. But pint includes a portable debugger that works the same and provides the same capabilities on any machine. It also provides capabilities that are difficult or impossible to do on a real machine, but easy to provide on a virtual machine. The price for this is run speed.

There are two levels you can debug a Pascal-P6 program at, the interpreter (byte code) level using pint and machine code level using gdb. With optimizing compilers, parts of the code can be reordered, changed or even completely removed. It is difficult, and sometimes impossible to track source lines positions in the code. In addition, gdb was not designed for the Pascaline language, so the ability to print values at machine code time can be poor.

For this reason I believe you will find debugging at the interpreter level a valuable tool. Using debug mode, you can:

- Trace through the code at source level.
- Print the contents of any variable in Pascal formatted form.
- Print what blocks are currently running.
- Watch changes in variables.
- Place breakpoints at source lines.
- Run profiles on the code.

And many other operations.

Debug mode is invoked in two different ways. You can enter debug mode before the program is run with the $w/$debug option, or you can enter debug mode only after a fault occurs with the $a/debugflt option.

The following options apply to debug mode:

Short option	Long option	Description
w+/-	debug+/-	Starts debugging before code is run.
a+/-	debugflt+/-	Starts debugging when fault is encountered.
f+/-	debugsrc+/-	A modifier, sets debugger to source mode

Note that these options are invoked by ‘$’ in the source code, but ‘--’ (double dash) or ‘-’ (single dash) on the command line.

The w/debug option is used to debug the program always, starting from the first executed instruction. The $a/$debugflt option is used to enter the debugger mode only after a fault is encountered. The w/debug option is primary and will override $a/$debugflt.

The $f/$debugsrc option modifies the behavior of the w/debug or $a/$debugflt flags. It performs two actions:

1. The program is stopped at the first statement in the program block.

2. Program status, the location report after stepping, breakpoints, etc., are reported in source code terms.

4.1 Commands

The commands possible in debug mode are:

Commands:

Command	Parameters	Description
h|help		Help
l	[m] [s[e|:l]	List source lines
lc	[s[e|:l]	List source and machine lines coordinated
li	[s[e|:l]	List machine instructions
p	v	Print expression
d[b|l][8|16|32|64]	[s[e|:l]	Dump memory
e	a v[v]...	Enter byte values to memory address
st	d v	Set program variable
pg		Print all globals
pl	[n]	print locals for current/number of enclosing blocks
pp	[n]	print parameters for current/number of enclosing blocks
ds		Dump storage parameters
dd	[n]	Dump display frames
df	[n]	Dump frames formatted (call trace)
dst	[n]	Dump stack words
b	[m] a	Place breakpoint at source line number/routine
tp	[m] a	Place tracepoint at source line number/routine
bi	a	Place breakpoint at instruction
tpi	a	Place tracepoint at instruction
c	[a]	Clear breakpoint/all breakpoints
lb		List active breakpoints
w	a	Watch variable
lw		List watch table
cw	[n]	Clear watch table entry/all watch entries
lia		List instruction analyzer buffer
lsa		List source analyzer buffer
s	[n]	Step next source line execution
ss	[n]	Step next source line execution silently
si	[n]	Step instructions
sis	[n]	Step instructions silently
so	[n]	Step next source line execution with routine skipover
sso	[n]	Step next source line execution silently with routine skipover
sio	[n]	Step instructions with routine skipover
siso	[n]	Step instructions silently with routine skipover
ret		Return from subroutine
hs		Report heap space
ti		Turn instruction tracing on
nti		Turn instruction tracing off
tr		Turn system routine tracing on
ntr		Turn system routine tracing off
ts		Turn source line tracing on

nts	Turn source line tracing off
spf	Turn on source level profiling
nspf	Turn off source level profiling
an	Turn on analyzer mode
nan	Turn off analyzer mode
r	Run program from current pc
ps	Print current registers and instruction
q	Quit interpreter
!	Comment (can appear anywhere in the line)

4.2 Sample program for debug

The following program will be used for reference in the text. The sample run is here:

```
$ p6 test
Compiling test...
P6 Pascal compiler vs. 0.2.x
Pascal-P6 complies with the requirements of Pascaline version 0.4
and the following annexes: A,B,C,E.


     1        -8 program test(output);
     2        -8
     3        -8 var a: array 10 of integer;
     4        -8     i: integer;
     5        -8
     6        -8 function y(add: integer): integer;
     7       -16
     8       -16 var i: integer;
     9       -24
    10       -24 function q(x: integer): integer;
    11       -24
    12       -24 var z: integer;
    13       -32
    14       -32 begin
    15         5
    16         5     z := 42;
    17         7
    18         7     result x+i
    19         8
    20         8 end;
    21        12
    22        12 begin
    23        12
    24        12     i := 10;
    25        14
    26        14     result q(add)
    27        15
    28        15 end;
    29        18
    30        18 begin
    31        18
    32        18     for i := 1 to 10 do
    33        28         a[i] := y(i);
    34        46     for i := 10 downto 1 do writeln('Value: ', a[i]);
    35        83
    36        83 end.

Errors in program: 0
P6 Pascal interpreter vs. 0.2.x

Assembling/loading program
Running program

Value:          20
```

```
Value:          19
Value:          18
Value:          17
Value:          16
Value:          15
Value:          14
Value:          13
Value:          12
Value:          11

program complete
```

4.3 Debug mode invocation

You invoke debug mode with a w/debug (debug always) or a/debugflt (debug on fault) option specified in the source or command line. The modifier for debug mode is f/debugsrc (debug source level).

To invoke the debug mode with source debugging on, we add the option comment "${w,f}" to the top of the program:

```
{$w,f}
program test(output);

...
```

Or by specifying:

```
$ p6 -–debug -–debugsrc test
```

As the command line.

As run, it executes:

```
$ p6 --list- --debug --debugsrc test
Compiling test...
P6 Pascal compiler vs. 0.2.x
Pascal-P6 complies with the requirements of Pascaline version 0.4
and the following annexes: A,B,C,E.


Errors in program: 0
P6 Pascal interpreter vs. 0.2.x

Assembling/loading program
Running program


P6 debug mode


  31:      1:
  32:      1:  *     for i := 1 to 10 do
  33:      0:            a[i] := y(i);

debug>
```

Note that it is stopped at the first line of the program block.

If the program is debugged with P-code machine mode, the run is a bit different:

```
$ p6 --list- --debug test
Compiling test...
P6 Pascal compiler vs. 0.2.x
Pascal-P6 complies with the requirements of Pascaline version 0.4
and the following annexes: A,B,C,E.


Errors in program: 0
P6 Pascal interpreter vs. 0.2.x

Assembling/loading program
Running program


P6 debug mode


pc: 000000 sp: 1000000 mp: 1000000 np: FFFFFFFFFFFFFFFF
  * 000000: 14 lnp*           00000000000005AC

debug>
```

In this case, the execution starts at location 0. The location printout here is in machine mode, which shows the registers **pc**, **sp**, **mp** and **np**.

4.4 Debug mode expressions

Where a debug mode command takes a value, it can usually take an expression. Expressions follow (loosely) Pascal expression rules, from lowest to highest priority:

a = b, a <> b, a <= b, a >= b, a < b, a > b a in b

a + b, a – b, a or b, a xor b

a * b, a / b, a div b, a and b

not a, (a), [set]

Operands can be integer, real, string or set. Constants are:

Constant	Meaning
123	Number
$ac0	hex number
&654	octal number
%10101	binary number
‘hello’’s’	string
0.1	Real

Variables are any standard Pascaline variable reference. Qualident notation can be used.

```
test.y.i
```

Refers to the identifier i in the function y of the module test. Unlike Pascaline, qualidents can be used to refer to any given nested symbol.

Qualidents need only be used for symbols that are not local to the current execution context. So while executing inside function y:

```
i
y.i
```

and

```
test.y.i
```

All refer to the local variable i of the function y in module test.

All of the Pascaline variable operators function in debug:

Code reference	Meaning
a[i]	**Reference to element I of array a.**
r.f	Reference to field f of record r.
p^	Reference to the object p points to.
***v**	Address of variable v.

The debugger can also read and write a set of special variables in the simulator:

Variable	Function
@pc	Current program counter.
@sp	Stack pointer.
@mp	Mark or "frame" pointer.
@np	Top/end of heap.
@constants	Start of constants area.
@globals	Start of globals area.
@heapbotto	Start of heap area.

Note that setting these special variables can cause the P-Machine to malfunction.

4.5 Executing multiple commands

Any number of commands can be executed on a single command line by separating the commands with ";" (semicolon):

```
debug> p 1;p 2
1
2
```

4.6 Breaking runs

The break key, usually Control-C, can be used to break out of any code run, listing run, or other continuous print in debug mode. If the running program is broken out of, the printout is:

```
*** Program stopped by user break
```

Note that Control-C also qualifies as a fault, so specifying the option $a/$debugflt will cause debug mode to be entered after the program is broken. If no debug mode is active, the program run will simply halt and pint will exit.

4.7 Handling overloaded routines

At this writing, debug mode cannot deal with overloaded routines. It truncates the type information off of symbols. If an overloaded group of routines is present, debug mode will only refer to the first routine in the group.

4.8 Debug mode Command descriptions

h or help Print help menu

The help or h command simply prints the command menu:

```
debug> help

Commands:

h|help                              Help (this command)
l                  [m] [s[ e|:l]    List source lines
lc                 [m] [s[ e|:l]    List source and machine lines coordinated
li                 [s[ e|:l]        List machine instructions
p                  v                Print expression
d[b|l][8|16|32|64] [s[ e|:l]        Dump memory
e                  a v[ v]...       Enter byte values to memory address
st                 d v              Set program variable
pg                                  Print all globals
pl                 [n]              print locals for current/number of
                                    enclosing blocks
pp                 [n]              print parameters for current/number of
                                    enclosing blocks
ds                                  Dump storage parameters
dd                 [n]              Dump display frames
df                 [n]              Dump frames formatted (call trace)
dst                [n]              Dump stack words
b                  [m] a            Place breakpoint at source line
                                    number/routine
tp                 [m] a            Place tracepoint at source line
                                    number/routine
bi                 a                Place breakpoint at instruction
tpi                a                Place tracepoint at instruction
c                  [a]              Clear breakpoint/all breakpoints
lb                                  List active breakpoints
w                  a                Watch variable
lw                                  List watch table
cw                 [n]              Clear watch table entry/all watch entries
lia                                 List instruction analyzer buffer
lsa                                 List source analyzer buffer
s                  [n]              Step next source line execution
ss                 [n]              Step next source line execution silently
si                 [n]              Step instructions
sis                [n]              Step instructions silently
so                 [n]              Step over next source line execution
sso                [n]              Step over next source line execution
silently
sio                [n]              Step over instructions
siso               [n]              Step over instructions silently
ret                                 Return from subroutine
hs                                  Report heap space
ti                                  Turn instruction tracing on
nti                                 Turn instruction tracing off
tr                                  Turn system routine tracing on
ntr                                 Turn system routine tracing off
ts                                  Turn source line tracing on
nts                                 Turn source line tracing off
```

```
spf                                 Turn on source level profiling
nspf                                Turn off source level profiling
an                                  Turn on analyzer mode
nan                                 Turn off analyzer mode
r                                   Run program from current pc
ps                                  Print current registers and instruction
q                                   Quit interpreter

!                                   Anywhere in line starts a comment
```

l [m] [s[e|:l]] List source lines

Lists source lines in the program:

```
debug> l

   1:       1:    program test(output);
   2:       0:
   3:       0:    var a: array 10 of integer;
   4:       0:        i: integer;
   5:       0:
   6:       0:    function y(add: integer): integer;
   7:       0:
   8:       0:    var i: integer;
   9:       0:
  10:       0:    function q(x: integer): integer;
```

The columns to the left:

```
   2:       1: b* program test(output);
```

Have the following meaning. The first column is the source line number. The second number is the profile number, it is a count of the number of times that line has been executed. Next, if the line is marked with a “b”, it means there is a breakpoint on the line. If there is a “t”, it means there is a tracepoint on the line[5]. Next, if the column contains a “*” it means that this is the currently executing line.

If the l command is followed by a module, then the source is printed from that module. Thus:

```
l test
```

is the same command while executing in test as:

```
l
```

Even if there are not multiple modules in the current program, this can be useful:

[5]Note that breakpoints and tracepoints set at the machine level show on the source line that contains them.

```
Running program


P6 debug mode


pc: 000000 sp: 1000000 mp: 1000000 np: FFFFFFFFFFFFFFFF
  * 000000: 14 lnp*           0000000000000574

debug> l
*** Module must be active
debug> l test

   1:       0:    program test(output);
   2:       0:
   3:       0:    var a: array 10 of integer;
   4:       0:        i: integer;
   5:       0:
   6:       0:    function y(add: integer): integer;
   7:       0:
   8:       0:    var i: integer;
   9:       0:
  10:       0:    function q(x: integer): integer;
```

Recall when we started the program in machine mode, it began in system code, outside of any module. But we simply specified a particular module, test, and then we can list it's source.

The list command can specify a starting source line to list:

```
debug> l 20

  20:       0:    begin
  21:       0:
  22:       0:       for i := 1 to 10 do
  23:       0:           a[i] := y(i);
  24:       0:       for i := 10 downto 1 do writeln('Value: ', a[i]);
  25:       0:
  26:       0:    end.
```

You can also specify an end line:

```
debug> l 20 22

  20:       0:    begin
  21:       0:
  22:       0:       for i := 1 to 10 do
```

Or alternatively, you can use a length, or number of lines to list:

```
debug> l 20:4

  20:       0:    begin
```

```
  21:       0:
  22:       0:         for i := 1 to 10 do
  23:       0:            a[i] := y(i);
```

Note that the default number of lines to list, if not specified, is 10.

Note that lines outside of a module cannot be listed.

lc [s[e|:l] List source and machine lines coordinated

The lc command combines the l (list source) and li (list instructions) commands. For each source line printed, the machine code generated by that source line is also printed:

```
debug> lc 6:10

   6:       0:    function y(add: integer): integer;
    00008E: AE mrkl*          0000000000000006
    000097: AE mrkl*          0000000000000007
   7:       0:
    000097: AE mrkl*          0000000000000007
    0000A0: AE mrkl*          0000000000000008
   8:       0:    var i: integer;
    0000A0: AE mrkl*          0000000000000008
    0000A9: AE mrkl*          0000000000000009
   9:       0:
    0000A9: AE mrkl*          0000000000000009
    0000B2: AE mrkl*          000000000000000A
  10:       0:    function q(x: integer): integer;
    0000B2: AE mrkl*          000000000000000A
    0000BB: AE mrkl*          000000000000000B
  11:       0:
    0000BB: AE mrkl*          000000000000000B
    0000C4: AE mrkl*          000000000000000C
  12:       0:    var z: integer;
    0000C4: AE mrkl*          000000000000000C
    0000CD: AE mrkl*          000000000000000D
  13:       0:
    0000CD: AE mrkl*          000000000000000D
    0000D6: AE mrkl*          000000000000000E
  14:       0:    begin
    0000D6: AE mrkl*          000000000000000E
    0000DF: AE mrkl*          000000000000000E
    0000E8: 0B mst         02,FFFFFFFFFFFFFFE0,FFFFFFFFFFFFFFF0
    0000FA: AE mrkl*          000000000000000F
  15:       0:
    0000FA: AE mrkl*          000000000000000F
    000103: AE mrkl*          0000000000000010
```

This can be very useful if you are interested in what P-machine code goes with what source line.

The numbers used with the command are source line numbers.

Note that the default number of lines to list, if not specified, is 10.

Note that lines outside of a module cannot be listed.

li [s[e|:l] List machine instructions

The list instructions command is the same as source list, but lists machine instructions:

```
debug> li

    Addr     Op Ins          P  Q
----------------------------------
 *  000000: 14 lnp*            00000000000004E0
    000009: 15 cal             000000000000004E
    000012: 3A stp*
    000013: F2 eext*
    000014: F2 eext*
    000015: F2 eext*
    000016: F2 eext*
    000017: F2 eext*
    000018: F2 eext*
    000019: F2 eext*
```

Note that you cannot specify which module to list from.

Just as for list source, you can specify start, start and end, or start and length:

```
debug> li 0 10

    Addr     Op Ins          P  Q
----------------------------------
 *  000000: 14 lnp*            00000000000004E0
    000009: 15 cal             000000000000004E
```

The numbers used for the command are the addresses in program store. The length, if specified, is the number of instructions to list after the starting address.

The meaning of the fields in the instruction listing are:

1. b,t,* Gives the break, trace, and current execution status of the line.
2. Addr Address of the instruction.
3. Op Opcode (byte code) of the instruction.
4. Ins Memnonic of the instruction.
5. P P or routine nesting index.
6. Q 0 or more operands of the instruction.

Note that the starting list address must be a valid instruction address. If not, the instruction listing will be invalid.

p v Print expression

Prints a Pascaline/debug mode expression.

The expression can be any of the Pascaline-like expressions shown in “Debug mode expressions”. Examples (at the source location line 15):

```
14:      1:
15:      1: b*     result add+i
16:      0:
debug> p i
10
debug> p test.i
1
debug> p i+42

52
debug> p a
array 11, 12, 13, 14, 15, 16, 17, 18, 19, 20 end
```

Note in the function y(), there is a I that is local, and another that is global that we access via test.i.

The array a that is specified is printed in total. Any structured type that is printed is printed in whole with the exception of files. An example complex structure is:

```
var r: record a: (one, two, three);
              b: integer;
              c: array 5 of integer
       end;


debug> p r

record
  two(2),
  42,
  array -9, -8, -7, -6, -5 end
end
```

The p command prints structured values using the same syntax as the Pascaline “fixed” declaration.

The p command also obeys Pascal-P6 radix conversions:

```
debug> p 42$
2A
debug> p 42&
52
debug> p 42%
101010
debug> p $42$
42
```

Note that “42” means convert hex 42 into hex 42, IE., no-op.

If the value printed is undefined, a “*” will be printed:

```
debug> b test 23
debug> r

=== break ===
```

```
  22:     10:            a[i] := y(i);
  23:      1: b*     for i := 10 downto 1 do writeln('Value: ',
a[i]);
  24:      0:

debug> p i

*
```

We broke in after the for loop. Why is I undefined after the for loop? Its actually in the ISO 7185 specification: the loop variable on a for loop is specified as undefined after the for loop.

Note that when the print command prints an encoded value such as an enumerated type or character, it prints the decimal value in parentheses:

```
var c: char;

debug> p c

'c'(99)
```

d[b|l][8|16|32|64] [s[e|:l] Dump memory

Dumps byte machine memory.

```
debug> d 0:50

000000: 14 E0 04 00 00 00 00 00 00 15 4E 00 00 00 00 00   ..........N.....
000010: 00 00 3A F2 F2 F2 F2 F2 F2 F2 F2 F2 F2 F2 F2 F2   ..:.............
000020: F2 F2 F2 F2 F2 F2 F2 F2 F2 F2 F2 F2 F2 F2 F2 F2   ................
000030: F2 F2
```

Note that the ASCII characters equivalent to the bytes are printed to the right. If the character is unprintable, defined as any character less than space or greater then 126, it is printed as ‘.’ (period).

Note also that dumping memory that is undefined (never has it’s value set) will be printed as U’s in both the hex and ASCII displays.

As with source line lists, you can specify a start address, a start and end address, or a start address and a length.

Note that the default length, if not specified, is 256 bytes.

The default dump size is byte or 8 bits. The command d8 is an alias for byte dump. In addition, the size of the dump words can be specified as 8, 16, 32, or 64 bits. The endian mode can also be specified, as b or big endian, and l or little endian. Big endian places the bytes of word in memory order, but little endian reverses them.

```
debug> d16 0 20

000000: E014 0004 0000 0000 1500 004E 0000 0000   .. .. .. .. .. .N .. ..
000010: 0000 F23A F2F2
```

Note the words are grouped in both the hex and ASCII sections.

Note that the bytes in the 16 bit words are reversed, since the dump mode is little endian by default.

```
debug> db16 0 20

000000: 14E0 0400 0000 0000 0015 4E00 0000 0000   .. .. .. .. .. .. .. ..
000010: 0000 3AF2 F2F2
```

In this dump the bytes are in order, since it is big endian.

The dump endian mode has nothing to do with the machine endian mode. The bytes or words are dumped in address order regardless of the machine endian mode. Thus it is up to you to determine what endian mode the machine is using, and choose a dump format accordingly.

```
debug> d64 0 20

000000: 000000000004E014 00000000004E1500   ........ .....N..
000010: F2F2F2F2F23A0000
```

This is a 64 bit little endian dump.

e a v[v]... Enter byte values to memory address

Enters values to byte machine memory. The first value is the address to enter to. This is followed by 1 to n values to be placed into memory in turn:

```
debug> d 0:20

000000: 14 98 02 00 00 15 0B 00 00 00 3A AE 01 00 00 00
000010: AE 02 00 00

debug> e 0 1 2 3
debug> d 0:20

000000: 01 02 03 00 00 15 0B 00 00 00 3A AE 01 00 00 00
000010: AE 02 00 00
```

Note that there is no restriction on where you enter bytes into memory. You can just as easily rewrite the program code in memory. Enter is a sharp tool.

st d v Set program variable

Sets a variable in the current context. The first parameter is the variable to set. The second is the value to set the variable to. The variable to set can be any variable reference:

```
=== break ===

  22:     10:            a[i] := y(i);
  23:      1: b*     for i := 10 downto 1 do writeln('Value: ', a[i]);
  24:      0:

debug> p a
array 11, 12, 13, 14, 15, 16, 17, 18, 19, 20 end
debug> st a[3] 42
debug> p a
array 11, 12, 42, 14, 15, 16, 17, 18, 19, 20 end
```

Set program variable is fairly flexible:

```
var s: packed array 10 of char;

debug> p s

'hi there  '

debug> st s 'lo there  '
debug> p s

'lo there  '

var st: set of char;

debug> p st

['a'..'d','z']

debug> st st ['0'..'9']
debug> p st

['0'..'9']
```

Note that special variables (variables starting with '@') can also be set. See "4.4 Debug mode expressions"

pg Print all globals

Prints the globals for the current program.

debug> pg

Globals:

```
i                    *
a                    array 11, 12, 13, 14, 15, 16, 17, 18, 19, 20 end
```

pl [n] print locals for current/number of enclosing blocks

Prints the locals for the current block or enclosing blocks:

```
debug> b q
debug> r

=== break ===

  15:      1:
  16:      1: b*     z := 42;
  17:      0:

debug> s
```

```
  17:      1:
  18:      1:   *     result x+i
  19:      0:

debug> pl

Locals for block: q@f_i

z                    42
```

If a number of blocks argument appears, then that number of enclosing blocks are printed:

```
debug> pl 2

Locals for block: q@f_i

z                    42


Locals for block: y@f_i

i                    10
```

Parameters are not considered part of the locals.

pp [n] print parameters for current/number of enclosing blocks

Prints parameters for the current or surrounding blocks:

```
debug> pp

Parameters for block: q@f_i

x                    1

debug> pp 2

Parameters for block: q@f_i

x                    1


Parameters for block: y@f_i

add                  1
```

ds Dump storage parameters

ds prints the storage areas of the byte machine:

debug> ds

Storage areas occupied

Program 000000-0004C3 (1220)

Constants 0004C4-0004FB (56)

Globals 0004FC-0005AB (176)

Stack/Heap 0005AC-FFFFFF (16775764)

The program area is where the bytecode program lives. Constants is the location of the constants deck. Globals contains all of the program globals. Finally, the stack/heap contains the rest of the byte machine space, with the heap growing up, and the stack growing down.

dd [n] Dump display frames

Dumps the contents of all active display frames. This is mainly for debugging the interpreter. It shows all of the active stack marks and their contents.

```
debug> b q
debug> r

=== break ===

  15:      1:
  16:      1: b*     z := 42;
  17:      0:

debug> dd

Mark @FFFF28
ep: 00FFFF30: 00FFFF58
sb: 00FFFF38: 00FFFF08
et: 00FFFF40: 00FFFEF8


Mark @FFFF78
ep: 00FFFF80: 00FFFF98
sb: 00FFFF88: 00FFFF60
et: 00FFFF90: 00FFFF58


Mark @FFFFD0
ep: 00FFFFD8: 00000005
sb: 00FFFFE0: 00FFFFB8
et: 00FFFFE8: 00FFFF98
```

The number, if present, will specify how many stack frames to dump. The default is to dump all active stack frames.

df [n] Dump frames formatted (call trace)

The df or dump formatted command is like the dd command, but tells you what block was executing by name, what address within the block it was executing, and what the start and end address of the block of local variables is for that frame.

```
debug> b q
debug> r

=== break ===

  15:      1:
  16:      1: b*     z := 42;
  17:      0:

debug> df

q@f_i: addr: 0000010C locals/stack: 00FFFEF8-00FFFF10 (24)
  15:      1:
  16:      1: b*     z := 42;
  17:      0:


y@f_i: addr: 000001EB locals/stack: 00FFFF58-00FFFF60 (8)
  25:      1:
  26:      1:        result q(add)
  27:      0:


test: addr: 00000308 locals/stack: 00FFFF98-00FFFFB8 (32)
  32:      2:        for i := 1 to 10 do
  33:      1:            a[i] := y(i);
  34:      0:        for i := 10 downto 1 do writeln('Value: ', a[i]);
```

Note that the program/module frame has very no locals, since its variables are global.

dst Dump stack words

Dump stack words.

```
debug> lc 34:1

  34:      0:        for i := 10 downto 1 do writeln('Value: ', a[i]);
    000366: AE mrkl*          0000000000000022
    00036F: 7B ldci           000000000000000A
    000378: 02 stri        01,FFFFFFFFFFFFFFF0
    000382: 7B ldci           0000000000000001
    00038B: 02 stri        01,FFFFFFFFFFFFFFE8
    000395: 00 lodi        01,FFFFFFFFFFFFFFF0
    00039F: 03 sroi           00000000000005A4
    0003A8: AE mrkl*          0000000000000022
    0003B1: 01 ldoi           00000000000005A4
    0003BA: 00 lodi        01,FFFFFFFFFFFFFFE8
    0003C4: 95 geqi
    0003C5: 18 fjp            0000000000000493
    0003CE: 38 lca            00000000000004D4
    0003D7: 05 lao            00000000000004FE
```

```
    0003E0: 76 swp            0000000000000008
    0003E9: 7B ldci           0000000000000007
    0003F2: 76 swp            0000000000000008
    0003FB: 7B ldci           0000000000000007
    000404: 0F csp            0000000000000006
    000406: 05 lao            0000000000000554
    00040F: 01 ldoi           00000000000005A4
    000418: 1A chki           00000000000004C4
    000421: 39 deci           0000000000000001
    00042A: 10 ixa            0000000000000008
    000433: 09 indi           0000000000000000
    00043C: 7B ldci           000000000000000B
    000445: 0F csp            0000000000000008
    000447: 0F csp            0000000000000005
    000449: 75 dmp            0000000000000008
    000452: 01 ldoi           00000000000005A4
    00045B: 00 lodi        01,FFFFFFFFFFFFFFE8
    000465: 89 equi
    000466: 77 tjp            0000000000000493
    00046F: 01 ldoi           00000000000005A4
    000478: 39 deci           0000000000000001
    000481: 03 sroi           00000000000005A4
    00048A: 17 ujp            00000000000003A8
    000493: AE mrkl*          0000000000000022
    00049C: 05 lao            00000000000005A4
    0004A5: BD inv
    0004A6: AE mrkl*          0000000000000023

debug> b $445
*** Invalid source line
debug> bi $445
debug> r
Value:

=== break ===

  33:     21:            a[i] := y(i);
  34:      2: b*     for i := 10 downto 1 do writeln('Value: ', a[i]);
  35:      0:

debug> dst
00FFFFA0: 000000000000000B (11)
00FFFFA8: 0000000000000014 (20)
00FFFFB0: 00000000000004FE (1278)
00FFFFB8: 0000000000000001 (1)
00FFFFC0: 000000000000000A (10)
00FFFFC8: 0000000000FFFFD0 (16777168)
00FFFFD0: 0000000001000000 (16777216)
00FFFFD8: 0000000000000005 (5)
00FFFFE0: 0000000000FFFFB8 (16777144)
00FFFFE8: 0000000000FFFF98 (16777112)
```

dst dumps either the specified number of words on the P-machine stack or the default 10 words. The first field is the address of the stack word, the second is the contents of the word in hex, then the contents in decimal.

dst is a low level facility. Here we have stopped the execution before a csp instruction that makes a wri system call, with the field width, the integer to print, then the address of the file variable.

The word size dumped is the word size of the machine. There is no intellgence to a stack dump, it does not know what the types are on the stack or how big the stack is. It just dumps the number f words you tell it to.

b [m] l|r Place breakpoint at source line number/routine

The b or break command places a source line or routine breakpoint. If the program is run, it will stop at that breakpoint.

```
debug> b 33
debug> r

=== break ===

  32:      2:        for i := 1 to 10 do
  33:      1: b*         a[i] := y(i);
  34:      0:        for i := 10 downto 1 do writeln('Value: ', a[i]);
```

When the break occurs, the line the execution stopped on is printed, along with the line above and the line below, if they are available (the currently executing line could be at the start or end of the program).

There is a limit of 10 breakpoints outstanding. The module containing the source line can optionally be specified, otherwise the default is the current module executing.

Note that the breakpoint command will skip any source line markers, and will skip over the start of a routine if found (the mst or frame start instruction). The reason is to break at an active instruction inside of a routine.

tp [m] l|r Place tracepoint at source line number/routine

The tp or tracepoint command sets a tracepoint at the given source line or routine. Specifying the module containing the source line is optional.

Tracepoints are like breakpoints, but they do not stop after printing the currently executing line. Thus they will effectively “trace” the program execution through that point in the code.

```
debug> tp 23
*** Module must be active
debug> tp test 23
debug> r


  22:      1:        for i := 1 to 10 do
  23:      1: t*         a[i] := y(i);
  24:      0:        for i := 10 downto 1 do writeln('Value: ', a[i]);



  22:      1:        for i := 1 to 10 do
  23:      2: t*         a[i] := y(i);
  24:      0:        for i := 10 downto 1 do writeln('Value: ', a[i]);
```

```
  22:       1:        for i := 1 to 10 do
  23:       3: t*         a[i] := y(i);
  24:       0:        for i := 10 downto 1 do writeln('Value: ', a[i]);

...
```

Just as for source breakpoints, the module can be specified or left to the current default.

Note that the tracepoint command will skip any source line markers, and will skip over the start of a routine if found (the mst or frame start instruction). The reason is to break at an active instruction inside of a routine.

bi a Place breakpoint at instruction

Places a machine instruction level breakpoint. These breakpoints can be placed anywhere in the program, and thus no module is required.

```
debug> lc test 1 1000

   1:       1:    program test(output);
   2:       0:
    00006A: AE mrkl*          0000000000000002
    000073: AE mrkl*          0000000000000003
   3:       0:    var a: array 10 of integer;
    000073: AE mrkl*          0000000000000003
    00007C: AE mrkl*          0000000000000004
   4:       0:        i: integer;

...

    000353: AE mrkl*          0000000000000021
    00035C: 05 lao            00000000000005A4
    000365: BD inv
    000366: AE mrkl*          0000000000000022
  34:       0:        for i := 10 downto 1 do writeln('Value: ', a[i]);
    000366: AE mrkl*          0000000000000022
    00036F: 7B ldci           000000000000000A
    000378: 02 stri        01,FFFFFFFFFFFFFFF0
    000382: 7B ldci           0000000000000001
    00038B: 02 stri        01,FFFFFFFFFFFFFFE8
    000395: 00 lodi        01,FFFFFFFFFFFFFFF0
    00039F: 03 sroi           00000000000005A4
    0003A8: AE mrkl*          0000000000000022
    0003B1: 01 ldoi           00000000000005A4
    0003BA: 00 lodi        01,FFFFFFFFFFFFFFE8
    0003C4: 95 geqi
    0003C5: 18 fjp            0000000000000493

debug> bi $3c5
debug> r

=== break ===
```

```
  33:     21:            a[i] := y(i);
  34:      2: b*     for i := 10 downto 1 do writeln('Value: ', a[i]);
  35:      0:

debug>
```

Note that the break instruction print will be in source mode unless you change to machine mode.

Note also that there is only one breakpoint table, and it is shared by all source and machine level breakpoints and tracepoints.

Note that the breakpoint must be placed at the start of a valid instruction, or the result will be a crash.

tpi a Place tracepoint at instruction

Places an instruction level tracepoint.

Note that the break instruction print will be in source mode unless you change to machine mode.

Note that the tracepoint must be placed at the start of a valid instruction, or the result will be a crash.

c [a] Clear breakpoint/all breakpoints

Clears either a single breakpoint or tracepoint, or all of them from the table. The number to clear corresponds to the entry number in the table.

```
debug> lb

Breakpoints:

No  Src  Addr   Trc/brk
=======================
 1:    1: 000000 b
 2:****: 00013E b

debug> c 2
debug> lb

Breakpoints:

No  Src  Addr   Trc/brk
=======================
 1:    1: 000000 b
```

lb List active breakpoints

Lists the breakpoints in the table.

```
debug> b test 15
debug> tp test 18
debug> bi 5
debug> tpi 10
debug> lb

Breakpoints:
```

```
No  Src  Addr   Trc/brk
=======================
 1:   1: 000000 b
 2:  15: 000079 b
 3:  18: 000096 t
 4:****: 000005 b
 5:****: 00000A t
```

The first entry in the table is the logical entry number. This is what you use to clear the breakpoint. The second entry is the source line number. This will be all "****" if there is no source line associated with it (it is a machine level breakpoint). This is followed by the address of the breakpoint, and then a "b" (for breakpoint) or "t" for tracepoint.

w a Watch variable

Set a variable watch. A variable watch prints a diagnostic every time the indicated variable is changed. Any Pascaline variable in the current scope can be watched.

```
debug> b test 22
debug> r

=== break ===

  21:      1:
  22:      1: b*    for i := 1 to 10 do
  23:      0:           a[i] := y(i);

debug> w i
debug> r

Watch variable: @000000D1: i@00000298: * -> 1
Watch variable: @0000012E: i@00000298: 1 -> 2
Watch variable: @0000012E: i@00000298: 2 -> 3
Watch variable: @0000012E: i@00000298: 3 -> 4
...
```

The watch message line tells you what program instruction modified the variable, followed by what the variable was that was modified, and its' address, then what the value of the variable was, and what it was changed to.

Only simple variables can be watched, not structured. If you want to watch a variable within a structured type, indicate what element you wish to watch:

```
debug> b test 22
debug> r

=== break ===

  21:      1:
  22:      1: b*    for i := 1 to 10 do
  23:      0:           a[i] := y(i);
```

```
debug> w a[5]
debug> r

Watch variable: @00000112: a@00000280: * -> 15
```

When any block ends, any watches to variables within that block are automatically evicted.

lw List watch table

Lists the watch table:

```
debug> lw

Watch table:

1: 00000270
```

This gives the logical number of the watch entry, followed by the address the watch was placed on.

cw [n] Clear watch table entry/all watch entries

Clears either a specific watch entry by logical number, or clears the entire watch table.

lia List instruction analyzer buffer

Lists the contents of the instruction analyzer buffer. The instruction analyzer buffer is a queue that continually stores the address of the executing instructions and evicting the oldest addresses.

```
debug> an
debug> b test 22
debug> r

=== break ===

  21:      1:
  22:      1: b*    for i := 1 to 10 do
  23:      0:           a[i] := y(i);

debug> lia

last instructions executed:

b * 0000B5: 7B ldci           00000001
    0000B0: AE mrkl*          00000016
    0000AB: AE mrkl*          00000015
    0000A6: AE mrkl*          00000014
    0000A1: AE mrkl*          00000013
    00009C: AD ente           FFFFFFF0
    000097: 0D ents           FFFFFFD8
    000017: 0C cup         00,00000097
    000015: 0B mst         00
    000010: AE mrkl*          00000002
```

```
debug>
```

Because running instruction analysis slows down instruction execution a bit, it must be specifically enabled. This is done with the an (analysis on) command.

lsa List source analyzer buffer

Lists the contents of the source analyzer buffer. The source analyzer buffer is a queue that continually stores the address of the executing source lines and evicting the oldest addresses.

```
debug> b test 24
debug> an
debug> r

=== break ===

  23:     10:           a[i] := y(i);
  24:      1: b*    for i := 10 downto 1 do writeln('Value: ', a[i]);
  25:      0:

debug> lsa

last source lines executed:

  23:     10:           a[i] := y(i);
  24:      1: b*    for i := 10 downto 1 do writeln('Value: ', a[i]);
  18:     10:    end;
  17:     10:
  16:     10:       result add+i
  15:     10:
  14:     10:       i := 10;
  13:     10:
  12:     10:    begin
  11:     10:
```

s [n] Step next source line execution

Steps source line execution. The current source line is executed and stopped at the following instruction.

```
P6 debug mode


  31:      1:
  32:      1:   *     for i := 1 to 10 do
  33:      0:             a[i] := y(i);

debug> s

  32:      2:         for i := 1 to 10 do
  33:      1:   *         a[i] := y(i);
  34:      0:         for i := 10 downto 1 do writeln('Value: ',
a[i]);
```

```
debug> s

  23:      1:
  24:      1:   *     i := 10;
  25:      0:

debug> s

  25:      1:
  26:      1:   *     result q(add)
  27:      0:

debug> s

  15:      1:
  16:      1:   *     z := 42;
  17:      0:

debug>
```

As stated, a side use of the s command is to go from the startup code to the first source line.

If a number appears on the s command, then that many steps are done:

```
P6 debug mode


  31:      1:
  32:      1:   *     for i := 1 to 10 do
  33:      0:             a[i] := y(i);

debug> s 5

  32:      2:         for i := 1 to 10 do
  33:      1:   *         a[i] := y(i);
  34:      0:         for i := 10 downto 1 do writeln('Value: ',
a[i]);


  23:      1:
  24:      1:   *     i := 10;
  25:      0:


  25:      1:
  26:      1:   *     result q(add)
  27:      0:


  15:      1:
  16:      1:   *     z := 42;
  17:      0:
```

```
  17:      1:
  18:      1:  *     result x+i
  19:      0:

debug>
```

ss [n] Step next source line execution silently

The ss (step silent) command is the same as the s (step) command except that it does not print.

```
P6 debug mode


  31:      1:
  32:      1:  *     for i := 1 to 10 do
  33:      0:            a[i] := y(i);

debug> ss 5
debug> ps

  17:      1:
  18:      1:  *     result x+i
  19:      0:

debug>
```

si [n] Step instructions

Steps a single machine level instruction, or optionally the number of instructions specified.

```
P6 debug mode


pc: 000000 sp: 1000000 mp: 1000000 np: FFFFFFFFFFFFFFFF
  * 000000: 14 lnp*           00000000000005AC

debug> si

pc: 000009 sp: 1000000 mp: 1000000 np: 0005AC
  * 000009: 15 cal            000000000000004E

debug> si

pc: 00004E sp: FFFFF8 mp: 1000000 np: 0005AC
  * 00004E: AE mrkl*          0000000000000001

debug>
```

sis [n] Step instructions silently

Steps a single machine level instruction silently, or optionally the number of instructions specified.

```
P6 debug mode


pc: 000000 sp: 1000000 mp: 1000000 np: FFFFFFFFFFFFFFFF
  * 000000: 14 lnp*           00000000000005AC

debug> sis
debug> sis
debug> sis
debug> ps

pc: 000057 sp: FFFFF8 mp: 1000000 np: 0005AC
  * 000057: F5 sfr            0000000000000000

debug>
```

so [n] Step next source line execution over routines

Steps source line execution. The current source line is executed and stopped at the following instruction. Any subroutine calls are skipped over, that is, executed until they return. This is the same as s, but skips routine calls.

```
P6 debug mode


  31:      1:
  32:      1:  *     for i := 1 to 10 do
  33:      0:            a[i] := y(i);

debug> so

  32:      2:        for i := 1 to 10 do
  33:      1:  *         a[i] := y(i);
  34:      0:        for i := 10 downto 1 do writeln('Value: ',
a[i]);

debug> so

  32:      2:        for i := 1 to 10 do
  33:      2:  *         a[i] := y(i);
  34:      0:        for i := 10 downto 1 do writeln('Value: ',
a[i]);

debug> so

  31:      1:
  32:      3:  *     for i := 1 to 10 do
  33:      2:            a[i] := y(i);
```

```
debug> p i

2

debug>
```

sso [n] Step next source line execution over routines silently

Steps source line execution. The current source line is executed and stopped at the following instruction. Any subroutine calls are skipped over, that is, executed until they return. This is the same as s, but skips routine calls. No status print results. This is the same as ss, but steps over routine calls.

```
P6 debug mode


  31:      1:
  32:      1:  *     for i := 1 to 10 do
  33:      0:            a[i] := y(i);

debug> sso
debug> sso
debug> sso
debug> ps

  31:      1:
  32:      3:  *     for i := 1 to 10 do
  33:      2:            a[i] := y(i);
q
debug> p i

2

debug>
```

sio [n] Step instructions over routines

Steps a single machine level instruction, or optionally the number of instructions specified, skipping over subroutine calls. This is the same as si, but skips over routine calls.

```
debug> bi $2f6
debug> r

=== break ===

pc: 0002F6 sp: FFFFA8 mp: FFFFD0 np: 0005AC
b * 0002F6: 01 ldoi           00000000000005A4

debug> sio

pc: 0002FF sp: FFFFA0 mp: FFFFD0 np: 0005AC
```

```
  * 0002FF: F6 cuf            000000000000016B

debug> sio

pc: 000308 sp: FFFFA8 mp: FFFFD0 np: 0005AC
  * 000308: AE mrkl*          0000000000000021

debug>
```

siso [n] Step instructions silently over routines

Steps a single machine level instruction silently, or optionally the number of instructions specified, skipping over subroutine calls.

```
P6 debug mode


pc: 000000 sp: 1000000 mp: 1000000 np: FFFFFFFFFFFFFFFF
  * 000000: 14 lnp*           00000000000005AC

debug> bi $2f6
debug> r

=== break ===

pc: 0002F6 sp: FFFFA8 mp: FFFFD0 np: 0005AC
b * 0002F6: 01 ldoi           00000000000005A4

debug> siso
debug> siso
debug> ps

pc: 000308 sp: FFFFA8 mp: FFFFD0 np: 0005AC
  * 000308: AE mrkl*          0000000000000021

debug>
```

ret Return from routine

Continues execution until the currently executing routine exits.

```
P6 debug mode

  31:      1:
  32:      1:   *     for i := 1 to 10 do
  33:      0:             a[i] := y(i);

debug> s

  32:      2:         for i := 1 to 10 do
  33:      1:   *         a[i] := y(i);
  34:      0:         for i := 10 downto 1 do writeln('Value: ', a[i]);
```

```
debug> s

  23:      1:
  24:      1:  *     i := 10;
  25:      0:

debug> ret

  32:      2:        for i := 1 to 10 do
  33:      2:  *         a[i] := y(i);
  34:      0:        for i := 10 downto 1 do writeln('Value: ', a[i]);

debug>
```

hs Report heap space

Prints the space allocated on the heap. This is mainly used for diagnostic purposes.

```
debug> b test 23
debug> r

=== break ===

  22:      1:      new(p);
  23:      1: b*   for i := 1 to 10 do
  24:      0:          a[i] := y(i);

debug> hs

Heap space breakdown

addr: 0002B0:      8: alloc
```

The first field is the address of the heap entry. The second is the length. The last indicates the entry is allocated.

ti Turn instruction tracing on

Turns on instruction tracing. When instruction tracing is on, a single line for each bytecode machine instruction is printed.

```
debug> b 20
*** Module must be active
debug> b test 20
debug> ti
debug> r
b * 000000/1000000: 14 lnp*           00000298
  * 000005/1000000: 15 cal            0000000B
  * 00000B/FFFFFC: AE mrkl*          00000001
  * 000010/FFFFFC: AE mrkl*          00000002
  * 000015/FFFFFC: 0B mst         00
  * 000017/FFFFDC: 0C cup         00,00000092
  * 000092/FFFFDC: 0D ents           FFFFFFD8
  * 000097/FFFFD4: AD ente           FFFFFFF0
```

```
  * 00009C/FFFFD4: AE mrkl*          00000012
  * 0000A1/FFFFD4: AE mrkl*          00000013
  * 0000A6/FFFFD4: AE mrkl*          00000014
  * 0000AB/FFFFD4: AE mrkl*          00000015
b * 0000B0/FFFFD4: 13 brk

=== break ===

  19:      1:    begin
  20:      1: b*
  21:      1:       for i := 1 to 10 do
```

The instruction trace lines consist of the following:

1. A column with space or “b” to indicate that instruction has a breakpoint set.
2. A column with space or “*” to indicate that the point of execution is on this instruction. Note that since the instruction is always active when tracing, this is always set.
3. The value of the pc register.
4. The value of the sp register.
5. The bytecode instruction value.
6. The memnonic for the instruction.
7. The p value for the instruction.
8. One or more parameters for the instruction.

nti Turn instruction tracing off

Turns off instruction tracing.

tr Turn system routine tracing on

Turns on system routine tracing. In this mode, a message line is produced each time a system routine is called.

```
debug> tr
debug> r
   400/16777156->  6
Value:
   437/16777160->  8
         20
   439/16777168->  5

   400/16777156->  6
Value:
   437/16777160->  8
         19
  439/16777168->  5

   400/16777156->  6
Value:
   437/16777160->  8
         18
   439/16777168->  5
```

```
   400/16777156->  6
Value:
   437/16777160->  8
         17
   439/16777168->  5
```

Note the routine messages here are intermixed with the program output.

The first value printed is the pc register. The second value is the sp register. The last value is the call number.

ntr Turn system routine tracing off

Turns system routine tracing off.

ts Turn source line tracing on

Turns source line tracing on. Source line tracing prints a trace each time a source line is executed.

```
P6 debug mode


  31:      1:
  32:      1:   *     for i := 1 to 10 do
  33:      0:             a[i] := y(i);

debug> b 33
debug> ts
debug> r

  31:      1:
  32:      2:   *     for i := 1 to 10 do
  33:      0: b           a[i] := y(i);


  32:      2:         for i := 1 to 10 do
  33:      1: b*          a[i] := y(i);
  34:      0:         for i := 10 downto 1 do writeln('Value: ',
a[i]);


=== break ===

  32:      2:         for i := 1 to 10 do
  33:      1: b*          a[i] := y(i);
  34:      0:         for i := 10 downto 1 do writeln('Value: ',
a[i]);

debug>
```

For each source line executed, the line before, the current line executing, and the next line are printed.

nts Turn source line tracing off

Turns off source line tracing.

spf Turn on source level profiling

Turns on source level profiling. Source level profiling is a count kept for each source line that is incremented each time that line is executed.

```
debug> r
Value:          20
Value:          19
Value:          18
Value:          17
Value:          16
Value:          15
Value:          14
Value:          13
Value:          12
Value:          11

*** Stop instruction hit

=== break ===

*** No active module

debug> l test

   1:      0: b  {$w,f}
   2:      1:    program test(output);
   3:      0:
   4:      0:    var a: array 10 of integer;
   5:      0:        i: integer;
   6:      0:
   7:      0:    function y(add: integer): integer;
   8:      0:
   9:      0:    var i: integer;
  10:     10:
  11:     10:    begin
  12:     10:
  13:     10:       i := 10;
  14:     10:
  15:     10:       result add+i
  16:     10:
  17:     10:    end;
  18:      1:
  19:      1:    begin
  20:      1:
  21:      1:       for i := 1 to 10 do
  22:     10:           a[i] := y(i);
  23:      1:       for i := 10 downto 1 do writeln('Value: ', a[i]);
```

```
  24:      1:
  25:      1:   * end.
```

The source line profile count is the second number on the source listing after the line number.

Source line profiling is not time intensive, and defaults to on.

nspf Turn off source level profiling

Turns source line profiling off.

```
debug> nspf
```

The listing will have the source line profiling column removed.

an Turn on analyzer mode

Turns on analyzer mode. Both source and instruction analyzer collection is turned on. Note that analyzer mode does take a small amount of execution time, and so is normally set off.

nan Turn off analyzer mode

Turns off analyzer mode.

r Run program from current pc

The byte code interpreter runs from the current pc until a stop or breakpoint is hit.

ps Print current registers and instruction

Prints the current machine execution status. The format of the printout will depend on what mode the debugger is in, either source level or machine level debugging.

```
debug> b test 22
debug> r

=== break ===

  21:      1:       for i := 1 to 10 do
  22:      1: b*        a[i] := y(i);
  23:      0:       for i := 10 downto 1 do writeln('Value: ', a[i]);

debug> ps

  21:      1:       for i := 1 to 10 do
  22:      1: b*        a[i] := y(i);
  23:      0:       for i := 10 downto 1 do writeln('Value: ', a[i]);
```

For source level. Note that the status is printed each time the program breaks, automatically.

```
debug> b test 22
debug> r

=== break ===
```

```
pc: 0000E7 sp: FFFFD4 mp: FFFFFC np: 000298
b * 0000E7: 05 lao             0000026C
```

For machine level.

How can source level breakpoints be set even when not in source debugging mode (The “b test 22” above)? Debug mode understands line numbers even if it does not load the source text for the program.

q Quit interpreter

Exits the pint interpreter.

5 Different generation and run options: pint, pmach and cmach, and pgen

pint

pint, the traditional interpreter for the Pascal-P series, can generate a binary deck in Pascal-P6 to be run by a separate byte code machine using the $e/$machdeck option. See “Compiler options”. A separate bye code machine does not have the overhead of assembly or debugging of the intermediate. Thus it can be smaller and (in some cases) faster than pint. There are two alternate byte code machines available:

pmach

This is the byte machine core from pint, and directly tracks pint. Because it comes from the same code base, it has identical run time. pmach tracks pint, meaning that updates to the pint byte code machine are copied to pmach.

cmach

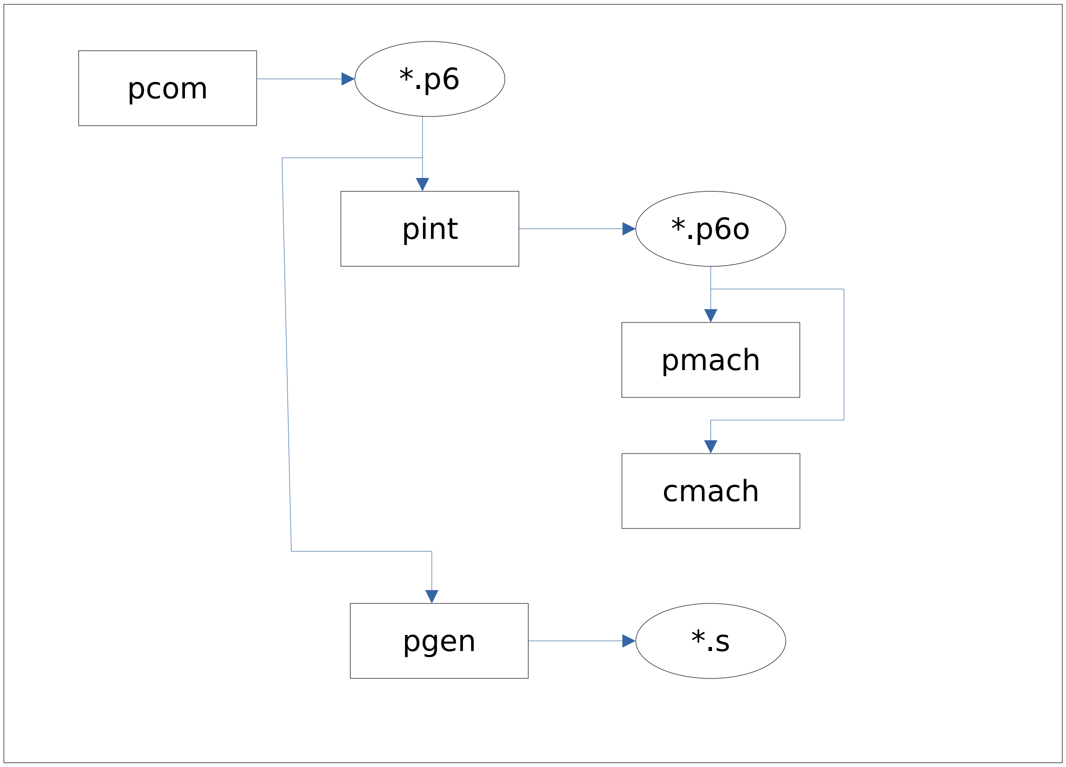
This is the byte machine core from pint, but translated into the C language according to ISO 9899:1990 or ANSI/ISO C (no C99 constructs are used). The purpose of cmach is as a porting tool for Pascal-P6. Any compiler that obeys the original ANSI C language can be used to implement a Pascal-P6 system using this module. It is also can be nearly an order of magnitude faster than the mainline pint/pmach machine (with the proper options set).

package

cmach features a “packaged mode”, which enables the generation of executables from a Pascal-P6 source deck.

pgen

Besides the interpretation options, Pascal-P6 can also use the option to directly generate machine code for a particular processor. See “9 pgen – AMD64 code generator”.



As shown, pcom produces *.p6 intermediate files as output. This can be fed to pint or pgen. pint can produce a "machine deck" consisting of the object file for the Pascal-P6 "virtual machine", which pint can either run itself or export to a file, *.p6o (or .p6 "object"). This file can then be run on either pmach or cmach. pgen takes a *.p6 intermediate and generates a *.s assembly file, which is then fed to a compiler/assembler such as gcc to become part of a binary executable.

5.1 Running the different machines

The p6 script features flags to optionally run programs on the different machines:

–pgen	Compile directly to executable binary (the default).
--pint	Run on the pint interpreter.
--pmach	Run on the pmach machine.
--cmach	Run on the cmach machine.
–package	Run in packaged mode.

Example:

```
p6 –pmach test
```

To run program test on the pmach machine.

5.2 Difference between different generation modes

The differences between the number of source code lines and run times for different machines are detailed (at current writing, and using the "prime.pas" test in the sample_programs directory):

Machine	Run time for "prime.pas"/100 iterations
pint	28.726s
pmach	27.319s
cmach	2.208s
package	2.298s
pgen	0.013s
gcc(C)	0.006s
gpc	0.010s

Note that for pint, pmach and cmach modes, the total time includes loading time for the intermediate. For pgen and package, it does not, since they are executables.

5.3 Setting machine options on pmach and cmach

Because both pmach and cmach do not have access to the intermediate, they use the defaults for several run time options that are detailed in "Compiler options". For both pmach and cmach, these options must be set in the source and then the modules recompiled.

For cmach, the options can be set via compiler flags as follows:

Option name	Char	Function
WRDSIZ16	-	Sets 16 bit word size.
WRDSIZ32	-	Sets 32 bit word size.
WRDSIZ64	-	Sets 64 bit word size.
DOCHKOVF	$o/$chkoverflo	Check arithmetic overflow.
DOSRCLIN	$h/$sourceset	Add source line sets to code.
DORECYCL	$n/$recycle	Obey heap space recycle requests.
DOCHKRPT	$p/$chkresuse	Check reuse after dispose attempts.
DONORECPAR	$m/$breakheap	Do not recycle second part of disposed entries.
DOCHKDEF	$q/$chkundef	Check undefined variable accesses.
ISO7185	$s/$iso7185	Check strict adherence to the ISO 7185 Pascal standard.

Where "-" means "does not apply". pint and pmach do not need their word size defined externally.

Note that all of the options are true/false except for WRDSIZ16, WRDSIZ32 and WRDSIZ64, which are defined/not defined options. This means they must be set to 0 (false) or 1 (true).

5.4 Packaged application mode

cmach has the ability to create "packaged" applications. This means the given application byte code is united with the cmach interpreter and generated as an executable. The resulting program looks and behaves just as a fully machine compiled application would, but does not execute any faster than the interpreted version. A packaged application may be smaller than the equivalent machine compiled application, because byte machine code is often more dense than target machine code. This needs to be determined on a case by case basis.

An application does not typically get the "interpretation bonus" until it is large enough to overcome the overhead of needing to include its' interpreter in the program, as well as the need to carry a full set of library routines, instead of just the minimal routines needed.

"running as a bytecode machine" may be a good idea on very small machines such as 16 bit or even 8 bit microprocessors[6]. For these types of machines, the key is finding a good, compact C compiler for

[6] Typically 8 bit microprocessors and 16 bit microprocessors use the same word length, because the word length goes by address capability, not register length.

cmach.c, or even recoding the interpreter in native assembly language. This was done, for example, with UCSD Pascal.

Packaged applications can be generated by the p6 script:

```
p6 --package test
```

Will generate a test or test.exe executable.

Using the $e/$machdeck option, pint generates a byte instruction code file in hex format. The program genobj takes this byte code and converts it to a static array in the C language, then it is compiled together with cmach.c to make a final program.

The pint generated hex file format

The generated bytecode from pint using the $e format appears as:

```
:1000000000000000000141C250000150B0000003AAE010000005E
:1000000000000000010AE02000000AE03000000AE04000000AEC1
:1000000000000000002005000000AE06000000AE07000000AE0824
:1000000000000000030000000AE09000000AE0A000000AE0B0028
…
:1000000000000004A065726174696F6E7301000000FF1F000084
:00000000000000000000
```

It is based on a modified form of “Intel hex” format, see:

https://en.wikipedia.org/wiki/Intel_HEX

However, note it is not exactly compatible with Intel Hex format. It does not use a record type field.

The fields present in each line are:

1. Start code, the character “:”.
2. Byte count, two hex digits or 8 bits, indicating the length of the data in the record. If the byte count is zero, this is the last record in the file, and terminates the file.
3. Address, 16 hex digits or 64 bits in big endian or most significant byte to least significant byte order. This carries the address the data in the record is to be loaded to. It is all zeros on the last or “stop” record.
4. Data, 2 hex digits or 8 bits for each of the data record bytes specified by the byte count.
5. checksum, 2 hex digits or 8 bits. This is the sum of all the data bytes in the record, modulo 256, meaning that any overflow fro m the 8 bit sum is discarded. The checksum starts with a value of 0. It is all zeros on the last or “stop” record, since there are no data bytes in that record.

For further details on the hex bytecode format, see the program genobj.pas.

5.5 Using packaged mode to port to a machine not supported by a Pascal compiler

cmach can be used to form a working set of Pascal-P6 programs on a machine that only supports an ANSI C compiler. To perform this port, you will need to package at least the set of applications:

pcom Compiler.

pint Assembler/interpreter.

genobj Byte code to C source code generator.

Note that although you can use cmach itself to run the programs pcom generates, and not pint, you need pint to perform the assembly and link step to generate input decks to cmach.

Running pint via cmach works, but should be avoided since it is slow. The better option is to simply run intermediates via cmach.

6 Output Decks

Pascal-P6 has two formats to carry machine independent code to the program that will compile or execute it, the intermediate deck and the binary deck.

6.1 Portability of intermediate decks

Pascal-P6 incorporates a lot of machine specific parameters into the intermediate, using the MPB or "machine parameter block" system. Indeed, this is how the system was able to port to a variety of different machines over the 45 years since it was first written.

However, modern microprocessors have very similar designs, and such things as byte addressability, object alignment and other concerns are standard across machines. Pascal-P6 does not even have endian dependencies. Thus, intermediate decks are typically only dependent on their machine word size. Thus at this writing, there are:

16 bit intermediate	Covers 8 and 16 bit microprocessors.
32 bit intermediate	Covers 32 bit microprocessors.
64 bit intermediate	Covers 64 bit microprocessors.

6.2 Portability of hex/binary decks

The portability of hex/binary decks emitted by pint using the $e/$machdeck option are similar to intermediate decks, but, because they have encoded machine values in them, they add endian concerns to the decks. At the present time, there is no option to generate a binary with different endian mode than the host.

The hex/binary decks are:

Word size	Endiam mode	Description
16 bit hex/binary	Little endian	Covers 8 and 16 bit microprocessors.
16 bit hex/binary	Big endian	Covers 8 and 16 bit microprocessors.
32 bit hex/binary	Little endian	Covers 32 bit microprocessors.
32 bit hex/binary	Big endian	Covers 32 bit microprocessors.
64 bit intermediate	Little endian	Covers 64 bit microprocessors.
64 bit intermediate	Big endian	Covers 64 bit microprocessors.

7 Pascal-P6 implementation language

Pascal-P6 accepts the language Pascaline. However, Pascal-P6 is itself written in ISO 7185 Pascal. This means that Pascal-P6 can be run on any host compiler that complies with the ISO 7185 Pascal language, but then itself implements the full Pascaline language. Thus it can be used to "bootstrap" any ISO 7185 Pascal installation into the Pascaline language.

To do this, it utilizes two basic "tricks" to get beyond the limitations in ISO 7185 Pascal. First, Pascal-P6 uses the Unix/Linux cpp preprocessor to enable things like file includes and conditional compilation. cpp is run via a script pascpp or pascpp.bat. It takes a *.pas pascal input source and creates a file by the name *.mpp.pas, or the processed output file, then it uses the ISO 7185 Pascal host compiler to compile that file.

To make cpp work on a non-C based language, the options:

cpp -P -nostdinc -traditional-cpp

Are used. This makes cpp run as close to as possible to not relying on any interpretation of the source language.

If you are going to make changes and compile the compiler, you should expect that if you get errors, you need to look in the *.mpp.pas files, not the original *.pas files. The reason is because while C compilers can compensate for the line and character location differences of error reporting in the source file, Pascal compilers (esp. Pascal-P6) cannot do that. Thus you must examine the cpp output files to make sense of the errors encountered.

7.1 Language extension routines

Although it may seem strange that a limited compiler as an ISO 7185 Pascal source compiler can compile for a language much more powerful than its source language, in fact it is not difficult and is done commonly. The biggest difference is in fundamental operating system features covered by the language. Thus, access to named files, seeking within those files, and access to the command line passed to the program are common functions that are beyond the ISO 7185 Pascal language. These are handled by so called "language extension routines". These are short routines with standard ISO 7185 call sequences that implement the extended feature. Note these are not routines you directly call from Pascaline source. Instead, see the Pascaline language manual for routines that can be called. They are:

procedure assigntext(var f: text; var fn: filnam);

Assign name to text file.

procedure assignbin(var f: bytfil; var fn: filnam);

Assign name to binary file.

procedure closetext(var f: text);

Close text file.

procedure closebin(var f: bytfil);

Close binary file.

function lengthbin(var f: bytfil): integer;

Find length binary file.

function locationbin(var f: bytfil): integer;

Find location binary file.

procedure positionbin(var f: bytfil; p: integer);

Position binary file.

procedure updatebin(var f: bytfil);

Update binary file.

procedure appendtext(var f: text);

Append text file.

procedure appendbin(var f: bytfil);

Append binary file.

function existsfile(var fn: filnam): boolean;

Find file exists by name.

procedure deletefile(var fn: filnam);

Delete file by name.

procedure changefile(var fnd, fns: filnam);

Change filename.

procedure getcommandline(var cb: cmdbuf; var l: cmdnum);

Get the shell command line.

For each different host compiler, a complete library implementing these calls in the particular host language exists. The following are the host support library files at this writing:

extend_iso7185_pascal.inc

> This file is a dummy, and simply gives an error when any of the routines are called. This allows Pascal-P6 to be compiled with a strict ISO 7185 compiler (like Pascal-P5), and still function, but without the extended capabilities.

extend_pascaline.inc

> Implements the extension routines using Pascaline extensions. This file is used when there is a native Pascaline implementation to simply self define the routines.

8 Building the Pascal-P6 system

8.1 Compiling and running Pascal-P6

You do not need to compile Pascal-P6 unless you are using an alternative compiler or installation. The current Passcal-P6 has been compiled and run with its own code generator, pgen.

However, if you are doing development work on the compiler, you can compile Pascal-P6 by simply executing:

$ make

In the main directory. This will also install the binaries in the ./bin directory.

9 pgen – AMD64 code generator

pgen is the program that takes the intermediate files, *.p6, and generates an equivalent *.s assembly file that will give you a final binary.

The naming convention for pgen is:

pgen_<c compiler>_<machine model>

Currently the C compiler is gcc. The machine model is AMD64, the 64 bit extended x86 processor model. Pgen generates assembly files that gcc can accept, and Pascal-P6 can call both C routines and Pascaline routines.

pgen, specifically pgen_gcc_amd64, is a code generator for 64 bit AMD/Intel CPUs. It is also dependent on gcc/gas (the GNU C compiler and GNU assembler for AMD64 cpus[7]). pgen is executed as:

```
$ pgen <input file> <output file> <options>
```

pgen translates Pascal-P6 intermediate files to gas assembly files, which are then assembled, along with C language support files, into target programs. An example run is:

```
$ pcom hello.pas hello.p6
$ pgen hello.p6 hello.s
$ gcc source/psystem.c source/psystem_asm.s main.s hello.s -o hello -lm
```

This sequence is given in the script file p6 , which has the form:

$ p6 <input file> [<input file>]…

or

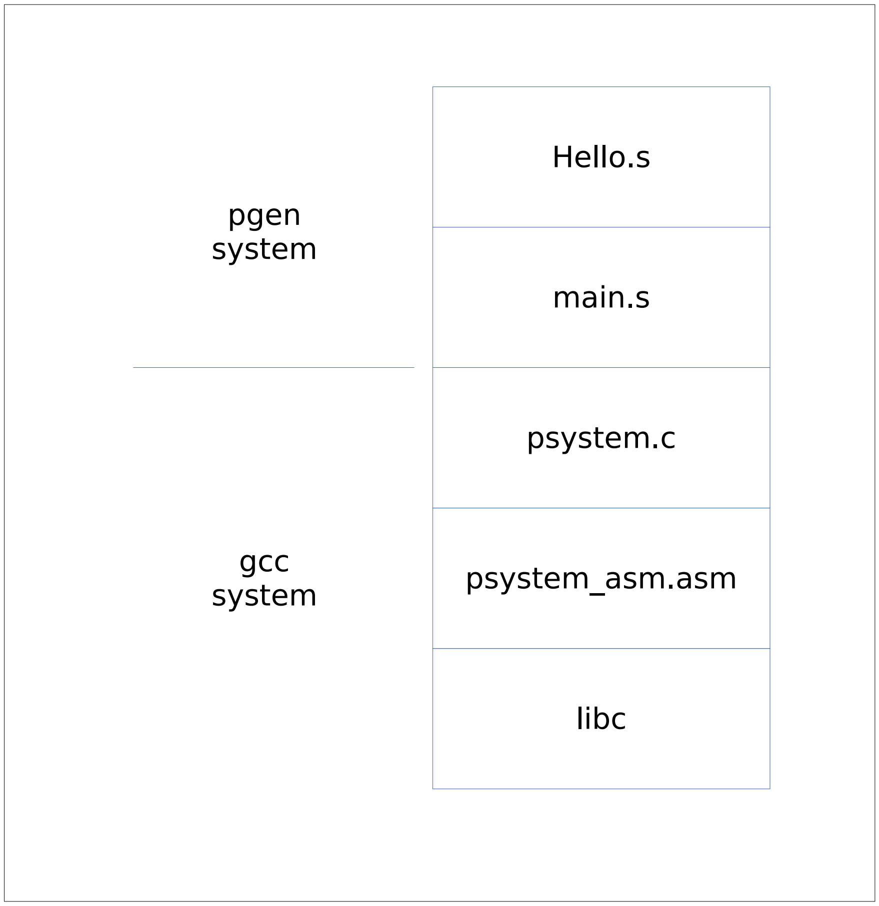
$ compile <input file> [<input file>]…

The difference is that p6 compiles and runs the file. compile simply compiles the file to a binary of the same name.

The components of a pgen deck are:

psystem.c	The C runtime support library for Pascal-P6
psystem_asm.asm	The assembly language runtime support library for Pascal-P6
main.s	The startup card for Pascal-P6, defines the location of “main”.
hello.s	The assembly code generated by pgen.
hello	The output executable file.
-lm	Links the C math library.

[7]You may also use LLVM compiler/assembler, which is compatible.



The bottom level components, psystem.c/.asm, libc, are in the gcc system of initialization, using pragmas. The top level components, main.s, and hello.s and any other pgen modules, are in the pgen system of initialization.

9.1 Calling convention

Pascal-P6 uses a modified version of the System V AMD64 ABI register based calling convention. In this convention the following register assignments are used:

Integer/pointer arguments 1-6	RDI, RSI, RDX, RCX, R8, R9
Floating point arguments 1-16	XMM0-XMM7
Return value	RAX,RDX

All parameters are also passed on the stack. The register arguments are copies of the stacked arguments. The caller is responsible for cleanup.

The Pascal-P6 calling convention is different from the System V AMD64 ABI register based calling convention in that the first parameter at top of stack is the last parameter of the procedure or function, that is, parameters on the stack are pushed from left to right, instead of the C based calling convention of parameters stacked from right to left, so that the first parameter on stack is the first parameter of the function. The reason for this is that C supports so called “variadic functions”, where the parameters can be any number. Pascal does not.

Besides floating point, integers and simple pointers, Pascal-P6 supports so called “wide pointers”, which are arrays with templates or lengths following. If passed as a parameter, such pointers take two registers in a row, such as:

```
type a = array of integer;
procedure x(y: a);
```

Would take registers:

rdi Address of array y.

rsi Length of array y.

If a wide pointer is returned from a function as a result, it would occupy the registers:

```
type a = array of integer;
     b = ^a;

function x: b;
```

rax Address of array returned.

rdx Length of array returned.

Pascal-P6 aligns the stack to 64 bits/16 bytes.

9.2 Calling C from Pascaline

When using from 1 to 6 parameters, the calling conventions of C and Pascaline are compatible. The parameters and return values will line up correctly:

Pascal

```
procedure x(a, b: integer; r: real);
```

C

void x(int a, int b, double r);

Pascal-P6 does this for any container argument. If the container array has more than one dimension, it will be passed with a template:

Pascal

Type a = array of array of integer;

Procedure x(b: a);

C

int template = { 10, 20 };

Void x(integer b[][], int t[]);

The C function will get the template as a list of integers, one per “order” or number of dimensions in the array. Thus in this example, there are two dimensions and two sizes in the template list for the multidimensional array.

9.2.1 No value parameters for structured parameters

Pascal-P6 does not pass value or copy parameters for structured parameters. In the procedure

Pascal

type a = array [1..10] of char;

Procedure x(b: a);

C

void x(char* b);

In Pascal-P6 procedures/functions, this value parameter is done by having the callee make a local copy of the parameter. Thus it is up to the C routine to perform this function.

9.2.2 Stack inversion

If the procedure or function called from Pascal to C has more than 6 parameters, the C function must get parameters past 6 off of the stack. For this, you must understand that the stack is both inverted from the usual C stack ordering, as well as the fact that ***all*** parameters appear on stack, including those found in registers. It is up to the callee to compensate for this.

9.2.3 Translation of strings

In C, string data is often zero terminated. This tends to be deprecated these days, especially in system calls, because the convention can cause overflow problems. Pascaline always uses the convention of a string address with a length following. If what is wanted is a zero terminated string, a simple translation can be used:

```
void wrapmyfunction(char s[], int l)

{

      char buffer[100];
      char* p;

      p = buffer;
      while (l--) do *p++ = *s++;
      *s = 0;

      myfunction(buffer);

}
```

9.2.4 Pointers an VAR parameters

Pascaline and C pointers are equivalent in that they both are addresses of a base type. However VAR parameters are not equivalent to pointer types as in C, nor can any object be pointed to at will as in C. Pascaline is a type secure language, and not all C methods can be used in Pascaline. This means that C interfaces have to be designed for more general use, and not use methods specific to C. Alternatively, wrappers can be used for translation.

9.3 Return values from functions

Pascal-P6 obeys the convention that scalar parameters (non-structured) are passed back in the rax register. However, Pascal-P6 always creates a "pad" before the call to the function that contains the return value. When calling C routines, this is of course ignored. However, it must be removed from the stack after a call to a C function.

9.3.1 Module name coining

Pascal-P6 uses what is called (in Pascal-P6 terminology) "coining" to produce module names. Each name in an external module has it's filename prepended along with a '_' character:

mymodule with symbol myfunction

becomes

mymodule_myfunction

Thus to link external modules you must either create global functions with the filename coined as shown, or create a wrapper module that translates the names to that of the existing functions in C. Such a wrapper can also be used for translations as required, for example conversion to and from C "zero terminated" strings.

If the (fairly small) overhead of C function entry and exit sequences is not desired, it is possible to create an assembly file that just creates name aliases for functions that don't need wrappers.

9.4 Calling Pascaline from C

Calling from C to Pascaline works, but only to top level routines in Pascal. You must obey the module coining convention as above. If a routine that is nested is called from C, the result is a crash. In general, callbacks are a C convention that is better avoided in nested procedure/function languages such as Pascal.

9.5 Pascal-P6 module stacking sequence

Pascal-P6 uses a different method of module startup and shutdown than C. First of all, a series of Pascaline modules are entered at the bottom or starting address:

main mod1 mod2 program

Since the program is started at the bottom and not the "main" function as in C, a "shim" is provided as main.s, which specifies the starting location of the program. Each module in Pascaline starts by performing its initialization, then calling the next module above it. So in the example mod1 calls mod2 and finally mod2 calls program. The program module executes the program function, and when it terminates, it returns to mod2, which executes its finalization block, then returns to mod1, etc. Thus:

1. All "startup" blocks are executed in series before the program starts.

2. All “finalization” blocks are executed in reverse series after the program ends.

The modules should always be stacked in dependence order. That is, if mod2 uses mod1, it must appear in the sequence ***after*** mod1. Since the program uses both mod1 and mod2, it must appear after them both. This means that a module or program that uses another module, must not access the data for that module unless that module has had a chance to initialize itself.

Non-Pascal-P6 modules ***must not*** be inserted in the Pascal-P6 module chain. This will cause a crash, since Pascal-P6 modules will attempt to execute the non-Pascal-P6 module in the chain. The place for non-Pascal-P6 modules is before or after the entire Pascal-P6 module chain.

9.6 Writing wrappers for C external calls

Considering all of the factors in calling C discussed above, a sample call will illustrate what is needed to create a wrapper for calls to C. In this example, the Linux function getpid() is used, which returns an integer representing the process identifier for the current program. The external module is declared in Pascaline as:

```
module external_c_call;

function getpid: integer; external;

begin
end.
```

This module is then the target of a **uses** or **joins** statement in a Pascaline program. This satisfies the definition of the function. The actual contents of the external module can then be created by an assembly file:

```
        .text

        jmp     1f          # skip stack sequence

        .globl   test1.getpid$f
        .type    test1.getpid$f@function

test1.getpid$f:
        call    getpid
        pop     %rcx        # get return address
        pop     %rbx        # remove dummy function result
        jmp     *%rcx       # go return
1:
```

The .s or .asm[8] file for this is then substituted in the final link phase for the .s from the Pascaline compile.

There are several features of this file that should be explained:

1. The assembly file starts with a jump over the body of the code. This satisfies the module stacking requirement.

[8]The .asm extension is used to make sure that the file is not overwritten or erased by cleanup processes.

2. The Pascaline symbol for the function is test1.getpid$f, which is coined by the module name, test1, and has a type function, $f. The C name for the function is getpid. Symbol types are discussed in 11.2.11 “Symbols”.

3. The return value allocation on the stack that is done by Pascal-P6 is removed by first saving the return address, then removing the dummy return variable, then jumping to the return address.

9.7 Debugging Pascaline assembly code

Using gdb or gdbtui (the assembly language version of gdb) you can easily debug Pascal-P6 assembly language files. First of all, all of the lines of the Pascal-P6 source code and the intermediate code is included into the assembly .s source files as comments of the form:

comment

pgen also places running commentary for both the intermediate code and the generated assembly code in the file. The intermediate code contains line markers of the form:

:<line number>

That show where the original source lines were parsed during intermediate generation.

The assembly generated symbols in the file are of the form:

<module>.<routine>.<variable>

The module name is the same as the file name in most cases. The routine name(s) can be nested to any level, and then this is followed by the variable name. Pascal-P6 does not need label names to do its work. Instead, labels are generated as “compiler labels”, which are a series of numbered labels in the file of the form:

<module>.<number>

The only case where the compiler must use named labels is to link to other modules.

Where possible, pgen replaces the compiler numeric labels with the original symbolic labels of the program.

9.8 Overloads

pgen accounts for overloaded routines. Each overload is counted in the order of encounter, and also by type. The type is output with “type spagetti” of the form:

<routine name>$f_i

In this case it is a function (“f”) with a single integer argument (“I”). This is covered in 11.2.11 “Symbols”. The enumerated routines appear as:

<routine name>$1

<routine name>$2

…

The instance #1 of the outine is also output in shorthand as the “prime” instance of the overload, so just:

<routine name>

Can be used to refer to the routine.

A debug example

For the Pascal source:

```
program test(output);

begin

    writeln('Hello, world')

end.
```

An abbreviated .s file for this is:

```
#       0:       1:  !
#       0:       2:  ! Pascal intermediate file Generated by P6 Pascal compiler vs. 0.2
#       0:       3:  !
#       0:       4:  o prtlab
#       0:       5:  ! program test(output);
#       1:       6:  :1
#       1:       7:  !
#       1:       8:  ! Program test
#       1:       9:  !
        .globl  main
        .type   main, @function
main:
# Align stack
        pushq   %rax
# Set up default files
        movb    $inputfn,globals_start+inputoff(%rip)
        movb    $outputfn,globals_start+outputoff(%rip)
        movb    $prdfn,globals_start+prdoff(%rip)
        movb    $prrfn,globals_start+prroff(%rip)
        movb    $errorfn,globals_start+erroroff(%rip)
        movb    $listfn,globals_start+listoff(%rip)
        movb    $commandfn,globals_start+commandoff(%rip)
        call    1f
        popq    %rax
        sub     %rax,%rax
        ret
1:
#       1:      10:  b p test
test:
#       1:      11: 245: sfr     l test.6                ! Set function result
#       1:      12:  l test.6=0
test.6 = 0
#       1:      13:  12: cup     l test.3 0              ! Call user procedure
# assigning:        1:      13:  12: cup  0 rs: [] ~rf: []
# assigning~:       1:      13:  12: cup  0 rs: [] ~rf: []
#     expr:
#       1:      13:  12: cup  0 rs: []
#   call start:
#       1:      11: 245: sfr  0 rs: []
# generating:       1:      13:  12: cup  0 rs: []
# generating:       1:      11: 245: sfr  0 rs: []
        subq    $test.6,%rsp            # allocate function result on stack
# generating~:      1:      11: 245: sfr  0 rs: []
        call    test.3                  # call user procedure
# generating~:      1:      13:  12: cup  0 rs: []
#       1:      14:  22: ret                             ! Return code strip
        ret
```

```
#      1:     15:  !
#      1:     16:  ! begin
#      1:     17:  !
#      1:     18:  l test.3
test.3:
#      2:     19:  :2
#      3:     20:  :3
#      3:     21:  :3
#      3:     22:  11: mst     0 l test.7 l test.8     ! Mark(frame) stack
# generating:  11: mst
        pushq   $0                      # place current ep
        pushq   $0                      # place bottom of stack
        pushq   $0                      # place previous ep
        enterq  $0,$1                   # enter frame
        movq    %rsp,%rax               # copy sp
        subq    $test.7+test$_tmpspc,%rax # find sp-locals
1:
        cmpq    %rax,%rsp               # check have reached stack
        je      2f                      # skip if so
        pushq   $0                      # push 0 word for locals
        jmp     1b                      # loop
2:
        movq    %rsp,16(%rbp)           # set bottom of stack
        andq    $0xfffffffffffffff0,%rsp # align stack
        pushq   %rbx                    # save protected registers and keep aligned
        pushq   %r12
        pushq   %r13
        pushq   %r14
        pushq   %r15
        pushq   %r15                    # second push aligns
#      3:     23:  !     writeln('Hello, world')
#      4:     24:  :4
#      5:     25:  :5
#      5:     27:  !
#      5:     28:  56: lca     12 "Hello, world"       ! Load constant string address
#      5:     29:   5: lao     2                       ! Load global address
#      5:     30: 118: swp     8                       ! Swap tos with sos
#      5:     31: 123: ldci    12                      ! Load constant(t)
#      5:     32: 118: swp     8                       ! Swap tos with sos
#      5:     33: 123: ldci    12                      ! Load constant(t)
#      5:     34:  15: csp     wrs                     ! Call system procedure/function: Write
string to text file
# assigning:       5:     34:  15: csp  6: wrs  rs: [] ~rf: []
# assigning:       5:     29:   5: lao  2 dr1: rdi rs: [] ~rf: [rdi]
# assigning~:      5:     29:   5: lao  2 r1: rdi rs: [] ~rf: [rdi]
# assigning:       5:     31: 123: ldci 12 dr1: rsi rs: [] ~rf: [rsi, rdi]
# assigning~:      5:     31: 123: ldci 12 r1: rsi rs: [] ~rf: [rsi, rdi]
# assigning:       5:     28:  56: lca  0 dr1: rdx rs: [] ~rf: [rdx, rsi, rdi]
# assigning~:      5:     28:  56: lca  0 r1: rdx rs: [] ~rf: [rdx, rsi, rdi]
# assigning:       5:     33: 123: ldci 12 dr1: rcx rs: [] ~rf: [rcx, rdx, rsi, rdi]
# assigning~:      5:     33: 123: ldci 12 r1: rcx rs: [] ~rf: [rcx, rdx, rsi, rdi]
# assigning~:      5:     34:  15: csp  6: wrs  rs: [] ~rf: [rcx, rdx, rsi, rdi]
#    expr:
#       5:     34:  15: csp  6: wrs  rs: []
#   Parameter:
#       5:     29:   5: lao  2 r1: rdi rs: []
#   Parameter:
#       5:     31: 123: ldci 12 r1: rsi rs: []
#   Parameter:
#       5:     28:  56: lca  0 r1: rdx rs: []
#   Parameter:
#       5:     33: 123: ldci 12 r1: rcx rs: []
# generating:       5:     34:  15: csp  6: wrs  rs: []
# generating:       5:     29:   5: lao  2 r1: rdi rs: []
        leaq    globals_start+2(%rip),%rdi # load address of global
# generating~:      5:     29:   5: lao  2 r1: rdi rs: []
# generating:       5:     31: 123: ldci 12 r1: rsi rs: []
        movq    $12,%rsi                # load quad constant
# generating~:      5:     31: 123: ldci 12 r1: rsi rs: []
# generating:       5:     28:  56: lca  0 r1: rdx rs: []
        leaq    string1(%rip),%rdx      # load string constant address
```

```
# generating~:      5:     28:  56: lca  0 r1: rdx rs: []
# generating:       5:     33: 123: ldci 12 r1: rcx rs: []
        movq    $12,%rcx                # load quad constant
# generating~:      5:     33: 123: ldci 12 r1: rcx rs: []
        call    psystem_wrs             # call system procedure/function
# generating~:      5:     34:  15: csp  6: wrs  rs: []
#      5:     35:  ! end.
#      5:     36:  15: csp     wln                     ! Call system procedure/function: Write
next line to text file
# assigning:       5:     36:  15: csp  5: wln  rs: [] ~rf: []
# assigning:       5:     29:   5: lao  2 dr1: rdi rs: [] ~rf: [rdi]
# assigning~:      5:     29:   5: lao  2 r1: rdi rs: [] ~rf: [rdi]
# assigning~:      5:     36:  15: csp  5: wln  rs: [] ~rf: [rdi]
#    expr:
#       5:     36:  15: csp  5: wln  rs: []
#  Parameter:
#       5:     29:   5: lao  2 r1: rdi rs: []
# generating:       5:     36:  15: csp  5: wln  rs: []
# generating:       5:     29:   5: lao  2 r1: rdi rs: []
        leaq    globals_start+2(%rip),%rdi # load address of global
# generating~:      5:     29:   5: lao  2 r1: rdi rs: []
        call    psystem_wln             # call system procedure/function
# generating~:      5:     36:  15: csp  5: wln  rs: []
#      5:     37: 117: dmp     8                       ! Dump tos
#      6:     38:  :6
#      7:     39:  :7
#      7:     40:  !
#      7:     41:  14: retp    0                       ! Return from procedure/function(t)
# generating:  14: retp
        popq    %r15                    # undo alignment push
        popq    %r15                    # restore protected registers
        popq    %r14
        popq    %r13
        popq    %r12
        popq    %rbx
        leave                           # undo frame
        addq    $24,%rsp                # remove frame data
        popq    %rax                    # get return address
        addq    $0,%rsp                 # remove caller parameters
        pushq   %rax                    # replace return address
        ret                             # return to caller
```

Executing debug on this file:

$ gdbtui ./test

(gdb) b main

Breakpoint 1 at 0x7cfe: file test.s, line 188.

(gdb) r

Starting program: /home/samiam/projects/pascal/pascal-p6/test

Breakpoint 1, main () at test.s:188

(gdb)

```
│   186         main:
│
│   187         # Align stack
B+>188                 pushq   %rax
│
│   189         # Set up default files
│
```

```
190                 movb    $inputfn,globals_start+inputoff(%rip)
191                 movb    $outputfn,globals_start+outputoff(%rip)
192                 movb    $prdfn,globals_start+prdoff(%rip)
193                 movb    $prrfn,globals_start+prroff(%rip)
194                 movb    $errorfn,globals_start+erroroff(%rip)
195                 movb    $listfn,globals_start+listoff(%rip)
196                 movb    $commandfn,globals_start+commandoff(%rip)
197                 call    1f
198                 popq    %rax
199                 sub     %rax,%rax
200                 ret
201         1:
202         #      1:     10:  b p test
203         test:
204         #      1:     11: 245: sfr     l test.6               ! Set function result
205         #      1:     12:  l test.6=0
206         test.6 = 0
207         #      1:     13:  12: cup     l test.3 0             ! Call user procedure
```

Here we broke out of the code at main, the start of the program. The line numbers on the left for the .s file can be used as breakpoints as well:

(gdb) b 285

Breakpoint 2 at 0x555555555bd73: file test.s, line 285.

(gdb) c

Continuing.

```
Breakpoint 2, test () at test.s:285
   283         # generating:       5:     34:  15: csp  6: wrs  rs: []
   284         # generating:       5:     29:   5: lao  2 r1: rdi rs: []
B+>285                 leaq    globals_start+2(%rip),%rdi # load address of global
   286         # generating~:      5:     29:   5: lao  2 r1: rdi rs: []
   287         # generating:       5:     31: 123: ldci 12 r1: rsi rs: []
   288                 movq    $12,%rsi                # load quad constant
```

To find a source line in the assembly code, search for a source line marker in the .s file such as “:100”, then you can find where to breakpoint by the .s line number.

10 Files in the Pascal-P6 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.

Note that the top level files are structured according to standard methods for GNU projects, with configure, Makefile, INSTALL, LICENSE, NEWS, README and TODO files.

configure.bat configure	Sets the current compiler to use to create Pascal-P6 binaries.
INSTALL	Contains instructions for installation of Pascal-P6.
LICENSE	The software distribution license for Pascal-P6.
Makefile	This is the central makefile for the system, and contains all the instructions needed to build system components. Note that this file is copied from one of the individual host directories.
NEWS	Contains any news concerning the current release.
README	The starting reference for Pascal-P6 documentation. Note that this file is what the repositories (github and sourceforge) will display.
regress_report.txt	The output of the regression report. This is updated, usually with each push to the repo.
setpath setpath.bat	Script files that add ./bin to the current path of execution.
TODO	Remaining project bugs and goals to be completed.

10.1 Directory: basic

Contains the basic interpreter in Pascal.

basic.pas	Contains the interpreter source.

10.1.1 Directory: prog

Contains various basic programs, games, etc, used to test the basic interpreter.

10.2 Directory: bin

Contains binary executables and script files.

chkfiles chkfiles.bat	Runs an md5sum on all relievant components of the Pascal-P6 test and binaries. This is used to check those files match in version.
cmach cmach64le	The cmach or C interpreter binary.

compile compile.bat	Batch mode compile for Pascal-P6. 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).
diffnolestrip	As diffnole, but also ignores common Pascal-P6 decorations.
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.
flip flip.exe	Changes line ending to match either Unix or Windows.
genobj	Generates a C constant array with the contents of a *.p6o file. Used to create package mode apps.
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.
p6 p6.bat	A batch file that compiles and runs a single Pascal program and its modules. It uses input and output from the terminal, so is a good way to run arbitrary programs.
pascpp	

pascpp.bat	Runs cpp, the C preprocessor, over Pascal programs and expands macros, performs includes, etc.
pcom pcom16 pcom32 pcom64 pcom.exe	The IP Pascal compiled pcom binary for Windows/Unix. See comments in 3.3 “Compiling and running Pascal programs with Pascal-P” for how to use this. All of the supplied batch files are customized for this version. The different endings signify the word length it was compiled for. Pcom without an ending matches the host architecture.
pgen pgen_gcc_AMD64	The machine code generator. Pgen is the same file, with defaults for the current host.
pint pint16be pint16le pint32be pint32le pint64be pint64le pint.exe	The Pascaline intermediate interpreter. The different endings are for different endian modes and word lengths (not all may exist). Pint without an ending is pint for the current host endian and word width.
regress regress.bat	Runs all of the tests for Pascal-P6.
run run.bat	Batch mode run for Pascal-P6. It takes all input and output from supplied files, and is used by all of the other testing scripts. It uses input and output from the terminal, so is a good way to run arbitrary programs.
setok	Sets a given test number as passing in the PRT test.
strip	Strips decorations from Pascal listing files. Used to clean up run comparisons.
strips	Strips “#” comments from *.s files (assembly files).
testdebug	Runs the debug mode test.
testiso7185pat	Runs the ISO 7185 acceptance test.
testiso7185prt	Runs the ISO 7185 rejectance test.
testp2 testp2.bat	Runs the Pascal-P2 test (Pascal-P2 on Pascal-P6).
testp4 testp4.bat	Runs the Pascal-P4 test (Pascal-P4 on Pascal-P6).

testp5 testp5.bat	Runs the Pascal-P5 test (Pascal-P5 on Pascal-P6).
testp6 testp6.bat	Runs the Pascal-P6 test (Pascal-P6 on Pascal-P6).
testpascaline	Runs the Pascaline test.
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 Pascal-P6: hello, roman, match, startrek, basics and iso7185pat.
unixeol unixeol.bat	Fixes the line endings on text files to match the Unix convention, LF.

10.3 Directory: build

This directory is used to store the build products of compiles, the objects, binaries, etc. The structure of it reflects the source directory.

10.4 Directory: doc

Pascaline_cover.docx	The cover for "the Pascaline computer language" book.
The_Pascal-P6_Compiler_cover.pdf	The cover for "The Pascal-P6 compiler" book.
basic.pdf	A document describing the language for the basic language on Pascal-P6.
Iso7185.html	The ISO 7185 standard for Pascal.
iso7185rules.html	A description of the ISO 7185 Pascal language.
Pascaline.pdf	Contents of "the Pascaline computer language" book.
the_P6_compiler.pdf	This document in word 2007 form.

10.5 Libs

strings.pas	The string library source.

10.6 pascaline Tests

Contains the test suite for Pascaline extensions, libraries, and debug mode.

debug_test	Binary for debug test.
debug_test[1].pas	

debug_test.cmp debug_test.inp	Contains tests for debug mode. See “Testing Pascal-P6”.
headertest1 headertest2	Test files used by the Pascaline test.
pascaline	Binary for Pascaline test.
pascaline1.pas pascaline2.pas pascaline.pas pascaline.cmp pascaline.inp	Program and test files for the Pascaline test.
readtest.txt	Input test file for Pascaline test.
services.pas	Header file for services.
services_test.pas services_test1.pas services_test.cmp services_test.inp	Test file for services library.

10.6.1 Directory: test_results

Contains the results of different run conditions. Each of cmach, package, pgen, pint and pmach have a directory here. See the chapter “Testing Pascal-P6”.

10.7 Directory: Petit_ami

This directory is a submodule for Petit-Ami. The contents are described in the Petit-Ami documents.

10.8 Directory: sample_programs

The sample programs directory is used for sample test programs. Each program will have all of a *.pas source file, a *.inp file, a *.cmp file, and a *.dat file. The description of these files can be found in the section on “Testing Pascal-P6”.

basics.pas	A tiny basic interpreter in Pascal.
drystone.pas	A benchmark program.
fbench.pas	A floating point benchmark program.
hello.pas	One of several test programs used to prove the Pascal-P6 system. This is the standard "hello, world" program.
match.bas	The basic version of the match game.
match.pas	A game, place "match" a number game.
pascals.pas	Niklaus Wirth’s Pascal-s subset interpreter.

roman.pas	A slightly more complex test program, prints roman numerals. From Niklaus Wirth's "User Manual and Report".
startrek.pas	The startrek game.

10.8.1 Directory: test_results

Contains the results of different run conditions. Each of cmach, package, pgen, pint and pmach have a directory here. See the chapter “Testing Pascal-P6”.

10.9 Directory: source

extend_iso7185_pascal.inc	
	Contains extensions for Pascaline functions used by pcom and pint. This file satisfies then with no-ops, since ISO 7185 has no extensions.
extend_pascaline.inc	contains extensions for Pascaline functions used by pcom and pint. This file connects them to Pascaline native functions.
externals_iso7185_pascal.inc	
	Contains linkages to external library routines for pint. This file satisfies them with no-ops, since ISO 7185 has no external mechanisim.
externals_pascaline.inc	Contains linkages to external library routines for pint. This uses the Pascaline language to satisfy externals.
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.
genobj.pas	Source for genobj, which generates a C constant array with the contents of a *.p6o file. Used to create package mode apps.
mpb16.inc mpb32.inc mpb64.inc	Machine parameter blocks for each model of CPU, 16, 32, and 64 bit words.
pcom.pas	The compiler source in Pascal.
pint.pas	The interpreter source in Pascal.
pmach.pas	Contains the stand-alone P-machine interpreter.
spew.c	Contains the spew test.
version.inc	Contains the version numbers for pcom, pint, pmach and pgen.

10.9.1 Directory: AMD64

Contains code specifically for the AMD64 processor model, currently used by Intel and AMD. This codebase is further categorized by compiler, of which gcc is currently the only one.

10.9.1.1 Directory: gcc

Contains code for the gcc/gas compiler/assembler combination.

pgen.pas	Generates assembly code from intermediate files.
psystem_asm.asm	The support library for pgen generated files, the assembly language section.
psystem.c	The support library for pgen generated files, the C source language section.

10.9.2 Directory: cmach

Contains the cmach interpreter system.

cmach.c The C source version of pmach, used to interpret machine decks made from intermediates.

externals.inc Contains external library linkages for cmach.

Mpb16.inc
mpb32.inc
mpb64.inc Machine parameter blocks for cmach. Contains each of the machine models for 16 bit, 32 bit, and 64 bit word lengths.

10.10 Directory: standard_tests

iso7185pat.cmp	Contains the output from the PAT file with the IP Pascal compiled Pascal-P6 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-P6 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.

11 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.

The intermediate is input by both the interpreter, pint, and the compiler, pgen_x_x. If the source program consists of more than one module (program or module), then the intermediate code from each module run is concatenated in definition order. That is, each module that uses definitions from another module must follow that module in the concatenated desk. Then the resulting combined deck is input to pint. pint will handle linking the modules together.The deck must end with a “program” module.

Modules in Pascal-P6 “stack”, meaning that the first module initializes itself and calls the next one after it. This continues until the program module is executed, then control flow goes backwards down the stack again executing finalization sections until the first module is reached.

If the compiler pgen_x_x is used, only one module at a time is input. Linking modules together is done after the output of the compiler is given as input to the linker. The module “stacking” mechanisim of pint is simulated by using the constructor and destructor attributes of gcc. See the section on pgen for more information.

11.1 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.

11.2 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.
b	b <type>	Block start.
e	e <type>	Block end.
s	s <name> <offset> <digest>	Symbol.
t	<label> <number of dimentions> <dimension1> [<dimentionn>]…	Fixed array template.
n	<label> <length>	Constant table begin.
c	<type> <value>	Constant table entry.
x		Constant table end.

11.2.1 Comments

A comment appears as:

    !<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.

11.2.2 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.

11.2.3 End of section

Marks the end of a startup or main code section:

q

11.2.4 Intermediate code

Intermediate code lines are introduced by a blank character in the first collumn.

11.2.5 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.

11.2.6 Options

Options appear as:

o a+b-c+…z+

Options are a series of pairs of single characters and either '+' or '-'. The possible options are listed in Compiler options 3.5.

11.2.7 Global space count

The global space contains the total space in globals used by the current block. It is used to merge multiple, separately compiled program blocks for simulation. It is not used in compilation. It is of the form:

g n

Where n is the total size of globals in the current block.

11.2.8 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.

11.2.9 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.

11.2.10 Block start and end

The block start and end marker show where program, module, procedure and function sections begin and end. They are of the form:

b t <name>

e t

A block begin contains the type of block, and the name of the block. The type of block is:

p Program block.

m Module block.

r Procedure.

f Function.

Blocks can be nested to any level, but program and module blocks do not nest in other blocks.

11.2.11 Symbols

Symbols carry the names of source constants, variables, procedures, etc. They are of the form:

s <name> <storage> <offset> <type digest>

The name is the source name. The storage type is one of:

g Global.

p Parameter.

l Local.

The offset is the offset address of the symbol, ie, the start of globals, parameters or locals. The type digest carries the type of the symbol and is used in the debugger. This is referred to in Pascal-P6 as “type spagetti”, and is a recursive description of the symbol’s type. The base types are denoted by the sequences:

i	Integer
b	boolean
c	Char
n	Real
x(id[,id]…)	Enumerated type.
x(min,max)<type>	Subrange

Enumerated types are types like (one, two, three), and each id appears. So an example is:

For the type:

(one, two, three)

The digest form is:

x(one,two,three)

Subrange is similar:

For the type:

1..10

The digest form is:

x(1,10)i

Note that it is terminated by it’s base type. Note also that pint/pgen can tell if an enumerated type is meant or a subrange because its either a label or a number. In a digest nothing is symbolic. If the source was:

const one = 1;

const two = 2;

And the declaration was:

one..two

The digest would be:

x(1,2)i

This applies to characters as well. If the source was:

set of '0'..'9'

The digest of the set’s base type would be:

x(48,57)c

In other words, a subrange starting with the ASCII code for ‘0’ (in decimal), and ending with the ASCII code for ‘9’, and the subrange base type is char.

The type digest is terminated by one of the above sequences, ie., these are the ultimate base types. The structured types then form collections of those types:

p <typ>	Pointer
s <typ>	Set
a <inx> <base>	Array
v <base>	Variable length array
r (<fld>[,<fld>])	Record
f <typ>	File
e	Exception

Each of the indicator characters is unique. For example reads are denoted by ‘n’ because ‘r’ is a record and ‘f’ is a file. Each of the structured type indicators is followed by its base type or more complex descriptions of it’s substructure. For example:

fi

is “file of integer” with no space. Similarly:

sx(1,9)i

Means:

set of 1..9

Arrays have both an index type and a base type. For example:

array [1..10] of integer

Appears in digest form:

ax(1,10)i

Variable arrays have no index type, since it is always integer.

Records are the most complex types of digests. ‘r’ is followed by a list of record fields in paranthesis. Each field is of the form:

<name>:<offset>:<type>

The name is the field name. The offset is the net offset from the start of the record in bytes. The type is the field type. Thus:

record a: integer; b: char end

Would be in digest form:

r(a:0:i,b:8:c)

If a variant appears in the record, it has the special notation:

<tag name>:<offset>:type(<tag constant>(<field>)[<tag constant>(<field>)]…

So the record:

```
r: record a: integer; b: char
  case c: boolean of
     true: (d: real);
     false: (e: boolean);
  end;
```

In digest form:

r(a:0:i,b:8:c,c:9:b(0(e:12:b)1(d:12:n)))

In short, type digests can get pretty complex. They are not meant for humans to read.

11.2.12 Template tables

Templates are sent to pint/pgen by a line of the form:

t <label> <number of dimentions> <dimension1> [<dimentionn>]…

The label is the address of the template. Following that is the number of dimensions in the table, then all of the dimentions in the table.

See the section 11.3 “Templates” for the format of templates.

11.2.13 Constant tables

Constant tables are a means for fixed types to be represented in the intermediate. Any number of tables can appear in the intermediate. Each table has a start and end marker, and any number of constant entries can appear within the table.

The format of a start marker is:

n <label> <length>

The label gives the address the constant is placed at. The length gives the total size, in bytes, of the constant data.

The constants are introduced by:

c <type> <value>

One line appears for each constant. The type of the constants are:

i	Integer
r	Real
p	Set (powerset)
s	String
c	Char
b	Boolean
x	Byte

For all except string, the value is a simple integer constant. Strings appear in single quotes, like ‘sandy’. Fixed constants can be structured, but that is not marked in the intermediate. The constant table is just a collection of values.

The constant section is terminated by a line:

x

An example of a fixed type and the constant table it generates is:

```
fixed a: record a: integer; b: char end = record 1, 'c' end;
```

n l test.12 9

c i 1

c c 99

x

Here the constant table length is 9, for an 8 byte integer and a 1 byte character. This is followed by the two values, and the end marker.

11.3 Templates

Pascal-P6 implements variable length arrays with so called “step” templates. There are several intermediate instructions dealing with step templates. The basis of a step template is a “tagged pointer” of the form:

<base pointer><length or template pointer>

The base pointer is type address. The length is type integer. The template pointer is type address. If the array that the pointer indexes is a single dimension or vector, the tag is a length. If the index is 2 or more, then the tag is a pointer to a template table. The template table is a list of array dimensions in major to minor order. So the template for a complex array is:

array 10, 20, 5 of …

10

20

5

What makes the system “step” templates is that they advance as array slices are taken. Thus:

a: array 10, 20, 5 of ...;

a[6]

Yields a tagged pointer:

<base address of a>

<pointer to template at 20>

As an array reference is advanced from major to minor index, it goes through the template table, thus 10, 20 and 5. When it gets to 5, it performs what is called “stepping off”. Because the template is at its end, it picks up the final dimension from the template, and the tagged pointer becomes:

<base address of a>

5

All single dimension arrays are what are called “simple” variable arrays, that is, their references consist of a base pointer/length pair. Complex arrays that use templates are converted to simple arrays if the slice taken yeilds a single dimension array.

All variable dimension arrays are dynamically allocated, although pint/pgen often hides that fact by using stack allocation, which is automatically freed when the routine exits. They can also be returned from functions on the stack.

The location of the template also changes with the type of allocation. For a dynamically allocated array, the template appears at the start of the dynamic allocation, and the array data appears after that. For stack allocated containers, the address of the variable appears before the template, followed by the template. The data for the array is either allocated dynamically for global arrays, or on stack for procedure/function arrays.

11.4 Variant record tables

Pascal-P6 can verify that variant records allocated dynamically obey rules such as not accessing inactive variants, not accessing variants that have references, etc. To do this Pascal-P6 must know what tags were used to allocate a variant record. This table must be created at runtime when the variant record is allocated.

In Pascal-P6 this is done by allocating the table alongside the record data itself. When the record is allocated, space is added for the table and the record itself is placed ***after*** the table. The base address of the record is returned to the client program of the record address only. pint/pgen finds the table by looking in “negative space” below the variant record. Since the runtime does not know the size of the table, the length of the table is stored above the table, and pint/pgen can simply look one machine word below the variant record to determine both the size of the table as well as how to find the start of the table.

The format of the tag list is

```
record address ->
                           Number of tags
                           Tag N
                           …
                           Tag 3
                           Tag 2
                           Tag 1
```

Note: pint adds a bias of the size of an address+1 to the number of tags. This is done to make sure that an allocation that is accessed after it has been freed is not mistaken for a tag count. See the workings of pint for more information.

11.5 Undefined accesses

Pascal-P6 can optionally keep track of accesses to undefined variables. This requires a database that is 1/8 the size of memory, one bit for each byte in memory. For this to work, the database must cover all of global variables, stack and heap.

For the most part, this option is transparent to both the program and to P-machine instructions. However, there are a few instructions that directly manipulate this database. These handle cases such as returning record variants that are no longer active to undefined status, marking the index variable of a “for” loop as undefined after the for loop has ended, etc.

11.6 Code strips

When Pascal-P6 compiles parameterized variable declarations, there is a catch 22. It must generate code for simple expressions, but it does not have the information it needs to start the procedure or function the declaration is a part of. The compiler handles this by generating “code strips”, or small sections of code to process the declaration expression(s). Then these are called by the procedure or function startup code, using a simple form of call and return that does no framing, and has no parameters or return value. Code strips are called and returned from by special instructions.

11.7 Exception frames

Exception frames are a series of linked frames placed on the stack that set up a chain of exception handlers. They are machine dependent, but pint uses the format (in stack top to bottom order):

vector	The current exception variable as thrown.
expmrk	The mark address of the exception handler.
expstk	The stack address of the exception handler.
expadr	The address of the current/topmost exception handler.

What the exception frame does is give sufficient information to recover from an error, reset the stack and mark, then execute the exception handler. The exception handler matches a series of exception variables to the onstack exception address, including a “wild card” or any exception handler, then if not found, climbs the chain of exception handlers until one is found.

11.8 Operator overload calling frames

When Pascal-P6 performs an operator overload, it does not know until the expression is parsed what type of call is going to be performed, built in or overload. Thus at the time of the overload, it has not set up a calling frame for the overload. It gets around this by setting up a calling frame using the mst instruction, then uses the cpp instruction to “hoist” or copy each of the parameters to the overload function from their place over the mark down to the bottom of the stack. After the call is made, the result is placed back above the frame by a cpr instruction.

11.9 Calling frame format

The calling frame format is the information the P-machine uses to keep track of the locals in the current procedure or function, how to find the locals of the procedures or functions it may be nested in, where the function result is kept, and other information.

The stack frame is “thrown”, or placed on the stack at the start of the procedure or function called by the mst (mark stack) instruction. After the routine starts, it appears as:

```
      +------------------------+
      | Dummy function result  | This varies in size by the size of the function
      |                        | result, but is aligned to stack.
      +------------------------+
      | Parameters             | Each parameter is evaluated and left on stack in
      |                        | turn.
      +------------------------+
      | Return address         | The return address is pushed to stack.
      +------------------------+
      | Mark                   | Mark bookkeeping information
      |                        |
      +------------------------+
      | Saved MP               | The caller MP is saved.
MP->  +------------------------+
      | Display                | Level number of MPs are copied.
      |                        |
      +------------------------+
      | Locals                 | Local variables
      |                        |
SP->  +------------------------+
```

Each of these fields will be described in turn.

11.9.1 Dummy function result

This is created on stack with dummy data (usually 0) with the size of the function result aligned to the stack. When the function result is assigned, it will be overwritten. On a procedure, the size allocated for the function result is 0.

11.9.2 Parameters

Space for each of the parameters of the routine, in left to right order. Each parameter is stack aligned. If the routine has no parameters, the space allocated is 0.

11.9.3 Return address

The address to return to after the routine completes.

11.9.4 Saved MP

The caller's MP is saved. This will also appear in the display, but this a fixed and easily restored version of of it.

11.9.5 Mark

Contains bookkeeping information for the P-Machine. This is of the format:

- Maximum frame size (ep)
- Stack bottom
- Current ep

For these fields, it helps to reference "Pascal implementation, the P4 system" by S. Pemberton and M.C.Daniels.

11.9.5.1 Maximum frame size (ep)

The ep pointer indicates the maximum extent of the stack, as determined by compile time, and is used to determine if the stack (which grows downward) has overlapped the heap, which grows up, as determined by the np pointer. It is saved into the mark during and mst instruction, and restored during a retx instruction (where x is the type of return).

11.9.5.2 Stack bottom

The stack bottom holds a copy of the sp (stack pointer) after a new frame is thrown onto the stack. The purpose of it is to set the location of the stack on an ipj or interprocedural jump instruction. Recall that gotos between procedures are limited to jump to the outer level of the target procedure/function, so that is where the sp points to after the goto.

11.9.5.3 Current ep (et)

The current ep field contains the ep of the currently running procedure/function (as opposed to the saved callers ep). It is used to restore the ep after either an interprocedure jump or ipj instruction, and also when an exception frame is restored from the stack (see 11.7 “Exception frames”).

11.9.6 Display

The display contains a frame or mp pointer for each level of procedure or function that is currently active. This starts with the program (or other module type) block, and proceeds with each nested procedure or function. In the program:

program test;

procedure a;

procedure b;

begin

end;

begin { a }

end;

begin { test }

end.

The program is level 1, procedure a is level 2, and procedure b is level 3. Thus when the program block is activated, there is 1 display pointer. When procedure a is activated, there are 2 display pointers, and when procedure b is activated, there are 3 display pointers. Because each mst (start of frame) instruction copies down the display pointers from the procedure or function that called it, the display represents the actual dynamic set of framing pointers for the nested procedures or functions, even if they are recursive.

The ordering of the display pointers is from top level to current level. Thus, in the above example, when procedure a is called, the display looks like:

```
MP-> +------------------------+
     | Test mp                |
     +-------------------------
     | a mp                   |
     +------------------------+
     | b mp                   |
     +------------------------+
```

When the program wants to fetch the frame pointer for a given block level, it finds mp+level-(level-vlevel), or the current level minus the target frame level offset negative to the current mp.

11.9.7 Locals

The locals are the space occupied by the variables local to that procedure or function.

11.10 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 (2/4/8 bytes)
x	Byte (1 byte)
r	Real (8 bytes)
s	Set (32 bytes)
b	Boolean (1 byte)
a	Address (2/4/8 bytes)
m	Memory (or memory block)
c	Character (1 byte)

Note that all boolean, character and byte values are extended to 2/4/8 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 Pascal-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).

Some instructions use a result type code. These are:

1	Real type
2	Set
3	Structured return types (array, record, etc.)

Note that some instructions and/or features of instructions are only designed to direct pgen how to generate code for the intermediate, and have no function in the interpreter(s).

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
apc lvl size	210 qn qn	sadr stmp dadr dtmp	

Assign pointer complex. Expects the number of levels in the array and the size of the base element in the instruction. The stack has the source address at top, followed by the source template address, followed by the destination address, followed by the destination template. Calculates the size of the complex array using the templates, then moves that many bytes from the source address to the destination address.

Instruction	Opcode	Stack in	Stack out
aps size	178	addr int addr int	

Assign simple pointer data. The size indicates the size of the base element. The tagged pointer data at stack top is assigned to the tagged pointer data at second on stack. Both tagged pointers are removed.

Instruction	Opcode	Stack in	Stack out
bge eadr	207		eadr sadr madr vec

Begin exception frame. Establishes a new exception frame. Expects an exception handler address in the instruction, then saves a new exception frame consisting of the previous exception handler address, stack address, mark address, and a dummy exception vector, then sets up the current exception variables.

Instruction	Opcode	Stack in	Stack out
brk	19		

Break execution. Used by pint only. Stops execution and enters the debugger, if enabled.

Instruction	Opcode	Stack in	Stack out
cal adr	21 qn		raddr

Call initalizer code strip. The current address is pushed onto the stack, and the address of the specified location called.

Instruction	Opcode	Stack in	Stack out
ccs lvl siz	223	dadr tadr	dadr tadr

Copy complex container to stack. Expects the number of levels and the base size in the instruction. On stack are the data address and the template address/length. Finds the total size of the array and copies it onto the stack. Replaces the original data address and template address with the on stack version. This instruction is used while passing a complex container as a value parameter.

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

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
cif pn rslt	247	address	

Call indirect function. The number of parameters is indicated by pn. The result type is given in rslt. The top of stack has the address of a mp/address pair pushed by lpa. The current mp is replaced by the new mp, the current address is saved on stack, and the address in the pair is jumped to. The mp/ad address is removed from stack. Note that since this instruction destroys the current mp, it must be restored after the call by a rip instruction.

Instruction	Opcode	Stack in	Stack out
cip pn	113	address	

Call indirect procedure. The number of parameters is given in pn. The top of stack has the address of a mp/address pair pushed by lpa. The current mp is replaced by the new mp, the current address is saved on stack, and the address in the pair is jumped to. The mp/ad address is removed from stack. Note that since this instruction destroys the current mp, it must be restored after the call by a rip instruction.

Instruction	Opcode	Stack in	Stack out
cjp lval hval adr	8 qn qn qn	val	

Compare and jump. Expects a value on the stack to compare with. The instruction contains the low value, high value, and address to jump to. The value is checked to lie within the range from the low value to high value, inclusive, and the jump is taken if so, and he value is removed from the stack. If the jump is not taken, the value is left on the stack.

Instruction	Opcode	Stack in	Stack out
cke	188	boolean tagcst	

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 and 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	boolean tagval

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 qn	boolean tagval	boolean tagval
ckvc val	180 qn	boolean tagval	boolean tagval
ckvi val	175 qn	boolean tagval	boolean tagval
ckvx val	203 qn	boolean tagval	boolean tagval

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
cpc lvl	177	addr len addr len	addr len addr len

Compare complex templates. Expects two tagged pointers on stack, which is an address followed by a template pointer. The number of levels in the templates are in the instruction. The two templates are compared, and an error generated if they don't match. The two tagged pointers remain on stack.

Instruction	Opcode	Stack in	Stack out
cpl	251	dadr/len	len dadr/len

Duplicate length from complex pointer. Expects a data address/length pair on stack. The length is duplicated and is place on stack at tos.

Instruction	Opcode	Stack in	Stack out
cpp poff psiz	239 qn qn		par

Copy procedure parameter. Used to prepare operator overload parameters. Expects the offset to the parameter location and the parameter size in the instruction. The parameter is located and copied down into the stack. The offset is from the stack pointer. After the instruction, the parameter is left on stack. The size will depend on the parameter type, rounded up to the stack alignment.

Instruction	Opcode	Stack in	Stack out
cpr rsiz roff	240 qn qn		fres

Copy result. Expects the size of the function result and the offset to its location in the frame in the instruction. Used to copy back the result of an overloaded function to its frame. At the end of instruction, the original parameters are discarded and only the function result remains.

Instruction	Opcode	Stack in	Stack out
cps	176	addr len addr len	addr len addr len

Compare simple templates. Expects two tagged pointers on stack, which is an address followed by a length. The two lengths are compared, and an error generated if they don't match. The two tagged pointers remain 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 lvt	191 qn qn qn	newtagval tagaddr	newtagval tagaddr

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 location of the logical variant table. If 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
ctb len off	12 qn qn	badr data	

Copy to buffer. The instruction contains the length of data on stack, and the actual allocation on stack after alignment. The address of a buffer is expected at stack top, followed by the data on stack. The data on stack is copied from the stack to the addressed buffer, then the data is removed from stack, leaving the buffer address. This instruction is used to copy structured function results off the stack.

Instruction	Opcode	Stack in	Stack out
cuf l addr pn rslt	246 qn		

Call user function. The instruction contains the address of the procedure to call, the number of parameters, and the result type. The current pc is saved on stack, and the provided address is 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
cup l addr pn	12 qn		

Call user procedure. The instruction contains the address of the procedure to call, and the number of parameters. The current pc is saved on stack, and the provided address is 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
cuv l addr pn	27 qn		

Call user virtual procedure vector. The instruction contains the address of the vector to the procedure to call, and the number of parameters. The current pc is saved on stack, and the address at the given address is jumped to (vectored).

Instruction	Opcode	Stack in	Stack out
cvbi off size lvnt	100 qn qn qn	ntagval tagaddr	ntagval tagaddr
cvbx off size lvt	115 qn qn qn	ntagval tagaddr	ntagval tagaddr
cvbb off size lvt	116 qn qn qn	ntagval tagaddr	ntagval tagaddr
cvbc off size lvt	121 qn qn qn	ntagval tagaddr	ntagval 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
cvf l addr pn rslt	27 qn		

Call user virtual procedure/function vector. The instruction contains the address of the vector to the function to call, the number of parameters, and the result type. The current pc is saved on stack, and the address at the given address is jumped to (vectored).

Instruction	Opcode	Stack in	Stack out
cxc lvl siz	212	inx dadr tadr	dadr tadr

Complex container index. Expects the size of the base type in the instruction. The index is at top of stack, followed by the address of the array, then the address of the template. The index is checked to lie within the array data, then multiplied by the base size and all levels of array, from the present level down to the last, then added to the base address of the array to find the element. The template address is moved to the next level and placed on stack, followed by the element address at stack top. The index, array address and template address are removed, and replaced by the new element address and template address. Note that this instruction is only used to advance from one complex container to an enclosed one. The cxs instruction is always used on the last level, because it picks up the last template entry and carries the length with the pointer instead of the template address (this is a so called “pick up template”).

Instruction	Opcode	Stack in	Stack out
cxs siz	211 qn	inx adr len	adr

Simple container index. Expects the size of the base type in the instruction. The index is at top of stack, followed by the address of the array, then the length. The index is checked to lie within the array data, then multiplied by the base size and added to the array address to find the element address. The index, array address and len are removed from stack and replaced by the element address.

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

The unsigned cnt parameter is added to 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
ede	208	eadr sadr madr vec	

End exception frame. Expects an exception handler address, stack address, mark address, and vector variable on stack. Removes all and continues. This instruction is used after the exception has been successfully handled.

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 qn	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
equv	215	sadr len sadr len	boolean

Compare two vectorized strings. Expects the first vector address on stack top, followed by the length, then the address of the second vector, then the length of the second vector. Vectorized strings are those that are passed or indexed as variable length arrays. Finds the strings are equal, and returns true if so, otherwise false. Removes the two lengths and two addresses, and replaces them with the truth value.

Instruction	Opcode	Stack in	Stack out
eext	242		

Execute external. This is a pint internal instruction. It is used to execute an externally defined routine. A table in pint is filled with eext instructions, and the address of the instruction determines which external routine is executed.

Instruction	Opcode	Stack in	Stack out
fjp addr	24 qn	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 qn	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
geqv	220	sadr len sadr len	boolean

Compare two vectorized strings. Expects the first vector address on stack top, followed by the length, then the address of the second vector, then the length of the second vector. Vectorized strings are those that are passed or indexed as variable length arrays. Finds if the second string is greater than or equal to the first string, and returns true if so, otherwise false. Removes the two lengths and two addresses, and replaces them with the truth value.

Instruction	Opcode	Stack in	Stack out
grtb	157	boolean boolean	boolean
grtc	159	character character	boolean
grti	155	integer integer	boolean
grtm size	160 qn	address address	boolean
grtr	156	real real	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
grtv	218	sadr len sadr len	boolean

Compare two vectorized strings. Expects the first vector address on stack top, followed by the length, then the address of the second vector, then the length of the second vector. Vectorized strings are those that are passed or indexed as variable length arrays. Finds if the second string is greater than the first string, and returns true if so, otherwise false. Removes the two lengths and two addresses, and replaces them with the truth value.

Instruction	Opcode	Stack in	Stack out
inca cnt	90 qn	address	address
incb cnt	93 qn	boolean	boolean
incc cnt	94 qn	character	character
inci cnt	10 qn	integer	integer
incx cnt	201 qn	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 qn	address	address
indb off	88 qn	address	boolean
indc off	89 qn	address	character
indi off	9 qn	address	integer
indx off	198 qn	address	integer
indr off	86 qn	address	real
inds off	87 qn	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	set value	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	address	

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 qn		

Interprocedure jump. The instruction contains the display offset 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 lvt	192 qn qn	newtagval tagaddr	newtagval tagaddr
ivtx off size lvt	101 qn qn	newtagval tagaddr	newtagval tagaddr
ivtb off size lvt	102 qn qn	newtagval tagaddr	newtagval tagaddr
ivtc off size lvt	111 qn qn	newtagval tagaddr	newtagval tagaddr

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 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 entire variant is set undefined. 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
ixa size	16 qn	index address	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 qn		address

Load address with offset. Loads the address in the globals 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 qn		address

Load string address. Pascal-P6 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
lcp	135	addr	addr integer/addr

Load complex pointer. Expects the address of a complex pointer on stack. Loads the address/length or address/template address pair onto the stack with the address at stack top, followed by the length or template.

Instruction	Opcode	Stack in	Stack out
lda p off	4 p8 qn		address

Load local address. Expects the display offset 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 qn		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 qn		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 qn		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 qn		address

ldob off	68 qn	boolean
ldoc off	69 a32	character
ldoi off	1 qn	integer
ldox off	194 qn	integer
ldor off	66 qn	real
ldos off	67 qn	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
ldp	225	adr	adr taddr

Load complex pointer. Expects the address of the complex pointer as a address/length pair. Loads the complex pointer with the address first on stack, followed by the template. The original address is removed.

Instruction	Opcode	Stack in	Stack out
leqb	163	boolean boolean	boolean
leqc	165	character character	boolean
leqi	161	integer integer	boolean
leqm size	166 qn	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
leqv	219	sadr len sadr len	boolean

Compare two vectorized strings. Expects the first vector address on stack top, followed by the length, then the address of the second vector, then the length of the second vector. Vectorized strings are those that are passed or indexed as variable length arrays. Finds if the second string is less than or equal to the first string, and returns true if so, otherwise false. Removes the two lengths and two addresses, and replaces them with the truth value.

Instruction	Opcode	Stack in	Stack out
lesb	169	boolean boolean	boolean

lesc	171	character character	boolean
lesi	167	integer integer	boolean
lesm size	172 qn	address address	boolean
lesr	168	real real	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**
lesv	217	sadr len sadr len	boolean

Compare two vectorized strings. Expects the first vector address on stack top, followed by the length, then the address of the second vector, then the length of the second vector. Vectorized strings are those that are passed or indexed as variable length arrays. Finds if the second string is less than the first string, and returns true if so, otherwise false. Removes the two lengths and two addresses, and replaces them with the truth value.

Instruction	**Opcode**	**Stack in**	**Stack out**
lft tadr	213 qn	adr	adr tadr

Load complex fixed container. Expects the address of a container on stack, and the address of the template for the container in the instruction. The template address is placed on stack over the container address. This instruction is used to pick up a statically declared array and convert it to a complex container.

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

load procedure/function address. Expects the offset of the display in 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**
lnp gadr	20		

This is an internal setup instruction for pint. It contains the address of the globals, which are then cleared to zero, and other setup operations are performed.

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 qn		mp pfaddr

Load procedure address. The current mark pointer is loaded onto the stack, followed by the target procedure or function address. The p parameter gives the display offset of the current procedure. 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
lsa off	241		adr

Load stack address. Expects an offset to the current stack in the instruction. The offset is added to the current stack and the resulting address pushed onto stack. Used in overloaded operators to index parameters on the stack.

Instruction	Opcode	Stack in	Stack out
lsp	250	adr	adr taddr

Load stack complex pointer. Expects the address of the complex pointer as a address/length pair. Loads the complex pointer with the address first on stack, followed by the template. The original address is removed. This instruction is identical to the ldp instruction, but is ignored by pgen.

Instruction	Opcode	Stack in	Stack out
ltcb off	231 qn		boolean
ltcc off	232 qn		char
ltci off	228 qn		integer
ltcr off	229 qn		real
ltcs off	230 qn		sadr
ltcx off	233 qn		integer

Load from constants area. Expects an offset address to the constants area in the instruction. The constant is loaded by type and placed on stack.

Instruction	Opcode	Stack in	Stack out
lto off	234 qn		adr

Load constant address. Expects an offset address to the constants area in the instruction. An address to the constant is loaded to stack.

Instruction	Opcode	Stack in	Stack out
max lvl	214	lvl dadr tadr	integer

Find maximum dimension of array. Expects a level in the instruction, a level argument on stack, a data address followed by a template address or length. The length of the array at the level indicated is found and replaces the level, data address and template address on stack.

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
mpc dpth rev	248	dadr/tadr dadr/tadr	dadr/tadr

Make complex pointer. Takes a data address and template address/length pair from the stack and makes a complex pointer from those. The instruction indicates the depth in the stack to find the pair, and rev indicates if the template address is at stack top or the data address. This instruction is only used by pgen to find out when complex pointer pairs should be treated as one unit.

Instruction	Opcode	Stack in	Stack out
mov size	55 qn	srcaddr destaddr	

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
mse	209	vec madr, sadr, eadr	

Handle next exception frame. Expects the exception vector, mark address, stack address and exception address on stack. The current exception frame is discarded and the previous frame restored. The exception is then "thrown" to the new frame/next frame in stacking sequence, which then matches the exception. If there are no more frames in the frame stack, the exception goes to the unhandled exception handler. This instruction is used when the current exception handler does not match any condition, direct match with vector, wildcard match, or else. All parameters are removed from the stack.

Instruction	Opcode	Stack in	Stack out
mst lvl lcl sd	11 p8 qn qn		

Start new frame. This instruction is used at the start of a routine. The lvl parameter indicates the nesting depth of the procedure being activated, the lcl parameter gives the amount of locals space, and the sd parameter gives the required stack size. The callers frame pointer is saved on stack, then the mark record is placed on stack, consisting of the current ep, then the stack bottom, then the previous ep. Then lvl number display pointers are fetched from the previous frame pointer, and the new display pointer added below that. Then the locals space indicated by lcl is allocated to the stack, then the bottom of the stack is set from sd.

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
neqv	216	sadr len sadr len	boolean

Compare two vectorized strings. Expects the first vector address on stack top, followed by the length, then the address of the second vector, then the length of the second vector. Vectorized strings are those that are passed or indexed as variable length arrays. Finds if the second string is not equal to the first string, and returns true if so, otherwise false. Removes the two lengths and two addresses, and replaces them with the truth value.

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
notb	42	boolean	boolean
noti	205	integer	integer

Logical ‘not’. The Boolean or integer 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 Pascal-P6 always converts values to 32 bit integers on load to stack.

Instruction	Opcode	Stack in	Stack out
pck sizep sizeu	63 qn qn	parr inx uprr	

Convert unpacked array to packed array. Because Pascal-P6 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
ret	22	adr	

Return from initializer code strip. Returns to the caller. This instruction is used to return from an initializer code strip, which is a short section of code used to set up parameterized variables. The return address is removed from stack.

Instruction	Opcode	Stack in	Stack out
reta psize	132		address
retb psize	131		boolean
retc psize	130		character
reti psize	128		integer
retm psize	237 qn		structure
retx psize	204		integer
retp psize	14		
retr psize	129		real
rets psize	236		set

Return from procedure or function with result. Returns from the current procedure or function. The pc, ep and mp pointers are restored from the saved data in the stack. 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. If the instruction is retm, a structure (record or array) is returned on stack. The parameter total size is indicated in the instruction.

Instruction	Opcode	Stack in	Stack out
rgs	110	high low	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
rip off	13 qn		

Restore from indirect procedure call. The instruction contains the offset to the stack location of the current mark. The mp is fetched from the 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
scp	224	dadr tadr adr	

Store complex pointer. Expects an array data address on stack top, followed by a template address or length, then the destination address. The complex pointer is stored at the given address, with the array data address first, followed by the template or length. All parameters are removed from stack.

Instruction	Opcode	Stack in	Stack out
sfr rs	245		

Set function result. Expects the size of the function result for an upcoming function call as rs. rs bytes are allocated on the stack. This instruction is used to reserve space for the function result.

Instruction	Opcode	Stack in	Stack out
sfs siz stk	252	addr struct	

Store from stack. The instruction contains the size of the stack variable, and the size of the allocation. The stack contains the destination address. The variable is stored to the given address, then both the address and the variable on stack are removed.

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
spc	222	addr addr	addr integer

Simplify complex pointer. Expects a complex pointer at stack top, with the base address at top, followed by a template pointer. The value at the template pointer replaces the template pointer, thus simplifying the pointer. This is used when a complex pointer is at the lowest index of the template.

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 qn	address	
srob off	78 qn	boolean	
sroc off	79 qn	character	
sroi off	3 qn	integer	
sror off	76 qn	real	
sros off	77 qn	set	
srox off	196 qn	integer	

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	boolean address	
stoc	84	character address	
stoi	6	integer address	
stom size skip	235 qn qn	structure address	
stor	81	real address	
stos	82	set address	
stox	197	integer address	

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. If the instruction is stom, the value on stack is a structure (record or array) of arbitrary length. The first value in the instruction is the length of the structure, and the second is span of the allocated space on stack. This second value is required because the structure allocated is rounded up to the stack alignment.

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 offset of the display pointer 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
suv radr vadr	91 qn qn		

Set user virtual procedure/function vector. The first parameter of the instruction contains the new routine address (procedure/function) for the virtual routine. The second address contains the vector. The new override procedure is placed atop the existing virtual routine vector. The original vector is usually stored locally. The stack is unchanged.

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 the word size of the machine. 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 qn		

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 instruction is a dummy, and contains zero. It 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 qn qn	sindex upackarr packarr	

Unpack a packed array. Pascal-P6 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. All parameters are removed from the stack.

Instruction	Opcode	Stack in	Stack out
vbe	96 qn	addresss	

Variable reference block end. Ends a variable reference.

Instruction	Opcode	Stack in	Stack out
vbs len	92 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
vdd	227	adr	

Vector dispose array. Expects the address of a dynamically allocated array on stack. Disposes of the array. The address is removed from stack. This instruction is used to deallocate dynamically allocated arrays.

Instruction	Opcode	Stack in	Stack out
vdp	221	adr	

Vector dispose array. Expects the address of a dynamically allocated array on stack. Disposes of the array. The address is removed from stack. This instruction is used to deallocate global parameterized arrays.

Instruction	Opcode	Stack in	Stack out
vin lvl siz	226 qn qn	adr siz [siz]...	

Vector initialize dynamic. Allocate container array. Expects the address of the container dynamic variable on stack top, followed by one or more sizes of array dimensions. The instruction contains the level or number of dimensions, and the size contains the base element size. The total size of the array is calculated along with a template size, with one element for each dimension. The array is then allocated, and the template for it filled in at the start of the array. Dynamically created container arrays have their templates placed with the array at the start. All elements are removed from the stack.

Instruction	Opcode	Stack in	Stack out
vip lvl siz	133 qn qn	adr siz [siz]...	

Vector initialize pointer global. Expects the address of the container dynamic variable on stack top, followed by one or more sizes of array dimensions. The instruction contains the level or number of dimensions, and the size contains the base element size. The total size of the array is calculated along with a template size, with one element for each dimension. The template is placed in global memory after the array address. The array is then allocated dynamically, and the address of that placed before the template. All elements are removed from the stack.

Instruction	Opcode	Stack in	Stack out
vis lvl siz	122 qn qn	adr siz [siz]… raddr	raddr

Vector initialize stack. Expects the address of the container dynamic variable on stack top, followed by one or more sizes of array dimensions. The instruction contains the level or number of dimensions, and the size contains the base element size. The total size of the array is calculated along with a template size, with one element for each dimension. The template is placed in local memory after the array address. All elements are removed from the stack, then the array is then allocated on stack, and the address of that placed before the template. Because vis allocates on the stack, and assumes that it was called as a code strip, it moves the return address on top of the stack to the top of the new allocation on stack.

Instruction	Opcode	Stack in	Stack out
wbe	244		

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	243	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 qn	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.

Instruction	Opcode	Stack in	Stack out
xor	206	int int	int

‘xor’s integers or booleans. Expects two integers on stack or two booleans, which are treated the same. The integers are ‘xor’ed and the result replaces them on stack. If either integer is negative, an error results.

11.10.1 Instructions by number

0	lodi
1	ldoi
2	stri
3	sroi
4	lda
5	lao
6	stoi
7	ldcs
8	cjp
9	indi
10	inci
11	mst
12	cup
13	ents
14	retp
15	csp
16	ixa
17	equa
18	neqa
19	brk
20	lnp
21	cal
22	ret
23	ujp
24	fjp
25	xjp
26	chki
27	cuv
28	adi
29	adr
30	sbi
31	sbr
32	sgs
33	flt
34	flo
35	trc
36	ngi
37	ngr
38	sqi
39	sqr

40	abi
41	abr
42	notb
43	and
44	ior
45	dif
46	int
47	uni
48	inn
49	mod
50	odd
51	mpi
52	mpr
53	dvi
54	dvr
55	mov
56	lca
57	deci
58	stp
59	ordi
60	chr
61	ujc
62	rnd
63	pck
64	upk
65	ldoa
66	ldor
67	ldos
68	ldob
69	ldoc
70	stra
71	strr
72	strs
73	strb
74	strc
75	sroa
76	sror
77	sros
78	srob
79	sroc
80	stoa

81	stor
82	stos
83	stob
84	stoc
85	inda
86	indr
87	inds
88	indb
89	indc
90	inca
91	suv
92	vbs
93	incb
94	incc
95	chka
96	vbe
97	chks
98	chkb
99	chkc
100	cvbi
101	ivtx
102	ivtb
103	decb
104	decc
105	loda
106	lodr
107	lods
108	lodb
109	lodc
110	rgs
111	ivtc
112	ipj
113	cip
114	lpa
115	cvbx
116	cvbb
117	dmp
118	swp
119	tjp
120	lip
121	cvbc

122	vis
123	ldci
124	ldcr
125	ldcn
126	ldcb
127	ldcc
128	reti
129	retr
130	retc
131	retb
132	reta
133	vip
134	ordb
135	lcp
136	ordc
137	equi
138	equr
139	equb
140	equs
141	equc
142	equm
143	neqi
144	neqr
145	neqb
146	neqs
147	neqc
148	neqm
149	geqi
150	geqr
151	geqb
152	geqs
153	geqc
154	geqm
155	grti
156	grtr
157	grtb
158	grts
159	grtc
160	grtm
161	leqi
162	leqr

163	leqb
164	leqs
165	leqc
166	leqm
167	lesi
168	lesr
169	lesb
170	less
171	lesc
172	lesm
173	ente
174	mrkl
175	ckvi
176	cps
177	cpc
178	aps
179	ckvb
180	ckvc
181	dupi
182	dupa
183	dupr
184	dups
185	dupb
186	dupc
187	cks
188	cke
189	inv
190	ckla
191	cta
192	ivti
193	lodx
194	ldox
195	strx
196	srox
197	stox
198	indx
199	chkx
200	ordx
201	incx
202	decx
203	ckvx

204	retx
205	noti
206	xor
207	bge
208	ede
209	mse
210	apc
211	cxs
212	cxc
213	lft
214	max
215	equv
216	neqv
217	lesv
218	grtv
219	leqv
220	geqv
221	vdp
222	spc
223	ccs
224	scp
225	ldp
226	vin
227	vdd
228	ltci
229	ltcr
230	ltcs
231	ltcb
232	ltcc
233	ltcx
234	lto
235	stom
236	rets
237	retm
238	ctb
239	cpp
240	cpr
241	lsa
242	eext
243	wbs
244	Wbe

245	sfr
246	cuf
247	cif
248	mpc
249	cvf
250	lsp
251	cpl
252	sfs

11.11 System calls

The Pascal-P6 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 from top of stack first at left, to the bottommost operand at the right.

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
aefb	79	len sadr filadr	

Assign external filename to binary file. Expects the length of the filename at stack top, followed by the filename address, then the file address. The filename passed is the name of the variable for the file. The standard Pascaline behavior is to read the filename off the command line. However, other behaviors are possible, such as using the variable name for the filename. The compiler garantees that the assignments are carried out in order. The length, the filename address and the file address are all removed from stack.

System Call	Number	Stack in	Stack out
aeft	78	len sadr filadr	

Assign external filename to text file. Expects the length of the filename at stack top, followed by the filename address, then the file address. The filename passed is the name of the variable for the file. The standard Pascaline behavior is to read the filename off the command line. However, other behaviors are possible, such as using the variable name for the filename. The compiler garantees that the assignments are carried out in order. The length, the filename address and the file address are all removed from stack.

System Call	Number	Stack in	Stack out
appb	58	filadr	

Append binary file. Expects a file address on stack. The file is set to write mode and positioned to the end. The file is removed from the stack.

System Call	Number	Stack in	Stack out
appt	50	filadr	

Append text file. Expects a file address on stack. The file is set to write mode and positioned to the end. The file is removed from the stack.

System Call	Number	Stack in	Stack out
assb	56	len addr addr	

Assign file name binary. Associates the file name with a binary file. The length of the filename is expected on stack top, followed by the address of the filename string, then the address of the binary file itself. All stack parameters are removed.

System Call	Number	Stack in	Stack out
asst	46	len sadr filadr	

Assign file name text. Associates the file name with a text file. The length of the filename is expected on stack top, followed by the address of the filename string, then the address of the text file itself. All stack parameters are removed.

System Call	Number	Stack in	Stack out
ast	60	integer	

Assert. Expects a truth value on stack. If the value is true, the execution continues. If not, exection stops. The integer value is removed.

System Call	Number	Stack in	Stack out
asts	61	len str int	

Assert with message. Expects the string length, followed by the string address, and a truth value under that. The value is checked for true, and if false, the program stops with an error message given by the string. Otherwise execution continues. The length, string address, and the integer are all removed.

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
chg	52	osadr oslen nsadr nslen	

Change the name of a file. Expects the existing name string on stack top, the length of that below it, then the new string, and the new string length. The filename is changed. All strings and lengths are removed.

System Call	Number	Stack in	Stack out
clsb	57	filadr	

Close binary file. Expects the file address on stack top. Closes the file, and removes it if it is a temp file. Removes the file address from stack.

System Call	Number	Stack in	Stack out
clst	47	filadr	

Close text file. Expects the file address on stack top. Closes the file, and removes it if it is a temp file. Removes the file address from stack.

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
del	51	sadr len	

Delete file by name. Expects the filename string at stack top, followed by the length. Removes both string and length.

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

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, translated to lvn form, 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	size addr	

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
exs	55	len str	boolean

Find if file exists. Expects the length of the filename at stack top, followed by the string address. Finds and returns true if the file exists, otherwise false. Both length and string are removed.

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	size fileaddr	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	size fileaddr	

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
hlt	59		

Halt program. Simply halts the running program.

System Call	Number	Stack in	Stack out
len	53	filadr	

Find length in elements of binary file. Expects the file address on stack. Find the number of base elements in the file. Removes the file.

System Call	Number	Stack in	Stack out
loc	54	filadr	integer

Find location of read/write in a binary file. Expects the file address on stack. Find the location in the file and places on stack. Removes the file.

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	size tagcnt tagcst… addr	

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 constants, translated to lvn form, 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	size filadr	

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
pos	36	loc filadr	

Position file binary. Expects the location of the file element on stack, followed by the address of a file variable on stack. The file access point is moved to the specified location if it exists. The location and file address are discarded.

System Call	Number	Stack in	Stack out
put	1	filadr	

Put 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	len varaddr filadr	filadr

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
rcb	38	max min vaddr filadr	filadr

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
rcbf	74	max min fld vadr filadr filadr	

Read character from text file with range check and field. 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, then the field 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. Only reads from characters within the field.

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	varaddr filadr	filadr

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
rdcf	75	field varadr filadr	filadr

Read character from text file with field. Expects the file variable address on stack, and the variable address to read to, then the field 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	varaddr filadr	filadr

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
rdie	80	len sadr vadr	

Read external integer. Expects the length of the header name, followed by the header variable name address, followed by the address of the integer to read. Reads the header integer to the variable. The standard Pascaline behavior is to read the integer from the command line. The name of the header variable is passed to enable other behaviors. Removes the length, header name string, and variable address.

System Call	Number	Stack in	Stack out
rdif	72	fld varaddr filadr	filadr

Read integer from text file with field. Expects the file variable address on stack, and the variable address to read to, then the field above that. Reads a single integer from the file to the variable. Only the characters from the field are read.

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	varaddr filadr	filadr

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
rdre	81	len sadr vadr	

Read external real. Expects the length of the header name, followed by the header variable name address, followed by the address of the real to read. Reads the header integer to the variable. The standard Pascaline behavior is to read the integer from the command line. The name of the header variable is passed to enable other behaviors. Removes the length, header name string, and variable address.

System Call	Number	Stack in	Stack out
rdrf	73	fld varadr filadr	fileaddr

Read real from text file with field. Expects the file variable address on stack, and the variable address to read to, then the field above that. Reads a single real from the file to the variable. Only the characters in the field are read.

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
rds	70	sadr len filadr	filadr

Read string. Expects the length of the string on stack top, followed by the string address, then the address of the file to read. Only the number of characters in the string are read. The length and string address are removed.

System Call	Number	Stack in	Stack out
rdsf	76	fld sadr len filadr	filadr

Read string with field. Expects the length of the string on stack top, followed by the field, and then the string address, then the address of the file to read. If the field is larger than the string, then trailing blanks are expected. If the field is shorter than the string, then only the number of characters in the field are read, and the rest of the string is left uninitialized. The length, field and string address are removed.

System Call	Number	Stack in	Stack out
rdsp	77	sadr len filadr	filadr

Read padded string. Expects the length of the string at stack top, followed by the base address of the string, then the file address under that. Reads characters into the string until either the string is full, or eoln occurs. If the string is full, and more characters exist on the line, an error results. If eoln occurs before the string is filled, then the string is padded out until the end with blanks. The length and string address are removed.

System Call	Number	Stack in	Stack out
rib	37	max min vaddr filadr	filadr

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
ribf	72	max min fld vadr filadr	filadr

Read an integer from text file with range check and field. 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, and the field 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. The read length is limited by the field.

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	filadr	filadr

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	filadr	

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	filadr	

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
thw	2	evadr	

Throw exception. The exception variable is at stack top. The exception stack is unwound by disposing of the stack to the last exception handler, then the exception variable is replaced on stack. The exception statement then does one or more matches for the exception variable, and throws another exception level if not found.

System Call	Number	Stack in	Stack out
upd	49	filadr	

Update file. Expects a file address on stack. The file is changed to write mode and positioned at the start. The file is removed from the stack.

System Call	Number	Stack in	Stack out
wbb	31	boolean fileaddr	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	char fileaddr	fileaddr

Write character to binary file. Expects the file variable address on stack, and the character 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	size varaddr fileaddr	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	integer fileaddr	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	real fileaddr	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	45	integer fileaddr	fileaddr

Write byte to binary file. Expects the file variable address on stack, and an integer to write to above that. Writes a single byte 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
wiz	66	width integer filadr	filadr

Write integer to text file in decimal form (base 10) with leading zeros. 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, using zeros to fill out the field.

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
wizb	69	width integer filadr	

Write integer to text file in binary form (base 2) with leading zeros. 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, using zeros to fill out the field.

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
wizh	67	width integer filadr	

Write integer to text file in hexadecimal form (base 16) with leading zeros. 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, using zeros to fill out the field.

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
wizo	68	width integer filadr	

Write integer to text file in octal form (base 8) with leading zeros. 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, using zeros to fill out the field.

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
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	width boolean fileaddr	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	width char fileaddr	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	frac width real fileaddr	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	width integer fileaddr	fileaddr

Write integer to text file in decimal form (base 10). 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
wrib	64	width integer fileaddr	fileaddr

Write integer to text file in binary form (base 2). 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
wrih	62	width integer fileaddr	

Write integer to text file in hexadecimal form (base 16). 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
wrio	63	width integer fileaddr	

Write integer to text file in octal form (base 2). 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	width real fileaddr	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	width saddr len fileaddr	fileaddr

Write string to text file. Expects the file variable address on stack, the length of the string above that, address of the string to write to above that, and the field width above that.

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.

System Call	Number	Stack in	Stack out
wrsp	65	sadr len filadr	

Write padded string to text file. Expects the string address first on stack, followed by the length, then the file address. The padded length of the string is determined, which is the position of the last non-space character in the string. Then the characters to the left of that position, inclusive, are output to the file. Removes the string address, length and file address.

11.11.1 System calls by number

0	get	1	put
2	thw	3	rln
4	new	5	wln
6	wrs	7	eln
8	wri	9	wrr
10	wrc	11	rdi
12	rdr	13	rdc
14	sin	15	cos
16	exp	17	log
18	sqt	19	atn
20	---	21	pag
22	rsf	23	rwf
24	wrb	25	wrf
26	dsp	27	wbf
28	wbi	29	wbr
30	wbc	31	wbb
32	rbf	33	rsb
34	rwb	35	gbf
36	pbf	37	rib
38	rcb	39	nwl
40	dsl	41	eof
42	efb	43	fbv
44	fvb	45	wbx
46	ass	47	clst
48	pos	49	upd
50	app	51	del
52	chg	53	len
54	loc	55	exs
56	ass	57	clsb
58	app	59	hlt
60	ast	61	asts
62	wri	63	wrio
64	wri	65	wrsp
66	wiz	67	wizh
68	wiz	69	wizb
70	rds	71	ribf
72	rdi	73	rdrf
74	rcb	75	rdcf
76	rds	77	rdsp
78	aef	79	aefb

80	rdi	81	rdre

Note: “---” indicates “unused”.

12 Testing Pascal-P6

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 Pascal-P6 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, 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 Pascal-P6, and now that is distributed with Pascal-P6 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.

12.1 Running a Full Regression Test

The script regress runs a regression test on Pascal-P6. The format is:

```
regress [--full|--short|--pint|--pmach|--cmach]…
```

The regression script runs the full suite of tests for Pascal-P6. Normally, a short test is done that does not include self compilation. This can be overridden with the --full option. A self compile and test can take considerable time, hours or even days depending on the host machine.

The regress script checks all of the outputs of individual tests, and produces a file:

regress_report.txt

That contains all of the output of the regression.

The regression is normally done on all P-Machine machine types, pint, pmach and cmach. It can be run against only one of these by specifying that machine's option, --pint, --pmach or –cmach.

Note: the –full option runs the pint interpreter as a self compiler. This is no longer as relevant, as it takes considerable time, and with pgen, the compiler is always self compiling without the drawbacks of self-interpretation.

12.2 Running Individual tests

12.2.1 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.

program.dat The data file for the program (fed to prd in pint)

testprog compiles and runs the target program, and checks its output against the reference file. Several files are produced during the process:

program.p6 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 Pascal-P6 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. A program that does not use a data file does not need the program.dat file. An example of this would be the "hello" program. However, testprog expects all of the files to exist, so the file must be present and empty.

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\P6_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\P6_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.

12.2.2 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. See the sections on individual test types for more details.

12.3 Test types

The Pascal-P6 tests are divided into two major categories, 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.

12.4 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

Normally the PAT is run via testprog.

12.5 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 strategy 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 possibility that the code could be changed by an aggressive compiler to eliminate or nullify 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.

12.5.1 List of tests

12.5.1.1 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

Field list

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'

<u>Actual Parameter List</u>

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

<u>Write Parameter List</u>

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

<u>Factor</u>

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

<u>Term</u>

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)

12.5.1.2 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.
iso7185prt1759	The execution of any action, operation, or function, defined to operate on a variable, is an error if the variable is a program-parameter and, as a result of the binding of the program-parameter, the execution cannot be completed as defined.

12.5.1.3 Class 3: Advanced error checking

These are advanced error checks that the compiler may or may not check for.

iso7185prt1800 Access to dynamic variable after dispose.

12.5.1.4 Class 4: Field checks

These tests are a collection of issues found while running the compiler.

iso7185prt1900 Access to dynamic variable after dispose.

12.5.2 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.

12.5.2.1 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.

12.5.2.2 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.

12.5.2.3 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.

12.5.2.4 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.

12.5.3 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.

12.6 The Pascaline Acceptance Test

Because the Pascaline language can specify language constructs across multiple source files, it consists of three different files:

pascaline.pas Tests Pascaline extended language constructs.

pascaline1.pas Tests a uses module.

pascaline2.pas Tests a joins module.

Thus pascaline.pas uses pascaline1.pas and joins pascaline2.pas to form a complete test program.

The pascaline test uses both a special command line as well as input from the standard input file (input), which is the file:

pascaline.inp

[Note the pascaline.inp file is empty at this time]

The Pascaline acceptance test is normally run via the testpascaline script.

12.7 The Pascaline Rejection Test

There is no Pascaline rejection test defined at this time.

12.8 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 Pascal-P6 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.

All of these except for Pascal-S are run using testprog. Pascal-s is run via the script testpascals.

12.9 Previous Pascal-P versions test

As part of the regression tests, Pascal-P6 runs the older versions of itself, namely Pascal-P2 and Pascal-P4. These are the only versions of the compiler available. See the section “1.1 History of Pascal-P6”, 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 Pascal-P6 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.

12.9.1 Compile and run Pascal-P2

Pascal-P2 runs on Pascal-P6 virtually unmodified. It needed only the declarations of the **prd** and **prr** files removed. This is required because they are predefined in Pascal-P6. In a stand-alone use of Pascal-P2, those files are real external files and have to be declared.

Pascal-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 Pascal-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.

Pascal-P2 is run via script file testp2.

12.9.2 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 Pascal-P4 running under Pascal-P6 cannot execute a for loop of the form:

```
for b := false to true do ...
```

The reason for this is non-trival. The way that Pascal-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. Pascal-P6 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-P6? Pascal-P4, as well as Pascal-P6, 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 Pascal-P6 simply does not.

Pascal-P4 is run via the script file testp4.

12.10 Compile and Run Pascal-P5

Pascal-P5 has the usual correction for prd and prr. One difference with Pascal-P5 is that it can be run unmodified on Pascal-P6. For this reason the Pascal-P5 directory is a clone of the Pascal-P5 repo on github.

Pascal-P5 is run via the script file testp5.

12.11 Compile and Run Pascal-P6

Compiling Pascal-P6 on Pascal-P6 is a self compilation test. The source used for this comes from the Pascal-P6 source directory itself.

Pascal-P6 is run via the script file testp6.

12.12 Self compile

One of the more difficult tests for Pascal-P6 (and the most time consuming) is to have Pascal-P6 compile and run itself in interpretive mode. 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 compiling 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-P6 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.

The self compile requires minor changes to the input program. The changes required to get pcom and pint to self compile are implemented by the macro switch SELF_COMPILE. What this does for each program will be listed below. The changes are implemented as part of the macro processor, pascpp. See “7 Pascal-P6 implementation language”.

12.12.1 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 batch file to control a self compile and check is:

cpcoms

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.

12.12.1.1 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-P6 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-P6 file vs. another compiler. A regular ISO 7185 Pascal compiler isn't going to have a predefined prr file. Thus the SELF_COMPILE macro switch being true removes the type definitions for prd and prr, and removes the reset() and rewrite() calls for those.

12.12.2 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. 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 SELF_COMPILE macro switch removes the prr and prd definitions, and the reset() and rewrite() calls for same, as in pcom. It also changes the size of the program storage array to be smaller so that it will fit into the enclosing pint machine.

The batch file required to self compile pint is:

cpints

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.

Self compiled files and sizes

The resulting sizes of the self compiled files are:

pcomm.P6

Storage areas occupied

Contents	Range of storage	Net size
Program	0-114657	(114658)
Stack/Heap	114658-1987994	(1873337)
Constants	1987995-2000000	(12005)

pintm.P6

Storage areas occupied

Contents	Range of storage	Net size
Program	0- 56194	(56195)
Stack/Heap	56195-1993985	(1937791)
Constants	1993986-2000000	(6014)

12.13 The Debug Mode Test

Because the debug CLI mode is a complex language in and of itself, there is an extensive test for debug mode that runs through all of the available commands and options on a sample program. The sample program is in two parts, because debug mode can debug programs with external routines. The two parts are:

debug_test.pas The main debug test program.

debug_test1.pas Joined routines for testing.

An important part of the debug mode test is the commands that are input. These are contained in:

debug_test.inp

Normally the debug test is run via the testdebug script.

Note: the debug mode test outputs a lot information such as assembly listings and dumps that change when the underlying compiler changes. Thus it will often need to be recompared by hand.

13 Preparing a Pascal-P6 release

A release, defined as any set of Pascal-P6 file containing a version number, is a promise to users that the code and files contained within meet quality standards. Nothing is worse than a version that must have follow on versions to correct bugs that could have been found by simple testing.

Several items must be accomplished to create a Pascal-P6 Release:

1. The version **must** run a full regression. No exceptions.
2. Advance the version number(s) on all applicable sources.
3. Create a news file for the release, containing new features added and bugs/problems existing in it. Follow the format of previous releases. It should contain all of the issues from Github that are marked as bugs. If there are bugs that are not properly marked as bugs, this is the time to fix them. The closed issues list is a good place to find new features, as well as the commit log after the date of the last release. Commit this to the archive.
4. Create a candidate release. This can be done on https://github.com/samiam95124/Pascal-P6/releases "Draft a new release". Github will create .zip and .gz files for you. Enter in the discription "Candidate release, DO NOT USE". This will be changed after verification.
5. Download the release to a scratch directory.
6. Enter the directory with a newly created shell.
7. Follow the steps to build Pascal-P6, . setpath, ./configure, make.
8. Rerun regression in that directory.
9. On Github change the release description to active.
10. Put announcement for the release in the discussions area. The contents are the same as NEWS.

14 Filing bugs against Pascal-P6

To file bugs against Pascal-P6, please use the "issues" section of the online Pascal-P6 repo:

https://github.com/samiam95124/Pascal-P6/issues

To properly fix a bug, the following information is needed:

1. A description of the bug or problem at hand.
2. The system it was encountered on (Linux, Windows, etc.).
3. The version number of that system, complete, like "Ubuntu 22.04 LTS").
4. The version number of Pascal-P6 where the bug or problem was found. This is printed out when Pascal-P6 programs run, as "P6 Pascal compiler vs. 0.2". If the version number ends with an x (".x"), it means it is not an official release, and was taken from the archive. If that is so, please include the complete commit number of the version. This can be obtained with the "git log" command in the repo. Note that it is not possible to file bugs against a repo that has custom changes on it, IE, your own copy of the repo.
5. A **short** example program that causes the issue, including the steps used to compile it.

An example of a problem submission is:

```
samiam@samiam-h-pc-2:~/projects/pascal/pascal-p6$ p6 test
Compiling test...
P6 Pascal compiler vs. 0.2.x
Pascal-P6 complies with the requirements of Pascaline version 0.4
and the following annexes: A,B,C,E.


     1       -8 program hello(output);
     2       -8
     3       -8 begin
     4        5
     5        5     writeln('Hello, world')
     6       13
     7       13 end.

Errors in program: 0
P6 Pascal AMD64/gcc 64 bit code generator vs. 0.2.x

Generating program

Program generation complete
Running with pgen
/usr/bin/ld: /tmp/cckCUvhi.o: in function `resetfn':
/home/samiam/projects/pascal/pascal-p6/source/AMD64/gcc/
psystem.c:1846: warning: the use of `tmpnam' is dangerous, better use
`mkstemp'
Hello, world
```

(obviously this is a working program).

Please cut the program down as much as possible, but still reveals the error. Typically this can be done by removing parts of the program that are not needed to demonstrate the issue.

15 Licensing information

Pascal-P6 is covered by the BSD license:


```
Note that the original project from which this code is based, Pascal-p4, was public domain. The
BSD license covers only the changes/and or additions made to the original source code. To
determine what is and what is not covered by public domain vs. the BSD license, compare the
original Pascal-P4 sources to Pascal-P6.

The easiest way to obtain the public domain portion of Pascal-P6 is to simply obtain the
Pascal-P4 source code, which is freely available online.
```

16 Using, copying, and obtaining and distributing this manual

This manual is covered by the same license as the software Pascal-P6. It may be freely distributed or printed. You may print and distribute the manual, whether for free or for profit.

16.1 Obtaining a printed version

A set of perfect bound manuals is available for $32.50. Please contact the author at samiam@moorecad.com for where to send the check and provide your shipping address.