PRIDE - II Physical Layout Program

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Modifying Forth for "Non-Believers"

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Abstract

What does one do to make Forth more palatable to IC and hybrid designers who need the power of a procedural layout language but don't normally program? The interactiveness of Forth helps to get them interested, but the alien environment doesn't help. This paper tells what was done to a standard Forth environment to make it more suitable to these engineers and scientists.

What PRIDE II does

PRIDE II is a CAD layout program used for designing integrated circuits, circuit boards, hybrids, and various other physical design tasks for which a mask style output is desired. One user has drawn schematics with PRIDE II, and I have used it to develop my office floor plan. Designs consist of cells, which can contain instances of other cells and primitive objects. Primitive objects include rectangles, polygons, wires (a path of fixed width), circles, and donuts, and can be "drawn" on any of up to 31 mask layers.

Cells can be designed with a graphic editor, which is part of the Forth program, but for highly repetitive or algorithmically designed features the cells can be designed using the procedural layout language, SLAP. SLAP is a wordset extension of Forth that adds cell descriptions to the design database.

A SLAP description for a cell containing two rectangles might look like this:

```
DEFINE 2-Rectangles      \ start the definition

POLY  10 10  20 20 BOX   \ draw a box in layer POLY with corners

                         \ at 10,10 and 20,20

METAL  30 30  10 DELTA  20 DELTA BOX \ and another in layer METAL

                         \ with a corner at 30,30 and width of 10

                         \ and height of 20

ENDDEF                   \ end the definition
```

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PRIDE II has features labeling and referencing connection points, as well as rotating, translating, scaling, and rounding the coordinates to make the design task easier.

The program can handle designs of any arbitrary size without concern for running out of memory because the SLAP definitions are executed when loaded rather than compiled. The Forth language was originally selected because its outer interpreter feature allows this.

Currently, PRIDE II is implemented in Laboratory Microsystem's PC/Forth+. The system runs on IBM PCs with the EGA display and a mouse.

Enhancements to Forth

When PRIDE was first released to designers within Tektronix, there was considerable rebellion because of the unusual environment presented by Forth. It was important, when developing the improved PRIDE II program, to present to the user an environment as close as possible to that with which the designer would be familiar. Part of the goal was realized by using PC/Forth+'s access to the host file system rather than a file system built upon screens. But changes still had to be made.

Virtually abolish screens

The original version of PRIDE required SLAP definitions to be placed in Forth screens. The awkwardness of the format, difficulty in editing across screen boundaries, and the requirement of learning yet another editor turned many potential users off. The solution was to allow loading from standard ASCII text files. Since all the source files were screen files, and I was quite happy using screen files, traditional loading had to be supported as well.

The command "INCLUDE filename" opens the given file (trying several filename extensions if none is supplied) then checks to see if it is an ASCII or screen file by looking for line feeds in the first 1k block. If the file is a screen file, a "1 LOAD" command is issued for it. If the file is ASCII, then QUERY is redirected so that the file appears to be lines typed at the keyboard (but without echo to the display). Tabs are converted to spaces so that tabs can be placed in the source files.

The ABORT process was modified so that the file name, error line contents and line number would be displayed if an error occurred during an ASCII file load. The system already gave this information for screen file loads.

As an extra added touch, an "include stack" was added so that INCLUDE commands could be nested.

New numeric formats

Let's face it, having a decimal point mean "double integer" is bizarre. Especially in a Forth environment offering floating point! The PRIDE II numeric input code was modified so that a number ending with a digit and containing a decimal point is considered to be a floating point number.

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Suffixes are used to indicate special number formats. An integer ending with "d" is used to represent a double integer. Since the standard integer format is 32 bits in PC/Forth+, double integers are rarely used.

The basic unit of measurement in PRIDE II is a centi-micron; all coordinates are stored as integers in centi-microns. To specify numbers in units of microns, centimeters, and meters the suffixes "u", "c", and "m", respectively, are added. When these scaling suffixes are used, the number can contain a decimal point. For instance "12300", "123u", and ".00123c" represent the same value.

To aid readability, commas may be placed in numbers. All commas are ignored for purposes of numeric conversion. "123,456", "2,103.5u", and "-0.314,159E1" are valid numbers.

"To" variables and arrays

The arcane words "@" and "!" are confuse most people. Executing variables in PRIDE II return their values rather than their addresses. To store into a variable, the word TO or IS is executed first. This concept, first presented by Paul Bartholdi in Forth Dimensions, Vol. 1, No. 4 (and attributed to Chuck Moore), adds to the readability of the cell descriptions and improves performance as well.

The concept was extended to include arrays and certain record structures. For instance "10u IS TOP_CABLE WIRE_WIDTH" sets the wire width entry of cable structure TOP_CABLE to 10 microns. In traditional Forth, the expression "1000 TOP_CABLE OFFSET.WIRE_WIDTH + !" would be needed, which is opaque to the "Non-Believer".

Transient definitions

Transient colon definitions were added to solve the problem of iterating while in interpret state. A transient colon definition is a nameless colon definition which executes and deletes itself immediately upon completion of compilation. A Forth implementation which always compiled its input, such as STOIC, would also solve this problem.

To make Forth more STOIC-like, yet keeping the advantages of Forth (DOES> words and faster interpretation), all of the control structure words were redefined to work with the transient definition facility. Thus the words IF, BEGIN, DO, ?DO, and CASE will cause a transient colon definition to start if executed in interpret state. The matching THEN, UNTIL, REPEAT, LOOP, +LOOP, and ENDCASE words will cause compilation to complete and the definition to execute.

Interpreted IF

To allow for conditional layout generation, the words #IF #ELSE and #THEN were added -- interpret state IF. #IF statements can be nested as deeply as desired.

Note that transient definitions do not eliminate the need for #IF since condititional layout frequently includes constant, variable, and colon definitions and definitions cannot be nested in Forth.

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Graceful function aborts

The file loading process, which is SLAP execution, can take several minutes because of the considerable amount of calculations that can be performed. Other data format conversion programs, part of PRIDE II, can also take several minutes. It is nice to be able to abort these functions without re-booting the system. Likewise, errors during these processes must recover gracefully without leaving the files open.

PC/Forth+ allows hitting the "Break" key to abort execution (by executing the word QUIT), but files are left open since the application routine is exited.

The solution to the problem was in abort routine chaining of QUIT. QUIT must be a vectored word (it is in PC/Forth+). When a program starts, or INCLUDE is executed, the program saves the current QUIT routine, and revectors QUIT to a new QUIT routine. Upon successful completion, the program restores the QUIT vector. If the program is aborted, either by the "Break" key or by error (ABORT processing ends with QUIT), the programs QUIT routine will be invoked. This routine closes any files used by the program and performs any other fixes (INCLUDE routine must unnest, for instance), it then restores the QUIT vector, and executes QUIT!

If program execution is nested, then all the QUIT routines will be successively executed from the innermost program out.

Conclusion

Most users of the PRIDE II system now find the Forth environment acceptable. Additional work still needs to be done in the area of error detection. Values on the stack need to be tagged as to their types so that type checking can be performed. This is now the most common mistake.

Users also would like strings handled in the same manner as other data types (passed on the stack). The consistency of Forth is not readily apparent to users who have not studied Forth implementation. While SLAP functions are passed string arguments on the stack, defining words and certain PRIDE II commands do not. STOIC has an intrinsic string literal which allows, in fact requires, defining words to be passed names on the stack.