$10 Volume XIV, Number 6 March 1993 April

FORTH DIMENSIONS

GETB and PUTB

Math—Who Needs It?

Charles Moore's Fireside Chat

One-Screen Unified Control Structure

Optimizing in BSR/JSR-Threaded Forth

Contents

Features

Departments

Editorial

What if Forth businesses and associations teamed up to improve general awareness of Forth? They'd have to do something they all could agree on, benefit from, and contribute funds for. Something like a public-service ad for trade journals: "Sure, Forth fosters innovation by enabling programmers to explore highly personalized methods of problem solving. Some of your best people probably use it already, or know something about it—that's no coincidence. But did you also know that today's Forth systems can accommodate the rigorous methods and conventions of well-managed programming teams? That multi-tasking and metacompilation are no problem—never have been—and that Forth can stand alone on its own considerable merits or peacefully co-exist with an operating system? Forth is a frequent flyer on the space shuttle, but also excels in earthbound applications like observatories, industrial automation, embedded controllers, medical/scientific instrumentation, and benchtop environments, not to mention consumer applications. Write or call for a free brochure and list of participating businesses..." Or, if funds were scarce, one might only be able to promote one of those low-brow, stick-in-your-mind jingles: "Go Forth, and *your* computer will say OK!"

* * *

Do you suffer from innumeracy in Forth, or just need a touch-up to your understanding about how to deal with digits? Dr. Ting's "Numbers" tutorial encourages beginners with the power of integer arithmetic. But if you need more than a beginner's dose, Prof. Tim Hendtlass' "Math—Who Needs It?" will further your understanding of different math packages, and will help you to choose the right routines—kindly provided—for the right jobs. (Hint: it's another instance in which too much power can corrupt performance.)

Speaking of performance, Windows makes an appearance in this issue. Forth for Windows has been implemented by two developers that we know of, Laboratory Microsystems, Inc. and Harvard Softworks. But for the determined, do-it-yourself hacker or the doggedly curious, not a lot has been forthcoming. Well, there's nothing like starting at the beginning, which would have to be reading and writing characters in the Windows format; see Hank Wilkinson's "GETB and PUTB" to get started.

One time, a hacker thought Forth had suffered long enough as a skeletal system with little help and no protection for the naive user. Thus was born a newer and better Forth with, among other things, a fully fleshed-out, interactive help and error-handling subsystem that relied on a separate stack to manage the many system-message strings. It was automatically invoked by the lower-level word `HEY!` (as in, "Hey, you clutz!") every time a user did something unexpected. But the system died in beta testing when a couple of Forth gurus agreed, "Serious programmers will find it hard, being needled by a `HEY!` stack." *[SFX: rim shot, groans]*

* * *

Just a reminder... We greatly value the continued participation of each reader and FIG member, so please renew by mail, telephone, or fax at your earliest convenience. At the same time, consider giving a subscription to *Forth Dimensions* to a business, library, or colleague. We will look forward to sharing with them—and with you—the good work of the Forth community.

—Marlin Ouverson

On the stack...

Advertisers Index

Forth Dimensions
Volume XIV, Number 6
March 1993 April

Published by the
Forth Interest Group

Editor
Marlin Ouverson

Circulation/Order Desk
Frank Hall

Forth Dimensions welcomes editorial material, letters to the editor, and comments from its readers. No responsibility is assumed for accuracy of submissions.

Subscription to *Forth Dimensions* is included with membership in the Forth Interest Group at $40 per year ($52 overseas air). For membership, change of address, and to submit items for publication, the address is: Forth Interest Group, P.O. Box 2154, Oakland, California 94621. Administrative offices: 510-89-FORTH. Fax: 510-535-1295. Advertising sales: 805-946-2272.

The Forth Interest Group

The Forth Interest Group is the association of programmers, managers, and engineers who create practical, Forth-based solutions to real-world needs. Many research hardware and software designs that will advance the general state of the art. FIG provides a climate of intellectual exchange and benefits intended to assist each of its members. Publications, conferences, seminars, telecommunications, and area chapter meetings are among its activities.

"*Forth Dimensions* (ISSN 0884-0822) is published bimonthly for $40/46/52 per year by the Forth Interest Group, 1330 S. Bascom Ave., Suite D, San Jose, CA 95128. Second-class postage paid at San Jose, CA. POSTMASTER: Send address changes to *Forth Dimensions*, P.O. Box 2154, Oakland, CA 94621."

Letters

Letters to the Editor—and to your fellow readers—are always welcome. Respond to articles, describe your latest projects, ask for input, advise the Forth community, or simply share a recent insight. Code is also welcome, but is optional. Letters may be edited for clarity and length. We want to hear from you!

Strength Mistaken

Dear Editor,

"A Lesson in Economics" by Russell L. Harris (On the Back Burner, *FD* XIV/5) was a welcome piece of additional ammunition I'll be able to use the next time I'm nagged to use a DOS machine for an embedded or instrument-control application. Mr. Harris hits squarely on several key problems that crouch waiting to pounce on the naive IBM PC enthusiast who falls for the mirage.

On another note, along with Walter J. Rottenkolber, whose letter to the editor appeared in the same issue, I too have to disagree with Mike Elola on his article (*FD* XIV/4) about styling Forth to preserve the "expressiveness" of C.

Part of Forth's strength will always lie in its simplicity. However, this same simplicity is wrongly viewed as a weakness when it lets a programmer write unreadable code. The lack of expressiveness Elola refers to (that is, the lack of clarity as to where the stack cells come from, what they are, and what consumes them) is due to how the words are arranged in the source code just as much as to poor commenting; and yet, so often I see code written such that the breaks between lines, the space between words, and the words' starting columns have almost nothing to do with what the code is supposed to do. I even see things like a `BEGIN` in the middle of a line, with its corresponding `UNTIL` buried somewhere in the middle of another line and starting in a different column. Mr. Elola's indenting may help, but I fear this will constitute overuse of indenting, defeating much of the purpose of indenting, which is to make structures and program flow more obvious.

I'm tempted to write an article about writing readable code. I believe Mr. Elola has correctly identified a common problem. What I don't agree with is that it's a weakness of Forth itself. There are several things about C that I hope I have left in my past for the most part, and those include piles of parentheses and punctuation.

A third subject matter— What's happening with those ultra-fast stack microprocessors I hear a little bit about here and there? One blurb I read recently cited 100+ MIPs (and Forth MIPs, at that) at a relatively low cost. This is certainly something I would expect to see get a lot of attention in *EDN*, *Computer Design*, and other trade magazines; yet I haven't seen a thing in those.

I was glad to see FIG would be at the Embedded Systems Conference *[see letter below]*.

Sincerely,
Garth Wilson
11123 Dicky Street
Whittier, California 90606

Thanks for your comments, Garth. Please do write that article about readable Forth code—it continues to be important. The most thorough treatment I recall was by Kim Harris, whose paper about coding conventions was presented several years ago at a FORML conference; and FIG distributes a cumulative index to FD *articles, which contains some references to Forth style (see the first two items on the mail-order form). But, as evidenced by much Forth code, those ideas either were not distributed well or were not adopted widely for some reason. Your further treatment of the subject might help.*

As to stack-oriented CPUs, we welcome press releases about real products, articles by developers, and the experiences of users—as would, I presume, other publications like those you mention. Meanwhile, check out the "More on Forth Engines" series on the FIG mail-order form in this magazine. —Ed.

Volvos Drove Him to Forth, & Forth's Missing Link

I have just returned from the Silicon Valley FIG Chapter meeting—have not missed more than four or five of them since June 23, 1990, when I first signed up. I enjoyed a chat with John and Frank Hall during the lunch break, and I want to follow up with the note I said I wanted to write to *Forth Dimensions*.

I am a mechanical engineer, have been designing cranes and heavy machinery for 30 years. I do not sing and dance like Leo Brodie, but I do drive old Volvos, and that is how I came to know Forth. You see, my wife and I started in computers when we bought our first Apple IIc; we started to look into the computer section at the library more often, and that is where, one day in April of 1990, the face of young Leo appeared on page v of the first edition of *Starting Forth*. I believe I had heard about Forth before that, probably through a Harris ad in one of the engineering trade magazines, and, seeing that a fellow who liked driving classic Volvos had written a book about it, I figured that Forth might not be all too bad.

Well, there is a long story of struggle, frustration, feelings of futility and defeat, but, even though I have not produced any masterpieces of Forth programming, I go to the meetings, I enjoy your magazine, I preach Forth. I have even gone to the torture of taking a C class at the local college, to see how bad things can be on the other side.

There are two reasons for me wanting to write this note:

First, I wish to thank you for publishing Olaf Meding's fine article, "Forth-Based Message Service." I understood it, liked it, and would like to see more articles with the same Fogg Index (or should I say "Fig Index?"). I have a problem with the arcane and esoteric articles that remind me of my early struggles with De Bello Gallico, organic chemistry, Laplace transforms, etc.

Secondly, I have to voice my concern that there is

something missing in the Forth community that would attract newcomers, or I would not still be the novice of the group almost three years after I joined. It seems that we can cater only to the seasoned Forth programmers, perhaps to some degree to other programmers, but beginners cannot find any "Forth kits," as I would like to call them, that are inexpensive, readily available, work, have good documentation, and allow one to experiment and create without frustration. I think there is a need for a Forth interpreter package that can compete at least with the likes of GWBasic, in terms of size, availability, documentation, graphics, and floating-point math. Have I missed it somewhere along the way?

Sincerely,
Henry Vinerts
36139 Chelsea Drive
Newark, CA 94560

Erratum

Olaf Meding, author of last issue's "Forth-based Message Service," is employed by Amtelco, 4800 Curtin Drive, McFarland, Wisconsin 53558; telephone 608-838-4194. The article was originally titled "To Boldly Go Forth Where No One Has Gone Before."

Embedded Systems Conference

Dear Mr. Ouverson,

I had the opportunity to browse the displays at the recent Embedded Systems Conference and see firsthand the hardware and software available. I was surprised at the number of sizzling, color-windowed, integrated C/C++ programming systems. Even the purveyors of Ada, the number two language there, tended to be a bit defensive. The once-ubiquitous BASIC was represented by only a couple of vendors. And Forth had only the Forth Interest Group waving the banner—a lonely island in the C's. Is the real world trying to tell us something?

These C compilers integrate an editor, syntax checker, compiler, and debugger that can work with either C or assembly source. Watch Expressions let you run C functions or display C variables interactively. In other words, these C systems seem to have a programming environment once exclusive to Forth. It would be interesting if someone familiar with both the new C compilers and Forth would compare them, especially regarding programming ease and productivity.

Programming controllers with the power systems would set you back $12,000 for software and hardware, and to this you would have to add a hefty computer. Most of the vendors' demonstrations used Sun workstations. But at the other end of the scale, ZWorld offers a line of Z180 controllers designed to be programmed with their $195 C compiler, which runs on a PC.

(Continued on page 16.)

GETB and PUTB

Hank Wilkinson
Greensboro, North Carolina

Working on my teaching certificate for high school physics at the University of North Carolina at Greensboro, it hit me that I want to use Forth in Windows when I teach. Since I earned my B. S. Physics previously at Guilford College (also Greensboro), only a year's study remains for my certification. This article describes simple commands found useful exploring Windows' files.

What do I mean by "use Forth in Windows"? Here is what I think I mean:

a) load Forth code contained in *.WRI files
b) write from Forth into *.WRI files
c) draw from Forth into *.BMP files
d) be "in" Windows when in Forth

Note that vectoring KEY and EMIT will not achieve any of the above goals. The first three goals require knowledge of the Windows data files. Simply put, the last goal requires knowledge of how Windows works. Frankly, a vendor could easily solve my dilemma.

Meanwhile, concepts described in *Software Tools* (Kernighan and Plauger; Addison-Wesley, 1976) help. Analogous to K&P's getc and putc, I have made GETB and PUTB. GETB reads exactly one byte from a file and leaves it on the stack. PUTB writes one byte from the stack into a file.

So you may follow, here is my system. My computer is a VSI PC '286 name-brand "compatible," with VGA, 40-meg hard drive, both a 5.25" and a 3.5" floppy, a mouse, HP DeskJet 500, a modem, and four megs. of memory. I have DOS 5, Windows 3.1, and HS/Forth (regular—i.e., uses segmented memory).

I learned of HS/Forth and VARs in this journal, so will only review them. A VAR is a data structure with the behavior of both VARIABLEs and CONSTANTs, while faster than either. CONSTANT-like, a VAR's value goes to the stack upon use. VARIABLE-like, the VAR's new value comes from the stack by placing IS before the use of the VAR. Later uses of the VAR return its latest value.

Refer to the code at the end of this article. First we define TRUE and FALSE. Next, the handle and end-of-file-flag containers appear. Initializing the file's handle to TRUE (as opposed to FALSE) will not confuse an unopened file with the handle for the keyboard. For the end-of-file flag, logic dictates an unopened file has reached its end.

HS/Forth's MS-DOS system interface may be set to ABORT with a message upon error condition (FATAL), or pass the error on (INFORM). The words defined here assume HS/Forth will ABORT, giving immediate feedback

To open a file for reading, we pass the address of the file's path\name to the HS/Forth word OPEN-R wrapped inside OPEN-GETB. Any error leaves G-H and G-EOF set TRUE. If successfully opened, G-H receives the file's handle and G-EOF receives FALSE.

To close the file, HS/Forth's CLOSEH is used. The file's handle goes on the stack for CLOSEH, which ABORTs upon any error condition. In that case, the VARs do not get touched. Otherwise, CLOSE-GETB closes the file and sets G-H and G-EOF to TRUE.

GET-BUF serves as the buffer for MS-DOS to put the byte read. HS/Forth's READH needs the memory segment, offset, number of bytes to read, and the handle. GETB encapsulates these functions and sets G-EOF. Notice that a successful read will return one byte. Reading past the end of file returns a zero (FALSE), and sets G-EOF TRUE.

Using GETB on, say, "c:\path\filename.ext," we first open the file. From the command line,

```
$" c:\path\filename.ext" OPEN-GETB [Enter]
```

does that. If successful,

```
GETB . [Enter]
```

would display the byte's value, while

```
GETB EMIT [Enter]
```

would display the byte as an ASCII character. To determine if a byte read is valid, consider this code.

```
GETB G-EOF . [Enter]
```

A zero (FALSE) displayed indicates a valid byte, while -1 (TRUE) shows the byte did not actually come from the file. Once finished playing, we issue:

```
CLOSE-GETB [Enter]
```

Now find the example code after the definition of GETB. A double number DVAR COUNTER holds a count of the number of bytes in a file. The routine COUNT-BYTES expects an opened file and proceeds counting bytes until G-EOF becomes TRUE.

Notice the test for the end of file inside the loop yields zero for an empty file or an unopened file. At any rate, COUNT-BYTES counts the bytes, while COUNT-FILE performs administration.

Writing to a file is slightly simpler than reading. We only need a VAR to hold the P-H (put handle). OPEN-PUTB makes use of HS/Forth's MKFILE, which creates or erases an existing file. The handle passed by MKFILE goes into P-H.

CLOSE-PUTB is analogous to CLOSE-GETB.

PUTB stores the byte on the stack in the PUT-BUF and passes the memory segment, offset, byte count, and handle to WRITEH, which returns the number of bytes written.

Testing the actual number of bytes written serves as error checking.

For an example using PUTB, we show copying a file. Buffers for filenames make the process easier. The names GB$ and PB$ allow quick typing. In COPY-FILE, the user is shown the path\filenames from both buffers. Either a "Y" or "y" are required for copying to take place.

With a proper response, the corresponding files are opened and the copying—byte by byte—begins. As soon as the end-of-file flag is found TRUE, the copying stops and the files are closed. During copying, any key hit stops the process.

These routines are simple to use and understand, and are robust enough for use from the command line. Their simplicity allows easy modification. For something to get into use quickly, use them as is.

From time to time, the need for faster file-handling code becomes apparent. In that case, use larger buffers and design buffer handling. (I have spent more time optimizing code than I have saved by executing optimizing code. Routines shown here reflect that experience.)

GETB and PUTB form crucial elements of routines I used exploring Windows' files. One routine counts the frequency of bytes. Another finds the occurrence of arbitrary byte patterns. A third routine creates a file dump. The ability to read and write one byte at a time is fundamental.

Hank Wilkinson and his wife of nineteen years have two children in high school and one in elementary school. He has been employed in the construction trade (five years) and in the wholesale supply business (thirteen years), and operated his own programming firm (five years). Currently, he is a graduate student working on public school teacher certification. He has used Forth for twelve years.

```
 0 VAR FALSE
-1 VAR TRUE

TRUE VAR G-H     \ Get-Handle storage
TRUE VAR G-EOF   \ Get End Of File flag
                 \ TRUE = EOF, FALSE = not EOF

\ use: $" \path\filename" OPEN-GETB
:  OPEN-GETB  (  address  --  )
   OPEN-R ( addr -- handle )
   IS G-H
   FALSE IS G-EOF ;

\ use: CLOSE-GETB
:  CLOSE-GETB  (  --  )
   G-H CLOSEH
   TRUE IS G-H
   TRUE IS G-EOF ;

CREATE GET-BUF 1 ALLOT \ 1 byte buffer

\ use: GETB
:  GETB  (  --  byte  )
   \ G-EOF TRUE,  invalid file byte
   \ G-EOF FALSE,   valid file byte
LISTS @ GET-BUF 1 G-H READH
0= IF TRUE IS G-EOF FALSE EXIT THEN  \ file empty
 GET-BUF C@  ;

0 S->D DVAR COUNTER

\ use: COUNT-BYTES
  ( file must be open, counter cleared

:  COUNT-BYTES  (  --  )
BEGIN
 GETB DROP
 G-EOF FALSE = WHILE  \ ie., not end of file
    COUNTER 1 M+ IS COUNTER
    ?TERMINAL IF EXIT THEN
REPEAT ;

\ use: $" \path\filename.ext" COUNT-FILE D.
:  COUNT-FILE  (  n  --  d  )
\ n = offset of counted string to file's \path\name
CR ." Counting bytes in " DUP COUNT TYPE CR
." Hit any key to stop." CR
0 0 IS COUNTER  \ clear count to start
OPEN-GETB
COUNT-BYTES
CLOSE-GETB
COUNTER ;

 TRUE VAR P-H   \ Get-Handle storage

\ use: $" \path\name" OPEN-PUTB
:  OPEN-PUTB  (  address  --  )
   MKFILE ( addr -- handle )
    IS P-H ;

\ use: CLOSE-PUTB
:  CLOSE-PUTB  (  --  )
   P-H CLOSEH
   TRUE IS P-H ;

CREATE PUT-BUF 1 ALLOT \ 1 byte buffer

\ use: 0 PUTB ( writes 0 to file )
:  PUTB  (  byte  --  )
PUT-BUF C!
LISTS @ PUT-BUF 1 P-H WRITEH
0= IF ." Write error! " EXIT THEN ;

\ FILE NAME HOLDERS
CREATE GB$ 128 ALLOT \ GETB file name
CREATE PB$ 128 ALLOT \ PUTB file name

\ initialize filenames to something
$" GETPUT.FTH" GB$ $!
    $" XX.FTH" PB$ $!

\ use: ( filenames string variable already set )
\      COPY-FILE
:  COPY-FILE  (  --  )
CR
   ." Copying file named " GB$ $.
CR ."     into file named " PB$ $.
CR ." Is this correct? (Y/y)"
   KEY ASCII Y OVER = SWAP ASCII y = OR
    IF   ." Okay, we're copying. "
    ELSE ." Not Copying" CR EXIT THEN
CR ." Hit any key to abort COPY-FILE."
CR

 GB$ OPEN-GETB
 PB$ OPEN-PUTB

BEGIN
 GETB
 G-EOF FALSE = WHILE
    PUTB
 ?TERMINAL IF ." Quiting, so delete partial file." CR
              CLOSE-PUTB CLOSE-GETB EXIT THEN
REPEAT
DROP \ drop spurious byte read when file was empty
CLOSE-PUTB
CLOSE-GETB ;
```

One-Screen Unified Control Structure

Gordon Charlton
Hayes, Middlesex, U.K.

This article was prompted by Kourtis Giorgio's Curly Control Structure Set. Giorgio stated that his intention was to include every good idea he had come across. This turned out to be a good many good ideas, so Giorgio has provided the archetypal Fat Forther's solution. Although I am not a devout minimalist, I do concur with the principal that less is more. Therefore I pose the question, What is the smallest group of words that constitutes a workable control set?

Three Non-Solutions

The ultimate reductionist solution is ?GOTO. This is not a solution, as it is unstructured. It is demonstrable that a zero-tripping FOR NEXT can be coerced into sufficing, at the cost of outrageous inefficiency and complexity. This is not a viable solution. One can also get by with IF, THEN, and RECURSE. Although popular with the AI community, this solution does have certain problems with efficiency and readability. Therefore, this is not a solution either.

The Solution

Although three words do not cut the mustard, we will see that four words are enough. In fact, I will introduce two extra ones, for convenience and to remove a slight inefficiency. The Unified Control Structure (UCS) is derived from two previous proposals which do not appear in Giorgio's comprehensive bibliography: they are the Hainsworth Extended Case and the Universal Delimiter.

One Screen

When commencing a project, I will often attempt to come up with a solution that fits within one screen. This is a very rigid discipline and focuses the mind excellently. A lot has to give in compressing code into a space with an absolute limit of one thousand and twenty four characters. Certainly, neat presentation goes out the window, along with potentially meaningful names, stack comments, and even the title line. Naturally, one tries to retain as many of these as possible. More importantly, everything that is trivial or superfluous has to be stripped out mercilessly. This leaves only the core of the program, its essence. Divining the essence of a problem is the beginning of understanding.

Normally I would throw away the one-screen version once it was stable, and start coding a fuller solution afresh. As the primary design criterion here is brevity, I present the one-screen version in all its muck and glory.

Comparison

Although prompted by the Curly Control Set, I will compare UCS to the ANSI control set, as I do not wish to do Giorgio any injustices by erroneously criticizing a wordset that I am not familiar with.

Syntax

A control structure starts with BEGIN and ends with either END or AGAIN. Within a structure, any number of WHENs may appear. WHEN must be paired with END or AGAIN. WHEN substructures may not be nested. BEGIN structures, however, may be nested. WHILE is functionally equivalent to 0= WHEN END, and should be treated as a WHEN pair for syntax purposes. The same considerations apply to UNTIL, which is equivalent to 0= WHEN AGAIN.

Semantics

BEGIN has no run-time action, it simply marks the beginning of a structure. The END that pairs up with BEGIN equally has no run-time action. AGAIN, whether paired with BEGIN or WHEN, gives an unconditional branch to just after BEGIN. END, when paired with WHEN, gives an unconditional branch to just after the final END or AGAIN. WHEN takes a flag. On false, it skips to just after its closing END or AGAIN. On true, execution continues sequentially. As stated above, WHILE has the same action as 0= WHEN END, but is more efficient. On false, it skips to just after the final END or AGAIN. Otherwise execution continues sequentially. Similarly, UNTIL is more efficient than 0= WHEN AGAIN. Execution continues just after BEGIN on false, and sequentially otherwise.

Usage

Usage is compared to the proposed ANSI control set on screens two and three of the accompanying listing . BEGIN AGAIN is the same with both ANSI and UCS. BEGIN AGAIN is one of two basic structures in UCS. The other is BEGIN END. BEGIN END has no equivalent in ANSI. It does not affect the flow of control at all and is, therefore, the structural equiva-

Figure One.

```
BEGIN
      [ ... WHEN ... END/AGAIN ]
      [ ... WHEN ... END/AGAIN ]
         .
         .
         .
        ...
END/AGAIN
```

Figure Two.

```
UNTIL   ==   0= WHEN AGAIN
WHILE   ==   0= WHEN END
```

lent of a no-op. Nonetheless, it does have a use. When one has chosen not to factor out a long definition, it serves to delimit logically distinct sections of code for readability purposes.

As with all variations on UCS, the simple WHILE loop is an extension of one of the basic structures, in this case BEGIN AGAIN. This is simpler than ANSI, which requires a new word to be introduced: REPEAT.

The simple UNTIL loop loses out in UCS for complexity, requiring a terminating END.

IF and IF ELSE are notably worse in UCS, although one small redeeming feature exists. The BEGIN can be used to delimit the test preceding the WHILE or WHEN, in the same way that CASE is used. (I.e., one writes CASE KEY 65 OF etc. instead of the equivalent KEY CASE 65 OF etc.)

The UCS equivalent of the CASE statement is rather more general, and is better compared to the LISP COND or the Occam extended IF. The extra code in the illustration (the DUPs, etc.) shows what typically would be required to simulate an Eaker CASE.

On the final screen is what may be deemed advanced usage of the ANSI set. The first structure is more understandable in UCS, as the exit conditions (a) and (b) are positioned next to the decision to branch, rather than at the end of the structure in reverse order (!). It is, however, less efficient, as leaving via condition (a) incurs an overhead of one unconditional forward branch in UCS. Given that this only occurs with the first exit path, no matter how many WHENs are present, this is not too detrimental.

ANSI, on the other hand, starts to suffer as the number of WHILEs increases, as one hops and skips out of terminating ELSE ... THEN ELSE ... THENs. It is perfectly possible to use WHILE ... ELSE in ANSI to avoid this but, as I have never seen the construct published, must assume that this is not typical usage. The 0=s are irrelevant, and are merely there to indicate that the logic of WHEN is reversed with respect to WHILE. (WHILE ELSE, in ANSI, would also demand reversed logic to WHILE.)

The ANSI rationale (at least the first draft proposal) states, "The use of more than one additional WHILE is possible but not common." This is convenient, as two exits represents about the limit of legibility. This is illustrated with the final example, which is less than crystal clear in ANSI. (In case you were wondering, if the first WHILE succeeds, the section labeled (a) is executed and the structure exited. If the second WHILE succeeds, (b) is executed and the structure left. If the third, then section (c) runs and execution continues at the BEGINs. If none succeed, execution continues at the BEGINs.) This took some time to construct, whereas the UCS equivalent was trivial. UCS suffers no increase in complexity as the number of WHENs increases. Perhaps the use of more than one additional WHILE would be more common, if not for its complexity and unreadability.

ANSI is complete, in that it can be used to create any conceivable system of branches, but there comes a point when GOTOs would be more comprehensible. UCS, on the other hand, is not complete, but does deliver a useful subset without

Figure Three.

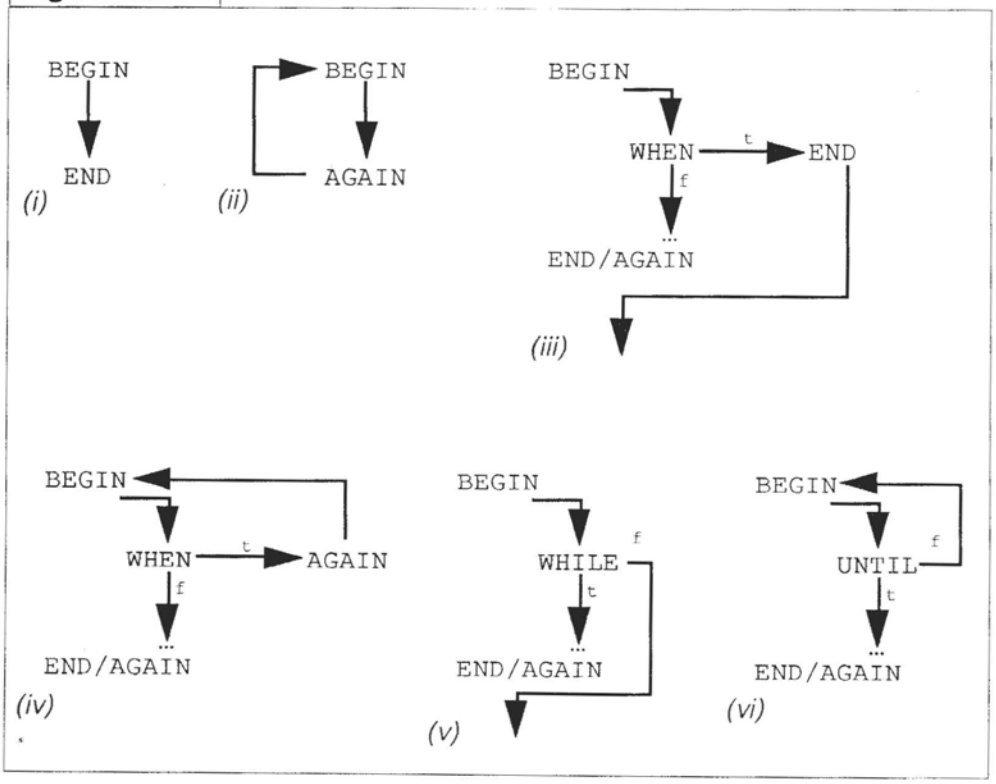
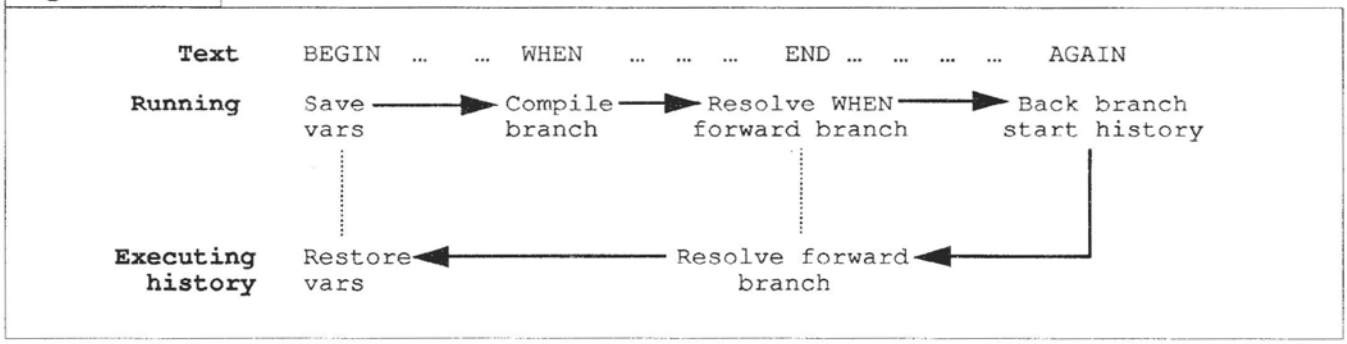


Figure Four.



increasing complexity. It is not compatible with previous systems, but the effects of maintaining compatibility at any cost are amply illustrated by the development of the IBM PC. You pays your money and you takes your choice.

Assumptions

In order to fit the code into one screen, certain assumptions have been made. It is assumed that the words BRANCH and ?BRANCH are present, and that they expect the following cell in the code space to contain an absolute address for them to branch to. Furthermore, it is assumed that the code and data space are contiguous, so that it is meaningful to use HERE and , (comma) to provide these branch addresses. Finally, it is assumed that the compilation stack is the data stack.

Stack Comments

Although I have been able to retain stack comments in the space available, they are rather terse and deserve some explanation. "a" represents an address and "e" an execution token. Where a word finishes with EXECUTE, the stack comment assumes that the EXECUTEd word has no stack effect. The comments for IMMEDIATE words show the compile-time stack effects only. At run time, the words BEGIN, END, and AGAIN have no stack effect, and WHEN, WHILE, and UNTIL absorb a flag.

Overloading

In order to reduce the number of structure words, AGAIN and END are overloaded, each having two distinct operations depending on context. This is achieved by using vectored execution. BEGIN sets the execution vectors 'E and 'A to the actions associated to closing a BEGIN, B-END, and B-AGAIN. WHEN sets them to W-END and W-AGAIN. When a WHEN is closed, 'E and 'A are reset—by W-END or W-AGAIN—to B-END and B-AGAIN, respectively. To allow for nesting, the contents of 'E and 'A are saved on the stack by BEGIN and are restored when the structure is complete.

Resolving Backward References

The address in the code being compiled when BEGIN is encountered is held in a variable B-H (BEGIN-HERE) so that it is accessible at all times, and backward references can be resolved when they are encountered. To allow for nesting, the contents of B-H are saved on the stack by BEGIN and are restored when the structure is complete.

Resolving Forward References

There are two types of forward references. The simpler is that created by WHEN. The address to be filled is left on top of the stack, and is resolved by the WHEN's closing partner. When the partner is END, a forward reference of the second type is made. This cannot be resolved until the final END or AGAIN is reached. Each of these forward references is covered on the stack by an execution token, to form part of the executable history.

The Executable History

As a control structure is written into the code space, a program is built up on the stack, which will be executed when the control structure is completed. BEGIN lays down the first part of this program, which is called FINISH and will be the last part to be executed before control is handed back to the compiler. It has three data items associated with it, which are the original values of the three variables. FINISH restores these, allowing nesting to work. Above FINISH may come zero or more E-RES's, whose function is to resolve one unresolved forward reference each. E-RES forces execution of the stack program to continue, by ending with EXECUTE. The final END or AGAIN initiates execution by also ending with EXECUTE.

Glossary

Variable 'E ;
Execution vector. Contains execution token for END.

Variable 'A ;
Execution vector. Contains execution token for AGAIN.

Variable B-H ;
Contains HERE when BEGIN was executed.

Colon FINISH (e e a) ;
Executable history word. Restores variables, terminates history execution.

Colon E-RES (e a) ;
Executable history word. Resolves forward branch from W-END, continues history execution.

Colon B-END (e) ;
Vector word. Called by END when paired with BEGIN, initiates history execution.

Colon B-AGAIN (e) ;
Vector word. Called by AGAIN when paired with BEGIN, compiles branch to BEGIN, initiates history execution.

Colon B-E,A ( ) ;
Sets execution vectors to actions associated with BEGIN.

Colon W-END (a--a e) ;
Vector word. Called by END when paired with WHEN. Resolves WHEN's forward branch. Compiles branch to be resolved during history execution, and places HERE and E-RES on stack. Calls B-E,A.

Colon W-AGAIN (a--a e) ;
Vector word. Called by AGAIN when paired with WHEN. Resolves WHEN's forward branch. Compiles branch to BEGIN. Calls B-E,A.

Colon BEGIN (--e e a e) ;
User word ( ). Saves variables on stack, places FINISH on stack to be executed at end of history execution. Calls B-E,A.

Colon WHEN (--a) ;
User word (f). Compiles conditional forward branch and leaves address to be resolved on stack. Sets execution vectors to WHEN action.

Colon END ( ) ;
User word ( ). Action specified by 'E.

Colon AGAIN ( ) ;
User word ( ). Action specified by 'A.

Colon UNTIL ( ) ;
User word (f). Compiles conditional branch to BEGIN.

Colon WHILE (--a e) ;
User word (f). Compiles conditional branch to be resolved during history execution. Places HERE and E-RES on stack.

Compiler Security

Compiler security is not included in the code presented here, because of space considerations. Standard techniques can be used, and the syntax is sufficiently simple and rigid that all illegal constructs are readily detected. Overloading END and AGAIN reduces the number of possible illegal constructs.

Extensions

The use of the executable history technique means that any extension may be added without altering existing code. Certain constructs are poorly named and would benefit from synonyms. Unfortunately, IF (ELSE) THEN would have to be quite smart, and probably could not be written in terms of existing words. I have not attempted to incorporate counted loops, as I have certain opinions on this subject which would distract from the intent of this article. Best to let sleeping dogs lie, as the old saw goes.

Conclusion

At its most spartan, a powerful control set can be constructed out of four words (UNTIL and WHILE do not add any functionality to the word set). More importantly, the disparate control structures can be unified into a single adaptive structure. The prices to pay are non-compatibility and overloaded operators.

References

Kourtis Giorgio's Curly Control Set (brilliant name, reminds me of a British advertising slogan: "Watch out, they taste curly!") appears in *Forth Dimensions,* XIII/6 and XIV/1.

The FOR NEXT demonstration referred to in the second paragraph was made in *Forthwrite* issue 47, in the article about Loopy, a minimal subset language. *Forthwrite* is the FIG-UK chapter magazine.

The one-screen discipline was suggested by Mike Lake in *Forth Dimensions,* XIII/3.

Chris Hainsworth's Extended Case appears in *Forthwrite* issue 40. This gave the basic structure of UCS.

The Universal Delimiter appears in *Forthwrite* issue 53 and shows an extension of the techniques used in UCS.

The comparison with ANSI is based on Wil Baden's marvelous pieces in the *FORML Proceedings,* particularly '89 and '90.

My opinion of DO LOOP is expressed in more issues of *Forthwrite* than I care to mention. Of particular relevance here is issue 47, which melds it into the Hainsworth structure; and issue 58, which proposes a radical refactoring.

Gordon Charlton is a part-time hobbyist programmer and full-time house-spouse who migrated to Forth from LISP and Pascal after a Turkish friend told him that Forth was a weird language and that he would consequently like it. He was right. Gordon is also, probably, the world's only Loopy programmer. He is currently the Events and Meetings Secretary of FIG-UK, and contributes regularly to *Forthwrite.* His last major project was a string-pattern matcher which was presented at euroFORMLs '91 and '92. If anyone can provide a rigorous description of the Ratcliffe-Obershelp algorithm, he would be pleased to hear from them.

One-Screen Unified Control Structure

```
\ One-Screen Unified Control Structure      G Charlton  27Sep92
variable 'E    variable 'A    variable B-H
: FINISH ( a a a)  b-h !  'e !  'a ! ;
: E-RES ( e a)  here swap !  execute ;  : B-END ( e)  execute ;
: B-AGAIN ( e)  compile branch  b-h @ , execute ;
: B-E,A  ['] b-end 'e !  ['] b-again 'a ! ;
: W-END ( a-a e)  compile branch  here 0 ,  here rot !
                                          ['] e-res  b-e,a ;
: W-AGAIN ( a) compile branch b-h @ , here swap !  b-e,a ;
: BEGIN ( -a e) 'a @  'e @  b-h @  here b-h !  ['] finish
                                            b-e,a ; immediate
: WHEN ( -a)  compile ?branch  here 0 ,  ['] w-end 'e !
                                  ['] w-again 'a ! ; immediate
: END 'e @ execute ; immediate : AGAIN 'a @ execute ; immediate
: UNTIL  compile ?branch  b-h @ , ; immediate
: WHILE ( -a e) compile ?branch  here 0 , ['] e-res ; immediate


\ Screen 2
\ One-Screen Unified Control Structure -- Usage

 BEGIN ... AGAIN             -> BEGIN ... AGAIN

 BEGIN ... WHILE ... REPEAT -> BEGIN ... WHILE ... AGAIN

 BEGIN ... UNTIL             -> BEGIN ... UNTIL END

 IF ... THEN                 -> BEGIN WHILE ... END

 IF ... ELSE ... THEN        -> BEGIN WHEN ... END ... END

 CASE ...                    -> BEGIN ...
      ... OF ... ENDOF            dup ... = WHEN drop ... END
      ... OF ... ENDOF            dup ... = WHEN drop ... END
      ... ENDCASE                 ... drop END


\ Screen 3
\ One-Screen Unified Control Structure -- Usage, continued

 BEGIN ... WHILE             -> BEGIN ... 0= WHEN ... (a) END
       ... WHILE                      ... 0= WHEN ... (b) END
       ...                            ...
 REPEAT                          AGAIN
 ... (b) ELSE ... (a) THEN

 BEGIN BEGIN ... WHILE       -> BEGIN ... 0= WHEN ... (a) END
             ... WHILE              ... 0= WHEN ... (b) END
             ... WHILE              ... 0= WHEN ... (c) AGAIN
             ...                    ...
 REPEAT                          AGAIN
 ... (c) [ 2 ] SO REPEAT
 ... (b) ELSE ... (a) THEN
```

Charles Moore's Fireside Chat '92

As related by C.H. Ting

Chuck discussed the newly released 386 OK, its implementation and its philosophy. OK is the next incarnation of Forth. It has many of Forth's attributes, but is simpler and more powerful. It exists in code only, no source. The best way to deal with a computer is through its code—not the source, which is only a description of the code, not the code itself. "The map is not the territory; a description is not the program." Chuck also discussed his CAD implementation on OK and the general characteristics of the P21 chip, which is under development.
—Dr. C.H. Ting

OK is the future of Forth. It is what Forth should become. For 20 years, I tried to make Forth more readable and more compatible to other programming languages. Now, I give up. The problem is fundamental. All programming languages, including Forth, are text-based languages. The problem is intrinsic, in that the language is used to describe a program. A text-based language has problems in syntax, like infix notation... Forth has less trouble in this respect, but it is still a description, not the program itself.

Forth has the advantage that the source and object code are all accessible to the programmer. The programmer can express himself and modify his code quite freely. The industry is moving in the opposite direction. Intel goes out of its way to make it difficult for programmers to modify code in the code segment. There is a dialectic contrast here. Forth empowers the programmer, but the establishment wants constraints and control.

The problem in programming languages is the syntax of the underlying text. English description of a program is impossible, just as symbolic expression of mathematics is impossible. Goethe said that mathematical truth cannot be proven. Symbology cannot be the description. It is impossible to describe a program by text. A program is best expressed by the binary bits, but the binary bits have no intrinsic meaning. A program runs; it does what you want to control. Text, the description of the program, cannot do it.

In OK-CAD, you have all the code you need to deal with the task you have to do, and that's all there is to it. There is no source. The closest thing to the source code are the pages of notes I keep in a binder. The temptation to document the code is strong, but the value is nil.

OK is not text based. The map is not the territory. Description is not the real thing.

The industry is very much in virtual reality, in modeling and simulation. Boeing is very strong in modeling on computers. Mechanics would not agree that the models would work. It is a typical GIGO, garbage-in, garbage-out.

OK exists in code. It allows you to do whatever you want. Never mind how it came to being. I wrote it first using DEBUG... Most of the time I trust the code is there and I don't worry about it. OK is the incarnation of Forth in the '90s.

Forth is based on a virtual machine with two stacks. Phil Koopman, Jr. said in a recent paper that Forth is a way of factoring. Forth is kind of modular, and OK is very modular. I will give you a few examples. The names in OK are spelled funny. The most common symbols are the arrows: ^ (the up arrow), v (the down arrow), > (the right arrow), and < (the left arrow). I used them often and consistently. ^ always means increase, moving up, and so forth. Here are some words:

```
:  ^   1 CHANGE  ;
:  v   -1 CHANGE  ;
:  >   100 CHANGE  ;
:  <   -100 CHANGE  ;
```

These fragments are used very often. In fact, I have 12 versions of them in OK and CAD. Since they are used so often, one might want to code a generic version which could be used everywhere. In a generic version, you may want to clip the value in the register, and do other things like range checking, etc. However, a universal version does not exist. Instead, I have a universal construct like this:


```
CHANGE ... AX +! ;
```

Using the 386 machine instructions, each invocation of CHANGE uses only three 386 instructions. Here, a high-level language is not helpful. These small pieces of code fragments are best done in machine code.

Most of the code is not in subroutines, it is in code fragments to be jumped to, not called. You jump to a piece of code. Eventually you jump to another menu, not return to some caller.

Look at all the computer applications. Most often you are presented with a screen, which gives you some choices. You scroll the screen, sometimes call other screens and use some keys to make the choices. The meaning of keys changes with the context. Giving each key a special name will get you into trouble, because after the context changes the keys will have completely different meanings. The context is the whole screen. You do not need to have a word displayed on the screen to tell you what the screen context is.

I use the 386 only as a historic instance. OK is really designed for P20. When P20 is available, it will have OK and eForth. OK is more intuitive to use. It is easy, and you can use it to explore P20. If we make thing easy to get into, machine language programming can be taught in grade school. I am persuaded enough to build it and use it in the last four years. You should carefully monitor what I am doing, and jump in, if you will, when you are ready.

The CAD system is now complete. I have not spent much time changing it. The last thing I added was design rule checking. I originally thought it was not necessary; the chip should be correct by design, not by checking. However, I have to do it to convince myself that the design does not have any problem. I thought about it for a long time, about a month, before I started coding. I had one page of notes scribbled on a piece of paper, and I spent a couple of hours coding it. Rule checking has been a hot topic in the IC industry. There are a number of algorithms. The one I chose was the one everybody else rejected, of course.

I kept a table of rectangles in memory. The layer of first metal is the most complicated, and it has 20,000 rectangles. I simply compare the rectangles one by one to see if any two of them get too close. The code is very short, but it takes a long time to run through 20,000 x 20,000 comparisons. It took half an hour to check the first metal layer. This is the longest program I ever ran on OK. The other layers are much simpler, and take about ten seconds to run through. The rule checker stops when an error is detected, and the screen shows the tiles around the erroneous rectangles, with the cursor sitting on one of the rectangles. I can correct the mistakes and run it over again.

The code of this design rule checker is only a few hundred bytes long. It is so small because of Forth. I indeed have a Forth system, well factored and easy to use.

Questions from the Audience

Does OK have two stacks?

OK has one stack for subroutine calls and for temporarily storing register contents. I have a virtual data stack in the 386 registers. The order is AX, BX, BP, and so forth. The registers are generally used in that order. My convention is that, in a subroutine, all the registers are assumed to be free to use. The caller is responsible for saving and restoring registers that might get changed. This practice is, again, contrary to other conventions. It was done just to irritate people.

How did you implement OK on a '386?

The 386 is a very complicated machine. It has more than 500 instructions. I keep a well-thumbed Intel 386 manual. P20 has only 28 instructions and I have memorized all of them. Most people would start with a cross-compiler. Implementing 386 OK, I started using DEBUG to enter the code until the menu system worked. Then I could modify the system and add new code by using OK itself. For major changes, I still use DEBUG.

Is OK an 'O' and a 'K' or is it 'Zero K'?

Let me say a few words about the CAD system.

I did the chip layout in tiles. There are 600 x 600 tiles in the P20 design. Each tile has five layers, internally represented by a 32-bit word. The entities contained in a tile have different meanings depending on where they are. The meaning of the layout cannot be carried in words, but they are carried fully in the tiles.

Most CAD systems try to use symbolic description of the layout of a chip. I used it to lay out the pads around the core of the chip. I used it in ShBoom because I didn't have enough memory to hold the pads. The symbolic description was terrible. I cannot move them easily, and I cannot align them to the coordinates I want, so that the pad can be connected correctly to the signal traces. Finally, I moved the design to 386 OK, which has more memory. All the pads were laid out in tiles and the problems disappeared. The best representation of a picture is the picture itself, not its description.

OK is distributed in code. How can other people contribute to OK?

OK takes 64 Kbytes. People can change it and build new applications in the 64K chunk. We can collect these images and distribute them on a single floppy disk.

Compatibility is a taboo, here. I have no intention to make OK system compatible. The code of OK 1.1 on Novix, OK 2.1 on ShBoom and OK 3.1 on 386 are all similar but not identical.

You have no source listings. How do you move OK to a new processor?

The most important structure in OK is the menus. The menu structure can be implemented on any processor, using different techniques. The details will change, but the menu structure will be the same. You can get much closer to a machine without a language. It is like music and the score. The score is not the music. Different musicians play the same score. Some will produce beautiful music, others will produce terrible music—even if they all play correctly according to the same score. There are lots of things the score does not tell about the music.

Getting back to P20, MuP21 will be out in another week, and OK 4.1 on P21 will be the ultimate OK. So far, the chip doesn't work. However, I followed the sequence of evolution without the benefit of working silicon. The design has been changed and improved greatly since it was first conceived. It got simpler. An example is the master clock. I started with one clock, then it was necessary to have a second. The synchronization between the two clocks became a real problem. Now there is no clock. I am using an analog delay line to control the timing. The circuits are much simpler and more powerful.

The reasons the chip didn't work were many. The key suspect is the distance between rectangles. The design rules published by the manufacturers are not clear what the distance really means. Is it the absolute diagonal distance between corners of rectangles or the lateral distance between the edges of the rectangles? I have to move to a fail-safe direction, consistent with my understanding of the rules.

The chip area is 100 mil square. It is divided into 600 x 600 tiles, which I laid out one by one. The image of the layout is 1.5 Mb in size. I converted the tiles into rectangles, and saved the rectangles to a file. Interestingly, the rectangle file is also 1.5 Mb. The rectangle file is then ZIPped down to 300 Kb.

The code of CAD is about 3 Kb. Very small, compared to industry standards. The risk of software is that it becomes bigger and more complicated. Simpler software is always more reliable. 700,000 lines of code cannot be reliable. You cannot check them all. Simpler software means that you can check it completely... I read that the problem of the Patriot missile was traced to its floating-point calculation. In a long sequence of calculations to follow the trajectory of the target missile, the truncation errors in the floating-point calculation made the missile unworkable. I was a great believer in software until I learned hardware.

In developing the P20 chip, I rely heavily on my simulator. I want to trust my simulator, but it is not yet proven. If I get the simulator proven, I will be able to move on to design other chips. I have lots of chips lined up in the pipeline to be designed.

How do you decompile the machine code?

P20 code can decompile very easily into Forth. However, there is no room for comments. One important clue is the names, which one can assign to any location in the memory. The decompiler in 386 OK is not yet complete. It groups the bytes in a 386 instruction and displays them in one line. The instruction and its arguments are not translated to their Intel mnemonics.

If a map is not the territory, is it necessary to have a map?

A map is useful, but it is different from the territory. When the difference is subtle, you may confuse yourself.

I am working on P32 and P24. In P21, the last bit was added to take care of the carry in the ALU operations and it is also used to control memory addressing, to differentiate DRAM from SRAM. The clocks are done in analog delay lines. The T and N registers are tied to the ALU. You just enable the output and the results are latched back into T. It takes 10 ns. from enabling of address input, through the ALU, to get the data to the output pins.

Silicon design is very challenging. A NAND gate has many inputs and an output. If you want more driving current from a NAND gate, you may use another output driver and then invert the driver. Or you can invert the inputs. Or you can invert the output. There are so many different approaches, and it becomes a holistic problem. I don't know how to come to an optimal implementation. Short of doing the experiments yourself and get experience the hard way, you don't have a note on how to get it done right.

In the meantime, OK is now out and I hope you will have fun with it. Thank you.

(Letters, continued from page six.)

I was glad to see the FIG presence, but without other Forth vendors I question if many conventioneers got the Forth message. Too bad there weren't some controller-operated, fun gizmos, like the traveling display at the Anaheim (1988) programming contest, to show that Forth actually works. It could give some Forth vendors a chance to show off their hardware. If the gizmos are made transportable, they could be made available to FIG displays at other conventions. And demos of Forth programming (there's a lot of postfix paranoia) would let the curious actually see some of the Forth systems available. Forth definitely needs more marketing pizzazz.

Someone at the FIG booth demonstrated a clever method of creating and then downloading headerless Forth code through a serial port to the controller. Perhaps he would describe it further in an article?

Motorola won the "Chutzpah" award in marketing, hands down. For the Oktoberfest beer bust at the convention, Intel handed out fancy glass mugs imprinted with their logo. Motorola then passed out blue insulating blankets that wrapped around the mug, covering Intel's logo with their own. I presume a suitable revenge is being planned...

Yours truly,
Walter J. Rottenkolber
P.O. Box 1705
Mariposa, California 95338

Kelly's Comparisons Clarified

Dear Marlin,

There may be some confusion about the meaning of the timing information contained in Tables Two and Three of my article, "Forth Systems Comparisons" (*FD* XIII/6), as evidenced by comments one and two in the much-appreciated letter by Don Kenney in *FD* XIV/3.

The comments accompanying the benchmark code were meant to illustrate that the empty loop times were subtracted from all the other raw times (except for the Sieve). Hence, for instance, the empty loop time for riFORTH is shown as greater than the threading time because it has already been subtracted from the raw time.

The probable reason that riFORTH did not perform better in the Sieve benchmark is that the version tested used a high-level `DO LOOP` construct, and the loop times were not subtracted from the Sieve times.

I would have to disagree with Mr. Kenney that hand calculating the times would have been easier, considering the number of versions of Forth tested, the number of words and tests per Forth, and the fact that the timing differences were in the same ball park (approximately ten to 30 percent) that the hand timings were in error (reported as four and seven percent).

My thanks to all those who took the time to comment on the article, it made it all worthwhile!

Sincerely,
Guy M. Kelly
2507 Caminito La Paz
La Jolla, California 92037

HARVARD SOFTWORKS

NUMBER ONE IN FORTH INNOVATION

(513) 748-0390 P.O. Box 69, Springboro, OH 45066

By now you know that HS/FORTH gives you more speed, power, flexibility and functionality than any other language or implementation. After all, the majority of the past several years of articles in Forth Dimensions has been on features found in HS/FORTH, often by known customers. And the major applications discussed had to be converted to HS/FORTH after their original dialects ran out of steam. Even the public domain versions are adopting HS/FORTH like architectures. Isn't it time you tapped into the source as well? Why wait for second hand versions when the original inspiration is more complete and available sooner.

Well, it was a dirty job, but we finally had to do it. Now you can run lots of copies of HS/FORTH from **Microsoft Windows** in text and/or graphics windows with various icons and pif files available for each. Talk about THE tool for hacking Windows! But, face it, what I really like is cranking up the font size so I can still see the characters no matter how late it is. Now that's useful.

Good news, we've redone our **DOCUMENTATION!** The big new fonts look really nice and the reorganization makes all that functionality so much easier to find. Thanks to excellent documentation, all this awesome power is now relatively easy to learn and to use.

Naturally we continue tweaking and improving the internals, but by now the system is so well tuned that these changes are not individually of any significance. They just continue to improve performance a bit at a time, and enhance error detection and recovery. **Update to Revision 5.0**, including new documentation, from all 4.xx revisions is $99. and from really old systems the update is $149.

And since Spring is coming, IT IS TIME FOR OUR **SPRING SALE**. Thru the end of May you get to pick two extra utility packages free for each Professional or Production Level system purchased, or get a free Online Glossary with help file utility with each Personal Level system purchased.

HS/FORTH runs under MSDOS or PCDOS, or from ROM. Each level includes **all** features of lower ones. Level upgrades: $25. plus price difference between levels. Source code is in ordinary ASCII text files.

HS/FORTH supports megabyte and larger programs & data, and runs as fast as 64k limited Forths, even without automatic optimization -- which accelerates to near assembler language speed. Optimizer, assembler, and tools can load transiently. Resize segments, redefine words, eliminate headers without recompiling. Compile 79 and 83 Standard plus F83 programs.

PERSONAL LEVEL $299.
NEW! Fast direct to video memory text & scaled/clipped/windowed graphics in bit blit windows, mono, cga, ega, vga, all ellipsoids, splines, bezier curves, arcs, turtles; lightning fast pattern drawing even with irregular boundaries; powerful parsing, formatting, file and device I/O; DOS shells; interrupt handlers; call high level Forth from interrupts; single step trace, decompiler; music; compile 40,000 lines per minute, stacks; file search paths; format to strings. software floating point, trig, transcendental, 18 digit integer & scaled integer math; vars: A B * IS C compiles to 4 words, 1..4 dimension var arrays; **automatic optimizer delivers machine code speed.**

PROFESSIONAL LEVEL $399.
hardware floating point - data structures for all data types from simple thru complex 4D var arrays - operations complete thru complex hyperbolics; turnkey, seal; interactive dynamic linker for foreign subroutine libraries; round robin & interrupt driven multitaskers; dynamic string manager; file blocks, sector mapped blocks; x86&7 assemblers.

PRODUCTION LEVEL $499.
Metacompiler: DOS/ROM/direct/indirect; threaded systems start at 200 bytes, Forth cores from 2 kbytes; C data structures & struct+ compiler; MetaGraphics TurboWindow-C library, 200 graphic/window functions, PostScript style line attributes & fonts, viewports.

ONLINE GLOSSARY $ 45.

PROFESSIONAL and PRODUCTION LEVEL EXTENSIONS:

FOOPS+ with multiple inheritance **$ 79.**
TOOLS & TOYS DISK $ 79.
286FORTH or **386FORTH $299.**
16 Megabyte physical address space or gigabyte virtual for programs and data; DOS & BIOS fully and freely available; 32 bit address/operand range with 386.
ROMULUS HS/FORTH from ROM **$ 99.**

Shipping/system: US: $9. Canada: $21. foreign: $49. We accept MC, VISA, & AmEx

Numbers

C.H. Ting
San Mateo, California

In this lesson, we shall discuss the way Forth handles integers. Integers are numbers from -32768 to 32767. This range of numbers is most convenient to be stored and processed in Forth. It is very surprising that many real-world problems can be represented and solved using numbers in this range. Forth can handle larger numbers, and even floating-point numbers, but these are topics outside the scope of this lesson.

Example One. Money Exchange

The first example we will use to demonstrate how numbers are used in Forth is a money exchange program, which converts money represented in different currencies. Let's start with the following currency exchange table:

24.55 NT	1 Dollar
7.73 HK	1 Dollar
5.47 RMB	1 Dollar
1 Ounce Gold	356 Dollars
1 Ounce Silver	4.01 Dollars

We shall use the U.S. dollar as the standard currency, and convert all other currencies to dollars first. All arithmetic operations will be carried out in dollars. The dollars can then be converted back to any other currency.

We define words to convert other currencies to the dollar by using the names of the corresponding currencies. To convert from dollars to another currency, the word is preceded by the $ sign.

```
: NT     ( nNT -- $ )      10 245 */ .s ;
: $NT    ( $ -- nNT )      245 10 */ .s ;
: RMB    ( nRMB -- $ )     100 547 */ .s ;
: $jmp   ( $ -- nJmp )     547 100 */ .s ;
: HK     ( nHK -- $ )      100 773 */ .s ;
: $HK    ( $ -- $ )        773 100 */ .s ;
: gold   ( nOunce -- $ ) 356 * .s ;
: $gold  ( $ -- nOunce ) 356 / .s ;
: silver ( nOunce -- $ ) 401 100 */ .s ;
: $silver ( $ -- nOunce ) 100 401 */ .s ;
: ounce ( n -- n, used to improve syntax )  ;
: dollars ( n -- )        . ;
```

With this set of money exchange words, we can do some tests:

```
5 ounce gold .
10 ounce silver .
100 $NT .
20 $RMB .
```

If you have many different currencies in your wallet, you can add them in dollars:

```
1000 NT 500 HK +
320 RMB +
dollars ( prints total worth in dollars )
```

If I am in Hong Kong at the time, the total amount can be readily converted to Hong Kong dollars:

```
1000 NT 500 HK + 320 RMB +
$HK dollars
( converts to Hong Kong dollars and prints it)
```

Exercise One. A business trip.

Now we have a fairly powerful money exchange computer with us. Suppose you depart San Francisco with 1000 dollars in your pocket. You go to Hong Kong and buy a VCR with 1200 HK. Go to Shanghai and sell it for 2000 RMB. Then come back to Hong Kong and spend 900 HK for fun. Go to Taipei and buy a portable PC with 30000 NT. How much money in U.S. dollars do you have remaining?

The answer typed backwards is:

```
srallod - TN 00003 - KH 009 + BMR 0002 - KH
0021 0001
```

Try it.

Example Two. Temperature conversion.

Converting temperature readings between Celsius and Fahrenheit is also an interesting problem. The difference between temperature conversion and money exchange is that the two temperature scales have an offset in addition to the scaling factor.

```
: F>C ( nFarenheit -- nCelcius )
        32 -
        10 18 */
        ;

: C>F ( nCelcius -- nFarenheit )
        18 10 */
        32 +
        ;
```

`90 F>C .` shows the temperature on a hot summer day and

`0 C>F .` shows the temperature in the cold winter.

In the above examples, we use the following Forth arithmetic operators:

+ (n1 n2 -- n1+n2)	Add n1 and n2 and leave sum on stack.
- (n1 n2 -- n1-n2)	Subtract n2 from n1 and leave difference on stack.
* (n1 n2 -- n1*n2)	Multiply n1 and n2 and leave product on stack.
/ (n1 n2 -- n1/n2)	Divide n1 by n2 and leave quotient on stack.
*/ (n1 n2 n3 -- n1*n2/n3)	Multiply n1 and n2, divide the product by n3 and leave quotient on the stack.
.s (... -- ...)	Show the topmost four numbers on stack.

Here we have to introduce the concept of a stack. A stack is a memory area in the computer where numbers are stored and retrieved implicitly. It is different from variables (discussed in Lesson One). Variables are named locations in memory, which are accessed by referring to the assigned names. A stack is a first-in-last-out list. When a number is given to Forth, it is pushed on the stack. Any operator which uses numbers pops the required numbers from the stack. The most accessible number is on the top of the stack, like the card on top of a card deck. Various Forth operators may produce one or many numbers, and the numbers are pushed on the stack as they are generated.

+ thus pops the two topmost numbers off the stack, adds them, and then pushes the sum back on the stack. -, *, and / are other operators commonly used to do simple math. One must notice that the order of the two numbers used by + and * is immaterial, while the order is important for - and /. Exchanging the two numbers will produce different differences or quotients, respectively.

*/ is a scaling operator in Forth, which is useful in scaling integer numbers. It multiplies n1 by the ratio of (n2/n3). As shown in Examples One and Two, this operator is very useful in scaling quantities from one unit to another. Scaling is a very powerful operation which eliminates the necessity of using floating-point numbers.

.s is a debugging tool which shows you the contents of the topmost four items on the stack. It is used often during debugging to make sure the stack has the correct numbers for your calculations. It is generally not used in the final program, to avoid printing too many intermediate values.

Several other important, but less commonly used, math operators are:

MOD (n1 n2 -- rem)	Divide n1 by n2 and leave the remainder on stack.
/MOD (n1 n2 -- rem quot)	Divide n1 by n2 and leave both remainder and quotient on stack.
1+ (n -- n+1)	Increment n on stack.
1- (n -- n-1)	Decrement n on stack.
2* (n -- 2n)	Double n on stack.
2/ (n -- n/2)	Halve n on stack.
ABS (n -- |n|)	Convert top number on stack to absolute.
NEGATE (n -- -n)	Negate n on stack.

As we go along, some of these operators will be used as occasions arise.

Stack Operators

The stack is the most important place where the results of previously executed operators can be passed to the operators yet to be executed. Operators take parameters from the stack and leave results there for subsequent operators to use. A program can be built easily by stringing together subroutines. The subroutines can call other subroutines, and so on. The subroutines are Forth operators, and can be nested almost indefinitely. This is a very important reason why Forth is simple in its architecture and also in its syntactical structure.

However, it happens very often that the order of the numbers on the stack is not correct for an operator which needs them, like - and /. There is a set of stack operators to rearrange numbers on the stack. The five most important, classic stack operators are:

DUP (n -- n n)	Duplicate the top of stack.
SWAP (n1 n2 -- n2 n1)	Exchange top two numbers on stack.
OVER (n1 n2 -- n1 n2 n1)	Duplicate the second number on stack.
ROT (n1 n2 n3 -- n2 n3 n1)	Rotate third number to the top of stack.
DROP (n --)	Discard the top of stack.

Example Three. Rectangles.

A rectangle is specified by the (x,y) coordinates of its upper-left and lower-right corners. With these four integers on the stack, we can compute the area, the center, and the perimeter of a rectangle:

```
: area ( x1 y1 x2 y2 -- area )
        ROT -    ( x1 x2 y2-y1 )
        SWAP ROT - ( y2-y1 x2-x1 )
        * ( area )
        ;
: center ( x1 y1 x2 y2 -- x3 y3 )
        ROT - 2/ ( x1 x2 y3 )
        SWAP ROT - 2/ ( y3 x3 )
        SWAP ( x3 y3 )
        ;
: sides ( x1 y1 x2 y2 -- sides )
        ROT - ABS ( x1 x2 y2-y1 )
        SWAP ROT - ABS ( y2-y1 x2-x1 )
        + ( sides )
        ;
```

Logic Operators

Computers use logic operators to determine and follow different execution paths. Logic operators themselves are very simple and easy to understand. However, the combination of many levels of logic operations, and the multitude of different pathways in a large program, makes the computer

seem very complicated, even to the point of showing some intelligence.

Here we introduce some of the logic operators associated with numbers, and the branching operators which use the results of logic operators to select different operations.

Forth uses numbers to represent logic levels. There are only two logic levels, true and false. True is represented by any number which is not zero (usually a -1), and false is represented by zero. The number representing logic levels is often called a *flag*.

>	(n1 n2 -- f)	Return true if n1>n2. Otherwise, return false.
<	(n1 n2 -- f)	Return true if n1<n2.
=	(n1 n2 -- f)	Return true if n1=n2.
0=	(n -- f)	Return true if n=0.
0<	(n -- f)	Return true if n<0.
NOT	(f1 -- f2)	Return true if f1 is false. Otherwise, return false.

A flag can be used to select one of the two execution paths by the following constructs inside a colon definition:

```
( f ) IF <true clause> ELSE <false clause> THEN
( f ) IF <true clause> THEN
```

Example Four. Weather Reporting.

The following colon definition illustrates the use of logic and the branch:

```
: weather ( nFarenheit -- )
  DUP   85 >
  IF    ." Too hot!" DROP
  ELSE  55 <
    IF      ." Too cold."
    ELSE    ." About right."
    THEN
  THEN
  ;
```

You can type the following commands and get some responses from the computer:

```
90 weather  Too hot!
70 weather  About right.
32 weather  Too cold.
```

Loop Operators

We shall be concerned now with only the definite loop operators used in the following format in a colon definition:

```
( nLimit nIndex ) DO <repeat_clause> LOOP
```

DO takes two parameters off the stack. The top number is the starting index of the loop and the second number is the upper limit of the loop index. After entering the loop, the repeat clause is repeatedly executed. LOOP increments the loop index from nIndex to nLimit. When the index is equal to nLimit, the loop is terminated. In the repeat clause, a special operator I returns the current loop index on the stack.

A simple example of the loop structure follows:

Example Five. Print the multiplication table.

```
: OneRow ( nRow -- )
  CR
  DUP 3 .R 3 SPACES
  13 1
  DO    I OVER *
        4 .R
  LOOP
  DROP ;

: Table ( -- )
  CR CR 6 SPACES
  13 1
  DO   I 4 .R  LOOP ( display column numbers )
  13 1
  DO    I OneRow
  LOOP
  ;
```

Typing TABLE will cause the multiplication table to be displayed in a neat format.

With these new Forth operators, we can now write a fairly substantial program, using many of the operators to demonstrate how they are combined to do useful work.

Dr. C.H. Ting is a noted Forth authority who has made many significant contributions to Forth and the Forth Interest Group. His tutorial series will continue in succeeding issues of *Forth Dimensions*.

Optimizing in BSR/JSR-Threaded Forth

Charles Curley
Gillette, Wyoming

The purpose of this paper is to describe a code optimizer for a 68000-based JSR/BSR-threaded Forth interpreter/compiler. The code operates in the traditional Forth single-pass compiler, optimizing on the fly. The result includes words which execute in fewer instructions than the words called out in the source code.

Historical Note

The Forth used for the code described herein is FastForth, a full 32-bit BSR/JSR-threaded Forth for the 68000, described in unmitigated detail in "Optimization Considerations" (*Forth Dimensions* XIV/5). It is a direct modification of an indirect-threaded Forth, real-Forth. This is, in turn, a direct descendent of fig-Forth. (Remember fig-Forth?) fig-Forth's vocabulary, word names, and other features have been retained.

For those not familiar with 32-bit Forths, the memory operators with the prefix `W` operate on word, or 16-bit, memory locations. FastForth uses the operators `F@` and `F!` for 32-bit memory operations where the address is known to be an even address. To avoid odd-address faults, the regular Forth operators `@` and `!` use byte operations.

This optimizer is a complete unit, and is dependent only upon the nature of the target processor

The assembler used to illustrate is descended from the fig 68000 assembler by Dr. Kenneth Mantei. It is a typical Forth reverse Polish notation assembler. Typical syntax is: source, destination, opcode. The addressing modes relevant to the paper are as follows:

`[`	Address register indirect
`[+`	Address register indirect with post-increment
`-[`	Address register indirect with pre-decrement
`&[`	Register indirect with a word of displacement
`@#L`	Absolute long address
`#`	Immediate data, word
`#L`	Immediate data, long

There is nothing particularly new conceptually here. Chuck Moore's cmForth includes an optimizer for the Novix NC-4000. The present paper describes an optimizer for a more traditional CISC instruction set, the Motorola 68000.

The Compiler

The compiler used in FastForth looks very much like a traditional indirect-threaded Forth. However, it lays down opcodes which call (via BSR or JSR instructions) lower-level words, rather than a list of addresses for `NEXT` to interpret.

For example, the traditional word `L` is defined as follows:

```
: L    SCR F@ LIST ;
```

In an indirect-threaded, 32-bit Forth, the compiler would build the header for `L`. This would be followed by a four-byte address for the code to be executed to interpret the word. The code field address is followed by a four-byte address for each of the three words called out in the source. This would be followed by the address of the exit code, laid down by the compiler directive `;`.

In a BSR/JSR-threaded Forth, the compiler lays down BSRs ("branch to subroutine') or JSRs (jump to subroutine), as appropriate, to the words called out. The return code consists of an RTS instruction. The result may or may not be smaller than the indirect-threaded version, but it certainly will be faster. Whether the result is smaller or not depends on the mix of short BSRs (two bytes), long BSRs (four bytes), and JSRs (six bytes) laid down at compile time.

One optimization discussed in "Optimization Considerations" is to examine the last instruction of a word. If it is a BSR or JSR, that instruction can be twiddled to produce a BRA or JMP instruction.

Another optimization is to lay down in-line code instead of calls. This is particularly beneficial when calling short words (e.g., `F@`) from a distance, which would require a JSR instruction. Not only does the technique save run time (by eliminating a call and an RTS instruction), but it may reduce the size of words. One circumstance where this technique does not save space is where a four-byte word is copied in line to a location which would have required a short (two-byte) BSR.

Optimized definition vs. the original

Item	JSR/BSR	Indirect Threaded
code field	0 bytes	Four bytes
SCR	Six bytes laid down in line.	Four bytes
F@	Four bytes laid down in line.	Four bytes
LIST	Two, four or six bytes of BRA or JMP.	Four bytes
exit code	0 bytes	Four bytes
Total	*16, maximum*	*20 bytes*

Variables, constants, and user variables in FastForth are immediate words which compile in-line code, often a six-byte reference.

With these optimizations, the compiler produces the above for the sample word L given earlier.

The total is sixteen bytes at most, compared to a firm twenty bytes for the indirect-threaded version. So the JSR/BSR version may be smaller, but certainly will be much faster!

Two more typical Forth optimizations are common and won't be discussed very much.

If a phrase shows up a lot in a Forth program, it is common practice for the programmer to consolidate that phrase in a word with a meaningful name. This is optimizing for readability and dictionary size, rather than speed.

The second is to reduce words from high level to assembler. This requires the active intervention of the programmer, and the results are well worth it in terms of speed, and often worthwhile in terms of space. Alas, such optimizations only improve readability for those who know the relevant assembly language (and, sometimes, the relevant assembler), leaving the code more opaque to those without such skills.

The Optimizer Design

An optimizer for in-line code should be a single-pass optimizer, to be consistent with Forth's traditional single-pass compiler. This would make difficult, for example, replacing long forward branches with short ones on the fly, but would result in much simpler code in the compiler. It must, then, operate at compile time, and so must consist of immediate words.

The optimizer should be an add-on, so that the user can add to the optimizer if he wishes to. However, it should also be carried over to the cross-compiler so as to produce a very efficient nucleus.

The optimizer should work silently, as far as the user is concerned. That is, it should require no changes in source code to be useful. This requirement separates out the optimizing compiler from the two common optimizing methods described above.

Initially, the optimizer word could be developed as a series of discrete words, but these would be replaced by one or more defining words and their daughter words.

One key to single-pass optimization during compilation is to have immediate words which examine previously compiled opcodes, and twiddle certain ones to produce tighter code.

Another key is to look for certain phrases which can easily be detected and easily twiddled. We could look for the phrase `BLK F@`, which shows up all over the nucleus, and optimize that. Instead, let us generalize, and look for phrases of the general type:

```
<USER VARIABLE> F@.
```

To detail this example: a user variable is an immediate word, which lays down the following phrase:

```
<offset> &[ U AR0 MOV,  AR0 S -[ MOV,
```

Translated into English, the first instruction moves data from a user variable indicated by an offset from the user area register U to address register 0. The second pushes it out onto the stack. The result, examined in memory as word data, looks like:

```
| 41ee | <offset> | 2708 |
```

If the next word in the source code is `F@` and it is immediate, it can look at here-less-six for the opcode 41ee. Finding it, it can twiddle the dictionary to produce the following code:

```
<offset> &[ U AR0 MOV,  AR0 [ S -[ MOV,
```

This produces the following memory dump:

```
| 41ee | <offset> | 2710 |
```

The first instruction still moves the contents of the user variable into the address register, but the second instruction now reads data from the location pointed to by the register, and pushes it onto the data stack.

The phrase `<USER VARIABLE> F@` is now executed in two instructions instead of the previous four, and occupies six bytes instead of the previous ten. And the optimizer works for all user variables, even ones not defined at the time the optimizer is compiled.

Other two-word phrases were similarly identified and optimized, and some three-word phrases were also identified and optimized. As each phrase was identified, a defining word was built up, consisting of nested `IF ... ELSE ... THEN` clauses. The resultant words are monsters, and must be thoroughly understood by the programmer who seeks to modify them. In these two respects, they are un-Forthish, but the gain obtained by using them is worth the price.

These words must all be state smart. As they will run either at run time or at compile time, they must examine `STATE` and act accordingly. The action at run time is, of course, to execute their namesakes. Hence, in the run-time portion of the defining words, the phrase `STATE F@ IF ... ELSE @EXECUTE THEN`.

In order for that phrase to work correctly, we must have the run-time address of the namesake in the dictionary. We require the namesake to be explicitly stated: `'` it and comma

FIG
MAIL ORDER FORM

HOW TO USE THIS FORM: Please enter your order on the back page of this form and send with your payment to the Forth Interest Group. All items have one price and a weight marked with # sign. Enter weight on order form and calculate shipping based on location and delivery method.

"Were Sure You Wanted To Know..."

***Forth Dimensions*, Article Reference** 151 - $4 0#
★ An index of Forth articles, by keyword, from *Forth Dimensions* Volumes 1–13 (1978–92).

FORML, Article Reference 152 - $4 0#
★ An index of Forth articles by keyword, author, and date from the FORML Conference Proceedings (1980–91).

FORTH DIMENSIONS BACK VOLUMES

A volume consists of the six issues from the volume year (May–April)

Volume 1 Forth Dimensions (1979–80) 101 - $15 1#
Last 50 Introduction to FIG, threaded code, TO variables. fig-Forth.

Volume 3 Forth Dimensions (1981–82)
Forth-79 Standard, Stacks, HEX, Forth Basic, memory management, light level interrupts, string stack, BASIC compiler, recursive 8080 assembler.
OUT OF PRINT

Volume 6 Forth Dimensions (1984–85) 106 - $15 2#
Last 100 Interactive editors, anonymous variables, list handling, integer solutions, control structures, debugging techniques, recursion, semaphores, simple I/O words, Quicksort, high-level packet communications, China FORML.

Volume 7 Forth Dimensions (1985–86) 107 - $20 2#
Last 100 Generic sort, Forth spreadsheet, control structures, pseudo-interrupts, number editing, Atari Forth, pretty printing, code modules, universal stack word, polynomial evaluation, F83 strings.

Volume 8 Forth Dimensions (1986–87) 108 - $20 2#
Last 100 Interrupt-driven serial input, data-base functions, TI 99/A, XMODEM, on-line documentation, dual-CFAs, random numbers, arrays, file query, Batcher's sort, screenless Forth, classes in Forth, Bresenham line-drawing algorithm, unsigned division, DOS file I/O.

Volume 9 Forth Dimensions (1987–88) 109 - $20 2#
Last 100 Fractal landscapes, stack error checking, perpetual date routines, headless compiler, execution security, ANS-Forth meeting, computer-aided instruction, local variables, transcendental functions, education, relocatable Forth for 68000.

Volume 10 Forth Dimensions (1988–89) 110 - $20 2#
Last 50 dBase file access, string handling, local variables, data structures, object-oriented Forth, linear automata, stand-alone applications, 8250 drivers, serial data compression.

Volume 11 Forth Dimensions (1989–90) 111 - $20 2#
Last 100 Local variables, graphic filling algorithms, 80286 extended memory, expert systems, quaternion rotation calculation, multiprocessor Forth, double-entry bookkeeping, binary table search, phase-angle differential analyzer, sort contest.

Volume 12 Forth Dimensions (1990–91) 112 - $20 2#
Last 100 Floored division, stack variables, embedded control, Atari Forth, optimizing compiler, dynamic memory allocation, smart RAM, extended-precision math, interrupt handling, neural nets, Soviet Forth, arrays, metacompilation.

FORML CONFERENCE PROCEEDINGS

FORML (Forth Modification Laboratory) is an educational forum for sharing and discussing new or unproven proposals intended to benefit Forth, and is an educational forum for discussion of the technical aspects of applications in Forth. Proceedings are a compilation of the papers and abstracts presented at the annual conference. FORML is part of the Forth Interest Group.

1980 FORML PROCEEDINGS 310 - $30 2#
Address binding, dynamic memory allocation, local variables, concurrency, binary absolute & relocatable loader, LISP, how to manage Forth projects, n-level file system, documenting Forth, Forth structures, Forth strings. *231 pgs*
Last 10

1981 FORML PROCEEDINGS 311 - $45 4#
CODE-less Forth machine, quadruple-precision arithmetic, overlays, executable vocabulary stack, data typing in Forth, vectored data structures, using Forth in a classroom, pyramid files, BASIC, LOGO, automatic cueing language for multimedia, NEXOS—a ROM-based multitasking operating system. *655 pgs*
Last 50

1982 FORML PROCEEDINGS 312 - $30 4#
Rockwell Forth processor, virtual execution, 32-bit Forth, ONLY for vocabularies, non-IMMEDIATE looping words, number-input wordset, I/O vectoring, recursive data structures, programmable-logic compiler. *295 pgs*
Last 100

1983 FORML PROCEEDINGS 313 - $30 2#
Non-Von Neuman machines, Forth instruction set, Chinese Forth, F83, compiler & interpreter co-routines, log & exponential function, rational arithmetic, transcendental functions in variable-precision Forth, portable file-system interface, Forth coding conventions, expert systems. *352 pgs*
Last 75

1984 FORML PROCEEDINGS 314 - $30 2#
Forth expert systems, consequent-reasoning inference engine, Zen floating point, portable graphics wordset, 32-bit Forth, HP71B Forth, NEON—object-oriented programming, decompiler design, arrays and stack variables. *378 pgs*
Last 100

1986 FORML PROCEEDINGS 316 - $30 2#
Threading techniques, Prolog, VLSI Forth microprocessor, natural-language interface, expert system shell, inference engine, multiple-inheritance system, automatic programming environment. *323 pgs*
Last 100

1987 FORML PROCEEDINGS 317 - $40 3#
Includes papers from '87 euroFORML Conference. 32-bit Forth, neural networks, control structures, AI, optimizing compilers, hypertext, field and record structures, CAD command language, object-oriented lists, trainable neural nets, expert systems. *463 pgs*
Last 25

1988 FORML PROCEEDINGS 318 - $40 2#
Includes 1988 Australian FORML, Human interfaces, simple robotics kernel, MODUL Forth, parallel processing, programmable controllers, Prolog, simulations, language topics, hardware, Wil's workings & Ting's philosophy, Forth hardware applications, ANS Forth session, future of Forth in AI applications. *310 pgs*
Last 100

1989 FORML PROCEEDINGS 319 - $40 3#
Includes papers from '89 euroFORML. Pascal to Forth, extensible optimizer for compiling, 3D measurement with object-oriented Forth, CRC polynomials, F-PC, Harris C cross-compiler, modular approach to robotic control, RTX recompiler for on-line maintenance, modules, trainable neural nets. *433 pgs*
Last 50

1990 FORML PROCEEDINGS 320 - $40 3#
Forth in industry, communications monitor, 6805 development. 3-key keyboard, documentation techniques, object-oriented programming, simplest Forth decompiler, error recovery, stack operations, process control event management, control structure analysis, systems design course, group theory using Forth. *441 pgs*
Last 50

★ - These are your most up-to-date indexes for back issues of *Forth Dimensions* and the FORML proceedings.

Fax your orders 510-535-1295

1991 FORML PROCEEDINGS 321 - $50 3#
Includes 1991 FORML, Asilomar, euroFORML '91, Czechoslovakia and 1991 China FORML, Shanghai. Differential File Comparison, LINDA on a Simulated Network, QS2: RISCing it all, A threaded Microprogram Machine, Forth in Networking, Forth in the Soviet Union, FOSM: A FOrth String Matcher, VGA Graphics and 3-D Animation, Forth and TSR, Forth CAE System, Applying Forth to Electric Discharge Machining, MCS96-FORTH Single Chip Computer. *500 pgs*

BOOKS ABOUT FORTH

ALL ABOUT FORTH, 3rd ed., June 1990, Glen B. Haydon 201 - $90 4#
Annotated glossary of most Forth words in common usage, including Forth-79, Forth-83, F-PC, MVP-Forth. Implementation examples in high-level Forth and/or 8086/88 assembler. Useful commentary given for each entry. *504 pgs*

THE COMPLETE FORTH, Alan Winfield 210 - $14 1#
A comprehensive introduction, including problems with answers (Forth-79). *131 pgs*

eFORTH IMPLEMENTATION GUIDE, C.H. Ting 215 - $25 1#
eForth is the name of a Forth model designed to be portable to a large number of the newer, more powerful processors available now and becoming available in the near future. *54 pgs* (w/disk)

F83 SOURCE, Henry Laxen & Michael Perry 217 - $20 2#
A complete listing of F83, including source and shadow screens. Includes introduction on getting started. *208 pgs*

FORTH: A TEXT AND REFERENCE 219 - $31 2#
Mahlon G. Kelly & Nicholas Spies
A textbook approach to Forth, with comprehensive references to MMS-FORTH and the '79 and '83 Forth standards. *487 pgs*

THE FIRST COURSE, C.H. Ting 223 - $25 1#
This tutorial's goal is to expose you to the very minimum set of Forth instructions so that you can start to use Forth to solve practical problems in the shortest possible time. "... This tutorial was developed to complement *The Forth Course* which skims too fast on the elementary Forth instructions and dives too quickly in the advanced topics in a upper level college microcomputer laboratory. ..." A running F-PC Forth system would be very useful. *44 pgs*

THE FORTH COURSE, Richard E. Haskell 225 - $25 1#
This set of 11 lessons, called *The Forth Course*, is designed to make it easy for you to learn Forth. The material was developed over several years of teaching Forth as part of a senior/graduate course in design of embedded software computer systems at Oakland University in Rochester, Michigan. *156 pgs* (w/disk)

FORTH ENCYCLOPEDIA, Mitch Derick & Linda Baker 220 - $30 2#
A detailed look at each fig-Forth instruction. *327 pgs*

FORTH NOTEBOOK, Dr. C.H. Ting 232 - $25 2#
Good examples and applications. Great learning aid. poly-FORTH is the dialect used. Some conversion advice is included. Code is well documented. 286 pgs

FORTH NOTEBOOK II, Dr. C.H. Ting 232a - $25 2#
Collection of research papers on various topics, such as image processing, parallel processing, and miscellaneous applications. *237 pgs*

F-PC USERS MANUAL (2nd ed., V3.5) 350 - $20 1#
Users manual to the public-domain Forth system optimized for IBM PC/XT/AT computers. A fat, fast system with many tools. *143 pgs*

F-PC TECHNICAL REFERENCE MANUAL 351 - $30 2#
A must if you need to know the inner workings of F-PC. *269 pgs*

INSIDE F-83, Dr. C.H. Ting 235 - $25 2#
Invaluable for those using F-83. *226 pgs*

LIBRARY OF FORTH ROUTINES AND UTILITIES,
James D. Terry 237 - $23 2#
Comprehensive collection of professional quality computer code for Forth; offers routines that can be put to use in almost any Forth application, including expert systems and natural-language interfaces. *374 pgs*

OBJECT ORIENTED FORTH, Dick Pountain 242 - $35 1#
Implementation of data structures. First book to make object-oriented programming available to users of even very small home computers. *118 pgs*

SEEING FORTH, Jack Woehr 243 - $25 1#
"... I would like to share a few observations on Forth and computer science. That is the purpose of this monograph. It is offered in the hope that it will broaden slightly the streams of Forth literature ..." *95 pgs*

SCIENTIFIC FORTH, Julian V. Noble 250 - $50 2#
Scientific Forth extends the Forth kernel in the direction of scientific problem solving. It illustrates advanced Forth programming techniques with non-trivial applications: computer algebra, roots of equations, differential equations, function minimization, functional representation of data (FFT, polynomials), linear equations and matrices, numerical integration/Monte Carlo methods, high-speed real and complex floating-point arithmetic. *300 pgs* (Includes disk with programs and several utilities), **IBM**

STACK COMPUTERS, THE NEW WAVE 244 - $62 2#
Philip J. Koopman, Jr. (hardcover only)
Presents an alternative to Complex Instruction Set Computers (CISC) and Reduced Instruction Set Computers (RISC) by showing the strengths and weaknesses of stack machines (hard-cover only).

STARTING FORTH (2nd ed.), Leo Brodie 245 - $29 2#
In this edition of *Starting Forth*—the most popular and complete introduction to Forth—syntax has been expanded to include the Forth-83 Standard. *346 pgs*

WRITE YOUR OWN PROGRAMMING LANGUAGE USING C++,
Norman Smith 270 - $15 1#
This book is about an application language. More specifically, it is about how to write your own custom application language. The book contains the tools necessary to begin the process and a complete sample language implementation. [Guess what language!] Includes disk with complete source. *108 pgs*

ACM - SIGFORTH

The ACM SIGForth Newsletter is published quarterly by the Association of Computing Machinery, Inc. SIGForth's focus is on the development and refinement of concepts, methods, and techniques needed by Forth professionals.

Volume 1 Spring 1989, Summer 1989, #3, #4 911 - $24 2#
F-PC, glossary utility, euroForth, SIGForth '89 Workshop summary (real-time software engineering), Intel 80x8x. Metacompiler in cmForth, Forth exception handler, string case statement for UF/Forth. 1802 simulator, tutorial on multiple threaded vocabularies. Stack frames, duals: an alternative to variables, PocketForth.

Volume 2 #1, #2, #3, #4 912 - $24 2#
ACM SIGForth Industry Survey, abstracts 1990 Rochester conf., RTX-2000. BNF Parser, abstracts 1990 Rochester conf., F-PC Teach. Tethered Forth model, abstracts 1990 SIGForth conf. Target-meta-cross-: an engineer's viewpoint, single-instruction computer.

Volume 3, #1 Summer '91 913a - $6 1#
Co-routines and recursion for tree balancing, convenient number handling.

Volume 3, #2 Fall '91 913b - $6 1#
Postscript Issue, What is Postscript?, Forth in Postscript, Review: PS-Tutor.

1989 SIGForth Workshop Proceedings 931 - $20 1#
Software engineering, multitasking, interrupt-driven systems, object-oriented Forth, error recovery and control, virtual memory support, signal processing. *127 pgs*

1990-91 SIGForth Workshop Proceedings 932 - $20 1#
Teaching computer algebra, stack-based hardware, reconfig-urable processors, real-time operating systems, embedded control, marketing Forth, development systems, in-flight monitoring, multi-processors, neural nets, security control, user interface, algorithms. *134 pgs*

For faster service, fax your orders 510-535-1295

★ - Starting ★★ - Intermediate ★★★ - Advanced

DISKS: Contributions from the Forth Community

The "Contributions from the Forth Community" disk library contains author-submitted donations, generally including source, for a variety of computers & disk formats. Each file is determined by the author as public domain, shareware, or use with some restrictions. This library does not contain "For Sale" applications. *To submit your own contributions, send them to the FIG Publications Committee.*

Prices: Each item below comes on one or more disks any disks = 1 #.

FLOAT4th.BLK V1.4 Robert L. Smith C001 - $8
Software floating-point for fig-, poly-, 79-Std., 83-Std. Forths. IEEE short 32-bit, four standard functions, square root and log.
★★★ **IBM, 190Kb, F83**

Games in Forth C002 - $6
Misc. games, Go, TETRA, Life... Source.
★ **IBM, 760Kb**

A Forth Spreadsheet, Craig Lindley C003 - $6
This model spreadsheet first appeared in *Forth Dimensions* VII, 1-2. Those issues contain docs & source.
★ **IBM, 100Kb**

Automatic Structure Charts, Kim Harris C004 - $8
Tools for analysis of large Forth programs, first presented at FORML conference. Full source; docs incl. in 1985 FORML Proceedings.
★★ **IBM, 114Kb**

A Simple Inference Engine, Martin Tracy C005 - $8
Based on inf. engine in Winston & Horn's book on LISP, takes you from pattern variables to complete unification algorithm, with running commentary on Forth philosophy & style. Incl. source.
★★ **IBM, 162 Kb**

The Math Box, Nathaniel Grossman C006 - $10
Routines by foremost math author in Forth. Extended double-precision arithmetic, complete 32-bit fixed-point math, & auto-ranging text. Incl. graphics. Utilities for rapid polynomial evaluation, continued fractions & Monte Carlo factorization. Incl. source & docs.
★★ **IBM, 118 Kb**

AstroForth & AstroOKO Demos, I.R. Agumirsian C007 - $6
AstroForth is the 83-Std. Russian version of Forth. Incl. window interface, full-screen editor, dynamic assembler & a great demo. AstroOKO, an astronavigation system in AstroForth, calculates sky position of several objects from different earth positions. Demos only.
★ **IBM, 700 Kb**

Forth List Handler, Martin Tracy C008 - $8
List primitives extend Forth to provide a flexible, high-speed environment for AI. Incl. ELISA and Winston & Horn's micro-LISP as examples. Incl. source & docs.
★★ **IBM, 170 Kb**

8051 Embedded Forth, William Payne C050 - $20
8051 ROMmable Forth operating system. 8086-to-8051 target compiler. Incl. source. Docs are in the book *Embedded Controller Forth for the 8051 Family.*
★★★ **IBM, 4.3 Mb**

68HC11 Collection C060 - $16
Collection of Forths, Tools and Floating Point routines for the 68HC11 controller.
★★★ **IBM, 2.5 Mb**

F83 V2.01, Mike Perry & Henry Laxen C100 - $20
The newest version, ported to a variety of machines. Editor, assembler, decompiler, metacompiler. Source and shadow screens. Manual available separately (items 217 & 235). Base for other F83 applications.
★ **IBM, 83, 490 Kb**

NEW VERSION

F-PC V3.56 & **TCOM**, Tom Zimmer C200 - $30
A full Forth system with pull-down menus, sequential files, editor, forward assembler, metacompiler, floating point. Complete source and help files. Manual for V3.5 available separately (items 350 & 351). Base for other F-PC applications.
★ **IBM, 83, 3.5Mb**

F-PC TEACH V3.5, Lessons 0–7 Jack Brown C201 - $8
Forth classroom on disk. First seven lessons on learning Forth, from Jack Brown of B.C. Institute of Technology.
★ **IBM, F-PC, 790 Kb**

VP-Planner Float for F-PC, V1.01 Jack Brown C202 - $8
Software floating-point engine behind the VP-Planner spreadsheet. 80-bit (temporary-real) routines with transcendental functions, number I/O support, vectors to support numeric co-processor overlay & user NAN checking.
★★ **IBM, F-PC, 350 Kb**

F-PC Graphics V4.6, Mark Smiley C203 - $10
The latest versions of new graphics routines, including CGA, EGA, and VGA suppport, with numerous improvements over earlier versions created or supported by Mark Smiley.
★★ **IBM DSDD, F-PC, 605 Kb**

PocketForth V6.1, Chris Heilman C300 - $12
Smallest complete Forth for the Mac. Access to all Mac functions, Events, files, graphics, floating point, macros, create standalone applications and DAs. Based on fig & *Starting Forth*. Incl. source and manual.
★ **MAC, 640 Kb,** System 7.01 Compatable.

Kevo V0.9b4, Antero Taivalsaari C360 - $10
Complete Forth-like object Forth for the Mac. Object-Prototype access to all Mac functions, files, graphics, floating point, macros, create standalone applications. Kernel source not included, extensive demo files, manual.
★★★ **MAC, 650 Kb,** System 7.01 Compatable.

Yerkes Forth V3.6 C350 - $20
Complete object-oriented Forth for the Mac. Object access to all Mac functions, files, graphics, floating point, macros, create standalone applications. Incl. source, tutorial, assembler & manual.
★★ **MAC, 2.4Mb,** System 7.01 Compatable.

Pygmy V1.4, Frank Sergeant C500 - $20
A lean, fast Forth with full source code. Incl. full-screen editor, assembler and metacompiler. Up to 15 files open at a time.
★★ **IBM, 320 Kb**

KForth, Guy Kelly C600 - $20
A full Forth system with windows, mouse, drawing and modem packages. Incl. source & docs.
★★ **IBM, 83, 2.5 Mb**

Mops V2.2, Michael Hore C710 - $20
Close cousin to Yerkes and Neon. Very fast, compiles subroutine-threaded & native code. Object oriented. Uses F-P co-processor if present. Full access to Mac toolbox & system. Supports System 7 (e.g., AppleEvents). Incl. assembler, docs & source.
★★ **MAC, 3 Mb,** System 7.01 Compatable

BBL & Abundance, Roedy Green C800 - $30
BBL public-domain, 32-bit Forth with extensive support of DOS, meticulously optimized for execution speed. Abundance is a public-domain database language written in BBL. Incl. source & docs.
★★★ **IBM HD, 13.8 Mb, hard disk required**

New Version Replacement Policy

Return the old version with the FIG labels and get a new version replacement for 1/2 the current version price.

MISCELLANEOUS

T-SHIRT "May the Forth Be With You" 601 - $12 1#
(Specify size: Small, Medium, Large, Extra-Large on order form)
White design on a dark blue shirt.

POSTER (*Oct., 1980 BYTE* cover) 602 - $5 1#

FORTH-83 HANDY REFERENCE CARD 683 - free

FORTH-83 STANDARD 305 - $15 1#
Authoritative description of Forth-83 Standard. For reference, not instruction. *83 pgs*

BIBLIOGRAPHY OF FORTH REFERENCES 340 - $18 2#
(3rd ed., January 1987)
Over 1900 references to Forth articles throughout computer literature. *104pgs*

Last 10

THEY'RE BACK

JFAR BACK ISSUES

Volume 2, #4 JFAR (1984) 705 - $15 1#
Extended Addressing: Bionary Search, VAX & 79 Standard, Token Threaded Forth, 32 Bit Machine, Implementing Local Words in Forth

Volume 4, #1 JFAR (1986) 710 - $15 1#
Expert Systems in Forth: Natural Language Parsing, Micro-Computer Based Medical Diagnosis System, FORTES Polysomnographer, FORPS

Volume 4, #3 JFAR (1987) 712 - $15 1#
REPTL, Stand-Alone Forth System, Compiling Forth, Julian Day Numbers, Abstracts '86 FORML Conference.

Volume 4, #4 JFAR (1987) 713 - $15 1#
Embedding of Languages in Forth, Forth-based Prolog for Real-Time Expert Systems S/K/ID.

Volume 5, #2 JFAR (1988) 715 - $15 1#
Mathematics, ANS Standard, Exception Handling, Logarithmic Number Representation, 32 bit RTX Chip Prototype

Volume 5, #3 JFAR (1989) 716 - $15 1#
From Russia with Forth, Knowledge Engineering, Symbolic Stack Addressing.

Volume 5, #4 JFAR (1989) 717 - $15 1#
Forth Processors, Parallel Forth, Arithmetic-Stack Processor, Architecture of the SC32 Forth Engine, Error-Free Statistics in Forth

Volume 6, #1 JFAR (1990) 718 - $15 1#
Harris RTX2000, Scientific Programming

MORE ON FORTH ENGINES

Volume 10 January 1989 810 - $15 1#
RTX reprints from 1988 Rochester Forth Conference, object-oriented cmForth, lesser Forth engines. *87 pgs*

Volume 11 July 1989 811 - $15 1#
RTX supplement to *Footsteps in an Empty Valley*, SC32, 32-bit Forth engine, RTX interrupts utility. *93 pgs*

Volume 12 April 1990 812 - $15 1#
ShBoom Chip architecture and instructions, Neural Computing Module NCM3232, pigForth, binary radix sort on 80286, 68010, and RTX2000. *87 pgs*

Volume 13 October 1990 813 - $15 1#
PALs of the RTX2000 Mini-BEE, EBForth, AZForth, RTX-2101, 8086 eForth, 8051 eForth. *107 pgs*

Volume 14 814 - $15 1#
RTX Pocket-Scope, eForth for muP20, ShBoom, eForth for CP/M & Z80, XMODEM for eForth. *116 pgs*

Volume 15 815 - $15 1#
Moore: New CAD System for Chip Design, A portrait of the P20; Rible: QS1 Forth Processor, QS2, RISCing it all; P20 eForth Software Simulator/Debugger. *94 pgs*

Volume 16 816 - $15 1#
OK-CAD System, MuP20, eForth System Words, 386 eForth, 80386 Protected Mode Operation, FRP 1600 - 16Bit Real Time Processor. *104 pgs*

DR. DOBB'S JOURNAL

Annual Forth issue, includes code for various Forth applications.
Sept. 1982 422 - $5 1#
Sept. 1983 423 - $5 1#
Sept. 1984 424 - $5 1#

FORTH INTEREST GROUP

P.O. BOX 2154 OAKLAND, CALIFORNIA 94621 510-89-FORTH 510-535-1295 (FAX)

Name _____ Phone _____
Company _____ Fax _____
Street _____ eMail _____
City _____
State/Prov. _____ Zip _____
Country _____

U.S. Domestic Postage Rates	Surface $1.00/#	2 day Priority $1.50/#	
International Postage Rates	Surface All /#	AIR MAIL 1-4 #s/#	AIR MAIL >4 #s/#
Canada, Mexico	$1.00	$2.00	$1.30
Other Western Hemisphere	$1.00	$3.25	$2.25
Europe	$1.00	$6.00	$4.50
Other International	$1.00	$8.00	$6.00

Item #	Title	Qty.	Unit Price	Total	#

☐ CHECK ENCLOSED (Payable to: FIG)
☐ VISA ☐ MasterCard
Card Number _____
Signature _____
Expiration Date _____ MEMBERSHIP →

Sub-Total		
10% Member Discount, Member # _____	( )	#s times rate
**Sales Tax on Sub-Total (CA only)		
Postage: Rate _____ x #s		
*Membership in the Forth Interest Group ☐New ☐Renewal $40/46/52		

*MEMBERSHIP IN THE FORTH INTEREST GROUP

The Forth Interest Group (FIG) is a world-wide, non-profit, member-supported organization with over 1,500 members and 40 chapters. Your membership includes a subscription to the bi-monthly magazine *Forth Dimensions*. FIG also offers its members an on-line data base, a large selection of Forth literature and other services. Cost is $40 per year for U.S.A. & Canada surface; $46 Canada air mail; all other countries $52 per year. This fee includes $36/42/48 for *Forth Dimensions*. No sales tax, handling fee, or discount on membership.
When you join, your first issue will arrive in four to six weeks; subsequent issues will be mailed to you every other month as they are published—six issues in all. Your membership entitles you to a 10% discount on publications and functins of FIG. Dues are not deductible as a charitable contribution for U.S. federal income tax purposes, but may be deductible as a business expense.

MAIL ORDERS:
Forth Interest Group
P.O. Box 2154
Oakland, CA 94621
PHONE ORDERS:
510-89-FORTH Credit card orders, customer service.
Hours: Mon–Fri, 9–5 p.m.

PAYMENT MUST ACCOMPANY ALL ORDERS

PRICES: All orders must be prepaid. Prices are subject to change without notice. Credit card orders will be sent and billed at current prices. Checks must be in U.S. dollars, drawn on a U.S. bank. A $10 charge will be added for returned checks.

POSTAGE:
All orders calculate postage as number of #s times selected postage rate. Special handling available on request.

SHIPPING TIME:
Books in stock are shipped within seven days of receipt of the order. Please allow 4–6 weeks for out-of-stock books (deliveries in most cases will be much sooner).

**** CALIFORNIA SALES TAX BY COUNTY:**
7.5%: Sonoma; **7.75%**: Fresno, Imperial, Inyo, Madera, Orange, Riverside, Sacramento, San Benito, Santa Barbara, San Bernardino, San Diego, and San Joaquin; **8.25%**: Alameda, Contra Costa, Los Angeles San Mateo, Santa Clara, and Santa Cruz; **8.5%**: San Francisco; **7.25%**: other counties.

For faster service, fax your orders 510-535-1295

the address into memory. This is accomplished by the phrase

```
SMUDGE  -FIND
IF DROP ,  ELSE  0 ERROR  THEN
SMUDGE
```

(It is possible to dispense with the necessity for naming the namesake word by playing with the contents of the user variable IN [>IN to neo- and mezoforthwrights]. The implementation will be left as an exercise for the student. It was not implemented to save space in the dictionary, not because the author was lazy.)

Another general caveat is that the optimizer must not optimize across branch terminations. While it might be acceptable to optimize the phrase FOO F@, the phrase FOO THEN F@ is not readily optimized. As THEN is an immediate word and leaves nothing in the dictionary where the optimizer can detect its passage, we must redefine it to leave a flag. This is done on screen 585. This is why the run-time portions of our optimizers examine the variable OPT immediately after they examine STATE.

Two defining words have been produced. UNARY is used to optimize words which are unary operators. That is, they take one item from the stack and operate on it, leaving one or zero items on the stack. BINARY is for words which take two items on the stack, and leave one. For examples of daughter words, see screen 589.

The Implementation

With the basic concepts laid down, we can expand our optimizer in three ways. We can add new defining words, for new classes of optimizers. We can add new daughter words to the existing defining words. We can add new capabilities and, if needed, new parameters to the existing defining words and their daughter words.

The last method of extension is how the optimizer words were produced in the first place. The programmer started out with a default action (compile the namesake, as usual), and one test and one action for a desired condition. As new phrases were considered for optimization, the nesting of IF ... ELSE ... THEN clauses continued apace.

This methodology allowed for incremental testing of the words under development. Screen 590 shows a test for the binary operator AND. The test is done by compiling two words. One is a code definition, consisting of the desired output for the compiler. The other is a test high-level word which exercises the optimizer. Screens 591 and 592, not shown, contain the target defining word and daughter words.

The last two lines of the screen compare the two words and disassemble\decompile them both automatically as part of the compilation process. These two tests almost instantly indicate problem areas with words under development. Automated testing of compiler output in this manner allowed very fast, reliable development of the optimizers, and was essential to the success of the project.

Once the basics of the optimizing code have been worked out, it remains only to incrementally add functions to analyze the code and handle the phrases where optimization is desired.

Selecting Phrases for Optimization

If you have your own target compiler and nucleus source, the best way to optimize all possible applications is to improve the nucleus. Anything that improves BLOCK will improve words that call BLOCK. So as FastForth was developed, optimizers were added to the target compiler as well as to the FastForth environment. The choice of phrases to optimize reflects an effort to improve the nucleus first, with improvements elsewhere secondary.

As noted, the phrase <USER VARIABLE> F@ shows up all over the nucleus. Similarly, <USER VARIABLE> F!, <USER VARIABLE> OFF and <USER VARIABLE> 1+!. The optimizations of F@ and F! were primary, with the others secondary. These are the phrases to be optimized by the optimizer defining word UNARY, on screens 586 and 587.

These words also operate with variables and often with constants. Both variables and constants compile to in-line literals, either in the form of <value> @#L S -[MOV, or in the form of <value> # DR7 MOVQ, DR7 S -[MOV, for literals in the range of (hex) -80 to 7f. However, since most variables and constants used as variables will be long values, it is essential to detect long literals, with short ones a possible addition for the student.

The long literal form compiles into:

```
<value> @#L S -[ MOV,
```

After manipulation by F@ the code should look like this:

```
<value> @#L AR0 MOV,  AR0 [ S -[ MOV,
```

After manipulation by F! the code should look like this:

```
<value> @#L AR0 MOV,  S [+ AR0 [ MOV,
```

This means that the code in UNARY will twiddle the literal's opcode to change its destination, and lay down a new instruction. Since the instruction will vary with the word being compiled, this must be provided as an operand to each optimizer as it is compiled. This instance is handled on screen 587, lines three and four.

With nuclear optimization in mind, the phrase <USER VARIABLE> F@ F@ is handled as well. This phrase shows up in places that affect compiler speed, such as in -FIND or LATEST. Any applications which use double indirection will benefit.

The next defining word for optimizers is the family of binary words. These are words which, prior to optimization, take two operands from the stack and return one. These are +, -, etc., as indicated on screen 589. In code they take the form:

```
S [+ DR7 MOV,  DR7 S [ <opcode>,      NEXT
```

If we can detect literals and user variables, and see to it that their contents are left in DR7, we can then compile the appropriate opcode to complete the operation, saving a push

to and a pop from the data stack.

For example, adding a byte literal to the top of the stack becomes:

```
<value> # DR7 MOVQ,  DR7 S [ ADD,
```

Similarly, adding the contents of a user variable to the top of the stack goes from:

```
<user variable> U &[ DR0 MOV,  DR0 S -[ MOV,
S [+ DR7 MOV,  DR7 S [ ADD,
```

to:

```
<user variable> U &[ S [ ADD,
```

This optimization gets rid of three instructions and produces an optimization of fewer instructions than original source words. Not bad for not being an example of Moorish architecture.

To return to the original example, an updated table taking into account the optimizer is as follows:

Progressive optimization improves the example

Item	JSR/BSR w/ Optimizer	Indirect Threaded
code field	0 bytes	Four bytes
SCR	Part of a four-byte instruction laid down in line.	Four bytes
F@	The rest of the four-byte instruction.	Four bytes
LIST	Two, four or six bytes of BRA or JMP.	Four bytes
exit code	0 bytes	Four bytes
Total	*10 bytes, maximum*	*20 bytes*

Comparison: Traditional Compilers

A conceptually simple but very powerful Forth code optimizer can be had in five screens, less than two pages. One has problems imagining a traditional compiler with optimization occupying so small a source code space. Also, one has a hard time imagining the likes of AT&T or Microsoft releasing source for their compilers. And you don't have to call a 900 number to get support.

Furthermore, the optimizer presented here is a complete unit, and can be removed from the FastForth environment without any changes except, of course, in the size and speed of the generated code. It is dependent only upon the nature of the target processor.

Additional phrases may be selected for optimization by the user, who need only add them to the compiler in the traditional Forth manner. Eventually, a diminishing return of better speed and code size must be offset against development time and costs. Unlike the traditional compiler, this tradeoff may be made by the end user, the application programmer, if he wishes. In fine Forth tradition, the application programmer may modify the compiler to suit his application, rather than the usual methodology of modifying the application to fit the compiler's procrustean bed.

Indeed, the very notion of an application programmer having the ability to modify his compiler is a heresy to the ayatollahs of traditional computing.

Conclusions

The FastForth code optimizer produces fast, efficient code. It is easy to understand, and can be modified readily by the end user. It is very powerful and conceptually very simple. Indeed, anyone reasonably familiar with the instruction set of his target processor and the inner workings of his Forth can write one. Like Forth itself, it makes an abattoir of the sacred cows of computing.

Availability

In the best Forth tradition, the code is released to the public domain. Enjoy it in good health.

FastForth for the Atari ST, including the above code, may be had in alpha release from the author, Charles Curley, P.O. Box 2071, Gillette, Wyoming 82717-2071. Please consult the author for the current state of documentation, etc.

Charles Curley is a long-time Forth nuclear guru who lives in Wyoming. When not working on computers he teaches firearms safety and personal self defense. His forthcoming book *Polite Society* covers federal and state firearms legislation in layman's terms.

```
                                                        Scr #   585
 0 ( optimizers for : defs                      ( 22  3 92 CRC 11:05 )
 1 BASE F@ HEX
 2 0 VARIABLE OPT          ( not particularly re-entrant! )
 3
 4 : THEN   HERE OPT F!  [COMPILE] THEN  ;          IMMEDIATE
 5
 6 : BEGIN  HERE OPT F!  [COMPILE] BEGIN ;          IMMEDIATE
 7
 8 : OPGET         ( addr ct --- | get operand ct bytes from addr )
 9   + W@ ;
10
11
12 -->
13
14
15


                                                        Scr #   586
 0 ( optimizers: unary                          ( 15  4 92 CRC  8:37 )
 1 : UNARY  CREATE  SMUDGE  -FIND  IF DROP ,  ELSE  0 ERROR  THEN
 2   SMUDGE  W, W, W,  IMMEDIATE
 3   DOES>  STATE F@                          ( only if compiling... )
 4     IF  HERE OPT F@ -                      ( not following a begin)
 5       IF  HERE 6 - W@  273C =              ( following a literal? )
 6         IF  4 OPGET  HERE 6 - W!           ( yyy ** @#1 xxx,      )
 7         ELSE  HERE 2- W@  2708 =           ( ar0 s -[ mov, eg user)
 8           IF  -2 ALLOT  HERE 4- W@  41EE = ( user variable?     )
 9             IF  6 OPGET  HERE 4- W!        ( yyy u ** &[ xxx,     )
10             ELSE  8 OPGET  W, THEN   [     ( yyy ar0 [ xxx,       )
11 -->
12
13
14
15


                                                        Scr #   587
 0 ( optimizers: unary                          ( 21  4 92 CRC  8:15 )
 1 ]         ELSE  HERE 4- W@ 272E =          ( user f@ optimize     )
 2             IF  206E  HERE 4- W!  8 OPGET  W,
 3             ELSE  HERE 6 - W@  2739 =    ( literal f@ optimize  )
 4               IF  2079 HERE 6 - W!     8 OPGET W,
 5               ELSE    F@ <COMP>  THEN  THEN  THEN  THEN
 6       ELSE  F@ <COMP>  THEN      ( following br resolution      )
 7     ELSE  @EXECUTE  THEN ;       ( not compiling                )
 8
 9
10 : BINARY  CREATE  SMUDGE  -FIND  IF DROP ,  ELSE  0 ERROR  THEN
11   SMUDGE  W, W,  IMMEDIATE
12   DOES>  STATE F@  [                       ( only if compiling... )
13 -->
14
15


   fastForth on Atari ST              (c) 1985-92 by Charles Curley
   Tuesday  6/10/92 11:20:08
```

(Code continues on next page.)

```
                                                          Scr #   588
 0 ( binary defining word                          ( 21  4 92 CRC  8:15 )
 1 ]   IF  HERE OPT F@ -                          ( not following a begin)
 2       IF  HERE 4- C@  70 =                     ( byte literal?         )
 3         IF  HERE 4- E TOGGLE                   ( xx # dr7 moveq,       )
 4           -2 ALLOT  4 OPGET W,                 ( dr7 s [ xxx,          )
 5         ELSE  HERE 6 - W@ 273C =               ( large literal?        )
 6           IF  6 OPGET  HERE 6 - W!             ( yy #l s [ xxx,        )
 7           ELSE  HERE 4- W@  272E =             ( user f@ ??            )
 8             IF  HERE 4- 9 TOGGLE  4 OPGET W,   ( ofuser s [ add )
 9             ELSE  HERE 6 - W@  2739 =          ( literal f@ ??         )
10               IF  HERE 6 - 9 TOGGLE  4 OPGET W, ( lit dr7 mov, )
11               ELSE  F@ <COMP>  THEN  THEN  THEN  THEN
12       ELSE  F@ <COMP>  THEN      ( following br resolution       )
13     ELSE  @EXECUTE  THEN ;       ( not compiling                 )
14 -->
15

                                                          Scr #   589
 0 ( daughter words                                ( 20  4 92 CRC 13:22 )
 1 ( opget    8    6     4                                             )
 2           5290 52AE  52B9  UNARY 1+! 1+!
 3           4290 42AE  42B9  UNARY OFF OFF
 4           209B 2D5B  23DB  UNARY F!  F!
 5           2710 272E  2739  UNARY F@  F@
 6
 7 (             l.w. lit  byte lit                                    )
 8                693   DF93    BINARY +   +
 9                493   9F93    BINARY -   -
10                 93   8F93    BINARY OR  OR
11                293   CF93    BINARY AND AND
12                A93   BF93    BINARY XOR XOR
13 BASE F!
14
15

                                                          Scr #   590
 0 \ test area for macro mods                      ( 21  4 92 CRC  7:08 )
 1 DEBUG   FORTH DEFINITIONS       FORGET TASK
 2 : TASK ;                        BASE F@ >R      HEX
 3 : ?LEN:   [COMPILE] ' 2- W? ;
 4 0 VARIABLE SNARK
 5 CODE FOO   ofuser fld dr7 mov,  dr7 s [ and,
 6            snark @#l dr7 mov,   dr7 s [ and,
 7            7f # dr7 movq,       dr7 s [ and,
 8            ffff #l                  s [ and,
 9              NEXT ;C
10
11  1 2 +THRU
12 : BAR    fld f@ and  snark f@ and  7f and  ffff and  ;
13
14 R> BASE F!       EDITOR FLUSH  ?CR ?LEN: FOO ?LEN: BAR
15 ' FOO  DUP 2- W@  ' BAR EDITOR -CITEXT .  UN: BAR UN: FOO  ;S

   fastForth on Atari ST              (c) 1985-92 by Charles Curley
   Tuesday  6/10/92 11:20:14
```

Math— Who Needs It?

Prof. Tim Hendtlass
Hawthorn, Australia

The title of this article is a deliberate *double entendre*. Whatever one's feelings about mathematics in general, arithmetic (at least) is going to be needed sooner or later in your programs. One of the most striking things about Forth, quickly noticed by people who are used to another language, is that 16-bit integers are the only types of numbers apparently directly supported in basic Forth. A closer inspection shows that this is not strictly true, but certainly there are no floating-point numbers defined in the core words of Forth. The reason is, of course, that you can add anything you might want or need to Forth, so why saddle people with things they may not need? If floating point is really required, for example, you just add it, to whatever accuracy you need. The collection of routines in this article are my compilation of math words with varying precision, speed, and portability. I did not write all of them and have gratefully acknowledged the original authors in the text.

Before rushing in to add new math words with extra capabilities, it is wise to see if these capabilities are really needed. In some situations certainly, but not in others. Since, *provided the same algorithms are used*, floating-point math executes more slowly than fixed-point math, and fixed-point math executes more slowly than double precision, and double precision executes more slowly than single-precision math, it makes sense from the point of view of speed not to use any more capability than you need. Also, the code size in bytes will vary depending on the precision of the math you use, and whether it is written in high-level Forth or mainly in assembly language. As well as the code, there are tables showing the relative speeds and memory requirements of the words described; this is to allow the reader to pick the one that best meets the requirements of the task at hand.

First let us define a couple of terms concerning the representation of numbers: the resolution and the range. The resolution is the minimum possible change that can be represented in a number format. For integers it is one. The range is the difference between the largest and smallest (or, in the case of signed numbers, the most negative) numbers that can be expressed. Integers' resolution is always one, and the range goes up as the number of bits in the integer increases.

For fixed-point numbers, the number is expressed in a single quantity. Depending on how many bits of this quantity you allocate for the fixed decimal places, the resolution and the range vary inversely (e.g., the greater the resolution, the smaller the range). Fixed-point math is very closely related to integer math, except that all numbers are stored internally after having been multiplied by an integer scaling factor. They are divided by this scaling factor before being output. This allows a number of decimal places to be provided while still treating the numbers as integers. Since you still represent numbers in (say) 32 bits, the actual range would be that for 32-bit integers divided by the scaling factor. See Table One for signed numbers, for which the range is the difference between the largest and smallest numbers that can be represented. (For unsigned integers the range would be the same, but from zero to one more than twice the value shown under "Largest positive number.")

Floating-point numbers are stored in two parts, one expressing an integer number and the other the power of ten (usually) to which this integer should be raised to give the final number. If this power (the exponent) is positive, the number represented can be very large and the resolution small (ten to the power of the exponent). If this power is negative, the number represented can be very small and the resolution high. Using floating-point representation, this tradeoff between range and resolution can alter dynamically without any explicit attention by the programmer as the magnitude of the numbers being used changes.

Single-precision Integer Arithmetic

This is fully provided in F-PC, as in all Forths. The largest positive signed number that can be represented in 16 bits is +32767 and the largest negative signed number is -32768. The smallest number is zero. Of course, since we are dealing with integers, no decimal points are allowed. The four basic functions (add, subtract, multiply, and divide) are provided, plus modulus (`MOD`), absolute (`ABS`), and special routines to multiply or divide by two (`2*` and `2/`). In binary, multiplying and dividing by two are the same as just shifting all bits in the number left and right, respectively, by one place. In the case of a left shift, the bit moved into the least significant place is zero; in the case of a right shift, the bit moved in as the most significant bit must be the same as the previous most significant bit, in order to preserve the sign of the number.

Figure One. 32-bit integer arithmetic.

Multiply two double-precision numbers to give a double-precision product.

Unsigned with overflow check.

```
: UD*C  ( ud1 ud2 --  ud3 )     \ Unsigned double * unsigned double = unsigned double
  dup>r rot dup>r >r over >r          \ put a c c b on return stack
  >r swap dup>r                       \ put a d onto return stack
  um*                                 \ b*d
  0 2r> um* d+ 2r> um* d+             \ offset 16 bits, add on a*d+b*c
  0 2r> um* d+                        \ offset another 16 bits, add on a*c
  or 0<> abort" D* overflow"          \ check for overflow
;
```

Unsigned without overflow check.

```
: UD*   ( ud1 ud2 --  ud3 )     \ Unsigned double * unsigned double = unsigned double
  rot >r over >r >r over >r           \ put c b a d on return stack
  um*                                 \ b*d = part of 32 bit answer
  2r> * 2r> * + +                     \ a*d+b*c= addition to top 16 bits
;
```

Signed with or without overflow check (replace ud* by ud*c to check for overflow)

```
: D*    ( d1 d2 -- d3 )             \ Signed double * signed double = signed double
  dup>r dabs 2swap dup>r dabs         \ #s +ve, keep info to work out final sign
  ud*                                 \ get 32-bit answer (ud*c for overflow check)
  2r> xor ?dnegate                    \ work out and apply final sign
;
```

Division ($U_0 * 2^{16} + U_1$) / ($V_0 * 2^{16} + V_1$) = ($A_0 * 2^{16} + A_1$)

```
\ Use fast algorithm, remainder requires an additional
\ 32-bit multiplication and subtraction.
: T*  ( ud un -- ut )           \ Unsigned double * unsigned single = unsigned triple
  dup rot  um* 2>r                    \ high-part of answer to return stack
  um* 0 2r> d+                        \ get low-part ans offset 16 bits add on high-part
;
: T/  ( ut un -- ud )           \ Unsigned triple / unsigned single = unsigned double
  >r r@ um/mod swap                   \ divisor to r, divide top 16 bits, rem to top
  rot 0 r@ um/mod swap                \ combine with next 16, divide these by divisor
  rot r> um/mod swap drop             \ repeat for last 16 bits, lose final remainder
  0 2swap swap d+                     \ combine parts of answer to for final answer
;
: U*/  ( ud un1 un2 -- ud2 )         \ ud * un1 / un2, triple intermediate product.
  >r t* r> t/
;
: UD/   ( U1 U0 V1V0 -- A1 A0 )     \ Unsigned 32-bit by 32-bit divide. No remainder
  dup 0=                              \ top 16 bits of divisor = 0?
  if swap t/                          \ simple case, make it a triple, do the division
  else                                \ more involved case
    dup 65536. rot 1+ um/mod  >r      \ work out scaling factor D,save on return stack
    drop r@ t* drop 2>r               \ scale denominator, move to return stack
    dup 0 2r@ u*/ d-                  \ calculate (U-U0*W1/W0)
    2r> r> -rot nip u*/               \ multiply by (D/W0)
    nip 0                             \ /2^16, make answer double
  then
;
: D/MOD  ( dn1 dn2 --  drem dquot )  \ Divide two signed double numbers.
  2 pick over xor >r                  \ work out sign of answer
  dabs 2swap dabs 2swap               \ convert numbers to positive
  4dup ud/ 2dup 2>r                   \ do the division, save copy of quotient
  ud* d-                              \ calculate the remainder
  2r> r> ?dnegate                     \ retrieve answer, apply final sign
;
: D/  ( dn1 dn2 --   dquot )         \ Divide two signed doubles, no remainder.
  2 pick over xor >r                  \ work out sign of answer
  dabs 2swap dabs 2swap               \ convert numbers to positive
  ud/                                 \ do the division
  r> ?dnegate                         \ retrieve answer, apply final sign
;
```

Table One.

				<---------- Range ---------->		Resolution
	Word size	Decimal places	Scaling factor	Largest positive number	Largest negative number	Smallest increment
Integer	16	0	na	32767	-32768	1
Integer	32	0	na	2,147,483,647	-2,147,483,648	1
Fixed point	32	1	10	214,748,364.7	-214,748,364.8	.1
Fixed point	32	2	100	21,474,836.47	-2,147,483,648	.01
Fixed point	32	3	1000	2,147,483.647	-2,147,483.648	.001
Fixed point	32	4	10000	214,748.3467	-214,748.3468	.0001

Numbers can be entered in line by just typing them, and are printed with . (and its formatted cousins .R etc.).

Also provided are the words UM+, UM*, and UM/MOD, the building blocks on which all higher-precision arithmetic is built. The first two take two unsigned 16-bit numbers and add or multiply them to give an unsigned 32-bit result. UM/MOD divides an unsigned 32-bit number by an unsigned 16-bit number to give a 16-bit result and a 16-bit remainder. One thing Forth does not have is a carry bit—if the result of a mathematical operation is too large to fit into the available space, the topmost bit(s) will be lost. Since this can legitimately happen when performing multi-precision arithmetic, we need to find a way to allow for these "lost" bits—in short, to synthesize a carry bit. This is not hard, but adds a little to the time taken to do things. Routines written in assembler can use the internal carry bit of the processor, but will no longer be portable to other processors.

Double-precision Integer Arithmetic

A limited double-precision capability is built into all Forths with double-number extensions, and F-PC is no exception. A double-precision number is one that is expressed in 32 bits, rather than the 16 bits of a single-precision number. Since these are still integers, double-precision numbers can represent much larger numbers, from +2,147,483,647 to -2,147,483,648, in fact. When do you need them? When you can't express what you want with single precision, naturally. For example, suppose you wanted to store the number of cents you made per year; in all probability, 16 bits would not be enough, as it would only allow you to earn up to about $320 per year. If you think about that example, it may occur to you that, since cents are the fractional parts of a dollar, you have a sort of two-decimal-place, fixed-point arithmetic here. As long as you add or subtract numbers, the fixed implied decimal point will stay in place; but if you multiply or divide, the implied decimal point gets messed up. Below we will see how to correct that, but first let us consider what double-precision integer facilities are provided.

Of the four basic functions, only addition (D+) and subtraction (D-) are provided directly; in a moment we will generate D* and D/ (among others). To print a double number, there is D. (and its formatted cousin D.R). A double-precision absolute value word is provided (DABS). There are also limited double-precision comparisons: D=, D>, D<, and D0=. To input a double number, either from the keyboard or in line in a definition, all you need to do is put a decimal point in the number somewhere. This use of a decimal point to indicate a double number can lead to misunderstanding. It is intended for when you are using an implied fixed decimal place, but it often misleads people into believing that the decimal part will be correctly handled. It won't, unless you specifically use words that do so. If you were to enter the number 31415., the number in the two positions on the stack would be no different than if you had entered 3.1415. However, the number of digits after the decimal place is recorded in the system variable DPL, especially for when you need this information. (As the same variable is used for all number input, you had better collect the value from DPL and use it, or put it somewhere safe before the next number arrives.) In the first case above, DPL would contain zero; in the second case four.

The main words we need to add to flesh out our double-precision integer capability are D* and D/. D* may produce an answer that is too big to fit into 32 bits (just as * may produce an answer too big to fit in 16 bits). It is possible to provide a run-time check to detect this (just make sure that the top 32 bits of the answer are zero), but this takes time. If you are sure that overflow will not occur in a problem, there is no need to calculate the top 32 bits of the answer. Code to perform 32-bit by 32-bit multiplication, with and without overflow check, is given below. In each case, we do unsigned arithmetic (both numbers are assumed positive); for signed arithmetic, we work out the sign of the answer, make both numbers positive, do the multiplication, and then apply the correct answer sign.

The algorithm for 32-bit multiplication is built from the 16-bit multiplication we already know how to do. Consider the following,

$$(a*2^{16} + b) * (c*2^{16} + d) = (a*c)*2^{32} + (bc+ad)*2^{16} + b*d$$

$(a*2^{16} + b)$ is one 32-bit number and $(c*2^{16} + d)$ is the other. Note by expanding it we have reduced one 32-bit by 32-bit multiply to four 16-bit by 16-bit multiplies, which we know how to do.

If we want to perform an overflow check, we get the full 32-bit answer by doing four 16-bit multiplies, offsetting their answers by the correct number of bits, and adding. The result is a 64-bit (i.e., quad-precision) number. If the numbers were both positive and the top 32 bits of the result are not zero, the result was too big to fit into 32 bits.

If an overflow check is not needed, we proceed by noting that a*c must equal zero (otherwise the result would not fit

Figure Two. 32-bit fixed-point arithmetic.

Defining the fixed-point structure

```
VARIABLE  FDPL                          \ holds number of implied decimal places
VARIABLE  FSCL                          \ holds the scaling factor we are using
: FPLACES ( -- n ) fdpl @ ;             \ return number of implied decimal places
: FSCALE ( -- n ) fscl @ ;              \ return the scaling factor we are using
: FIXED   ( n -- )
  0  max  4  min  fdpl  !               \ clip to between 0 and 4 decimal places
  1  fdpl  @  0  ?do  10  *  loop  fscale  !
                                        \ store #places, calc. & store scaling factor
;
  3 FIXED                               \ default to three decimal places
```

Outputting numbers

```
: (F.) (  fn -- adr  len  )             \ prepare fixed-point # ready to output
  tuck                                  \ keep copy of top byte so we know sign
  dabs                                  \ convert to positive number
  <#  bl  hold                          \ start conversion with a leading blank
  fdpl  @  0  ?do  #  loop              \ convert places after decimal point
  ascii  .  hold                        \ put a decimal point in place
  #s                                    \ convert integer part
  rot sign  #>                          \ put sign in place, tidy stack
;
: F. ( fn   -- )  (f.)  type  ;         \ print fixed-point number
: F.R ( fn p -- )                       \ print right justified in a field of p places
  >r  (f.)  r>  over  -  0  ?do  bl  emit  loop  type
                                        \ convert, pad with blanks as needed, then type
;
```

Inputting numbers

```
: D10* ( d1 -- 10*d1)                   \ multiply a 32-bit number by 10
  d2*  2dup  d2*  d2*  d+               \ 8*d+2*d=10*d
;
: FIX ( dn -- fn )
  dpl  @  0<                            \ single or double number?
  if  s>d  0  dpl  !  then              \ if single, convert to double
  dpl  @  fplaces <>                    \ # decimal places entered not fplaces?
  if  dpl  @  fplaces <                 \ too few places specified?
    if  fplaces  dpl  @  ?do  d10*  loop    \ yes, too few so scale the number up
    else  abort" Too many decimal places"   \ no, too many - we can't handle this
    then
  then
;
```

Multiply two fixed-point numbers, producing a fixed-point result.

```
: FIX*   ( f1 f2 -- f1*f2 )
  rot 2dup xor >r                       \ sign of answer to return stack
  -rot dabs 2swap dabs                  \ make both numbers positive
  dup>r rot dup>r >r over >r            \ put a c c b on return stack
  >r swap dup>r                         \ put a d onto return stack
  um*                                   \ b*d
  0 2r> um* d+ 2r> um* d+               \ offset 16 bits, add on a*d+b*c
  2r> * +                               \ add on low byte of a*c
  fscale mu/mod                         \ divide ms32 bits, ans to R.
  0<> abort" Fixed * Overflow!" >r      \ unless overflow quotient to R....
  fscale mu/mod rot drop                \ divide remainder and last 16 bits
  r> +  r> ?dnegate                     \ assemble final answer, negate if required
;
```

Divide two fixed-point numbers, producing a fixed-point result.

```
: FIX/   ( f1 f2 --  fquot=f1/f2 )      \ Divide two fixed-point numbers
  2 pick over xor >r                    \ work out sign of answer and save
  dabs 2swap dabs 2swap                 \ make all numbers positive
  2dup >r >r                            \ keep copy of divisor
  d/mod fscale 0 d*                     \ scale integer part of answer
  2swap fscale 0 d*                     \ and then scale remainder
  r> r> d/                              \ divide remainder by divisor
  d+                                    \ add fract part of ans
  r> ?dnegate                           \ put on final sign
;
```

into 32 bits), so there is no point in performing this multiply. Similarly (bc+ad) must give an answer that is no bigger than 16 bits. So only b*d need be done to 32-bit precision, and (bc+ad) to 16-bit precision, and a*c need not be done at all. Naturally, this makes this version faster than the one with overflow check.

The traditional method to perform a 32-bit by 32-bit division is by a subtract-and-shift algorithm (the way we were taught at school, except bit by bit rather than digit by digit), which gives both the result and the remainder. This method can be used to provide division of any precision, not just 32 bits. The method shown here uses an algorithm designed (only) for 31-bit unsigned numbers (that is, 32-bit signed numbers without the sign). The advantage of this new algorithm is speed: it is more than twice as fast. The algorithm is described in Knuth's book[1], but I came across it first in an article by Nathaniel Grossman in *Forth Dimensions*[2]. I have recoded it completely for faster execution.

The algorithm works as follows. Let the dividend be $U_0*2^{16}+U_1$ and the divisor be $V_0*2^{16}+V_1$. Also let D be a large integer not bigger than $65536/V_0$. For simplicity of calculation, let $D = 65536/(V_0+1)$ as suggested by Knuth. Then our division sum is:

$$\frac{U_0*2^{16}+U_1}{V_0*2^{16}+V_1} = \frac{D*(U_0*2^{16}+U_1)}{W_0*2^{16}+W_1} \quad \text{where } D*(V_0*2^{16}+V_1) = W_0*2^{16}+W_1$$

and

$$\frac{U_0*2^{16}+U_1}{V_0*2^{16}+V_1} = \frac{D}{W_0*65536}*(U_0*2^{16}+U_1) - \frac{U_0*W_1}{W_0} \quad \text{plus an error term.}$$

The error term is so small it may be ignored, unless we wished to calculate the remainder. In practice, it is simpler to find the remainder (if we need it) by taking away the product of the answer and the divisor from the dividend. Also, we must check that V_0 is not zero; if it is, we must not use the relationship above, as we will be trying to divide by zero. However, if V_0 is zero, our problem is reduced to dividing a 32-bit number by a 16-bit number, a very much simpler task.

The code in Figure One implements the various versions of `D*` and `D/` in a straightforward way.

32-bit Fixed-point Arithmetic

The software to be described will allow you to choose the number of decimal places you want and, therefore, the scaling factor that will be used. The more decimal places you want, the smaller the largest positive and negative numbers you can handle, but the smaller the smallest number increment you can represent.

To perform fixed-point math, only the number input, number output, multiplication, and division words need to be changed. The addition, subtraction, and absolute value double-precision words still work. First you must decide how many decimal places you want to the right of the decimal point; for simplicity, let us call this N. Any number that does not have this number of decimal digits must be multiplied by the appropriate power of ten to get its implied decimal point to line up with all the others. After a normal double-precision multiply, the 64-bit answer will be too large by 10^N, so to get the correct answer simply requires a division by 10^N. Dividing by 10 is not as easy as dividing by two, unfortunately, so this extra step adds a bit to the execution time.

After a division, the result will be too small by 10^N. But just doing the division and then multiplying by 10^N would lose precision. We must do the division, scale the remainder up by 10^N, do an integer division of this remainder, and add this result to the previous result to get a final result to the fullest precision possible.

The word to print a fixed-point number, `F.` (or `F.R` to print the number right justified in a specified field), really prints two numbers: a number representing the integer part and a second representing the fractional part. These are printed with a decimal point in between (and leading blanks, as required, in the case of `F.R`).

In this simple package, the user has to specify with the word `FIX` that the number just entered is to be a fixed decimal point number. From the keyboard, this would be done by entering `123.4 FIX`, for example. To put the same fixed-point number in a colon definition, you would specify it as `[ 123.4FIX ] DLITERAL`.

The code in Figure Two implements these words in a straightforward way. By default, the number of implied decimal places is set to three; modify the line `3 FIXED` to alter the number of implied decimal places to any integer between zero and four.

32-bit Floating-point Arithmetic

If you need a greater dynamic range of numbers than can be readily accommodated in either 32-bit integer or 32-bit fixed-point arithmetic, but can tolerate lesser basic resolution than 32-bit integers provide, you might consider 32-bit floating point. Here, some of the 32 bits are used to hold an exponent, and the remainder are for the basic number. The code shown below allocates 16 bits each to the basic signed number and the signed exponent. The dynamic range is probably unreasonably high, and one might be tempted to increase the number of bits allocated to the basic number and decrease the number allocated to the exponent. The programming ease of staying with 16-bit quantities for each, and the speed penalty that would be incurred by dealing with smaller parts of the number, strongly dictate otherwise. The accuracy is a little better than four significant digits, about the accuracy of the traditional logarithm tables that school children suffered before the advent of calculators. The code shown below, which implements such a 32-bit floating-point number package, was originally written by Martin Tracy and has only been slightly modified for greater speed by this author. Martin called it "Zen" math. There is also an add-on

Figure Three. 32-bit floating-point math.

```
\ Trim a double-number mantissa and an exponent of ten to a floating number.
: TRIM      ( dn n = f)
  >r                                    \ exponent to return stack
  tuck dabs                             \ save copy of sign, make double positive
  begin over 0< over 0<> or             \ MSB low word set or top 16 bits no zero?
                                        \ if so, too big to fit into 16 bits when signed
  while
   0 10 um/mod >r 10 um/mod nip r>      \ and increase exponent
  repeat rot ?dnegate drop r>           \ apply sign and final exponent
;
\ 32 bit floating-point addition and subtraction
: F+
  rot 2dup -  dup 0<                    \ work out difference in exponents
  if                                    \ top number has the larger exponent
   negate rot >r nip >r swap r>         \ keep larger and diff, swap mantissas
  else                                  \ top has a smaller or equal exponent
   swap >r nip                          \ keep larger (on return stack) and diff
  then
  >r s>d r> dup 0                       \ convert larger to double, top 16 bits >r
  ?do >r d10* r> 1-                     \ multiply mantissa by 10, decrement exponent
   over abs 6553 >                      \ would a *10 cause overflow of these 16 bits?
   if leave then                        \ prematurely terminate loop if so
  loop
  r> over + >r                          \ calculate final exponent
  if rot drop                           \ top 16 bits were *ve lose copy of bottom 16
  else rot s>d d+                       \ top 16 bits -ve, convert to double and add on
  then r> trim                          \ get final exponent and trim
;
: FNEGATE       >r negate r> ;
: F-            fnegate f+ ;            \ add negative of the top value

\ 32-bit floating-point multiplication
: F*  ( f1 f2 -- f3 )
  rot + >r                              \ calc exp of answer, save on return stack
  2dup xor >r                           \ save xor of mantissas too (sign of answer)
  abs swap abs um*                      \ make mantissas positive and multiply
  r> ?dnegate r> trim                   \ apply sign and then get exponent and trim
;
\ 32-bit floating-point division
: F/
  over 0= abort" d/0 error!"            \ check for divide by zero
  rot swap - >r                         \ get exponent of answer, put on return stack
  2dup xor -rot                         \ get sign of answer, tuck down on stack
  abs dup 6553 min rot abs 0            \ make number +ve, ensure divisor < 6553
  begin 2dup d10* nip 3 pick <          \ would divisor * 10 be less than dividend?
  while  d10* r> 1- >r                  \ yes, divisor * 10, decrement answer exponent
  repeat 2swap drop um/mod              \ now do the division
  nip 0 rot ?dnegate r> trim            \ lose remainder, apply sign get exp and trim
;
\ 32-bit floating-point input and output
\ Numbers to be floated must include a decimal point when entered.
\ DPL contains the number of digits entered after the decimal point.
: FLOAT  ( n -- f)                      \ float the last entered number.
  dpl @ negate trim
;
: F.  ( f --)                           \ print a floating number in fixed format.
  >r dup abs 0
  <# r@ 0 max 0 ?do ascii 0 hold loop
  r@ 0<
  if r@ negate 0 max 0 ?do # loop ascii . hold
  then r> drop #s rot sign
  #> type space
;
```

to Zen which extends it to calculate transcendental functions (with an accuracy of only about three figures) written by Nathaniel Grossman. This is not reproduced here; it can be found in *Dr. Dobbs Toolbook of Forth* Volume Two, in the file of these words on GEnie's Forth RoundTable, or directly from this author. The code in Figure Three implements Zen math.

Forth or Assembly Code?

All the words above are written in Forth and are thus able to be transported from machine to machine. There are two reasons why words written in assembly code will run faster. (They will, of course, not be able to be ported to other processors nearly as readily.) One reason is that, although there is only a slight speed overhead involved in using the Forth inner interpreter, this can accumulate to a small but significant sum over enough operations. The second reason is not as obvious, but accounts for more of the speed penalty observed. Forth has no carry; if you add two 16-bit quantities and the sum is too large to fit into 16 bits, the uppermost (17th) bit of the answer is lost. In arithmetic involving more than 16 bits, a carry is needed in order to do the calculations—you have to synthesize one, which takes time. By writing in machine code, you can make direct use of the carry flag of the processor. The 48-bit floating-point package described below is written mainly in assembly language, and is significantly faster than any of the other packages given. Not all of this speed increase comes from using assembler—the algorithms used are highly optimized. If you want the fastest speed arithmetic possible for a given processor, you must use the most efficient algorithms and assembly language. The result will be larger than the simple algorithms described above, and totally non-portable. Of course, a hardware math processor will always perform faster than any software solution on the main processor.

48-bit Floating-point Arithmetic, SFLOAT

This is a full software assembly language floating-point package for F-PC written (and copyrighted) by Robert L. Smith. It is in the file SMITH.ZIP which comes as part of the F-PC package. The size of a floating-point number is 48 bits (six bytes). The largest difference to get used to when you load this software is the fact that you now have another (third) stack. Holding the floating-point numbers on the regular data stack would make stack operations an absolute nightmare, so they are given a stack of their own. By default, the floating-point stack is 100 floating-point numbers deep, but you can change this just by altering one constant before you load the software. Words expect their floating-point parameters on the floating-point stack and leave their floating-point results there. Any flags that result from operations on floating-point numbers are left on the normal data stack, and any integers needed are obtained from the normal data stack. Words are provided to manipulate the floating-point stack; the name used is almost always the name of the same operation of the data stack, but with a leading F. Thus, we have `FDUP` and `FROT`, for example.

`SFLOAT` not only provides a full set of arithmetic and transcendental functions, it may also alter the outer interpreter of F-PC. The new outer interpreter allows you to enter floating-point numbers in line. Any number with an embedded decimal point or with an exponent will be converted to a floating-point number. Any number without a decimal point will be treated as a single-precision integer and placed on the data stack. Any number with a decimal point at the end will be treated as a double-precision integer and put on the data stack. You can control whether you wish to use the normal or the new outer interpreter at any time, by using the words `FLOATING` and `NOFLOATING`. A list of words provided by `SFLOAT` can be found by inspecting the help file that comes with `SFLOAT`.

Relative Performance

Shown in Table Two are the timings for addition, subtraction, multiplication, and division for each of the 16- and 32-bit math capabilities shown above. All times are relative, with a 16-bit signed add used as reference, and have been rounded to two significant figures. The times were calculated by timing a loop that performed the required operation 65,536 times, and deducting the time for an empty loop. The actual times you get will depend on the processor speed; on my trusty old 25 MHz '386SX, a 16-bit signed add took about six microseconds. Also shown are timings for `SFLOAT`. Just looking at the figures can be misleading, as you may be unintentionally equating apples with oranges, so a number of explanatory comments are given below.

The multiply and divide times in row one are small, as the PC processor has hardware 16-bit integer multiply and divide. The far larger times for multiplication and division in row two show the penalty to be paid when you have to

Table Two.

Description	Add	Subtract	Multiply	Divide
16-bit signed integer, written in Forth, portable	1	1	1.1	1.3
32-bit unsigned integer, written in Forth, portable	2.4	3.8	8	13
32-bit signed integer, written in Forth, portable	2.4	3.8	13.1	19
32-bit fixed point, 3 decimal places, written in Forth, portable	2.4	3.8	36	93
32-bit Zen floating point, written in Forth, portable	19	22	16	69
48-bit floating point, SFLOAT, written in assembler, non-portable	2.9	3.1	2.1	2.9

synthesize operations on long numbers out of repeated use of short-length operators. Doubling the word size increased the execution time by a much higher factor. Row three shows that just adding the extra code to keep track of the implied decimal point for fixed-point multiplication and division has added about another 50% to the time; except for addition and subtraction, fixed-point arithmetic costs significant time over integer arithmetic.

For curiosity, the multiplication word in row three was rewritten as in-line code. This saves the time used by the inner interpreter (NEXT) and allows intermediate results to be kept in registers instead of being pushed at the end of one word and immediately reloaded again at the start of the next. This new version was faster, but only by about six percent. This modest speed increase must be weighed against the benefits of writing in Forth so that the word is portable to other Forth systems, no matter what the processor. Also, Forth code is much easier to understand and, therefore, to write and debug.

The 32-bit floating-point Zen package results may seem strange. The clue to understanding them lies in the way that a separate exponent simplifies multiplication and division, but complicates addition and subtraction. Since the actual number in Zen is a 16-bit quantity, multiplication is done by multiplying the 16-bit numbers and adding their exponents.

Table Three.

	Memory requirements in bytes			
Math Package	header space	code space	list space	total
32-bit integer, 4 functions	86	42	288	416
32-bit fixed point, 4 functions	216	102	768	896
32-bit floating point, 4 functions	106	50	1562	1718
SFLOAT, 4 functions only	671	2976	850	4488
SFLOAT full package	2380	7253	5756	15389

For division, the multiplication is replaced by division and the addition by subtraction. As a result, these words are faster than their fixed-point equivalents, which require a 32-bit multiplication and division of the result by a scaling factor. However, addition and subtraction of fixed-point numbers is trivial, while to do the same with floating-point numbers requires that the numbers be shifted (scaled) so that their exponents are equal before the required operation can be done.

The times shown in row six seem little short of amazing, considering that this is for 48-bit floating point, and show what can be done if you abandon the requirement for portability and write in highly optimized machine code. Note again the (relative) inefficiency of addition and subtraction compared to multiplication and division. The routines used are anything but trivial to understand (see the file SFLOAT.TXT, for example, for an explanation of the divide algorithm used). An assembly language routine using the same algorithm for fixed point would be faster than even these floating-point times.

Speed is only one criterion, another is the memory these routines take up. Table Three shows the memory needed in F-PC by each of the math packs. The smaller space quoted for SFLOAT is with only the basic four mathematical functions loaded; the larger figure is for the full package, which includes many more functions. If you have a math co-processor, there is an equivalent package to SFLOAT called FFLOAT, which also comes with F-PC and which is even faster and smaller. FFLOAT is, of course, totally non-portable.

Choose your math routines after considering your need for speed, precision, size, and portability. No one of them is always the best.

1. *Donald E.Knuth,* The Art of Computer Programming, *Volume Two, Addison-Wesley Publishing Company 1973.*
2. *Nathaniel Grossman, "Long Division and Short Fractions,"* Forth Dimensions *VI/3, September/October 1984.*

Tim Hendtlass, Ph.D., is an Associate Professor responsible for the Scientific Instrumentation major at Swinburne Institute of Technology. He discovered Forth in about 1980 and since has used it for research and for teaching to about 80 students a year. In research, he has used it in fields from intelligent adaptive technological support for the elderly, to highly distributed industrial data collection, to devices for the measurement of capacitance under adverse conditions.

```
\ Extra words needed to implement 32-bit integer, fixed, and floating-point arithmetic.
anew 32math
\               ************************************************************
\               *                 32-bit Integer Arithmetic                *
\               ************************************************************

\                       *********************************
\                       * 32-bit Integer Multiplication *
\                       *********************************

\ Unsigned double * unsigned double = unsigned double (No overflow check)
: UD*                           \ unsigned 32-bit answer, no overflow check
  rot >r over >r >r over >r     \ put c b a d on return stack
  um*                           \ b*d = part of 32-bit answer
  2r> * 2r> * + +               \ a*d+b*c= addition to top 16 bits
;
\ Signed double * signed double = signed double (No overflow check)
: D*                            \ signed, no overflow check
  dup>r dabs 2swap dup>r dabs   \ #s +ve, keep info to work out final sign
  ud*                           \ get 32-bit answer
  2r> xor ?dnegate              \ work out and apply final sign
;
\ Unsigned double * unsigned double = unsigned double (with overflow check)
: UD*C                          \ unsigned, with overflow check
  dup>r rot dup>r >r over >r    \ put a c c b on return stack
  >r swap dup>r                 \ put a d onto return stack
  um*                           \ b*d
  0 2r> um* d+ 2r> um* d+       \ offset 16 bits, add on a*d+b*c
  0 2r> um* d+                  \ off another 16 bits, add on a*c
  or 0<> abort" D* overflow"    \ check for overflow
;
\                       ****************************
\                       * 32-bit Integer Division *
\                       ****************************
comment:
\ Traditional algorithm, slow but gives remainder directly

: Q2*  ( qn= a b c d --  qn2)           \ Shift quad qn left one bit.
  2swap dup >r                         \ save copy of c to handle carry later
  d2*  2swap  d2*                      \ do the two shifts
  r> 0< negate s>d d+                  \ perform the carry if needed
;
: D/   ( dn1 dn2 -- dquot ) d/mod 2swap 2drop ;
: DMOD ( dn1 dn2 -- drem ) d/mod 2drop ;
comment;
\ Fast algorithm, remainder requires an additional multiplication and sutraction.
\ Unsigned double * unsigned single = unsigned triple
: T*  ( ud un -- ut )
  dup  \ ud un un
  rot  \ udl un un udh
  um*  \ udl un high-ans
  2>r  \ udl un
  um* 0 2r> d+ \ low-ans then add on high-answer after offsetting it 16 bits
;
\ Unsigned triple /  unsigned single = unsigned double
: T/  ( ut un -- ud )
  >r r@ um/mod swap  \ divisor to r, divide top two words, rem to top
  rot 0 r@ um/mod swap  \
  rot r> um/mod swap drop
  0 2swap swap d+
;
```

```
\ Calculate ud * un1 / un2.  Triple intermediate product.
: U*/ ( ud un1 un2 -- ud2 )
  >r t* r> t/ ;

\ Unsigned 32-bit by 32-bit divide.  No remainder.
: UD/  ( ud1 ud2 -- ud3 )
  dup 0=                          \ top 16 bits of divisor = 0?
  if swap t/                      \ make it a triple, do the division
  else
    dup 65536. rot 1+ um/mod >r   \ work out scaling factor,copy to return stack
    drop r@ t* drop 2>r           \ scale denominator, move to return stack
    dup 0 2r@ u*/ d-              \ calculate (U-U0*W1/W0)
    2r> r> -rot nip u*/           \ multiply by (D/W0)
    nip 0                         \ /2^16 (use top 16 bits only), make ans double
  then
;
\ Divides two double numbers.  All numbers are signed doubles.
2variable temp1                           \ to simplify stack management
: D/MOD  ( dn1 dn2 --  drem dquot )
  2 pick over xor >r                      \ work out sign of answer
  dabs 2swap dabs 2swap                   \ convert numbers to positive
  4dup ud/ 2dup 2>r                       \ do the division, save copy ans
  ud* d-                                  \ calculate remainder
  2r> r> ?dnegate                         \ retrieve answer, apply final sign
;
: D/  ( dn1 dn2 --  dquot )
  2 pick over xor >r                      \ work out sign of answer
  dabs 2swap dabs 2swap                   \ convert numbers to positive
  ud/                                     \ do the division
  r> ?dnegate                             \ retrieve answer, apply final sign
;

\             ***********************************************************
\             *                 32-bit Fixed-Point Arithmetic             *
\             ***********************************************************

\                     ****************************************
\                     *  Defining the fixed-point structure  *
\                     ****************************************
variable fdpl         variable fscl
: FPLACES ( -- n ) fdpl @ ;               \ number of implied decimal places
: FSCALE ( -- n ) fscl @ ;                \ scaling factor we are using
: FIXED   ( n -- )
  0 max 4 min fdpl !                      \ clip to between 0 and 4 decimal places
  1 fplaces 0 ?do 10 * loop fscl !        \ store scaling factor
;
  3 FIXED                                 \ default to three decimal places

\                     ****************************************
\                     *          Outputting numbers          *
\                     ****************************************
: (F.) ( fn -- adr len )                  \ prepare fixed-point # ready to output
  tuck                                    \ keep copy of top byte so we know sign
  dabs                                    \ convert to positive number
  <# bl hold                              \ start conversion with a leading blank
  fplaces 0 ?do # loop                    \ convert places after decimal point
  ascii . hold                            \ put a decimal point in place
  #s                                      \ convert integer part
  rot sign #>                             \ put sign in place, tidy stack
;
: FIX. ( fn   -- ) (f.) type ;            \ print fixed-point number
```

```
: FIX.R ( fn p -- )                        \ right justify in a field of p places
  >r (f.)                                  \ convert number
  r> over - 0 ?do bl emit loop type        \ pad with blanks as needed
;
\                       ****************************************
\                       *            Inputting numbers         *
\                       ****************************************
: D10* ( d1 -- 10*d1)                      \ multiply a 32-bit number by 10
  d2* 2dup d2* d2* d+                      \ 8*d+2*d=10*d
;
\ Convert number to fixed-point number - no check made for numbers too large
\ Example 1234.5 FIX. To compile a fixed-point number in a : definition, use
\ [ 1234.5 FIX ] DLITERAL
: FIX ( dn -- fn )
  dpl @ 0<\ single or double number?
  if  s>d 0 dpl ! then                      \ if single convert to double
  dpl @ fplaces <>                          \ # decimal places entered not fplaces?
  if dpl @ fplaces <                        \ too few places specified?
    if fplaces dpl @ ?do d10* loop          \ yes, too few so scale the number up
    else abort" Too mnay decimal places"    \ no, too many - we can't handle this
    then
  then
;
\                       ****************************************
\                       *     32-bit Fixed-Point Multiply      *
\                       ****************************************
\ Multiply two fixed-point numbers, producing a fixed-point result.
: FIX*   ( f1 f2 -- f1*f2 )
  rot 2dup xor >r                  \ sign of answer to return stack
  -rot dabs 2swap dabs             \ make both numbers positive
  dup>r rot dup>r >r over >r       \ put a c c b on return stack
  >r swap dup>r                    \ put a d onto return stack
  um*      \ b*d
  0 2r> um* d+ 2r> um* d+          \ offset 16 bits, add on a*d+b*c
  2r> * +                          \ add on low byte of a*c
\ fscale mu/mod >r >r              \ divide ms32 bits, ans to R. Remainder on stack
\  fscale mu/mod rot drop          \ and that remainder and last 16 bits
\  0 r> r> d+ r> +                 \ assemble final answer
\  r> ?dnegate                     \ yes, answer valid, negate if required
\  else abort" F* Overflow"   report if an overflow
\  then
;
\                       ****************************************
\                       *       32-bit Fixed-Point Divide      *
\                       ****************************************
: FIX/   ( f1 f2 --  fquot=f1/f2 )       \ Divide two numbers
  2 pick over xor >r                     \ work out sign of answer and save
  dabs 2swap dabs 2swap                  \ make all numbers positive
  2dup >r >r                             \ keep copy of divisor
  d/mod fscale 0 d*                      \ scale integer part of answer
  2swap fscale 0 d*                      \ and then scale remainder
  r> r> d/                               \ divide remainder by divisor
  d+                                     \ add fract part of ans
  r> ?dnegate                            \ put on final sign
;
```

```
\               ********************************************************
\               *              32-bit Floating-Point Arithmetic        *
\               *             Based on Zen Math by Martin Tracy        *
\               ********************************************************
\ Trim a double-number mantissa and an exponent of ten to a floating number.
: TRIM     ( dn n = f)
  >r      \ exponent to return stack
  tuck dabs                    \ save copy of high word for sign, make double positive
  begin over 0< over 0<> or    \ MSB low word set or top 16 bits no zero?
                               \ if so, too big to fit into 16 bits when signed
  while
   0 10 um/mod >r 10 um/mod nip r>        \ divide 32-bit mantissa by 10
   r> 1+ >r                               \ and increase exponent
  repeat rot ?dnegate drop r>             \ apply sign and final exponent
;
\               ************************************************
\               *  32-bit Floating-Point Addition and Subtraction  *
\               ************************************************
: F+
  rot 2dup -  dup 0<             \ work out difference in exponents
  if                             \ top number has the larger exponent
   negate rot >r nip >r swap r> \ keep larger (on return stack) and diff, swap mantissas
  else                           \ top has a smaller or equal exponent
   swap >r nip                   \ keep larger (on return stack) and diff
  then
  >r s>d r> dup 0                \ convert mantissa to be shift to double
  ?do >r d10* r> 1-              \ multiply mantissa by 10, decrement exponent
   over abs 6553 >               \ would a *10 cause overflow of these 16 bits?
   if leave then                 \ prematurely terminate loop if so
  loop
  r> over + >r                   \ calculate final exponent
  if rot drop                    \
  else rot s>d d+
  then r> trim                   \ get final exponent and trim
;
: FNEGATE       >r negate r> ;
: F-            fnegate f+      \ add negative of the top value
;
\               ***************************************
\               * 32-bit Floating-Point Multiplication *
\               ***************************************
: F*  ( f1 f2 -- f3 )
  rot + >r                       \ calc exp of answer,save on return stack
  2dup xor >r                    \ save xor of mantissas, too (sign of answer)
  abs swap abs um*               \ make mantissas positive and multiply
  r> ?dnegate r> trim            \ apply sign and then get exponent and trim
;
\                 ***********************************
\                 * 32-bit Floating-Point Division  *
\                 ***********************************
: F/
  over 0= abort" d/0 error!"     \ check for divide by zero
  rot swap - >r                  \ get exponent of answer, put on return stack
  2dup xor -rot                  \ get sign of answer, tuck down on stack
  abs dup 6553 min rot abs 0     \
  begin 2dup d10* nip 3 pick <   \
  while  d10* r> 1- >r           \
  repeat 2swap drop um/mod       \ now do the division
  nip 0 rot ?dnegate r> trim     \ lose remainder, apply sign get exp and trim
;
```

Code concludes in next issue *with 32-bit floating-point I/O and transcendental functions. It may be downloaded in its entirety from the Forth software library on GEnie.*

A Forum for Exploring Forth Issues and Promoting Forth

Fast FORTHward

Mike Elola
San Jose, California

From the last volume of *Forth Dimensions,* I have collected comments that reinforce one another and that speak to Forth and its future. The comments brought to you here have previously appeared in *FD*'s "Letters to the Editor" or "Best of GEnie" columns.

Not so long ago, I viewed the Forth community as a very divided community that was becoming even more divided. However, the views offered here reveal commonly held values and beliefs. Perhaps these values can also shape our vision about how to promote Forth.

John Wavrik is a professor at the University of California (San Diego, California) who has spoken of the strengths of Forth: "Conventional languages allow data structures only to be created by a limited set of mechanisms built into the language—and then impose further limitations on the status of these structures (how they can be passed to functions, how operators may act on them, etc.)."

He described the Forth advantage as "the ability to accomplish difficult things without fighting the language." He credits Forth with being the only language that always lets him do whatever he determines must be done, and speaks of fighting the rigid features of other languages (Best of GEnie, *FD* XIII/5). A theme that others will repeat is the relationship between power and knowledge: "Power in Forth comes, in great measure, from the user's ability to understand how the system works—and being able to harness that understanding."

Our concerns are focusing on management issues and on the development environment...

Steve Noll gave his testimonial about Forth's empowerment of the programmer. Crediting Forth for his speed of development, he briefly described five sophisticated machine-control applications that he completed in four years (Letters, *FD* XIII/5). Although he had come to Forth "kicking and screaming," he said he was won over. Given his experience, his suggestion for promoting Forth is a natural one: He suggested that a way to attract others to Forth is for FIG to distribute, market, and provide support for a low-cost Forth.

A winning submission in the programming contest held by FIG U.K. a couple of years back was a tiny editor from Mike Lake. He shared the story of the success of M.A.S.S., a company that converted to Forth around 1985 after BASIC, Pascal, and assembler had all been tried. He mentions that the company has distributed over 12,000 Forth applications worldwide (presumably, in a six-year period). Besides sharing his code with us, Lake described his company's deepening commitment to Forth, culminating in their development of an in-house Forth that gave them "absolute control" (Letters, *FD* XIII/3).

Dean Sanderson is a key software engineer with Forth Inc. He had this to say about Forth's future: "For Forth to survive as a respected language, it must prove its adaptability and change enough to support the concerns of management. These include: Integration, Maintenance, Documentation, Declining cost, Q[uality] A[ssurance], Configuration, and Scheduling. Though we've started late, we can survive by capitalizing on what others have learned" (Best of GEnie, *FD* XIII/3).

John Edgecombe described Forth as a language that enterprises resort to when conventional methods fail. He sympathizes with companies reluctant to use Forth because of the difficulty of getting good Forth help when they need it. He described why he uses Forth: "...I want something I can understand, that I will maintain, and which is economical of my limited resources" (Letters, *FD* XIII/1).

Tight, clever code is no longer as commercially valued as it once was. While asserting the prominence of the development environment, Laughing Water discounted the importance of Forth's compactness in today's marketplace: "[Forth's] virtues as a general programming language—compactness, speed, interactivity, flexibility (anarchy)—have become old fashioned indeed, and we are frequently superseded by mainstream languages in more fully evolved development environments..." (Letters, *FD* XIII/1).

By reporting that Macintosh Pascal has earned greater mindshare than Forth because of the environment it offers, Conrad Weyns added his voice to those proclaiming the prominence of the programming environment. This viewpoint asserts that a language such as Borland Pascal is popular due to the tools into which it is embedded rather than due to Pascal.

Weyns also joined those equating power and understanding: "A lot of Forth's power lies precisely in its accessibility: the ability to extend the compiler and interpreter, to add to it, to use or abuse it..." (Letters, *FD* XIII/3).

Mitch Bradley of Sun Microsystems said, "C is a viable,

usable and ubiquitous development environment, and Forth has to be competitive to succeed." He urged us to pay heed to the issue of the environment that accompanies our development systems and our applications, too: "The existence of the operating system cannot be ignored." Bradley claims that successful Forths have addressed the environment issue, "but without the guidance of a standard there has been great divergence" (Best of GEnie, *FD* XIII/1).

Divergence considered a flaw? Some would say that flexibility is the point of using Forth, because Forth offers the freedom to solve problems in novel ways. However, for pragmatic goals such as code reuse and code portability, divergence can indeed be our enemy. We have to be shrewd enough to know when a departure from standard technique will ultimately turn out to be a hindrance to our collective Forth future instead of a competitive advantage that will endure.

Brad Rodriguez shared his struggle to understand metacompiling (Letters, *FD* XIII/3). The understanding he sought finally arrived after he attended an advanced polyFORTH class. After presenting his struggles at the local FIG chapter meeting, he reports that others were able to unravel the secrets of the technique too.

Such an experience underscores our need for various forms of support. Opportunities to receive structured training are helpful, along with informal meetings. Rodriguez' experience also says something about our values and our requirements as programmers: Before something truly has value for us, we must be able to "access" exactly how it works. We feel penalized whenever program code or language features are inaccessible to us.

To make a language (or a programming technique) more accessible, books and training materials are always valued. Most of us read several journals each month besides *Forth Dimensions* in order to have better access to state-of-art practices and techniques

Tom Saunders of Sigma 3 Engineering in Edmonton (Alberta), Canada requested that FIG members participate in a survey so that every Forth dialect could be briefly outlined and its design goals described (Letters, *FD* XIII/2). This comment prompts me to question whether there is a way for us to pursue our diverse Forths and diverse programming techniques with any real hope of improving Forth's commercial standing—which currently seems to be flat growth for a relatively small number of businesses. Undoubtedly, our diverse solutions will also lead to many breakthroughs. But ignorance of these breakthrough techniques (or innovative Forth dialects) is widespread. How many receive only limited use in a handful of products, if that? Without doubt, the Forth systems comparisons offered by Guy Kelly have helped increase our awareness of the differences between some popular Forths (*FD* XIII/6).

Based on the comments I scanned, our concerns are becoming focused upon management issues and upon the prominence of the development environment. As we focus on issues such as support and training, we broaden our concept of the total cost of software. Our ability to profit from software will require us to be sensitive to all the issues of producing, deploying, and maintaining software.

Among its credits, Forth natively facilitates fast program development and easy program modification—two of the chief advantages claimed by makers of various development tools. Even without any of the extras that are part of a contemporary development environment, Forth systems are alleged to be perfectly suited to most programming needs. If you can make this claim, fortune may be smiling upon you. Those of us who require database languages with graphical interfaces may disagree.

We've also heard strong statements about how much we value our complete understanding of Forth, including the operation of its implementation code. In light of this, consider another of John Wavrik's comments. Here he questions where the proposed ANS Forth is headed—which he believes is away from Forth's past openness and low-level accessibility:

"My claim is that Forth has traditionally been a language which allows the user to build major language features. (There is Forth literature discussing variant methods for doing local variables, exception handling, adding object orientation, etc.) Forth has been a toolkit for building application-oriented languages. The ANSI team is heading in the direction of including some important features (local variables, exception handling, etc.) but removing the ability to build such things" (Best of GEnie, *FD* XIII/5).

I would like to thank everyone who made their thoughts known by submitting them to *Forth Dimensions* or to GEnie's Forth RoundTable. Through these forums, we all become better informed about the concerns facing our community.

—Mike Elola

Volume XIII Index

A subject index to Forth Dimensions *contents published from May '91–April '92. Prepared by Mike Elola.*

On the Back Burner #6

Transcendental Compilation

Conducted by Russell L. Harris
Houston, Texas

Among the things which make Forth unique among computer languages is the process of metacompilation. Also known by the terms *target compilation* and *cross-compilation*, metacompilation is, in simplest terms, a process by which an existing Forth system is used to generate a second, tailor-made Forth system. In this respect, metacompilation *transcends* the usual process of compilation. The new system may be a complete development environment, itself capable of metacompilation; it may be a ROMable application, having only the barest essentials to accomplish a specific and limited task; it may be an end-user application, with support for terminal and disk I/O, but without editor, assembler, and compiler. The new system may run on a machine identical to the development system on which the metacompilation takes place; it may run on a machine with word size, instruction set, and resources quite different from those of the development system; it may run from ROM on an embedded single-board computer. Whatever the case, metacompilation enables the programmer to create the new system with a minimum expenditure of time and effort, while giving him a degree of control he otherwise would have only in assembly language.

Daily association with Forth devotees via a local telephone call is an experience you shouldn't pass up.

The Emperor's New Clothes

Before proceeding with our discussion of metacompilation, it is necessary that several concepts be explained and that a number of terms be carefully defined. The matter of nomenclature is complicated by two factors. First, everyone seems to have his own name for a given item. Thus, what I call a *nucleus* you may call a *kernel*. Secondly, there's always someone trying to get rich by robbing others, specifically, by getting the government to hold a gun to everyone else's head while he, the robber baron, loots their pockets. If you believe in the non-entity commonly termed "intellectual property," be sure to promptly send me a substantial fee before proceeding further in this tutorial series; otherwise, I will be forced to dispatch a team of thugs with instructions to repossess my "property." (Those of you who have not bowed the knee to the idol of "intellectual property" may, with my blessing, proceed without charge.)

I plan to publish a paper on the subject of "intellectual property"; meanwhile, you might wish to visit the children's section of your local library and read again the faerie tale "The Emperor's New Clothes." If you care to research the matter of "intellectual property," I suggest you begin with the treatise entitled *The Law*, first published in 1850, authored by the Frenchman, Frederic Bastiat (1801–1850).

Nomenclature

Compilation is simply the process of writing to a dictionary. Compilation is a routine occurrence in Forth development environments, and also takes place in some Forth applications. Traditionally, on a disk-based Forth development system, the bootstrap loader or operating system brings up a small Forth nucleus of approximately 8K bytes. This nucleus then compiles or "loads" the balance of the Forth system, including an application, if any.

Forth words are typically classified into categories, much as routines in C are grouped into libraries. Categories outside the nucleus are termed *electives*. The set of electives to be loaded varies with the Forth implementation, the preferences of the user, and the requirements of the application, if any. When memory is limited, one need load only those electives necessary to support the application. Electives commonly loaded include those for printing, editing, and disk operations, in addition to the more basic functions such as clock, calendar, and double-length arithmetic.

The process of loading electives and applications is nothing other than compilation. Note, however, that loading the nucleus is not properly termed compilation: the bootstrap loader or operating system simply copies from disk to RAM an executable image. The source blocks which comprise electives and applications contain both high-level and code words. The high-level words are compiled by the colon compiler, while the code words are compiled by the assembler. The resulting executable code is compiled into the dictionary of the system on which the compiler and the assembler are executing; i.e., electives and applications are compiled into the *operating environment*. Thus, Forth words, both high-level and code, may be executed immediately after they have been compiled.

The *meta* in metacompilation indicates that the code being compiled is destined for an environment other than the operating environment. Unless the application environment is substantially the same as the development environment, it will not be possible to test metacompiled code within the development environment. Even if the development system and the application hardware share the same word size and instruction set, the complement and physical addresses of memory and peripherals may differ between the two systems.

Rather than attempting to metacompile into the operating environment, one generally sets aside, somewhere on the development system, an area of RAM or disk to receive the executable application code. Once metacompilation is complete, the code may be transferred elsewhere for testing.

In this and future columns, the terms *computer system*, *hardware*, and *machine* are synonymous, referring to a

physical computer system, including peripherals and the operating system, if any. The term *environment* will be used both for hardware and for software; the context will make clear which meaning is intended.

In metacompilation, there are, in principle, two computer systems. The hardware on which the metacompiler runs is termed the *development system* or *host*. The term *development system* is very appropriate for the computer used to write or develop an application, but the term is cumbersome, and I am open for suggestions as to a short yet descriptive name. The hardware on which the metacompiled application is to run is termed the *application hardware* or *target*. Again, *application hardware* is descriptive, but is awkward. Any suggestions? In some cases, the development system and the application hardware are the same machine. In our adventures, the development system will be the IBM-PC and the application hardware will be the 8051-family single-board computer presented in the last column.

A Forth metacompiler is a Forth application which runs on a development system. The metacompiler operates on Forth source code in order to produce executable application code. The source code may be a mixture of high-level and code words. Typically, the source code is read from disk and the application code is compiled to disk, but the application code may be compiled to RAM if the development system has sufficient available memory. Alternatively, the application code may be compiled directly to read/write memory in the application hardware, over a data link (typically, a serial line) connecting the development system and the application hardware.

If the development system and the application hardware have different instruction sets, the term *cross-compilation* is sometimes used instead of the more general term *metacompilation*.

To Be Continued...

Let us assume we have a Forth environment which does not include the capability of metacompilation. What must we do in order to add this capability? What problems and conflicts do we face? How do we solve and resolve them? What variations are possible and useful? Subsequent columns will address these matters, as we work our way through development of an 8051-family metacompiler which runs on the IBM-PC.

Collegiate Endeavours

A facet of university life I find compelling is the daily association with fellows who are pursuing the same or a similar course of study. A university experience in which one limits himself to attendance at lectures, laboratory sessions, and tests might as well be undertaken by correspondence or by attending night school. It is the opportunity outside the classroom to discuss, to reason, to hone mind against mind, that sets apart the university. In the collegiate environment, you can always find someone who recalls points you failed to note, someone who sees the underlying concept through detail you find impenetrable, someone willing to scrutinize your logic or verify a solution, someone content simply to listen as you think aloud, someone with an alternate perspective and approach to a problem which has you stumped. Conversely, you provide like function for your fellows. It is a give-and-take affair, somewhat like a climbing expedition, in which possession of the secure position is constantly passing from one member to another as progress is made.

While few of us can afford a return, even for a brief period, to full-time academic study, and few of us have employers which foster an interactive academic environment in the workplace, there yet remains a collegiate experience affordable and accessible to almost everyone. For a few dollars a month and a few dollars per hour of connect time, one may gain the potential of daily communication with a large number of individuals pursuing a common goal. I am speaking of the Forth Interest Group (FIG) bulletin board and real-time FIG conferences, currently hosted, along with the FIG software library, on the GEnie computer network.

The opportunity of daily association with fellow Forth devotees across the nation, via a local telephone call (Look Ma! No tolls!) is an experience you really shouldn't pass up. The monthly access fee buys unlimited electronic mail, which is great if you need to communicate directly with specific individuals. An hourly charge applies once you move to the Forth "round table," but it is at the round table that you gain access to the FIG community at large.

Once you know your way around GEnie, you can log on, check the FIG bulletin board for new messages in a given category, and log off, all in roughly a minute, so there is little excuse not to look in on a regular basis. You can download from GEnie a freebie utility called Aladdin with which PC users can automate the process, thus eliminating the time normally consumed in hurdling menus.

I urge readers of this column and every member of FIG to get a GEnie account and join us in an environment of mutual support and exploration. Our sysops have provided a bulletin board category, No. 19, for activity related to the "On the Back Burner" column. Under that category, several topics have been started and others can be added as needed. Readers having questions need to post those questions under the appropriate topic of category 19 and check back frequently, if not daily, for response. Readers knowledgeable in various areas are requested to frequently check topics in which they have expertise and to provide answers wherever possible. Readers having better or alternate solutions to common problems are invited to share their insight with the rest of us.

The gist of it is this: by way of the GEnie computing network, the FIG round table opens the door to interaction on a scale which would otherwise be impossible and on a frequency which would otherwise be prohibitive. Readers of this column who are following the ongoing tutorial need the type of support which only a collegiate environment or a resource such as a nation-wide, local-access bulletin board can provide. To readers who have mastered subjects and techniques covered by this column, the FIG round table offers the opportunity to share insight and to lend a helping hand. Everyone is welcome; everyone is needed. Won't you join us?

R.S.V.P.

Russell Harris is an independent consultant providing engineering, programming, and technical documentation services to a variety of industrial clients. His main interests lie in writing and teaching, and in working with embedded systems in the fields of instrumentation and machine control. He can be reached by phone at 713-461-1618, by fax at 713-461-0081, by mail at 8609 Cedardale Dr., Houston, Texas 77055, or on GEnie (address RUSSELL.H).

Call for Papers

13th Annual

Rochester Forth Conference

June 23 – 26, 1993

on

Process Control

Call for deadlines.
Conference includes introductory and advanced seminars on Forth technology and its application.

Announcing

Definitions: The Institute Newsletter

Call or write for a complimentary copy of the newsletter or the Journal and learn about our Associates Program.

Forth Institute
70 Elmwood Avenue
Rochester, NY 14611
(716)-235-0168 (716)-328-6426 fax
72050.2111@compuserve.com

Forth Interest Group
P.O. Box 2154
Oakland, CA 94621

Second Class
Postage Paid at
San Jose, CA