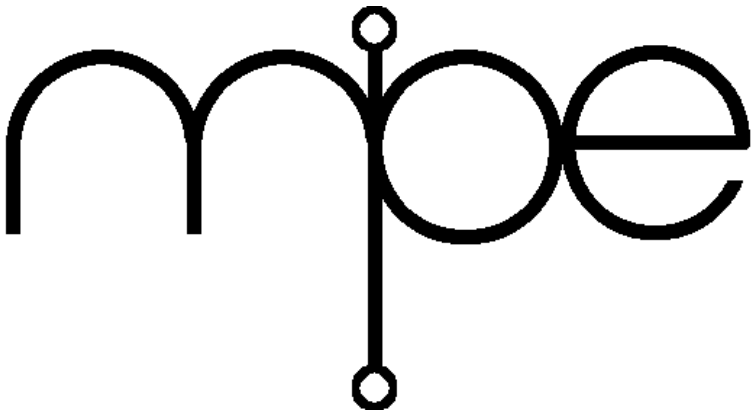
Common Target Code

v7.5

Microprocessor Engineering Limited



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1 High level kernel kernel62.fth

1.1 Configuration options

The following option equates are set if not already before *\i{kernel62.fth) is compiled.

```
0 equ DeferPrompt?      \ --
```
Set this true (non-zero) to defer the interactive prompt.

```
1 equ BigKernel?        \ --
```
Set this false to reduce the kernel size and lose some words.

1.2 User variables

```
variable next-user      \ -- addr
```
Next valid offset for a `USER` variable created by `+USER`.

```
: +user         \ size --
```
Creates a `USER` variable size bytes long at the offset given by `NEXT-USER` and updates it.

```
tcb-size +user SELF             \ task identifier and TCB
```
When multitasking is enabled by setting the equate `TASKING?` the task control block for a task occupies `TCB-SIZE` bytes at the start of the user area. Thus the user area pointer also acts as a pointer to the task control block.

```
cell +user S0           \ base of data stack
```
Holds the initial setting of the data stack pointer. N.B. `S0`, `R0`, `#TIB` and `'TIB` must be defined in that order.

```
cell +user R0           \ base of return stack
```
Holds the initial setting of the return stack pointer.

```
cell +user #TIB         \ number of chars currently in TIB
```
Holds the number of characters currently in `TIB`.

```
cell +user 'TIB         \ address of TIB
```
Holds the address of `TIB`, the terminal input buffer.

```
cell +user >IN          \ offset into TIB
```
Holds the current character position being processed in the input stream.

```
cell +user XON/XOFF     \ true if XON/XOFF protocol in use
```
True when console is using XON/XOFF protocol.

```
cell +user ECHOING      \ true if echoing
```
True when console is echoing input characters.

```
cell +user OUT          \ number of chars displayed on current line
```
Holds the number of chars displayed on current output line. Reset by CR.

```
cell +user BASE         \ current numeric conversion base
```
Holds the current numeric conversion base

```
cell +user HLD          \ used during number formatting
```
Holds data used during number formatting

```
cell +user #L           \ number of cells converted by NUMBER?
```
Holds the number of cells converted by `NUMBER?`

```
cell +user #D           \ number of digits converted by NUMBER?
```
Holds the number of digits converted by NUMBER?

```
cell +user DPL          \ position of double number character id
```
Holds the number of characters after the double number indicator character. DPL is initialised to -1, which indicates a single number, and is incremented for each character after the separator.

```
cell +user HANDLER      \ used in catch and throw
```
Holds the address of the previous exception frame.

```
cell +user OPVEC        \ output vector
```
Holds the address of the I/O vector for the current output device.

```
cell +user IPVEC        \ input vector
```
Holds the address of the I/O vector for the current input device.

```
cell +user 'AbortText   \ Address of text from ABORT"
```
Set by the run-time action of ABORT" to hold the address of the counted string used by ABORT" <text>".

```
    cell +user FSP      \ -- addr
```
Floating point stack pointer. Created if FP-SIZE is non-zero.

```
    cell +user FS0      \ -- addr
```
Top of floating point stack. Created if FP-SIZE is non-zero.

```
#64 chars dup +user PAD
```
A temporary string scratch buffer.

1.3 System Constants

Various constants for the internal system.

FALSE	The well formed flag version for a logical negative
TRUE	The well formed flag version for a logical positive
BL	An internal constant for blank space
C/L	Max chars/line for internal displays under C/LINE
#VOCS	Maximum number of Vocabularies in search order
VSIZE	Size of CONTEXT area for search order
XON	XON character for serial line flow control
XOFF	XOFF character for serial line flow control

1.4 System VARIABLEs and Buffers

1.4.1 Variables

Note that FENCE, DP and VOC-LINK must be declared in that order.

WIDTH	maximum target name size
FENCE	protected dictionary
DP	dictionary pointer
VOC-LINK	links vocabularies

RP	Harvard targets only. The equivalent of DP for DATA space.
SCR	If BLOCKS? true; for mass storage
BLK	If BLOCKS? true; user input dev: 0 for keyboard, >0 for block
CURRENT	Vocabulary/wordlist in which to put new definitions
STATE	Interpreting=0 or compiling=-1
CSP	Preserved stack pointer for compile time error checking
CONTEXT	Search order array
LAST	Points to name field of last definition
#THREADS	Default number of threads in new wordlists

1.5 Deferred words

```
defer NUMBER?   \ addr -- d/n/- 2/1/0
```

Attempt to convert the counted string at 'addr' to an integer. The return result is either 0 for failed, 1 for a single-cell return result (followed by that cell) or 2 for a double-cell return. The ASCII number string supplied can also contain implicit radix over-rides. A leading $ enforces hexadecimal, a leading # enforces decimal and a leading % enforces binary. Hexadecimal numbers can can also be specified by a leading '0x' or trailing 'h'. When one of the floating point packs is compiled, the action of NUMBER? may be changed.

```
defer ERROR     \ n -- ; error handler
```

The standard error handler reports error n. If the system is loading, the offending line will be displayed. Now implemented by default as a synonym for THROW. Removed from v6.2 onwards. Use THROW instead.

1.6 Predefined Vocabularies

FORTH	Is the standard general purpose vocabulary
ROOT	This vocabulary holds the bare minimum functions

1.7 Vectored I/O handling

1.7.1 Introduction

The standard console Forth I/O words (KEY?, KEY, EMIT, TYPE and CR) can be used with any I/O device by placing the address of a table of xts in the USER variables IPVEC and OPVEC. IPVEC (input vector) controls the actions of KEY? and KEY, and OPVEC(output vector) controls the actions of EMIT, TYPE and CR. Adding a new device is matter of writing the five primitives, building the table, and storing the address of the table in the pointers IPVEC and OPVEC to make the new device active. Any initialisation must be performed before the device is made active.

Note that for the output words (EMIT, TYPE and CR) the USER variable OUT is handled in the kernel before the funtion in the table is called.

1.7.2 Building a vector table

The example below is taken from an ARM implementation.

```
create Console1      \ -- addr
  ' serkey1i ,             \ -- char
  ' serkey?1i ,            \ -- flag
  ' seremit1 ,             \ char --
  ' sertype1 ,             \ c-addr len --
  ' serCR1 ,               \ --

Console1 opvec !  Console1 ipvec !
```

1.7.3 Generic I/O words

`: KEY?` `\ -- flag ; check receive char`
Return true if a character is available at the current input device.

`: KEY` `\ -- char ; receive char`
Wait until the current input device receives a character and return it.

`: EMIT` `\ -- char ; display char`
Display char on the current I/O device. `OUT` is incremented before executing the vector function.

`: TYPE` `\ caddr len -- ; display string`
Display/write the string on the current output device. Len is added to `OUT` before executing the vector function.

`: CR` `\ -- ; display new line`
Perform the equivalent of a CR/LF pair on the current output device. `OUT` is zeroed. before executing the vector function.

`: TYPEC` `\ caddr len -- ; display string`
Display/write the string from CODE space on the current output device. Len is added to `OUT` before executing the vector function. N.B. Harvard targets only. In non-Harvard targets, this is a synonym for `TYPE`.

`: SPACE` `\ --`
Output a blank space (ASCII 32) character.

`: SPACES` `\ n --`
Output 'n' spaces, where 'n' > 0. If 'n' < 0, no action is taken.

`: FlushKeys` `\ --`
Compiled for 32 bit systems to flush any pending input that might be returned by `KEY`.

`: SetConsole` `\ device --`
Sets `KEY` and `EMIT` and friends to use the given device for terminal I/O. Compiled for 32 bit systems, but is also part of *LIBRARY.FTH*.

`: [io` `\ -- ; R: -- ipvec opvec`
Save the current I/O devices on the return stack.

`: io]` `\ -- ; R: ipvec opvec --`
Restore the I/O devices from the return stack.

1.8 String and memory operations

Some of these words may be coded for performance. If they are predefined, the high level versions will not be compiled.

For byte-addressed CPUs (nearly all except DSPs) this kernel assumes that a character is an 8 bit byte, i.e. that:

```
char = byte = address-unit
```

`: PLACE` `\ c-addr1 u c-addr2 -- ; copies uncounted string to counted`
Place the string c-addr1/u as a counted string at c-addr2.

`: BOUNDS` `\ addr len -- addr+len addr`
Modify the address and length parameters to provide an end-address and start-address pair suitable for a `DO ... LOOP` construct.

`: UPC` `\ char -- char'`
If char is in the range 'a' to 'z' convert it to upper case. `UPC` is English language specific.

`: UPPER` `\ c-addr u --`
Convert the ASCII string described to upper-case. This operation happens in place. Note that this word is language specific and is written to handle English only.

`: ERASE` `\ a-addr u --`
Erase U bytes of memory from A-ADDR with 0.

`: BLANK` `\ a-addr u --`
Blank U bytes of memory from A-ADDR using ASCII 32 (space).

1.9 Dictionary management

`: HERE` `\ -- addr`
Return the current dictionary pointer which is the first address-unit of free space within the system.

`: ALLOT` `\ n --`
Allocate N address-units of data space from the current value of `HERE` and move the pointer.

`: aligned` `\ addr -- addr'`
Given an address pointer this word will return the next `ALIGNED` address subject to system wide alignment restrictions.

`: ALIGN` `\ --`
`ALIGN` dictionary pointer using the same rules as `ALIGNED`.

`: LATEST` `\ -- c-addr`
Return the address of the name field of the last definition.

`: SMUDGE` `\ --`
Toggle the `SMUDGE` bit of the latest definition.

`: ,` `\ x --`
Place the CELL value X into the dictionary at `HERE` and increment the pointer.

`: W,` `\ w --`
Place the WORD value X into the dictionary at `HERE` and increment the pointer. This word is not present on 16 bit implementations.

`: C,` `\ char --`
Place the CHAR value into the dictionary at `HERE` and increment the pointer.

`: there` `\ -- addr`
Harvard targets only: Return the DATA space pointer.

`: allot-ram` `\ n --`
Harvard targets only: `ALLOT` DATA space.

`: c,(r)` `\ b --`

Harvard targets only: The equivalent of `C,` for DATA space.

```
: ,(r)          \ n --
```
Harvard targets only: The equivalent of `,` for DATA space.

```
: N>LINK        \ a-addr -- a-addr'
```
Move a pointer from a NFA field to the Link Field.

```
: LINK>N        \ a-addr -- a-addr'
```
The inverse of `N>LINK`.

```
: >LINK         \ a-addr -- a-addr'
```
Move a pointer from an XT to the link field address.

```
: LINK>         \ a-addr -- a-addr'
```
The inverse of `>LINK`.

```
: >VOC-LINK     \ wid -- a-addr
```
Step from a wordlist identifier, wid, to the address of the field containg the address of the previously defined wordlist.

```
: >#THREADS     \ wid -- a-addr ; for XC5 compatibility
```
Step from a wordlist identifier, wid, to the address of the field containg the number of threads in the wordlist.

```
: >THREADS      \ wid -- a-addr
```
Step from a wordlist identifier, wid, to the address of the array containing the top NFA for each thread in the wordlist.

```
: >VOCNAME      \ wid -- a-addr
```
Step from a wordlist identifier, wid, to the address of the field pointing to the vocabulary name field.

```
: FIND          \ c-addr -- c-addr 0|xt 1|xt -1
```
Perform the `SEARCH-WORDLIST` operation on all wordlists within the current search order. This definition takes a counted string rather than a *c-addr/u* pair. The counted string is returned as well as the 0 on failure.

```
: .NAME         \ nfa --
```
The correct way to display a definition's name given an NFA. string for a word name, return the address of the dictionary name thread that will contain the name.

```
: makeheader    \ c-addr len --
```
Given a word name as a string in *addr/len* form, build a dictionary header for the word.

```
: $CREATE       \ c-addr --
```
Perform the action of `CREATE` (below) but take the name from a counted string. OBSOLETE: replace by:

```
 count makeheader docreate,
```

```
: CREATE        \ --
```
Create a new definition in the dictionary. When the new definition is executed it will return the address of the definition BODY.

1.10 String compilation

```
: (C")          \ -- c-addr
```
The run-time action for `C"` which returns the address of and steps over a counted string.

```
: (S")          \ -- c-addr u
```
The run-time action for S" which returns the address and length of and steps over a string.

```
: (ABORT")      \ i*x x1 -- | i*x
```
The run time action of ABORT".

```
: (.")          \ --
```
The run-time action of .".

1.11 Pre-ANS Exception handlers

Before the ANS Forth standard, these words were the primary error handlers. They are provided for compatibility, but wherever possible, the use of CATCH and THROW will be found to be more flexible.

```
: ABORT         \ i*x -- ; R: j*x --
```
Performs -1 THROW. This is a compatibility word for earlier versions of the kernel. Unfortunately, the earlier versions gave problems when ABORT was used in interrupt service routines or tasks. The new definition is brutal but consistent.

```
: ABORT"        \ Comp: "ccc<quote>" -- ; Run: i*x x1 -- | i*x ; R: j*x -- | j*x
```
If x1 is non-zero at run-time, store the address of the following counted string in USER variable 'ABORTTEXT, and perform -2 THROW. The text interpreter in QUIT will (if reached) display the text.

```
: (Error)       \ n --
```
The default action of ERROR. This definition has been removed from v6.2 onwards. See the section about the changes from v6.1 to v6.2.

```
: ?ERROR        \ flag n --
```
If flag is true, perform "n ERROR", otherwise do nothing. This definition has been removed from v6.2 onwards. See the section about the changes from v6.1 to v6.2.

1.12 ANS words CATCH and THROW

CATCH and THROW form the basis of all Forth error handling. The following description of CATCH and THROW originates with Mitch Bradley and is taken from an ANS Forth standard draft.

CATCH and THROW provide a reliable mechanism for handling exceptions, without having to propagate exception flags through multiple levels of word nesting. It is similar in spirit to the "non-local return" mechanisms of many other languages, such as C's **setjmp()** and **longjmp()**, and LISP's **CATCH** and **THROW**. In the Forth context, THROW may be described as a "multi-level EXIT", with CATCH marking a location to which a THROW may return.

Several similar Forth "multi-level EXIT" exception-handling schemes have been described and used in past years. It is not possible to implement such a scheme using only standard words (other than CATCH and THROW), because there is no portable way to "unwind" the return stack to a predetermined place.

THROW also provides a convenient implementation technique for the standard words ABORT and ABORT", allowing an application to define, through the use of CATCH, the behavior in the event of a system ABORT.

1.12.1 Example implementation

This sample implementation of CATCH and THROW uses the non-standard words described below. They or their equivalents are available in many systems. Other implementation strategies, including directly saving the value of DEPTH, are possible if such words are not available.

SP@ (– addr) returns the address corresponding to the top of data stack.

SP! (addr –) sets the stack pointer to addr, thus restoring the stack depth to the same depth that existed just before addr was acquired by executing SP@.

RP@ (– addr) returns the address corresponding to the top of return stack.

RP! (addr –) sets the return stack pointer to addr, thus restoring the return stack depth to the same depth that existed just before addr was acquired by executing RP@.

```
nnn USER HANDLER   0 HANDLER !  \ last exception handler
: CATCH  ( xt -- exception# | 0 ) \ return addr on stack
        SP@ >R  ( xt )  \ save data stack pointer
        HANDLER @ >R    ( xt )  \ and previous handler
        RP@ HANDLER !   ( xt )  \ set current handler
        EXECUTE ( )     \ execute returns if no THROW
        R> HANDLER !    ( )     \ restore previous handler
        R> DROP ( )     \ discard saved stack ptr
        0       ( 0 )   \ normal completion
;
: THROW  ( ??? exception# -- ??? exception# )
        ?DUP IF ( exc# )        \ 0 THROW is no-op
                HANDLER @ RP!   ( exc# )        \ restore prev return stack
                R> HANDLER !    ( exc# )        \ restore prev handler
                R> SWAP >R      ( saved-sp ) \ exc# on return stack
                SP! DROP R>     ( exc# )        \ restore stack
                \       Return to the caller of CATCH because return
                \       stack is restored to the state that existed
                \       when CATCH began execution
        THEN
;
```

The ROM PowerForth implementation is similar to the one described above, but not identical.

1.12.2 Example use

If THROW is executed with a non zero argument, the effect is as if the corresponding CATCH had returned it. In that case, the stack depth is the same as it was just before CATCH began execution. The values of the i*x stack arguments could have been modified arbitrarily during the execution of xt. In general, nothing useful may be done with those stack items, but since their number is known (because the stack depth is deterministic), the application may DROP them to return to a predictable stack state.

Typical use:

```
: could-fail    \ -- char
  KEY DUP [CHAR] Q =
  IF  1 THROW  THEN
;

: do-it         \ a b -- c
  2DROP could-fail
;

: try-it                \ --
  1 2 ['] do-it CATCH IF
    ( -- x1 x2 ) 2DROP ." There was an exception" CR
  ELSE
    ." The character was " EMIT CR
  THEN
;

: retry-it              \ --
  BEGIN
    1 2 ['] do-it CATCH
   WHILE
    ( -- x1 x2 ) 2DROP  ." Exception, keep trying" CR
  REPEAT ( char )
  ." The character was " EMIT CR
;
```

1.12.3 Gotchas

If a `THROW` is performed without a `CATCH` in place, the system will/may crash. As the current exception frame is pointed to by the `USER` variable `HANDLER`, each task and interrupt handler will need a `CATCH` if `THROW` is used inside it.

You can no longer use `ABORT` as a way of resetting the data stack and calling `QUIT`. `ABORT` is now defined as `-1 THROW`.

1.12.4 User words

`: CATCH         \ i*x xt -- j*x 0|i*x n`
Execute the code at XT with an exception frame protecting it. `CATCH` returns a 0 if no error has occurred, otherwise it returns the throw-code passed to the last `THROW`.

`: THROW         \ k*x n -- k*x|i*x n`
Throw a non-zero exception code n back to the last `CATCH` call. If n is 0, no action is taken except to `DROP` n.

`: ?throw        \ flag throw-code -- ; SFP017`
Perform a `THROW` of value throw-code if flag is non-zero, otherwise do nothing except discard flag and throw-code.

1.13 Formatted and unformatted i/o

1.13.1 Setting number bases

`: HEX           \ --`
Change current radix to base 16.

`: DECIMAL \ --`
Change current radix to base 10.

`: OCTAL \ --`
Change current radix to base 8. 32 bit targets only.

`: BINARY \ --`
Change current radix to base 2.

1.13.2 Numeric output

`: HOLD \ char --`
Insert the ascii 'char' value into the pictured numeric output string currently being assembled.

`: SIGN \ n --`
Insert the ascii 'minus' symbol into the numeric output string if 'n' is negative.

`: # \ ud1 -- ud2`
Given a double number on the stack this will add the next digit to the pictured numeric output buffer and return the next double number to work with. PLEASE NOTE THAT THE NUMERIC OP STRING IS BUILT FROM RIGHT (l.s. ddigit) to LEFT (m.s. digit).

`: #S \ ud1 -- ud2`
Keep performing `#` until all digits are generated.

`: <# \ --`
Begin definition of a new numeric output string buffer.

`: #> \ xd -- c-addr u`
Terminate defnition of a numeric output string. Return the address and length of the ASCII string.

`: -TRAILING \ c-addr u1 -- c-addr u2`
Modify a string address/length pair to ignore any trailing spaces.

`: D.R \ d n --`
Output the double number 'd' using current radix, right justified to 'n' characters. Padding is inserted using spaces on the left side.

`: D. \ d --`
Output the double number 'd' without padding.

`: . \ n --`
Output the cell signed value 'n' without justification.

`: U. \ u --`
As with . but treat as unsigned.

`: U.R \ u n --`
As with D.R but uses a single-unsigned cell value.

`: .R \ n1 n2 --`
As with D.R but uses a single-signed cell value.

1.13.3 Numeric input

`: SKIP-SIGN \ addr1 len1 -- addr2 len2 t/f ; true if sign=negative`
Inspect the first character of the string, if it is a '+' or '-' character, step over the string. Returning true if the character was a '-', otherwise return false.

`: +DIGIT \ d1 n -- d2 ; accumulates digit into double accumulator`

Multiply d1 by the current radix and add n to it.

```
: +CHAR          \ char -- flag ; true if ok
```

This routine handles non-numeric characters, returning true for valid characters. The only acceptable non-numeric character are the double-number separator ',' and the ignore separator ':', which is there to make 32 bit hex numbers more readable.

```
: +ASCII-DIGIT  \ d1 char -- d2 flag ; true=ok
```

Accumulate the double number d1 with the conversion of char, returning true if the character is a valid digit or part of an integer.

```
: (INTEGER?)    \ c-addr u -- d/n/- 2/1/0
```

The guts of `INTEGER?` but without the base override handling. See `INTEGER?`

```
: Check-Prefix  \ addr len -- addr' len'
```

If any `BASE` override prefices or suffices are used in the input string, set `BASE` accordingly and return the string without the override characters.

```
: Integer?      \ $addr -- n 1 | d 2 | 0
```

Attempt to convert the counted string at 'addr' to an integer. The return result is either 0 for failed, 1 for a single-cell return result followed by that cell)or 2 for a double return. The ASCII number string supplied can also contain implicit radix over-rides. A leading $ enforces hexadecimal, a leading # enforces decimal and a leading % enforces binary. The prefix '@' is supported for octal numbers in 32 bit systems, for which hexadecimal numbers can also be specified by a leading '0x' or a trailing 'h'.

```
: >NUMBER       \ ud1 c-addr1 u1 -- ud2 c-addr2 u2 ; convert all until non-digits
```

Accumulate digits from string c-addr1/u2 into double number ud1 to produce ud2 until the first non-convertible character is found. c-addr2/u2 represents the remaining string with c-addr2 pointing the non-convertible character. The number base for conversion is defined by the contents of `USER` variable `BASE`. `>NUMBER` is now case insensitive.

1.14 String input and output

```
: BS            \ -- ; destructive backspace
```

Perform a destructive backspace by issuing ASCII characters 8, 20h, 8. If `OUT` is non-zero at the start, it is decremented by one regardless of the actions of the device driver.

```
: ?BS           \ pos -- pos' step ; perform BS if pos non-zero
```

If pos is non-zero and `ECHOING` is set, perform `BS` and return the size of the step, 0 or -1.

```
: SAVE-CH       \ char addr -- ; save as required
```

Save char at addr, and output the character if `ECHOING` is set.

```
: ."            \ "ccc<quote>" --
```

Output the text upto the closing double-quotes character. Use `.( <text>)` when interpreting.

```
: $.            \ c-addr -- ; display counted string
```

Output a counted-string to the output device. Note that on Harvard targets (e.g. 8051) c-addr is in DATA space.

```
: ACCEPT        \ c-addr +n1 -- +n2 ; read up to LEN chars into ADDR
```

Read a string of maximum size n1 characters to the buffer at c-addr, returning n2 the number of characters actually read. Input may be terminated by CR. The action may be input device specific. If `ECHOING` is non-zero, characters are echoed. If `XON/XOFF` is non-zero, an XON character is sent at the start and an XOFF character is sent at the the end.

1.15 Source input control

`0 value SOURCE-ID \ -- n ; indicates input source`
Returns an indicator of which device is generating source input. See the ANS specification for more details.

`: TIB \ -- c-addr ; return address of terminal i/p buffer`
Returns the address of the terminal input buffer. Note that tasks requiring user input must initialise the `USER` variable `'TIB`. New code should use `SOURCE` and `TO-SOURCE` instead for ANS Forth compatibility.

`: TO-SOURCE \ c-addr u --`
Set the address and length of the system terminal input buffer. These are held in the user variables `'TIB` and `#TIB`.

`: SOURCE \ -- c-addr u`
Returns the address and length of the current terminal input buffer.

`: SAVE-INPUT \ -- xn..x1 n`
Save all the details of the input source onto the data stack. will do the job. If you want to move the data to the return stack, `N>R` and `NR>` are available in some 32 bit implementations.

`: RESTORE-INPUT \ xn..x1 n -- flag`
Attempt to restore input specification from the data stack. If the stack picture between `SAVE-INPUT` and `RESTORE-INPUT` is not balanced, a non-zero is returned in place of N. On success a 0 is returned.

`: QUERY \ -- ; fetch line into TIB`
Reset the input source specification to the console and accept a line of text into the input buffer.

`: REFILL \ -- flag ; refill input source`
Attempt to refill the terminal input buffer from the current source. This may be a file or the console. An attempt to refill when the input source is a string will fail. The return result is a flag indicating success with TRUE and failure with FALSE. A failure to refill when the input source is a text file indicates the end of file condition.

1.16 Text scanning

`: PARSE \ char "ccc<char>" -- c-addr u`
Parse the next token from the terminal input buffer using `<char>` as the delimiter. The next token is returned as a `c-addr/u` string description. Note that `PARSE` does not skip leading delimiters. If you need to skip leading delimiters, use `PARSE-WORD` instead.

`: PARSE-WORD \ char -- c-addr u ; find token, skip leading chars`
An alternative to `WORD` below. The return is a *c-addr/u* pair rather than a counted string and no copy has occured, i.e. the contents of `HERE` are unaffected. Because no intermediate global buffers are used `PARSE-WORD` is more reliable than `WORD` for text scanning in multi-threaded applications.

`: WORD \ char "<chars>ccc<char>" -- c-addr`
Similar behaviour to the ANS word `PARSE` but the returned string is described as a counted string.

1.17 Miscellaneous

`: HALT? \ -- flag`
Used in listed displays. This word will check the keyboard for a 'pause' key `<space>`, if the key is pressed it will then wait for a continue key or an abort key. The return flag is TRUE if abort is requested. Line Feed (LF, ASCII 10) characters are ignored.

`: origin-  \ addr -- addr'`
If addr is non-zero, subtract the start address of the first defined CDATA section. This word is only compiled if the start address of the first defined CDATA section is non-zero.

`: origin+  \ addr -- addr' ; denormalise NFA again`
If addr is non-zero, add the start address of the first defined CDATA section. This word is only compiled if the start address of the first defined CDATA section is non-zero.

`: nfa-buff  \ -- addr+len addr ; make a buffer for holding NFAs`
Form a temporary buffer for holding NFAs. A factor for `WORDS`.

`: MAX-NFA  \ -- addr c-addr ; returns addr and top nfa`
Return the thread address and NFA of the highest word in the NFA buffer. A factor for `WORDS`.

`: COPY-THREADS  \ addr --`
Copy the threads of the `CONTEXT` wordlist to a temporary NFA buffer for manipulation. A factor for `WORDS`.

`: WORDS  \ --`
Display the names of all definitions in the wordlist at the top of the search-order. For 32 bit targets, you can use

```
WORDS text
```

to display only those words containing *text*.

`: MOVE  \ src dest len -- ; intelligent move`
An intelligent memory move, chooses between `CMOVE` and `CMOVE>` at runtime to avoid memory overlap problems. Note that as ROM PowerForth characters are 8 bit, there is an implicit connection between a byte and a character.

`: DEPTH  \ -- +n`
Return the number of items on the data stack, excluding the count.

`: UNUSED  \ -- u ; free dictionary space`
Return the number of bytes free in the dictionary.

`: .FREE  \ --`
Return the free dictionary space.

1.18 Wordlist control

`: WORDLIST  \ -- wid`
Create a new wordlist and return a unique identifier for it.

`: VOCABULARY  \ -- ; VOCABULARY <name>`
Create a `VOCABULARY` which is implemented as a named wordlist.

`: FORTH  \ --`
Install `FORTH` wordlist into search-order.

`: FORTH-WORDLIST  \ -- wid`
Return the unique WID for the main FORTH wordlist.

`: GET-CURRENT  \ -- wid`
Return the WID for the Wordlist which holds any definitions made at this point.

`: SET-CURRENT  \ wid --`
Change the wordlist which will hold future definitions.

`: GET-ORDER \ -- widn...wid1 n`
Return the list of WIDs which make up the current search-order. The last value returned on top-of-stack is the number of WIDs returned.

`: SET-ORDER \ widn...wid1 n -- ; unless n = -1`
Set the new search-order. N is the number of WIDs to place in the search-order. If N is -1 then the minimum search order is inserted.

`: ONLY \ --`
Set the minimum search order as the current search-order.

`: ALSO \ --`
Duplicate the first WID in the search order.

`: PREVIOUS \ --`
Drop the current top of search-order.

`: DEFINITIONS \ --`
Set the current top WID of search-order as the current definitions wordlist.

1.19 Control structures

`: ?PAIRS \ x1 x2 --`
If x1<>x2, issue and error. Used for on-target compile-time error checking.

`: !CSP \ x --`
Save the stack pointer in `CSP`. Used for on-target compile-time error checking.

`: ?CSP \ --`
Issue an error if the stack pointer is not the same as the value previously stored in CSP. Used for on-target compile-time error checking.

`: ?COMP \ --`
Error if not in compile state.

`: ?EXEC \ --`
Error if not interpreting.

`: DO \ C: -- do-sys ; Run: n1|u1 n2|u2 -- ; R: -- loop-sys`
Begin a `DO ... LOOP` construct. Takes the end-value and start-value from the data-stack.

`: ?DO \ C: -- do-sys ; Run: n1|u1 n2|u2 -- ; R: -- | loop-sys`
Compile a `DO` which will only begin loop execution if the loop parameters are not the same. Thus `0 0 ?DO ... LOOP` will not execute the contents of the loop.

`: LOOP \ C: do-sys -- ; Run: -- ; R: loop-sys1 -- | loop-sys2`
The closing statement of a `DO ... LOOP` construct. Increments the index and terminates when the index crosses the limit.

`: +LOOP \ C: do-sys -- ; Run: n -- ; R: loop-sys1 -- | loop-sys2`
As with `LOOP` except that you specify the increment on the data-stack.

`: BEGIN \ C: -- dest ; Run: --`
Mark the start of a structure of the forms:

```
BEGIN ... UNTIL/AGAIN
BEGIN ... WHILE ... REPEAT
```

`: AGAIN \ C: dest -- ; Run: --`
The end of a `BEGIN ... AGAIN` construct which specifies an infinite loop.)

```
: UNTIL          \ C: dest -- ; Run: x --
```
Compile code into definition which will jump back to the matching BEGIN if the supplied condition flag is Zero/FALSE.

```
: WHILE          \ C: dest -- orig dest ; Run: x --
```
Separate the condition test from the loop code in a BEGIN ... WHILE ... REPEAT block.

```
: REPEAT         \ C: orig dest -- ; Run: --
```
Loop back to the conditional dest code in a BEGIN ... WHILE ... REPEAT construct.)

```
: IF             \ C: -- orig ; Run: x --
```
Mark the start of an IF ... [ELSE] ... THEN conditional block.

```
: THEN           \ C: orig -- ; Run: --
```
Mark the end of an IF ... THEN or IF ... ELSE ... THEN conditional construct.

```
: endif          \ C: orig -- ; Ru: -- ; synonym for THEN
```
An alias for THEN. Note that ANS Forth describes THEN not ENDIF.

```
: AHEAD          \ C: -- orig ; Run: --
```
Start an unconditional forward branch which will be resolved later.

```
: ELSE           \ C: orig1 -- orig2 ; Run: --
```
Begin the failure condition code for an IF.

```
: CASE           \ C: -- case-sys ; Run: --
```
Begin a CASE ... ENDCASE construct. Similar to C's **switch**.

```
: OF             \ C: -- of-sys ; Run: x1 x2 -- | x1
```
Begin conditional block for CASE, executed when the switch value is equal to the X2 value placed in TOS.

```
: ENDOF          \ C: case-sys1 of-sys -- case-sys2 ; Run: --
```
Mark the end of an OF conditional block within a CASE construct. Compile a jump past the ENDCASE marker at the end of the construct.

```
: ENDCASE        \ C: case-sys -- ; Run: x --
```
Terminate a CASE ... ENDCASE construct. DROPs the switch value from the stack.

```
: ?OF            \ C: -- of-sys ; Run: flag --
```
Begin conditional block for CASE, executed when the flag is true.

```
: END-CASE       \ C: case-sys -- ; Run: --
```
A Version of ENDCASE which does not drop the switch value. Used when the switch value itself is consumed by a DEFAULT condition.

```
: NEXTCASE       \ C: case-sys -- ; Run: x --
```
Terminate a CASE ... NEXTCASE construct. DROPs the switch value from the stack and compiles a branch back to the top of the loop at CASE.

```
: RECURSE        \ Comp: --
```
Compile a recursive call to the colon definition containing RECURSE itself. Do not use RECURSE between DOES> and ;. Used in the form:

```
: foo  ... recurse ... ;
```

to compile a reference to FOO from inside FOO.

1.20 Target interpreter and compiler

`: ?STACK \ --`

Error if stack pointer out of range.

`: ?UNDEF \ x --`

Word not defined error if x=0.

`: POSTPONE \ Comp: "<spaces>name" --`

Compile a reference to another word. `POSTPONE` can handle compilation of `IMMEDIATE` words which would otherwise be executed during compilation.

`: S" \ Comp: "ccc<quote>" -- ; Run: -- c-addr u`

Describe a string. Text is taken up to the next double-quote character. The address and length of the string are returned.

`: C" \ Comp: "ccc<quote>" -- ; Run: -- c-addr`

As `S"` except the address of a counted string is returned.

`: Z" \ Comp: "ccc<quote>" -- ; Run: -- z-addr`

As `S"` except the address of a zero-terminated string is returned. This word is only compiled if the run-time action `(Z")` has been compiled.

`: #LITERAL \ n1 .... nn n -- ; put in dictionary n1 first`

Compile n1..nn as literals so that the same stack order results when the code executes. This word will be removed in a future release. INTERNAL.

`: LITERAL \ Comp: x -- ; Run: -- x`

Compile a literal into the current definition. Usually used in the form `[ <expression ] LITERAL` inside a colon definition. Note that `LITERAL` is `IMMEDIATE`.

`: 2LITERAL \ Comp: x1 x2 -- ; Run: -- x1 x2`

A two cell version of `LITERAL`.

`: CHAR \ "<spaces>name" -- char`

Return the first character of the next token in the input stream. Usually used to avoid magic numbers in the source code.

`: [CHAR] \ Comp: "<spaces>name" -- ; Run: -- char`

Compile the first character of the next token in the input stream as a literal. Usually used to avoid magic numbers in the source code.

`: sliteral \ c-addr u -- ; Run: -- c-addr2 u ; 17.6.1.2212`

Compile the string c-addr1/u into the dictionary so that at run time the identical string c-addr2/u is returned. Note that because of the use of dynamic strings at compile time the address c-addr2 is unlikely to be the same as c-addr1.

`: [ \ --`

Switch compiler into interpreter state.

`: ] \ --`

Switch compiler into compilation state.

`: IMMEDIATE \ --`

Mark the last defined word as `IMMEDIATE`. Immediate words will execute whenever encountered regardless of `STATE`.

`: ' \ "<spaces>name" -- xt`

Find the xt of the next word in the input stream. An error occurs if the xt cannot be found.

```
: [']           \ Comp: "<spaces>name" -- ; Run: -- xt
```
Find the xt of the next word in the input stream, and compile it as a literal. An error occurs if the xt cannot be found.

```
: [COMPILE]     \ "<spaces>name" --
```
Compile the next word in the input stream. `[COMPILE]` ignores the `IMMEDIATE` state of the word. Its operation is mostly superceded by `POSTPONE`.

```
: (             \ "ccc<paren>" --
```
Begin an inline comment. All text upto the closing bracket is ignored.

```
: \             \ "ccc<eol>" --
```
Begin a single-line comment. All text up to the end of the line is ignored.

```
: ",            \ "ccc<quote>" --
```
Parse text up to the closing quote and compile into the dictionary at `HERE` as a counted string. The end of the string is aligned.

```
: .(            \ "cc<paren>" --
```
A documenting comment. Behaves in the same manner as `(` except that the enclosed text is written to the console at compile time.

```
: ASSIGN        \ "<spaces>name" --
```
A state smart word to get the XT of a word. The source word is parsed from the input stream. Used as part of an `ASSIGN xxx TO-DO yyy` construct.

```
: (TO-DO)       \ -- ; R: xt -- a-addr'
```
The run-time action of `TO-DO`. It is followed by the data address of the `DEFER`red word at which the xt is stored.

```
: TO-DO         \ "<spaces>name" --
```
The second part of the `ASSIGN xxx TO-DO yyy` construct. This word will assign the given XT to be the action of a `DEFER`ed word which is named in the input stream.

```
: exit          \ R: nest-sys -- ; exit current definition
```
Compile code into the current definition to cause a definition to terminate. This is the Forth equivalent to inserting an RTS/RET instruction in the middle of an assembler subroutine.

```
: ;             \ C: colon-sys -- ; Run: -- ; R: nest-sys --
```
Complete the definition of a new 'colon' word or `:NONAME` code block.

```
: INTERPRET     \ --
```
Process the current input line as if it is text entered at the keyboard.

```
: N>R           \ xn .. x1 N -- ; R: -- x1 .. xn n
```
Transfer N items and count to the return stack.

```
: NR>           \ -- xn .. x1 N ; R: x1 .. xn N --
```
Pull N items and count off the return stack.

```
: EVALUATE      \ i*x c-addr u -- j*x ; interpret the string
```
Process the supplied string as though it had been entered via the interpreter.

```
: .sysprompt    \ --
```
Default action of the deferred word `.prompt`.

```
defer .prompt   \ --
```
The deferred prompt. This is useful for large systems which need additional debug operations in the prompt, e.g. floating point packages.

`: .throw \ throw# --`

Display the throw code. Values of 0 and -1 are ignored.

`: QUIT \ -- ; R: i*x --`

Empty the return stack, store 0 in `SOURCE-ID`, and enter interpretation state. `QUIT` repeatedly `ACCEPT`s a line of input and `INTERPRET`s it, with a prompt if interpreting and `ECHOING` is on. Note that any task that uses `QUIT` must initialise `'TIB`, `BASE`, `IPVEC`, and `OPVEC`.

1.20.1 Compilation and Caches

Because some CPUs, e.g. XScale and ARM9s, have separate instruction and data caches, self-modifying code can cause problems when code is laid down (into the data cache) and then an attempt is made to execute it (the instruction cache will not necessarily contain the code). For this reason a word is provided that will synchronise the caches. This word is CPU specific and may reference code in a CPU and/or hardware specific file.

Synchronisation will usually only be necessary when creating words, constants, variables etc. interactively on the target and then executing them before the code has reached the instruction cache. Only executable code has to be synchronised, not data.

If the word `FLUSHCACHE ( -- )` is provided before *kernel62.fth* is compiled, it will be executed by the text interpreter before each line is processed. `FLUSHCACHE` is also executed by `;`.

1.21 Startup code

1.21.1 Cold chain

If enabled by the non-zero equate `COLDCHAIN?` the cold start code in `COLD` will walk a list and execute the xts contained in it. The xts must have no stack effect `( -- )` and are added to the list by the phrase:

```
' <wordname> AtCold
```

The list is executed in the order in which it was defined so that the last word added is executed last. This was done for compatibility with VFX Forth, which also contains a shutdown chain, in which the last word added is executed first.

If the equate `COLDCHAIN?` is not defined in the control file, a default value of 0 will be defined.

`l: ColdChainFirst \ -- addr`

Dummy first entry in ColdChain.

`variable ColdChain \ -- addr`

Holds the address of the last entry in the cold chain.

`: AtCold \ xt --`

Specifiy a new XT to execute when `COLD` is run. Note that the last word added is executed last. `ATCOLD` can be executed interpretively during cross-compilation. The cold chain is built in the current `CDATA` section.

`: WalkColdChain \ -- MPE.0000`

Execute all words added to the cold chain. Note that the first word added is executed first.

1.21.2 The COLD sequence

At power up, the target executes COLD or the word specified by MAKE-TURNKEY <name>.

`: copyRAMtab \ addr --`
Copy the given RAM table from Flash into RAM. The table may initialise multiple blocks of RAM.

`: (INIT) \ --`
Performs the high level Forth startup. See the source code for more details.

`: COLD \ --`
The first high level word executed by default. This word is set to be the word executed at power up, but this may be overridden by a later use of MAKE-TURNKEY <name>. See the source code for more details of COLD.

1.22 Kernel error codes

-1	ABORT
-2	ABORT"
-4	Stack underflow
-13	Undefined word.
-14	Attempt to interpret a compile only definition.
-22	Control structure mismatch - unbalanced control structure.
-121	Attempt to remove with MARKER or FORGET below FENCE in protected dictionary.
-403	Attempt to compile an interpret only definition.
-501	Error if not LOADing from a block.

1.23 Differences between the v6.1 and 6.2 kernels

1.23.1 Error handling

All error handling in the v6.2 kernel is defined in terms of CATCH and THROW. The earlier words ERROR and ?ERROR have been removed. If you need them, define them as synonyms for THROW and ?THROW.

The definition of ABORT has changed significantly. The old version was:

```
: ABORT         \ i*x -- ; R: j*x --
\ *G Empty the data stack and perform the action of QUIT, which includes
\ ** emptying the return stack, without displaying a message.
  xon/xoff off  echoing on              \ No Xon/Xoff, do Echo
  s0 @ sp!                              \ reset data stack
  quit                                  \ start text interpreter
;
```

The new version is:

```
: ABORT         \ i*x -- ; R: j*x --
\ *G Performs "-1 THROW". This is a compatibility word for earlier
\ ** versions of the kernel. Unfortunately, the earlier versions
\ ** gave problems when ABORT was used in interrupt service routines
\ ** or tasks. The new definition is brutal but consistent.
  -1 Throw
;
```

The old version worked 99% of the time, except that in tasks or interrupt service routines, the result was unpredictable. Because modern applications are larger and more complex, `ABORT` has to be completely predictable. The line

```
  xon/xoff off  echoing on              \ No Xon/Xoff, do Echo
```

is now part of `QUIT`. The phrase `S0 @ SP!` must now be provided by the `THROW` handler.

The previous definition of `THROW` checked for a previously defined `CATCH` and performed the old `ABORT` if no `CATCH` had been defined. The new version assumes that a `CATCH` has been defined and may/will crash if no `CATCH` has been performed. The result is a faster and smaller definition of `CATCH`. However, it is now the programmer's responsibility to provide a `CATCH` handler for ALL ISRs and tasks that may generate a `THROW`. This is actually very little different from the previous situation, except that the system is less forgiving if you forget to provide a handler.

Error codes have been made ANS compliant. It is MPE policy that all error and ior (i/o result) codes shall be distinct from now on.

1.23.2 Terminal input buffer and ACCEPT

The changes below simplifiy the source code, and permit multiple tasks to use `EVALUATE` without interaction. Note that compilation from multiple sources/tasks requires the interpreter/compiler to be interlocked with a semaphore.

The `2VARIABLE SOURCE-STRING` has been removed, and `TO-SOURCE` and `SOURCE` use `'TIB` and `#TIB` instead.

The state variables `ECHOING` and `XON/XOFF` are now `USER` variables. In most cases this will have no impact. However, tasks may now control these variables independently.

`QUIT` always enforces `ECHOING` on and disables XON/XOFF processing. `QUIT` does not select an I/O device. This change was made to allow the interpreter to be used on any channel in systems with several serial lines or with the Telnet service of the PowerNet TCP/IP stack. Note that any task that uses `QUIT` must initialise `IPVEC`, `OPVEC`, `ECHOING` and `XON/XOFF`.

Removed: `?EMIT` and `SOURCE-STRING`.

2 Character Queues

The file *Common\Cqueues.fth* provides circular character (byte) queues. If the equate `TASKING?` is non-zero, the blocking routines will use `PAUSE`. Interrupts are disabled for the queue empty/full checks.

2.1 Queue data structure

`struct /cqueue  \ -- size ; character queue structure in idata, buffer in udata`
Circular queue data structure.

```
  int >qhead            \ Offset of head, where characters are taken from
  int >qtail            \ Offset of tail, where characters are put
  int >qchars           \ Number of characters in the queue
  int >qmask            \ Mask to apply to pointers
  ptr >qbuffer          \ Base address of character buffer
end-struct
```

`: cqueue:       \ size -- ; -- cqueue ; size CQUEUE: <name>`
An interpreter definition to build a character queue of the specified size. The queue data structure is built in the current `IDATA` space, and the buffer itself is in the current `UDATA` space. Executing `<name>` returns the address of the queue data structure. N.B. The size of a queue must be a power of two, e.g. 32, 64 ...

`: init-cqueue   \ cqueue -- ; initialise queue`
Initialise the specified queue created by `CQUEUE:`.

`: init-hcqueue  \ size cqueue -- ; SFP002`
Initialise the specified queue created by `ALLOCATE`. When a queue is allocated from the heap by a phrase of the form `/CQUEUE <size> + ALLOCATE`, this word must be used.

2.2 Queue primitives

`: (>cqueue)     \ char cqueue -- ; put character on cqueue`
Put char into the queue with no checks.

`: (cqueue>)     \ cqueue -- char ; get next character from queue`
Get the next character from the queue with no checks.

`: (cqfull?)     \ queue -- flag ; TRUE if queue full`
Return true if the queue is full. No interrupt protection is provided.

`: cqfull?       \ queue -- flag ; TRUE if queue full`
Return true if the queue is full. Interrupt protection is provided.

`: cqchars       \ queue -- n`
Return the number of characters in the queue.

`: cqempty?      \ queue -- flag ; TRUE if queue empty`
Return true if the queue is empty.

`: cqnotempty?   \ queue -- flag ; TRUE if queue not empty`
Return true if the queue is not empty, i.e. if it contains any characters.

`: cqRoom        \ queue -- u`
Return the number of free bytes in the queue.

`: cqroom?  \ +n queue -- flag`
Return true if there is enough room in the queue for +n more characters.

`: >cqueue  \ char cqueue -- ; spins if full`
Put a character into the queue. If the queue is full, the system waits (blocks) until there is enough space.

`: cqueue>  \ queue -- char ; spins while queue empty`
Remove the next character, waiting if the queue is empty.

2.3 Extended queue operations

When queues are filled and emptied in blocks rather than character by character, faster operation can be achieved using these words. You may see additional benefit using the fast version of `CMOVE`.

The extended operations are compiled if the equate `extCQ?` is set non-zero before *Cqueues.fth* is compiled.

`0 equ extCQ?  \ -- flag`
If set non-zero here or before *Cqueues.fth* is compiled, the extended wordset below will be compiled.

2.3.1 Primitives

`: /tailw  \ queue -- len`
Number of bytes from the tail to the end.

`: /gapw  \ queue -- len`
Number of bytes from the tail to the head, assuming no wrap.

`: +tail  \ n queue --`
Add n characters to the tail pointer and count.

`: $>cq  \ caddr len n queue -- caddr' len' queue`
Copy *n* bytes of the the source block into the buffer.

`: $>tail  \ caddr len queue -- caddr' len' queue`
Add block in space between tail and end

`: $>gap  \ caddr len queue -- caddr' len' queue`
Add block in space between tail and head.

`: /headr  \ queue -- len`
Number of bytes from the head to the end.

`: /gapr  \ queue -- len`
Number of bytes from the head to the tail, assuming no wrap.

`: -head  \ n queue --`
Remove n characters from the head pointer and count.

`: cq>$  \ caddr len n queue -- caddr' len' queue`
Copy *n* bytes from the queue into the buffer *caddr/len.*

`: head>$  \ caddr len queue -- caddr' len' queue`
Copy queue block in space between head and end

`: gap>$  \ caddr len queue -- caddr' len' queue`
Add block in space between head and tail.

2.3.2 User words

```
: cqWrite       \ caddr len queue --
```
Write the given string to the queue. This word blocks until the operation is complete.

```
: cqStuff       \ caddr len queue -- n
```
Write as much data from the given string to the queue as there is room for. Return the number of bytes written.

```
: cqRead        \ caddr len queue --
```
Read the given string from the queue. This word blocks until the operation is complete.

```
: cqExtract     \ caddr len queue -- n
```
Read data from the queue to the buffer. The amount read is limited by the size of the buffer and the number of bytes in the queue. The number of bytes read is returned.

3 Heap Memory Allocation

3.1 Heap definition

The heap is allocated from a predefined section of memory. Facilities are provided for user expansion of the heap to mass storage, although the current code makes no provision for page management. When the heap is initialised, a free block and an end block are created. The end block is of zero size, and is used only as a marker. The address returned by `ALLOCATE` and `RESIZE` is the address of the first data byte, as is the address consumed by `FREE`.

The heap **must** be initialised before use by calling `INIT-HEAP`. Heap access words return status=0 for success, and status<>0 for error.

Two equates are required during compilation to allocate a contiguous block of RAM for the heap.

```
STARTOFHEAP is the start address of the heap
SIZEOFHEAP is the size of the RAM for the heap
```

There are two versions of this code provided. *Heap32.fth* is provided for 32-bit targets and is optimised for the VFX code generator. *Heap16.fth* is for 16 bit targets, and is optimised for code density.

3.1.1 32 bit targets - HEAP32.FTH

The heap is controlled using a single cell per block. This information is used in two parts:

```
bits 31..24: $EE - End, $FF - Free, $AA - Allocated
bits 23..0: 24 bits for number of data bytes in block.
```

A consequence of this is that the maximum block size that can be allocated is 16Mb-1 bytes.

If you use a pre-emptive scheduler or need to use the heap words inside interrupt routines, you must define suitable heap lock and unlock words and set the equate `LOCKHEAP?` to non-zero.

`LockHeap=0`
: no heap locking

`LockHeap=1`
: heap locking by turning off interrupts

`LockHeap=2`
: heap locking by semaphore.

3.1.2 16 bit targets - HEAP16.FTH

The heap is controlled using two cells per block. This information is used in three parts:

```
cell = #bytes, number of bytes in this block
cell = flag, split between a four bit and a 12 bit field
```

The top four bits of the flag are used to indicate the block type, where $E = End, $F = Free, $A = Allocated. Others may be added later for type management.

The bottom 12 bits of the flag are currently unused, and should be set to zero.

3.2 Gotchas

The heap routines must be protected if they are to be used both in normal code and in interrupts. In this case the code must be modified to be interrupt safe, but this may have a significant impact on interrupt latency. Examples may be found in *heap32.fth*.

If you use a pre-emptive scheduler, you must also define suitable heap lock and unlock routines.

The equate `LOCKHEAP?` controls the usage:

`LockHeap=0`
: no heap locking

`LockHeap=1`
: heap locking by turning off interrupts

`LockHeap=2`
: heap locking by semaphore.

3.3 Glossary

The glossary does not include all the factors used in the code. If you are interested in the implementation, please read the sources.

```
sizeofheap buffer: STARTOFHEAP  \ -- addr
```
The heap memory is defined at compile time.

```
STARTOFHEAP sizeofheap + equ ENDOFHEAP  \ -- addr
```
The end+1 of the heap.

```
: init-heap     \ --
```
The heap is initialised by creating 2 blocks. Block 1 starts at the beginning and is marked as a free block. Block 2 Is a null marker at the end of heap space.

```
: allocate      \ #bytes -- addr status
```
Attempt to allocate some memory from the heap. Walk the heap looking for a single big enough block. If the block is larger than than required split it into two blocks. Allocate part or all of the free block. Status=0 for success.

```
: free          \ addr -- status
```
Attempt to free a heap block. Status=0 for success. If *addr* is zero, no action is taken and zero is returned.

```
: resize        { *ptr newsize | currsize -- *newptr ior }
```
Try to resize an allocated block to a new size, allowing for alignment. If the existing memory block is not big enough, the data will be copied to a new block, and the returned addr2 will not be the same as addr1. Status=0 for success.

```
: size          \ *ptr -- currsize|-1
```
Return the size of an allocated block or -1 if there's an error.

3.4 Diagnostics

`: .heap \ --`
Walk the heap displaying block information.

`: heapok? \ -- t/f`
Walk the heap and return TRUE if the heap is "well".

4 Target VALUE and local variables

The file *COMMON\METHODS.FTH* implements the compilation of `VALUE`s and the ANS Forth `LOCALS|` syntax for compilation on the target. Compilation of this file requires CPU dependent support, usually called *LOCAL.FTH* in the *%CpuDir%* directory, and MPE standard control files will compile these files if the equate `TARGET-LOCALS?` is set non-zero in the control file.

Note that this file is only provided for full ANS compliance. The MPE extended local variable syntax is provided by the cross compiler, and is much more powerful and more readable.

Note also that compilation of %CpuDir%\LOCAL.FTH may be required if you cross compile words with more than four input arguments.

`: OPERATOR \ n -- ; define an operator in the cross compiler`
An interpreter definition that build new operators such as "to" and "addr".

`: VALUE \ n -- ; -- n ; n VALUE <name>`
Creates a variable of initial value n that returns its contents when referenced. To store to a child of VALUE use "n to <child>".

`: (LOCAL) \ Comp: c-addr u -- ; Exec: -- x ; define local var`
When executed during compilation, defines a local variable whose name is given by c-addr/u. If u is zero, c-addr is ignored and compilation of local variables is assumed to finish. When the word containing the local variable executes, the local variable is initialised from the stack. When the local variable executes, its value is returned. The local variable may be written to by preceding its name with TO. This word is provided for the construction of user-defined local variable notations. This word is only provided for ANS compatibility, and locals created by it cannot be optimised by the VFX code generator.

`: LOCALS| \ "name...name |" --`
Create named local variables <name1> to <namen>. At run time the stack effect is (xn..x1 –), such that <name1> is initialised with x1 and <namen> is initialised with xn. Note that this means that the order of declaration is the reverse of the order used in stack comments! When referenced, a local variable returns its value. To write to a local, precede its name with TO.
In the example below, a and b are named inputs.

```
: foo      \ a b --
  locals| b a |
  a b +  cr .
  a b *  cr .
;
```

5 Ethernet and IP devices generic I/O

5.1 Internet Protocol Devices

In order to ease changing devices and to permit systems with multiple ports, version 3 and above of the Powernet TCP/IP stack use a generalised interface to the hardware, which is usually an Ethernet driver or a serial driver.

The interface consists of a vector (table) of XTs corresponding to the particular function required. The layout of the table is as follows:

```
create IPdevice
  ' MyInit ,       \ 0: initialisation
  ' MyTerm ,    \ 1: shutdown
  ' MyRx? ,     \ 2: receive test
  ' MyRx                \ 3: receive packet
  ' MyTx? ,     \ 4: transmit test
  ' MyTx ,              \ 5: transmit packet
  ' MyGetAddr ,    \ 6: Get device addresses
  ' MySetAddr ,    \ 7: Set device addresses
  ' MySave ,    \ 8: Save IP device addresses and state
  ' MyDiscard , \ 9: Discard current receive packet
```

by default, the system code requires a default IP device called IPDevice. IPDevice will be used when PowerNet is started.

`cell +User IPDVec       \ -- addr`
IPDVec is a USER variable which contains the address of the current Internet Protocol Device (IPD) vector. All tasks must initialise IPDVEC before using the ETHERCOM interface.

```
  IPDevice IPDVec !
```

`: IPDinit       \ --`
Initialise (open) the current IP device.

`: IPDterm       \ --`
Shutdown (close) the current IP device.

`: IPDRx?        \ -- flag ; check receive char`
Return true if a packet is available at the current IP device.

`: IPDRx         \ buff size -- len ; receive packet`
Receive a packet into buff of size bytes, returning len the number of bytes received. Use IPDRX? to check that a packet is available.

`; IPDTx?        \ len -- flag ; check TX capability`
Return true if the current IP device can send a packet of size len bytes.

`: IPDTx         \ buff len -- ; send packet`
Transmit the given packet.

`: IPDGetAddr    \ -- ipaddr netaddr flags`

Returns: a pointer to the IP address used by this device, or 0 if it has not been set yet: a pointer to the network address of the device, e.g. the Ethernet MAC address or 0 if not set or irrelevant: and a set of flags which are currently 0 for IPv4 and Ethernet/SLIP/PPP devices.

```
: IPDSetAddr    \ ipaddr netaddr flags --
```
Consumes: a pointer to the IP address used by this device, or 0 for no change: a pointer to the network address of the device, e.g. the Ethernet MAC address or 0 for no change: and a set of flags which are currently 0 for IPv4 and Ethernet/SLIP/PPP devices.

```
: IPDSave       \ --
```
Save the device state to non-volatile storage so that it can be reloaded at the next power up or IPDinit.

```
: IPDDiscard    \ --
```
Discard the current receive packet, usually because PowerNet has run out of buffer space. This is only valid if IPDRX? has returned true to say that a packet is available.

6 Romtools.fth

The file *Common/Romtools.fth* contains debugging tools and various utilities.

6.1 Debugging tools

If you only want the debug tools, compile *Common/dump.fth* or *Common/Devtools.fth* (32 bit systems) rather than *Common/Romtools.fth*.

`: .BYTE \ b8 --`
Display a byte as two hex digits.

`: .WORD \ w16 --`
Display a 16 bit word as four hex digits.

`: .DWORD \ l --`
Display a 32 bit item as eight hex digits.

`: .ASCII \ b --`
Display a byte as a character if the code is printable, otherwise display a dot.

`: dump \ addr len --`
Dump a block of memory byte by byte. 16 bit version.

`: Cdump \ addr len --`
Dump a block of code memory byte by byte. 16 bit Harvard version.

`: dump \ addr len --`
Dump a block of memory byte by byte. 32 bit version.

`: Cdump \ addr len --`
Dump a block of code memory byte by byte. 32 bit Harvard version.

`: .S \ i*x -- i*x`
Non-destructive stack display.

`: ? \ addr --`
Display the contents of *addr* in the current base.

6.2 FORGET and friends

In an embedded system `FORGET` and friends are only useful when compiling code into RAM. `FORGET` is used to remove words recently compiled.

`: Trim \ nfa-to-forget wid --`
Trim the threads in a wordlist.

`: (forget) \ nfa -- ; forgets back to given nfa`
Forget all words back to the given nfa.

`: $FORGET \ $addr --`
Forget a word whose name is given as a counted string.

`: FORGET \ -- ; FORGET <name>`
The name to forget follows in input stream

`: Vocs \ --`
Display a list of all the vocabularies in the system.

`: .Voc  \ addr --`
Try to display the vocabulary whose wid is at *addr*.

`: Order  \ --`
Display the `CONTEXT` search order and the `CURRENT` vocabulary.

7 Debugging tools

The file *Common\DebugTools.fth* provides debugging tools for MPE embedded systems created by Forth 6 Cross Compilers. The emphasis is on 32 bit systems and interactive testing. The tools can easily be ported to other systems. Copyright is retained by MPE. The code may be freely used on non-MPE systems for non-commercial use. The copyright notice must be preserved.

Porting the code to other systems is up to you. This code may require some carnal knowledge of how your system works. Most Forths contain the required words, but they may not have the same names that MPE use.

7.1 Implementation dependencies

In MPE embedded systems, the `USER` variables `IPVEC` and `OPVEC` contain the address of the device structure used for input and output by `KEY`, `EMIT` and friends. In VFX Forth for Windows/Linux, the variables are `IP-HANDLE` and `OP-HANDLE`.

```
: consoleIO     \ --
```

Select debug console for output. By default this is the `CONSOLE` device.

```
  console  dup opvec !  ipvec !
  Echoing on  Xon/Xoff off
;


: name?         \ addr -- flag                                  MPE.0000
```

Check to see if the supplied address is a valid NFA, returning true if the address appears to be a valid NFA. This word is implementation dependent. For MPE cross compilers, a valid NFA for MPE embedded systems satisfies the following:

- All characters within string are printable ASCII within range 33..126
- String Length is non-zero in range 1..31 and bit 7 is set, ignore bits 6, 5

```
  count                                 \ c-addr u --
  dup  $9F and  $81 $9F within? 0=      \ NFA first byte = 1SIxxxxx, count = xxxxx
                                        \ mask           = 10011111
  if  2drop  0  exit  then
  $01F and bounds ?do
    i c@ #33 #126 within? 0=            \ check all ascii chars
    if  unloop  FALSE exit  then
```

```
  loop
  TRUE
;

: ip>nfa        \ addr -- nfa
```
Attempt to move backwards from an address within a definition to the relevant NFA.
```
  2-                            \ NFA must be at least 'n' bytes backwards
  begin
    dup name? 0=
   while
    1-
  repeat
;

: >name         \ xt -- nfa
```
Move from a word's xt to its name field. If `>NAME` does not exist `IP>NFA` will be used.
```
  ip>nfa
;

: .name         \ nfa --
```
Given a word's NFA display its name.
```
  count $1F and type
;

: .DWORD        \ dw --
```
Display the 32 bit long word 'dw' as an 8 digit hex number.
```
  base @ hex  swap
  0 <# # # # # ascii : hold # # # # #> type
  base !
;
```

7.2 Miscellaneous

MPE systems use `TICKS ( -- ms)` to return a running time count in milliseconds. Windows systems can use the **GetTickCount** API call.

```
: times         \ n -- ; n TIMES <word>
```
Execute `<word>` n times, and display the execution time. The ticker interrupt must be running.
```
  ticks  '  rot 0                       \ -- ticks xt n 0
  ?do  dup execute  loop
  drop
  ticks swap - . ." ms"
;

: .ColdChain    \ --
```
Display all words added to the cold chain. Note that the first word added is displayed first. In VFX Forth this word is called ShowColdChain.

```
  cr  ColdChainFirst
  begin
    dup
   while
    dup cell + @ >name .name            \ execute XT
    @                                   \ get next entry
  repeat
  drop
;

: .decimal      \ n --
```

Display a value as a decimal number.

```
  base @ >r  decimal .  r> base !
;

: .hex          \ n --
```

Display a value as a hexadecimal number.

```
  base @ >r  hex u.  r> base !
;

: [con          \ -- ; R: -- consys
```

Saves `BASE` and the current i/o vectors on the return stack, and then switches to the console and `DECIMAL`.

```
   r>
   base @ >r  opvec @ >r  ipvec @ >r
   ConsoleIO decimal
   >r
;

: con]          \ -- ; R: consys --
```

Restores `BASE` and the current i/o vectors from the return stack.

```
  r>
  r> ipvec !  r> opvec !  r> base !
  >r
;

: CheckFailed   \ ip caddr len --
```

Given the address where the fault occurred and a string, output the string and some diagnostic information.

```
  [con
    cr type  ."  failed at "
    dup .dword ."  in " ip>nfa .name
  con]
;
```

7.3 Stack checking

Especially in multi-tasked systems, stack errors can be fatal. Detecting them as early as possible reduces debugging time. These words rely on Forth return stack cells containing return addresses. This is true on the vast majority of Forth systems except for some 8051 and real-mode 80x86 systems. If you find others, please let us know.

```
: ?StackDepth   \ +n --
```

If the stack depth before +n is not n, issue a console warning message and clear the stack. Note that this word is implementation dependent.

```
  dup 2+ depth =
  if  drop  exit  endif                  \ no failure
  [con
  cr ." *** Stack fault: depth = " depth 1- 0 .r ." (d) "
[ tasking? ] [if]
  ." in task " self .task                \ indicate current task
[then]
  >r  s0 @ sp!  r> 0 ?do  0  loop        \ set required depth
  cr ."   Stack updated."
  con]
;


: ?StackEmpty   \ --
```

If the stack depth is non-zero, issue a console warning message and clear the stack.

```
  0 ?StackDepth  ;


: TaskChecks    \ --
```

Use in task to check for creeping stacks and so on. This word can be extended to provide additional internal consistency checks.

```
  ?StackEmpty  ;


: SF{           \ n -- ; R: -- depth
```

n SF{ .... }SF will check for stack faults. n describes the stack change between SF{ and }SF. If the stack change is different, an error message is generated. This word will work on most systems in which the return address is held on the return stack.

```
  r>  swap depth 2- + >r  >r
;


: }SF           \ -- ; R: depth -- ; perform stack check
```

The end of an SF{ ... }SF structure. This word is not strictly portable as it assumes that the Forth return stack holds a valid return address. In the vast majority of cases the assumption is true, but beware of some 8051 implementations. See SF{

```
  r>
  r> depth 2- <> if
    dup s" Stack check" CheckFailed
  endif
  >r
;
```

7.4 Assertions

Assertions are a useful way to check that the system is behaving correctly. When the phrase:

```
[ASSERT <test> ASSERT]
```

is compiled into a piece of code, the test is performed and generates an error report if the result is false. If you do not want the performance overhead of the test, set the value `ASSERTS?` to zero. To remove even the small overhead of of testing `ASSERTS?`, comment out the line.

```
-1 value assert?        \ -- n
```
Returns non-zero if asserts will be tested.

```
: (assert)      \ flag --
```
If flag is zero, report an ASSERT error.

```
  if  exit  endif                       \ faster on some CPUs
  r@ s" ASSERT" CheckFailed
;
```

```
: [assert       \ --
```
Compile the code to start an assert.

```
  ?comp                                 \ must be compiling
  postpone assert?  postpone if
; immediate
```

```
: assert]       \ --
```
Compile the code to end an assert.

```
  ?comp                                 \ must be compiling
  postpone (assert)  postpone then
; immediate
```

Here is a simple assert that will fail if `BASE` is not `DECIMAL`.

```
: foo     \ --
  [assert  base @ #10 =  assert]
;
```

7.5 Return stack trace

```
: rpick         \ n -- x
```
Get a copy of the Nth return stack item. This works on most systems with a grow-down return stack in main memory.

```
: rdepth        \ -- n
```
Return the number of items on the return stack. This works for most systems with a grow-down stack in main memory.

7.6 Cold Chain

```
: ShowColdChain \ --
```
Display the cold chain

8 AIDE Auxiliary Debug Displays

From AIDE 6.6 onwards, AIDE's PowerTerm can provide additional debug displays. These are separate from the main PowerTerm console, and behave like traditional cursor-addressable units with a fixed-width font.

The displays are controlled by sending control sequences starting with <ESC><!>. The whole of the command sequence must be performed with inter-character gaps less than 100 ms.

```
<ESC>!'0'       Use the main PowerTerm console - char 0
<ESC>!'1'       Use the the first debug display - char 1
<ESC>!'2'       Use the the second debug display - char 2
<ESC>!...
<ESC>!'8'       Use the the eighth debug display - char 8
                If a display is not open, it is created.
                If it has not been defined, the default is
                80x25 in a 10 point font.
<ESC>!'9'n      Close display n (1..8).
<ESC>!'10'nwhf  Define the display size and open it
                n is the display in the range 1..8
                w (width) and h (height) are 1..255.
                f (font height) is 6..24
                The display is not selected for output.
<ESC>!'11'n#<txt>  Set the caption of an open display
                n is the display, 1..8
                # is the number of characters in the string
                txt is the string (no terminator)
<ESC>!'12'nfffbbb Set the foreground and background colours
                n is the display in the range 1..8
                fff is a 24 bit foreground colour
                bbb is a 24 bit background colour
<ESC>!'13'n     Clear the display to the background colour
                n is the display in the range 1..8
<ESC>!'14'nxy   Goto the given position
                n is the display in the range 1..8
                x is the X position from the left
                y is the Y position from the top
<ESC><ESC>      Pass a single Escape character to the host.
```

An example of using these displays can be found in *Examples/hanoi.fth*.

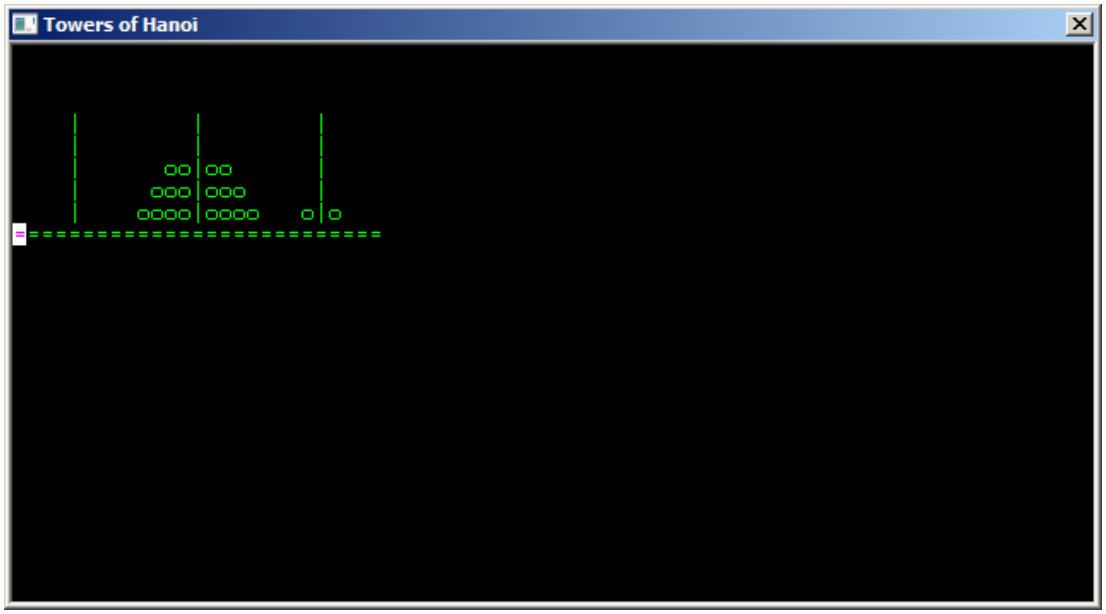

Figure 8.1: Towers of Hanoi

`: esc!  \ --`
Send escape prefix.

`semaphore SerChannel  1 SerChannel !  \ -- addr`
Exclusive access semaphore.

`: [d  \ disp -- ; disp=0..8`
Select/Launch the given display. The auxiliary consoles are numbered 1..8. This is the multi-tasking version which includes a semaphore for the serial channel.

`: d]  \ --`
End a display sequence and return to the main console. This is the multi-tasking version which includes a semaphore for the serial channel.

`: [d  \ disp -- ; disp=0..8`
Select/Launch the given display. The auxiliary consoles are numbered 1..8. This is the single-tasking version.

`: d]  \ --`
End a display sequence and return to the main console. This is the single-tasking version.

`: dclose  \ disp -- ; disp=0..8`
Close the given display. If this is the current display, the main display is used.

`: dopen  \ w h f disp -- ; disp=1..8`
Open an auxiliary display with width=w, height=h and font size f points. The display is not selected.

`: dcaption  \ caddr len disp -- ; disp=1..8`
Set the string as the caption of the display.

`: dcolours  \ forecolor backcolor disp -- ; disp=0..8`
Set the foreground and background colours of the given display. Some colours will cause problems on the console (disp=0). Colours are of the form `00bbggrr`.
A few standard colours:

```
$000000 constant RGB_BLACK      \ -- colorref
$DFDFDF constant RGB_LTGRAY     \ -- colorref
$FFFFFF constant RGB_WHITE      \ -- colorref
$0000FF constant RGB_RED        \ -- colorref
$00FF00 constant RGB_GREEN      \ -- colorref
$FF0000 constant RGB_BLUE       \ -- colorref
```

```
: dclear        \ disp -- ; disp=0..8
```
Clear the display.

```
: datxy         \ x y disp -- disp=1..8
```
Goto the given position. Does not work on the console (disp=0).

9 ANS Environment System

The file *Common/Environ.fth* provides the ANS Forth word `ENVIRONMENT?`, and some basic environment data.

```
Vocabulary Environment                    \ used for enviroment? queries
```

The vocabulary within which environment data is kept.

```
: ENVIRONMENT?  \ c-addr u --  false | i*x true
```

The string is treated as a word name. If it is found in the `ENVIRONMENT` vocabulary, the word is executed, the results of executing it plus true are returned, otherwise just false is returned.

10 Software Floating Point (32SX)

10.1 Introduction

Software floating-point is supplied with the cross-compiler and the target Forth. The target floating point wordset is not ANS or Forth-2012 compliant, but satisfies the needs of embedded systems without undue complexity. The Forth data stack and the floating point stack are the same (combined) in *Common/SoftFP32CX.fth* and separate in *Common/SoftFP32SX.fth*. The floating point data storage format is not IEEE, but is optimised for performance on small controllers. If you need a separate floating point stack or IEEE double format storage, please contact MPE. Any variations in the implementation will be documented in the target specific section of the manual.

The cross-compiler has a more limited floating-point support than the target. Some words are available during compilation of colon definitions, but not while interpreting.

10.2 Source code

The source code is in two sets of files, one for 32 bit Forth targets, the other for 16 bit targets. The files are:

```
Common\SoftFP32SX current 32 bit code for separate stacks
Common\SoftFP32CX current 32 bit code for a combined stack
Common\sfp32hi    old 32 bit primitives
Common\sfp32com   old 32 bit high level code
Common\sfp16hi    16 bit primitives
Common\sfp16com   16 bit high level code
```

The *SoftFP32xx* files use no assembler definitions. Some targets have code versions of the primitives, and these will be found in the CPU-specific code directory. An increase in performance can be obtained by using the code files.

10.3 Entering floating-point numbers

Floating point number entry is enabled by `REALS` and disabled by `INTEGERS`.

Floating-point numbers of the form 0.1234e1 are required (see `FNUMBER?`) during interpretation and compilation of source code. Floating-point numbers are compiled as literal numbers when in a colon definition (compiling) and placed on the stack when outside a definition (interpreting). Inside a colon definition, a floating point literal number must be preceded by `F#`.

```
: foo  ... f# 1.234e0 ...  ;
```

The more flexible word `>FLOAT` accepts numbers in two forms, 1.234 and 0.1234e1. Both words are documented later in this chapter. See also the section on *Gotchas* later in this chapter.

Note also that by default, MPE Forths use ',' as the double number indicator - it makes life much easier for Europeans.

10.4 The form of floating-point numbers

A floating-point number is placed on the Forth data stack. In the Forth literature, this is referred to as a combined floating point and data stack. For 32 bit targets, a floating point number consists of two 32-bit numbers, one for the mantissa and one for the exponent. For 16 bit targets, it consists of a 32-bit double mantissa and a single 16-bit exponent. The mantissa is normalised. The exponent is on the top of the stack. Note that for 16 bit targets, number conversion is affected by the cross-compiler directives `HOST-MATH` and `TARGET-MATH`. `HOST-MATH` leaves double numbers and floats in 32-bit form, whereas `TARGET-MATH` leaves them in 16-bit form.

10.5 Creating and using variables

To create a variable, use `FVARIABLE`. `FVARIABLE` works in the same way as `VARIABLE`. For example, to create a floating-point variable called `VAR1` you code:

```
FVARIABLE VAR1
```

When `VAR1` is used, it returns the address of the floating-point number.

Two words are used to access floating-point variables, `F@` and `F!`. These are analogous to `@` and `!`.

10.6 Creating constants

To create a floating-point constant, use `FCONSTANT`, which is analogous to `CONSTANT`. For example, to generate a floating-point constant called `CON1` with a value of 1.234, you enter:

```
1.234e0 FCONSTANT CON1
```

When `CON1` is executed, it returns 1.234 on the Forth stack.

10.7 Using the supplied words

The supplied words split into several groups:

- sines, cosines and tangents
- arc sines, cosines and tangents
- arithmetic functions
- logarithms
- powers
- displaying floating-point numbers
- inputting floating-point numbers

The following functions only exist as target words so you cannot use them in calculations in your source code when outside a colon definition.

10.7.1 Calculating sines, cosines and tangents

To calculate sine, cosine and tangent, use `FSIN`, `FCOS` and `FTAN` respectively. Angles are expressed in radians.

10.7.2 Calculating arc sines, cosines and tangents

To calculate arc sine, cosine and tangent, use `FASIN`, `FACOS`

and `FATAN` respectively. They return an angle in radians.

10.7.3 Calculating logarithms

Two words are supplied to calculate logarithms, `FLOG` and `FLN`. `FLOG` calculates a logarithm to base 10 (decimal). `FLN` calculates a logarithm to base e. Both take a floating-point number in the range from 0 to Einf.

10.7.4 Calculating powers

Three power functions are supplied:

```
FE^X F10^X X^Y
```

10.8 Degrees or radians

The angular measurement used in the trigonometric functions are in radians. To convert between degrees and radians use `RAD>DEG` or `DEG>RAD`. `RAD>DEG` converts an angle from radians to degrees. `DEG>RAD` converts an angle from degrees to radians.

10.9 Displaying floating-point numbers

Two words are available for displaying floating-point numbers, `F.` and `E.`. The word `F.` takes a floating-point number from the stack and displays it in the form xxxx.xxxxx or x.xxxxxEyy depending on the size of the number. The word `E.` displays the number in the latter form.

10.10 Number formats, ANS and Forth200x

The ANS Forth standard specifies that floating point numbers must be entered in the form 1.234e5 and must contain a point '.' and 'e' or 'E', and that double integers are terminated by a point '.'.

This situation prevents the use of the standard conversion words in international applications because of the interchangable use of the '.' and ',' characters in numbers. Because of this, the cross-compiler's host VFX Forth uses two four-byte arrays, `FP-CHAR` and `DP-CHAR`, to hold the characters used as the floating point and double integer indicator characters. By default, `FP-CHAR` is initialised to '.' and `DP-CHAR` is initialised to to ',' and '.'. For strict ANS compliance, you should set them as follows **before** `CROSS-COMPILE` is run.

```
\ ANS standard setting
  char . dp-char !
  char . fp-char !
: ans-floats    \ -- ; for strict ANS compliance
  [char] . dp-char !
  [char] . fp-char !
;
\ MPE defaults
  char , dp-char !
  char . dp-char 1+ c!
  char . fp-char !
: mpe-floats    \ -- ; for existing and most legacy code
  [char] , dp-char !
  [char] . dp-char 1+ c!
  [char] . fp-char !
;
\ Legacy defaults, including ProForth
  char , dp-char !
  char . fp-char !
: legacy-floats \ -- ; for legacy code
  [char] , dp-char !
  [char] . fp-char !
;
```

You can of course set these arrays to hold any values which suit your application's language and locale. Note that integer conversion is always attempted before floating point conversion. This means that if the `FP-CHAR` and `DP-CHAR` arrays contain the same character, floating point numbers must contain 'e' or 'E'. If the arrays are all different, a number containing the `FP-CHAR` will be successfully converted as a floating point number, even if it does not contain 'e' or 'E'.

10.11 Glossary

10.11.1 Separators

Before July 2010, the floating point separator, '.', was fixed. To ease internationalisation, it is now variable.

`variable fp-char        \ -- addr`

Holds up to four character(s) to be treated as floating point indicators. Set to '.' for ANS compatibility. Note that this should be accessed as a one to four byte array. The first character is used as the point character for output.

`0 equ SepArray? \ -- flag`

If the equate is non-zero, `fp-char` is treated as a four byte array, otherwise as a one byte array. This is a flag for future expansion.

`: isSep?        \ char addr -- flag`

Return true if *char* is one of the four bytes at *addr*. If less than than four bytes are needed, a zero byte acts as a terminator. Used when `SepArray?` is true.

`: isSep?  c@ =  ;`

A compiler macro used when `SepArray?` is false.

10.11.2 FP Stack primitives

```
8 equ FPCELL    \ -- u
```
Size of a floating point number.

```
: finit         \ F: i*f -- ; resets FPU and FP stack
```
Reset the floating point stack. Do not forget to use this in a task before using floating point.

```
: fdepth        \ -- #f
```
Floating point equivalent of `DEPTH`. The result is returned on the Forth data stack.

```
: fs@           \ -- f ; F: f -- f
```
Copy the top of the floating point stack to the data stack.

```
: fs>           \ F: f -- ; -- f
```
Move the top of the floating point stack to the data stack.

```
: fs!           \ f1 -- ; F: f2 -- f1
```
Move a float from the data stack and overwrite the top of the float stack.

```
: >fs           \ f -- ; F: -- f
```
Move a float from the data stack to a new position on the float stack.

```
: exp@          \ F: f -- f ; -- exp
```
Copy the exponent of the top float to the data stack.

```
: exp!          \ exp -- ; F: f -- f'
```
Change/Set the exponent of the top float.

```
: mant@         \ F: f -- f ; -- mant
```
Copy the mantissa of the top float to the data stack.

```
: mant!         \ F: f -- f ; -- mant
```
Change/Set the mantissa of the top float.

10.11.3 High Level primitives

The software floating point pack requires several support primitives. High level versions are provided in *SFP16HI.FTH* and *SFP32HI.FTH* for 16 and 32 bit targets. Some targets have coded versions in the CPU directory and these will provide much better performance. The support file should be compiled before the common file.

In *SoftFP32CX.fth* and *SoftFP32SX.fth* a set of high-level primitives are compiled if the primitives have not yet been supplied.

```
: S->           \ n1 carry-in-flag --- n2 carry-out-flag
```
Perform a right shift, applying the carry in to the m.s. bit and returning the carry out as 1 or 0.

```
: <-S           \ n1 carry-in-flag --- n2 carry-out-flag
```
Perform a left shift, applying the carry in to the l.s. bit and returning the carry out as 1 or 0.

```
: d<<1          \ xd -- xd<<1
```
One bit double left shift.

```
: d>>1          \ xd -- xd>>1
```
One bit double right logical shift.

```
: D>>N          \ d n -- d>>n
```
N bit double right logical shift.

```
: rshiftx       \ x u -- x' ; right shift
```
Used for right shifts that may exceed 31 bits. In the ANS and Forth 2012 standards, this is an ambiguous condition. We need shifts over 31 bits to return 0. On x86 targets, a check is made for shifts over 31 bits.

10.11.4 Basic stack and memory operators

```
: F!            \ F: r -- ; addr --
```
Stores r at addr

```
: F@            \ addr -- ; F: -- r
```
Fetches r from addr.

```
: F,            \ F: r --
```
Lays a real number into the dictionary, reserving 8 bytes.

```
: FDUP          \ F: r -- r r
```
Floating point equivalent of `DUP`.

```
: FOVER         \ F: r1 r2 -- r1 r2 r1
```
Floating point equivalent of `OVER`.

```
: FSWAP         \ F: r1 r2 -- r2 r1
```
Floating point equivalent of `SWAP`.

```
: FPICK         \ F: fu..f0 u -- fu..f0 fu
```
Floating point equivalent of `PICK`.

```
: FROT          \ F: r1 r2 r3 -- r2 r3 r1
```
Floating point equivalent of `ROT`.

```
: F-ROT         \ F: r1 r2 r3 -- r3 r1 r2
```
Floating point equivalent of `-ROT`.

```
: FROLL         \ F: f1 f2 f3 --  f2 f3 f1
```
Floating point equivalent of `ROLL`.

```
: FDROP         \ F: r --
```
Floating point equivalent of `DROP`.

```
: FNIP          \ F: r1 r2 -- r2
```
Floating point equivalent of `NIP`.

10.11.5 Floating point defining words

```
: FVARIABLE     \ "<spaces>name" -- ; Run: -- f-addr
```
Use in the form: `FVARIABLE <name>` to create a variable that will hold a floating point number.

```
: FCONSTANT     \ r "<spaces>name" -- ; Run: -- r
```
Use in the form: `<float> FCONSTANT <name>` to create a constant that returns a floating point number.

```
: FARRAY        \ "<spaces>name" fn-1..f0 n -- ; Run: i -- ri
```
Create an initialised array of floating point numbers. Use in the form:

```
fn-1 .. f1 f0 n FARRAY <name>
```

to create an array of n floating point numbers. When the array `name` is executed, the index i is used to return the address of the i'th 0 zero-based element in the array. For example:

```
4e0 3e0 2e0 1e0 0e0 5 FARRAY TEST
```

will set up an array of five elements. Note that the rightmost float (0e0) is element 0. Then `i TEST` will return the *\{i}th element. If you create this array in `IDATA`, restore `CDATA` afterwards.

`: FBUFF \ u "name" -- ; i -- addr`
Creates a buffer for u floats in the current memory section. The child action is to return the address of the ith element (zero-based).

```
10 fbuff foo
```

Creates an buffer for ten float elements in the current memory section.

```
3 foo
```

Returns the address of element 3 in the buffer.

The default section is `CDATA`, and we recommend that you leave it that way! To create a ten element array in `UDATA` space, you can use:

```
udata
10 fbuff MyFloats
cdata
```

10.11.6 Type conversions

`: NORM \ n exp -- f`
Normalise a single integer and a single exponent to produce a floating point number on the data stack. INTERNAL.

`: DNORM \ d exp -- fn ; normalise a 64 bit double`
Normalise a double integer and a single exponent to produce a floating point number on the data stack. INTERNAL.

`: (FSIGN) \ fn -- |fn| flag ; true if negative`
Return the absolute value of fn and a flag which is true if fn is negative. Data stack operation.

`: FSIGN \ F: fn -- |fn| ; -- flag ; true if negative`
Return the absolute value of fn and a flag which is true if fn is negative. F.P. stack operation.

`: S>F \ n -- ; F: -- fn`
Converts a single integer to a float.

`: D>F \ d -- ; F: -- fn`
Converts a double integer to a float.

`: F>S \ F: fn -- ; -- n`
Converts a float to a single integer. Note that `F>S` truncates the number towards zero according to the ANS specification. If `|fn|` is greater than maxint, `+`/-maxint is returned.

`: F>D \ F: fn -- ; -- d`
Converts a float to a double integer. Note that `F>D` truncates the number towards zero according to the ANS specification. If `|fn|` is greater than dmaxint, `+`/-dmaxint is returned.

`: FINT \ F: f1 -- f2`
Chop the number towards zero to produce a floating point representation of an integer.

10.11.7 Arithmetic

```
: FNEGATE       \ F: r1 -- r2
```

Floating point negate.

```
: ?FNEGATE      \ n -- ; F: fn -- fn|-fn
```

If n is negative, negate fn.

```
: FABS          \ F: fn -- |fn|
```

Floating point absolute.

```
: F*            \ F: r1 r2 -- r3
```

Floating point multiply.

```
: F/            \ F: r1 r2 -- r3
```

Floating point divide.

```
: F+            \ F: r1 r2 -- r3
```

Floating point addition.

```
: F-            \ F: r1 r2 -- r3
```

Floating point subtraction, r3=r1-r2

```
: FSEPARATE     \ F: f1 f2 -- f3 f4
```

Leave the signed integer quotient f4 and remainder f3 when f1 is divided by f2. The remainder has the same sign as the dividend.

```
: FFRAC         \ f1 f2 -- f3
```

Leave the fractional remainder from the division f1/f2. The remainder takes the sign of the dividend.

10.11.8 Relational operators

```
: F0<           \ F: f1 -- ; -- flag
```

Floating point `0<`.

```
: F0>           \ F: f1 -- ; -- flag
```

Floating point `0>`.

```
: F0=           \ F: f1 -- ; -- flag
```

Floating point `0=`.

```
: F0<>          \ F: f1 -- ; -- flag
```

Floating point `0<>`.

```
: F=            \ F: f1 f2 -- ; -- flag
```

Floating point `=`.

```
: F<            \ F: r1 r2 -- ; -- flag
```

Floating point `<`.

```
: F>            \ F: f1 f2 -- ; -- flag
```

Floating point `>`.

```
: FMAX          \ F: r1 r2 -- r1|r2
```

Floating point `MAX`.

```
: FMIN          \ F: r1 r2 -- r1|r2
```

Floating point `MIN`.

10.11.9 Miscellaneous

`: FALIGNED \ addr -- f-addr`
Aligns the address to accept an 8-byte float.

`: FALIGN \ --`
Aligns the dictionary to accept an 8-byte float.

`: FLOAT+ \ f-addr1 -- f-addr2`
Increments addr by 8, the size of a float.

`: FLOATS \ n1 -- n2`
Returns n2, the size of n1 floats.

10.11.10 Powers of ten operations

`1 s>f 10 s>f f/ fconstant %.1`
Floating point 0.1.

`1 s>f fconstant %1`
Floating point 1.0.

`10 s>f fconstant %10`
Floating point 10.0.

`1250000000 34 fconstant %10^10`
Floating point 10^10.

`1844674407 -33 fconstant %10^-10`
Floating point 10^-10.

`F# 1.0E256 FCONSTANT %10^256`
Floating point 10^256.

`F# 1.0E-1 FCONSTANT %10E-1`
Floating point 10^-1.

`F# 1.0E-10 FCONSTANT %10E-10`
Floating point 10^-10.

`F# 1.0E-256 FCONSTANT %10^-256`
Floating point 10^-256.

`16 FARRAY POWERS-OF-10E1`
An array of 16 powers of ten starting at 10^0 in steps of 1.

`17 FARRAY POWERS-OF-10E16`
An array of 17 powers of ten starting at 10^0 in steps of 16.

`16 FARRAY POWERS-OF-10E-1`
An array of 16 powers of ten starting at 10^0 in steps of -1.

`17 FARRAY POWERS-OF-10E-16`
An array of 17 powers of ten starting at 10^0 in steps of -16.

`: RAISE_POWER \ exp(10) -- ; F: f -- f'`
Raise the power in preparation for number formatting.

`: SINK_FRACTION \ exp(10) -- ; F: f -- f'`
Reduce the power in preparation for number formatting.

`: *10^X \ exp(10) -- ; F: f -- f'`
Generate float' = float *10^dec_exp. INTERNAL.

10.11.11 Floating point input

Note that number conversion takes place in PAD.

`: FLITERAL \ Comp: F: r -- ; Run: F: -- r`
Compiles a float as a literal into the current definition. At execution time, a float is returned. For example, `[ %PI F2* ] FLITERAL` will compile 2PI as a floating point literal. Note that FLITERAL is immediate.

`: CONVERT-EXP \ c-addr --`
If the character at c-addr is 'D' convert it to 'E'. INTERNAL.

`: CONVERT-FPCHAR \ c-addr --`
Convert the f.p. char '.' to the double char ',' for conversion. INTERNAL.

`: ALL-BLANKS? \ c-addr len -- flag`
Return true if string is all blanks (spaces). INTERNAL.

`: FCHECK \ -- am lm ae le e-flag .-flag`
Check the input string at PAD, returning the separated mantissa and exponent flags. The e-flag is returned true if the string contained an exponent indicator 'E' and the .-flag is returned true if a '.' was found. INTERNAL.

`: doMNUM \ c-addr u -- d 2 | 0`
Convert the mantissa string to a double number and 2. If conversion fails, just return 0. INTERNAL.

`: doENUM \ c-addr u -- n 1 | 0 ; str as above`
Convert the exponent string to a single number and 1. If conversion fails, just return 0. INTERNAL.

`: FIXEXP \ dmant exp(10) -- ; F: -- f`
Convert a double integer mantissa and a single integer exponent into a floating point number. INTERNAL.

`: FNUMBER? \ addr -- 0/.../mant exp 2`
Behaves like the integer version of NUMBER? except that if the number is in F.P. format and BASE is decimal, a floating point conversion is attempted. If conversion is successful, the floating point number is left on the float stack and the result code is 2. This word only accepts text with an 'E' as a floating point indicator, e.g, 1.2345e0. If *\fo{BASE is not decimal all numbers are treated as integers. The integer prefixes '#','$','0x' etc. are recognised and cause integer conversion to be used.

`: >FLOAT \ c-addr u -- true|false ; F: -- [f]`
Try to convert the string at c-addr/u to a floating point number. If conversion is successful, flag is returned true, and a floating number is returned on the float stack, otherwise just flag=0 is returned. This word accepts several forms, e.g. 1.2345e0, 1.2345, 12345 and converts them to a float. Note that double numbers (containing a ',') cannot be converted. Number conversion is decimal only, regardless of the current BASE.

`: (F#) \ addr -- 2|0 ; F: -- [f]`
The primitive for F# and F#IN below.

`: F#IN \ -- 2|0 ; F: -- [f]`
Attempts to convert a token from the input stream to a floating-point number. Numbers in integer format will be converted to floating-point. An indicator (0 or 2/3) is returned in the same way as an indicator is returned by FNUMBER?.

`: F#  \ F: -- [f] ; or compiles it [ state smart ]`
If interpreting, takes text from the input stream and, if possible converts it to a f.p. number on the stack. Numbers in integer format will be converted to floating-point. If compiling, the converted number is compiled.

`: REALS  \ -- ; allow f.p input`
Switch `NUMBER?` to permit floating point input using `FNUMBER?`. This action can be reversed by `INTEGERS`. Both `REALS` and `INTEGERS` are in the `FORTH` vocabulary.

`: INTEGERS  \ -- ; no f.p input`
Switch `NUMBER?` to restore integer only input.

10.11.12 Floating point output

`variable places  8 places !  \ -- addr`
Number of digits output after the decimal point.

`: ROUND  \ F: f1 -- f2`
Rounds least significant eight bits to 0 if higher 2 bits are all 0s or all 1s.

`: ?10PWR  \ F: f -- f ; -- exp[10]`
Generate the power of ten corresponding to the float's power of two.

`: SIGFIGS  \ F: f -- f' ; n -- dec_exponent`
Scale f and generate a decimal exponent corresponding to n significant digits.

`: op-prepare  \ F: fn -- ; -- d exp(10) sign`
From fn, generate a double number corresponding to 8 significant digits, a decimal exponent and a sign indicator (nz=negative). INTERNAL.

`: .EXP  \ exp --`
Display the exponent. INTERNAL.

`: N#  \ d n -- d'`
Convert n digits. INTERNAL.

`: .FPsign  \ flag --`
If flag is non-zero, generate a '-' otherwise a space.

`: .FPsep  \ --`
Issue the FP separator, usually '.'.

`: E.  \ F: f --`
Print the f.p. number on the stack in exponential form, x.xxxxxEyy.

`: REPRESENT  \ F: r -- ; c-addr u -- n flag1 flag2`
Assume that the floating number is of the form +/-0.xxxxEyy. Place the significand xxxxx at c-addr with a maximum of u digits. Return n the signed integer version of yy. Return flag1 true if f is negative, and return flag2 true if the results are valid. In this implementation all errors are handled by exceptions, and so flag2 is always true.

`: F.  \ F: f --`
Print the f.p. number in free format, xxxx.yyyy, if possible. Otherwise display using the x.xxxxEyy format.

10.11.13 Rounding

`f# 1.0 fconstant %ONE`
Floating point 1.0.

```
: FLOOR          \ r1 -- r2
```
Floored round towards -infinity.

```
: FROUND         \ r1 -- r2
```
Round the number to nearest or even.

10.11.14 Trigonmetric functions

N.B. All angles are in radians.

```
: DEG>RAD        \ F: n1 -- n2
```
Convert degrees to radians.

```
: RAD>DEG        \ F: n1 -- n2
```
convert radians to degrees.

```
: FSQR           \ F: f1 -- f2 ; FSQR by Heron's formula
```
F2=sqrt(f1) by Heron's formula.

```
: FSIN           \ F: f1 -- f2
```
f2=sin(f1).

```
: FCOS           \ F: f1 -- f2
```
f2=cos(f1).

```
: FTAN           \ f1 -- f2
```
f2=tan(f1).

```
: FASIN          \ F: f1 -- f2
```
f2=arcsin(f1).

```
: FACOS          \ F: f1 -- f2
```
f2=arccos(f1).

```
: FATAN          \ F: f1 -- f2
```
f2=arctan(f1).

10.11.15 Logarithmic and Power functions

```
: FLN            \ F: f1 -- f2
```
Take the logarithm of f1 to base e and return the result.

```
: FLOG           \ F: f1 -- f2
```
Take the logarithm of f1 to base 10 and return the result.

```
: FE^X           \ F: f1 -- f2
```
f2=e^f1.

```
: F10^X          \ F: f1 -- f2
```
f2=10^f1

```
: FX^N           \ x-real n-integer -- fx^n
```
fx^n=x^n where x is a float and n is an integer.

```
: FX^Y           \ F: fx fy -- fx^fy
```
fn=X^Y where Y and Y are both floats.

10.11.16 IEEE format conversion

`: FP>IEEE \ F: fp -- ; -- ieee32`
Convert native FP value to IEEE 32 bit format.

`: IEEE>FP \ ieee32 -- ; F: -- fp`
Convert IEEE 32 bit float to native format.

10.12 Gotchas

The ANS and Forth200x specifications define the format of floating point numbers during text interpretation as:

```
Convertible string := <significand><exponent>

<significand> := [<sign>]<digits>[.<digits0>]
<exponent>    := E[<sign>]<digits0>
<sign>        := { + | - }
<digits>      := <digit><digits0>
<digits0>     := <digit>*
<digit>       := { 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 }
```

This format is handled by the word `FNUMBER?`. The word `>FLOAT` accepts a more relaxed format.

```
Convertible string := <significand>[<exponent>]

<significand> := [<sign>]{<digits>[.<digits0>] | .<digits> }
<exponent>    := <marker><digits0>
<marker>      := {<e-form> | <sign-form>}
<e-form>      := <e-char>[<sign-form>]
<sign-form>   := { + | - }
<e-char>      := { D | d | E | e }
```

This restriction makes it difficult to use the text interpreter during program execution as it requires floating point numbers to contain 'D' or 'E' indicators, which is not profane practice. A quick kluge to fix this is to change `FNUMBER?` as below.

```
Replace:
  fcheck drop if                        \ valid f.p. number?
with:
  fcheck or if                          \ valid f.p. number?
```

Note that this change can/will cause problems if number base is not `DECIMAL`.

11 Software Floating Point

11.1 Introduction

Although most embedded applications only require integer arithmetic, some do require floating-point. Therefore software floating-point is supplied with the cross-compiler and the target Forth. The target floating point wordset is not fully ANS compliant, but satisfies the needs of embedded systems without undue complexity. The Forth data stack and the floating point stack are the same. The floating point data storage format is not IEEE format, but is optimised for performance on small controllers. If you need a separate floating point stack or IEEE double format storage, please contact MPE. Any variations in the implementation will be documented in the target specific section of the manual.

The cross-compiler has a more limited floating-point support than the target. Some words are avaliable during compilation of colon definitions, but not while interpreting.

11.2 Source code

The source code is in two sets of files, one for 32 bit Forth targets, the other for 16 bit targets. The files are:

```
Common\sfp32hi    32 bit primitives
Common\sfp32com   32 bit high level code
Common\sfp16hi    16 bit primitives
Common\sfp16com   16 bit high level code
```

These files use no assembler definitions. Some targets have code versions of the primitives, and these will be found in the CPU specific code directory. A significant increase in performance can be obtained by using the code files.

11.3 Entering floating-point numbers

Floating point number entry is enabled by `REALS` and disabled by `INTEGERS`.

Floating-point numbers of the form 0.1234e1 are required (see `FNUMBER?`) during interpretation and compilation of source code. Floating-point numbers are compiled as literal numbers when in a colon definition (compiling) and placed on the stack when outside a definition (interpreting).

The more flexible word `>FLOAT` accepts numbers in two forms, 1.234 and 0.1234e1. Both words are documented later in this chapter. See also the section on *Gotchas* later in this chapter.

Note also that MPE Forths use ',' as the double number indicator - it makes life much easier for Europeans.

11.4 The form of floating-point numbers

A floating-point number is placed on the Forth data stack. In the Forth literature, this is referred to as a combined floating point and data stack. For 32 bit targets, a floating point

number consists of two 32-bit numbers, one for the mantissa and one for the exponent. For 16 bit targets, it consists of a 32-bit double mantissa and a single 16-bit exponent. The mantissa is normalised. The exponent is on the top of the stack. Note that for 16 bit targets, number conversion is affected by the cross-compiler directives `HOST-MATH` and `TARGET-MATH`. `HOST-MATH` leaves double numbers and floats in 32-bit form, whereas `TARGET-MATH` leaves them in 16-bit form.

11.5 Creating and using variables

To create a variable, use `FVARIABLE`. `FVARIABLE` works in the same way as `VARIABLE`. For example, to create a floating-point variable called `VAR1` you code:

```
FVARIABLE VAR1
```

When `VAR1` is used, it returns the address of the floating-point number.

Two words are used to access floating-point variables, `F@` and `F!`. These are analogous to `@` and `!`.

11.6 Creating constants

To create a floating-point constant, use `FCONSTANT`, which is analogous to `CONSTANT`. For example, to generate a floating-point constant called `CON1` with a value of 1.234, you enter:

```
1.234e0 FCONSTANT CON1
```

When `CON1` is executed, it returns 1.234 on the Forth stack.

11.7 Using the supplied words

The supplied words split into several groups:

- sines, cosines and tangents
- arc sines, cosines and tangents
- arithmetic functions
- logarithms
- powers
- displaying floating-point numbers
- inputting floating-point numbers

The following functions only exist as target words so you cannot use them in calculations in your source code when outside a colon definition.

11.7.1 Calculating sines, cosines and tangents

To calculate sine, cosine and tangent, use `FSIN`, `FCOS` and `FTAN` respectively. Angles are expressed in radians.

11.7.2 Calculating arc sines, cosines and tangents

To calculate arc sine, cosine and tangent, use `FASIN`, `FACOS`

and `FATAN` respectively. They return an angle in radians.

11.7.3 Calculating logarithms

Two words are supplied to calculate logarithms, `FLOG` and `FLN`. `FLOG` calculates a logarithm to base 10 (decimal). `FLN` calculates a logarithm to base e. Both take a floating-point number in the range from 0 to Einf.

11.7.4 Calculating powers

Three power functions are supplied:

```
FE^X F10^X X^Y
```

11.8 Degrees or radians

The angular measurement used in the trigonometric functions are in radians. To convert between degrees and radians use `RAD>DEG` or `DEG>RAD`. `RAD>DEG` converts an angle from radians to degrees. `DEG>RAD` converts an angle from degrees to radians.

11.9 Displaying floating-point numbers

Two words are available for displaying floating-point numbers, `F.` and `E.`. The word `F.` takes a floating-point number from the stack and displays it in the form xxxx.xxxxx or x.xxxxxEyy depending on the size of the number. The word `E.` displays the number in the latter form.

11.10 Number formats, ANS and Forth200x

The ANS Forth standard specifies that floating point numbers must be entered in the form 1.234e5 and must contain a point '.' and 'e' or 'E', and that double integers are terminated by a point '.'.

This situation prevents the use of the standard conversion words in international applications because of the interchangable use of the '.' and ',' characters in numbers. Because of this, the cross-compiler's host VFX Forth uses two four-byte arrays, `FP-CHAR` and `DP-CHAR`, to hold the characters used as the floating point and double integer indicator characters. By default, `FP-CHAR` is initialised to '.' and `DP-CHAR` is initialised to to ',' and '.'. For strict ANS compliance, you should set them as follows **before** `CROSS-COMPILE` is run.

```
\ ANS standard setting
  char . dp-char !
  char . fp-char !
: ans-floats    \ -- ; for strict ANS compliance
  [char] . dp-char !
  [char] . fp-char !
;
\ MPE defaults
  char , dp-char !
  char . dp-char 1+ c!
  char . fp-char !
: mpe-floats    \ -- ; for existing and most legacy code
  [char] , dp-char !
  [char] . dp-char 1+ c!
  [char] . fp-char !
;
\ Legacy defaults, including ProForth
  char , dp-char !
  char . fp-char !
: legacy-floats \ -- ; for legacy code
  [char] , dp-char !
  [char] . fp-char !
;
```

You can of course set these arrays to hold any values which suit your application's language and locale. Note that integer conversion is always attempted before floating point conversion. This means that if the `FP-CHAR` and `DP-CHAR` arrays contain the same character, floating point numbers must contain 'e' or 'E'. If the arrays are all different, a number containing the `FP-CHAR` will be successfully converted as a floating point number, even if it does not contain 'e' or 'E'.

11.11 Glossary

11.11.1 Error Strings/Codes

These strings describe the various FP maths errors. The string address is

```
CREATE FP_FLN_ERR       \ -- addr
  ," Invalid argument to FLN/FLOG"
CREATE FP_FSQR_ERR      \ -- addr
  ," Square root of negative no.!"
CREATE FP_FE^X_ERR      \ -- addr
  ," Overflow in FE^X"
CREATE FP_F10^X_ERR     \ -- addr
  ," Overflow in f10^x"
CREATE FP_EX^Y_ERR      \ -- addr
  ," Result of FX^Y is complex"
CREATE FP_TRIG_ERR      \ -- addr
  ," Overflow in trig. function"
```

11.11.2 Separators

Before July 2010, the floating point separator, '.', was fixed. To ease internationalisation, it is now variable.

`variable fp-char \ -- addr`
Holds up to four character(s) to be treated as floating point indicators. Set to '.' for ANS compatibility. Note that this should be accessed as a one to four byte array. The first character is used as the point character for output.

`0 equ SepArray? \ -- flag`
If the equate is non-zero, `fp-char` is treated as a four byte array, otherwise as a one byte array. This is a flag for future expansion.

`: isSep? \ char addr -- flag`
Return true if *char* is one of the four bytes at *addr*. If less than than four bytes are needed, a zero byte acts as a terminator. Used when `SepArray?` is true.

`: isSep? c@ = ;`
A compiler macro used when `SepArray?` is false.

11.11.3 Basic stack and memory operators

`: F! \ r addr --`
Stores r at addr

`: F@ \ addr -- r`
Fetches r from addr.

`: F, \ r --`
Lays a real number into the dictionary, reserving 8 bytes.

`: FDUP \ r -- r r`
Floating point equivalent of `DUP`.

`: FOVER \ r1 r2 -- r1 r2 r1`
Floating point equivalent of `OVER`.

`: FROT \ r1 r2 r3 -- r2 r3 r1`
Floating point equivalent of `ROT`.

`: FPICK \ fu..f0 u -- fu..f0 fu`
Floating point equivalent of `PICK`.

`: FROLL \ f1 f2 f3 -- f2 f3 f1`
Floating point equivalent of `ROLL`.

`: FSWAP \ r1 r2 -- r2 r1`
Floating point equivalent of `SWAP`.

`: FDROP \ r --`
Floating point equivalent of `DROP`.

`: FNIP \ r1 r2 -- r2`
Floating point equivalent of `NIP`.

11.11.4 Floating point defining words

`: FVARIABLE \ "<spaces>name" -- ; Run: -- f-addr`
Use in the form: `FVARIABLE <name>` to create a variable that will hold a floating point number.

`: FCONSTANT \ r "<spaces>name" -- ; Run: -- r`
Use in the form: `<float> FCONSTANT <name>` to create a constant that returns a floating point number.

`: FARRAY \ "<spaces>name" fn-1..f0 n -- ; Run: i -- ri`
Create an initialised array of floating point numbers. Use in the form:

```
fn-1 .. f1 f0 n FARRAY <name>
```

to create an array of n floating point numbers. When the array `name` is executed, the index i is used to return the address of the i'th 0 zero-based element in the array. For example:

```
4e0 3e0 2e0 1e0 0e0 5 FARRAY TEST
```

will set up an array of five elements. Note that the rightmost float (0e0) is element 0. Then `i TEST` will return the *\{i}th element. If you create this array in `IDATA`, restore `CDATA` afterwards.

`: FBUFF \ u "name" -- ; i -- addr`
Creates a buffer of u floats in the current memory section. The child action is to return the address of the ith element (zero-based).

```
10 fbuff foo
```

Creates an buffer for ten float elements in.

```
3 foo
```

Returns the address of element 3 in the buffer.

The default section is `CDATA`, and we recommend that you leave it that way! To create a ten element array in `UDATA` space, you can use:

```
udata
10 fbuff MyFloats
cdata
```

11.11.5 Type conversions

`: NORM \ n exp -- f`
Normalise a single integer and a single exponent to produce a floating point number. INTERNAL.

`: DNORM \ d exp -- fn ; normalise a 64 bit double`
Normalise a double integer and a single exponent to produce a floating point number. INTERNAL.

`: FSIGN \ fn -- |fn| flag ; true if negative`
Return the absolute value of fn and a flag which is true if fn is negative.

`: S>F \ n -- fn`
Converts a single integer to a float.

`: F>S \ fn -- n`
Converts a float to a single integer. Note that `F>S` truncates the number towards zero according to the ANS specification. If `|fn|` is greater than maxint, +/-maxint is returned.

`: D>F \ d -- fn`

Converts a double integer to a float.

```
: F>D           \ fn -- d
```
Converts a float to a double integer. Note that F>D truncates the number towards zero according to the ANS specification. If |fn| is greater than dmaxint, +/-dmaxint is returned.

```
: FINT          \ f1 -- f2
```
Chop the number towards zero to produce a floating point representation of an integer.

11.11.6 Arithmetic

```
: FNEGATE       \ r1 -- r2
```
Floating point negate.

```
: ?FNEGATE      \ fn n -- fn|-fn
```
If n is negative, negate fn.

```
: FABS          \ fn -- |fn|
```
Floating point absolute.

```
: F*            \ r1 r2 -- r3
```
Floating point multiply.

```
: F/            \ r1 r2 -- r3
```
Floating point divide.

```
: F+            \ r1 r2 -- r3
```
Floating point addition.

```
: F-            \ r1 r2 -- r3
```
Floating point subtraction.

```
: FSEPARATE     \ f1 f2 -- f3 f4
```
Leave the signed integer quotient f4 and remainder f3 when f1 is divided by f2. The remainder has the same sign as the dividend.

```
: FFRAC         \ f1 f2 -- f3
```
Leave the fractional remainder from the division f1/f2. The remainder takes the sign of the dividend.

11.11.7 Relational operators

```
: F0<           \ f1 -- flag
```
Floating point 0<.

```
: F0>           \ f1 -- flag
```
Floating point 0>.

```
: F0=           \ f1 -- flag
```
Floating point 0=.

```
: F0<>          \ f1 -- flag
```
Floating point 0<>.

```
: F=            \ f1  f2 -- flag
```
Floating point =.

```
: F<            \ r1  r2 -- flag
```
Floating point <.

```
: F>            \ f1  f2 -- flag
```

Floating point >.

```
: FMAX          \ r1 r2 -- r1|r2
```
Floating point MAX.

```
: FMIN          \ r1 r2 -- r1|r2
```
Floating point MIN.

11.11.8 Rounding

```
f# 1.0 fconstant %ONE
```
Floating point 1.0.

```
: FLOOR         \ r1 -- r2
```
Floored round towards -infinity.

```
: FROUND        \ r1 --  r2
```
Round the number to nearest or even.

11.11.9 Miscellaneous

```
: FALIGNED      \ addr -- f-addr
```
Aligns the address to accept an 8-byte float.

```
: FALIGN        \ --
```
Aligns the dictionary to accept an 8-byte float.

```
: FDEPTH        \ -- +n
```
Returns the number of floats on the stack.

```
: FLOAT+        \ f-addr1 -- f-addr2
```
Increments addr by 8, the size of a float.

```
: FLOATS        \ n1 -- n2
```
Returns n2, the size of n1 floats.

11.11.10 Floating point output

```
1 s>f 10 s>f f/ fconstant %.1
```
Floating point 0.1.

```
          1 s>f fconstant %1
```
Floating point 1.0.

```
         10 s>f fconstant %10
```
Floating point 10.0.

```
  1250000000 34 fconstant %10^10
```
Floating point 10^10.

```
 1844674407 -33 fconstant %10^-10
```
Floating point 10^-10.

```
F# 1.0E256 FCONSTANT %10^256
```
Floating point 10^256.

```
F# 1.0E-1 FCONSTANT %10E-1
```
Floating point 10^-1.

```
F# 1.0E-10 FCONSTANT %10E-10
```
Floating point 10^-10.

```
F# 1.0E-256 FCONSTANT %10^-256
```
Floating point 10^-256.

```
16 FARRAY POWERS-OF-10E1
```
An array of 16 powers of ten starting at 10^0 in steps of 1.

```
17 FARRAY POWERS-OF-10E16
```
An array of 17 powers of ten starting at 10^0 in steps of 16.

```
16 FARRAY POWERS-OF-10E-1
```
An array of 16 powers of ten starting at 10^0 in steps of -1.

```
17 FARRAY POWERS-OF-10E-16
```
An array of 17 powers of ten starting at 10^0 in steps of -16.

```
: RAISE_POWER   \ mant exp -- mant' exp'
```
Raise the power in preparation for number formatting.

```
: SINK_FRACTION \ mant exp -- mant' exp'
```
Reduce the power in preparation for number formatting.

```
variable places  8 places !     \ -- addr
```
Number of digits output after the decimal point.

```
: ROUND         \ f1 -- f2
```
Rounds least significant eight bits to 0 if higher 2 bits are all 0s or all 1s.

```
: ?10PWR        \ exp[2] -- exp[2] exp[10]
```
Generate the power of ten corresponding to the power of two. INTERNAL.

```
: SIGFIGS       \ fn n -- d dec_exponent
```
From fn, generate a double number corresponding to n significant digits and a decimal exponent. INTERNAL.

```
: op-prepare    \ fn -- d exp sign
```
From fn, generate a double number corresponding to n significant digits, a decimal exponent and a sign indicator (nz=negative). INTERNAL.

```
: .EXP          \ exp --
```
Display the exponent. INTERNAL.

```
: N#            \ d n -- d'
```
Convert n digits. INTERNAL.

```
: .FPsign       \ flag --
```
If flag is non-zero, generate a '-' otherwise a space. INTERNAL.

```
: .FPsep        \ --
```
Issue the FP separator, usually '.'. INTERNAL.

```
: E.            \ n exp --
```
Print the f.p. number on the stack in exponential form, x.xxxxxEyy.

```
: REPRESENT     \ r c-addr u -- n flag1 flag2
```
Assume that the floating number is of the form +/-0.xxxxEyy. Place the significand xxxxx at c-addr with a maximum of u digits. Return n the signed integer version of yy. Return flag1 true if f is negative, and return flag2 true if the results are valid. In this implementation all errors are handled by exceptions, and so flag2 is always true.

```
: F.            \ f --
```

Print the f.p. number in free format, xxxx.yyyy, if possible. Otherwise display using the x.xxxxEyy format.

11.11.11 Floating point input

Note that number conversion takes place in PAD.

`: FLITERAL \ Comp: r -- ; Run: -- r`
Compiles a float as a literal into the current definition. At execution time, a float is returned. For example, `[ %PI F2* ] FLITERAL` will compile 2PI as a floating point literal. Note that FLITERAL is immediate.

`: CONVERT-EXP \ c-addr --`
If the character at c-addr is 'D' convert it to 'E'. INTERNAL.

`: CONVERT-FPCHAR \ c-addr --`
Convert the f.p. char '.' to the double char ',' for conversion. INTERNAL.

`: ALL-BLANKS? \ c-addr len -- flag`
Return true if string is all blanks (spaces). INTERNAL.

`: FCHECK \ -- am lm ae le e-flag .-flag`
Check the input string at PAD, returning the separated mantissa and exponent flags. The e-flag is returned true if the string contained an exponent indicator 'E' and the .-flag is returned true if a '.' was found. INTERNAL.

`: MNUM \ c-addr u -- d 2 | 0`
Convert the mantissa string to a double number and 2. If conversion fails, just return 0. INTERNAL.

`: ENUM \ c-addr u -- n 1 | 0 ; str as above`
Convert the exponent string to a single number and 1. If conversion fails, just return 0. INTERNAL.

`: *10^X \ float dec_exponent -- float'`
Generate float' = float *10^dec_exp. INTERNAL.

`: FIXEXP \ dmant exp -- mant' exp'`
Convert a double integer mantissa and a single integer exponent into a floating point number. INTERNAL.

`: FNUMBER? \ addr -- 0/.../mant exp 2`
Behaves like the integer version of NUMBER? except that if the number is in F.P. format and BASE is decimal, a floating point conversion is attempted. If conversion is successful, the floating point number is left on the float stack and the result code is 2. This word only accepts words with an 'E' as a floating point indicator, e.g, 1.2345e0. If BASE is not decimal all numbers are treated as integers. The integer prefixes '#','$','0x' etc. are recognised and cause integer conversion to be used.

`: >FLOAT \ c-addr u -- r true | false`
Try to convert the string at c-addr/u to a floating point number. If conversion is successful, flag is returned true, and a floating number is returned on the float stack, otherwise just flag=0 is returned. This word accepts several forms, e.g. 1.2345e0, 1.2345, 12345 and converts them to a float. Note that double numbers (containing a ',') cannot be converted. Number conversion is decimal only, regardless of the current BASE.

`: (F#) \ addr -- fn 2 | 0`
The primitive for F# and F#IN below.

```
: F#IN          \ -- fn 2 | 0
```
Attempts to convert a token from the input stream to a floating-point number. Numbers in integer format will be converted to floating-point. An indicator (0 or 2/3) is returned in the same way as an indicator is returned by `FNUMBER?`.

```
: F#            \ -- [f] ; or compiles it [ state smart ]
```
If interpreting, takes text from the input stream and, if possible converts it to a f.p. number on the stack. Numbers in integer format will be converted to floating-point. If compiling, the converted number is compiled.

```
: REALS         \ -- ; allow f.p input
```
Switch `NUMBER?` to permit floating point input using `FNUMBER?`. This action can be reversed by `INTEGERS`. Both `REALS` and `INTEGERS` are in the `FORTH` vocabulary.

```
: INTEGERS      \ -- ; no f.p input
```
Switch `NUMBER?` to restore integer only input.

11.11.12 Trigonmetric functions

N.B. All angles are in radians.

```
: DEG>RAD       \ n1 -- n2
```
Convert degrees to radians.

```
: RAD>DEG       \ n1 -- n2
```
convert radians to degrees.

```
: FSQR          \ f1 -- f2 ; FSQR by Heron's formula
```
F2=sqrt(f1) by Heron's formula.

```
: FSIN          \ f1 -- f2
```
f2=sin(f1).

```
: FCOS          \ f1 -- f2
```
f2=cos(f1).

```
: FTAN          \ f1 -- f2
```
f2=tan(f1).

```
: FASIN         \ f1 -- f2
```
f2=arcsin(f1).

```
: FACOS         \ f1 -- f2
```
f2=arccos(f1).

```
: FATAN         \ f1 -- f2
```
f2=arctan(f1).

11.11.13 Power and logarithmic functions

```
: FLN           \ f1 -- f2
```
Take the logarithm of f1 to base e and return the result.

```
: FLOG          \ f1 -- f2
```
Take the logarithm of f1 to base 10 and return the result.

```
: FE^X          \ f1 -- f2
```
f2=e^f1.

```
: F10^X         \ f1 -- f2
```

f2=10^f1

`: FX^N \ x-real n-integer -- fx^n`
fx^n=x^n where x is a float and n is an integer.

`: FX^Y \ x-real y-real -- fn`
fn=X^Y where Y and Y are both floats.

11.11.14 IEEE format conversion

`: FP>IEEE \ fp -- ieee32`
Convert native FP value to IEEE 32 bit format.

`: IEEE>FP \ ieee32 -- fp`
Convert IEEE 32 bit float to native format.

11.12 Gotchas

The ANS and Forth200x specifications define the format of floating point numbers during text interpretation as:

```
Convertible string := <significand><exponent>

<significand> := [<sign>]<digits>[.<digits0>]
<exponent>    := E[<sign>]<digits0>
<sign>        := { + | - }
<digits>      := <digit><digits0>
<digits0>     := <digit>*
<digit>       := { 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 }
```

This format is handled by the word `FNUMBER?`. The word `>FLOAT` accepts a more relaxed format.

```
Convertible string := <significand>[<exponent>]

<significand> := [<sign>]{<digits>[.<digits0>] | .<digits> }
<exponent>    := <marker><digits0>
<marker>      := {<e-form> | <sign-form>}
<e-form>      := <e-char>[<sign-form>]
<sign-form>   := { + | - }
<e-char>      := { D | d | E | e }
```

This restriction makes it difficult to use the text interpreter during program execution as it requires floating point numbers to contain 'D' or 'E' indicators, which is not profane practice. A quick kluge to fix this is to change `FNUMBER?` as below.

```
Replace:
  fcheck drop if                        \ valid f.p. number?
with:
  fcheck or if                          \ valid f.p. number?
```

Note that this change can/will cause problems if number base is not `DECIMAL`.

11.13 Changes from v6.0 to v6.1

Renamed DINT to F>D for consistency. F>D is the ANS word. The original F>D was just a synonym. Similarly SINT was renamed to F>S.

The word FLOATS that enabled floating point number conversion has been renamed to REALS to avoid a name conflict with the ANS word of the same name.

The F-PACK vocabulary has been removed as no one liked it, and it could be considered contrary to the ANS Forth specification. If you wish to retain the F-PACK vocabulary, add the following lines before and after the compilation of the floating point code:

```
only forth definitions          \ *** added ***
vocabulary f-pack               \ *** added ***
also f-pack definition          \ *** added ***
include %CommonDir%\Sfp32Hi     \ primitives
include %CommonDir%\Sfp32Com    \ common high level code
previous definitions            \ *** added ***
```

The code enabling floating point to work in degrees or radians has been commented out for ANS compatibility. All trig functions now operate in radians. The commented out code may be uncommented if you need backward compatibility.

11.13.1 32 bit targets: software floating point

Overhauled 32 bit software floating point and incorporated improvements contributed by Hiden Analytical. These include more complete special case detection, faster high level code, and more accurate number input and output.

Removed all use of global variables except PLACES to make the floating point code usable in interrupt routines and in multitasked systems. If the output routines are to be multitasked, change the definition of PLACES from:

```
VARIABLE PLACES  8 PLACES !
```

to:

```
CELL +USER PLACES
```

and remember to initialise PLACES before using the floating point output routines.

Many words that are only useful as factors have been made headerless to save target memory space.

11.13.2 16 bit targets: software floating point

Note that the 16 bit floating point pack is not re-entrant. If you need to use the floating point pack in a multitasking system, you should convert the global variables to USER variables. The word +USER can be used

```
<size> +USER <name>
```

to define a `USER` variable of a given size (normally a CELL) at the next free offset in the USER area. Only `PLACES` will need initialisation.

11.14 High Level primitives

The software floating point pack requires several support primitives. High level versions are provided in *SFP16HI.FTH* and *SFP32HI.FTH* for 16 and 32 bit targets. Some targets have coded versions in the CPU directory and these will provide much better performance. The support file should be compiled before the common file.

`: <<1 \ n -- n<<1`
A compiler synonym for `2*` or `1 LSHIFT`.

`: >>1 \ n -- n>>1`
A compiler synonym for `u2/` or `1 RSHIFT`.

`: S-> \ n1 carry-in-flag --- n2 carry-out-flag`
Perform a right shift, applying the carry in to the m.s. bit and returning the carry out as 1 or 0.

`: <-S \ n1 carry-in-flag --- n2 carry-out-flag`
Perform a left shift, applying the carry in to the l.s. bit and returning the carry out as 1 or 0.

`: d<<1 \ xd -- xd<<1`
One bit double left shift.

`: d>>1 \ xd -- xd>>1`
One bit double right logical shift.

`: D>>N \ d n -- d>>n`
N bit double right logical shift.

12 Time Delays

The code in *Common\Delays.fth* allows you to handle time delays specified in milliseconds. If you use the multitasker or *Common\Timebase.fth*, *Common\Delays.fth* should be compiled after them.

```
: pause          \ -- ; multitasker hook
```
Allows the sytem multitasker to get a look in. If the multitasker has not been compiled, `PAUSE` is defined as a compiler `NOOP`.

```
0 value ticks    \ -- n
```
Return current clock value in milliseconds. This value can treated as a 32 bit unsigned value that will wrap when it overflows. Compiled if not already defined.

```
: later          \ n -- n'
```
Generates the timebase value for termination in n millseconds time.

```
: expired        \ n -- flag ; true if timed out
```
Flag is returned true if the timebase value n has timed out. N.B. Calls `PAUSE`.

```
: timedout?      \ n -- flag ; true if timed out
```
Flag is returned true if the timebase value n has timed out. `TIMEDOUT?` does not call `PAUSE`, so it can be used in interrupt handlers. In particular, `TIMEDOUT?` should be used rather than `EXPIRED` inside timer action words to reduce timer jitter.

```
: ms             \ n --
```
Waits for n milliseconds. Uses `PAUSE` through `EXPIRED`.

13 Periodic Timers

13.1 Introduction

This code provides a timer system that allows many timers The Forth words in the user accessible group documented below are compatible with the code supplied with MPE's embedded targets, and with VFX Forth. This code assumes the presence of a global value `TICKS` which holds a time value incremented in milliseconds. The timebase is approximate. Granularity and jitter are affected by the timer ISR and the time taken by your own code to execute. By default, the ticker is set to run every 1..100 ms, usually defined by the `EQU`ate `TICK-MS`. The source code is in the the file *TIMEBASE.FTH*.

The file *DELAYS.FTH* should be compiled after *TIMEBASE.FTH*. The code to start and stop the timebase system is part of the ticker interrupt system, which is compiled after *DELAYS.FTH*. If you need to write a new ticker interrupt handler, there will be examples to start from in the <*CPU*>*DRIVERS* folder. The required compilation order is this:

```
multitasker (optional)
TIMEBASE.FTH (optional)
DELAYS.FTH
Ticker driver
```

The timer chain is built using a buffer area, and two chain pointers. Each timer is linked into either the free timer chain, or into the active timer chain.

All time periods are in milliseconds. Note that on a 32 bit system, these time periods must be less than 2^31-1 milliseconds, say 596 hours or 24 days, whereas if the code is on a 16 bit system, time periods must be less than 2^15-1 milliseconds, say 32 seconds.

13.2 The basics of timers

These basic words are defined for applications to use the timer system. Other words are detailed elswhere in this chapter.

```
START-TIMERS        \ -- ; must do this first
STOP-TIMERS         \ -- ; closes timers
AFTER               \ xt period -- timerid/0 ; runs xt once after period ms
EVERY               \ xt period -- timerid/0 ; runs xt every period ms
TSTOP               \ timerid -- ; stops the timer
MS                  \ period -- ; wait for period ms
```

After the timers have been started, actions can be added. The example below starts a timer which puts a character on the debug console every two seconds. Note that when using generic I/O, the output and input devices MUST be specified.

```
start-timers
: t        \ -- ; will run every 2 seconds
  console opvec !
  [char] * emit
;
' t 2 seconds every  \ returns timer id, use TSTOP to stop it
```

The item on stack is a timer handle, use TSTOP to halt this timer.

AFTER is very useful for creating timeouts, such as required to determine if something has happened in time. AFTER returns a timerid. If the action you are protecting happens in time, just use TSTOP when the action happens, and the timer will never trigger. If the action does not happen, the timer event will be triggered.

13.3 Considerations when using timers

All timers are executed within a single interrupt, and so all timer action words share a common user area. This has some impact on timer action words. Since you do not know in which order timer action words are executed, you must set up any USER variables such as BASE that you use, either directly or indirectly.

The interrupt that handles all the timers does not set IPVEC and OPVEC to a default value. If you use I/O words such as EMIT and TYPE within a timer action, you MUST set IPVEC and OPVEC before using the I/O. For the sake of other timer action routines that may still be using default I/O, it is polite to save and restore IPVEC and OPVEC in your timer action words.

Do not worry about calling TSTOP with a timerid that has already been executed and removed from the active timer chain; if TSTOP cannot find the timer, it will ignore the request.

Under some conditions, the execution time of all the timer routines may be longer than the requested period of the timer. In addition, the timer interrupt may be subject to jitter.

13.4 Implementation issues

The following discussion is relevant if you want to modify this code. Functionally equivalent code is provided with MPE's VFX Forth systems. In the Windows environment, timer interrupts are implemented by callbacks and critical sections.

By default, the word DO-TIMERS is run from within the periodic timer interrupt. If interrupts are not re-enabled after resetting the timer interrupt, you may have latency issues if a number of timers is used, or if one of the timer routines takes a considerable time, or if you want to use KEY or EMIT in the timer action. In this case, it would be better to set up the timer routine to RESTART a task which calls DO-TIMERS,e.g.

```
: TIMER-TASK    \ --
  <initialise>
  BEGIN
    DO-TIMERS STOP
  AGAIN
;
```

Such a strategy also permits you to use a fast interrupt, say 1 ms, for the clock, and to trigger the TIMER-TASK every say 32 ms. Another strategy is to leave DO-TIMERS in the interrupt routine and for each timer action be to put a different character into a circular buffer (and to restart a task).

```
16 cqueue: timerQ

: TimerAction    \ --
  <initialise>
  begin
    case  timerQ cqueue>
      [char] A of  ...  endof
      [char] B of  ...  endof
           ...
    endcase
  again
;
```

Providing that the queue is big enough, no events are lost and event order is preserved. However, an action that takes 20 seconds may/will delay all subsequent actions.

The best handler structure depends heavily on your application design. You need to consider things like

- Required interrupt latency
- Required handler latency
- Must handlers use comms?
- Have I enough RAM for a task?

As with all software design, it's usually a trade-off. The default "all in the interrupt" design is good enough for many users. For all the rest, adding a task is a good first step.

13.5 Timebase glossary

`0 value ticks   \ -- addr ; holds timer count`

Get current clock value in milliseconds.

`#8 constant #timers     \ -- n ; maximum number of timers`

A constant used at compile time to set the maximum number of timers required. Each timer requires RAM as defined by the ITIMER structure.

`: do-timers     \ --`

Process all the timers in the chain

`: after         \ xt period -- timerid/0 ; xt is executed once,`

Starts a timer that executes once after the given period. A timer ID is returned if the timer could be started, otherwise 0 is returned.

`: every         \ xt period -- timerid/0 ; periodically`

Starts a timer that executes every given period. A timer ID is returned if the timer could be started, otherwise 0 is returned. The returned timerID can be used by TSTOP to stop the timer.

```
: tstop          \ timerid --
```
Removes the given timer from the active list.

14 Vocabulary and wordlist tools

`: VOC?  \ wid -- flag`
Return TRUE if 'wid' is actually a vocabulary.

`: .VOC  \ wid --`
If wid represents a vocabulary, display its name, otherwise just display its value.

`: ORDER  \ --`
Display the current search order and definitions vocabularies.

`: VOCS  \ --`
Display all vocabularies.

`: $FORGET  \ c-addr --`
Forgets word name in given string. See FORGET.

`: FORGET  \ "<spaces>name" --`
Used in the form "FORGET <name>", <name> and all following words are removed from the dictionary. This word is marked obsolescent in the ANS specification, and is replaced by MARKER.

`: MARKER  \ "<spaces>name" -- ; Exec: --`
MARKER <name> creates a word that when executed removes itself and ALL following definitions from the dictionary. MARKER is the ANS replacement for FORGET. MARKER automatically trims all wordlist and vocabulary based chains.

`: EMPTY  \ --`
Removes all words added since power up. Use only when compiling into RAM.

15 XMODEM Receiver and Transmitter

15.1 Introduction

The file *Common\XmodemTxRx.fth* implements the XMODEM 128 and 1024 byte protocols in both directions. Use with AIDE requires AIDE release 3.00 upwards. A very simplified version of the 128 byte checksum receive code may be found in **Common\MinXmodemRx.fth** and is ideal for Flash reprogramming.

The original shorter code that just handles the 128 byte protocol is available as *Common\XmodemTxRx128.fth*.

No test code is provided for this file as the system has been tested by comparison of transferred binary files.

15.2 Words in XmodemTxRx.fth

15.2.1 Configuration

```
1 equ XmodemTx? \ -- n
```
Non-zero to compile transmit code

```
1 equ XmodemRx? \ -- n
```
Non-zero to compile receive code.

15.2.2 Constants and variables

```
$0101 equ blkerror
```
A block number error has occurred.

```
$0103 equ noreply
```
There was no reply within one second.

```
$0104 equ crcerror
```
Bad CRC or checksum.

```
$0105 equ overflow
```
Too many blocks were sent.

```
$010 equ maxerrs        \ -- n
```
Maximum number of errors before transfer is aborted.

```
#1024 Buffer: x-buffer  \ -- addr
```
Holds a 128 or 1024 byte Xmodem data block.

```
#128 value /Xblk        \ -- n
```
Holds Xmodem block size, 1024 or 128.

```
0 value Xmode           \ -- n
```
Holds 0 for checksum mode, nz for CRC-16.

15.2.3 Common code

```
: init-blks             \ addr #bytes -- #blks
```
Given the size of an image, return the number of complete 128 byte blocks, set the variable CUR-ADDRESS to ADDR and set the variable BLK# to 1.

`: +Xcrc \ crc char -- crc'`
Update the XMODEM CRC with the given character. The initial value should be zero.

15.2.4 XMODEM transmission

`: (To-Buffer) \ --`
Move 128/1024 bytes from the memory pointed to by `CUR-ADDRESS` into `X-BUFFER`. This is the default action of `TO-BUFFER`. The variable `CUR-ADDRESS` is set by `BIN-DOWN` and friends.

`Defer To-Buffer \ --`
Copy the next 128/1024 bytes to transmit to `X-BUFFER`. They are then transmitted from `X-BUFFER`. You can change this action as required by your application. The default action is `(TO-BUFFER)`.

`: ?Ack \ -- ; wait for char, abort if not ACK`
Wait for a character and terminate the transfer and abort if the character is not an ACK.

`: Send-Block \ Blk# -- ; transmit a block`
Transmit the 128/1024 byte contents of `X-BUFFER` to the host.

`: Bin-Down \ addr #bytes -- ; transfer memory to host`
Download (transmit) the given block of memory to the host using the XMODEM 128/1024 byte block protocol. On entry, the variable `CUR-ADDRESS` is set to *addr* on entry and *#bytes* is rounded up to a 128/1024 byte unit.

15.2.5 XMODEM reception

`: ser-flush \ -- ; flush the link input`
Flush all input characters from the host/target link.

`: send-ack \ -- ; send ACK`
Transmit an ACK character.

`: send-nak \ -- ; Transmit a NAK character`
Transmit a NAK character, usually to trigger a retransmit.

`: send-can \ -- ; send CAN character`
Transmit a CAN character.

`: toomanyerrs? \ -- T|F ; true if too many errors`
Return true if too many comms errors have occurred.

`: (From-Buffer) \ --`
Move 128/1024 bytes from `X-BUFFER` into the memory pointed to by `CUR-ADDRESS`.

`Defer From-Buffer \ --`
Move 128/1024 bytes from `X-BUFFER` into the memory pointed to by `CUR-ADDRESS`. `CUR-ADDRESS` is set up by `BIN-UP` and friends. The default action is `(FROM-BUFFER)`. You can modify the action to suit your own application.

`: TimedKey \ -- char|-1`
As `KEY` but returns -1 on timeout of 100 ms

`: Get-Block \ --`
Receive an XMODEM 128/1024 byte data block from the host, processing the header and checksum data.

`: (WaitResponse) \ --`
Wait for up to one second for a character.

`: SendReq \ --`
If Xmode is set, send a C character, otherwise send a NAK.

`0 value /RXms \ --`
Holds the transfer time in milliseconds.

`: Bin-Up \ addr len -- status ; status 0 = GOOD`
Upload (receive) a block of data of the given size into memory using the XMODEM 128/1024 byte block protocol. An error status is returned, 0 indicating success. On entry, the variable `CUR-ADDRESS` is set to *addr* on entry and `len` is rounded up to a 128/1024 byte unit. Note that an error return of $0105 indicates the the file being sent is larger than the *len* input parameter.

`: RecvXmodem \ addr len -- len' status ; status=0=good`
Upload (receive) a block of data of the given maximum size into memory using the XMODEM 128/1024 byte block protocol. The number of bytes correctly received and an error status are returned, 0 indicating success. See `BIN-UP` above for more details.

15.2.6 Defaults

If you have changed the operation of the buffer handling routines, you can restore them.

`: Xmodem-1k \ --`
Default to 1k byte Xmodem blocks with CRCs. This usually gives the fastest transfers and best error checking.

`: Xmodem-128 \ --`
Default to 128 byte Xmodem blocks with checksums. This works with virtually all terminal emulators.

`: XmodemDefaults \ --`
Set the XModem transfer routines to their default host copy operations.

15.3 Test code

`: (NullFrom) \ --`
Dummy for testing receive.

`: +NullRecv \ --`
Use the dummy receiver.

16 ROM PowerForth utilities

16.1 Introduction

Supplied as source in the ROMFORTH directory are utilities to:

- compile source code on your target board from the cross-compiler IDE
- upload a binary image from your target to your PC
- download a binary image to your target from your PC.

Note that the target source code supplied with cross compiler versions 6.02 onwards is incompatible with code supplied for previous versions of the cross compiler.

These utilities can be used to generate an image that has all the tools required to develop an application, or can be used during development to transfer modules to and from your PC. All the code is designed to be used with the MPE development environment, AIDE. The code will also work with other compatible terminal emulators.

Users who wish to distribute images containing the ROM PowerForth utilities should contact MPE for details of the OEM licence, which includes documentation on disc of the Forth kernel and the ROM PowerForth utilities.

16.2 Compiling text files

Source text files can be compiled from the host PC onto the target system. This saves time in not having to cross-compile the entire source if a small modification is made. The utilities permit text file to be split into pages for better layout when printed. An ASCII Form Feed character (decimal 12) separates one page from another.

16.2.1 The required files

To compile text files from your target board, cross-compile the files *IODEF.FTH* and *TEXTFILE.FTH*.

16.2.2 Compiling a specified text file

To compile all or part of a specified text file onto your target, use `INCLUDE` in the form:

```
INCLUDE <filename>
```

This compiles the file <filename> into the target's dictionary. AIDE's internal file server must be enabled (in the console window configuration), and will be triggered automatically.

16.3 Downloading a binary image

A binary image can be downloaded from the target to your host PC. Two utilities are provided:

- Intel hex download
- XMODEM download

For both utilities the cross-compiler IDE or a suitable communications package will be required.

16.3.1 XMODEM binary image download

Binary images can be downloaded to your PC using the XMODEM protocol.

Required files

To use this utility you must cross-compile the file *COMMON\XMODEMTXRX.FTH.*

Using the XMODEM binary download utility

To download a binary image from the target system to your PC, use `BIN-DOWN` in the form:

```
addr #bytes BIN-DOWN
```

where *addr] is the start address and *\i{#bytes* is the number of bytes to down-load starting from addr. For example,

```
1200 400 BIN-DOWN
```

sends the area of memory from 1200 to 1599 to your host PC. AIDE's internal file server must be enabled (in the console window configuration), and will be triggered.

16.3.2 Intel hex download

Binary images can be downloaded to your PC using the Intel hex format. Because this format only uses the standard printable character and CR/LF, the data can be captured by very simple tools.

Required files

To use this utility you must cross-compile the file *INTELHEX.FTH.*

Using the Hex download utility

To download a binary image from the target system to your PC, use `HEX-DOWN` in the form:

```
addr #bytes HEX-DOWN
```

where *addr* is the start address and *#bytes* is the number of bytes to down-load starting from addr. For example,

```
1200 400 HEX-DOWN
```

sends the area of memory from 1200 to 1599 to your host PC. In AIDE, turn on console logging to receive the file. In other packages this may be referred to as file capture.

16.4 ROM PowerForth

ROM PowerForth can be used to generate a stand-alone Forth system. With these utilities, you can generate an image that contains an interactive Forth with the ability to develop an application. Note: A licence is required to distribute open Forth systems. Contact MPE for more details.

16.4.1 Hardware requirements

To develop an application using ROM PowerForth, your board requires an area which:

- is always Flash
- is always RAM
- is RAM for development and Flash for application

16.4.2 Flash area

The area that is always Flash contains the development kernel.

16.4.3 RAM area

The area that is always RAM is used for variables and all changeable data.

16.4.4 RAM/Flash area

This area is used to develop your application. Therefore, it must be RAM while developing. Once your application is developed, the application's image must be saved into battery-backed RAM or Flash. Therefore, this area must have the ability to be alterable but also be non-volatile.

16.4.5 Types of board

The type of board that can be used to develop using ROM PowerForth is restricted to:

- three site boards
- two site boards with battery backed RAM
- two site boards with socket converter.

Three site boards

The three areas are provided by three memory sockets:

- Flash holding development kernel
- RAM which holds the variables and changeable data
- Flash or RAM which is selectable by a link on the board

Two site boards with battery backed RAM

The three areas are provided by two sockets:

- Flash holding the development kernel
- battery-backed RAM which is split into two areas.

Two site boards with socket converter

On many boards, there is unused space in the Flash as ROM PowerForth occupies less than

32k bytes of memory. A RAM image can be saved to Flash or external serial EEPROM and then restored at power up. Such code is device-specific and is *not* part of the generic ROM PowerForth.

16.4.6 Making your application turnkey

Once your application has been developed, it needs to be made turnkey so that it is always available. The application can be made semi-permanent by compiling into battery-backed RAM in the RAM/Flash area. Alternatively, it can be copied into Flash if the board allows.

Configuring a turnkey application

The word `SETUP` takes the address of the word passed to it and marks this in the RAM/Flash header as the address of the word to be run at power-up. If a value of zero is passed to *SETUP*, the interactive Forth kernel will be run at power up.

For example, the word `JOB` is to be run at power-up. Therefore you type,

```
' JOB SETUP
```

16.4.7 Discarding the application RAM area

The application can be discarded by typing:

```
0 ROM !
```

16.4.8 Changing the application RAM start address

The constant ROM returns the start address of the application RAM area. If the address of this area is to be changed, the Flash must be modified. To do this, the cell value in ROM must be changed.

16.4.9 AIDE file server protocols

AIDE's file server must be enabled for automatic file handling. Details of the protocols used should be obtained from this manual and the source code in the *COMMON\ROMFORTH* directory.

16.5 IODEF.FTH

The file *Common/ROMFORTH/IODEF.FTH* provides equates and protocol primitives for AIDE.

Before compiling this file, synonyms may need to be defined for `SER-EMIT`, `SER-KEY?` and `SER-KEY`. Add these in the control file before compiling *IODEF.FTH*.

16.5.1 AIDE support

```
variable disk-error     \ -- addr ; set non-zero on error
```

This variable is set true when a transfer error occurs.

```
: wait-ack      \ -- ; wait for ACK character
```

This word waits for the host to send an ACK at the end of part of a transfer. INTERNAL.

```
: wait-ack/nack \ -- t/f ; true for NACK
```

This waits for either a NACK or an ACK from the host and leaves true or false on stack. INTERNAL.

`: send-block#  \ n -- ; send block number to server`
Sends a single length number as two bytes 00-FF, low byte first. INTERNAL.

`: synch-to-host \ -- ; sync host to us`
Waits for a START (0x01) character, flushes the input, and sends an ACK. INTERNAL. INTERNAL.

16.6 Miscellaneous

`: cls  \ --`
Clear PowerTerm screen

16.7 Application Extensions

ROM PowerForth can be used to generate a stand-alone Forth system. With these utilities, you can generate an EPROM that contains an interactive Forth with the ability to develop an application. Note: A licence is required to distribute open Forth systems. Contact MPE for more details.

The code in *COMMON\ROMFORTH\LINK.FTH* provides the facilities to link the extension area into the ROM PowerForth kernel.

`appl-rom equ ROM  \ start of ROM/RAM area`
Define the address of a Flash/RAM area in which applications are to be developed. This area is RAM during development. When development is complete, the word `SETUP` is executed to initialise the memory area. The compiled image is then downloaded to the PC using the tools in the ROMFORTH directory. The image is then programmed into Flash, which can then replace the RAM. If the word `RELINK` is added to `COLD`, the application Flash will be automatically linked in when the target powers up.

`variable rp  EM rp !  \ top of RAM area`
If your processor has separate CODE and DATA address spaces, it has a HARVARD architecture. This word is only compiled for Harvard targets such as 8051s. The working RAM area has the interactive RAM dictionary at the bottom and the application buffer space at the top. Define the initial value of RP to be the highest available free location in the RAM area. Application variable and buffer space will then be allocated downwards from this address. When creating an application to be ROMmed, download the code for `BUFFER` and the redefined `VARIABLE` first of all.

`: setup  \ xt|0 -- ; sets up for ROM generation`
Use XT as the xt of the word to be run when the extension is found.

`: use-setup-data  \ --`
Apply the data in the setup area.

`: link-rom  \ --`
Link in the application ROM area.

`: link-ram  \ -- ; link in application RAM area`
Link in the application RAM area.

`: link-nv-ram  \ -- ; link in for NV-RAMs`
Link in the application NV-RAM area.

```
: relink        \ -- ; re-link application if there
```
Link in the application ROM/RAM/NV-RAM area.

16.8 INCLUDE source code from AIDE

The file *COMMON\ROMFORTH\TEXTFILE.FTH* provides support for compiling a source file from the AIDE server. It also provides some additional words to enhance compatibility between cross-compiled and directly compiled code.

16.8.1 INCLUDE and friends

```
: end-load      \ -- ; switch back to keyboard input
```
This word is automatically performed at the end of a download to tidy up the comms.

```
: file-error    \ n --
```
Handle an error when a file is being INCLUDEd.

```
: $include      \ $addr -- ; compile host file, counted string
```
Given a counted string for a file name, compile a file across the serial line from the AIDE file server. Use in the form:

```
  c" <filename>" $include
```

The filename extension must be supplied. The file name may include spaces.

```
: include       \ "<filename>" -- ; load file from host
```
Compile a file across the serial line from the AIDE file server. Use in the form:

```
  include <filename>
```

The filename extension must be supplied. The file name must not include spaces.

16.8.2 Making life easier

This section provides words that make your life easier when including files during development that will be cross compiled for production. You can always ask us to add some more if you really need them; otherwise you can add them yourself.

```
: ((             \ -- ; (( ... ))
```
Block comment operator. Any source following this is ignored upto and including the terminator, '))', which must be white space separated.

```
: const          \ x -- ; -- x
```
A synonym for CONSTANT.

```
: equ            \ x -- ; -- x
```
A synonym for CONSTANT.

```
: buffer:        \ len "name" -- ; -- addr
```
Reserve *len* bytes of space to form a named buffer. Only for targets compiling to RAM.

```
  len buffer: name
```

```
: wvariable      \ -- ; -- addr
```
A variable holding two bytes. Only in 32 bit targets. Only for targets compiling to RAM.

```
: cvariable      \ -- ; -- addr
```
A variable holding one byte. Only for targets compiling to RAM.

`: compiler ; immediate`
A cross-compiler directive treated as a `NOOP`. It may lead to redefinitions.

`: interpreter ; immediate`
A cross-compiler directive treated as a `NOOP`. It may lead to redefinitions.

`: target ; immediate`
A cross-compiler directive treated as a `NOOP`.

16.9 Simple source file loader

The code in *COMMON\ROMFORTH\FILETRAN.FTH* provides a simple source file loader which can be used with most terminal emulators. The download is controlled by XON/XOFF flow control. When using the PowerTerm terminal emulator in AIDE, use the `INCLUDE <filename>` system which supports nested files and needs no special termination.

Each file compiled must include a single line
`END-UP-LOAD`

at the end to reset the interpreter.

For slow 8 bit CPUs without queued serial input, the terminal server may need to include pacing delays after each character and an additional after CR/LF pairs.

`: Up-Load \ -- ; Load ASCII text`
Compile a file delivered by the terminal emulator. This word is intolerant of compilation errors.

`: End-Up-Load \ -- ; Finish Up-Loading`
Used on the target to restore the Forth interpreter after a file has been compiled.

16.10 Intel Hex transfers

The code in *COMMON\ROMFORTH\INTELHEX.FTH* provides a simple way to transfer binary images from ROM PowerForth to a host. The Intel Hex format is printable and can be captured (logged) by most terminal emulators including AIDE.

`: HEX-DOWN \ addr #bytes --`
Send *#bytes* at *addr* from ROM PowerForth to the host in Intel Hex format.

16.11 Block support

BLOCKS.FTH provides support for the transfer of 1k blocks between a host PC and the embedded target. Although the use of blocks as source screens is now obsolete, blocks are still useful for the transfer of binary data, especially for data loggers which use paged RAM or Flash for data storage. AIDE version 3 or above is required.

Despite the comment about the obsolescence of screens, the code in *BLOCKS.FTH* provides screen file support for legacy systems.

16.11.1 Primitives

`: BLK-READ \ addr blk# --`
Reads one block from host to addr.

```
: BLK-WRITE     \ addr blk# --
```
Sends given block number to host.

16.11.2 Application words

```
$400 equ /block                 \ -- size ; size of a block
```
The size of a block.

```
/first buffer: FIRST            \ -- addr ; first element is block no.
```
The data buffer. The first cell contains the block number and is followed by /BLOCK data bytes.

```
: SAVE-BUFFERS  \ --
```
Save the data buffer if it has been modified.

```
: EMPTY-BUFFERS \ --
```
Mark the data buffer as empty.

```
: UPDATE        \ --
```
Mark the data buffer as modified.

```
: FLUSH         \ --
```
Force a changed buffer to be uploaded to the host.

```
: BLOCK         \ u -- addr
```
Addr is the address of the first character of the block buffer assigned to mass-storage block u. An ambiguous condition exists if u is not an available block number. If block u is already in a block buffer, a-addr is the address of that block buffer. If block u is not already in memory and there is an unassigned block buffer, transfer block u from mass storage to an unassigned block buffer. Addr is the address of that block buffer. If block u is not already in memory and there are no unassigned block buffers, unassign a block buffer. If the block in that buffer has been UPDATEd, transfer the block to mass storage and transfer block u from mass storage into that buffer. Addr is the address of that block buffer. At the conclusion of the operation, the block buffer pointed to by addr is the current block buffer and is assigned to u.

16.11.3 Block file management

```
: -trailing     \ addr len -- addr len' ; strip trailing spaces
```
This word strips the trailing spaces from a string. It is most useful when displaying lines from a screen to strip the trailing spaces from the 64 byte fixed length lines.

```
: .LINE         \ line# blk# --
```
Display line# from blk#.

```
: ?LOADING      \ --
```
THROW #-501 if input from console.

```
: LIST          \ blk# -- ; display screen given
```
Display screen blk# as 16 lines of 64 characters.

```
: L             \ --
```
LIST the current screen in SCR.

```
: N             \ --
```
LIST the Next screen.

```
: P             \ --
```
LIST the Previous screen.

```
: Index         \ n1 n2 --
```
Display the top lines in the (inclusive) range of screens.

`: Qx \ --`
INDEX all available screens.

`: LOAD \ blk# -- ; compile given screen`
Save the current input-source specification. Store u in BLK (thus making block u the input source and setting the input buffer to encompass its contents), set >IN to zero, and interpret. When the parse area is exhausted, restore the prior input source specification. Other stack effects are due to the words LOADed.

`: THRU \ first last --`
LOAD screens from first to last in that order.

`: --> \ --`
LOAD the next screen.

`: $using \ $addr --`
Select the file specified by the counted string at $addr as the current block/screen file.

`: using \ "<file>" --`
Use in the form "USING <filename>" to select the current block/screen file. The AIDE file server is required. AIDE takes care of creating non-existent files.

16.12 Target BUFFER: and VARIABLE

The definitions below reorganise the use of RAM for ROM PowerForth applications which are themselves to be put in Flash.

The variable RP points to the top of available RAM, and is decremented by the amount of RAM required. The word `BUFFER:` allocates memory from this space, returning its base (low) address. Words such as `VARIABLE` can then be defined in terms of `BUFFER:`.

`: Buffer: \ n -- ; -- addr`
Return the address of an n byte buffer. Use in the form:

```
<size> BUFFER: <name>
```

`: variable \ -- ; -- addr ; replacement`
Create a new variable. Use in the form:

```
VARIABLE <name>
```

16.13 Some simple tools

The file *COMMON\ROMFORTH\TOOLS.FTH* provides some simple application tools.

The words `(#IN)` and `#IN` are provided to collect numbers from the keyboard in decimal. `(#IN)` is useful because it returns the number of digits converted so that 0 digits indicates that the user just pressed <Enter>, rather than entering a valid number of value 0.

`: (#in) \ -- n #chars`
Read a decimal number from the keyboard returning the number and the number of digits converted.

`: #in \ -- n`
Collect a decimal number from the keyboard.

17 Examples directory

The *EXAMPLES* directory contains much useful code, ranging from simple tools to fully documented extensions. The best way to use the *EXAMPLES* directory is to browse through the source code. If you want to modify the code, we recommend that you move it to become part of your own application directory structure.

17.1 Main directory

The following is a partial list of files.

`CALENDAR.FTH`
: A perpetual calendar by Christophe Lavarenne. A choice of calendars is provided.

`COSINE.FTH`
: Integer 14 bit cosine generation, suitable for 16 bit systems. Tested on an RTX2000.

`DALLAS.Z80`
: Driver for Dallas smart watch. Derived from source code provided by Gerry Coe of Devantech Electronics (good low cost boards) and modified by MPE.

`DEFINE.FTH`
: Provides an example of using defining words in both the cross compiler and the target.

`DOUBLES.HI`
: This file implements double and some quad precision number support using the primitives of PowerForth and high level definitions. To obtain better performance some definitions should be coded. These are indicated in the source code.

`FUZZY.FTH`
: A fuzzy logic implementation by Rick van Norman.

`HEXPAD.FTH`
: Keypad read routine for hex matrix keypad. The example was written for an 8051 port using four input bits and four output bits.

`MATH.FTH` Miscellaneous math functions.

`NetBoot.fth`
: Permits a bootloader to replace applications over a network.

`SerBoot.fth`
: Permits a bootloader to replace applications over a serial line.

`RC4.FTH` An implementation of the simple but very effective ARCFOUR (RC4 clone) encryption mechanism.

`SHA-1.FTH`
: An implementation of SHA-1 encryption process.

`SINCOS.FTH`
: Integer trig words from Kurt Heinz at Synics. These words provide a simple implementation of sine, cosine, and tangent functions.

`TESTCODE.FTH`
: A test harness for verifying the stack effect of of Forth words and phrases.

17.2 FATfiler subdirectory

Contains the FAT file system code and manual. The FAT file system supports FAT12, FAT16 and FAT32 devices with autodetection. It is ideal for use with CompactFlash, SD cards and USB memory sticks.

17.3 PowerFile subdirectory

Contains the PowerFile system code and manual. PowerFile is a Unix style file system.

17.4 PowerView subdirectory

Contains the PowerView embedded GUI code and manual.

17.5 USB subdirectory

Contains the USB system code and manual. Example hardware drivers, Virtual Serial Port (CDC/ACM), memory stick (MSC) and composite driver layers are provided. These have been tested with Windows XP/Vista, Linux and Mac OSX 10.4/5.

17.6 Drivers subdirectory

`29F0X0.FTH`
: 29F010/40 Driver code assuming a 16 bit bus using 2 devices.

`CANREAL.FTH`
: This file provides a set of words to act has a hardware abstraction layer for the i82527 drivers when using the physical device on the MPE H8 Board.

`I82527.FTH`
: i82527 CAN Controller Device Driver.

`DARTCTC.FTH`
: Serial i/o drivers for Z80/64180 + DART + CTC.

`KEYBRD.DRV`
: Code for 4x4 matrix keyboard connected via the MPE User Interface Card containing an 8255 PIA.

`LCD.DRV` Code for Hitachi LMG6400PLGR LCD Display. This will drive the Hitachi display connected via the MPE User Interface Card containing an 8255 PIA at base address defined in USERBRD.DRV.

`SCSI5380.FTH`
: SCSI interface words for RTX-2000 with a 5380 SCSI controller.

`SER2681.FTH`
: 2681 serial driver. This driver was written for a Cavendish Automation board

`SMC91C9X.FTH`
: SMC9192/94/96 Ethernet Driver Code.

`USERBRD.DRV`
: Code for MPE User Interface Board Setup for card containing an 8255 PIA at base address 0F000h. A glossary can be found in USERBRD.TXT

17.7 I2C subdirectory

`I2CLOAD.BLD`
: Build file for other I2C files.

`BCD.FTH` BCD to binary conversion and back

`I2CBASE.FTH`
: I2C primitives. This file requires an I2C bit-banging I/O driver to have been compiled.

`I2CNOTES.DOC`
: I2C documentation in Word format.

`DEVICES\8574DRV.FTH`
: Driver for an 8574.

`DEVICES\8583DRV.FTH`
: Driver for an 8583.

`DRIVERS\I2CVFXDRV.FTH`
: Bit banging parallel port driver for VFX Forth for Windows.

17.8 SPI subdirectory

`SPINOTES.DOC`
: SPI documentation in Word format.

`SPILOAD.BLD`
: Build file that pulls in other SPI files.

`PPDRV.FTH`
: PC printer port access for VFX Forth for Windows.

`SPIVFXDRV.FTH`
: SPI primitives for VFX Forth for Windows. Requires PPDRV.FTH.

`SPIBASE.FTH`
: SPI byte read and write primitives. A lower level driver is required.

`25LCDRV.FTH`
: Driver for a Microchip 25LC series SPI EEPROM.

17.9 Benchmarks subdirectory

This director contains several benchmarks used by MPE to test various Forth systems.

17.10 Contributions subdirectory

This directory contains code contributed by users for others to use, and MPE thanks the contributors.

The contents of this directory are untouched by MPE who provide no warranty at all on this code. Sorry about that.

`AD.FTH` 68HC11 A/D handler.

`CW.FTH` This program will display text in CW (Morse Code) upon either the system's console or the system's LEDs.

`DATES.FTH`
: Conversions between calendar date and Julian day number from ACM# 199. Forth Scientific Library Algorithm #22

`HIDEN.FTH`
: This code replaces REQUEST and SIGNAL in the MPE multitasker because they allow a task to lock a semaphore multiple times.

`IEEE.FTH`
: Converts between MPE software floating point format for 32 bit systems and IEEE 32 bit format.

`LANDER.FTH`
: Lunar Landing Simulation.

18 PowerView Embedded GUI system

The PowerView embedded GUI system in the *Examples\PowerView* directory is derived from several years work with industrial displays. The code is designed to be a reasonable compromise between code space, RAM space and facilities. It is not intended as a replacement for a desktop windowing system.

Drivers are provided for several CPU and LCD panel combinations:

- STM3240G-EVAL board wirh 16 bit colour panel: see *MB785_STM32F4.bld*.
- Sharp LH77790B ARM and QVGA mono panel: see *LH77790_x2.bld*.
- Nokia 6610 with Epson controller: limited support for Olimex LCD module on UEXT connector.

The supplied example code in this manual is for the MPE ARM Development Kit, which uses a Sharp LH77790B ARM with an on-chip LCD controller. To compile the code, set up the text macro *GuiDir* to point to the PowerView folder, and compile the following files:

```
include %GuiDir%\FontDefs             \ font structs and data
include %GuiDir%\Font\Font12x8x2      \ 12x8 font
include %GuiDir%\Font\Font16x12x2     \ 16x12 font
include %GuiDir%\Font\Font16x16x2     \ 16x16 font
include %GuiDir%\Drivers\LcdQvgaMono5 \ hardware specific driver
include %GuiDir%\GUI                  \ GUI kernel
include %GuiDir%\DemoMono2            \ GUI demo
```

18.1 Configuration

The configuration equates below are only used if they have not already been defined, e.g. in your control file.

`1 equ GUIdiags? \ -- n`
Set this non-zero to compile some diagnostics.

18.2 Tools

`: c+!          \ n c-addr --`
Add n to the byte at c-addr.

`: addchar      \ char string --`
Add the character to the end of the counted string.

`: append       \ c-addr u $dest --`
Add the string described by C-ADDR U to the counted string at $DEST. The strings must not overlap.

`: -leading     \ caddr len -- caddr' len'`
Ignore leading spaces.

`: split        \ addr len char -- laddr llen raddr rlen`
Extract a substring at the start of addr/len, returning the string remaining after char and the substring addr/sslen which does not include char. If the string does not contain the character, raddr is addr+len and rlen=0.

18.3 Unpacking rectangles

In the GUI system, much use is made of rectangles stored in `/Rect` structures.

```
struct /Rect    \ -- size
```

Rectangle structure.

```
  int r.x               \ x,y position
  int r.y
  int r.w               \ width
  int r.h               \ height
end-struct


: r>coords      \ rect -- x y w h
```

Return the coordinates of the given rectangle.

18.4 Buttons

```
: centred       \ rect len -- xleft ytop
```

Given the length of a string and a rectangle in which to display it, form the x/y start point at which the string should be displayed.

```
: button        \ caddr len rect --
```

Display a button - a rectangle with centred text.

```
: 3D-Button     \ caddr len rect --
```

Display a 3D effect button. This is achieved by varying the colour of the borders, and so is specific to the display hardware.

18.5 Text formatting

```
: nInter        \ c-addr u -- n
```

Gets number of interword spaces in a string by counting the number of spaces in the string.

```
#40 buffer: jText       \ -- addr
```

Temporary buffer that holds justified text.

```
: AddNext       \ caddr len -- caddr' len'
```

Extract the leftmost string (delimited by a space), and add it to the justified text buffer, returning the string to the right of the first space.

```
: AddSpaces     \ n --
```

Add n spaces to the justified text buffer.

```
: FindLine      \ caddr1 len1 n -- caddr2 len2
```

Return a line of maximum length n containing complete words of text.

```
: BuildJustified        \ caddr len w -- caddr' w
```

Build a justified line of text of size w in a buffer, and return the buffer address and length.

```
: ShowJLines    \ x y caddr len w --
```

Display a block of justified text starting at pixel position x,y in a width of w pixels. The text must contain single spaces as word separators. N.B. No word may be longer than *w/fontwidth-1* characters, otherwise the display may hang.

18.6 Drawing the GUI

The drawing routines for the GUI are all given the item's data structure.

`struct /GUIdef  \ -- len`
All elements of the GUI are controlled by this data structure which is usually built at compile time.

```
\ -- Chains
  int pNext             \ points to next child
  int pParent           \ points to parent
  int pChild            \ points to first child
\ -- Processing
  int idSel             \ user specified identifier
  int xtDraw            \ holds xt of routine that draws this
  int xtAction          \ holds xt of associated action, e.g. when pressed
\ -- Rectangle, text and font
  /Rect field Grect     \ holds X Y W H
  int ppFont            \ points to a pointer to the required font
  int pText             \ Points to counted string text for buttons etc
\ -- Type specific data
  0 field Gprivate      \ Item specific data follows.
\ MENU only
  int ppMenuFont        \ points to pointer to the font for the MENU
  4 -
end-struct
```

The following two words are compiled if the equate `GUIdiags?` is non-zero.

`: .GuiItem      \ item --`
Display the data structure for a GUI element.

`: .GuiChain     \ item --`
Display the chain of data structures for a compund GUI structure such as a menu.

`: SetItemFont   \ item -- font`
Return the current font and set the font for this item.

`: DrawButton    \ item --`
Draw a 3D button with centred text.

`: DrawCtext     \ item --`
Draw text centred in the rectangle.

`: DrawLtext     \ item --`
Draw text left justified in the rectangle.

`: DrawRtext     \ item --`
Draw text right justified in the rectangle.

`: DrawJText     \ item --`
Draw justified text in the rectangular area.

`: DrawBox       \ item --`
Draw a box (rectangle).

`: DrawTextBox   \ item --`

Draw a box filled with justified text.

`: DrawImage \ item --`
Display an image. The image data follows the item.

`: DrawPicture \ item --`
Display an image. The address of the image data follows the item.

`: DrawMenuFrame \ item --`
Draw the menu frame and caption.

`: DrawMenu \ item --`
Draw a menu and its first level children.

`Defer ActOnMenu \ id item --`
Perform the action specified by ID (usually a GUI item structure or an x,y pair from a touch screen) for the given menu. The default action is `2DROP`. Define your own action for this word. It should walk the menu chain, select which item if any that ID refers to, and execute the selected action word in the item data structure.

18.7 Defining a GUI

`variable LastItem \ -- addr`
Holds the address of the last item defined

`variable CurrItem \ -- addr`
Holds the address of the item being defined

`variable ParentItem \ -- addr`
Holds the address of the item's parent

`create Null$ 0 , \ -- addr`
A null string which may be used as a counted string or a zero-terminated string.
Please note that the following words are only available during cross-compilation. If you need them on the target, just make copies outside the `INTERPRETER ... TARGET` structure.

`: pNext, \ -- ; lay next pointer`
INTERPRETER: lay the pointer to the next item. The list is anchored at the parent's `pChild` field.

`: parent, \ -- ; lay pointer to parent`
INTERPRETER: Lay the pointer to the parent item.

`: child, \ -- ; lay pointer to children`
INTERPRETER: Lay a pointer to any children.

`: +ParX \ x -- x'`
INTERPRETER: Add the parent's x offset.

`: +ParY \ y -- y'`
INTERPRETER: Add the parent's Y offset.

`: ident, \ --`
Lay default user identifier.

`: Rect, \ x y w h -- ; lay rectangle`
INTERPRETER: Add the parent's x offset.

`: GuiDef, \ x y w h xt --`

INTERPRETER: Lay down the basic `/GuiDef` structure using the given rectangle data and the xt of the word that draws the item.

```
: text",        \ -- ; followed by delimited text
```

INTERPRETER: Lay down the following text string and set the `pText` field in the current item being defined.

18.8 GUI application words

These words are used to generate menus which can contain buttons, text, boxes and graphics. The menu is displayed by the word `DrawMenu ( menu -- )` and actions can be performed by the user-defined action of `ActOnMenu ( x menu -- )`.

With the exception of `MENU` the application words construct data structures without names. If you want to refer to a specific item, use

```
create <name>
```

before the item. The data structures are held in linked lists, so having additional code and data between items is permitted.

```
: MENU          \ x y w h "<name>" -- par last ; -- addr
```

INTERPRETER: Use in the form:

```
 x y w h MENU <name>
```

to start a `MENU ... END-MENU` definition. When data structure. The positions of the internal elements are relative to the top left hand corner of the menu. A title bar is generated only if a caption is defined (see below).

```
: CAPTION"      \ -- ; followed by delimited text
```

INTERPRETER: Use in the form:

```
 CAPTION" <text>"
```

to add a caption and title bar to a menu.

```
: MENUFONT      \ fonttable --
```

INTERPRETER: Use in the form:

```
 <fonttable> MENUFONT
```

to define the default font used by all items within a menu. If no font is set, the current font will be used.

```
: FONT          \ fonttable --
```

INTERPRETER: Use in the form:

```
 <fonttable> FONT
```

to define the font used by an item. The defined font will only apply to that item. If no font is set, the current font will be used.

INTERPRETER: Ends a `MENU ... END-MENU` definition.

```
: SetID         \ x --
```

Give the current item an identifier that can be used to select the item. This may be a character or any other unique identifier for this menu.

```
: BUTTON"       \ x y w h <"text"> --
```
INTERPRETER: Use in the form below to create a button:
```
 x y w h BUTTON" <text>"
```
```
: RUNS          \  -- ; name follows inline
```
INTERPRETER: Use in the form:
```
 RUNS <name>
```

to set the `xtAction` field of the item being defined.

```
: CTEXT"        \ x y w h <"text"> --
```
INTERPRETER: Use in the form:
```
 x y w h CTEXT" <text>"
```

to produce text centred in the given rectangle.

```
: LTEXT"        \ x y w h <"text"> --
```
INTERPRETER: Use in the form:
```
 x y w h LTEXT" <text>"
```

to produce text left justified in the given rectangle.

```
: RTEXT"        \ x y w h <"text"> --
```
INTERPRETER: Use in the form:
```
 x y w h RTEXT" <text>"
```

to produce text right justified in the given rectangle.

```
: BOX           \ x y w h --
```
INTERPRETER: Use in the form:
```
 x y w h BOX
```

to produce a rectangular outline.

```
: JTEXT"        \ x y w h <"text"> --
```
INTERPRETER: Use in the form:
```
 x y w h JTEXT" <lots of text on one source line>"
```

to produce fully justfied text that may spread over several lines. Note that there should be only one space between each word for best results.

```
: JTEXTBOX"     \ x y w h <"text"> --
```
INTERPRETER: Use in the form:
```
 x y w h JTEXTBOX" <lots of text on one source line>"
```

to produce a rectangular outline filled with justfied text. Like `JTEXT"` but with a box around it.

```
: GRAPHIC       \ x y w h --
```
INTERPRETER: Use in the form:

```
 x y w h GRAPHIC <filename>
```

to produce an image loaded with the top left hand corner at x,y. The width and height are at present unused. The image file is loaded into the dictionary at compile time.

```
: PICTURE       \ x y w h --
```
INTERPRETER: Use in the form:
```
 x y w h addr PICTURE
```

to produce an image loaded with the top left hand corner at x,y. The width and height are at present unused. The image data is at addr.

```
: Image:        \ -- ; -- addr
```
INTERPRETER: Create a dictionary entry and load a graphics file to the current section, e.g.
```
 Image: demo1 %GuiDir%\Pics\demo1.bin
```

The image can be displayed using code of the for:
```
 x y demo1 load-image
```

18.9 Image Conversion

Before use, images created on a PC must be converted to the format required by the particular LCD panel. The The conversion tools are now part of the AIDE compiler front-end.

Although it is possible to convert standard graphics formats "on the fly" for display, it usually requires considerably more image storage space, is usually slower, and requires a more complicated (larger and slower) image display routine. If your display system is running at 8 or 16 bits per pixel, and/or images are frequently changed, it may well be worthwhile to consider this approach.

18.9.1 AIDE

The tool in the AIDE front end is the current version. Source code for AIDE is available on request. In AIDE, select *Utilities -> BMP to LCD converter*. There are options to flip the image vertically, generate little or big-endian data, and to add the header needed by PowerView to display the image.

18.9.2 Legacy code

The older tool for the QVGA 2-bit mono is in the folder *Examples\PowerView\BMPcnv* folder, together with full source code to compile on VFX Forth for Windows.

When generating images for use with a 2 bit LCD panel, ensure that the image width is a multiple of four bits. Save the image as 4 bits per pixel grayscale if this is available, or as a 16-colour image, e.g. in MS Paint (file *mspaint.exe*} the selection of output file type is "16 Colour Bitmap".

BMPcnv.exe is a Windows-32 tool for converting 16 colour (4-bit) images to the four-level (2-bit) grayscale format required by the GiantPlus GPG3224TWE3 and equivalent panels for which we have provided a driver. It is assumed that the bitmap being converted is a .BMP file with a 4 bit Windows standard pallette (preferably grayscale) and has been flipped vertically prior to conversion. To convert a file:

- Run the application *bmpcnv.exe*.
- Either enter the file name in the "16bit Grey BMP File" box, or select the file using the "Browse" button.
- To preview the image use the "Preview" button
- Either enter the output file name in the "Output Binary" box, or select the file using the "Browse" button.
- Click the "Ok" Button

18.10 Using different hardware

If you are not using a panel with the same RAM layout as one of the supplied example drivers, or you are not using one of the example LCD controllers, you will have to modify the files:

`Fontxxxx.fth`
: contains the font used for text display.

`LCDxxxx.fth`
: contains the LCD driver and graphics primitives.

`GUI.fth` contains the high level code.

If your hardware requires an LCD layout that is not currently supported, you will need to add a new output format to AIDE's *BmpCnv* utility. Source code for AIDE is available on request. If the panel operates at 8 or 16 bits per pixel, you may find it more convenient to modify `LOAD-IMAGE` in the video driver to operate with BMP file images.

18.11 Example code

The example code in *PowerView\GUIdemo.fth* may be compiled as an example or to test changes you may have made.

```
2 equ GUIexamples?      \ -- n
```

Set this non-zero to compile some examples. If set greater than one, an example with several graphics images will be compiled. The full set of graphics requires 100+ kb of memory in the current `CDATA` section. This equate is only used if it has not already been defined, e.g. in your control file.
The following examples define two menus and their actions. The menu position is given in absolute pixel coordinates. The positions of the internal elements are relative to the top left hand corner of the menu. A title bar is generated only if a caption is defined.

18.11.1 Menu examples

```
: test1         ( -- )  cr ." ONE"  ;
: test2         ( -- )  cr ." TWO"  ;
: test3         ( -- )  cr ." THREE"  ;
: test4         ( -- )  cr ." FOUR"  ;

40 0 240 230 MENU MainMenu  Font16x12x2 MENUFONT
  CAPTION" MPE PowerView"  Font16x16x2 FONT
  40  36 160 32 BUTTON" Button 1"  RUNS test1
  40  76 160 32 BUTTON" Button 2"  RUNS test2
  40 116 160 32 BUTTON" Button 3"  RUNS test3
  40 156 160 32 BUTTON" Button 4"  RUNS test4
```

```
  0  196 240 32 CTEXT" Try me!"  Font16x16x2 FONT
END-MENU

0 0 320 240 MENU JustMenu
  CAPTION" MPE Embedded GUI"  Font16x12x2 FONT
    0  16 80 32 LTEXT" TLHC"  RUNS test1
  240  16 80 32 RTEXT" TRHC"  RUNS test2
    0 208 80 32 LTEXT" BLHC"  RUNS test3
  240 208 80 32 RTEXT" BRHC"  RUNS test4
create mpe
   88  24 160 80 GRAPHIC %GuiDir%\Pics\mpe.bin
   48 128 224 80 JTEXTBOX" This box is filled and justified with several lines of text"
END-MENU
```

`: tt  \ --`
Draw the menu `MainMenu`.

`: uu  \ --`
Draw the menu `JustMenu`.

18.11.2 Mixed text and graphics

The next example is of a slide presentation run as a separate task.

`: Image:  \ -- ; -- addr`
INTERPRETER: Create a dictionary entry and load a graphics file to the current section, e.g.
`Image: demo1 %GuiDir%\Pics\demo1.bin`

`: demo  \ -- ; graphics demo`
The action of the demonstration task.

`task DemoTask  \ -- addr`
Task that runs the demonstration.

`: StartDemo  \ --`
Start the demonstration task.

`: StopDemo  \ --`
Stop the demonstration task.

18.12 Example Monochrome LCD driver

The file *LcdQvgaMono5.fth* is a driver for a 320*240*2 bits monochrome QVGA panel for the Sharp LH77790B CPU with an on-chip LCD controller.

18.12.1 Low level driver

`variable Fcolor \ -- addr`
Holds the colour used for display - the foreground colour.

`variable Bcolor \ -- addr`
Holds the colour used for the background.

`variable TColor \ -- addr`
Holds the colour used for text. For displays that have more than one pixel per byte, `TColor` holds a cell-width colour mask.

`: setFColor \ colour --`
Set the foreground colour.

`: SetBColor \ colour --`
Set the background colour.

`: setTColor \ colour --`
Set the text drawing colour.

`: clear-lcd \ --`
Clear the LCD screen.

`: init-lcd \ --`
Initialise the LCD hardware. Performed at power-up.

`: PutPixel \ x y --`
Set the pixel to the current drawing (line) colour.

`: PutByte \ x y --`
Set a byte (4 pixels) to the current drawing (line) colour.

`: PutCell \ x y --`
Set a cell (16 pixels) to the current drawing (line) colour.

`: h-line \ x y len --`
Draw a horizontal line of length *len* pixels starting at *x,y*.

`: v-line \ x y len --`
Draw a vertical line of length *len* pixels starting at *x,y*.

`: absRect \ x y w h --`
Draw a rectangle at *x,y* with width and height *w,h*.

`: absFilledRect \ x y w h --`
Draw a filled rectangle at *x,y* with width and height *w,h*.

18.12.2 Font display

`: DrawChar \ char vbuff bytes/row --`
Draw the character at the given video buffer address or offset. The number of bytes or pixels per video row is also given. Note that `DrawChar` just calls the routine given in the current font table.

`: .fchar \ px py char --`
Write a character at the given pixel address, which is stepped to the nearest byte boundary.

`: sout \ px py caddr len --`
Write a string at the given pixel address, which is stepped to the nearest byte boundary.

18.12.3 Image handling

Before use, images created on a PC must be converted to the format required by the particular LCD panel. There are tools to do this in the *Tools\BMPcnv* folder.

`: load-image \ x y imageaddr --`
Display a graphics image in memory at imageaddr at pixel position x,y. If part of the image is off the screen, the displayed image is clipped to the screen size.

18.12.4 Font handling

Each font requires a word that draws a character from the font.

`[defined] Font12x8x2 [if]`
Words for a 12x8 font.

`: v@ \ addr -- 24bit`
COMPILER: Unaligned 16 bit fetch.

`: v! \ 24bit addr --`
COMPILER: Unaligned 16 bit store.

`: !fontrow \ 32b vaddr --`
Write one row/line of the font map into video memory

`: Draw12x8x2 \ char vbuff bytes/row --`
Write a character at the given video address, given the number of bytes per video row.

`[defined] Font16x12x2 [if]`
Words for a 16x12 font.

`: v@ \ addr -- 24bit`
COMPILER: Unaligned 24 bit fetch.

`: v! \ 24bit addr --`
COMPILER: Unaligned 24 bit store.

`: !fontrow \ 32b vaddr --`
Write one row/line of the font map into video memory

`: Draw16x12x2 \ char vbuff bytes/row --`
Write a character at the given video address, given the number of bytes per video row.

`[defined] Font16x16x2 [if]`
Words for a 16x16 font.

`: v@ \ addr -- 32bit`
COMPILER: Unaligned 32 bit fetch.

`: v! \ 32bit addr --`
COMPILER: Unaligned 32 bit store.

`: !fontrow \ 32b vaddr --`
Write one row/line of the font map into video memory

`: Draw16x16x2 \ char vbuff bytes/row --`
Write a character at the given video address, given the number of bytes per video row.

18.13 Font managment

The file *%GuiDir%\FontDefs.fth* contains the structure definition for font tables. It must be compiled before any font tables are compiled. Six example font table files are provided:

`Font12x8x1.fth`
: 12x8 font, 1 bit per pixel

`Font16x12x1.fth`
: 16x12 font, 1 bit per pixel

`Font16x16x1.fth`
: 16x16 font, 1 bit per pixel

`Font12x8x2.fth`
: 12x8 font, 2 bit gray scale

`Font16x12x2.fth`
: 16x12 font, 2 bit gray scale

`Font16x16x2.fth`
: 16x16 font, 2 bit gray scale

Each font table structure includes the xt of the word that draws a character into video RAM. In the example fonts, this word is in the font file after the table. The word must have the stack effect:

```
char vbuff bytes/row --
```

where **char** is the ASCII code of the character to be displayed, **vbuff** is the address of the first location in the video buffer and **bytes/row** is the number of bytes in each row of pixels in the video buffer. It is assumed that the rows are contiguous in video memory, that video RAM is byte addressable and that video rows are displayed horizontally. Characters are always set on byte boundaries. This means that for displays with more than one pixel per byte, character placement will be restricted in the X (horizontal) axis.

`struct /Font \ -- len`
The font table data structure

```
  int f.link            \ link to previous font
  int f.height          \ height of character in pixels
  int f.width           \ width of character in pixels
  int f.mwidth          \ width of character in bytes/row
  int f.first           \ ASCII code of first character
  int f.end             \ ASCII code of last+1 character
  int f.charsize        \ size of character in bytes
  int f.xtDrawChar      \ xt of character drawing routine
                        \ char vbuff bytes/row --
  0 field f.map         \ start of character table
end-struct


variable CurrFont       \ -- addr
```

Holds the current font.

`variable FontLink \ -- addr`
Anchor for list of fonts.

`: char>map \ char font -- map`
Convert a character number into the address of the bitmap in the current font table.

`: drawChar \ char sys --`
Draw the character at the given video buffer address or offset. The *sys* parameter(s) are implementation dependent. Note that `DrawChar` just calls the routine given in the current font table. See the hardware driver for the parameter details.

`: /fwidth \ -- pw`
Return the current character width in pixels.

```
: /fheight      \ -- ph
```
Return the current character height in pixels.

18.14 A basic font

The file *Fonts/Font16x12x2* contains a simple 16x12 font for use with 2 bit grayscale panels. It supports the standard ASCII characters with codes from 32 to 126. Each font requires a drawing word as defined by the `/Font` structure in FontDefs.fth.

```
struct /Font    \ -- len
```
The font table data structure from FontDefs.fth

```
  int f.link            \ link to previous font
  int f.height          \ height of character in pixels
  int f.width           \ width of character in pixels
  int f.mwidth          \ width of character in bytes/row
  int f.first           \ ASCII code of first character
  int f.end             \ ASCII code of last+1 character
  int f.charsize        \ size of character in bytes
  int f.xtDrawChar      \ xt of character drawing routine
                        \ char vbuff bytes/row --
  0 field f.map         \ start of character table
end-struct


create Font16x12x2      \ -- addr
```
Font table starting at char 32. Each character is defined as 16 24-bit items, each defining 12 bits as 2 bits per pixel for a 16x12 character.

19 Target test suites

19.1 MPE test harness

The code in the files *Common\TESTS\MPE\7-1-A.FTH* and *Common\TESTS\MPE\7-1-B.FTH* contains a test harness and tests respectively for MPE kernels. The files for previous v5 and v6 compilers are still present in the directory, but are no longer supported.

Test code may be cross-compiled or used interactively.

19.1.1 Target harness words

This section just describes the mechanics of the test harness. How to use it is covered in the next section.

```
variable Stack1          \ -- addr
```
Stack depth marker. Depth at entry to stack check.

```
variable Stack2          \ -- addr
```
Stack depth marker. Depth before entry of test word.

```
variable Stack3          \ -- addr
```
Stack depth marker. Depth after execution of test word.

```
variable Test-Line#      \ -- addr
```
Holds line number of word under test

```
variable Left-Loop       \ -- addr
```
Holds flag for early loop exit

```
: .decimal      ( n -- )        base @ swap  decimal .  base !  ;
```
Display in decimal.

```
: Check-Element \ element# -- t/f
```
Check a value on the output stack.

```
: Check-Stack   \ sentinel  --
```
Check stack for corruption.

19.1.2 Target testing words

A word is executed surrounded by formal stack definitions containing the test inputs and required outputs. A test is written in the form:

```
DS( inputs --) <WORD> (-- outputs )DS
```

for example:

```
ds( $05555 $0aaaa --) or (-- 0ffff )ds
```

Note that the input and output expressions can contain executable Forth as well as literals. You are not restricted to a single word under test: you can use a phrase.

```
: Ds(            \ -- sentinel
```
Start defining the input data.

```
: --)            \ .. -- ..
```

Finish defining the input data.

```
: (--           \ .. -- ..
```

Start defining the correct outputs.

```
: )Ds           \ ... --
```

Finish defining the correct outputs.

19.2 ANS tester by Jon Hayes

After the ANS Forth process, John Hayes at JHU/APL developed an ANS test suite. A version slightly modified by MPE for use with cross compilers can be found in *Common\Tests\ANS*. Cross compile *Tester.fth*, and then `INCLUDE` test files as required.

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