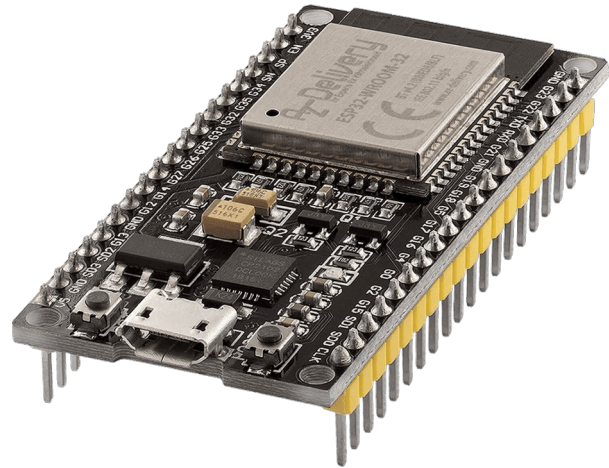


# Word Glossary for ESP32forth v7.0.7.3

**ESP32forth** is a powerful forth tool set created by **Bradley D Nelson** and the late **Dr. Hanson Ting** for the low cost ESP32 module. This document is a word glossary for reference whilst programming. There are also some useful links to reference material at the back.

The headings and words in the following tables are in alphabetic order to speed up searches. Most document readers will show a bookmark strip you can click on to jump to a particular section. Use ctrl F to search for a specific word. Immediate words (that run at compile time) are shown in **red**. The right-hand column indicates the ESP32forth vocabulary in which the word is located.

There are plenty of gaps and probably a few errors. Any contributions welcome via the [Forth2020 forum](#) on Facebook



*ESP32 is a series of low-cost, low-power system on a chip microcontrollers with integrated Wi-Fi and dual-mode Bluetooth. The ESP32 series employs either a Tensilica Xtensa LX6 microprocessor in both dual-core and single-core variations, Xtensa LX7 dual-core microprocessor or a single-core RISC-V microprocessor and includes built-in antenna switches, RF balun, power amplifier, low-noise receive amplifier, filters, and power-management modules.*

## ANSI terminal control

<b>at-xy</b>	( x y - )		forth
<b>bel</b>	( - )	Sound the terminal bell	ansi
<b>bg</b>	( n - )		forth
<b>clear-to-eol</b>	( - )	Clear the line from the cursor position to the right margin	ansi
<b>esc</b>	( - )	sends the esc char to the terminal - many ANSI terminal commands start with the esc character	ansi
<b>fg</b>	( n - )		forth
<b>hide</b>	( - )	Hide the cursor	ansi
<b>normal</b>	( - )		forth
<b>page</b>	( - )		forth
<b>scroll-down</b>	( - )	Scroll the cursor down one line	ansi

<b>scroll-up</b>	( - )	Scroll the cursor up one line	ansi
<b>set-title</b>	( a n - )		forth
<b>show</b>	( - )	Make the cursor visible	ansi
<b>terminal-restore</b>	( - )	Scroll the terminal back down, restoring the terminal to the state when terminal-save was executed	ansi
<b>terminal-save</b>	( - )	Scroll the present terminal up off the screen, leaving a blank screen	ansi

## Block File System

<b>block</b>	( n -- a )	Get a 1024 character block	forth
<b>block-fid</b>	( - n )	value, default = -1	forth
<b>block-id</b>	( -- n )	value, default = -1	forth
<b>buffer</b>	( n -- a )	Get a 1024 byte block without regard to old contents	forth
<b>copy</b>	( from to -- )	Copy contents of block 'from' to block 'to'	forth
<b>default-use</b>		deferred word, defaults to common-default-use	forth
<b>empty-buffers</b>	( -- )	Empty all buffers	forth
<b>flush</b>	( -- )	Save and empty all buffers	forth
<b>list</b>	( n -- )	List block n of 1024 characters to the display	forth
<b>load</b>	( n -- )	Evaluate block n of 1024 characters as the input stream	forth
<b>open-blocks</b>	( a n -- )	Open a file as the block file	forth
<b>save-buffers</b>	( -- )	Save all buffers	forth
<b>scr</b>	( -- adr )	Pointer to last listed block	forth
<b>thru</b>	( a b -- )	Load blocks a thru b	forth
<b>update</b>	( -- )	Mark the last block modified	forth
<b>use</b>	( "name" -- )	Use "name" as the blockfile, e.g. USE /spiffs/foo	forth

## Block File Editor

<b>a</b>	( n "text" -- )	Add (insert) a line in the current block with the words that follow in the input stream, terminated with <cr>	editor
<b>d</b>	( n -- )	Delete a line in the current block	editor
<b>e</b>	( n -- )	Clear a line in the current block	editor
<b>l</b>	( - )	List the current 1024 character block	editor
<b>n</b>	( - )	Move to the next 1024 character block	editor

<b>p</b>	( – )	Move to the previous 1024 character block	editor
<b>r</b>	( n "text" -- )	Replace a line in the current block with the words that follow in the input stream, terminated with <cr>	editor
<b>wipe</b>	( -- )	Erase the 1024 character block	editor
<b>editor</b>	( -- )	vocabulary name of the block file editor	forth

## Branching

<b>[ELSE]</b>	( – )	Interpret time ELSE *	forth
<b>[IF]</b>	( f – )	Interpret time IF ( conditional interpretation of words that follow, dependent on flag f ) *	forth
<b>[THEN]</b>	( – )	Interpret time THEN *	forth
<b>aft</b>	( -- )	: aft-example ( n -- ) for <words that run only 1st iteration> aft <words that run for all but the 1st iteration> then <words that run on all iterations> next ;	forth
<b>ahead</b>	( -- )	continue execution after then e.g. : myword333 ahead 222 444 then ; running myword would leave 333 on the stack	forth
<b>DEFINED?</b>	( "name" -- xt   0 )	If the name that follows in the input stream is found in the dictionary, the execution address of the word is placed on the stack, else 0 if not found e.g. DEFINED? CREATE returns 1073637288. DEFINED? BABA returns 0	forth
<b>else</b>	( – )	part of a conditional structure e.g. if <forth words> else <more forth words> then e.g. if <forth words> then	forth
<b>if</b>	( flag – )	Conditional structure, which executes depends on flag e.g. if <forth words> else <more forth words> then e.g. if <forth words> then	forth
<b>then</b>	( -- )	part of a conditional structure e.g. if <forth words> else <more forth words> then e.g. if <forth words> then	forth

\* [IF] [ELSE] [THEN] are limited to appearing on the same line only – not multiline

### CASE code

The CASE structure is missing in ESP32forth, but is easily added if required

```
internals
: case 0 ; immediate
```

```

: of [ ] over , [ ] = , [ ] 0branch , here 0 , [ ] drop , ; immediate
: endof [ ] branch , here 0 , swap here swap ! ; immediate
: endcase [ ] drop , begin ?dup while here swap ! repeat ; immediate

```

example:

```

: test      ( n -- )
  case
    0 of ." zero" endof
    1 of ." one" endof
    2 of ." two" endof
    ." many"
  endcase ;

```

\ this code runs if none of the cases are met

**[IF] [THEN] example**      ( n1 n2 -- )      Demonstrates creating words with no names, which can nevertheless be executed by execution token - saves space in the dictionary if the word is never used by name

\ Place this at the top of a forth source file

```

DEFINED? *codename* [IF] forget *codename* [THEN]
: *codename* ;

```

\ the string \*codename\* can be anything unique to suit the code file being loaded  
 \ if that word is already defined, then the compiled words are forgotten from the  
 \ dictionary before being recompiled

## Camera

<b>camera-server</b>	( -- )		forth
<b>s-&gt;set_xclk</b>	( s time xclk )		camera
<b>s-&gt;set_pll</b>	( s bypass mul sys root pre seld5 pclk pclk )		camera
<b>s-&gt;set_res_raw</b>	( s startX startY endX endY offsetX offsetY totalX totalY outputX outputY scale binning )		camera
<b>s-&gt;set_reg</b>	( s reg mask value )		camera
<b>s-&gt;get_reg</b>	( s reg mask )		camera
<b>s-&gt;set_lenc</b>	( s enable )		camera
<b>s-&gt;set_raw_gma</b>	( s enable )		camera
<b>s-&gt;set_ae_level</b>	( s level )		camera
<b>s-&gt;set_wb_mode</b>	( s mode )		camera
<b>s-&gt;set_special_effect</b>	( s effect )		camera
<b>s-&gt;set_aec_value</b>	( s gain )		camera

<b>s-&gt;set_agc_gain</b>	( s gain )		camera
<b>s-&gt;set_awb_gain</b>	( s enable )		camera
<b>s-&gt;set_aec2</b>	( s enable )		camera
<b>s-&gt;set_vflip</b>	( s enable )		camera
<b>s-&gt;set_hmirror</b>	( s enable )		camera
<b>s-&gt;set_exposure_ctrl</b>	( s enable )		camera
<b>s-&gt;set_gain_ctrl</b>	( s enable )		camera
<b>s-&gt;set_whitebal</b>	( s enable )		camera
<b>s-&gt;set_colorbar</b>	( s enable )		camera
<b>s-&gt;set_quality</b>	( s quality )		camera
<b>s-&gt;set_gainceiling</b>	( s gainceil )		camera
<b>s-&gt;set_denoise</b>	( s level )		camera
<b>s-&gt;set_sharpness</b>	( s level )		camera
<b>s-&gt;set_saturation</b>	( s level )		camera
<b>s-&gt;set_brightness</b>	( s level )		camera
<b>s-&gt;set_contrast</b>	( s level )		camera
<b>s-&gt;set_framesize</b>	( s framesize )		camera
<b>s-&gt;set_pixformat</b>	( s pixformat )		camera
<b>s-&gt;reset</b>	( s )		camera
<b>s-&gt;init_status</b>	( s )		camera
<b>s-&gt;xclk_freq_hz</b>	( a )		camera
<b>fb-&gt;usec</b>			camera
<b>fb-&gt;sec</b>			camera
<b>fb-&gt;format</b>			camera
<b>fb-&gt;height</b>			camera
<b>fb-&gt;width</b>			camera
<b>fb-&gt;len</b>			camera
<b>fb-&gt;buf</b>			camera
<b>field@</b>	( n -- n )		camera
<b>camera-format</b>		constant	camera
<b>camera-frame-size</b>		constant	camera
<b>camera-jpeg-quality</b>		constant	camera
<b>camera-fb-count</b>		constant	camera
<b>camera-config</b>			camera
<b>FRAMESIZE_UXGA</b>	( – 13 )	constant	camera

<b>FRAMESIZE_SXGA</b>	( – 12 )	constant	camera
<b>FRAMESIZE_HD</b>	( – 11 )	constant	camera
<b>FRAMESIZE_XGA</b>	( – 10 )	constant	camera
<b>FRAMESIZE_SVGA</b>	( – 9 )	constant	camera
<b>FRAMESIZE_VGA</b>	( – 8 )	constant	camera
<b>FRAMESIZE_HVGA</b>	( – 7 )	constant	camera
<b>FRAMESIZE_CIF</b>	( – 6 )	constant	camera
<b>FRAMESIZE_QVGA</b>	( – 5 )	constant	camera
<b>FRAMESIZE_240x240</b>	( – 4 )	constant	camera
<b>FRAMESIZE_HQVGA</b>	( – 3 )	constant	camera
<b>FRAMESIZE_QCIF</b>	( – 2 )	constant	camera
<b>FRAMESIZE_QQVGA</b>	( – 1 )	constant	camera
<b>FRAMESIZE_96x96</b>	( – 0 )	constant	camera
<b>PIXFORMAT_RGB555</b>	( – 7 )	constant	camera
<b>PIXFORMAT_RGB444</b>	( – 6 )	constant	camera
<b>PIXFORMAT_RAW</b>	( – 5 )	constant	camera
<b>PIXFORMAT_RGB888</b>	( – 4 )	constant	camera
<b>PIXFORMAT_JPEG</b>	( – 3 )	constant	camera
<b>PIXFORMAT_GRAYSCALE</b>	( – 2 )	constant	camera
<b>PIXFORMAT_YUV422</b>	( – 1 )	constant	camera
<b>PIXFORMAT_RGB565</b>	( – 0 )	constant	camera

## Character I/O

<b>#tib</b>	( -- addr )	variable, holds number of chars currently in buffer tib	forth
<b>&gt;in</b>	( -- addr )	variable, holds number of chars currently in tib	forth
<b>."</b>	( "string" – )	display the string that follows in the input stream until a terminating "	forth
<b>accept</b>	( b u1 -- u2 )	accepts u1 characters to buffer b. u2 returned is the actual count of characters received. Terminates when cr entered or u1 chars received. Supports delete for input correction	forth
<b>bl</b>	( -- 32 )	returns the value of the SPACE char	forth
<b>char</b>	( "character" -- c )	Convert the non-space char that follows in the input stream and place it's value to e.g. char 0 places 48	forth

		on top of the stack	
<b>cr</b>	( -- )	send carriage return, line feed to the display	forth
<b>emit</b>	( c – )	display the ascii character c	forth
<b>key</b>	( – chr )	deferred word - reads the next character in the input stream - defaults to word serial-key	forth
<b>key?</b>	( -- cnt )	deferred word - returns cnt, the number of characters waiting to be read. cnt=0 if no characters waiting - defaults to word serial-key?	forth
<b>nl</b>	( -- 10 )	the value of the NEWLINE character	forth
<b>ok</b>	( -- )	display the string ok	forth
<b>page</b>	( -- )	Emit 30 CR characters to the display	forth
<b>PARSE</b>	( c "wordtoparse" -- addr cnt )	Parse the next word in the input stream, terminating on character c. Leave the address and character count cnt of word.If the parse area was empty then cnt=0	forth
<b>prompt</b>		send ok and <cr> to the display	forth
<b>space</b>	( -- )	Emit a space character to the display	forth
<b>tib</b>	( -- addr )	returns the address of the the terminal input buffer where input text string is held	forth
<b>type</b>	( addr n -- )	deferred word - display an n long character string, located at addr, on the display - as a default executes serial-type	forth
<b>ip.</b>	( n -- )	print n in IP address format e.g. 192.168.1.2	web-interface
<b>ip#</b>	( n1 -- n2 )	print one section of an ip address	web-interface

## Comment

<b>(</b>	( "string"-- )	Start of a 1 line comment, terminated with ). Most often used to document the stack effect of word	forth
<b>\</b>		Start of a 1 line comment, no termination needed	forth

## Comparison

<b>&lt;</b>	( n1 n2 -- f )	f=true of n1 less than n2, else f=false	forth
<b>&lt;=</b>	( n1 n2 -- f )	f=true if n1 less than or equal n2, else f=false	forth
<b>&lt;&gt;</b>	( n1 n2 -- f )	f=true if n1 not equal n2, else f=false	forth
<b>=</b>	( n1 n2 -- f )	f=true if n1 equals n2, else f=false	forth

<b>&gt;</b>	( n1 n2 -- f )	f=true if n1 greater than n2, else f=false	forth
<b>&gt;=</b>	( n1 n2 -- f )	f=true if n1 greater than or equal n2, else f=false	forth
<b>0&lt;</b>	( n -- f )	f=true if n less than zero, else f=false	forth
<b>0&lt;&gt;</b>	( n -- f )	f=true if n not equal zero, else f=false	forth
<b>0=</b>	( n -- f )	f=true if n equals zero, else f=false	forth

## Debug

<b>.s</b>	( - )	display the data stack depth and data stack on one line of the display	forth
<b>dump</b>	( addr n - )	display memory starting at addr, for n longs	forth
<b>see</b>	( "text" -- )	Attempt to decompile the word which follows in the input stream	forth
<b>vlist</b>	( -- )	List the words in the context vocabulary (not chains) e.g. vlist WiFi only lists words in the Wifi vocabulary	forth
<b>words</b>	( -- )	List the words in the context vocabulary (including chains)	forth

### See – example

Define a word:- `: demo 1 2 3 + . cr cr ;`

'see demo' will show a decompiled view of the word to check for errors `: demo 1 2 3 + . cr cr ;`

## Dictionary

<b>&gt;body</b>	( xt -- addr )	addr is the data-field address corresponding to execution token xt	forth
<b>&gt;flags</b>	( xt -- flags )	returns the flags of the word corresponding to execution token xt:- 1 if an immediate word 0 if a normal high level word 8 if a normal assembly language word	forth
<b>&gt;flags&amp;</b>			
<b>&gt;link</b>	( xt -- addr )	addr is the link-field address corresponding to execution token xt	forth
<b>&gt;link&amp;</b>	( xt -- addr )	used internally by >link	forth
<b>&gt;name</b>	( xt -- addr n   0 )	convert execution token xt to a name located at addr with n characters, else return 0 if not possible	forth



<b>&gt;params</b>			
<b>&gt;size</b>			
<b>FIND</b>	( addr n -- xt   0 )	using the counted string at addr with n characters, look a word up in the current dictionary stack, returning the execution token xt if found, else 0	forth
<b>forget</b>	( "name" -- )	find the word that follows in the input stream; if it exists in the current dictionary, remove it and all words that followed it from the dictionary and the corresponding compiled code	forth
<b>here</b>	( -- addr )	returns the address of the first free location above the code dictionary, where new words are compiled	forth
<b>transfer</b>	( "name" -- )	Move a word from its current dictionary to the current vocabulary. Useful for "hiding" helper words that aren't useful in normal programming	forth
<b>transfer{</b>	( -- )	Move all the words that follow in the input stream up until a terminating } to the current vocabulary. All the words must have been defined beforehand	forth

## Exceptions

<b>assert</b>	( f -- )	if flag f=true, execute throw	forth
<b>catch</b>	( xt -- err#   0 )	CATCH is very similar to EXECUTE except that it saves the stack pointers before EXECUTEing the guarded word at xt, removes the saved pointers afterwards, and returns a flag indicating whether or not the guarded word completed normally. 0=normal	forth
<b>handler</b>	( -- addr )	holds the return stack pointer for error handling - zero if no error occurred.	forth
<b>throw</b>	( err# -- )	For any non-zero err#, throws the system back to CATCH so that the error condition can be processed. CATCH is backtracked by restoring the return stack from the pointer stored in 'handler' and popping the old handler and SP off the error frame on the return stack. So - 0 THROW does nothing	forth

See [Appendix 3](#) for an explanation of catch and throw.

# Files

<b>BIN</b>	( fam1 -- fam2 )	Modify the implementation-defined file access method fam1 to additionally select a "binary", i.e., not line oriented, file access method, giving access method fam2.	forth
<b>CLOSE-FILE</b>	( fh -- ior ) ior= Input Output Result	Close the file identified by fileid. ior is the implementation-defined I/O result code.	forth
<b>CREATE-FILE</b>	( c-addr u fam -- fileid ior )	Create the file named in the character string specified by c-addr and u, and open it with file access method fam. The meaning of values of fam is implementation defined. If a file with the same name already exists, recreate it as an empty file.	forth
<b>DELETE-FILE</b>	( c-addr u -- ior )	Delete the file named in the character string specified by c-addr u. ior is the implementation-defined I/O result code.	forth
<b>dump-file</b>	( a1 n1 a2 n2 -- )	a1,n1 text string to be saved in file: a2,n2 text string containing filename. Dump-file saves text to the spiffs using filename	forth
<b>FILE-POSITION</b>	( fileid -- ud ior )	ud is the current file position for the file identified by fileid. ior is the implementation-defined I/O result code. ud is undefined if ior is non-zero.	forth
<b>FILE-SIZE</b>	( fileid -- ud ior )	ud is the size, in characters, of the file identified by fileid. ior is the implementation-defined I/O result code. This operation does not affect the value returned by FILE- POSITION. ud is undefined if ior is non-zero.	forth
<b>FLUSH-FILE</b>	( fileid -- ior )	Attempt to force any buffered information written to the file referred to by fileid to be written to mass storage, and the size information for the file to be recorded in the storage directory if changed. If the operation is successful, ior is zero. Otherwise, it is an implementation-defined I/O result code.	forth
<b>include</b>	( "name" -- )	Using the next word in the input stream, name ...	forth
<b>included</b>	( c-addr u -- )	Remove c-addr u from the stack. Save the current input source specification, including the current value of SOURCE-ID. Open the file specified by c-addr u, store the resulting fileid in SOURCE-ID, and make it the input source. Store zero in BLK. Other stack effects are due to the words included. Typical use: ... S" filename" INCLUDED	forth
<b>needs</b>	( "name" -- )		forth

<b>OPEN-FILE</b>	( a n mode -- fh ior )	Open the file named in the character string specified by c-addr u, with file access method indicated by fam. The meaning of values of fam is implementation defined. If the file is successfully opened, ior is zero, fileid is its identifier, and the file has been positioned to the start of the file. Otherwise, ior is the implementation-defined I/O result code and fileid is undefined. Typical use: : X ... S" TEST.FTH" R/W OPEN-FILE ABORT" OPEN-FILE FAILED" ... ;	forth
<b>R/O</b>	( -- mode )	read only mode - used with OPEN-FILE	forth
<b>R/W</b>	( -- mode )	read write mode - used with OPEN-FILE	forth
<b>READ-FILE</b>	( c-addr u1 fileid -- u2 ior )	Read u1 consecutive characters to c-addr from the current position of the file identified by fileid. If u1 characters are read without an exception, ior is zero and u2 is equal to u1. If the end of the file is reached before u1 characters are read, ior is zero and u2 is the number of characters actually read. If the operation is initiated when the value returned by FILE-POSITION is equal to the value returned by FILE-SIZE for the file identified by fileid, ior is zero and u2 is zero. If an exception occurs, ior is the implementation-defined I/O result code, and u2 is the number of characters transferred to c-addr without an exception.	forth
<b>remember</b>	( -- )	Save a snapshot to the default file (./myforth or /spiffs/myforth on ESP32)	forth
<b>RENAME-FILE</b>			forth
<b>REPOSITION-FILE</b>	( n fh -- ior ) ( ud fileid -- ior )	Reposition the file identified by fileid to ud. ior is the implementation-defined I/O result code. An ambiguous condition exists if the file is positioned outside the file boundaries. At the conclusion of the operation, FILE-POSITION returns the value ud.	forth
<b>required</b>	( a n – )		forth
<b>RESET</b>	( -- )	Delete the default filename.	forth
<b>RESIZE-FILE</b>	( ud fileid -- ior )	Set the size of the file identified by fileid to ud. ior is the implementation-defined I/O result code. If the resultant file is larger than the file before the operation, the portion of the file added as a result of the operation might not have been written.	forth

		At the conclusion of the operation, FILE-SIZE returns the value ud and FILE- POSITION returns an unspecified value.	
<b>restore</b>	( "name" -- )	Restore a snapshot from a file	forth
<b>revive</b>	( -- )	Restore the default filename	forth
<b>save</b>	( "name" -- )	Saves a snapshot of the current dictionary to a file	forth
<b>startup:</b>	( "name" -- )	Save a snapshot to the default file arranging for "name" to be run on startup	forth
<b>W/O</b>	( -- mode )	write only mode - used with OPEN-FILE	forth
<b>WRITE-FILE</b>	( c-addr u fileid -- ior )	Write u characters from c-addr to the file identified by fileid starting at its current position. ior is the implementation-defined I/O result code. At the conclusion of the operation, FILE- POSITION returns the next file position after the last character written to the file, and FILE-SIZE returns a value greater than or equal to the value returned by FILE-POSITION.	forth

**Autoexec.fs example** ( -- ) Demonstrates how to load source code automatically on switch on and run the program

```
r| z" NETWORK-NAME" z" PASSWORD" webui | \ create a string to start the web server
s" /spiffs/autoexec.fs" dump-file \ save it to file autoexec.fs
```

**startup: example** ( -- ) snapshotting the dictionary and restoring it at startup, with a start word which exits to forth (alternatively it could be a complete application which never exits)

```
: welcome ." Hello!" cr 100 0 do i . loop cr ;
startup: welcome
bye ( Next boot will run a custom startup message )

reset ( Reset removes the custom message )
```

# Floating Point Maths

Single precision floating-point support is available as a work in progress.

While initially left out in the name of minimalism, hardware support for floating-point argues some advantages to limited support.

Floating point numbers, denoted *r* below, are kept on a separate floating point stack.

**NOTE: Tasks currently don't support floating point. A single floating point stack is shared by all tasks.**

<b>1/F</b>	( r1 -- r2 )	$r2 = 1/r1$	forth
<b>AFLITERAL</b>	( r -- )	Compile <i>r</i> inline	forth
<b>DOFLIT</b>	( -- )	Puts a float from the next cell onto float stack	forth
<b>F-</b>	( r1 r2 -- r3 )	$r3 = r1 - r2$	forth
<b>F.</b>	( n-- )	Display, with a trailing space, the top number on the floating-point stack using fixed-point notation:	forth
<b>F.S</b>	( -- )	Print float stack	forth
<b>F*</b>	( r1 r2 -- r3 )	$r3 = r1 * r2$	forth
<b>F**</b>	( r1 r2 -- r3 )	$r3 = r1$ to the power $r2$	
<b>F/</b>	( r1 r2 -- r3 )	$r3 = r1 / r2$	forth
<b>F+</b>	( r1 r2 -- r3 )	$r3 = r1 + r2$	forth
<b>F&lt;</b>	( r1 r2 -- flag )	flag = true if $r1 < r2$	forth
<b>F&lt;=</b>	( r1 r2 -- r3 )	flag = true if $r1 \leq r2$	forth
<b>F&lt;&gt;</b>	( r1 r2 -- r3 )	flag = true if $r1 \neq r2$	forth
<b>F=</b>	( r1 r2 -- r3 )	flag = true if $r1 == r2$	forth
<b>F&gt;</b>	( r1 r2 -- r3 )	flag = true if $r1 > r2$	forth
<b>F&gt;=</b>	( r1 r2 -- r3 )	flag = true if $r1 \geq r2$	forth
<b>F&gt;S</b>	( r -- n )	$n$ = integer part of <i>r</i> (no rounding)	forth
<b>F0&lt;</b>	( r -- f )	flag=true if <i>r</i> less than 0	forth
<b>F0=</b>	( r -- f )	flag-true if $r == 0$	forth
<b>FABS</b>	( r1 – r2 )	$r2$ = absolute value of $r1$	forth
<b>FATAN2</b>	( r1 – r2 )	$r2 = \text{atan}(r1)$	forth
<b>FCONSTANT</b>	( r "name" )	creates a floating point constant	forth
<b>FCOS</b>	( r1 – r2 )	$r2 = \cos(r1)$	forth
<b>FDROP</b>	( r -- )	drop $r1$ from the floating point stack	forth

<b>FDUP</b>	( r -- r r )	duplicate the top of floating point stack	forth
<b>FEXP</b>	( r1 – r2 )	$r2 = \exp(r1)$	forth
<b>FLITERAL</b>	( r -- )	Compile r inline	forth
<b>FLN</b>	( r1 – r2 )	$r2 = \ln(r1)$	forth
<b>FLOOR</b>	( r1 – r2 )	$r2 = \text{floor}(r1)$	forth
<b>FMAX</b>	( r1 r2 – r3 )	R3 = the larger of r1 or r2	forth
<b>FMIN</b>	( r1 r2 – r3 )	R3 = the smaller of r1 or r2	forth
<b>FNEGATE</b>	( r1 – -r1 )	Negate r1	forth
<b>FNIP</b>	( ra rb -- rb )	Remove the 2 <sup>nd</sup> item on the floating stack	forth
<b>FOVER</b>	( ra rb -- ra rb ra )	Copy the 2 <sup>nd</sup> item on the floating stack to the top	forth
<b>FP!</b>	( a -- )		forth
<b>FP@</b>	( -- a )		forth
<b>FROT</b>			forth
<b>FSIN</b>	( r1 – r2 )	$r2 = \sin(r1)$	forth
<b>FSINCOS</b>	( r1 – r2 r3 )	$r2 = \sin(r1)$ , $r3 = \cos(r1)$	forth
<b>FSQRT</b>	( r r -- r )		forth
<b>FSWAP</b>	( ra rb -- rb ra )		forth
<b>FVARIABLE</b>	( "name" )	<i>create a floating point variable</i>	forth
<b>PI</b>	( -- r )		forth
<b>precision</b>	( – 6 )	value – default = 6	forth
<b>set-precision</b>	( n – )	set the value of precision to n	forth
<b>S&gt;F</b>	( n -- r )		forth
<b>SF,</b>	( r -- )		forth
<b>SF!</b>	( r a -- )	single precision store	forth
<b>SF@</b>	( a -- r )	single precision load	forth
<b>SFLOAT</b>	( -- 4 )		forth
<b>SFLOAT+</b>	( a -- a+4 )		forth
<b>SFLOATS</b>	( n -- n*4 )		forth

# HTTPD

<b>notfound-response</b>	( -- )		httpd
<b>bad-response</b>	( -- )		httpd
<b>ok-response</b>	( mime\$ -- )		httpd
<b>response</b>	( mime\$ result\$ status -- )		httpd
<b>send</b>	( a n -- )		httpd
<b>path</b>	( -- a n )		httpd
<b>method</b>	( -- a n )		httpd
<b>hasHeader</b>	( a n -- f )		httpd
<b>handleClient</b>			httpd
<b>read-headers</b>			httpd
<b>completed?</b>	( -- f )		httpd
<b>body</b>	( -- a n )		httpd
<b>content-length</b>	( -- n )		httpd
<b>header</b>	( a n -- a n )		httpd
<b>crnl=</b>	( n -- f )		httpd
<b>eat</b>	( n ch -- n a n )		httpd
<b>skipover</b>	( n ch -- n )		httpd
<b>skipto</b>	( n ch -- n )		httpd
<b>in@&lt;&gt;</b>	( n ch -- f )		httpd
<b>end&lt;</b>	( n -- f )		httpd
<b>goal#</b>	( – a )	variable	httpd
<b>goal</b>	( – a )	variable	httpd
<b>strcase=</b>	( a n a n -- f )		httpd
<b>upper</b>	( ch -- ch )		httpd
<b>server</b>	( port -- )		httpd
<b>client-cr</b>	( – )		httpd
<b>client-emit</b>	( ch -- )		httpd
<b>client-read</b>	( -- n )		httpd

<b>client-type</b>	( a n -- )		httpd
<b>client-len</b>	( – a )	variable	httpd
<b>client</b>	( – a )	sockaddr	httpd
<b>httpd-port</b>	( – a )	sockaddr	httpd
<b>clientfd</b>	( – n )	value, default = -1	httpd
<b>sockfd</b>	( – n )	value, default = -1	httpd
<b>body-read</b>	( – n )	value, default = 0	httpd
<b>body-1st-read</b>	( – n )	value, default = 0	httpd
<b>body-chunk</b>	( – a )	block of allotted data, body-chunk-size bytes long	httpd
<b>body-chunk-size</b>	( – 256 )	constant	httpd
<b>chunk-filled</b>	( – n )	value, default = 0	httpd
<b>chunk</b>	( – a )	block of allotted data, chunk-size bytes long	httpd
<b>chunk-size</b>	( – 2048 )	constant	httpd
<b>max-connections</b>	( – 1 )	constant	httpd



# Input / Output

<b>adc</b>	( pin# -- n )	alias for analogRead	forth
<b>analogRead</b>	( pin -- n )	Analog read from 0-4095	forth
<b>dacWrite</b>	( pin 0-255 -- )	Write to DAC (pin 25, 26)	forth
<b>digitalRead</b>	( pin -- value )	Read GPIO state	forth
<b>digitalWrite</b>	( pin value -- )	Set GPIO pin state	forth
<b>pin</b>	( value pin# -- )	Set GPIO pin value e.g. HIGH 3 pin LOW 3 pin	forth
<b>pinMode</b>	( pin mode -- )	Set GPIO pin mode e.g. 14 input pinMode \ set pin 14 as input	forth
<b>pulseIn</b>	( pin value usec -- usec/0 )	Wait for a pulse	forth
<b>tone</b>	( channel freq )	Write tone frequency	Forth

**PIN example** ( -- ) Demonstrates toggling GPIO23 at max rate using the PIN word

```
: maxtoggle
  23 output pinMode
  begin
    HIGH 23 pin
    LOW 23 pin
  key? Until ;
```

A scope showed that the pin remained high for 625nS or so. It was low for around 2.6uS because of the key? function slowing things up. So a reasonable speed, all considered

**Read digital input example** ( gpiono -- ) Continuously display the state of a digital input until a key is pressed

```
: test ( gpiono -- )
  DUP INPUT pinMode \ set 'gpiono' as an input
  begin
    DUP digitalRead . cr \ display the state of 'gpiono'
  key? until \ until a key is pressed
  DROP ; \ stack tidy
```

**Analogue input example** ( -- ) Demonstrates reading the voltage present on GPIO14 for 128 samples at 10 samples / s

```
100 value del \ this value determines the data sample rate
: delay del ms ; \ time delay used to pace reading samples
: read ( -- )
  128 0 do \ Read 128 the input 128 times
    14 ADC . CR \ Read the voltage on GPIO14
    DELAY \ And pause for 100 mS between each sample
  loop
;
```

# Interrupts

<a href="#">timer_isr_register</a>	( group timer xt arg ret -- 0/err )		forth
<a href="#">esp_intr_alloc</a>	( source flags xt args handle* -- 0/err )		interrupts
<a href="#">ESP_INTR_FLAG_DEFAULT</a>	( -- 0 )	Default handler allows per pin routing	interrupts
<a href="#">ESP_INTR_FLAG_EDGE</a>	( -- 512 )	gpio_install_isr_service flag	interrupts
<a href="#">ESP_INTR_FLAG_INTRDISABLED</a>	( -- 2048 )	gpio_install_isr_service flag	interrupts
<a href="#">ESP_INTR_FLAG_IRAM</a>	( -- 1024 )	gpio_install_isr_service flag	interrupts
<a href="#">ESP_INTR_FLAG_LEVELn</a>	( n1 -- n2 )	n2 = 2 to the power n1, gpio_install_isr_service	interrupts
<a href="#">ESP_INTR_FLAG_NMI</a>	( -- 128 )	gpio_install_isr_service flag	interrupts
<a href="#">ESP_INTR_FLAG_SHARED</a>	( -- 256 )	gpio_install_isr_service flag	interrupts
<a href="#">esp_intr_alloc</a>			interrupts
<a href="#">esp_intr_free</a>	( handle -- 0/err )		interrupts
<a href="#">gpio_config</a>	( gpio_config _t* -- 0/err )	GPIO common configuration. Configure GPIO's Mode,pull-up,PullDown,IntrType from a GPIO configure structure gpio_config_t	interrupts
<a href="#">gpio_deep_sleep_hold_dis</a>	( -- )	Disable all digital gpio pad hold function during Deep-sleep	interrupts
<a href="#">gpio_deep_sleep_hold_en</a>	( -- )	Enable all digital gpio pad hold function during Deep-sleep. When the chip is in Deep-sleep mode, all digital gpio will hold the state before sleep, and when the chip is woken up, the status of digital gpio will not be held. Note that the pad hold feature only works when the chip is in Deep-sleep mode, when not in sleep mode, the digital gpio state can be changed even you have called this function. Power down or call gpio_hold_dis will disable this function, otherwise, the digital gpio hold feature works as long as the chip enter Deep-sleep	interrupts

<b>gpio_get_drive_capability</b>	( pin cap* -- 0/err )		interrupts
<b>gpio_get_level</b>	( pin -- level )	GPIO get input level of 'pin'	interrupts
<b>gpio_hold_dis</b>	( pin -- 0/err )		interrupts
<b>gpio_hold_en</b>	( pin -- 0/err )		interrupts
<b>gpio_install_isr_service</b>	( a -- )	a = combination of gpio_install_isr_service flags - Install the driver's GPIO ISR handler service, which allows per-pin GPIO interrupt handlers	interrupts
<b>#GPIO_INTR_ANYEDGE</b>	( -- 3 )	constant - set interrupt for either +ve or -ve edge e.g. 2 #GPIO_INTR_ANYEDGE gpio_set_intr_type	interrupts
<b>#GPIO_INTR_DISABLE</b>	( -- 0 )	constant - disable interrupt e.g. 2 #GPIO_INTR_DISABLE gpio_set_intr_type	interrupts
<b>gpio_intr_disable</b>	( pin -- 0/err )	Disable GPIO module interrupt signal for 'pin'	interrupts
<b>gpio_intr_enable</b>	( pin -- 0/err )	Enable GPIO module interrupt signal for 'pin'	interrupts
<b>#GPIO_INTR_HIGH_LEVEL</b>	( -- 5 )	constant - e.g. 2 #GPIO_INTR_HIGH_LEVEL gpio_set_intr_type	interrupts
<b>#GPIO_INTR_LOW_LEVEL</b>	( -- 4 )	constant - e.g. 2 #GPIO_INTR_LOW_LEVEL gpio_set_intr_type	interrupts
<b>#GPIO_INTR_NEGEDGE</b>	( -- 2 )	constant - set interrupt on -ve edge e.g. 2 #GPIO_INTR_NEGEDGE gpio_set_intr_type	interrupts
<b>#GPIO_INTR_POSEDGE</b>	( -- 1 )	constant - set interrupt on +ve edge e.g. 2 #GPIO_INTR_POSEDGE gpio_set_intr_type	interrupts
<b>gpio_isr_handler_add</b>	pin xt 0 -- 0/err )	Having already set up the interrupt type, attach a new entry to the interrupt list, so that when the entry fires, the execution token 'xt' is called. If adding this entry was successful return true, else return an error code e.g. 2 ' myinterrupthandlerword 0 gpio_isr_handler_add	interrupts
<b>gpio_isr_handler_remove</b>	( pin -- 0/err )	Remove ISR handler for the corresponding GPIO pin	interrupts
<b>gpio_pulldown_dis</b>	( pin -- 0/err )	Disable pull down load on 'pin'	interrupts
<b>gpio_pulldown_en</b>	( pin -- 0/err )	Enable pull down load on 'pin'	interrupts
<b>gpio_pullup_dis</b>	( pin -- 0/err )	Disable pull up load on 'pin'	interrupts
<b>gpio_pullup_en</b>	( pin -- 0/err )	Enable pull up load on 'pin'	interrupts
<b>gpio_reset_pin</b>	( pin -- 0/err )	Reset a gpio to default state (select gpio	interrupts

		function, enable pullup and disable input and output)	
<a href="#">gpio_set_direction</a>	( pin mode -- 0/err )	Set gpio signal direction of 'pin'	interrupts
<a href="#">gpio_set_drive_capability</a>	( pin cap -- 0/err )	Set GPIO pad 'pin' drive capability or strength 'cap'	interrupts
<a href="#">gpio_set_intr_type</a>	( pin type -- 0/err )	Set the required i/o pin to the interrupt type, returning true if successful, else an error code	interrupts
<a href="#">gpio_set_level</a>	( pin level -- 0/err )	GPIO set the output level pf 'pin' =1 or 0	interrupts
<a href="#">gpio_set_pull_mode</a>	( pin mode -- 0/err )	Configure GPIO 'pin' pull-up/pull-down resistors by means of 'mode'. GPIO 34-39 don't have this facility	interrupts
<a href="#">gpio_uninstall_isr_service</a>	( -- )	Uninstall the driver's GPIO ISR service, freeing related resources	interrupts
<a href="#">gpio_wakeup_disable</a>	( pin -- 0/err )	Disable GPIO wake-up function on 'pin'	interrupts
<a href="#">gpio_wakeup_enable</a>	( pin type -- 0/err )	Enable GPIO wake-up function on 'pin' - only type #GPIO_INTR_LOW_LEVEL or #GPIO_INTR_HIGH_LEVEL can be used	interrupts
<a href="#">pinchange</a>	( xt pin -- )	Call xt when pin changes e.g. 17 input pinMode : test ." pinvalue: " 17 digitalRead . cr ; ' test 17 pinchange	interrupts

### Sense a digital input change using interrupt

( -- )

When the 'boot' button is pressed or released, that change of state is reported on the display

interrupts

0 input pinmode

\ set GPIO0 as an input

: input. ( -- )

\ display the state of GPIO0

." GPIO0 input ="

0 digitalRead . cr

;

: pinanyedge ( xt pin -- )

\ add an ANYEDGE interrupt handler

dup GPIO\_INTR\_ANYEDGE gpio\_set\_intr\_type throw

swap 0 gpio\_isr\_handler\_add throw

;

' input. 0 pinanyedge ( -- )

\ If GPIO0 changes state, report it

: disableinterrupt ( pin -- )

GPIO\_INTR\_DISABLE gpio\_set\_intr\_type throw

;

0 disableinterrupt

\ stop reporting GPIO0 changes

\ This is just a demo - generally you want an interrupt to be as brief as possible

\ so printing from an interrupt routine is not recommended for real programs

## LED control – pulse width modulation

<b>duty</b>	( channel duty -- )	like ledcWrite, with bounds check and scaling i.e. : duty 255 min 8191 255 */ ledcWrite ;	forth
<b>freq</b>	( channel freq -- )	like ledcSetup, with scaling i.e. : freq ( n n -- ) 1000 * 13 ledcSetup drop ;	forth
<b>ledcAttachPin</b>	( pin channel -- )	Assigns which 'channel' (0-15) of the PWM engine the 'pin' is connected to	ledc
<b>ledcDetachPin</b>	( pin -- )	Detaches #pin' from the pwm engine	ledc
<b>ledcRead</b>	( channel -- n )	Read the current dutycycle setting for 'channel'	ledc
<b>ledcReadFreq</b>	( channel -- freq )	Get frequency (x 1,000,000)	ledc
<b>ledcSetup</b>	( channel freq resolution -- freq )	Setup one of the 16 pwm channels (0-15) at frequency=freq*1000 Hz with 'resolution'	ledc
<b>ledcWrite</b>	( channel duty -- )	Set 'channel' (0-15) at 'duty' level (0-100)	ledc
<b>ledcWriteNote</b>	( channel note octave -- freq )	channel 0-12, octave 0-8, note 0-12 (note is as per the western musical scale)	ledc
<b>ledcWriteTone</b>	( channel freq -- n )	Write tone frequency (x 1000) e.g. 23 0 ledcAttachPin \ attach GPIO23 to channel 0 0 1000000 ledc WriteTone drop \ o/p 1kHz tine	ledc

## Logic

<b>AND</b>	( n1 n2 – n3 )	n3 = n1 AND n2 (bit wise)	forth
<b>ARSHIFT</b>	( n1 – n1/2 )	Arithmetic right shift	
<b>invert</b>			forth
<b>LSHIFT</b>	( x1 u -- x2 )	Perform a logical left shift of u bit-places on x1, giving x2. Put zeroes into the least significant bits vacated by the shift. An ambiguous	forth

		condition exists if u is greater than or equal to the number of bits in a cell.	
<b>OR</b>	( n1 n2 -- n3 )	n3 = n1 OR n2 ( bit-wise )	forth
<b>RSHIFT</b>	( x1 u -- x2 )	Perform a logical right shift of u bit-places on x1, giving x2. Put zeroes into the most significant bits vacated by the shift. An ambiguous condition exists if u is greater than or equal to the number of bits in a cell.	forth
<b>XOR</b>	( n1 n2 -- n3 )	n3 = n1 XOR n2 ( bit-wise)	forth

## Looping

<b>?do</b>	( n1 n2 -- )	e.g. : test ?do i . loop ; if n1 = n2, then inside ?do .. loop is NOT executed if n1 <> n2, it behaves like do .. loop	forth
<b>+loop</b>	( n -- )	e.g. : +looptest 20 0 do i . 2 +loop ; results when run in 0 2 4 6 8 10 12 14 16 18 being displayed	forth
<b>again</b>	( -- )	begin <forth words> again	forth
<b>begin</b>	( -- )	begin <forth words> until	forth
<b>do</b>	( n1 n2 -- )	: test 10 4 do i . loop ; produces 4 5 6 7 8 9 on the display	forth
<b>EXIT</b>	( -- )	Return control to the calling definition. Before executing EXIT within a do-loop, a program shall discard the loop-control parameters by executing 'unloop'	forth
<b>for</b>	( n -- )	: test 10 for i . next ; produces 10 9 8 7 6 5 4 3 2 1 0 on display n.b. n will make the for loop run n+1 times by design	forth
<b>i</b>	( -- n )	Place current loop index on top of stack	forth
<b>j</b>	( -- n )	Place index count for next outer loop top of stack	forth
<b>leave</b>	( -- )	Force do loop termination	forth
<b>loop</b>	( -- )	part of do <forth words> loop construct	forth
<b>next</b>	( -- )	part of for <forth words> next construct	forth
<b>repeat</b>	( -- )	part of begin <forth words that leave f on the stack> while < more forth words> repeat	forth
<b>unloop</b>	( -- )	Discard the loop-control parameters for the	forth

		current nesting level e.g. Typical use: : unlooptest <limit> <first> DO ... test IF ... UNLOOP EXIT THEN ... LOOP ... ;	
<b>until</b>	( f -- )	begin <forth words that leave f on stack> until	forth
<b>while</b>	( f -- )	part of begin <forth words that leave f on the stack> while < more forth words> repeat	forth

### unloop example

Demonstrates a loop being terminated before  
completion by UNLOOP

```
: test
1000 0 do
key? if
  key drop
  cr ." loop terminating "
  unloop
  exit
then
cr ." loopcount = " i .
500 ms
loop
;
```

```
\ start a 1000 long loop
\ if a key was pressed
\ read the key and drop it

\ get rid of the loop
\ return to the calling word

\ show us the loop count
\ loop every 1/2 s
```

# Maths

-	( n1 n2 -- n3 )	$n3 = n1 - n2$	forth
*	( n1 n2 -- n3 )	$n3 = n1 * n2$	forth
*/	( n1 n2 n3 -- n4 )	Multiply n1 by n2 producing the intermediate double-cell result d. Divide d by n3 giving the single-cell quotient n4	forth
*/MOD	( n1 n2 n3 -- n4 n5 )	Multiply n1 by n2 producing the intermediate double-cell result d. Divide d by n3 producing the single-cell remainder n4 and the single-cell quotient n5	forth
/	( n1 n2 -- n3 )	Divide n1 by n2, giving the single-cell quotient n3	forth
/mod	( n1 n2 -- n3 n4 )	Divide n1 by n2, giving the single-cell remainder n3 and the single-cell quotient n4	forth
+	( n1 n2 -- n3 )	$n3 = n1 + n1$	forth
2*	( n1 -- n2 )	$n2 = n1 * 2$	forth
2/	( n1 -- n2 )	$n2 = n1 / 2$	forth
4*	( n1 -- n2 )	$n2 = n1 * 4$	forth
4/	( n1 -- n2 )	$n2 = n1 / 4$	forth
abs	( n1 -- n2 )	n2 is the absolute value of n1	forth
max	( n1 n2 -- n3 )	$n3 = \text{the larger of } n1 \text{ or } n2$	forth
min	( n1 n2 -- n3 )	$n3 = \text{the smaller of } n1 \text{ or } n2$	forth
mod	( n1 n2 -- n3 )	Divide n1 by n2, giving the single-cell remainder n3	forth
negate	( n -- -n )	Two's complement of top of stack	forth
U/MOD	( u1 u2 -- rem quot )	Unsigned division, leaving remainder and quotient	forth
1+	( n-- n+1 )	increment value on the stack by 1	forth
1-	( n-- n1- )	decrement value on the stack by 1	forth



# Memory

ESP32forth stores numbers in little-endian format (the LS byte of the number is place at the lowest address in memory) unless noted otherwise (e.g. in ‘sockets’)

<b>!</b>	( n addr --> )	store x at addr	forth
<b>@</b>	( addr --n )	Retrieves the integer value n stored at address addr	forth
<b>+</b>	( n addr -- )	Increments the content of a variable by the value n	forth
<b>+to</b>	( n "valuenam" -- )	Adds n to the value whose name follows in the input stream e.g. 2 value myvalue \ define a value called myvalue = 2 3 +to myvalue \ myvalue now equals 5	forth
<b>to</b>	( n -- )	Change a value e.g. 10 value myvalue \ set up myvalue = 10 5 to myvalue \ myvalue now returns 5	forth
<b>2!</b>	( n1 n2 addr --> )	store n1, n2 as a 64 bit value at addr	forth
<b>2@</b>	( addr --n1 n2 )	read n1, n2 as a 64 bit value from addr	forth
<b>C!</b>	( c addr --> )	store byte c at addr	forth
<b>C@</b>	( addr --c )	read byte c from addr	forth
<b>allocate</b>	( n -- a ior )	reserve a memory chunk of n bytes, returns the start address, ior=true if successful, else false - see also free and resize	forth
<b>blank</b>	( addr n – )	Fill block starting at addr for n bytes with \$20	
<b>cell/</b>	( n1 -- n2 )	$n2 = n1 / 4$	forth
<b>cell+</b>	( n1 -- n2 )	$n2 = n1 + 4$	forth
<b>cells</b>	( n – n*4 )	Conversion, cells to bytes	forth
<b>cmove</b>	( addr1 addr2 n -- )	move n bytes from addr1 to addr2, starting at addr1 and proceeding toward high memory	forth
<b>cmove&gt;</b>	( addr1 addr2 n -- )	copy n bytes from memory starting at c-addr1 to that starting at c-addr2, proceeding from higher addresses to lower addresses	forth
<b>erase</b>	( addr n – )	Fill block starting at addr for n bytes with \$00	forth
<b>fill</b>	( addr n c )	fill memory from addr for n bytes with byte c	forth
<b>free</b>	( a -- )	free memory previously reserved allocate - see also resize	forth
<b>L!</b>	( n addr -- )	write n to addr in real ESP32 memory space	forth

<b>resize</b>	( a n -- a ior )	ior=true if a memory chunk reserved with MALLOC resized to n bytes correctly, else ior=false - see also allocate and free. The high-address end is adjusted. When increasing the size, all data is preserved. High end-data is not initialised. When decreasing the size, high-end address data may be lost	forth
<b>SL@</b>	( addr --n )	read signed long n from real ESP32 memory space	forth
<b>SW@</b>	( addr -- sw )	Read signed word from real ESP32 memory space	forth
<b>UL@</b>	( addr --u )	read unsigned long u from real ESP32 memory space	forth
<b>UW@</b>	( addr -- uw )	Read unsigned word uw from real ESP32 memory space	forth
<b>W!</b>	( w addr -- )	Store word w at address addr	forth

## Number I/O

<b>?</b>	( addr -- )	display value at addr	forth
<b>.</b>	( n -- )	display top of stack	forth
<b>#</b>	( ud1 -- ud2 )	Convert next digit of ud1 and HOLD it	forth
<b>#&gt;</b>	( ud -- addr n )	Drop ud and prepare string for TYPE	forth
<b>#s</b>	( ud -- 0 0 )	Convert and HOLD all remaining significant digits	forth
<b>&lt;#</b>	( -- )	Begin a formatted number conversion	forth
<b>base</b>	( -- addr )	Stores the current number display base - defaults to 10 decimal	forth
<b>binary</b>	( -- )	Set current number base to 2 decimal	forth
<b>decimal</b>	( -- )	Set current number base to 10 decimal	forth
<b>extract</b>	( n base -- n c )	extracts the least significant digit from a number n. n is divided by the radix in BASE and returned on the stack	forth
<b>hex</b>	( -- )	Set current number base to 16 decimal	forth
<b>hold</b>	( c -- )	Insert character into formatted string	forth
<b>n.</b>	( n -- )	display n in decimal, regardless of current number base	forth
<b>octal</b>	( -- )	Set current number base to 8 decimal	forth

<b>pad</b>	( -- addr )	returns the address of the text buffer where numbers are constructed and text strings are stored temporarily	forth
<b>sign</b>	( n ud -- ud )	HOLD minus sign only if n is negative	forth
<b>u.</b>	( n -- )	display n in the current number base	forth
<b>f.</b>	( r -- )		forth

## OLED display

To include the following words requires a change to the source code:-

<b>#define</b> <b>ENABLE_OLED_SUPPORT</b>	#define ENABLE_OLED_SUPPORT to activate the lib.
<b># include &lt;Adafruit_GFX.h&gt;</b>	install in your system the Adafruit libraries
<b># include &lt;Adafruit_SSD1306.h&gt;</b>	install in your system the Adafruit libraries

<b>OledInit</b>	( -- )	initialize the display to accept commands	oled
<b>OledDelete</b>	( n -- a )		oled
<b>OledBegin</b>	( n -- a )	initialization	oled
<b>OledHOME</b>	( n -- a )	send cursor to upper left home position	oled
<b>OledCLS</b>	( n -- a )	clears the display	oled
<b>OledTextc</b>	( n -- a )		oled
<b>OledPrintln</b>	( n -- a )	print a zero= null terminated string from the stack	oled
<b>OledNumln</b>	( n -- a )	print + CR a number on the stack (int)	oled
<b>OledNum</b>	( n -- )	print a number on the stack (int)	oled
<b>OledDisplay</b>	( -- )	show the buffer on the OLED display	oled
<b>OO</b>	( n -- a )	is an abbreviation of Oleddisplay	oled
<b>OledPrint</b>	( z" " addr -- )	print a zero= null terminated string from the stack	oled
<b>OledInvert</b>	( -- )	invert the background & foreground colors	oled
<b>OledTextsize</b>	( n -- )		oled
<b>OledSetCursor</b>	( n -- )		oled
<b>OledPixel</b>	( x y C -- )	draw a pixel x y coordinates C= Color , f.e.use 1	oled
<b>OledDrawL</b>	( x y x2 y2 1 -- )	draw a line x y x2 y2 coordinates C= Color , f.e. 1	oled
<b>OledCirc</b>	( x y r 1 -- )	draw a circle	oled

<b>OledCircF</b>	( x y r 1 -- )	draw a circle filled	oled
<b>OledRect</b>	( x y x2 y2 1 -- )	draw a rectangle	oled
<b>OledRectF</b>	( x y x2 y2 1 -- )	draw a rectangle filled	oled
<b>OledRectR</b>	( x y x2 y2 1 -- )	draw a rectangle rounded edges	oled
<b>OledRectRF</b>	( n -- a )	draw a rectangle rounded edges filled	oled
<b>OledAddr</b>	( n -- a )	address of I2C device	oled
<b>OledNew</b>	( n -- a )		oled

**OLED example** ( – ) *Demonstrates how to talk to the OLED 128x64 pixels*

```
Oled
OLEDINIT          \ initialise display / greeting message
123 Olednum Oleddisplay \ print the number top of stack
Oledhome oledcls OO  \ home the cursor, clear the screen
1 1 35 35 1 Oledrect OO \ draw rectangle
Oledinvert OO        \ invert the display
```

## Registers

<b>m!</b>			registers
<b>m@</b>			registers

## RMT Remote Control Transceiver

<b>rmt_set_clk_div</b>	( channel div8 -- err )		RMT
<b>rmt_get_clk_div</b>	( channel @div8 -- err )		RMT
<b>rmt_set_rx_idle_thresh</b>	( channel thresh16 -- err )		RMT
<b>rmt_get_rx_idle_thresh</b>	( channel @thresh16 -- err )		RMT
<b>rmt_set_mem_block_num</b>	( channel memnum8 -- err )		RMT
<b>rmt_get_mem_block_num</b>	( channel @memnum8		RMT

	-- err )		
<a href="#">rmt_set_tx_carrier</a>	( channel enable highlev lowlev carrierlev -- err )		RMT
<a href="#">rmt_set_mem_pd</a>	( channel f -- err )		RMT
<a href="#">rmt_get_mem_pd</a>	( channel @f -- err )		RMT
<a href="#">rmt_tx_start</a>	( channel f -- err )		RMT
<a href="#">rmt_tx_stop</a>	( channel -- err )		RMT
<a href="#">rmt_rx_start</a>	( channel f -- err )		RMT
<a href="#">rmt_rx_stop</a>	( channel -- err )		RMT
<a href="#">rmt_tx_memory_res et</a>	( channel -- err )		RMT
<a href="#">rmt_rx_memory_res et</a>	( channel -- err )		RMT
<a href="#">rmt_set_memory_ow ner</a>	( channel owner -- err )		RMT
<a href="#">rmt_get_memory_ow ner</a>	( channel @owner -- err )		RMT
<a href="#">rmt_set_tx_loop_mo de</a>	( channel f -- err )		RMT
<a href="#">rmt_get_tx_loop_mo de</a>	( channel @f -- err )		RMT
<a href="#">rmt_set_rx_filter</a>	( channel enable thresh8 -- err )		RMT
<a href="#">rmt_set_source_clk</a>	( channel baseclk -- err )		RMT
<a href="#">rmt_get_source_clk</a>	( channel @baseclk --		RMT

	err )		
<b>rmt_set_idle_level</b>	( channel enable level -- err )		RMT
<b>rmt_get_idle_level</b>	( channel @enable @level -- err )		RMT
<b>rmt_get_status</b>	( channel @status -- err )		RMT
<b>rmt_set_rx_intr_en</b>	( channel enable -- err )		RMT
<b>rmt_set_err_intr_en</b>	( channel enable -- err )		RMT
<b>rmt_set_tx_intr_en</b>	( channel enable -- err )		RMT
<b>rmt_set_tx_thr_intr_en</b>	(channel enable thresh -- err )		RMT
<b>rmt_set_gpio</b>	( channel mode gpio# invertsigs -- err )		RMT
<b>rmt_config</b>	( rmt_config_ t* )		RMT
<b>rmt_isr_register</b>	( fn arg allocflags handle -- err )		RMT
<b>rmt_isr_deregister</b>	( handle -- err )		RMT
<b>rmt_fill_tx_items</b>	( channel @items items# offset -- err )		RMT
<b>rmt_driver_install</b>	( channel rxbufsize allocflags --		RMT

	err )		
<a href="#">rmt_driver_uinstall</a>	( channel -- err )		RMT
<a href="#">rmt_get_channel_status</a>	( channel @status -- err )		RMT
<a href="#">rmt_get_counter_clock</a>	( channel @clockhz -- err )		RMT
<a href="#">rmt_write_items</a>	( channel @items items# wait -- err )		RMT
<a href="#">rmt_wait_tx_done</a>	( channel time -- err )		RMT
<a href="#">rmt_get_ringbuf_handle</a>	( channel @handle -- err )		RMT
<a href="#">rmt_translator_init</a>	( channel fn -- err )		RMT
<a href="#">rmt_translator_set_context</a>	( channel @context -- err )		RMT
<a href="#">rmt_translator_get_context</a>	( channel @@context -- err )		RMT
<a href="#">rmt_write_sample</a>	( channel src src# wait -- err )		RMT
<a href="#">rmt_register_tx_end_callback</a>		NOT SUPPORTED	RMT
<a href="#">rmt_memory_rw_rst</a>		DEPRECATED USE rmt_tx_memory_reset or rmt_rx_memory_reset	RMT
<a href="#">rmt_set_intr_enable_mask</a>		DEPRECATED interrupt handled by driver	RMT
<a href="#">rmt_clr_intr_enable_mask</a>		DEPRECATED interrupt handled by driver	RMT
<a href="#">rmt_set_pin</a>		DEPRECATED use rmt_set_gpio instead	RMT

## RTOS support

<a href="#">rtos-builtins</a>			RTOS
<a href="#">vTaskDelete</a>			RTOS
<a href="#">xPortGetCoreID</a>			RTOS
<a href="#">xTaskCreatePinnedToCore</a>			RTOS

## SD Card

<a href="#">SD.begin</a>	( -- )	uses all the defaults "/sd" etc.	SD
<a href="#">SD.beginDefaults</a>	( -- sspin SPIClass frequency mountpointsz maxfiles format_if_empty )	( SS SPI 4000000 "/sd" 5 false )	SD
<a href="#">SD.beginFull</a>	( sspin SPIClass frequency mountpoint maxfiles format_if_empty -- )		SD
<a href="#">SD.end</a>	( -- )		SD
<a href="#">SD.cardType</a>	( -- n )		SD
<a href="#">SD.totalBytes</a>	( -- n )		SD
<a href="#">SD.usedBytes</a>	( -- n )		SD

## SD\_MMC Card

<a href="#">SD_MMC.begin</a>	( mount mode1bit )	default mode1bit=false	SD_MMC
<a href="#">SD_MMC.beginDefaults</a>			SD_MMC
<a href="#">SD_MMC.beginFull</a>			SD_MMC
<a href="#">SD_MMC.cardType</a>	( -- n )		SD_MMC
<a href="#">SD_MMC.end</a>	( -- )		SD_MMC
<a href="#">SD_MMC.totalBytes</a>	( -- n )		SD_MMC
<a href="#">SD_MMC.usedBytes</a>	( -- n )		SD_MMC

## Serial communication

‘Serial’ is the default forth terminal, pin GPIO1 is data out from the ESP32, GPIO3 is data in.

‘Serial2’ is unused by default. Pin GPIO17 is data transmit from the ESP32, GPIO16 is data in.

<a href="#">Serial.available</a>	( -- f )	Get the number of bytes (characters) available	serial
----------------------------------	----------	--	--------



<b>Serial2.available</b>		for reading from the serial port. This is data that's already arrived and stored in the serial receive buffer (which holds 64 bytes)	
<b>Serial.begin</b> <b>Serial2.begin</b>	( baud -- )	Start serial port. Sets the data rate in bits per second (baud) for serial data transmission	serial
<b>Serial.end</b> <b>Serial2.end</b>	( -- )	Disables serial communication, allowing the RX and TX pins to be used for general input and output. To re-enable serial communication, call Serial.begin	serial
<b>Serial.flush</b> <b>Serial2.flush</b>	( -- )	Waits for the transmission of outgoing serial data to complete	serial
<b>Serial.readBytes</b> <b>Serial2.readBytes</b>	( a length -- n )	Serial.readBytes reads characters from the serial port into a buffer, address a. The function terminates if the determined length has been read. The number of bytes, n is returned	serial
<b>Serial.write</b> <b>Serial2.write</b>	( a n -- n )	Writes n bytes of data to the serial port from buffer at address a	serial

# Serial Bluetooth

<b>esp_bt_dev_get_address</b>	( -- a )	<i>addr of 6 byte mac address</i>	<i>bluetooth</i>
-------------------------------	----------	-----------------------------------	------------------

Serial Bluetooth:-

<b>SerialBT.new</b>	( -- bt )	Allocate new BT object	bluetooth
<b>SerialBT.delete</b>	( bt -- )	Free BT object	bluetooth
<b>SerialBT.begin</b>	( localname ismaster bt -- f )		bluetooth
<b>SerialBT.end</b>	( bt -- )		bluetooth
<b>SerialBT.available</b>	( bt -- f )		bluetooth
<b>SerialBT.readBytes</b>	( a n bt -- n )		bluetooth
<b>SerialBT.write</b>	( a n bt -- n )		bluetooth
<b>SerialBT.flush</b>	( bt -- )		bluetooth
<b>SerialBT.hasClient</b>	( bt -- f )		bluetooth
<b>SerialBT.enableSSP</b>	( bt -- )		bluetooth
<b>SerialBT.setPin</b>	( z bt -- f )		bluetooth
<b>SerialBT.unpairDevice</b>	( addr bt -- f )		bluetooth
<b>SerialBT.connect</b>	( remotename bt -- f )		bluetooth
<b>SerialBT.connectAddress</b>	( addr bt -- f )		bluetooth
<b>SerialBT.disconnect</b>	( bt -- f )		bluetooth
<b>SerialBT.connected</b>	( timeout bt -- f )		bluetooth
<b>SerialBT.isReady</b>	( checkMaster timeout -- f )		bluetooth

## SPI FLASH memory

<a href="#">esp_partition_check_id entity</a>			spi_flash
<a href="#">esp_partition_erase_range</a>			spi_flash
<a href="#">esp_partition_find</a>			spi_flash
<a href="#">esp_partition_find_first</a>			spi_flash
<a href="#">esp_partition_get</a>			spi_flash
<a href="#">esp_partition_get_sha256</a>			spi_flash
<a href="#">esp_partition_iterator_release</a>			spi_flash
<a href="#">esp_partition_mmap</a>			spi_flash
<a href="#">esp_partition_next</a>			spi_flash
<a href="#">esp_partition_read</a>			spi_flash
<a href="#">esp_partition_t</a>			spi_flash
<a href="#">esp_partition_t_size</a>			spi_flash
<a href="#">esp_partition_verify</a>			spi_flash
<a href="#">esp_partition_write</a>			spi_flash
<a href="#">list-partition-type</a>			spi_flash
<a href="#">list-partitions</a>			spi_flash
<a href="#">p.</a>			spi_flash
<a href="#">p&gt;address</a>			spi_flash
<a href="#">p&gt;gap</a>			spi_flash
<a href="#">p&gt;label</a>			spi_flash
<a href="#">p&gt;size</a>			spi_flash
<a href="#">p&gt;subtype</a>			spi_flash

p>type			spi_flash
spi_flash_cache_enabled			spi_flash
spi_flash_cache2phys			spi_flash
spi_flash_erase_range			spi_flash
spi_flash_erase_sector			spi_flash
spi_flash_get_chip_size			spi_flash
spi_flash_init			spi_flash
spi_flash_mmap			spi_flash
spi_flash_mmap_dump			spi_flash
spi_flash_mmap_get_free_pages			spi_flash
spi_flash_munmap			spi_flash
spi_flash_phys2cache			spi_flash
spi_flash_read			spi_flash
spi_flash_read_encrypted			spi_flash
spi_flash_write			spi_flash
spi_flash_write_encrypted			spi_flash
spi_flash-builtins			spi_flash
SPI_PARTITION_SUBTYPE_ANY			spi_flash
SPI_PARTITION_TYPE_APP			spi_flash
SPI_PARTITION_TYPE_DATA			spi_flash

## Serial Peripheral Interface Flash File System (SPIFFS)

<b>SPIFFS.begin</b>	( format-on-fail path-z max-files -- f )	Mounts file system. It must be called before any other SPIFFS words are used. Returns true if file system was mounted successfully, false otherwise. If format-on-fail is true the 'disk' will be formatted	SPI filesystem
<b>SPIFFS.end</b>	( -- )	Unmounts the flash memory file system	SPI filesystem
<b>SPIFFS.format</b>	( -- f )	Format the flash memory 'disk'. returns true if successful	SPI filesystem
<b>SPIFFS.totalBytes</b>	( -- n )	Returns the total capacity of the flash memory 'disk'	SPI filesystem
<b>SPIFFS.usedBytes</b>	( -- n )	Returns the total space occupied by flash memory files	SPI filesystem

## Sockets

Addrln is a parameter in quite a few Sockets words. Unless otherwise noted, addrln is just the number 16 defining the length in bytes of a sockaddr structure for IPv4. When calling words **sockaccept** and **recvfrom**, addrln must be the address of a variable, so that these two functions can update the value.

<b>-&gt;addr!</b>	( n a -- )	set big-endian address in sockaddr	sockets
<b>-&gt;addr@</b>	( a -- n )	get big-endian address from sockaddr	sockets
<b>-&gt;h_addr</b>	( hostent – a )	Get host address from a hostent structure (returned by gethostbyname)	sockets
<b>-&gt;port!</b>	( n a -- )	set port in sockaddr	sockets
<b>-&gt;port@</b>	( a -- n )	get port from sockaddr	sockets
<b>ip.</b>	( n -- )	Print address as x.y.z.w IP address.	sockets
<b>ip#</b>		Part of ip.	sockets
<b>AF_INET</b>	( -- 2)	constant	sockets
<b>bind</b>	( sock addr addrln -- 0/err )	The bind function assigns an address to an unnamed socket. Sockets created with <a href="#">socket()</a> function are initially unnamed; they are identified only by their address family	sockets
<b>bs,</b>	( n – )	Compile 16 bit number ( as 2 bytes) into a	sockets

		definition, big-endian ( ms byte in lowest address )	
<b>connect</b>	( sock addr addrlen -- 0/err )	The connect function requests a connection to be made on a socket. N.B. A socket is closed again with <sock> CLOSE-FILE	sockets
<b>errno</b>	( -- err )	f = the error number of the last sockets action	sockets
<b>gethostbyname</b>	( hostnamez -- hostent/0 )		sockets
<b>l,</b>	( n – )	Compile 32 bit number n ( as 4 bytes) into a definition	sockets
<b>listen</b>	( sock backlog -- 0/err )	Listen for socket connections and limit the queue of incoming connections - 'backlog' is the max no. of connections that can be put on hold	sockets
<b>NON-BLOCK</b>	( sock – 0/err )	Certain words in the socket, file or serial port vocabs normally block until complete. NON-BLOCK converts these to non-blocking. If a function would have normally blocked, it now returns -1 and errno is set to ESP_ERR_WIFI_WOULD_BLOCK = \$300E	forth
<b>poll</b>	( pollfds n timeout -- fd/err )	A file descriptor for a socket that is listening for connections will indicate that it is ready for reading, once connections are available. A file descriptor for a socket that is connecting asynchronously will indicate that it is ready for writing, once a connection has been established.	sockets
<b>recv</b>	( sock a n1 flags -- n2/err )	receive data to buffer at address a, required size n1. returns number of bytes actually read n2. It's up to you to call recv again until all the data is read. Will block if the receive buffer is empty. Use NON-BLOCK to alter that	sockets
<b>recvfrom</b>	( sock a n1 flags addr addrlen -- n2/err )	Works like recv, albeit addr , addrlen is a sockaddr showing who sent the message. <b>N.B. make sure here that addrlen is an address of a variable, not a number !</b> Will block if the receive buffer is empty. Use NON-BLOCK to alter that	sockets
<b>recvmsg</b>	( sock msg flags -- n/err )	Will block if the receive buffer is empty. Use NON-BLOCK to alter that	sockets
<b>s,</b>		Compile 16 bit number ( as 2 bytes) into a definition	sockets
<b>select</b>	( numfds	A file descriptor for a socket that is listening for	sockets

	readfds writefds errfds timeout -- fd/err )	connections will indicate that it is ready for reading, when connections are available. A file descriptor for a socket that is connecting asynchronously will indicate that it is ready for writing, when a connection has been established	
<b>send</b>	( sock a n1 flags -- n/err )	send data at address a, n1 bytes long. Return n2 the actual number of bytes received or -1 as an error flag. Will block if the transmit buffer is full. Use NON-BLOCK to alter that	sockets
<b>sendmsg</b>	( sock msg flags -- n/err )	Returns the actual number of bytes received or -1 as an error flag. Will block if the transmit buffer is full. Use NON-BLOCK to alter that	sockets
<b>sendto</b>	( sock a n flags addr addrlen -- n/err )	Like send, but the recipient is specifically addressed with sockaddr addr, addrlen. Return the actual number of bytes received or -1 as an error flag	sockets
<b>setsockopt</b>	( sock level optname optval optlen -- 0/err )	The setsockopt() function sets the option specified by the option_name argument, at the protocol level specified by the level argument, to the value pointed to by the option_value argument for the socket associated with the file descriptor specified by the socket argument.	sockets
<b>sizeof(sockaddr_in)</b>	( -- 16 )	Constant – the size of a standard IPv4 sockaddr is 16 bytes	sockets
<b>SO_REUSEADDR</b>	( – 2 )	constant	sockets
<b>SOCK_DGRAM</b>	( – 2 )	constant	
<b>SOCK_RAW</b>	( – 3 )	constant	
<b>SOCK_STREAM</b>	( -- 1 )	constant	sockets
<b>socketaccept</b>	( sock1 addr addrlen -- sock2/err )	The socketaccept function extracts the first connection on the queue of pending connections, creates a new socket sock2 with the same socket type protocol and address family as the specified socket, and returns a new file descriptor for sock2 in sockaddr addr, addrlen. <b>N.B. make sure here that addrlen is an address of variable, not a number! It must be set to 16 ( sockaddr size in bytes ) before calling socketaccept.</b> Normally blocks until a remote client connects. Use NON-BLOCK to alter that	sockets
<b>sockaddr</b>	( "name" -- )	creates a sockaddr structure	sockets
<b>socket</b>	( domain	domain is usually AF_INET for tcpip using a 4	sockets

	type protocol – sock/err )	byte internet address. type is SOCK_STREAM for tcp or SOCK_DGRAM for udp; protocol is 0 for internet: returns a reference sock	
<b>sockets-builtins</b>			sockets
<b>SOL_SOCKET</b>	( – 1)	constant	sockets

## Stack functions

<b>-rot</b>	( a b c – c a b )	rotate top cell to 3rd	forth
<b>?DUP</b>	( x -- 0   x x )	Duplicate x if it is non-zero.	
<b>&gt;R</b>	( n – )	move n to the return stack	forth
<b>2drop</b>	( n1 n2 – )	discard the top of stack	forth
<b>2dup</b>	( n1 n2 – n1 n2 n1 n2 )	duplicate the top two items on the data stack	forth
<b>depth</b>	( – n )	return the data stack depth on the top of stack e.g. 3 2 1 depth displays 3 2 1 3	forth
<b>DROP</b>	( n – )	discard the top of stack	forth
<b>DUP</b>	( n – n n )	duplicate the top of stack	forth
<b>f.s</b>	( – )	displays the floating point number stack	forth
<b>nip</b>	( n1 n2 -- n2 )	remove the 2nd item on the data stack	forth
<b>OVER</b>	( n1 n2 -- n1 n2 n1 )	duplicate 2nd item on the data stack	forth
<b>R@</b>	( -- n )	copy the top of the return stack to the top of data stack	forth
<b>R&gt;</b>	( – n )	Move top of return stack to data stack	forth
<b>rdrop</b>	( -- )	drop the top of the return stack	forth
<b>rot</b>	( a b c -- b c a )	rotate 3rd cell to top	forth
<b>RP!</b>	( addr -- )	set the return stack pointer	forth
<b>RP@</b>	( -- addr )	read the return stack pointer	forth
<b>rp0</b>	( -- addr )	constant - the initial value of the return stack pointer at switch-on	forth
<b>SP!</b>	( addr -- )	set the data stack pointer	forth
<b>SP@</b>	( -- addr )	read the data stack pointer	forth



<b>sp0</b>	( -- n )	constant - the initial value of the data stack pointer at switch-on	forth
<b>SWAP</b>	( n1 n2 -- n2 n1 )	swap the top two data stack entries	forth

## Streams

These words enable the creation of first-in first-out buffers or queues of chrs or bytes, useful where a stream of data is to be handled. The words are multitask compatible.

<b>&gt;offset</b>	( n st -- a )	internal word	streams
<b>&gt;read</b>	( st -- rd )	internal word	streams
<b>&gt;stream</b>	( a n st -- )	read string, a n , from stream. Terminate when n chrs received or stream empty	streams
<b>&gt;write</b>	( st -- wr )	internal word	streams
<b>ch&gt;stream</b>	( ch st -- )	wait until there is space, then write one char	streams
<b>empty?</b>	( st -- f )	returns true if stream empty	streams
<b>full?</b>	( st -- f )	returns true if stream full	streams
<b>stream</b>	( n "name" -- )	define a stream, size n, using the next word in the input stream as the name e.g. 200 stream myinputstream 20000 stream myoutputstream	streams
<b>stream#</b>	( st -- n )	returns the number of chrs waiting to be read in stream st	streams
<b>stream&gt;</b>	( a n st -- )	send string, a n , to stream st	streams
<b>stream&gt;ch</b>	( st -- ch )	wait until data is available then read one char	streams
<b>wait-read</b>	( st -- )	wait until there is data ready to read from st	streams
<b>wait-write</b>	( st -- )	wait until there is space to write to stream st	streams

## String functions

ESP32forth supports both null terminated strings used in calling the various C based vocabularies and counted strings as used by many forth systems.

<b>[char]</b>	( -- )	compile the first letter of the following word in the definition e.g. : my-char [char] ALPHABET emit char emit ; executing my-char fred will display:- Af	forth
<b>r"</b>	( "string" -- a n )	Creates a temporary counted string	forth
<b>r </b>	( string  -- a n )	Creates a temporary counted string ending with	forth

<b>s"</b>	( -- addr cnt )	Creates a zero terminated string. Leaves the string address addr and the character count cnt on the stack e.g. s" Hello Bob"	forth
<b>S&gt;NUMBER?</b>	( addr cnt -- n f=true   f=false )	converts the counted ascii string stored at addr to number n with f=true, else just returns f=0, no n	forth
<b>s&gt;z</b>	( a n -- z )	Convert a counted string string to null terminated string	forth
<b>startswith?</b>	( addr1 n1 addr2 n2 -- f )	f=true if string at addr1 starts with string at addr2, else f=false	forth
<b>str</b>	( n -- addr cnt )	convert n to a counted string	forth
<b>str=</b>	( addr1 n1 addr2 n2 -- f )	f=true if the two counted strings are equal, else f=false	forth
<b>z"</b>	( "string" -- addr )	Creates a null terminated string on the heap at addr	forth
<b>z&gt;s</b>	( addr -- addr n )	Convert a null terminated string at addr to a counted string	forth

**r| example** ( -- ) Demonstrates making a standalone application with the aid of of a temporary string made with r|

```
r| z" NETWORK-NAME" z" PASSWORD" webui | \ create a string to start the web server
s" /spiffs/autoexec.fs" dump-file      \ save it to file autoexec.fs
```

## Structures

<b>align-by</b>	( a1 n -- a2 )	Adjust address a up to an n byte boundary	structures
<b>field</b>	( n "name" )	Define a field in the structure	structures
<b>i16</b>	( - 2 )	Used to define a 16 bit field	structures
<b>i32</b>	( - 4 )	Used to define a 32 bit field	structures
<b>i64</b>	( - 8 )	Used to define a 64 bit field	structures
<b>i8</b>	( - 1 )	Used to define a 8 bit field	structures
<b>last-align</b>	( - a )	variable	structures
<b>last-struct</b>	( - a )	variable	structures
<b>long</b>	( - 4 )	Used to define a 32 bit field for a long	structures
<b>ptr</b>	( - 4 )	Used to define a pointer field of one cell	structures
<b>struct</b>	( "name" ) ( - total )	Start a structure definition. When "name" is execute it returns the total byte count of the	structures

		structure	
<b>struct-align</b>	( n -- )	Set the last structure defined to be on an n byte boundary	structures
<b>typer</b>	( align sz "name" )	define a field type with alignment 'align' and 'sz' bytes in size	structures

## STRUCTURES example ( -- ) Demonstrates definition and use of a structure

First a recipe for a structure is defined:-

```
struct timer
i32 field counter
i32 field limit
```

Now we create a variable based on that structure:-

```
create mytimer timer allot
```

Now we can access fields within that variable:-

```
mytimer limit @      20 mytimer counter !
```

## System

<b>bye</b>	( -- )	deferred word, defaults to esp32-bye	forth
<b>CELL</b>	( -- 4 )	returns the number of bytes per standard forth number - 32 bits	forth
<b>echo</b>	( -- addr )	All input stream is echoed on output stream if echo = -1, else only partial echo ( --> ok and errors) if set 0	forth
<b>evaluate</b>	( addr cnt -- )	evaluate the counted string at addr, as if typed in at the command line	forth
<b>EXECUTE</b>	( xt -- )	Execute the word whose execution token is top of stack	forth
<b>HIGH</b>	( -- 1 )	Logic high is represented by 1 e.g. HIGH 1 pin	forth
<b>hld</b>	( -- adr )	holds a pointer in building a numeric output string	forth
<b>INPUT</b>	( -- 1 )	constant used to set a pin as an input e.g. 2 INPUT pinMode	forth
<b>LED</b>	( -- 2 )	Some ESP32 modules have an LED fitted on GPIO pin 2	forth
<b>LOW</b>	( -- 0 )	Logic low is represented by 0 e.g.	forth

		LOW 4 pin	
<b>OUTPUT</b>	( -- 2 )	constant used to set a pin as an output e.g. 4 OUTPUT pinMode	forth
<b>quit</b>	( -- )	Leave stack intact, but return control to input stream	forth
<b>state</b>	( -- addr )	system variable, state=true system is interpreting, state=false system is compiling	forth
<b>TERMINATE</b>	( n -- )	Call system exit	forth

## Tasks – multitasking

<b>.tasks</b>	( -- )	List running tasks	tasks
<b>pause</b>	( -- )	yield to other tasks	forth
<b>start-task</b>	( task -- )	Activate a task	forth
<b>task</b>	( xt dsz rsz "name" -- )	Create a new task, named using the next word in the input stream, with 'dsz' size data stack, and 'rsz' size return stack, execution to start at 'xt' execution token	forth
<b>main-task</b>			tasks
<b>task-list</b>	( – addr )	Return the start address of the task list	tasks

**Tasks example** ( -- ) Demonstrates adding a 10 second timer task

```
: hi begin ." Time is: " ms-ticks . cr 10000 ms again ;      \ Print the tick every 10sec.
' hi 100 100 task my-counter                                \ define my-counter task
my-counter start-task                                       \ start the my-counter task
```

\ in between print outs, type tasks .tasks <cr> and observe the active tasks are  
 \ main-task my-counter yield-task

Actually the word 'hi' above could have been written as:-

```
: hi ." Time is: " ms-ticks . cr 10000 ms ;                  \ Print the tick and pause 10s
```

The word 'task' compiles:-

```
again: xt of 'hi'
      pause
      branch to again
```

So any word written as a 'one-shot' will in fact repeat when assigned to a task and a 'pause' is already built in to ensure task switching

# Telnet

<b>broker</b>	( -- )	Deferred word - executes broker-connection by default	telnetd
<b>broker-connection</b>	( -- )	Processing loop for the active TELNET link	telnetd
<b>client</b>			telnetd
<b>client-len</b>	( -- adr )	variable	telnetd
<b>clientfd</b>	( -- flag )	value, default to -1	telnetd
<b>connection</b>			telnetd
<b>server</b>	( port -- )	Start telnet server daemon on port	telnetd
<b>sockfd</b>	( -- flag)	value, default to -1	telnetd
<b>telnet-emit</b>	( c -- )	Emit c character on the active telnet port	telnetd
<b>telnet-emit'</b>			telnetd
<b>telnet-key</b>	( -- c )	Retrieve a character c from the active telnet port	telnetd
<b>telnet-port</b>	( a n -- )		telnetd
<b>telnet-type</b>	(adr len -- )	Send a counted string on the active telnet port	telnetd

## Telnet example

( -- )

Demonstrates starting the telnet server to enable terminal communication with ESP32forth over WiFi

z" yourrouterid" z" yourpassword" login cr  
telnetd  
552 server

\ Login to your Wifi router  
\ vocabulary TELNET  
\ start the telnet server on port 552

# Time / Timers

*n* = group (0/1)

*x* = timer (0/1)

*m* = watchdog (0-5)

*There are two groups of two timer channels*

<b>ms</b>	( n1 -- )	pause for "n" milliseconds.	forth
<b>MS-TICKS</b>	( -- n1 )	Time since start in milliseconds	forth
<b>alarm</b>	( t -- a )		timers
<b>alarm-enable!</b>	( f t -- )	Alarm enable	timers
<b>alarm-enable@</b>	( t -- f )	Alarm enabled?	timers
<b>autoreload!</b>	( v t -- )		timers
<b>divider!</b>	( n t -- )	Timer divider 2 - 65535	timers
<b>edgeint!</b>	( f t -- )	Edge trigger	timers
<b>enable!</b>	( v t -- )	Timer enable/disable	timers

<b>increase!</b>	( v t -- )	Timer increasing/decreasing	timers
<b>int-enable!</b>	( f t -- )		timers
<b>interval</b>	( xt usec t -- )	Setup timer t to call execution token xt after usec delay	timers
<b>levelint!</b>	( v t -- )	Level trigger	timers
<b>onalarm</b>	( xt t -- )	Set callback	timers
<b>rerun</b>	( t -- )	Rerun timer t triggering	timers
<b>t&gt;nx</b>	( t -- n x )	x=1 if bit0 of t=1, else x=0 n=1 if bit1 of t=1, else n=0	timers
<b>timer!</b>	( lo hi t -- )		timers
<b>timer@</b>	( t -- lo hi )		timers
<b>TIMG_BASE</b>	( -- \$3ff5f000 )	constant	timers
<b>TIMGn</b>			timers
<b>TIMGn_RTCCALICFG_REG</b>	( n -- a )		timers
<b>TIMGn_RTCCALICFG1_REG</b>	( n -- a )		timers
<b>TIMGn_Tx</b>	( n x -- a )		timers
<b>TIMGn_Tx_INT_CLR_REG</b>	( n -- a )		timers
<b>TIMGn_Tx_INT_ENA_REG</b>	( n -- a )		timers
<b>TIMGn_Tx_INT_RAW_REG</b>	( n -- a )		timers
<b>TIMGn_Tx_INT_ST_REG</b>	( n -- a )		timers
<b>TIMGn_Tx_WDTCONFIGm_REG</b>	( n m -- a )		timers
<b>TIMGn_Tx_WDTFEE D_REG</b>	( n -- a )		timers
<b>TIMGn_Tx_WDTWPROTECT_REG</b>	( n -- a )		timers
<b>TIMGn_TxALARMLOHI_REG</b>	( n x -- a )		timers
<b>TIMGn_TxCONFIG_REG</b>	( n x -- a )		timers
<b>TIMGn_TxLOAD_REG</b>	( n x -- a )		timers

<b>TIMGn_TxLOADLOHI_REG</b>	( n x -- a )		timers
<b>TIMGn_TxLOHI_REG</b>	( n x -- a )		timers
<b>TIMGn_TxUPDATE_REG</b>	( n x -- a )		timers

**Interval example** ( -- ) Demonstrates starting a timed word with interval  
timers  
: hellobob ." hello bob" cr 0 rerun ; \ Print a message and restart timer 0  
' hellobob 10000000 0 interval \ and run that every 10 seconds

\ note the input terminal remains reponsive whilst the timer is counting down  
\ there are a total of only four timer channels - so turn to multitasking if more is needed

## Two Wire Interface / I2C

<b>Wire.available</b>	( -- f )	Returns the number of bytes available for retrieval with Wire.read. This should be called on a master device after a call to Wire.requestFrom	Wire
<b>Wire.begin</b>	( -- f )	Initiate the Wire library and join the I2C bus as a master. This should normally be called only once.	Wire
<b>Wire.beginTransmission</b>	( n -- )	Begin a transmission to the slave device at address n. Subsequently, queue bytes for transmission with the Wire.write function and transmit them by calling Wire.endTransmission	Wire
<b>Wire.busy</b>	( -- f )		Wire
<b>Wire.endTransmission</b>	( sendstop -- f )	Ends a transmission to a slave device that was begun by Wire.beginTransmission and transmits the bytes that were queued by Wire.write Sends a stop message if sendstop=true	Wire
<b>Wire.flush</b>	( -- )		Wire
<b>Wire.getClock</b>	( -- frequency )	Read the clock frequency set by Wire.setClock	Wire
<b>Wire.getErrorText</b>	( n -- z )		Wire
<b>Wire.getTimeout</b>	( -- ms )		Wire
<b>Wire.lastError</b>	( -- n )		Wire
<b>Wire.peek</b>	( -- ch )		Wire
<b>Wire.read</b>	( -- ch )	Reads a byte that was transmitted from a slave device to a master after a call to Wire.requestFrom or was transmitted from a	Wire

		master to a slave	
<b>Wire.readTransmission</b>	( addr a n sendstop -- err )		Wire
<b>Wire.requestFrom</b>	( address quantity sendstop -- n )	Used to request bytes from a slave device. The bytes may then be retrieved with the Wire.available and Wire.read functions. A stop message is sent after the request if sendstop is true	Wire
<b>Wire.setClock</b>	( frequency -- )	Modifies the clock frequency for I2C communication. I2C slave devices have no minimum working clock frequency, however 100KHz is usually the baseline	Wire
<b>Wire.setTimeout</b>	( ms -- )	Default is 50ms	Wire
<b>Wire.write</b>	( a n -- n )	Writes data from a slave device in response to a request from a master, or queues bytes for transmission from a master to slave device (in-between calls to Wire.beginTransaction and Wire.endTransmission)	Wire
<b>Wire.writeTransmission</b>	( addr a n sendstop -- err )		Wire

## Vectored Execution

<b>defer</b>	( "vectornam e" -- )	Define a deferred execution vector e.g. defer myemit	forth
<b>is</b>	( -- )	Set the vector of a deferred word e.g. ' emit is myemit - sets the deferred word myemit to execute emit when called	forth



## Vocabulary (or Wordlist)

<b>}transfer</b>		transfer the words enclosed in curly brackets to the current library e.g. { word1 word2 word3 ... }transfer	forth
<b>also</b>	( -- )	Duplicate the vocabulary at the top of the vocabulary stack	forth
<b>context</b>	( -- a )	an area to specify vocabulary search order - defaults to forth. context @ puts the current vocab id on the stack context @ @ puts the xt of the last word defined in the current vocab	forth
<b>current</b>	( -- addr )	points to a vocabulary thread to which new definitions are to be added	forth
<b>definitions</b>	( -- )	Make the context vocabulary the current vocabulary	forth
<b>forth</b>	( -- )	Make the forth vocabulary the current vocabulary	forth
<b>internals</b>		Make the internals vocabulary the current vocabulary	forth
<b>interrupts</b>		Make the interrupts vocabulary the current vocabulary	forth
<b>ledc</b>		Make the ledc vocabulary the current vocabulary	forth
<b>only</b>	( -- )	Reset context stack to one item, the FORTH dictionary	forth
<b>order</b>	( - )	Print the vocabulary search order	forth
<b>registers</b>	( -- )	set the current vocabulary to registers	forth
<b>rtos</b>		Make the rtos vocabulary the current vocabulary	forth
<b>SD_MMC</b>		Make the SD_MMC vocabulary the current vocabulary	forth
<b>sealed</b>	( -- )	Alter the last vocabulary defined so it doesn't chain	forth
<b>Serial</b>		Make the Serial vocabulary the current vocabulary	forth
<b>sockets</b>		Make the sockets vocabulary the current vocabulary	forth
<b>SPIFFS</b>		Make the SPIFFS vocabulary the current vocabulary	forth
<b>streams</b>	( -- )	set the current vocabulary to streams	forth

<b>tasks</b>		make tasks vocabulary the current one	forth
<b>telnetd</b>		Make the telnetd vocabulary the current vocabulary	forth
<b>timers</b>	( -- )	Make the timers vocabulary the current vocabulary	forth
<b>vocabulary</b>	( "name" -- )	Create a vocabulary with the current vocabulary as parent	forth
<b>web-interface</b>		Make the web-interface vocabulary the current vocabulary	forth
<b>WebServer</b>		Make the WebServer vocabulary the current vocabulary	forth
<b>WiFi</b>		Make the WiFi vocabulary the current vocabulary	forth
<b>Wire</b>	( -- )	Make the Wire vocabulary the current vocabulary	forth
<b>previous</b>	( -- )	Drop the vocabulary at the top of the vocabulary stack	forth

## Visual

<b>edit</b>	( "filename" -- )	ANSI terminal file editor e.g. visual edit /spiffs/autoexec.fs	visual
-------------	-------------------	---	--------

Key strokes:	Action:
Ctrl-S	Save now
Ctrl-X / Ctrl-Q	Quit, asking Y/N to save
Ctrl-L	Redraw the screen
Backspace	Delete a character backwards
Arrow keys	Move the cursor up, down, left right
PgUp /PgDown	Scroll up / down a page

## Web Interface

<b>do-serve</b>			<i>web-interface</i>
<b>handle-index</b>			<i>web-interface</i>
<b>handle-input</b>			<i>web-interface</i>
<b>handle1</b>			<i>web-interface</i>
<b>index-html</b>			<i>web-interface</i>
<b>index-html#</b>	( – 2268 )	constant	<i>web-interface</i>
<b>input-stream</b>	( – a )	stream of size 200	<i>web-interface</i>
<b>out-size</b>	( – 2000 )	constant	<i>web-interface</i>
<b>out-string</b>		block of storage, size out-size+1	<i>web-interface</i>
<b>output-stream</b>	( – a )	stream of size out-size	<i>web-interface</i>
<b>serve-key</b>	( -- n )		<i>web-interface</i>
<b>serve-type</b>	( a n -- )		<i>web-interface</i>
<b>server</b>	( port -- )		<i>web-interface</i>
<b>webserver</b>	( – a )	variable	<i>web-interface</i>
<b>webserver-task</b>		multitasker task	<i>web-interface</i>
<b>webui</b>	( network-z password-z -- )	login and start webui e.g. z" NETWORK-NAME" z" PASSWORD" webui	forth

## WiFi

<b>login</b>	( network-z password-z	login to wifi only e.g. z" NETWORK-NAME" z" PASSWORD" login	forth
--------------	---------------------------	--	-------

	-- )		
<b>WIFI_MODE_AP</b>	( -- 2 )	access point mode: stations can connect to the ESP32 e.g. WIFI_MODE_AP WiFi.mode	WiFi
<b>WIFI_MODE_APSTA</b>	( -- 3 )	access point and a station connected to another access point e.g. WIFI_MODE_APSTA WiFi.mode	WiFi
<b>WIFI_MODE_NULL</b>	( -- 0 )		WiFi
<b>WIFI_MODE_STA</b>	( -- 1 )	station mode: the ESP32 connects to an access point e.g WIFI_MODE_STA WiFi.mode	WiFi
<b>WiFi.begin</b>	( ssid-z password-z -- )	Initializes the WiFi library's network settings and provides the current status. e.g. z" mySSID" z" myPASSWORD" WiFi.begin	WiFi
<b>WiFi.config</b>	( ip dns gateway subnet -- )	Allows you to configure a static IP address as well as change the DNS, gateway, and subnet addresses on the WiFi shield. Packaged a.b.c.d little-endian	WiFi
<b>WiFi.disconnect</b>	( -- )	Disconnects the WiFi shield from the current network	WiFi
<b>WiFi.getTxPower</b>	( -- powerx4 )	Get power x4	WiFi
<b>WiFi.localIP</b>	( -- ip )	Get local IP	WiFi
<b>WiFi.macAddress</b>	( a -- )	Gets the MAC Address of your ESP32 WiFi port	WiFi
<b>WiFi.mode</b>	( mode -- )	Set WiFi mode example below	WiFi
<b>WiFi.setTxPower</b>	( powerx4 -- )	Set power x4	WiFi
<b>WiFi.softAP</b>	( ssid password/0 -- success )	Software enabled Access Point – essentially behaviour like a Router	WiFi
<b>WiFi.softAPIP</b>	( -- ip )	Return IP address of the soft access point's network interface.	WiFi
<b>WiFi.softAPBroadcastIP</b>	( -- ip )	Function to get the AP IPv4 broadcast address	WiFi
<b>WiFi.softAPConfig</b>	( localip gateway subnet -- success )	Configure the soft access point's network interface.	WiFi
<b>WiFi.softAPdisconnect</b>	( wifioff --	Disconnect stations from the network	WiFi

	success )	established by the soft-AP.	
<b>WiFi.softAPgetStationNum</b>	( -- num )	Get the count of the stations that are connected to the soft-AP interface.	WiFi
<b>WiFi.softAPNetworkID</b>	( -- id )	Get the softAP network ID	WiFi
<b>WiFi.status</b>	( -- n )	Returns the connection status	WiFi

**WiFi.mode** ( mode – ) Set Wifi mode

**0 WIFI\_MODE\_NULL** In this mode, the internal data struct is not allocated to the station and the AP, while both the station and AP interfaces are not initialized for RX/TX Wi-Fi data. Generally, this mode is used for Sniffer, or when you only want to stop both the STA and the AP to unload the whole Wi-Fi driver.

**1 WIFI\_MODE\_STA** Station mode: in this mode, will init the internal station data, while the station's interface is ready for the RX and TX Wi-Fi data.

**2 WIFI\_MODE\_AP** AP mode: in this mode, init the internal AP data, while the AP's interface is ready for RX/TX Wi-Fi data. Then, the Wi-Fi driver starts broadcasting beacons, and the AP is ready to get connected to other stations.

**3 WIFI\_MODE\_APSTA** Station-AP coexistence mode: in this mode, will simultaneously init both the station and the AP. This is done in station mode and AP mode. Please note that the channel of the external AP, which the ESP Station is connected to, has higher priority over the ESP AP channel.

**WiFi.status** ( n – ) Returns the connection status – n can take the following values:-

255 WL\_NO\_SHIELD - no WiFi shield is present

0 WL\_IDLE\_STATUS - WiFi.begin is called and remains active until the number of attempts expires (resulting in WL\_CONNECT\_FAILED) or a connection is established (resulting in WL\_CONNECTED)

1 WL\_NO\_SSID\_AVAIL - no SSID are available

2 WL\_SCAN\_COMPLETED - scan networks is completed

3 WL\_CONNECTED - connected to a WiFi network

4 WL\_CONNECT\_FAILED - connection fails for all the attempts

5 WL\_CONNECTION\_LOST - connection is lost

6 WL\_DISCONNECTED - disconnected from a network

**WiFi connection example** ( -- ) Connect and disconnect from WiFi demo web-interface also WiFi

```
: status. ( -- ) \ print WiFi connection status
." Current WiFi status = " WiFi.status . cr
;
```

```

: test      ( -- )
WIFI_MODE_STA WiFi.mode          \ set to connect to an access point
z" yourroutername" z" yourpassword" WiFi.begin \ attempt to connect
3000 ms
status.                          \ report our Wifi link status
." Your assigned IP address = " WiFi.localIP
ip. cr                          \ report local IP address
WiFi.disconnect                  \ disconnect
." Now disconnecting" cr
3000 ms
status.                          \ report WiFi status again
;

```

\ N.B. edit the above with your router's name and password!!

## Word definition

,	( n -- )	store a value into the dictionary space	forth
;	( -- )	stop compiler, and finish word definition e.g. : gday ." good day to you" ;	forth
:	( "wordname " -- )	start compiler mode, creates a word definition e.g. : hi ." hello world" ;	forth
:noname	( -- xt )	Create a word with no name, leaving it's execution token on the stack. The xt would then usually be stored elsewhere from which the word can be executed	forth
'	( "wordname " -- xt )	xt = execution token of the word that follows in the input stream e.g. ' words puts 1073654684 on the stack. Errors if word not found, stopping execution	forth
[	( -- )	stop compiling the input stream and start executing - sets state=true	forth
[ ]	( -- xt )	xt = execution of the word that follows inside a : definition e.g. : COMING [ ] HELLO 'aloha ! ;	forth
]	( -- )	Stop executing and start compiling the input stream, sets state=false	forth
{	( -- )	Mark the start of a local variable block	forth
align			forth
aligned	( addr1 -- addr2 )	converts an address on the stack to the next higher cell boundary, to help accessing memory by cells	forth
allot	( n -- )	Allocate n bytes for storage and increment HERE by that space. See also the word	forth

		ALLOCATE	
<b>c,</b>	( c -- )	compile byte c at the next available location in the word definition	forth
<b>constant</b>	( n "name" -- )	create a constant whose name follows in the input stream, value n. e.g. 12 constant dozen	forth
<b>CREATE</b>	( -- ; -- pfa )	create an empty dictionary entry <name>, returns the parameter field address when executed	forth
<b>DOES&gt;</b>	( -- addr )	Used with create in defining new defining words e.g. : array ( n -- ; i -- addr ) \ new array type variable create cells allot does> swap cells + ; 10 array baba \ create a 10 cell array named baba 0 baba puts the 1st element address on the stack 1 baba puts the 2nd element address on the stack 10 0 baba ! stores 10 in the 1st element.	forth
<b>IMMEDIATE</b>		Marks the last defined word as immediate - it will execute immediately if called whilst compiling a word	forth
<b>literal</b>	( n -- ; -- n )	add top of stack into the word being compiled at the next free memory location. When the word is run, place n top of stack	forth
<b>postpone</b>	( "text" -- )	Skip leading space delimiters. Parse name delimited by a space. Find name. Append the compilation semantics of name to the current definition. Useful when an immediate word needs to be compiled in a word definition instead of immediately executing. Use instead of the obsolete COMPILE or [COMPILE] , you don't have to remember if word is immediate or normal	forth
<b>recurse</b>	( -- )	Allows a word to call itself e.g. : FACTORIAL DUP 2 < IF DROP 1 EXIT THEN DUP 1- RECURSE * ; so 5 FACTORIAL leaves 120 on the stack	forth
<b>SMUDGE</b>	( -- )	stops the current word being defined being found during a dictionary lookup	forth
<b>to</b>	( n "valuenam" -- )	e.g. 24 to myvalue - sets myvalue = 24	forth

<b>+to</b>	( n "valuenname" – )	e.g. 4 +to myvalue – set myvalue = myvalue+4	forth
<b>value</b>	( n "valname" -- ; -- n )	creates a value, named with the word that follows in the input stream, initialised n	forth
<b>value-bind</b>	( xt-val xt – )		forth
<b>variable</b>	( "varname" -- ; -- addr )	variable takes the next word in the input stream as the name and reserves space for a variable	forth



**Local variables** ( n1 n2 -- ) Demonstrates defining a word where the input parameters on the stack are labelled for enhanced readability

```
: summ { foo bar }
    foo bar + .
;
```

\ so 2 3 summ results in 5 displayed

**:NONAME example** ( - ) Demonstrates creating words with no names, which can nevertheless be executed by execution token - saves space in the dictionary if the word is never used by name

```
:noname ." Saturday" ;
:noname ." Friday" ;
:noname ." Thursday" ;
:noname ." Wednesday" ;
:noname ." Tuesday" ;
:noname ." Monday" ;
:noname ." Sunday" ;
```

```
create (day) ( --- addr) \ an array of execution tokens for the 7 headerless words
, , , , , , ,
```

```
: day. ( n -- ) \ valid n=0-6
cells (day) + @ execute ;
```

\ executing 2 day. displays Tuesday etc.

## Useful documentation

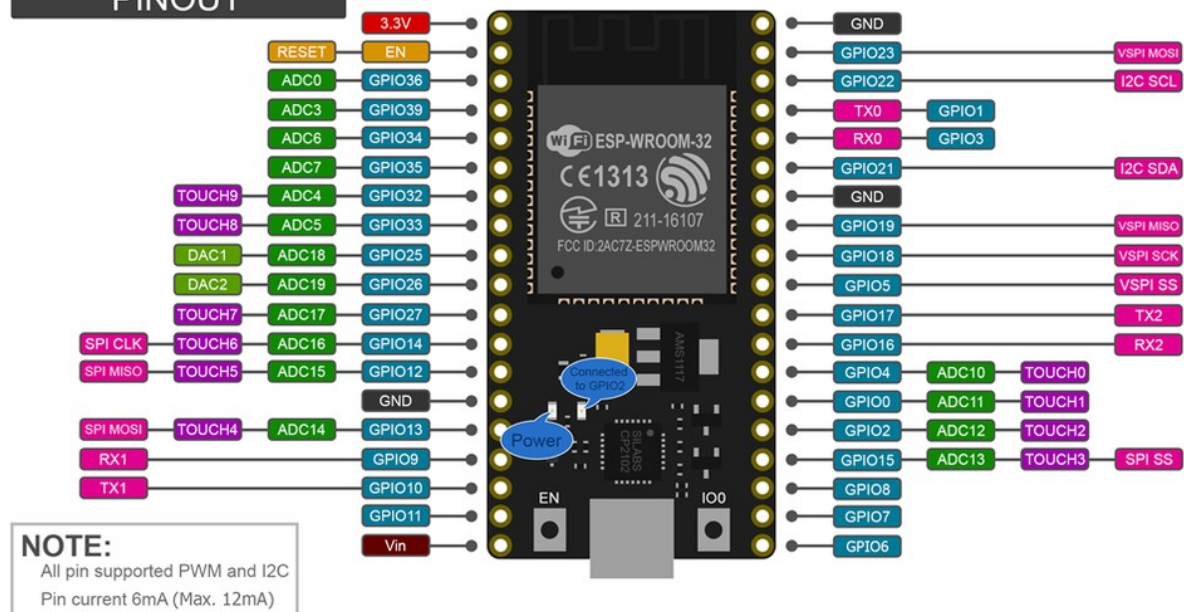
Bradley Nelsons's [ESP32forth home page](#), which includes downloads & **installation instructions**  
 Marc PetreMann's excellent webpage on [ESP32forth programming](#)  
[Forth2020](#) on facebook  
 ESP32 module [buying guide](#)  
 The [latest version of this document](#) is found here

## Useful Code

The Forth2020 group's [archive of examples](#) is very useful  
 Marc Petremann's [ESP32forth github](#) page  
 The github [ESP32forth / forth2020group code page](#)  
[My code](#) on github

# NodeMCU-32 pin-out

## NodeMCU-32 PINOUT



## Conclusion

This glossary was compiled in Aug 2022 by Bob Edwards, retired EMC engineer in SW U.K. He always has it open, on screen, when he programs ESP32forth and hopes you will find it useful too.

## Appendix 1 Internal Words

The following words are system internal 'worker words' and are liable to change from version to version of ESP32forth. For that reason they are non-preferred for User programs – caveat emptor. Nevertheless, when nothing else will do – here they are:-

### Block File system

<b>arduino-default-use</b>	( -- )	attempt to open block file "/spiffs/blocks.fb"	internals
<b>block-data</b>	( -- addr )	A 1024 byte buffer for handling block file data	internals
<b>block-dirty</b>	( -- n )	value, default=0	internals
<b>clobber</b>	( a -- )	fill one block of 1024 characters with spaces	internals
<b>clobber-line</b>	( a -- a' )	fill one block file line with spaces	internals
<b>common-default-use</b>	( -- )	attempt to open block file "blocks.fb"	internals
<b>grow-blocks</b>	( n -- )	Increase the size of the file by n blocks	internals

### Block File Editor

<b>e'</b>	( n -- )	used internally by e	internals
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### Branching

<b>0BRANCH</b>			internals
<b>BRANCH</b>			internals
<b>[SKIP]</b>		deferred word, defaults to [SKIP]', used internally in [ELSE]	internals
<b>[SKIP]'</b>		used internally in [ELSE]	internals

### Character I/O

<b>?arrow.</b>	( -- )	If system variable arrow is true, the user prompt of an arrow followed by the data stack contents shows the system is ready for user input	internals
<b>?echo</b>	( c -- )	If system variable echo=true, then display the ascii character c, else if echo=false, c is dropped	internals
<b>*emit</b>	( n – )		internals
<b>*key</b>	( – n )		internals
<b>dump-line</b>	( a – )	print address line leaving room – part of the	internals

		dump word	
<b>eat-till-cr</b>			internals
<b>input-buffer</b>	( -- addr )	character buffer, size input-limit	internals
<b>input-limit</b>	( -- 200 )	constant - the maximum permitted input char count before being terminated with <cr>	internals
<b>line-pos</b>	( – n )	value,	internals
<b>line-width</b>	( -- n )	value, defaults to 75 = the number of characters per line on the output stream	internals

## Debug

<b>raw.s</b>	( -- )	display the data stack on one line of the display	internals
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## Files

<b>arduino-remember-filename</b>	( -- addr cnt )	returns the filename "/spiffs/myforth"	internals
<b>dirname</b>	( a n -- )		internals
<b>ends/</b>	( a n -- f )		internals
<b>include-file</b>	( fh -- )		internals
<b>include+</b>			internals
<b>included-files</b>		value, default = 0	internals
<b>path-join</b>	{ a a# b b# -- a n }		internals
<b>raw-included</b>	( a n -- )		internals
<b>remember-filename</b>	( -- a n )	Deferred word specifying the platform specific default snapshot filename - defaults to arduino-remember-filename = "/spiffs/myforth"	internals
<b>restore-name</b>	( "name" -- )	Restore a snapshot from a file	internals
<b>save-name</b>	( a n -- )	Save a snapshot of the current vocabulary to a file	internals
<b>sourcedirname</b>	( -- a n )		internals
<b>sourcefilename</b>	( -- a n )		internals
<b>sourcefilename!</b>	( a n -- )		internals
<b>sourcefilename&amp;</b>		value, default =0	internals
<b>sourcefilename#</b>		value, default =0	internals
<b>starts../</b>	( a n -- f )		internals
<b>starts./</b>	( a n -- f )		internals

## Internal words

<b>'cold</b>	( – a )		internals
<b>(local)</b>	( addr n -- )		internals
<b>)leaving</b>			internals
<b>@line</b>	( n -- )		internals
<b>ALITERAL</b>			internals
<b>default</b>			
<b>default-remember-filename</b>	( – string )	default value is “myforth”	
<b>DOLIT</b>			internals
<b>evaluate-buffer</b>			internals
<b>EVALUATE1</b>			internals
<b>exit=</b>	( xt -- f )	f=true if the execution token at top of stack is that of 'exit', else f=false	internals
<b>leaving</b>	( -- addr )	variable	internals
<b>leaving,</b>			internals
<b>leaving(</b>			internals
<b>notfound</b>	( addr cnt n -- )		internals
<b>onlines</b>	( n xt -- n xt )		internals
<b>park-forth</b>	( -- addr )		internals
<b>park-heap</b>	( -- addr )		internals
<b>parse-quote</b>	( -- addr cnt )		internals
<b>RAW-YIELD</b>	( -- )		internals
<b>restore-name</b>	( “name” – )		
<b>save-name</b>			
<b>saving-base</b>			internals
<b>scope</b>	( -- addr )	variable	internals
<b>scope-clear</b>		reset the r stack and set scope=0	internals
<b>scope-create</b>	( a n -- )		internals
<b>scope-depth</b>	( -- addr )	variable	internals
<b>scope-doer</b>		creates a new word of type scope-doer	internals
<b>scope-template</b>		is an instance of a scope-doer	internals
<b>see-all</b>			internals
<b>see-loop</b>			internals

<b>see-one</b>	( xt -- xt+1 )		internals
<b>see-xt</b>	( xt -- )		internals
<b>see.</b>	( xt -- )		internals
<b>setup-saving-base</b>	( -- )		
<b>tib-setup</b>			internals
<b>use?!</b>			internals
<b>voc-stack-end</b>	( -- addr )		internals
<b>voc.</b>	( voc -- )		internals
<b>xt-find&amp;</b>	( xt -- xt& )		internals
<b>xt-hide</b>	( xt -- )		internals
<b>xt-transfer</b>	( xt -- )		internals

## Memory

<b>'heap-size</b>			internals
<b>'heap-start</b>			internals
<b>ca@</b>	( a – n )		internals
<b>fill32</b>			internals
<b>heap_caps_free</b>			internals
<b>heap_caps_malloc</b>			internals
<b>heap_caps_realloc</b>			internals
<b>LONG-SIZE</b>	( – 4 )	Returns the size of a 32 bit long in bytes	internals
<b>MALLOC</b>	( n -- a   0 )	System malloc - reserve n bytes of memory, returns start address a if successful, else returns 0 on failure	internals
<b>MALLOC_CAP_32BIT</b>	( -- 2 )	constant	internals
<b>MALLOC_CAP_8BIT</b>	( -- 4 )	constant	internals
<b>MALLOC_CAP_DEFAULT</b>	( -- 4096 )	constant	internals
<b>MALLOC_CAP_DMA</b>	( -- 8 )	constant	internals
<b>MALLOC_CAP_EXEC</b>	( -- 1 )	constant	internals
<b>MALLOC_CAP_INTERNAL</b>	( -- 2048 )	constant	internals
<b>MALLOC_CAP_IRAM_8BIT</b>	( -- 8192 )	constant	internals
<b>MALLOC_CAP_PID</b>	( n1 -- n1 n2 )	n1 range is 3-28, then n2 = 32*2 <sup>n1-3</sup> e.g. if n1=3, n2=32; if n1=4. n2=64 etc	internals

<b>MALLOC_CAP_RETENTION</b>	( -- 8192 )	constant	internals
<b>MALLOC_CAP_SPIRAM</b>	( -- 1024 )	constant	internals
<b>mem=</b>	( a1 a2 n -- f )	f=true if the memory contents at a1 is equal to that at a2 for n bytes	internals
<b>REALLOC</b>	( a n -- a   0 )	System realloc	internals
<b>SYSFREE</b>	( a -- )	System free - release memory previously reserved with MALLOC?	internals

## Number I/O

<b>#f+s</b>	( r - )		internals
<b>digit</b>	( u -- c )	converts an integer to an ascii char e.g. 5 is converted to 53	internals

## Serial Communication

<b>serial-key</b>	( -- c )	reads the next character from the serial port	internals
<b>serial-key?</b>	( -- f )	an alias for Serial.available	internals
<b>serial-type</b>	(addr count -- )	send the counted string at addr to the serial port	internals

## Stack functions

<b>?stack</b>	( - )	throws an error if stack underflow or overflow has occurred	internals
<b>'stack-cells</b>			internals

## String functions

<b>'tib</b>			internals
<b>\$@</b>			internals
<b>\$place</b>	( addr cnt -- )		internals

## System

<b>'context</b>	( -- addr )	system variable	internals
<b>'heap</b>	( -- addr )	system variable	internals
<b>'notfound</b>	( -- addr )	system variable	internals

'SYS	( -- addr )	system variable - used as the base address for system variables e.g. : 'context 'SYS 7 cells + ;	internals
'boot			internals
'boot-size			internals
'cold	( – addr )	Address of the word that will run on start-up	internals
arrow	( -- addr )	variable, default=true if so, the user will be prompted by --> to show the forth system is ready for user input	internals
autoexec	( -- )	at system start, check for autoexec.fs on the flash drive and run if present	internals
default-remember-filename	( -- addr cnt )	returns the string myforth	internals
esp32-bye	( – )	Restarts ESP32forth as though from switch-on	internals
esp32-stats	( – )	Displays chip model, type, clock speed, number of cores, flash chip size, system heap stats	internals
free.	( nf nu -- )	Part of the sign-on message printed by raw-ok	internals
growth-gap	( -- \$4000	constant	internals
raw-ok	( – )	Sign-on message – displays version, clockrate, number of cores, space, dictionary status, stack info	internals

## Tasks – multitasking

YIELD			internals
yield-step		Assigned to yield-task	internals
yield-task			internals

## Vocabulary

'context			internals
'latestxt			internals
'notfound			internals
>vocnext	( xt -- xt )		internals
forth-wordlist	( -- n )	constant, defined as current @	internals
last-vocabulary	( – n )		internals
latesttext	( – xt )		internals
nonvoc?	( xt – f )		internals
see-all	( – )		internals



<b>see-vocabulary</b>	( voc )		internals
<b>size-all</b>	( – )		internals
<b>size-vocabulary</b>	( voc )		internals
<b>voc.</b>	( voc – )		internals
<b>vocs.</b>	( voc -- )		internals
<b>voclist</b>	( – )	Display all vocabularies	internals
<b>voclist-from</b>	( voc – )		internals

## Word definition

<b>-TAB</b>	( – 64 )	constant	internals
<b>}?</b>	( addr cnt -- )	used internally by { in defining local variables	internals
<b>+TAB</b>	( – 32 )	constant	internals
<b>BUILTIN_FORK</b>	( – 4 )	constant	internals
<b>DOCOL</b>			internals
<b>DOCON</b>			internals
<b>DOCREATE</b>			internals
<b>DODOES</b>			internals
<b>DOSET</b>			internals
<b>DOVAR</b>			internals
<b>IMMEDIATE_MARK</b>	( – 1 )	constant	internals
<b>immediate?</b>	( xt -- f )	f=true if the word whose execution token is on the stack is an immediate word e.g. ' if immediate? returns true ' load immediate? returns false	internals
<b>MARK</b>	( – 128 )	constant	internals
<b>NONAMED</b>	( – 16 )	constant	internals
<b>SMUDGE</b>	( – 2 )	constant	internals

## Orphan Words

<b>'argc</b>			internals
<b>'argv</b>			internals
<b>'runner</b>			internals
<b>RAW-YIELD</b>			internals
			internals

			internals
			internals
			internals
			internals
			internals
			internals

## Appendix 2 Notes on using the Sockets Dictionary

A very useful guide to programming with Internet Sockets [is located here](#).

### Addresses

IPv4 internet addresses are represented by a 'sockaddr' structure in memory:-

← 32 bit cell →				len = 16, the number of bytes in the structure family = 2, AF_INET for internet use
long1	[ len ]	[family]	port ]	
long2	[	address	]	
long3	[	unused		
]				
long4	[	unused		
]				

A sockaddr can be created like a variable with a user provided name e.g. sockaddr data\_in

len and family fields are set automatically.

All 16 bit fields and upwards are 'big-endian' i.e. The ms byte of the number resides at the lowest memory address. Since ESP32forth is 'little-endian' a number of transfer words are available to read and write fields in sockaddr structures:-

->addr!	( n a -- )	set big-endian address in sockaddr	sockets
->addr@	( a -- n )	get big-endian address from sockaddr	sockets
->port!	( n a -- )	set big-endian port in sockaddr	sockets
->port@	( a -- n )	get big-endian port from sockaddr	sockets

### Making a Transmission Control Protocol (TCP) Connection

When making connections a 'server' is the name given to the semi-permanent entity which can be connected to by one or more less-permanent 'clients'. These clients can disconnect from the server when done. e.g. A thermometer server in your greenhouse may be connected to by a client running on your PC in the house. Before shutting down the PC, the client application disconnects from the thermometer. It's all a bit like making a telephone call: Dial, Accept Call, Chat, Hangup.

The tcp server has to execute the following steps in sequence:-

<b>gethostbyname</b>	( hostnamez -- hostent/0 )	Look up the host by name, using a zero terminated string. Returns a pointer to a hostent structure or 0 if failed
<b>-&gt;h_addr</b>	( hostent – a )	Get host address from hostent

		(returned by gethostbyname)
<b>socket</b>	( domain type protocol – sock/err )	Make a socket
<b>bind</b>	( sock addr addrlen -- 0/err )	A server will bind to an address
<b>listen</b>	( sock backlog -- 0/err )	Listen for socket connections and limit the queue of incoming connections - 'backlog' is the max no. of connections that can be put on hold. If you only want to ever allow one connection, set backlog = 0
<b>sockaccept</b>	( sock1 addr addrlen -- sock2/err )	The sockaccept function extracts the first connection on the queue of pending connections, creates a new socket sock2 with the same socket type protocol and address family as the specified socket, and returns a new file descriptor for sock2 in sockaddr addr, addrlen. <b>N.B. make sure here that addrlen is an address of variable, not a number! It must be set to 16 ( sockaddr size in bytes ) before calling sockaccept.</b>

Once the connection is established, the client and server can repeatedly exchange data with:-

<b>send</b>	( sock a n flags -- n/err )	send data at address a, n bytes long
<b>recv</b>	( sock a n1 flags -- n2/err )	receive data to buffer at address a, required size n1. returns number of bytes actually read n2. It's up to you to call recv again until all the data is read

After all communication is done, the connection is closed with:-

<b>CLOSE-FILE</b>	( sock -- ior )	close the socket
-------------------	-----------------	------------------

Let's look at the forth programming needed for a tcp client:-

## Get the host address

z" google.com" gethostbyname constant google.com \ look up the host details using the name

google.com → h\_addr

\ from the details extract the host ip addr

.ip 142.251.46.238 ok

\ .ip converts and displays the address

## Create a sockaddr and populate it with address + port

sockaddr googleaddr

\ create a sockaddr

80 googleaddr → port!

\ save the port address required

google.com → h\_addr googleaddr ->addr!  
googleaddr

\ get host address and save in

## Create a Socket

AF\_INET SOCK\_STREAM 0 socket value sock

\ create 'sock' SOCK\_STREAM = TCP

## Connect to the server

sock googleaddr sizeof(sockaddr\_in) connect throw

\ throw used because connect may fail

## Send an HTTP request

S" GET / HTTP/1.0" sock write-file throw

\ send a string using write-file

: semit (chr sock - ) swap >r rp@ swap 1 swap write-file throw rdrop ;

: semit (chr sock - ) swap >r rp@ 1 0 send 0< throw rdrop;  
character \ either version will send a

: scr 13 sock semit 10 sock semit ;

\ send CR-LF

scr scr

## Read part of the reply

here 100000 sock read-file throw constant len

\ read the response from google.com

here len type

\ using read-file

## Close the connection

sock close-file throw

## Another Example - Reading and Writing blocks of bytes

Another example which demonstrates sending data between two ESP32s is [shown here](#), including instructions on how to run the demo.

## Communication by User Datagram Protocol (UDP)

If TCP communication was like making a connection with a telephone, UDP is a bit like radio broadcasting – there's no end-to-end formal connection to be made. Consequently data can be missed, out of sequence or damaged.

In pseudo-code, the client has to execute the following steps:-

- `gethostbyname (hostname)`
- `socket (domain,type,protocol)`
- `bind (sock,addr,addrlen)`
- `sendto (sock,data, datalen, flags, addr, addrlen)`
- `recvfrom (sock,data,datalen,flags,addr, *addrlen)`
- `close (sock)`

Some example forth:-

### Create a 'listening' address

`sockaddr incoming`

`9999 incoming ->port!`

### Create a socket and bind to the address

`AF_INET SOCK_DGRAM 0 socket value sockfd`

`sockfd non-block throw`

`sockfd incoming sizeof(sockaddr_in) bind throw`

### Read an incoming packet

`sockaddr received`

`variable received-len`

`sizeof(sockaddr_in) received-len !`

`sockfd msg len 0 received`

`received-len recvfrom to len`

`received ->addr@ ip. .": received ->port@ .`

`space space msg swap type cr`

## Appendix 3 Catch and Throw

Another useful article on CATCH and THROW [appears here](#). The words CATCH and THROW, discussed in this section, provide a method for propagating error handling to any desired level in an application program. THROW may be thought of as a multi-level EXIT from a definition, with CATCH marking the location to which the THROW returns. Suppose that, at some point, word A calls word B, whose execution may cause an error to occur. Instead of just executing word B's name, word A calls word B using the word CATCH. Somewhere in word B's definition (or in words that B's definition may call) there is at least one instance of the word THROW, which is executed if an error occurs, leaving a numerical throw code identifier on the stack. After word B has executed and program execution returns to word A just beyond the CATCH, the throw code is available on the stack to assist word A in resolving the error. If the THROW was not executed, the top stack item after the CATCH is zero.

THROW ( errcode – )

When you detect an error in your program, you can use THROW to "throw an error". In practice, THROW is used with a number (on the stack) so that the type of error can be identified. Let's take an imaginary word, DIV which divides two numbers. You want to check for a division by zero, and if so, act upon it. First, the Forth 83 way:

```
: DIV ( quotient divisor -- result ) dup 0= abort" DIV: Divide by 0 error." / ;
```

That's about the best you can do in Forth 83 without having to resort to passing flags to indicate if the division succeeded or not. The problem is that in the event of 0 being passed, the running program will stop. That's what ABORT and ABORT" does. Even worse, DIV can't tell us which word passed 0 to DIV in the first place, so it's not particularly useful.

Let's look at how we would trap errors using THROW :-

```
: DIV ( quotient divisor -- result ) dup 0= if 99 throw else / then ;
```

Here, if the divisor is 0, we "throw" error code 99 (which, in our program, means "divide by zero" - I chose 99 at random - it could be any value you like). But to where do we "throw" this 99? Or put it another way, who, or what is going to catch this error?

Best to throw an error at the deepest convenient part of the program. Using THROW without CATCH is OK during development because the system has a CATCH which leads to the word Error being displayed. Just barely useful for debugging.

### CATCH ( xt – 0 | errorcode )

CATCH will catch an error thrown by THROW. The critical difference is, this allows your program to gracefully handle the error situation (prompt the user to change disks if the disk is full, rather than just abort, causing the user to lose his magnum opus in your word processor application). Let's have a look at how we would use CATCH with our DIV example above :-

```
: test-div ( quotient divisor -- result )  
  ['] div catch dup 0<> if  
    dup 99 = if  
      ." Divide by zero error"  
    else
```

```

        throw
    then
then ;

```

The stack signature for CATCH is as follows:

```
CATCH ( ... xt -- 0|error_code )
```

What this means is, CATCH expects the execution token (xt) of the word you want to execute, in our example, DIV, to be on the stack. CATCH itself will then execute that word on your behalf. After DIV executes, CATCH can determine if control came back to CATCH via THROW or by a normal termination of the word. If the word terminated normally, CATCH puts a 0 on the stack (meaning that CATCH did not catch anything). If control came back to CATCH via THROW, the THROW code will be on the stack.

Best to catch at the highest point convenient in the program, some say

Thusly, in our example test above we test the error code returned by CATCH. If it's 0 then DIV did not throw anything, everything worked. If the return code is not zero however, something went wrong in DIV. We then examine the code, and, if it's 99 we indicate a divide by zero error.

If the error code is not 99 (which is the only thing that test-div is interested in) then something else went wrong (maybe the word / threw a different error of its own). All we know is, we're interested in error codes 0 and 99, and if aint either of them then it's "sombodys else's problem". In this case, we can THROW the error again, which will cause it to be caught by the next higher CATCH in the chain (if there is one).

Another THROW – CATCH example:-

```
: 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 ;
```