

# ESP32 picoc C Language Interpreter

The sketch at [https://github.com/rlunglh/IOT\\_with\\_your\\_PC/blob/master/ESP32Program.zip](https://github.com/rlunglh/IOT_with_your_PC/blob/master/ESP32Program.zip) implements a C Language Interpreter on the ESP32 using the Arduino IDE to create and upload the sketch to your ESP32. There are many good explanations of setting up the Arduino IDE for the ESP32; a good place to look for this information is at <https://randomnerdtutorials.com/installing-the-esp32-board-in-arduino-ide-windows-instructions/>

Once the Arduino IDE is installed just unzip the ESP32Program.zip file into your Arduino folder. You need to edit and upload some files to the ESP32 for the sketch to run. First look at the WIFIname.data file in the ESP32Program/data/data folder on your PC. This file supplies the SSID for the ESP32 to use when connecting to WiFi as a station, so change its name to match your WiFi environment. You also need to edit the ESP32Program/data/data/WIFIpass.dat file to hold your WiFi network password for the ESP32 to use when connecting. After editing these files, you can use the Tool/ESP32 sketch data upload menu in the Arduino IDE item to upload the data folder to your ESP32. To install the ESP32 upload tool follow the instructions at <https://github.com/me-no-dev/arduino-esp32fs-plugin> You may want to make some changes to the ESP32Program file in the Arduino IDE prior to building and uploading your sketch to your ESP32. The first few lines of the sketch are shown below:

```
#define ALWAYS_STATION
// define ALWAYS_STATION to restart EPS32 if it can't connect to the specified SSID
// when defined it will not enter AP mode on a Station Connect
// failure. It will restart until it successfully connects
// to the SSID specified in /data/WIFIname.dat using the
// password specified in /data/WIFIpass.dat
//#define TFT
// define TFT to enable use of an attached 320x240 TFT Display
//#define OLED
// define OLED to enable use of an attached 128x64 OLED Display
//#define SSD1306OLED
// define SSD1306OLED if using the Wemos ESP32 WROOM with OLED
//#define BME280
// defining BME 280 will include support for BME280 sensor
//#define NEO_PIXEL
// defining NEO_PIXEL includes Adafruit_NeoPixel support functions;
//#define ePAPER
// defining ePAPER includes 1.54 in ePaper Display from WaveShare
```

As shown in the code comments ALWAYS\_STATION is defined to assure that the ESP32 will not enter Access Point mode. If a station connect fails the ESP32 will repeatedly restart and try to connect to the specified SSID until connection is successful. If you do have a problem connecting, make sure that the WIFIname.dat and WIFIpass.data files in ESP32Program/data/data on your PC have the correct information for your environment. If you want to use the esp32 in AP mode, just put a blank into the WIFIname.data file and comment out the #define ALWAYS\_STATION line. He ESP32PEogram supports an SPI connected TFT color graphic display or a 128x64 OLED display. These are enabled by uncommenting the //#define TFT . //#define OLED, and //#define ePAPER lines. You can use ePAPER, OLED, and TFT defines concurrently and get a sketch that will work with the defined displays. Once you have the setting needed in the sketch, build and Upload for your sketch to the ESP32. When running, the Serial Monitor (at 1000000 baud) will show the IP address where the picoc Interpreter is running when the ESP32 restarts. In my environment I have added the line 192.168.0.21 picoc to my ..\Windows\System32\drivers\etc\hosts file to allow me to use picoc as an alias for the server. In a browser, navigate to the ESP32 address to see the first display. An example browser view is show below:

← → ↻ ⓘ Not secure | picoc/

**FILE MANAGER** **SETTINGS** **CODE TEMPLATE** **HELP** **picoc Function Help**



Shows runnable files allowing Edit or Run along with Delete, Rename, and Newfile. Also allows you to Upload new files



System settings including WiFi SSID and password for Station Mode



Generates a new file named defaultx.c including setup and loop templates much like Arduino File/New



Displays this file in a new Browser Window



Shows function help more explained later in this document

The following paragraphs give a quick tour of operation. Click the File Manager button giving the display shown below:

**Choose File** No file chosen **Upload**

**Delete** **Edit** **Run** **Rename** Program Arguments  **NewFile**

```

/analogWrite.c
/backup
/debugPointers.c
/default.c
/default1.c
/defs.txt
/drawing.c
/dropGlobals.h
/ePaperDemo.c
/example.c
/fadeBuiltin.c
/gaugeDemo.c
/goback.html
/heartbeat.c
/hershey.c
/ls.c
/NeoDemo.c
/nested.c
/nestedDebug.c
/oledDdemo.c
/prime.c
/primes.c
/primeWithSubs.c
/quicksort.c
/scrollText.c
/simpleBME.c
/sums.c
/tester.c
/usefull.h

```

Double Click the /default.c line in the select giving:

```
/default.c Open Run Program Arguments  Reset ESP32 Screen Capture

int main()
{
    int i;
    printf("square root of 2 is %.5f\n",sqrt(2));
    printf("print with commas 123456789 is %, \n",123456789);
    printf("atoi(\"2000000000\") is %, \n",atoi("2000000000"));
    printf("size of char is %d\n",sizeof(char));
    printf("size of short is %d\n",sizeof(short));
    printf("size of int is %d\n",sizeof(int));
    printf("size of long is %d\n",sizeof(long));
    printf("size of float is %d\n",sizeof(float));
    printf("size of double is %d\n",sizeof(double));
    return i;
}
```

This shows the content of the /default.c file and allows editing the content and saving changes using the Save Button. The Save button will not appear unless you make a change in the edit textarea. When a Save is required, the display will appear as shown in the following figure.

```
/default.c Open Save Run Program Arguments  Reset ESP32 Screen Capture

int main()
{
    int i;
    printf("square root of 2 is %.5f\n",sqrt(2));
    printf("print with commas 123456789 is %, \n",123456789);
    printf("atoi(\"2000000000\") is %, \n",atoi("2000000000"));
    printf("size of char is %d\n",sizeof(char));
    printf("size of short is %d\n",sizeof(short));
    printf("size of int is %d\n",sizeof(int));
    printf("size of long is %d\n",sizeof(long));
    printf("size of float is %d\n",sizeof(float));
    printf("size of double is %d\n",sizeof(double)); |
    return i;
}
```

You can also change the edited file by changing the file name in the first text box and clicking Open. If the Save button is available, you can change the file name in the text box and the file will be saved to the named entered. File names must start with / and can include additional / to breakout files into different directories and you are free to organize the files any way you choose. The File Manager will list files showing each file's full path. The file manager only shows program files and does not show .jpg .ico or .dat files. The ls() function in the Interpreter will show all files along with their file sizes.

This example is done just to show a simple program's operation. Click the Run button giving the output shown in the following figure:

```
Program to run is /default.c

/default.c Open Run Program Arguments  Reset ESP32 Screen Capture

1 int main()
2 {
3     int i;
4     printf("square root of 2 is %.5f\n",sqrt(2));
5     printf("print with commas 123456789 is %, \n",123456789);
6     printf("atoi(\"2000000000\") is %, \n",atoi("2000000000"));
7     printf("size of char is %d\n",sizeof(char));
8     printf("size of short is %d\n",sizeof(short));
9     printf("size of int is %d\n",sizeof(int));
10    printf("size of long is %d\n",sizeof(long));
11    printf("size of float is %d\n",sizeof(float));
12    printf("size of double is %d\n",sizeof(double));
13    return i;
14 }

Global Level Outputs

Output from main( )

-> square root of 2 is 1.41421
-> print with commas 123456789 is 123,456,789
-> atoi("2000000000") is 2,000,000,000
-> size of char is 1
-> size of short is 2
-> size of int is 4
-> size of long is 4
-> size of float is 8
-> size of double is 8

Program returned 0, free memory is 71728
```

When programs are run, you'll be shown what file is running and any arguments passed along with a listing of the file, Global outputs, the program output, the return value, and the amount of free memory available on the ESP32 when the program completes. This example was chosen to let you see that int and long types are equivalent as both are 32 bit values, and that the float and double types are equivalent as both are 64 bit values in the Interpreter.

If a running program has a syntax error, you will be shown the Program Error Information. As an example, click the Edit button and change the 2nd occurrence of atoi to aatoi and click the Save button. Now when you click Run you'll see the display shown below:

The screenshot shows a software interface for running a program. At the top, it says "Program to run is /default.c". Below this is a toolbar with buttons for "Open", "Run", "Reset ESP32", and "Screen Capture". The "Run" button is highlighted in green. Below the toolbar is a code editor showing the following C code:

```
1 int main()
2 {
3     int i;
4     printf("square root of 2 is %0.5f\n",sqrt(2));
5     printf("print with commas 123456789 is %,\n",123456789);
6     printf("atoi(\"2000000000\") is %,\n",atoi("2000000000"));
7     printf("size of char is %d\n",sizeof(char));
8     printf("size of short is %d\n",sizeof(short));
9     printf("size of int is %d\n",sizeof(int));
10    printf("size of long is %d\n",sizeof(long));
11    printf("size of float is %d\n",sizeof(float));
12    printf("size of double is %d\n",sizeof(double));
13    return i;
14 }
```

Below the code editor is a section for "Global Level Outputs" and "Output from main( )". Below that is a section for "Program Error Information ...". The error message is:

```
Error at Line 6 and Character Pos 46
> printf("atoi(\"2000000000\") is %,\n",atoi("2000000000"));
/default.c:6:46 'aatoi' is undefined
```

Restarting ESP32 .....

Redirecting to Edit Page for /default.c in 30 seconds

You can also click Open button to go there quicker

```
-> square root of 2 is 1.41421
-> print with commas 123456789 is 123,456,789
```

The Program Error Information section shows the error, along with the line and character position where the interpreter reached an error condition. It also shows the error cause, in this case, 'aatoi' is undefined. This particular error is well diagnosed and you can verify that clicking Open and changing atoi to aatoi, Saving the file, and clicking Run causes the program to again run without errors.

The handlers around the picoc interpreter eliminate any Interpreter error cleanup problems by simply restarting the ESP32, then, after a delay of 30 seconds, you will be returned to the Edit page for program you are running. You can also click the Open button on the Run page to get back to the editor more quickly when you quickly recognize the error cause and are ready to make program changes to fix the problem.

Behind the screens, the interpreter collects all globally defines functions and variables and automatically deletes them after a program run so the program can be run repeatedly without having the interpreter complain that things such as main are already defined. This is accomplished by recording global scope object creation in the /DropGlobals.h file – when you ran the /default.c program, its contents were updated to what is shown below

```
drop("main");
drop("__exit_value");
```

This file is processed by the interpreter at program completion to cleanup globals to make the next run.

The SETTIGNS button on the Admin tool bar gives you the Settings dialog shown in the following figure.

## ESP32 picoc version v2.2 beta r C Interpreter

Station Mode (Connect to your router) :

Name:   
Pass:

Ap mode (ESP brocast out its own ap) :

Name:   
Pass:   
Must be at least 8 characters

Log In Key (For Security) :

Log In Key:

Display menu bar on index page:  Disable

Run default.c at startup :  Enable

Server listening port:

OTA URL. Leave blank for default:

Save

Format

Update

Restart

Important fields are the Station Mode Name and Pass fields if you want to run in Station mode these need to be set correctly for your environment. You can assure this, without the chicken and egg problem, by editing the data/data/WIFIname.dat and WIFIpass.dat files and doing a Tools/ESP32 Sketch Data Upload menu operation in the Arduino IDE. You may want to also Run default.c at startup by clicking its Enable box towards the bottom of the page. Be sure to click the Save button after any changes are made.

## Sample Programs without External Displays

There are sample programs included in the sketch data directory, and hence uploaded to the ESP32 using Tool/ESP32 Sketch Data Upload menu item ( make sure the Serial Monitor is closed before doing the upload ) that will let you explore picoc C Language Interpreter basics.

The programs

- AnalogWrite.c
- debugPointers.c
- default.c
- example.c
- fadeBuiltin.c

- heartbeat.c
- ls.c
- nested.c
- nestedDebug.c
- prime.c
- Primes.c
- primeWithSubs.c
- quicksort.c
- sums.c
- tester.c

Can all be run without needing an external TFT, OLED, or ePaper display. Each program has a short synopsis in the following paragraphs.

analogWrite.c – this program brightens and dims the built in LED on the ESP32, The program is set to use pin 2, if you use an ESP module other than the DH-ET line MiniKit, or the DOIT ESP32 DEVKIT that I have tested with, you may need to change the pin being used. For instance, on a HELTEC WiFi Kit 32 you need to use pin 25 which is accomplished by changing the line `int LED=2;` to `int LED=25;`

debugPointers.c – an example program showing how the interpreter presents pointer reference data in the Debug mode.

default.c – you’ve already been shown this program’s operation in the initial ESP32Program introduction.

example.c – shows some Debug output for nested loops.

fadeBuiltin.c – example program showing the `loop()` function in uninterrupted use. You can stop the loop by clicking the ResetESP32 button. This will restart the ESP32 and return you to the Edit view of the file being run

heartbeat.c – simply blinks the built in LED in a heartbeat fashion, again you may have to change the pin number for your specific board.

ls.c – lists the SPIFFS file system showing all file names and sizes.

nested.c – shows the operation of nested for loops in the interpreter and is really present to set the stage for nestedDebug.c

nestedDebug.c - This program introduces the interpreter’s debug features. Its output when run is shown in the following figure.

Program to run is /nestedDebug.c

The screenshot shows an IDE window with a C program named `/nestedDebug.c`. The program code is as follows:

```
1 int main(int argc, char ** argv)
2 {
3     Watch("i");
4     Watch("j");
5     for (int i=0; i<4; i++)
6     {
7         if (i==2) Debug();
8         if (i==3) stopDebug();
9         for (int j=0; j<4; j++)
10            printf("i*4+j = %d\n", i*4+j);
11    }
12    return 0;
13 }
```

Below the code, the "Global Level Outputs" section shows "Output from main( )". The output is a tabular format with two columns: the source line being executed (preceded by `->`) and the current values of watched variables `i` and `j`.

Source Line	Variable i	Variable j
<code>10: i*4+j = 0</code>	0	0
<code>10: i*4+j = 4</code>	4	0
<code>10: i*4+j = 8</code>	8	0
<code>10: i*4+j = 12</code>	12	0
<code>9: for (int j=0; j&lt;4; j++)</code>	2	0
<code>9: for (int j=0; j&lt;4; j++)</code>	2	1
<code>9: for (int j=0; j&lt;4; j++)</code>	2	2
<code>9: for (int j=0; j&lt;4; j++)</code>	2	3
<code>11: }</code>	2	3
<code>5: for (int i=0; i&lt;4; i++)</code>	2	3
<code>5: for (int i=0; i&lt;4; i++)</code>	3	3
<code>5: for (int i=0; i&lt;4; i++)</code>	4	3
<code>5: for (int i=0; i&lt;4; i++)</code>	0	3
<code>7: if (i==2) Debug();</code>	2	3
<code>8: if (i==3) stopDebug();</code>	3	3
<code>8: if (i==3) stopDebug();</code>	4	3
<code>12: return 0;</code>	4	3

At the bottom, it states "Program returned 0, free memory is 73320".

You see the program listing as in the program examples shown for default.c. Lines 3 and 4 set watches for variables `i` and `j`. Line 7 initiates debug operation when `i` is equal to 2. Line 8 stops debug operation when `i` is equal to 3. The interpreter gives you a conditional debugging feature since the `Debug()` functions can be called with any combination of conditional logic you'd like. The Output from `main()` section shows a tabular format. Outputs from the program ( here caused by `printf` functions ) are entered on a separate line preceded by `'->'`. The source lines being executed begin to show after the `Debug()` function is called. Line 7 of the program causes debug operation to start when `i` is 2. The display then begins showing debug trace output with a `line#: col# >` leader and the line being executed next shown with an inverse character at the position where the parser will scan next. Also shown in this table is a second column that presents any Watch variables. At the first trace line 8, `i` and `j` are shown to be 2 and 4 respectively. The next line shows that the for `j` statement is about to be executed. The 9:8 line shows that the for evaluation will next execute the `int j=0` assignment. Line 10:0 shows that the `printf` is the next statement to be executed and that `j` is now 0. After this the program output from the `printf` function is printed as `i*4+j = 8`. The for loop trace then continues until we get to 8:13 when the `stopDebug()` function is executed and tracing stops. After that the remaining program outputs are printed up to `i*4+j = 15` and the program returns the value 0.

These combinations of `Debug`, `stopDebug`, `Watch`, and `stopWatch` function, along with conditional execution of these statements, give you great flexibility in examining program execution and working out problems in C language code.

The `prime.c`, `primes.c` and `primeWithSubs.c` all explore computationally demanding application for the ESP32. These programs are all implementations of a prime number sieve that checks for integer divisors of a number with no remainder and if no even divisors are found the number is added to the prime number count. Also prime numbers found can be output for each `n` primes specified as range. Let's look at the output of `prime.c` as provided in the stock ESP32Program data directory.

Program to run is /prime.c

/prime.c

Open

Run

Program Arguments

```
1 int main(int argc, char ** argv)
2 {
3     int t1, start=1001, end=5000, mcount=0, k, n, lim, sn, p, pc=0, lastp=0, phold=0, rpt=100;
4     if (argc>=4)
5     {
6         argv++;
7         start=atoi((char *)*argv++);
8         end=atoi((char *)*argv++);
9         rpt=atoi((char *)*argv++);
10    }
11    //setConsoleOn(1);
12    n = start; lastp=n; lim = end; sn=n;
13    printf("Finding primes between %, and %, \n\n", n, lim);
14    t1=sysTime();
15    while (n<lim)
16    {
17        k = 3; p = 1; n = n + 2;
18        while ((k * k <= n) && p)
19        {
20            p = n%k; mcount++; k = k + 2;
21        }
22        if (p)
23        {
```

Global Level Outputs

Output from main( )

```
-> Finding primes between 1,001 and 5,000
-> prime # 100 is 1,721 in this range 13.89 % are primes
-> prime # 200 is 2,503 in this range 12.79 % are primes
-> prime # 300 is 3,323 in this range 12.20 % are primes
-> prime # 400 is 4,129 in this range 12.41 % are primes
-> prime # 500 is 4,993 in this range 11.57 % are primes
->
Found 501 primes
-> Last prime was 4,999
-> It took 3.810 seconds to process
-> 19,205 loops were performed, that's 5,040 per second
```

Program returned 501, free memory is 56672

As you can see above, it lists the prime found after each 100 discoveries, and processes over a range of 1001 to 5000. The program also times its execution and counts how many while ( (k\*k<=n && p) loops are performed to allow reporting the loops completed per second, in this case, 5,040 per second. I acknowledge that the interpreter completes 5,040 loops per second including a multiplication, two compares, a modulo divide, an increment and an add but, to say the least, this is not exceptional performance. The primes.c program illustrates how this can be improved by placing the while loop into compiled code that is called by the interpreter. Primes.c Run output is shown in the next figure.



Program to run is /primes.c 1001 5000 100

/primes.c

Open

Run

Program Arguments 1001 5000 100

```
1 int main(int argc, char ** argv)
2 {
3     int start=2000000001, end=2000100000, rpt=1000;
4     if (argc>=4){ argv++; start=atoi((char *)*argv++); end=atoi((char *)*argv++); rpt=atoi((char *)*argv++);
5     int pc=isprime(start, end, rpt);
6     return pc;
7 }
```

Global Level Outputs

Output from main( )

Finding primes between 1,001 & 5,000

```
prime #    100 is 1,72113.89 % are prime
prime #    200 is 2,50312.79 % are prime
prime #    300 is 3,32312.20 % are prime
prime #    400 is 4,12912.41 % are prime
prime #    500 is 4,99311.57 % are prime
Last prime was 4,999
```

```
501 primes found
19,205 prime check loops performed in 0.33 sec
That's 58,911 per second
```

Program returned 501, free memory is 59672

This shows that the compiled code ran over 10 times faster. We can realize even greater speed improvements if we run over larger numbers as shown below.

Program to run is /primes.c

---

OpenRun

```
1 int main(int argc, char ** argv)
2 {
3   int start=2000000001, end=2000100000, rpt=1000;
4   if (argc>4){ argv++; start=atoi((char *)*argv++); end=atoi((char *)*argv++); rpt=atoi((char *)*argv++); }
5   int pc=isprime(start, end, rpt);
6   return pc;
7 }
```

Global Level Outputs

---

Output from main( )

---

```
Finding primes between 2,000,000,001 & 2,000,100,000

prime # 1,000 is 2,000,021,137 4.73 % are prime
prime # 2,000 is 2,000,042,053 4.78 % are prime
prime # 3,000 is 2,000,062,553 4.88 % are prime
prime # 4,000 is 2,000,083,651 4.74 % are prime
Last prime was 2,000,099,957

4,745 primes found
126,207,107 prime check loops performed in 11.65 sec
That's 10,831,368 per second
```

---

Program returned 4745, free memory is 53264

---

Here we ran the prime number sieve over much larger numbers, to get more while loop iterations and showed results for every 1000 primes found. The startling thing is that when the Interpreter calls compiled code to do the computationally demanding parts of the program, the while loops soar to close to 11 million per second which is over a 21,000 times improvement. The compiler shouldn't get all the credit because this interpreter is particularly slow – but it does fit nicely on the ESP32.

ESP32Program can give you some very rewarding experiences if you are new to C programming – just put code that you want to verify into a file on the ESP32 and test away without the Arduino compile and upload delays, and with a conditional trace and watch facility. If you have a section of sketch code that is not operating as you expected or hoped – just paste the appropriate portion of the code into an ESP2 file and run the Debug and Watch functions to see what is really happening without reverting to myriad Serial.print(f) functions (not to mention recompiling and uploading for each Serial.print.. statement).

The primesWithSubs.c program illustrates using a subroutine to perform the while ((k\*k<n) && p) loop.

All three of these programs can be run using program arguments entered, logically enough in the Program Arguments text box. A run of the primeWithSubs.c program with program arguments is shown in the following figure.

Program to run is /primeWithSubs.c 1001 3000 100

/primeWithSubs.c **Open** **Run** Program Arguments 1001 3000 100 **Screen Capture**

```
1 drop("main");drop("_exit_value");drop("__argc");drop("__argv");drop("isprime");
2 int isprime(int start,int end,int range)
3 {
4     int n,lastp,lim,sn,t1,k,p,mcount=0,phold,pc=0;
5     n = start; lastp=n; lim = end;
6     if (n%2==0) n++;n-=2; sn=n;
7     printf("Finding primes between %i, and %i,\n\n",n,lim);
8     t1=sysTime();
9     while (n<lim)
10    {
11        k = 3; p = 1; n = n + 2;
12        while ((k * k <= n) && p)
13        {
14            p = n%k; mcount++; k = k + 2;
15        }
16        if (p)
17        {
18            pc = pc + 1; phold=n;
19            if (pc%range==0)
20            {
21                printf("prime # %5, is %7, in this range %5.2f %% are primes\n",pc,n,(float)range*100.0/(n-lastp));
22                lastp=n;
23            }
24        }
25    }
26 }
```

Global Level Outputs

Output from main( )

```
-> Finding primes between 999 and 3,000
-> prime # 100 is 1,721 in this range 13.89 % are primes
-> prime # 200 is 2,503 in this range 12.79 % are primes
->
Found 263 primes
-> Last prime was 3,001
-> It took 1.716 seconds to process
-> 8,362 loops were performed, that's 4,872 per second
```

Program returned 263, free memory is 84812

Quicksort.c – quicksort is a classic sorting algorithm that includes recursion and is included in the samples to illustrate a more complex program logic task being run on the interpreter. Its output is shown in the following figure, first it lists the String array to be sorted followed by the sort results.

Program to run is /quicksort.c

/quicksort.c

Open

Run

Program

```
1 char * array[16];
2
3 //Swap integer values by array indexes
4 void swap(int a, int b)
5 {
6 //Watch("a");Watch("b");
7     char * tmp = array[a];
8     array[a] = array[b];
9     array[b] = tmp;
10 }
11
12 //Partion the array into two halves and return the
13 //index about which the array is partitioned
14 //int partition(int a, int b, int p, int q)
```

Global Level Outputs

Output from main( )

```
-> this
-> is
-> a
-> tale
-> about
-> the
-> quick
-> sort
-> algorithm
-> sorting
-> sixteen
-> string
-> values
-> quicker
-> than
-> Lightning!
->
-> Lightning!
-> a
-> about
-> algorithm
-> is
-> quick
-> quicker
-> sixteen
-> sort
-> sorting
-> string
-> tale
-> than
-> the
-> this
-> values
->
```

Program returned 4745, free memory is 43804

Sums.c – is another recursion algorithm that is easier to follow since it is a small piece of code. The output of a sums.c run with Debug and Watch is shown in the following figure.

Program to run is /sums.c

/sums.c

Open

Run

Program Arguments

```
1 int sums(int top)
2 {
3     if (top==1) return 1;
4     return top+sums(top-1);
5 }
6 void main()
7 {
8     Debug();Watch("top");
9     int start=10;
10    int sum=sums(start);
11    printf("Sums of 1 to %d are %d\n",start,sum);
12 stopDebug();
13 }
```

Global Level Outputs

Output from main( )

```
8: 8 >Debug();Watch("top");
9: 0 > int start=10; top not defined
10: 0 > int sum=sums(start); top not defined
2: 0 > { top : int 10
3: 0 > if (top==1) return 1; top : int 10
4: 0 > return top+sums(top-1); top : int 10
2: 0 > { top : int 9
3: 0 > if (top==1) return 1; top : int 9
4: 0 > return top+sums(top-1); top : int 9
2: 0 > { top : int 8
3: 0 > if (top==1) return 1; top : int 8
4: 0 > return top+sums(top-1); top : int 8
2: 0 > { top : int 7
3: 0 > if (top==1) return 1; top : int 7
4: 0 > return top+sums(top-1); top : int 7
2: 0 > { top : int 6
3: 0 > if (top==1) return 1; top : int 6
4: 0 > return top+sums(top-1); top : int 6
2: 0 > { top : int 5
3: 0 > if (top==1) return 1; top : int 5
4: 0 > return top+sums(top-1); top : int 5
2: 0 > { top : int 4
3: 0 > if (top==1) return 1; top : int 4
4: 0 > return top+sums(top-1); top : int 4
2: 0 > { top : int 3
3: 0 > if (top==1) return 1; top : int 3
4: 0 > return top+sums(top-1); top : int 3
2: 0 > { top : int 2
3: 0 > if (top==1) return 1; top : int 2
4: 0 > return top+sums(top-1); top : int 2
2: 0 > { top : int 1
3: 0 > if (top==1) return 1; top : int 1
3: 14 > if (top==1) return 1; top : int 1
11: 0 > printf("Sums of 1 to %d are %d\n",start,sum); top not defined
-> Sums of 1 to 10 are 55
12: 0 >stopDebug(); top not defined
```

Program returned 4745, free memory is 69848

In the interpreter output, you can clearly see the value of top that is being passed to the sums function decreases from 10 to 1 and that at a value of 1 all the sums are returned and the total of Sums 1 to 10 is 55.

Tester.c – a simple program that illustrates the ls() and Cat() function outputs.

## Sample Programs Using External Displays

The programs

- drawing.c
- example.c
- hershey.c
- scrollText.c
- tester.c

Are used with a 320x240 TFT display which is my favorite way of running the ESP32.

If you use the MH-ET LIVE Minikit for ESP32 you get a Wemos mini D1 compatible footprint that can be used with the LOLIN TFT 2.4 Touch Shield making a simple, ready to use, ESP2 with a TFT color graphic display.

These programs are summarized in the following paragraphs.

When using a 320x240 TFT, the ESP32 will display the following after reset.

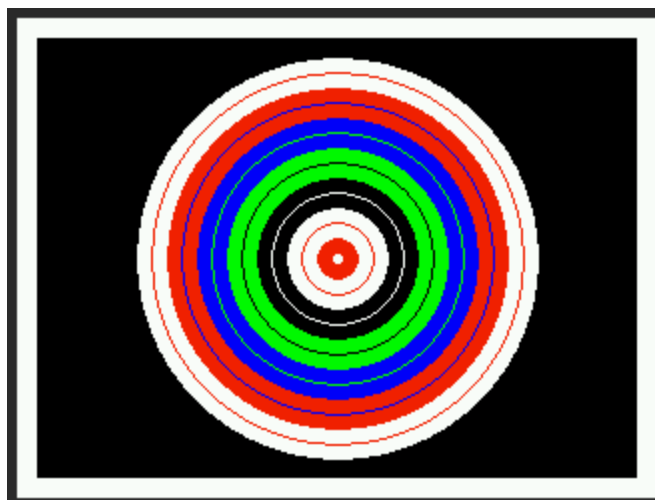


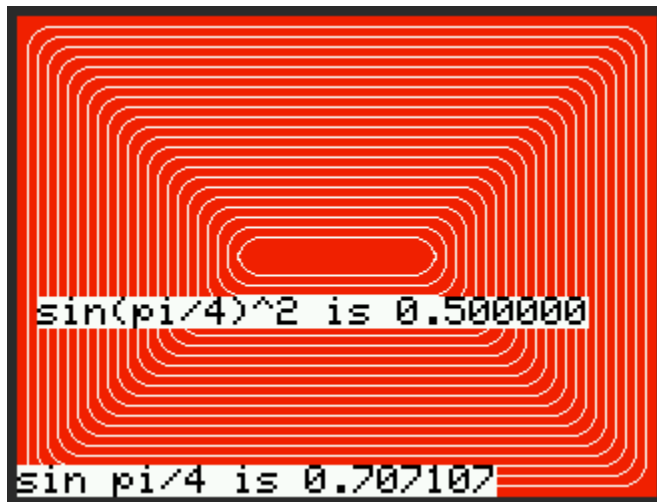
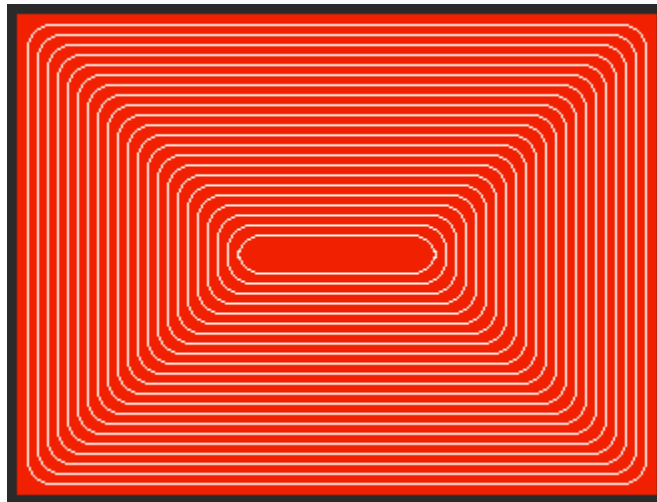
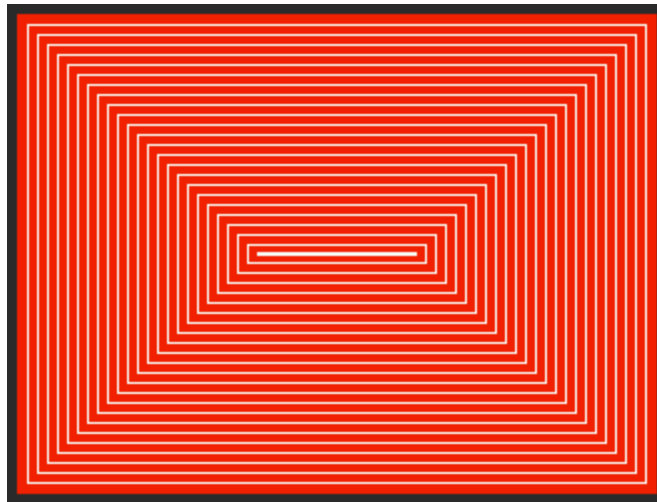
This display is a harmless advertisement for Micro Image Systems and the book *Building Blocks for IOT with your PC and WiFi Peripherals*. It also shows that the ESP32 is running in station mode with an IO address to 192.168.0.24 – your IP address will likely be different. If the ESP32 is running in AP mode it will show the display shown in the following figure.



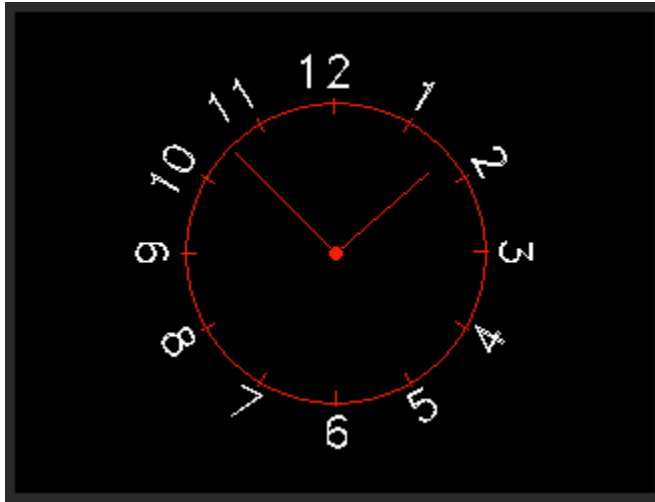
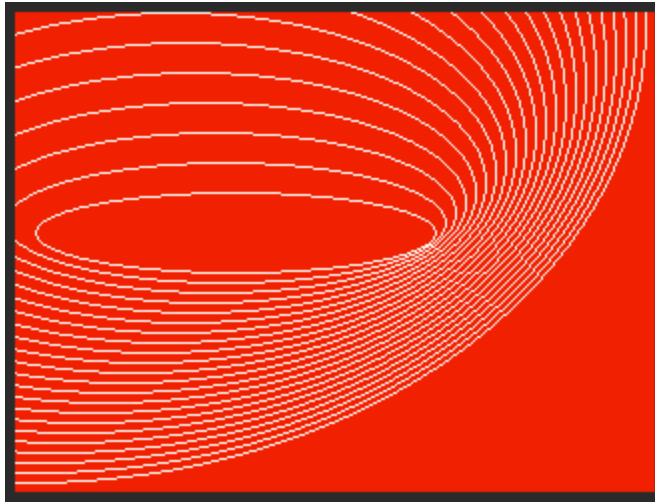
When in AP mode the Network Name will be ESP32PICOC but you can use the Settings page available from the Admin toolbar to change the name.

drawing.c – Produces some graphics drawings and then goes through a demo of the Hershey fonts built into the Interpreter by the author along with a slide show of images that are loaded on the ESP32. The drawing program calls screenCapture after each major display change and this will capture the TFT display images using the Processing platform and the Processing sketch ScreenCapture.pde available from the following URL [https://github.com/rlunglh/IOT\\_with\\_your\\_PC/blob/master/ScreenCapture.pde](https://github.com/rlunglh/IOT_with_your_PC/blob/master/ScreenCapture.pde) You will need the Processing environment to run the ScreenCapture.pde file and this can be downloaded and installed using the instructions at <https://processing.org/tutorials/gettingstarted/> The supplied ScreenCapture.pde sets the correct baud rate and is set to use your second enumerated COMM port. If you look at Device Manager and see only one device under Ports then you will need to change the Processing sketch line "int serial port = 1;" to "int serial port = 0;" The Processing ScreenCapture sketch will not run if the Arduino IDE Serial Monitor is running for your ESP32. Also, when ScreenCapture initially starts, it resets the ESP32. Therefore just get the ScreenCapture.pde running and then proceed with getting your programs running in the Interpreter. The Screen Capture button on the ESP32Proram web pages will trigger a TFT Screen Capture and the function screenCapture() will trigger a capture if placed within your programs. The following figures are the screen captures obtained automatically when running the drawing.c program.









Black On White???

White On Black???

Christmas Anyone???

*Hello World*

!"#\$%&'()\*+,-./0  
123456789:;<=>?@  
ABCDEFGHIJKLMNO  
PQRSTUVWXYZ[\]^  
\_`abcdefghijklmnop  
\_`abcdefghijklmnop  
pqrstuvwxyz{|}~

Serif Font

!"#\$%&'()\*+,-./0  
123456789:;<=>?@  
ABCDEFGHIJKLMNOP  
QRSTUVWXYZ[\]^\_`a  
bcdefghijklmnopqrs  
tuvwxyz{|}~

Sans Font

!"#\$%&'()\*+,-./0  
123456789:;<=>?@  
ABCDEFGHIJKLMNPO  
QRSTUVWXYZ[\]^\_`  
abcdefghijklmnopq  
rstuvwxyz<|>~

**Sans Font Bold**

!"#\$%&'()\*+,-./0  
123456789:;<=>?@  
ΑΒΧΔΕΦΓΗΙ·ΚΛΜΝΟΠ  
ΘΡΣΤΥ°ΩΞΨΖ[\]^\_`αβ  
χδεφγηι·κλμνοπρ  
στυ÷ωξψζ{|}~

**Greek Font**

!"#\$%&'()\*+,-./0  
123456789:;<=>?@  
ΑΒCDEFGHIJKL MN  
OPQ RSTUVWXYZ[\]  
]^\_`abcdefghijklmnopqr  
stuvwxyz{|}~

**Cursive Font**

!"#\$%&'()\*  
+,-./01234  
56789:;<=>  
?@ABCDEFGG  
Serif at Size=1.5

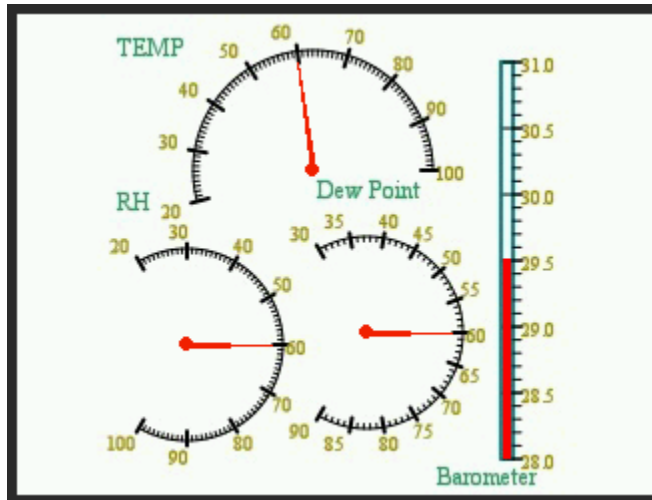
!"#\$%&'()\*+,-./0123456789:;<=>?  
@ABCDEFGHIJKLMN OPQRSTUVWXYZ[  
]\\_`abcdefghijklmnopqrstu vxyz{  
|}~

Serif at Size=0.5

!"#\$%&'()\*+,-./012345  
6789:;<=>?@ABCDEFGHI  
JKLMNOPQRSTUVWXYZ[\]  
^\_`abcdefghijklmnopqr  
stuvwxyz{|}~

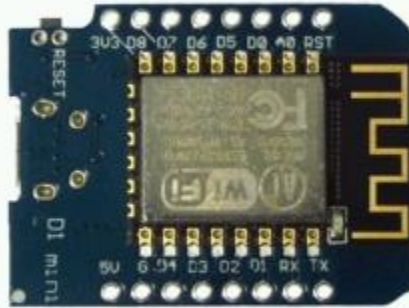
Serif at Size=0.75

A B C D E W X



**MIS** Micro  
Image  
Systems  
*picoc Interpreter*

WeMos





Even though all the displays presented by drawing.c have been shown in the preceding figures, you should watch it run if you have a TFT display because there are slow stroke drawings of the Cursive font and That's All Folks that are demonstrative regarding the drawing of the Hershey fonts.

This sample shows that you can display jpeg images on the TFT, draw any number of shapes and fills, along with Hershey Font text of varying sizes and colors, along with native TFT fonts in different fonts, sizes, and colors. These capabilities open a world of expressive peripherals that can communicate status, show sensor outputs, and provide a compelling display for your projects. With the Touch screen capability you can also make projects that have an interactive interface at the Touch Screen display.

example.c – was shown earlier without using the TFT display. This time uncomment the `TFTsetTextSize(1)` , `setConsoleOn(2)` and comment out the Debug related lines in the program, Save it, and click Run giving the cat function program outputs with console like output on the TFT display. A screen capture following program completion is shown in the following figure.

```

6 cat("/example.c",1);
7 Watch("i");
8 //Debug();
9 int i,start=1,end=11;
10 if (argc>3)
11 { printf("Running program %s", (char *)#argv++
),
12 start=atol(*argv++);
13 end=atol(*argv++);
14 printf(" %d %d\n",start,end);
15 for (i=start;i<end;i++) printf("%2d\n",i);
16 printf("%s\n","Done");
17 stopDebug(); // stopDebug before program ends
to prevent tracing in code areas not known to the De
bugger
18 return 0;
19 }
20 }
Done

```

hershey.c – this program illustrates most of the Hershey font built in functions and shows how to Invert the display for visual effects.

Years ago (1977), while working at IBM, I was introduced to a set of font definitions using vectors produced by Dr. Allen Vincent Hershey at the Naval Weapons Laboratory in 1967. Hence the name Hershey Fonts. These font definitions are quite well done and include serif and san serif fonts along with Greek and cursive fonts that are at least entertaining.

The Hershey functions are

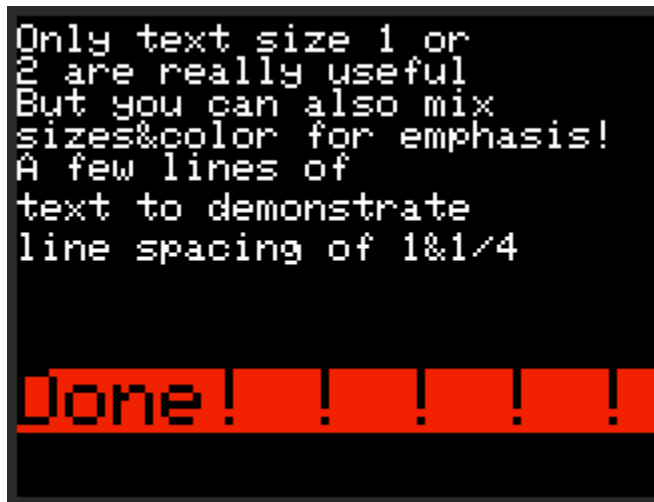
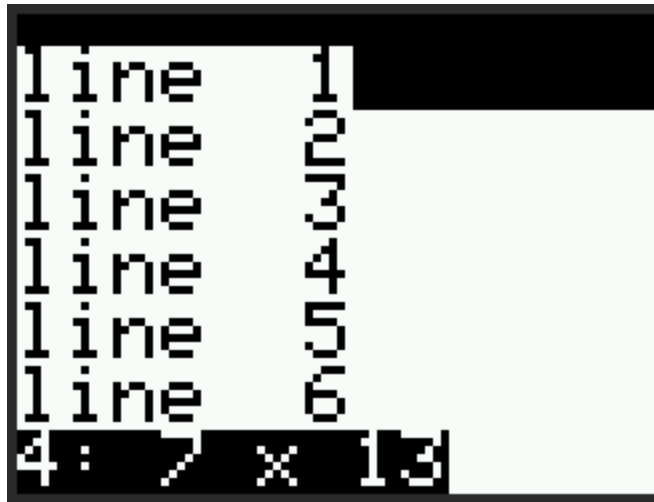
- void HFsetCursor(int,int); x,y
- void HFdraw(char,float,int); char,size,color
- void HFdrawRotated(int,int,char,float,int,float); xc,yx,char,size,color,angle
- void HFdrawStringRotated(int,int,float,int,float,char \*); x,y,radius,size,color,angle,char string
- int HFgetStringSize(char \*,float); char string,size -- returns length
- void HFdrawString(int,int,float,int,char \*); x,y,size,color,char string
- void HFdrawCenteredString(int,float,int,char \*); y,size,color,char string
- void HFdrawStringOpaque(int,int,float,int,int,char \*); x,y,size,foreColor,backColor,char string
- void HFsetFont(char \*); font name -- allowed values are serif sans sansbold greek cursive
- void HFsetStrokeDelay(int); set delay between strokes normally 0, non zero make for character drawing animation on screen

These provides for normal and opaque symbol strokes along with automatic centering and rotation.

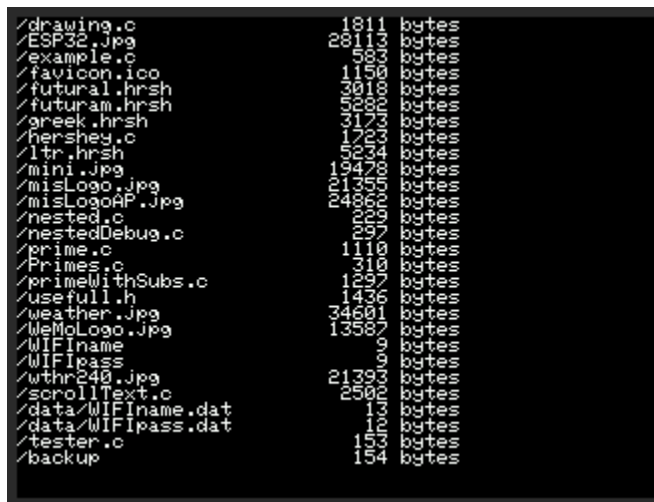
scrollText.c – this program does what the name implies and illustrates the scrolling of console output directed to the TFT display. A screenCapture of the TFT screens is shown in the following figures for various text sizes and colors.







tester.c – this program simply runs the cat() function. If you uncomment the line `///setConsoleOn(1);TFTsetTextSize(1); add screenCapture(); after the LS(); line, and then Save and Run you get the following output.`



```
/misLogoAP.jpg          24862 bytes
/nested.c                1000 bytes
/nestedDebug.c          1110 bytes
/prime.c                 1110 bytes
/Primes.c               1100 bytes
/primeWithSubs.c        1100 bytes
/usefull.h              1400 bytes
/weather.jpg            34681 bytes
/misLogo.JPG           13587 bytes
/WiFiname               1 bytes
/WiFipass               1 bytes
/wthr24g.jpg           2130 bytes
/scrollText.c          2500 bytes
/data/WiFiname.dat      1 bytes
/data/WiFipass.dat     1 bytes
/tester.c              150 bytes
/backup                154 bytes
```

```
cat("/tester.c", ...)
drop("main");
setConsoleOn(1);TFTsetTextSize(1);
ls();
screenCapture();
printf("\n");
cat("/tester.c",1);
void main()
{ printf("Program Done\n");}
Program Done
```

## Pulse Width Modulation and AnalogWrite

If you are going to be using the ESP32 in the Arduino environment it makes sense to have the analog, digital, and PWM capabilities of the Arduino IDE also available in the Interpreter. The interpreter includes the following functions with arguments that are integers unless otherwise indicated.

- `void pwmSetup(pin,frequency,range);` - set ESP32 pin to PWM output at frequency with values from 0 to range
- `void servoAngle(pin,angle);` set pin to PWM corresponding to float angle. Angle ranges from -90 - +90
- `void pwmServo(pin,duty);` set pin to float duty dutycycle, duty ranges from 0.0 to 1.0
- `void analogWrite(pin,value);` set pin to value – user must account for the pins range set in `pwmSetup` to get the value they really want. Generally the `analogWrite` function takes values of 0 to 4095.
- `void digitalWrite(pin,value);`
- `int digitalRead(pin);`
- `void pinMode(pin,char * mode);` set pin to mode "INPUT" "OUTPUT" or "INPUTPULLUP"

The `analogWrite` program makes use of the `setServoReport` and `analogWrite` functions.

## Interactive Help

You can also get function references directly from the ESP32Program web pages. The “picoc Function Help” button along with the textbox to the right of the button are your gateway to function definitions. Say that you want to see all TFT\_ functions, just put TFT-\* in the text box and click the Picoc Function Help button. This will give you the following results.

Help for function TFT\_\*

---

```
void TFT_draw(char *,int,int); filename,x,y -- must be a Jpeg file
void TFT_drawCircle(int,int,int,int); xc,yc,radius,color
void TFT_drawEllipse(short,short,short,short,short); xc,yc,radiusx,radiusy,color
void TFT_drawLine(int,int,int,int,int); x1,y1,x2,y2,color
void TFT_drawRect(int,int,int,int,int); x,y,width,height,color
void TFT_drawRoundRect(int,int,int,int,int,int); x,y,width,height,radius,color
void TFT_drawTriangle(int,int,int,int,int,int,int); x1,y1,x2,y2,x3,y3,color
void TFT_fillCircle(int,int,int,int); xc,yc,radius,color
void TFT_fillEllipse(short,short,short,short,short); xc,yc,radiusx,radiusy,color
void TFT_fillTriangle(int,int,int,int,int,int,int); x1,y1,x2,y2,x3,y3,color
void TFT_fillRect(int,int,int,int,int); x,y,width,height,color
void TFT_fillRoundRect(int,int,int,int,int,int); x,y,width,height,radius,color
void TFT_fillScreen(int); color
int TFT_Gauge(float xc,float yc,float sang,float eang,float radius,float sval,float eval,int divisions,float
increments,int color,char * fmt,char * valueFmt);
void TFT_Gauge_draw(int); gauge#
void TFT_Gauge_drawDanger(int,float,float,int); gauge#,startValue,endValue, color
void TFT_Gauge_drawDangerByValue(int,float,float,int); gsuge#,startValue,endValue, color
void TFT_Gauge_dropGauges(); frees all TFT_Gauge storage
void TFT_Gauge_setPosition(int,float); gauge#,value
```

```
int TFT_HbarGraph(float x,float y,int width,int height,float sval,float eval,int divisions,float increments,int
color,char * fmt,char * valueFmt
void TFT_HbarGraph_draw(int); gauge#
void TFT_HbarGraph_dropGauges(); frees all HbarGraph gauge storage
void TFT_HbarGraph_setPosition(int,float); gauge#,value
void TFT_invertDisplay(int);, pass 0 for normal 1 for inverse
void TFT_print(char *); char string to print
void TFT_pushRect(int,int,int,int,short *); startx,starty,width,height
void TFT_readRect(int,int,int,int,short *); startx,starty,width,height
void TFT_setCursor(int,int); x,y y increases from 0 at top of display
void TFT_setTextColor(int,int); foreColor,backColor
void TFT_setTextSize(int); size
int TFT_VbarGraph(float x,float y,int width,int height,float sval,float eval,int divisions,float increments,int
color,char * fmt,char * valueFmt
void TFT_VbarGraph_draw(int); gauge#
void TFT_VbarGraph_dropGauges(); frees all VbarGraph gauge storage
void TFT_VbarGraph_setPosition(int,float); gauge#,value
```

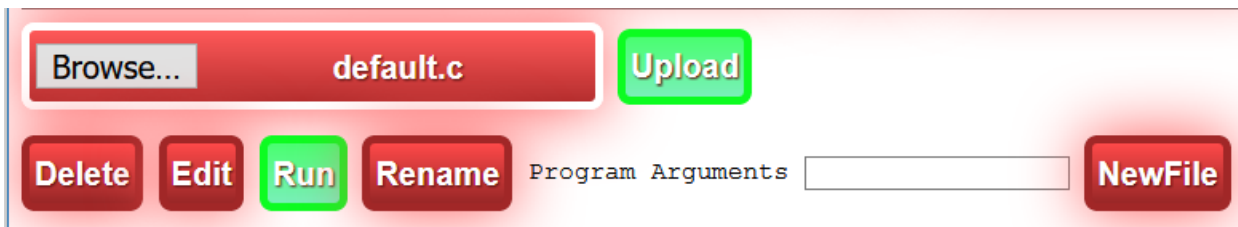
You can enter \* to get all functions - displays the defs.txt file, a full name, an empty string – to get the defs.txt file shown in a window with navigation, or as done above a string followed by \* to do a wildcard search. To return to your previous page just use the Go Back button.

## Miscellaneous Buttons on the File Manager Page

The Buttons on The File Manager page appear as shown in the following figure.



The top button, Browse... allows you to select a file to be uploaded to the ESP32. Once you click the Browse... button and select a file to upload, the Upload button will be made visible. As shown below.



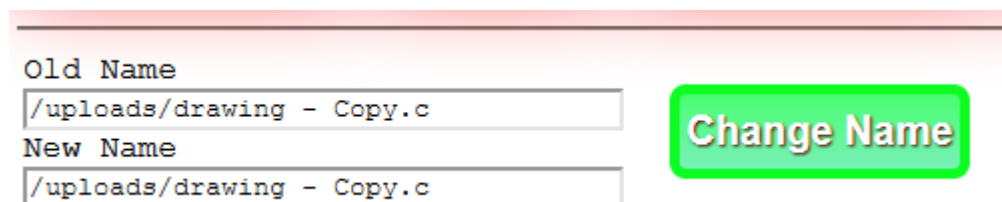
When you click Upload the selected file will be uploaded to the uploads folder on the ESP32 SPIFFS and you will be directed to an edit page for the uploaded file. **NOTE Only text type files can be uploaded in this manner.** If you want to add other file types to the ESP32 SPIFFS, put them in the ESP32Program's data folder and use the ESP32 Sketch Data Upload Tool. Be advised that any files in the SPIFFS that are not in the data directory, or that you have changed since the last upload, will be lost. I carefully copy and paste between the browser window and the PC's editor when I change a file on the ESP32 to prevent losing changes if I use the Arduino ESP32 Sketch Data Upload function.

As mentioned above, another means of transferring content from your PC to the ESP32 is to use the Edit file and use copy and paste between a file viewer/editor on your PC (my favorite is Notepad++) and the browser Edit page.

The Delete button does exactly what you'd expect it deletes the selected file in the file list from the ESP32 SPIFFS.

The Edit and Run buttons have already been discussed and their operation is intuitive.

The rename button lets you rename/move files on the ESP32 SPIFFS. Its dialog is shown in the following figure.



The Change Name button will rename the file from Old Name to New Name.

The New File button creates an empty file with the name newfile.txt and opens it in the edit view. If you do not save the file, for instance you click the File Manager button in the edit view before a Save, the file will not appear in the file system. Each New File button click will create files with higher sequence numbers than what already exists in the file system.

The Program Arguments filed lets you pass values to a program if it is coded with a main function following the main(int argc,char \*\* argv) {...} conventions. For instance the prime.c program accepts program arguments and its operation with Program Arguments is shown in two following figures.



Program to run is `/prime.c 1001 3000 100`



```
1 int main(int argc,char ** argv)
2 {
3     int t1,start=1001,end=5000,mcount=0, k, n, lim, sn, p, pc=0, lastp=0, phold=0,rpt=100;
4     if (argc>=4)
5     {
6         argv++;
7         start=atoi((char *)*argv++);
8         end=atoi((char *)*argv++);
9         rpt=atoi((char *)*argv++);
10    }
11    n = start; lastp=n; lim = end; sn=n;
12    printf("Finding primes between %, and %, \n\n",n,lim);
13    t1=sysTime();
14    while (n<lim)
15    {
16        k = 3; p = 1; n = n + 2;
17        while ((k * k <= n) && p)
18        {
19            p = n%k; mcount++; k = k + 2;
20        }
21        if (p)
22        {
23            pc = pc + 1; phold=n;
24        }
25    }
26    }
```

#### Global Level Outputs

#### Output from main( )

```
-> Finding primes between 1,001 and 3,000
-> prime #   100 is   1,721 in this range 13.89 % are primes
-> prime #   200 is   2,503 in this range 12.79 % are primes
->
Found 263 primes
-> Last prime was 3,001
-> It took 0.214 seconds to process
-> 8,359 loops were performed, that's 39,106 per second
```

Program returned 263, free memory is 69692

The program by default runs with start=1001, end=5000, and rpt=100. When at least 3 arguments are passed ( making argc=4 since argv[0] if the program name) the code uses the parameters to fill in start, end, and rpt sequentially. The lines

```
4     if (argc>=4)
5     {
6         argv++;
7         start=atoi((char *)*argv++);
8         end=atoi((char *)*argv++);
9         rpt=atoi((char *)*argv++);
10    }
```

Illustrate how to use the argv values to set integers, they can just as easily be assigned as character string pointers i.e. char \* by not using the atoi() function.

The Code Template and HELP buttons in the Admin toolbar are discussed in the following two paragraphs.

The Code Template button creates a simple program template much like the Arduino File/New button. The template includes main, setup, and loop functions as shown below:

```
void setup();
void loop();
int main(int argc, char ** argv)
{
    setup();
    //for (;;) loop();
    // Uncomment line above to run your loop() function forever.
    // When running loop forever,
    // you'll get no response to web events
    // unless you include doLoop();
    // in your interpreted loop() function
    return 0;
}
void setup()
{
}
void loop()
{
    doLoop();
}
```

The program's main function is set to return an int and uses argc and argv inputs which are gathered from the Program Arguments textbox when the program is run. Even though argc and argv are declared, you don't need to make any use of them. The main function calls setup and will thereafter repeatedly call loop() if the for (;;) loop(); line is uncommented. The template includes doLoop() in the loop function to allow the browser buttons to be active when the sketch is running. Note however, that if doLoop() is called, that program outputs to the console will stop since the browser session is closed when doLoop() is called. doLoop() exists to provide a means to stop programs that have continuous Loop operations since it enables the Screen Capture and ResetESP32 buttons to be used. There are two means of getting program outputs when running a loop() function continuously in a program. First, you can use the sprintf(char \*) function to send output to the Serial Monitor – I like to use Termite by CompuPhase since it supplies and RTS control that will also reset the ESP32.





Secondly, you can use a TFT, OLED, or ePaper display with the ESP32 and send output to those devices. Particularly useful is `void setConsoleOn(int) ; 0 turns console output off for printf function, 1 turns console output on.` So `setConsoleOn(1) ;` will send your program's printf output to a console on the TFT. As an example, if you add `setConsoleOn(1);` near the top of the prime.c program, Save the file, and click Run, the TFT output will appear as shown below.

```

Finding primes between 1,001 and 5,000
prime # 100 is 1,721 in this range 13.89 % are pr
imes
prime # 200 is 2,503 in this range 12.79 % are pr
imes
prime # 300 is 3,323 in this range 12.20 % are pr
imes
prime # 400 is 4,129 in this range 12.41 % are pr
imes
prime # 500 is 4,993 in this range 11.57 % are pr
imes

Last prime was 4,999
It took 7.590 seconds to process
19,205 loops were performed, that's 2,530 per second

```

A better example of using a continuously running Loop() function including doLoop() is contained in the simpleBME.c program. This program uses a BME280 sensor that measures pressure, temperature, and relative humidity and communicates over an I2C serial interface. The interpreter includes the following functions for the BME280 sensor.

```

void BME_init(); must be called before using the BME280 sensor
float BME_readPressure(); returns barometric pressure from BME280 sensor
float BME_readRH(); returns relative humidity from BME280 sensor
float BME_readTemp(); returns temp from BME280 sensor

```

The simpleBME.c program uses all four functions. Its primary BME 280 calls and output functions are

```

float temp=BME_readTemp();
float pressure=BME_readPressure();
float rh=BME_readRH();
float tc=(temp-32)*5/9;
//DP = 243.04*( LN(RH/100)+( 17.625*T )/ (243.04 + T )) / (17.625 - LN(RH / 100) - (17.625*T) / (243.04 + T ))
float dp = (243.04*(log(rh/100)+((17.625*tc) / (243.04 + tc)))/ (17.625 - log(rh / 100) - ((17.625*tc) / (243.04 + tc))))*9.0 / 5 + 32;
printf("\n");
printf(" Temp is %0.1f F\n",temp);
printf(" Pressure is %0.2f in HG\n",pressure);
printf(" RH is %0.1f %%\n",rh);
printf("Dew Point is %0.0f F\n",dp);

```

These lines read the temp, pressure, and relative humidity into float values temp, pressure, and rh and calculate the Dew Point using natural log functions as shown in the comment //DP=... Then the program format prints these values with appropriate labels and units. The program's last lines in the loop() function are shown below.

```

delay(5); // this delays 5 msec and doLoop() calls the ESP32Program loop() which adds another 5 msec of delay
// for a total of 10 msec delay per loop cycle thus lCount%3000==0 is true every 30 seconds

```

This approach to running loop with a fairly short delay, assures that the ESP32Program gets to process web events frequently (here, typically 100 times per second) and results in a good user response. The screen captures shown below were taken using the Screen Capture button while the program was continuously running on the ESP32.

```
Temp is 83.9 F
Pressure is 29.95 in HG
RH is 45.4 %
Dew Point is 54 F
```

```
Temp is 83.9 F
Pressure is 29.95 in HG
RH is 45.4 %
Dew Point is 54 F

Temp is 84.2 F
Pressure is 29.95 in HG
RH is 44.8 %
Dew Point is 53 F
```

```
Temp is 83.9 F
Pressure is 29.95 in HG
RH is 45.4 %
Dew Point is 54 F

Temp is 84.2 F
Pressure is 29.95 in HG
RH is 44.8 %
Dew Point is 53 F

Temp is 84.1 F
Pressure is 29.95 in HG
RH is 44.8 %
Dew Point is 53 F
```

The /oledDemo.c program on the ESP32 provides a simple example of using a 128x64 pixel OLED I2C attached display with the interpreter. To use the o\* functions, OLED must be defined when compiling the ESP32Program sketch. The program's setup function runs the following lines

```
int i;char buf[33];
oclear();
odrawString(0,0,"Display is 6x21");
for (i=1;i<6;i++) {
    sprintf((char *)&buf,"Display line %d is drawn here",i);
    odrawString(0,10*i,(char *)&buf);
}
odisplay();
delay(5000);
oclear();
odrawString(0,25,"Hello World");
odisplay();delay(3000);oconsoleInit();
for (i=0;i<21;i++)
{
    sprintf((char *)&buf,"Line %d is put on the display here",i);
    oconsolePrintln((char *)&buf);delay(250);
}
```

The help lines for these functions are

```
void oclear(void); clears OLED display, you still have to call odisplay to show
changes
void oconsoleInit(); must be called to start OLED console display
void oconsolePrintln(char *); draw char string at current cursor x,y
void odisplay(void); update display
void odrawLine(int,int,int,int); x1,y1,x2,y2
void odrawRect(int,int,int,int); x,y,width,height
void odrawString(int,int,char *); x,y in pixels,char string
void ofillRect(int,int,int,int); x,y,width,height
void oprint(char *); display in OLED at current cursor position
void oprintln(char *); display in OLED at current cursor position with [CR]
void osetCursor(int,int); x,y
void osetPixel(int,int); x,y
```

When using the OLED, be sure to call odisplay(); each time drawing operations are completed or your display changes will not be shown.

Similar to the OLED display, there is support for a 1.54 inch 200x200 ePaper display that is particularly useful on sensor projects since it provides a low power solution that runs well on batteries and can take advantage of the ESP32's deep sleep modes and still display its information during deep sleep. A fairly complete and useful example ePaper program is /ePaperDemo.c. This program provides an example temperature, relative humidity, barometric pressure, and dew point bar graph display. The ePAPER global must be defined when compiling the ESP32Program to use an EPaper display. The available functions are shown below.

```
void ePaper_drawLine(int,int,int,int,int) x1,y1,x2,y2,color
void ePaper_drawRect(int,int,int,int,int) x,y,width,height,color -- 0 is black 0xffff is white
void ePaper_fillRect(int,int,int,int,int) x,y,width,height,color
void ePaper_init() initialize ePaper display
void ePaper_powerDown(); put the ePaper display in powerDown mode
void ePaper_println(char *);" print char string
```

```
void ePaper_setCursor(int,int); x,y  
void ePaper_setTextColor(int); color
```

Color values are 0 for black and 0xffff for white.

## An Important Note

When testing the Interpreter I introduced two files with recursion. A simple implementation of quicksort, a case insensitive quicksort is used to sort the File Manager file list within the Interpreter, so I thought that it would also make a good program example. I also included a sums.c program that uses recursion to calculate the sum of numbers from a given n to 1. I found that, to my surprise, they both caused the Interpreter to crash. Oddly, they run fine on a Windows or Linux implementation of picoc. After some meaningful time with Google and some head scratching, I discovered that the ESP32 implementation for the Arduino IDE uses a very small stack allocation and that this was causing the crash. So to run these recursive programs successfully, you'll need to edit the code in your `..\ArduinoData\packages\esp32\hardware\esp32\1.0.2\cores\esp32\main.cpp` file and make the change highlighted in bold below.

```
extern "C" void app_main()  
{  
    loopTaskWDTEnabled = false;  
    initArduino();  
    xTaskCreateUniversal(loopTask, "loopTask", 1.5*16384, NULL, 1, &loopTaskHandle, CONFIG_ARDUINO_RUNNING_CORE);  
}
```

## Extending/Enhancing the Interpreter

When viewed in the Arduino IDE the ESP32Program appears to have a bewildering number of files and functions. Most modifications to ESP32Program will be made by changing code in the top level ESP32Program tab or with changes in clibrary. You can change the web interface and even translate the web interface elements all in ESP32Program. It goes without saying, that you need to be comfortable with the WebServer functions provided by the WebServer library and with C/C++ programming in general before attempting to successfully change parts of either the ESP32Program or clibrary. Always make a backup copy of these files before making changes so you have a safe fallback if things go horribly wrong after your changes.

The book *Building Blocks for IOT with your PC and WiFi Peripherals* available soon as a Kindle book goes into more detail about the picoc C Language Interpreter and many other Arduino IDE examples using the ESP32 or an ESP8266.

The clibrary tab is where you would make changes to add functions and peripherals to the Interpreter. These functions are basically marshalling function arguments provided by the interpreter and then using them to call the underlying C or C++ functions that your project requires. The OLED functions are a good examples of adding marshalling and calling functions. As an example, search for `odrawRect` in the clibrary tab. There will be three occurrences, we will first discuss the one nearest the top of the file. It defines a function which receives parameters from the Parser. What is most used in the marshalling of parameters for calls to native functions is the struct `Value** Param`. `Param` has an array of

parameters of length NumArgs. The interpreter makes sure that function calls to marshalling calls in clibrary have the right number of arguments and types.

```
void odrawRect(struct ParseState *Parser, struct Value *ReturnValue, struct Value **Param, int NumArgs)
{
    int x=Param[0]->Val->Integer;
    int y=Param[1]->Val->Integer;
    int w=Param[2]->Val->Integer;
    int h=Param[3]->Val->Integer;
    display.drawRect(x,y,w,h);
}
```

The assignment to int values of Param[x]->Val->Integer are collecting the values of x,y,w, and h to pass to a native object external to the interpreter. In this case it is the display object which is made know to clibrary by lines 270to 271 which read

```
#include "SSD1306Wire.h"
extern SSD1306Wire display;
```

This gives clibrary all it needs to interface to the display object and make calls to functions like display.drawRect(...) If you check, you will see that the display object is created in the ESP32Program tab.

With these underpinnings in place, we can successfully call display.drawRect(...) with parameters passed from the Interpreter code.

Now we need to let the interpreter know how to activate our odrawRect function. Searching again for odrawRect brings you to the line

```
{ odrawRect,    "void odrawRect(int,int,int,int);" }, // x,y,width,height
```

This is a declaration of a struct LibraryFunction that provides first the name of the function to call when the function prototype is encountered, in this case odrawRect. The part in quotes is a template for the function which says that the interpreter should recognize a void function named odrawRect with 4 int arguments. This approach allows you to have functions know to the Interpreter with names that are the same as native names in the Arduino IDE. With this information, the interpreter has enough information to parse calls to odrawRect in our interpreted programs and allows it to enforce argument counts and types before calling odrawRect. The struct LibraryFunction entries are all in this format and are enclosed with { },

***Be very careful when making changes in the CLibrary[] definitions, particularly since the function template – the part in quotes – is not evaluated until picoc is starting and any syntax errors within the quotes will cause a run time error and an immediate crash of the interpreter without giving any clue as to what or where the error is.***

In any event, **if you comprehend what the preceding material expressed**, you can add code to make new sensor/device or algorithm functions available in the interpreter.

Happy coding!