LCD Graphics Display

Introduction:

This lecture introduces the 480 x 320 graphics display on your Pico Breadboard Kit along with the driver routine (LCD.py). To use the LCD display, you need to copy the LCD.py library to your Pico board as well as to a /py subdirectory on your PC. Once copied, these LCD routines are available to be imported and used with Pytoon.

To use the LCD library:

- Copy LCD.py to your Pico chip
- Create a subdirectory on your PC named .../py
- Copy LCD.py to the .../py subdirectory on your PC

Hardware Connections & Data Communications

The heart of the LCD display is a ST77965 driver chip. This chip is hard-wired to your Pico using pins 2..7:

Pin	ST77865 Connection	Description
2	CLK	SPI Clock line. Runs at 40MHz (!)
3	DIN	Data In. Data sent from Pico to the LCD
4	DOUT	Data Out. Currently not used
5	CS	Chip Select. 0 indicated writing to the LCD
6	DC	Data / Command. 0 = Data, 1 = Command
7	RST	Reset. Pulse low to reset the display

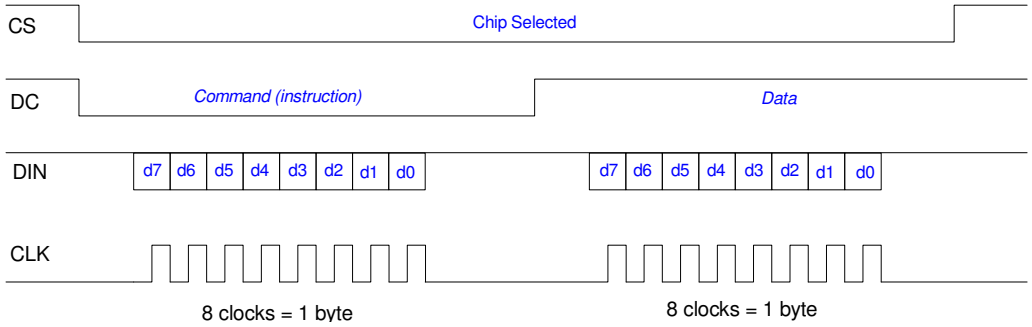
Note that pins 2..4 (SPI CLK, DIN, DOUT) can be used with other devices as well as long as each device has a separate chip select.

Also note that this means don't use mins 2..7 for other I/O devices if you plan on using the LCD display.

Data communications from the Pico to the LCD follows standard SPI protocol

- At the start of a message, Chip Select goes low
- DC is set to indicate if the message is a command (0) or data (1)
- Data is then sent on the DIN line, each bit valid on the rising edge of the clock
- Once the message is complete, Chip Select goes hith

Sample Data Communicaitons:



note: Each command or data must contain 8 bits

Abbreviated Instrution Set: ST77965

There are dozens of commands you can send to the ST77965 driver. A brief list of some used in the LCD.py library as follows. For a complete set of commands, please refer to the ST77865 data sheets.

Command	Description
0x01	Software Reset
0x11	Sleep Out (Wake Up)
0x3A	Set color mode to 16 bits per pixel
0x29	Display On
0x21	Inversion Off
0x2A aa bb	Set column range to [aa, bb]
0x2B aa bb	Set row range to [aa. bb]
0x2C xx xx xx xx xx xx	Memory Write

Color Encoding with the ST77965:

Note: There are two ways to encode RGB colors with this display

- 6-bit color (uses 3 bytes)
- 5/6/5-bit color (uses 2 bytes)

The LCD driver library uses the latter to speed up the display routines (makes them 33% faster). With this format, the color of each pixel is stored in 16 bits as

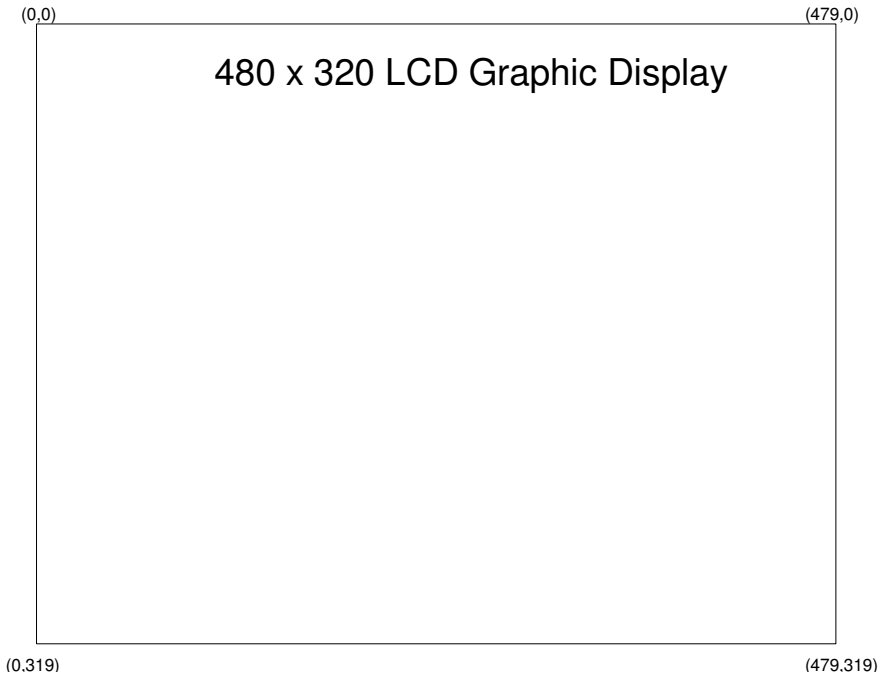
- first 5 bits: red
- Next 6 bits: green
- Last 5 bits: blue

color (16 bit variable)

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
red brightness 0x1F = 100%, 0x00 = 0%					green brightness 0x3F = 100%, 0x00 = 0%						blue brightness 0x1F = 100%, 0x00 = 0%				

The routine LCD.RGB(r,g,b) converts a desired red / green / blue intensity into this format.

The net result is the LCD is able to display 65,536 different colors with this format (16 bits). Each element of the display can be addressed separately, with point (0,0) in the upper-left corner and (479,319) in the lower right corner



LCD Library Summary

The following is a list of commands in the LCD library as of March 19, 2024. A more detailed description of these routines follows:

Command	Description
`import LCD`	Gain access to the LCD library functions
`LCD.Help()`	get a list of commands for the LCD display
`LCD.Init()`	Initialize the LCD display to 480x320
`color = LCD.RGB(r,g,b)`	Generate a 16-bit number for a given color
`LCD.Clear(color)`	Clear the LCD display. Set the color of each pixel
`LCD.Pixel(x,y,color)`	Set the color of pixel located at (x,y)
`LCD.Pixel2(x,y,color)`	Set the color of a 2x2 box at (x,y)
`LCD.Line(x0,y0,x1,y1,color)`	Draw a line from (x0,y0) to (x1,y1)
`LCD.Box(x0,y0,x1,y1,color)`	Draw a box
`LCD.Solid_Box(x0,y0,x1,y1,c)`	Draw a solid box
`LCD.Number(N,a,b,x,y,c1,c0)`	Place number N on the LCD, scaling = 1 fixed decimal format a digits, b decimal places location is (x,y) c1 = text color, c0 = background color Digits use a 16x8 character format
`LCD.Number2(N,a,b,x,y,c1,c0)`	Place a number N on the LCD, scaling = 2
`LCD.Text(Msg, x, y, c1, c0)`	Place text on the LCD with scaling = 1 location = (x,1) c1 = text color, c0 = background color Text uses a 16x8 character font
`LCD.Text2(Msg,x,y,c1,c0)`	Place text on the LCD with scaling = 2
`LCD.Light(OnOff, x, y, color)`	Draw a 10x10 box at location (x,y) OnOff = 1: solid box (LED on) OnOff = 0: hollow box (LED off)
`LCD.Binary_Out(N, x, y)`	Draw 16 boxes in a row starting at (x,y) The binary value of N determines which boxes are on and off
`LCD.Bar_Out(N, x, y)`	Draw 16 boxes in a row starting at (x,y) Box #N is turned on, the rest are off
`LCD.Dice(N, x, y, c1, c0)`	Draw a 6-sided die at (x,y) Value = N (1..6) c1 = color of pips, c0 = color of background
`LCD.Card(Value, Suit, x, y)`	Draw a playing card at (x,y) Value = 0..12 (Ace to King) Suit = 0..3 (club, diamond, hearts, spades)
`Y = LCD.Sort(X)`	Sort vector X Return the order of the elements of X
`Deck = LCD.Shuffle()`	Generate a 52-element matrix with the numbers 0..51 in random order (shuffle a deck of 52 cards)

LCD Library Instructions (greater detail)

LCD.Init()

Initialize the LCD display to

- 480 x 320 resolution
- Non-inversion (0,0,0 = black, 255,255,255 = white)
- Display On

LCD.Clear(color)

Sample Code:

```
Navy = LCD.RGB(0,0,50)
LCD.Clear(Navy)
```

Execution Time: 116ms

Clear the display. Set the color of each pixel to *color*

color = LCD.RGB(r, g, b)

Create a 16-bit color for the LCD display.

- r, g, b are the brightness of red / green / blue
- 255 is 100% on, 0 is 0% on

For example

```
Red = LCD.RGB(255,0,0)
Green = LCD.RGB(0,255,0)
Blue = LCD.RGB(0,0,255)
White = LCD.RGB(255,255,255)
Grey = LCD.RGB(100,100,100)
Black = LCD.RGB(0,0,0)
```

The resulting 16-bit value of *color* contains the values of r/g/b in a 5/6/5 format:

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
red					green						blue				

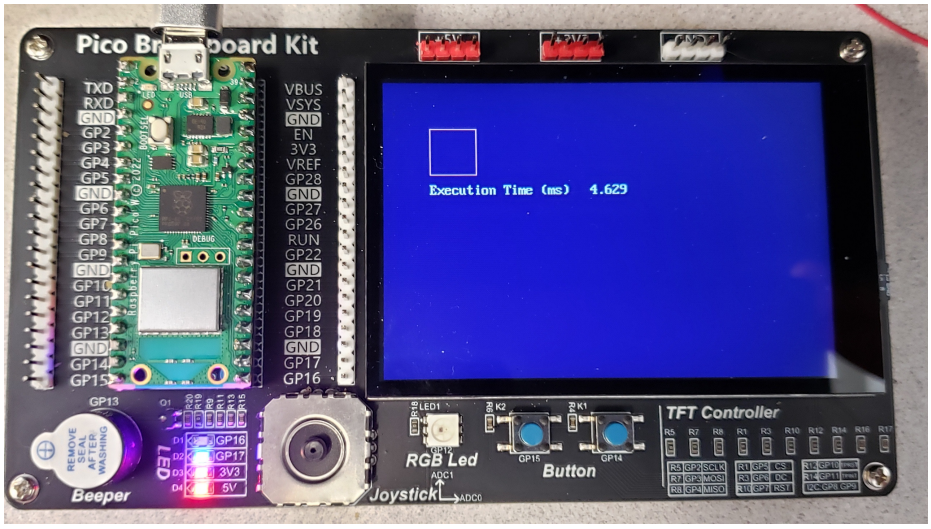
Box(x0, y0, x1, y1, color)

Draw a box on the LCD display

Example: Draw a pink box from (50,50) to (100,100)

```
import LCD
import time

White = LCD.RGB(150,150,150)
Navy = LCD.RGB(0,0,20)
Pink = LCD.RGB(150,80,80)
LCD.Clear(Navy)

X0 = time.ticks_us()

LCD.Box(50,50,100,100,Pink)

X1 = time.ticks_us()
LCD.Text('Execution Time (ms):', 50, 110, White, Navy)
LCD.Number((X1-X0)/1000, 6, 3, 200, 110, White, Navy)
```

Execution time = 4.62ms (varies with box size)

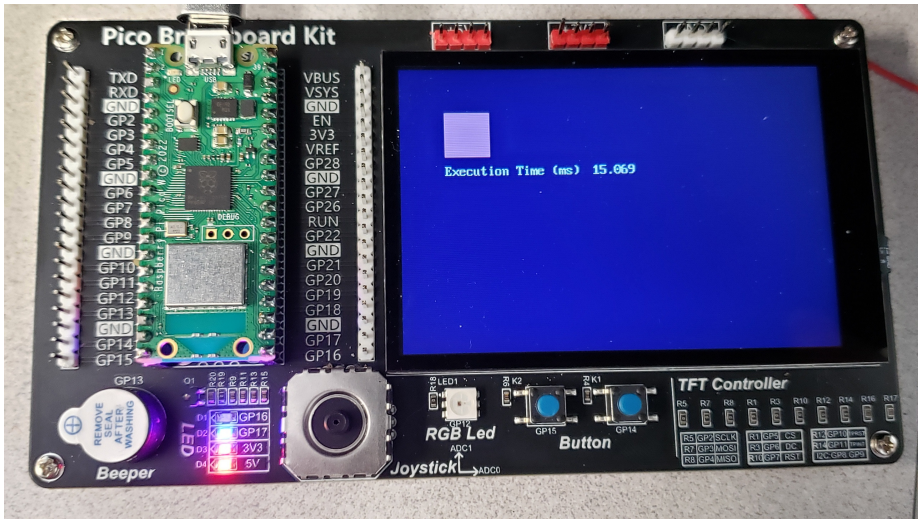


LCD.Solid_Box(x0,y0,x1,y1,color)

Draw a solid box on the LCD display. Execution time = 15.3ms (varies with box size)

Sample Code: Draw a pink box

```
import LCD
import time

White = LCD.RGB(250,250,250)
Navy = LCD.RGB(0,0,20)
Pink = LCD.RGB(250,100,100)

LCD.Clear(Navy)

X0 = time.ticks_us()

LCD.Solid_Box(50,50,100,100,Pink)

X1 = time.ticks_us()
LCD.Text('Execution Time (ms):', 50, 110, White, Navy)
LCD.Number((X1-X0)/1000, 6, 3, 200, 110, White, Navy)
```



LCD.Line(x0,y0,x1,y1,color)

Draw a line from (x0,y0) to (x1,y1) of the specified color

Execution time varies:

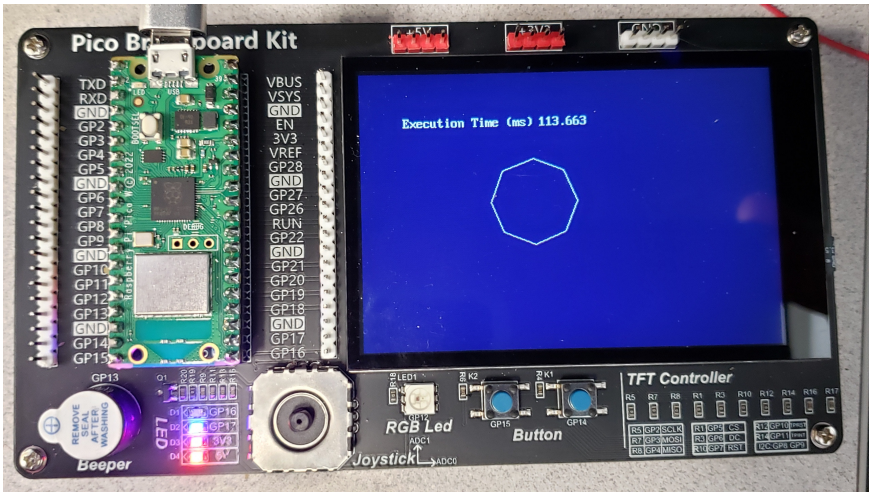
- horizontal of vertical lines: 3.0ms
- diagonal lines: 179.9ms

Example: Draw a an octagon on the display

- Center = (200,160)
- Radius = 50

Code:

```
import LCD
from math import sin, cos

White = LCD.RGB(250,250,250)
Navy = LCD.RGB(0,0,50)

x0 = 200
y0 = 150
r = 50
pi = 3.141592654
x = []
y = []
for i in range(0,9):
    x1 = int(x0 + r*cos(i*2*pi/8))
    y1 = int(y0 + r*sin(i*2*pi/8))
    x.append(x1)
    y.append(y1)
for i in range(0,8):
    LCD.Line(x[i],y[i],x[i+1],y[i+1],White)
```



LCD.Text(Message, x, y, color1, color0)

LCD.Text2(Message, x, y, color1, color0)

Display the string Message on the LCD with a scaling of 1 or 2

- at position (x,y)
- color1 = text color
- color2 = background color

Text is displayed as 16x8 characters with fixed spacing. Execution time 3.7ms per character

Text2 is displayed as 32x16 characters with fixed spacing. Execution time is 10.7ms per character

Example: Display the opening lines of Jaberwocky white with a navy background (note: each row is shifted down by 20 since each character is 16 tall)

```
import LCD

White = LCD.RGB(250,250,250)
Navy = LCD.RGB(0,0,50)

LCD.Clear(Navy)
LCD.Text2('Jaberwocky',20,20,White,Navy)
LCD.Text('Twas brillig, and the slighy toves',20,60,White,Navy)
LCD.Text('Did gyre and gimble in the wabe',   20,80,White,Navy)
LCD.Text('And mumsy were the borogoves,',     20,100,White,Navy)
LCD.Text('And the mome raths outgrabe',       20,120,White,Navy)
LCD.Text('Beware the Jaberwock, my son',      20,150,White,Navy)
LCD.Text('The jaws that bite, the claws that catch',20,170,White,Navy)
```

Number(N, decimal, digits, x, y, color1, color0)

Number2(N, decimal digits, x, y, color1, color0)

Display a number with fixed decimal format

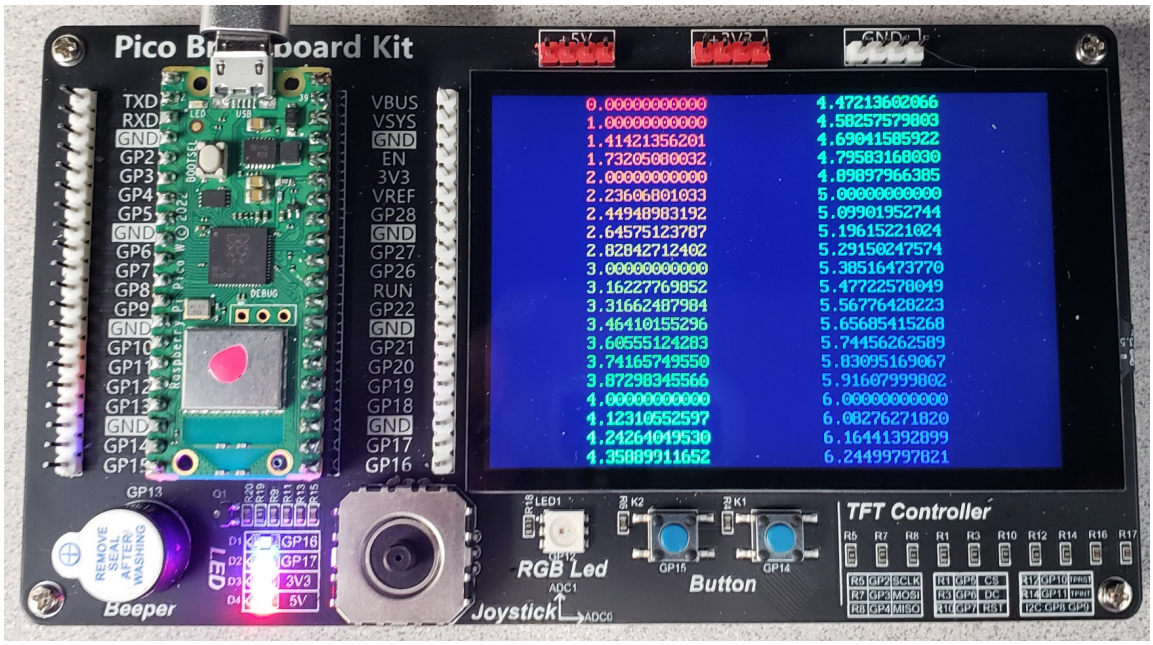
- N is the number
- digits is the number of digits to display
- decimal is the number of decimal places to display
- (x,y) is the location of the number
- color1 is the text color
- color2 is the background color

Text1 uses 16x8 characters. Text2 uses 32x16 characters (scaling x 2)

Execution time is the same as Text: 3.7ms/digit for Text1, 10.7ms/digit for Text2

Example: Display the square root of 1..40 with 13 digits and 11 decimal places in various colors

```
import LCD

Navy = LCD.RGB(0,0,10)

LCD.Clear(Navy)

for i in range(1,20):
    X = i ** 0.5
    LCD.Number(X, 13, 11, 50, i*16, LCD.RGB(i*10,200-i*10,0), Navy)
for i in range(1,20):
    X = (i+20) ** 0.5
    LCD.Number(X, 13, 11, 250, i*16, LCD.RGB(0,i*10,200-i*10), Navy)
```



LCD.Pixel(x, y, color)

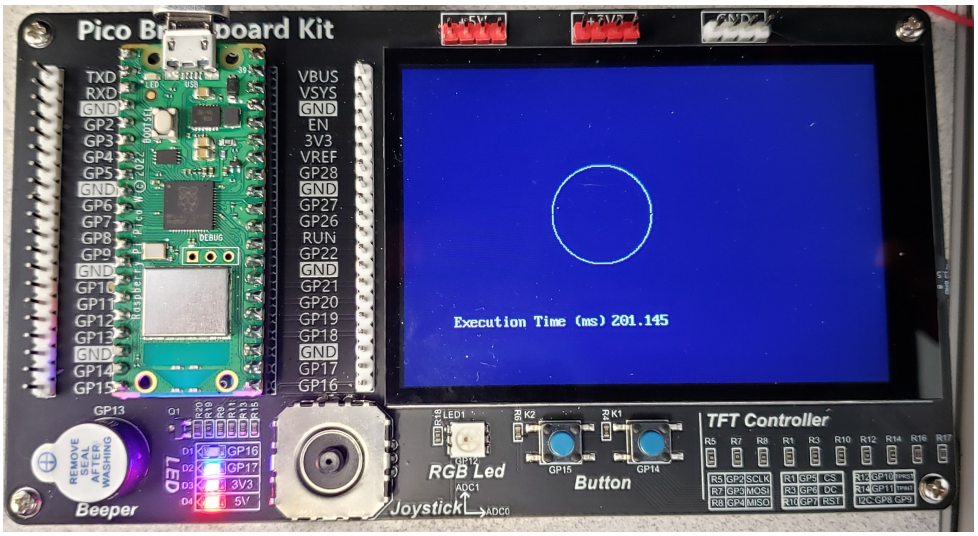
Set the color of the pixel at (x,y).

LCD.Pixel2(x,y,color)

Set the color of a 2x2 set of pixels at (x,y).

Example: Draw a circle with a radius of 50 centered at (200,150). Note, the circumference is 314 pixels, so draw 314 points at radius r

```
import LCD
from math import sin, cos
import time

White = LCD.RGB(250,250,250)
Navy = LCD.RGB(0,0,50)

x0 = 200
y0 = 150
r = 50
pi = 3.141592654
x = []
y = []

X0 = time.ticks_us()

for i in range(0,314):
    x = int(x0 + r*cos(i*2*pi/314))
    y = int(y0 + r*sin(i*2*pi/314))
    LCD.Pixel(x, y, White)

X1 = time.ticks_us()
LCD.Text('Execution Time (ms):', 50, 110, White, Navy)
LCD.Number((X1-X0)/1000, 6, 3, 200, 110, White, Navy)
```



LCD.Light(OnOff, x, y, color)

Display a 10x10 box (simulating an LED on the screen) at location (x,y) that's

- A solid box (OnOff = 1), or
- A hollow box (OnOff = 0)

color sets the color of the box. This routine is used in Binary_Out() and Bar_Out()

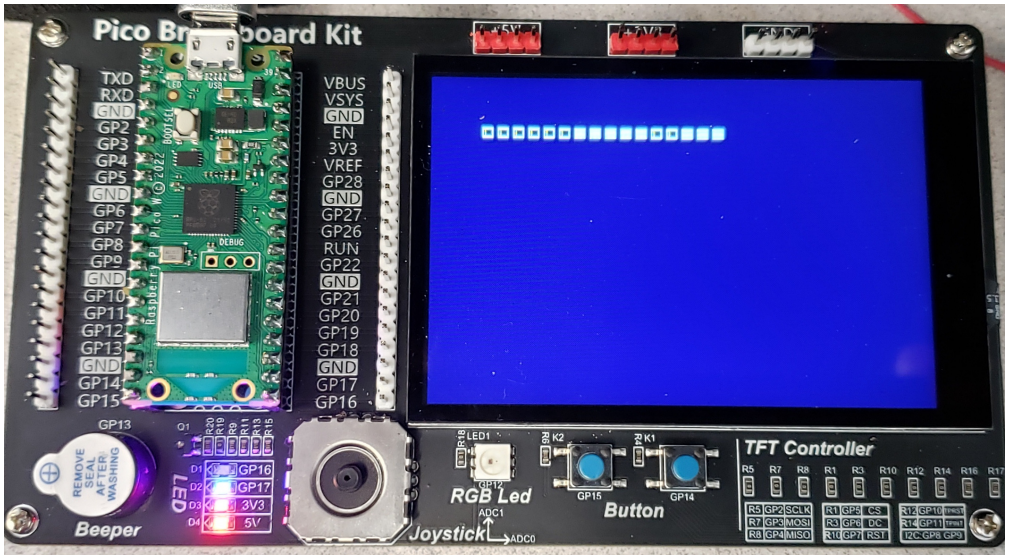
LCD.Binary_Out(N, x, y)

Display 16 boxes on the screen from left to right to simulate 16 LED lights.

- Turn on LEDs corresponding to the binary value of N
- Total display area is 250 x 10

Example: Count in binary

```
import LCD
import time

White = LCD.RGB(250,250,250)
Navy = LCD.RGB(0,0,50)

LCD.Clear(Navy)

for i in range(0, 1000):
    LCD.Binary_Out(i, 50, 50)
    time.sleep(0.001)
```



16 element LED showing the number 0x03E7 = 999

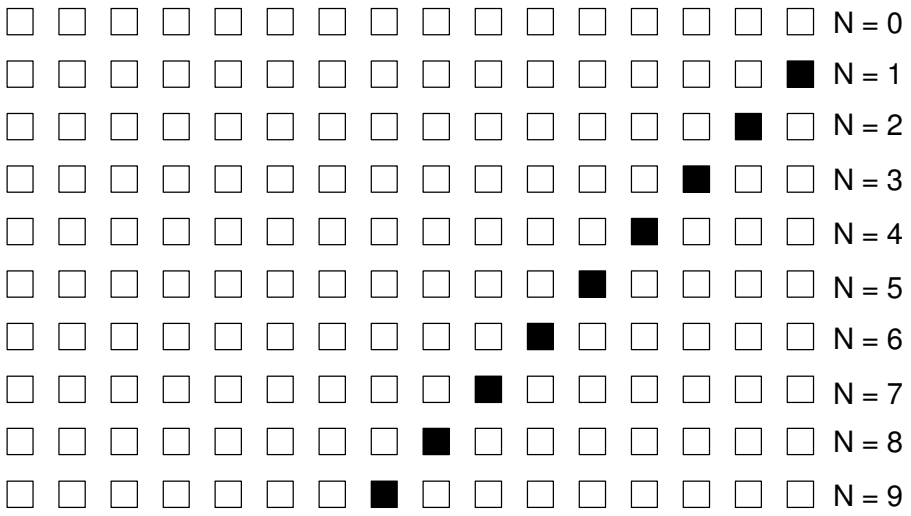
LCD.Bar_Out(N, x, y)

Display 16 boxes on the screen from left to right to simulate 16 LED lights.

- Turn on LED #N and turn the rest off
- Total display area is 250 x 10

Example: Make a light that bounces back and forth

```
import LCD
import time

White = LCD.RGB(250,250,250)
Navy = LCD.RGB(0,0,50)

LCD.Clear(Navy)

dX = 1
X = 0
while(1):
    if(X > 15):
       dX = -1
    if(X < 2):
       dX = 1
    X += dX
    LCD.Bar_Out(X, 50, 50)
    time.sleep(0.1)
```



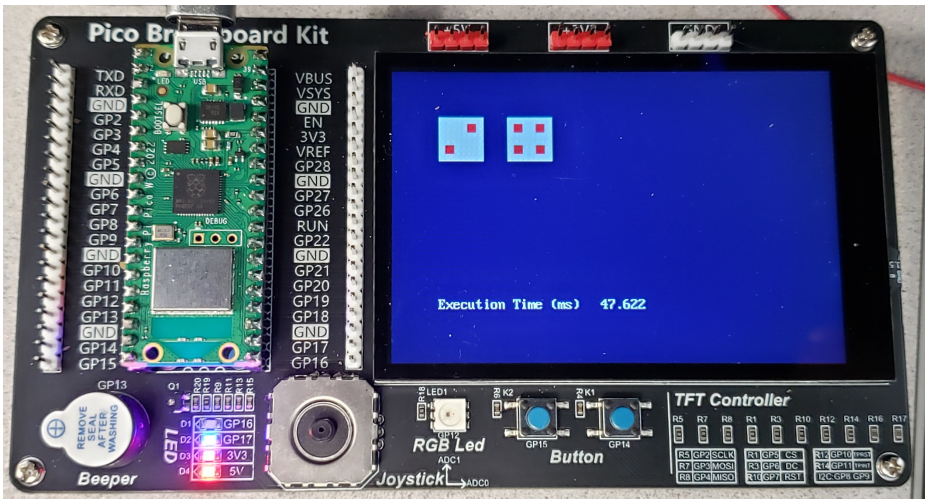
LCD.Dice(N, x, y, color1, color0)

Display a 6-sided die at location (x,y)

- The die is 50x50, with the upper left corner at (x,y)
- color1 is the color of the pips
- color2 is the color of the background

Example: Roll two 6-sided dice and display them on the LCD

```
import LCD
import random

White = LCD.RGB(250,250,250)
Navy = LCD.RGB(0,0,50)

LCD.Clear(Navy)

d1 = random.randrange(1,6)
d2 = random.randrange(1,6)
LCD.Dice(d1,50,50,Red,White)
LCD.Dice(d2,125,50,Red,White)
```



LCD.Card(Value, Suit, x, y)

Display a playing card at location (x,y)

- The playing card is 45 x 65 in size
- Value is 1..13 (1 = Ace, 2 = two, 11 = jack, 12 = queen, 13 = king)
- Suit is 1..4 (1 = club, 2 = diamond, 3 = heart, 4 = spade)

Y = LCD.Sort(X)

Return an array which shows the sort order of array X, sorted smallest to largest

Deck = LCD.Shuffle()

Return a 52-element array of numbers 0..51 in random order. Used to shuffle a deck of 52 playing cards.

Example: Shuffle a deck, draw the first five cards, and display them on the LCD

```
import LCD
import random

Hand = [0,0,0,0,0]
Value = [0,0,0,0,0]
Suit = [0,0,0,0,0]
X = LCD.Shuffle()
for i in range(0,5):
    Hand[i] = Y[i]
    Value[i] = (Hand[i] % 13) + 1
    Suit[i] = int(Hand[i] / 13) + 1
    LCD.Card(Value[i], Suit[i], 50+i*50, 150)
```