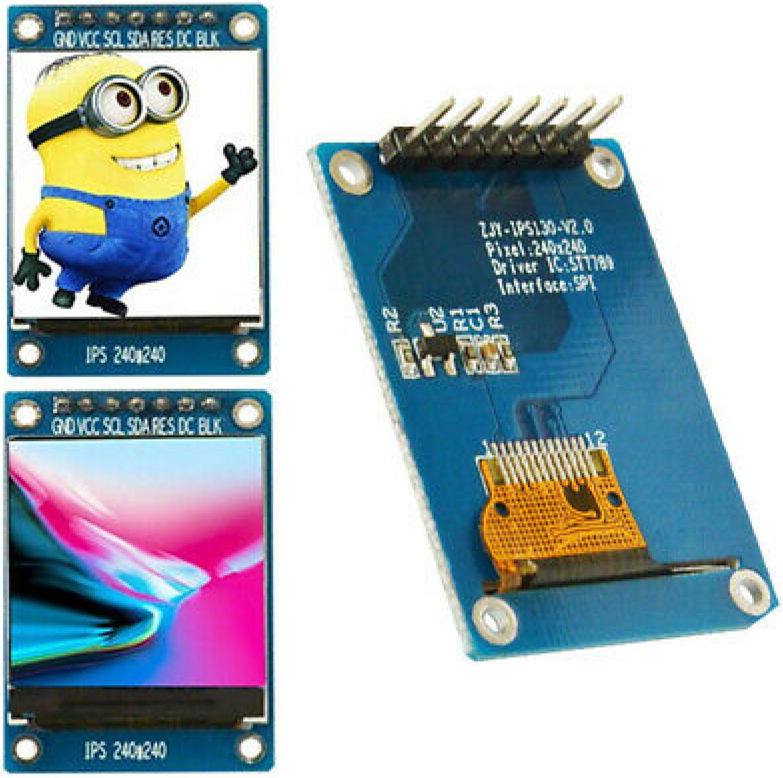
ST7789 Driver for MicroPython

Overview

This is a driver for MicroPython to handle cheap displays based on the ST7789 chip. The driver is written in C. Firmware is provided for ESP32, ESP32 with SPIRAM, pyboard1.1, and Raspberry Pi Pico devices.



Working examples

This module was tested on ESP32, STM32 based pyboard v1.1, and the Raspberry Pi Pico. You have to provide an `SPI` object and the pin to use for the `dc' input of the screen.

```
# ESP32

import machine
import st7789
spi = machine.SPI(2, baudrate=40000000, polarity=1, sck=machine.Pin(18),
mosi=machine.Pin(23))
display = st7789.ST7789(spi, 240, 240, reset=machine.Pin(4, machine.Pin.OUT),
dc=machine.Pin(2, machine.Pin.OUT))
display.init()
```

I could not run the display with a baud rate over 40MHZ.

Methods

- `st7789.ST7789(spi, width, height, dc, reset, cs, backlight, rotations, rotation, custom_init, color_order, inversion, options, buffer_size)`

  ## Required positional arguments:

  - `spi` spi device
  - `width` display width
  - `height` display height

  ## Required keyword arguments:

  - `dc` sets the pin connected to the display data/command selection input. This parameter is always required.

  ## Optional keyword arguments:

  - `reset` sets the pin connected to the display's hardware reset input. If the displays reset pin is tied high, the `reset` parameter is not required.
  - `cs` sets the pin connected to the displays chip select input. If the display's CS pin is tied low, the display must be the only device connected to the SPI port. The display will always be the selected device, and the `cs` parameter is not required.
  - `backlight` sets the pin connected to the display's backlight enable input. The display's backlight input can often be left floating or disconnected as the backlight on some displays is always powered on and cannot be turned off.
  - `rotations` sets the orientation table. The orientation table is a list of tuples for each `rotation` used to set the MADCTL register, display width, display height, start_x, and start_y values.
    Default `rotations` are included for the following st7789 and st7735 display sizes:

Display	Default Orientation Tables
240x320	[(0x00, 240, 320, 0, 0), (0x60, 320, 240, 0, 0), (0xc0, 240, 320, 0, 0), (0xa0, 320, 240, 0, 0)]
170x320	[(0x00, 170, 320, 35, 0), (0x60, 320, 170, 0, 35), (0xc0, 170, 320, 35, 0), (0xa0, 320, 170, 0, 35)]
240x240	[(0x00, 240, 240, 0, 0), (0x60, 240, 240, 0, 0), (0xc0, 240, 240, 0, 80), (0xa0, 240, 240, 80, 0)]
135x240	[(0x00, 135, 240, 52, 40), (0x60, 240, 135, 40, 53), (0xc0, 135, 240, 53, 40), (0xa0, 240, 135, 40, 52)]

Display	Default Orientation Tables
128x160	[(0x00, 128, 160, 0, 0), (0x60, 160, 128, 0, 0), (0xc0, 128, 160, 0, 0), (0xa0, 160, 128, 0, 0)]
128x128	[(0x00, 128, 128, 2, 1), (0x60, 128, 128, 1, 2), (0xc0, 128, 128, 2, 3), (0xa0, 128, 128, 3, 2)]
other	[(0x00, width, height, 0, 0)]

You may define as many rotations as you wish.

- `rotation` sets the display rotation according to the orientation table.

  The default orientation table defines four counter-clockwise rotations for 240x320, 240x240, 134x240, 128x160 and 128x128 displays with the LCD's ribbon cable at the bottom of the display. The default rotation is Portrait (0 degrees).

Index	Rotation
0	Portrait (0 degrees)
1	Landscape (90 degrees)
2	Reverse Portrait (180 degrees)
3	Reverse Landscape (270 degrees)

- `custom_init` List of display configuration commands to send to the display during the display init(). The list contains tuples with a bytes object, optionally followed by a delay specified in ms. The first byte of the bytes object contains the command to send optionally followed by data bytes. See the `examples/configs/t_dongle_s3/tft_config.py` file or an example.
- `color_order` Sets the color order used by the driver (st7789.RGB or st7789.BGR)
- `inversion` Sets the display color inversion mode if True, clears the display color inversion mode if false.
- `options` Sets driver option flags.

Option	Description
st7789.WRAP	pixels, lines, polygons, and Hershey text will wrap

Option	Description
	around the display both horizontally and vertically.
st7789.WRAP_H	pixels, lines, polygons, and Hershey text will wrap around the display horizontally.
st7789.WRAP_V	pixels, lines, polygons, and Hershey text will wrap around the display vertically.

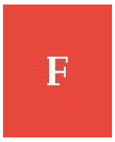
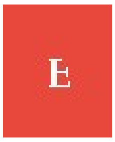
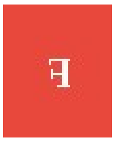
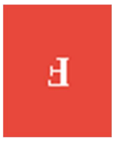
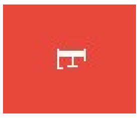
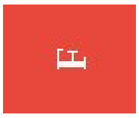
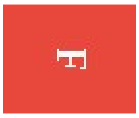
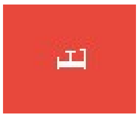
  - `buffer_size` If a buffer_size is not specified, a dynamically allocated buffer is created and freed as needed. If a buffer_size is set, it must be large enough to contain the largest bitmap, font character, and decoded JPG image used (Rows * Columns * 2 bytes, 16bit colors in RGB565 notation). Dynamic allocation is slower and can cause heap fragmentation, so garbage collection (GC) should be enabled.

- `inversion_mode(bool)` Sets the display color inversion mode if True, clears the display color inversion mode if False.
- `madctl(value)` Returns the current value of the MADCTL register or sets the MADCTL register if a value is passed to the method. The MADCTL register is used to set the display rotation and color order.

MADCTL constants

Constant Name	Value	Description
st7789.MADCTL_MY	0x80	Page Address Order
st7789_MADCTL_MX	0x40	Column Address Order
st7789_MADCTL_MV	0x20	Page/Column Order
st7789_MADCTL_ML	0x10	Line Address Order
st7789_MADCTL_MH	0x04	Display Data Latch Order
st7789_RGB	0x00	RGB color order
st7789_BGR	0x08	BGR color order

MADCTL examples

Orientation	MADCTL Values for RGB color order, for BGR color order add 0x08 to the value.
	0x00
	0x80 (MADCTL_MY)
	0x40 (MADCTL_MX)
	0xC0 (MADCTL_MX + MADCTL_MY)
	0x20 (MADCTL_MV)
	0xA0 (MADCTL_MV + MADCTL_MY)
	0x60 (MADCTL_MV + MADCTL_MX)
	0xE0 (MADCTL_MV + MADCTL_MX + MADCTL_MY)

- `init()`

  Must be called to initialize the display.

- `on()`

  Turn on the backlight pin if one was defined during init.

- `off()`

Turn off the backlight pin if one was defined during init.

- `sleep_mode(value)`

  If value is True, cause the display to enter sleep mode, otherwise wake up if value is False. During sleep display content may not be preserved.

- `fill(color)`

  Fill the display with the specified color.

- `pixel(x, y, color)`
  Set the specified pixel to the given `color`.
- `line(x0, y0, x1, y1, color)`
  Draws a single line with the provided `color` from (`x0`, `y0`) to (`x1`, `y1`).
- `hline(x, y, length, color)`
  Draws a single horizontal line with the provided `color` and `length` in pixels. Along with `vline`, this is a fast version with fewer SPI calls.
- `vline(x, y, length, color)`
  Draws a single horizontal line with the provided `color` and `length` in pixels.
- `rect(x, y, width, height, color)`
  Draws a rectangle from (`x`, `y`) with corresponding dimensions
- `fill_rect(x, y, width, height, color)`
  Fill a rectangle starting from (`x`, `y`) coordinates
- `circle(x, y, r, color)`
  Draws a circle with radius `r` centered at the (`x`, `y`) coordinates in the given `color`.
- `fill_circle(x, y, r, color)`
  Draws a filled circle with radius `r` centered at the (`x`, `y`) coordinates in the given `color`.
- `blit_buffer(buffer, x, y, width, height)`

  Copy bytes() or bytearray() content to the screen internal memory. Note: every color requires 2 bytes in the array

- `text(font, s, x, y[, fg, bg])`
  Write text to the display using the specified bitmap `font` with the coordinates as the upper-left corner of the text. The optional arguments `fg` and `bg` can set the foreground and background colors of the text; otherwise the foreground color defaults to `WHITE`, and the background color defaults to `BLACK`. See the `README.md` in the `fonts/bitmap` directory for example fonts.
- `write(bitmap_font, s, x, y[, fg, bg, background_tuple, fill_flag])`
  Write text to the display using the specified proportional or Monospace bitmap font module with the coordinates as the upper-left corner of the text. The foreground and background colors of the text can be set by the optional arguments `fg` and `bg`, otherwise the foreground color defaults to `WHITE` and the background color defaults to `BLACK`.
  Transparency can be emulated by providing a `background_tuple` containing (bitmap_buffer, width, height). This is the same format used by the jpg_decode method. See examples/T-DISPLAY/clock/clock.py for an example.
  See the `README.md` in the `truetype/fonts` directory for example fonts. Returns the width of the string as printed in pixels. Accepts UTF8 encoded strings.
  The `font2bitmap` utility creates compatible 1 bit per pixel bitmap modules from Proportional or Monospaced True Type fonts. The character size, foreground, background colors, and characters in the bitmap module may be specified as

parameters. Use the -h option for details. If you specify a buffer_size during the display initialization, it must be large enough to hold the widest character (HEIGHT * MAX_WIDTH * 2).

- `write_len(bitap_font, s)`

  Returns the string's width in pixels if printed in the specified font.

- `draw(vector_font, s, x, y[, fg, scale])`
  Draw text to the display using the specified Hershey vector font with the coordinates as the lower-left corner of the text. The foreground color of the text can be set by the optional argument `fg`. Otherwise the foreground color defaults to `WHITE`. The size of the text can be scaled by specifying a `scale` value. The `scale` value must be larger than 0 and can be a floating-point or an integer value. The `scale` value defaults to 1.0. See the README.md in the `vector/fonts` directory, for example fonts and the utils directory for a font conversion program.
- `draw_len(vector_font, s[, scale])`

  Returns the string's width in pixels if drawn with the specified font.

- `jpg(jpg, x, y [, method])`
  Draw a `jpg` on the display with the given `x` and `y` coordinates as the upper left corner of the image. `jpg` may be a string containing a filename or a buffer containing the JPEG image data.
  The memory required to decode and display a JPG can be considerable as a full-screen 320x240 JPG would require at least 3100 bytes for the working area + 320 * 240 * 2 bytes of ram to buffer the image. Jpg images that would require a buffer larger than available memory can be drawn by passing `SLOW` for the `method`. The `SLOW` `method` will draw the image one piece at a time using the Minimum Coded Unit (MCU, typically a multiple of 8x8) of the image. The default method is `FAST`.
- `jpg_decode(jpg_filename [, x, y, width, height])`

  Decode a jpg file and return it or a portion of it as a tuple composed of (buffer, width, height). The buffer is a color565 blit_buffer compatible byte array. The buffer will require width * height * 2 bytes of memory.

  If the optional x, y, width, and height parameters are given, the buffer will only contain the specified area of the image. See examples/T-DISPLAY/clock/clock.py examples/T-DISPLAY/toasters_jpg/toasters_jpg.py for examples.

- `png(png_filename, x, y [, mask])`
  Draw a PNG file on the display with upper left corner of the image at the given `x` and `y` coordinates. The PNG will not be clipped it must be able to fit fully on the display or it will not be drawn. The memory required to decode and display a PNG can be considerable, as such, the PNG will either be drawn one line at a time, or as many lines as will fit in the `buffer_size` if one was specified during the display initialization. Since the driver does not contain a frame buffer, transparency is not supported. Providing a `True` value for the `mask` parameter will prevent pixels with a zero alpha channel value from being displayed. Drawing masked PNG's is slower than non-masked as each visible line segment is drawn separately. For an example of using a mask, see the alien.py program in the examples/png folder.
- `polygon_center(polygon)`
  Return the center of the `polygon` as an (x, y) tuple. The `polygon` should consist of a list of (x, y) tuples forming a closed convex polygon.

- `fill_polygon(polygon, x, y, color[, angle, center_x, center_y])`
  Draw a filled `polygon` at the `x`, and `y` coordinates in the `color` given. The polygon may be rotated `angle` radians about the `center_x` and `center_y` point. The polygon should consist of a list of (x, y) tuples forming a closed convex polygon.
  See the TWATCH-2020 `watch.py` demo for an example.
- `polygon(polygon, x, y, color, angle, center_x, center_y)`
  Draw a `polygon` at the `x`, and `y` coordinates in the `color` given. The polygon may be rotated `angle` radians about the `center_x` and `center_y` point. The polygon should consist of a list of (x, y) tuples forming a closed convex polygon.
  See the T-Display `roids.py` for an example.
- `bounding({status, as_rect})`

  Bounding enables or disables tracking the display area that has been written to. Initially, tracking is disabled; pass a True value to enable tracking and False to disable it. Passing a True or False parameter will reset the current bounding rectangle to (display_width, display_height, 0, 0).

  Returns a four integer tuple containing (min_x, min_y, max_x, max_y) indicating the area of the display that has been written to since the last clearing.

  If `as_rect` parameter is True, the returned tuple will contain (min_x, min_y, width, height) values.
  See the TWATCH-2020 `watch.py` demo for an example.
- `bitmap(bitmap, x , y [, index])`
  Draw `bitmap` using the specified `x`, `y` coordinates as the upper-left corner of the `bitmap`. The optional `index` parameter provides a method to select from multiple bitmaps contained a `bitmap` module. The `index` is used to calculate the offset to the beginning of the desired bitmap using the modules HEIGHT, WIDTH, and BPP values.
  The `imgtobitmap.py` utility creates compatible 1 to 8 bit per pixel bitmap modules from image files using the Pillow Python Imaging Library.
  The `monofont2bitmap.py` utility creates compatible 1 to 8 bit per pixel bitmap modules from Monospaced True Type fonts. See the `inconsolata_16.py`, `inconsolata_32.py` and `inconsolata_64.py` files in the `examples/lib` folder for sample modules and the `mono_font.py` program for an example using the generated modules.

  The character sizes, bit per pixel, foreground, background colors, and the characters to include in the bitmap module may be specified as parameters. Use the -h option for details. Bits per pixel settings larger than one may be used to create antialiased characters at the expense of memory use. If you specify a buffer_size during the display initialization, it must be large enough to hold the one character (HEIGHT * WIDTH * 2).

- `width()`

  Returns the current logical width of the display. (ie a 135x240 display rotated 90 degrees is 240 pixels wide)

- `height()`

  Returns the current logical height of the display. (ie a 135x240 display rotated 90 degrees is 135 pixels high)

- `rotation(r)`

  Set the rotates the logical display in a counter-clockwise direction. 0-Portrait (0 degrees), 1-Landscape (90 degrees), 2-Inverse Portrait (180 degrees), 3-Inverse Landscape (270 degrees)

- `offset(x_start, y_start)` The memory in the ST7789 controller is configured for a 240x320 display. When using a smaller display like a 240x240 or 135x240, an offset needs to be added to the x and y parameters so that the pixels are written to the memory area corresponding to the visible display. The offsets may need to be adjusted when rotating the display.

  For example, the TTGO-TDisplay is 135x240 and uses the following offsets.

Rotation	x_start	y_start
0	52	40
1	40	53
2	53	40
3	40	52

  When the rotation method is called, the driver will adjust the offsets for a 135x240 or 240x240 display. Your display may require using different offset values; if so, use the `offset` method after `rotation` to set the offset values.
  The values needed for a particular display may not be documented and may require some experimentation to determine the correct values. One technique is to draw a box the same size as the display and then make small changes to the offsets until the display looks correct. See the `cfg_helper.py` program in the examples folder for more information.

The module exposes predefined colors: `BLACK`, `BLUE`, `RED`, `GREEN`, `CYAN`, `MAGENTA`, `YELLOW`, and `WHITE`

Scrolling

The st7789 display controller contains a 240 by 320-pixel frame buffer used to store the pixels for the display. For scrolling, the frame buffer consists of three separate areas; The (`tfa`) top fixed area, the (`height`) scrolling area, and the (`bfa`) bottom fixed area. The `tfa` is the upper portion of the frame buffer in pixels not to scroll. The `height` is the center portion of the frame buffer in pixels to scroll. The `bfa` is the lower portion of the frame buffer in pixels not to scroll. These values control the ability to scroll the entire or a part of the display.
For displays that are 320 pixels high, setting the `tfa` to 0, `height` to 320, and `bfa` to 0 will allow scrolling of the entire display. You can set the `tfa` and `bfa` to a non-zero value to scroll a portion of the display. `tfa` + `height` + `bfa` = should equal 320, otherwise the scrolling mode is undefined.

Displays less than 320 pixels high, the `tfa`, `height`, and `bfa` will need to be adjusted to compensate for the smaller LCD panel. The actual values will vary depending on the configuration of the LCD panel. For example, scrolling the entire 135x240 TTGO T-Display requires a `tfa` value of 40, `height` value of 240, and `bfa` value of 40 (40+240+40=320) because the T-Display LCD shows 240 rows starting at the 40th row of the frame buffer, leaving the last 40 rows of the frame buffer undisplayed.

Other displays like the Waveshare Pico LCD 1.3 inch 240x240 display require the `tfa` set to 0, `height` set to 240, and `bfa` set to 80 (0+240+80=320) to scroll the entire display. The Pico LCD 1.3 shows 240 rows starting at the 0th row of the frame buffer, leaving the last 80 rows of the frame buffer undisplayed.

The `vscsad` method sets the (VSSA) Vertical Scroll Start Address. The VSSA sets the line in the frame buffer that will be the first line after the `tfa`.

```
The ST7789 datasheet warns:

The value of the vertical scrolling start address is absolute (with reference to
the frame memory),
it must not enter the fixed area (defined by Vertical Scrolling Definition,
otherwise undesirable
image will be displayed on the panel.
```

- `vscrdef(tfa, height, bfa)` Set the vertical scrolling parameters.
  `tfa` is the top fixed area in pixels. The top fixed area is the upper portion of the display frame buffer that will not be scrolled.
  `height` is the total height in pixels of the area scrolled.
  `bfa` is the bottom fixed area in pixels. The bottom fixed area is the lower portion of the display frame buffer that will not be scrolled.
- `vscsad(vssa)` Set the vertical scroll address.
  `vssa` is the vertical scroll start address in pixels. The vertical scroll start address is the line in the frame buffer will be the first line shown after the TFA.

Helper functions

- `color565(r, g, b)`

  Pack a color into 2-bytes rgb565 format

- `map_bitarray_to_rgb565(bitarray, buffer, width, color=WHITE, bg_color=BLACK)`
  Convert a `bitarray` to the rgb565 color `buffer` suitable for blitting. Bit 1 in `bitarray` is a pixel with `color` and 0 - with `bg_color`.