ST7789 Driver for MicroPython

This driver is based on devbis' st7789_mpy driver. I modified the original driver for one of my projects to add:

- Display Rotation.
- Scrolling
- Writing text using bitmaps converted from True Type fonts
- Drawing text using 8 and 16 bit wide bitmap fonts
- Drawing text using Hershey vector fonts
- Drawing JPG's, including a SLOW mode to draw jpg's larger than available ram using the TJpgDec - Tiny JPEG Decompressor R0.01d. from http://elm-chan.org/fsw/tjpgd/00index.html
- Drawing and rotating Polygons and filled Polygons.
- Tracking bounds
- Support for st7735 displays

Included are 12 bitmap fonts derived from classic pc text mode fonts, 26 Hershey vector fonts and several example programs for different devices.

Display Configuration

Some displays may use a BGR color order or iverted colors. The `cfg_helper.py` program can use used to determine the color order, inversion_mode, colstart, and rowstart values needed for a display.

Color Modes

You can test the color order needed by a display by filling the display with the `st7789.RED` color and observing the color displayed.

- If the display is RED, the settings are correct.
- If the display is BLUE, `color_order` should be `st7789.BGR`.
- If the display is YELLOW, `inversion_mode` should be `True`.
- If the display is CYAN, `color_order` should be `st7789.BGR` and `inversion_mode` should be `True`.

colstart and rowstart

Some displays have a frame buffer memory larger than the physical LCD or LED matrix. In these cases the driver must be configured with the position of the first physcial column and row pixels relative to the frame buffer. Each rotation setting of the display may require different colstart and rowstart values.

The driver automatically adjusts the colstart and rowstarts values for common 135x240, 240x240 and 240x320 displays. These values can be overridden using the `offsets` method if the default values do not work for your display. The `offsets` method should be called after any calls of the `rotation` method.

128x128 st7735 cfg_helper.py example

```
inversion_mode(False)
color_order = st7789.BGR
for rotation 0 use offset(2, 1)
for rotation 1 use offset(1, 2)
for rotation 2 use offset(2, 3)
for rotation 3 use offset(3, 2)
```

128x160 st7735 cfg_helper.py example

```
inversion_mode(False)
color_order = st7789.RGB
for rotation 0 use offset(0, 0)
for rotation 1 use offset(0, 0)
for rotation 2 use offset(0, 0)
for rotation 3 use offset(0, 0)
```

Pre-compiled firmware files

The firmware directory contains pre-compiled firmware for various devices with the st7789 C driver and frozen python font files. See the README.md file in the fonts folder for more information on the font files.

MicroPython MicroPython v1.18-56-g517e82eb6 compiled with ESP IDF v4.2 using CMake

Directory	File	Device
GENERIC-7789	firmware.bin	Generic ESP32 devices
GENERIC_SPIRAM-7789	firmware.bin	Generic ESP32 devices with SPI Ram
GENERIC_C3	firmware.bin	Generic ESP32-C3 devices (JPG support not working)
PYBV11	firmware.dfu	Pyboard v1.1
RP2	firmware.uf2	Raspberry Pi Pico RP2040
T-DISPLAY	firmware.bin	LILYGO® TTGO T-Display
T-Watch-2020	firmware.bin	LILYGO® T-Watch 2020

Additional Modules

Module	Source
axp202c	https://github.com/lewisxhe/AXP202X_Libraries
focaltouch	https://gitlab.com/mooond/t-watch2020-esp32-with-micropython

Video Examples

Example	Video
PYBV11 hello.py	https://youtu.be/OtcERmad5ps
PYBV11 scroll.py	https://youtu.be/ro13rvaLKAc
T-DISPLAY fonts.py	https://youtu.be/2cnAhEucPD4
T-DISPLAY hello.py	https://youtu.be/z41Du4GDMSY

Example	Video
T-DISPLAY scroll.py	https://youtu.be/GQa-RzHLBak
T-DISPLAY roids.py	https://youtu.be/JV5fPactSPU
TWATCH-2020 draw.py	https://youtu.be/O_lDBnvH1Sw
TWATCH-2020 hello.py	https://youtu.be/Bwq39tuMoY4
TWATCH-2020 bitmap.py	https://youtu.be/DgYzgnAW2d8
TWATCH-2020 watch.py	https://youtu.be/NItKb6umMc4

This is a work in progress.

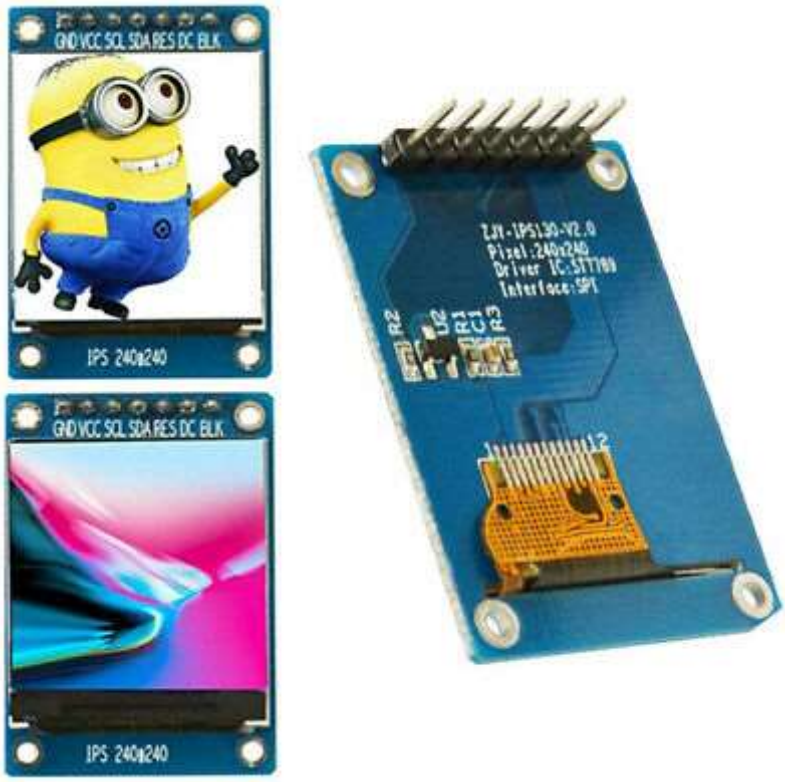
Thanks go out to:

- https://github.com/devbis for the original driver this is based on.
- https://github.com/hklang10 for letting me know of the new mp_raise_ValueError().
- https://github.com/aleggon for finding the correct offsets for a 240x240 display and discovering issues compiling for STM32 based boards.

-- Russ

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.

Setup MicroPython Build Environment in Ubuntu 20.04.2

See the MicroPython README.md if you run into any build issues not directly related to the st7789 driver. The recommended MicroPython build instructions may have changed.

Update and upgrade Ubuntu using apt-get if you are using a new install of Ubuntu or the Windows Subsystem for Linux.

```
sudo apt-get -y update
sudo apt-get -y upgrade
```

Use apt-get to install the required build tools.

```
sudo apt-get -y install build-essential libffi-dev git pkg-config cmake virtualer
```

Install a compatible esp-idf SDK

The MicroPython README.md states: "The ESP-IDF changes quickly and MicroPython only supports certain versions. Currently MicroPython supports v4.0.2, v4.1.1 and v4.2, although other IDF v4 versions may also work." I have had good luck using IDF v4.2.

Clone the esp-idf SDK repo -- this usually takes several minutes

```
git clone -b v4.2 --recursive https://github.com/espressif/esp-idf.git
cd esp-idf/
git pull
```

If you already have a copy of the IDF you can checkout a version compatible with MicroPython and update the submodules using:

```
$ cd esp-idf
$ git checkout v4.2
$ git submodule update --init --recursive
```

Install the esp-idf SDK.

```
./install.sh
```

Source the esp-idf export.sh script to set the required environment variables. It's important that you source the file and not run it using ./export.sh. You will need to source this file before compiling MicroPython.

```
source export.sh
cd ..
```

Clone the MicroPython repo.

```
git clone https://github.com/micropython/micropython.git
```

Clone the st7789 driver repo.

```
git clone https://github.com/russhughes/st7789_mpy.git
```

Update the git submodules and compile the micropython cross-compiler

```
cd micropython/
git submodule update --init
cd mpy-cross/
make
```

```
cd ..
cd ports/esp32
```

Copy any .py files you want to include in the firmware as frozen python modules to the modules subdirectory in ports/esp32. Be aware there is a limit to the flash space available. You will know you have exceeded this limit if you receive an error message saying the code won't fit in the partition or if your firmware continuously reboots with an error.

For example:

```
cp ../../../st7789_mpy/fonts/bitmap/vga1_16x16.py modules
cp ../../../st7789_mpy/fonts/truetype/NotoSans_32.py modules
cp ../../../st7789_mpy/fonts/vector/scripts.py modules
```

Build the MicroPython firmware with the driver and frozen .py files in the modules directory. If you did not add any .py files to the modules directory you can leave out the FROZEN_MANIFEST and FROZEN_MPY_DIR settings.

```
make USER_C_MODULES=../../../../st7789_mpy/st7789/micropython.cmake FROZEN_MANIFE
```

Erase and flash the firmware to your device. Set PORT= to the ESP32's usb serial port. I could not get the usb serial port to work under the Windows Subsystem (WSL2) for Linux. If you have the same issue you can copy the firmware.bin file and use the Windows esptool.py to flash your device.

```
make USER_C_MODULES=../../../../st7789_mpy/st7789/micropython.cmake PORT=/dev/tty
make USER_C_MODULES=../../../../st7789_mpy/st7789/micropython.cmake PORT=/dev/tty
```

The firmware.bin file will be in the build-GENERIC directory. To flash using the python esptool.py utility. Use pip3 to install the esptool if it's not already installed.

```
pip3 install esptool
```

Set PORT= to the ESP32's usb serial port

```
esptool.py --port COM3 erase_flash
esptool.py --chip esp32 --port COM3 write_flash -z 0x1000 firmware.bin
```

CMake building instructions for MicroPython 1.14 and later

for ESP32:

```
$ cd micropython/ports/esp32
```

And then compile the module with specified USER_C_MODULES dir

```
$ make USER_C_MODULES=../../../../st7789_mpy/st7789/micropython.cmake
```

for Raspberry Pi PICO:

```
$ cd micropython/ports/rp2
```

And then compile the module with specified USER_C_MODULES dir

```
$ make USER_C_MODULES=../../../st7789_mpy/st7789/micropython.cmake
```

Working examples

This module was tested on ESP32, STM32 based pyboard v1.1 and the Raspberry Pi Pico. You have to provide a `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 was not able to run the display with a baud rate over 40MHZ.

Methods

- `st7789.ST7789(spi, width, height, dc, reset, cs, backlight, rotations, rotation, 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 displays 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 displays 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 displays backlight enable input. The displays backlight input can often be left floating or disconnected as the backlight on some displays are always powered on and cannot be turned off.
- `rotations` sets the orientation table. The orientation table is a list of tuples for each `rotation` that defines the MADCTL register, width, 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)]
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 in the list as you wish.

- `rotation` sets the display rotation according to the orientation table. The default orientation table defines four counter-clockwise rotations as 0-Portrait (0 degrees), 1- Landscape (90 degrees), 2- Reverse Portrait (180 degrees), and 3- Reverse Landscape (270 degrees) for 240x320, 240x240, 134x240, 128x160 and 128x128 displays with the LCD's ribbon cable at the bottom of the display. The default rotation being Portrait (0 degrees).
- `color_order` set the color order used by the driver st7789.RGB and st7789.BGR are supported.
- `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 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 specified it must be large enough to contain the largest bitmap, font character and/or 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. Optionally sets the MADCTL register if a value is passed to the method.

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

- `init()`

  Must be called to initalize 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.

- `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 reduced number of 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 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` . 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 the characters to include 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 width of the string 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 then 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 width of the string in pixels if drawn with the specified font.

- `jpg(jpg_filename, x, y [, method])`

  Draw JPG file on the display at the given `x` and `y` coordinates as the upper left corner of the image. There 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 method. The `SLOW` method will draw the image a piece at a time using the Minimum Coded Unit (MCU, typically a multiple of 8x8) of the image.

- `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.

- `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`, `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`, `y` coordinates in the `color` given. The polygon may be rotated `angle` radians a bout 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 turns on and off tracking the area of the display that has been written to. Initially tracking is disabled, pass a True value to enable tracking and False to disable. 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 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 added to the x and y parameters so that the pixels are written to the memory area that corresponds 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