Let's play

with the STM32F746G

Objectives

Explore some properties of the µC STM32F746G

Get familiar with the LCD-TFT display

Useful references (they are really useful !)

- STM32F7 Online Training

http://www.st.com/content/st_com/en/support/learning/stm32f7-online-training.html

- Datasheet of the STM32F746

http://www.st.com/content/ccc/resource/technical/document/datasheet/96/ed/61/9b/e0/6c/45/0b/DM00166116.pdf/files/DM00166116.pdf/jcr:content/translations/en.DM00166116.pdf

- Datasheet of the LCD-TFT of STM32 µC

http://www.st.com/content/ccc/resource/technical/document/application_note/group0/25/ca/f9/b4/ae/fc/4e/1e/DM00287603/files/DM00287603.pdf/jcr:content/translations/en.DM00287603.pdf

Outline

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    3. LTDC Display Controller Configuration
    4. Let's practice

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    1. Overview of the Programmable LTDC Layers
    2. Flexible Window Position and Size Configuration
    3. Color Frame Buffer
    4. Let's practice

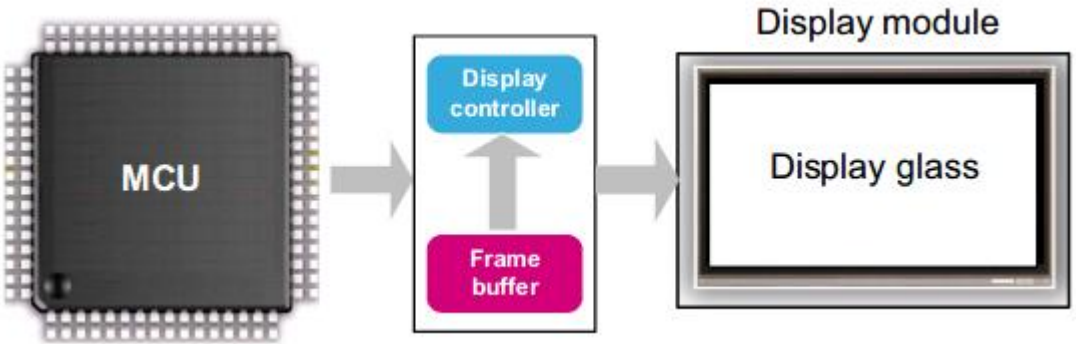
3. Using the touch screen
    1. LCD-TFT Touch Panel
    2. Let's Practice

Getting started with the display

Basic Graphic System

A basic embedded graphic system is composed of

- Microcontroller
- Frame buffer
- Display controller
- Display glass



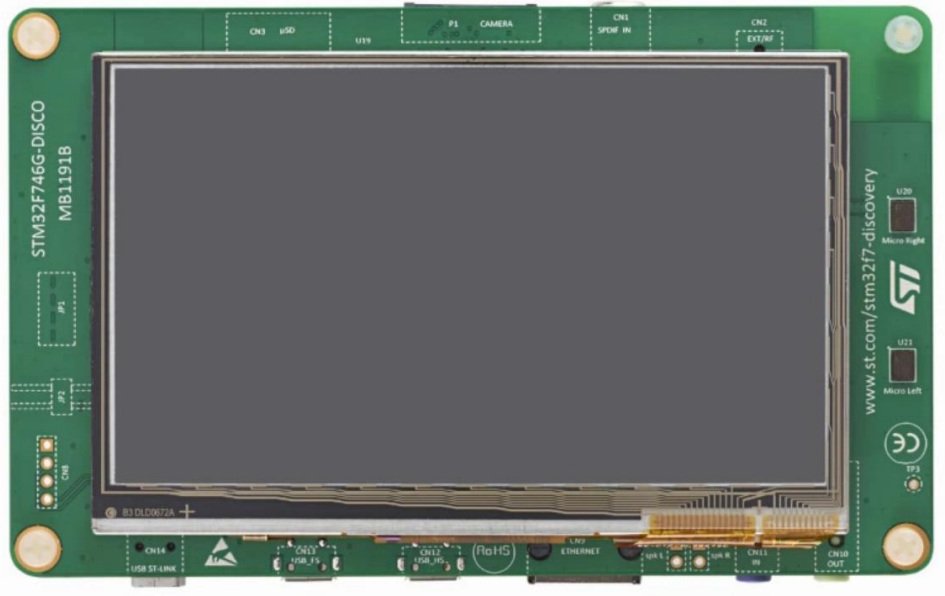
LCD-TFT Display

4.3-inch 480x272 color LCD-TFT

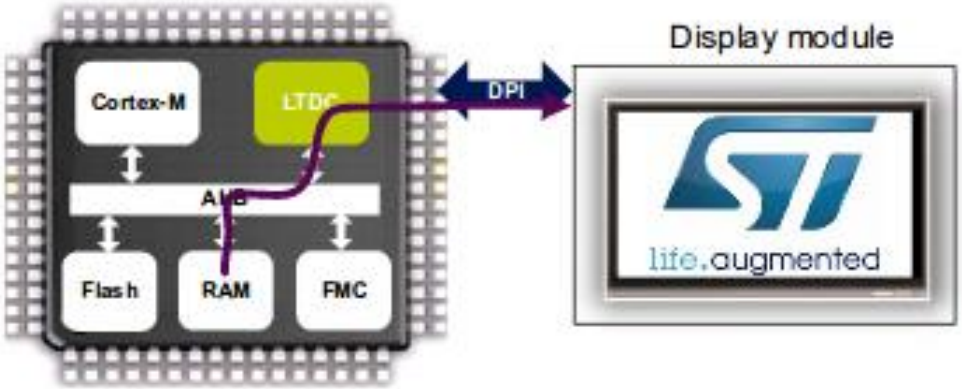
(Liquid Crystal Thin Film Transistor)

with capacitive touch screen is

on the front face of the STM32F7



LCD-TFT Display

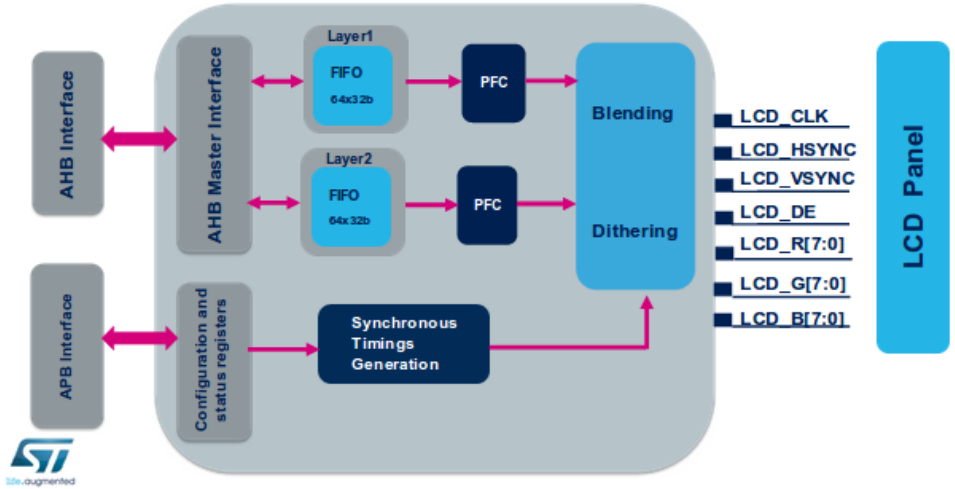


LTDC Display Controller Description

- is master on the AHB Bus Matrix and can access internal memories
- Reads the data of images in a line per line mode
- Provides 24-bit RGB interface with additional signals for horizontal and vertical synchronization

LTDC Display Controller Description

Block Diagram



LTDC Clock Domains

LTDC uses 3 clock domains:

- HCLK
  - AHB clk domain
  - Used to transfer data from memory to the frame buffer
- PCLK
  - To access the configuration and the status registers
- LCD_CLK
  - To generate LCD-TFT interface signals (LCD_HSYNC, LCD_VSYNC,...) and pixel data

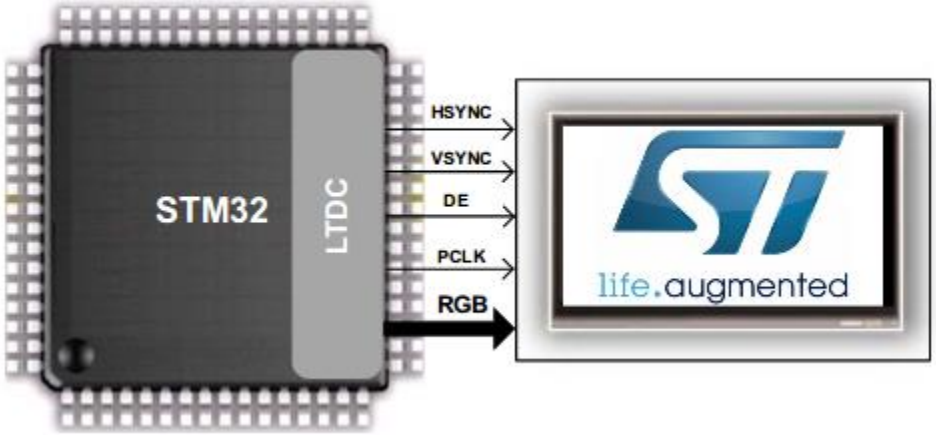
LTDC Reset

- Is managed by the Reset and Clock Controller (RCC)
- Is reset by setting the LTDC_RST bit in the RCC_APB2RSTR register

Reset and Clock Control (RCC)

- Manages the different system and peripheral resets
  - System reset
  - Power reset
  - Backup domain reset
- Has different clocks sources
  - 2 internal clock (HSI, LSI)
  - 2 external oscillators (HSE, LSE)
  - 3 PLLs (phase-locked loops)

Pins and Signal Interface



LTDC Pins and Signal Interface (2)

LTDC provides up to 28 signals including:

LCD-TFT Signals	Description
LCD_CLK	Pixel clock output
LCD_HSYNC	Horizontal synchronization
LCD_VSYNC	Vertical synchronization
LCD_DE	indicates that the data in the RGB bus is valid
LCD_R[7:0]	8-bit red data
LCD_G[7:0]	8-bit green data
LCD_B[7:0]	8-bit blue data

LTDC Pins and Signal Interface (3)

Other specific pins are :

LCD-TFT Signals	Description
LCD_DISP	enable/disable display standby mode
LCD_RST	reset the LCD-TFT
LCD_BL_A & LCD_BL_K	for LED backlight control

LTDC Display Controller Configuration

- GPIOs Configuration
- Peripheral Configuration
- FMC SDRAM Configuration

General-Purpose Input/Output (GPIO)

- enables the connectivity of the STM32F7 to the surrounding environment
- directly connected to AHB bus which allows faster operations
- ability to externally wake up the MCU
- enhanced robustness with the locking mode to freeze the I/O port configuration (GPIOx_LCKR)

General-Purpose Input/Output (GPIO) (2)

- 11 GPIOx ports on the STM32F7
- Each GPIO pin can be configured as
  - Input (floating, with or without pull-up or pull-down)
  - Output (push-pull or open-drain, with or without pull-up or pull-down)
- Each GPIO can host up to 16 I/O pins
- Bit set and reset operations using BSRR and BRR registers
- I/O pins are shared by several peripherals using an alternate function multiplexer

General-Purpose Input/Output (GPIO) (3)

- Declaration of the I/O

```
let mut gpio = Gpio::new(gpio_a,
                         gpio_b,
                         gpio_c,
                         gpio_d,
                         gpio_e,
                         gpio_f,
                         gpio_g,
                         gpio_h,
                         gpio_i,
                         gpio_j,
                         gpio_k);
```

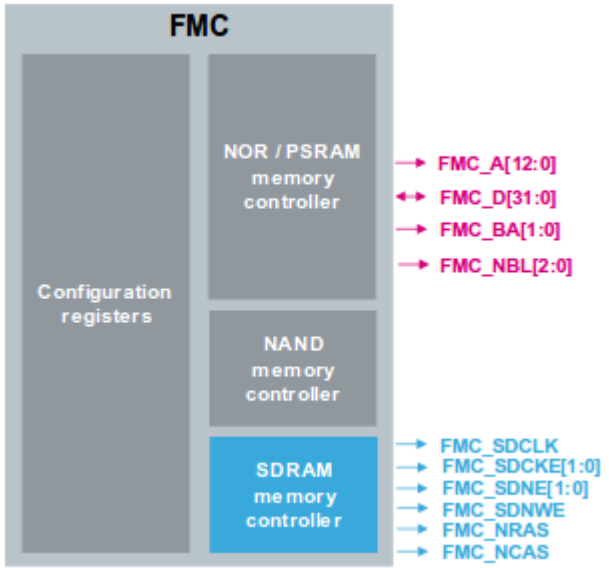
Peripheral Configuration

- System Clock (SYSCLK) configuration
- Pixel Clock (LCD_CLK) configuration
- LTDC Layer parameters configuration

FMC SDRAM Configuration

- The external SDRAM contains the LTDC framebuffer
- The Flexible Memory Controller (FMC)

generates the appropriate signals to drive the SDRAM memories



Configuration in Rust

- Hardware register structure

```
use stm32f7::{system_clock, sdram, lcd, board, embedded};
```

Configuration in Rust

- Hardware extraction in the main function

```
let board::Hardware {
        rcc,
        pwr,
        flash,
        fmc,
        ltdc,
        gpio_a,
        gpio_b,
        gpio_c,
        gpio_d,
        gpio_e,
        gpio_f,
        gpio_g,
        gpio_h,
        gpio_i,
        gpio_j,
        gpio_k,
        ..
    } = hw;
```

Configuration in Rust

- Initialisation of the LCD-TFT and the SDRAM in the main function

```
// init sdram (needed for display buffer)
sdram::init(rcc, fmc, &mut gpio);

// lcd controller
let mut lcd = lcd::init(ltdc, rcc, &mut gpio);
```

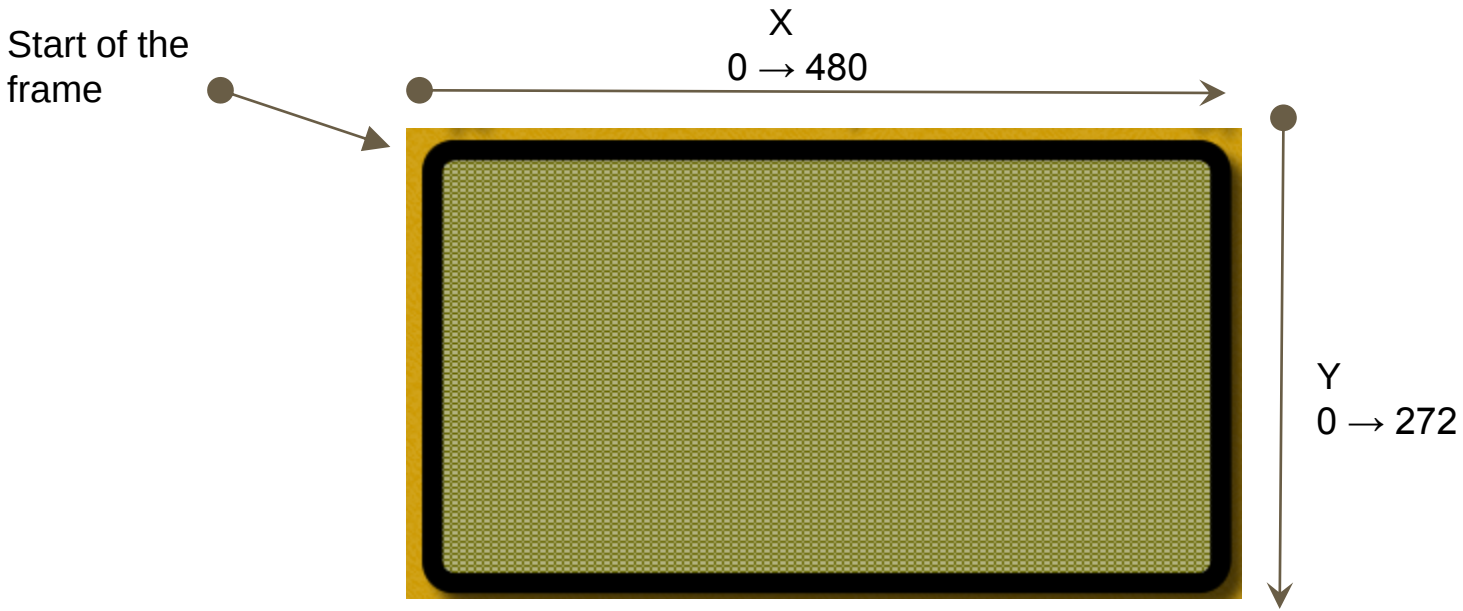
Let's Practice

- Clone / download the demo project from the GitHub

- Focus mainly on the main.rs file

```
fn main(hw: board::Hardware) -> ! {
    ...
    loop {
        // Add your code
    }
}
```

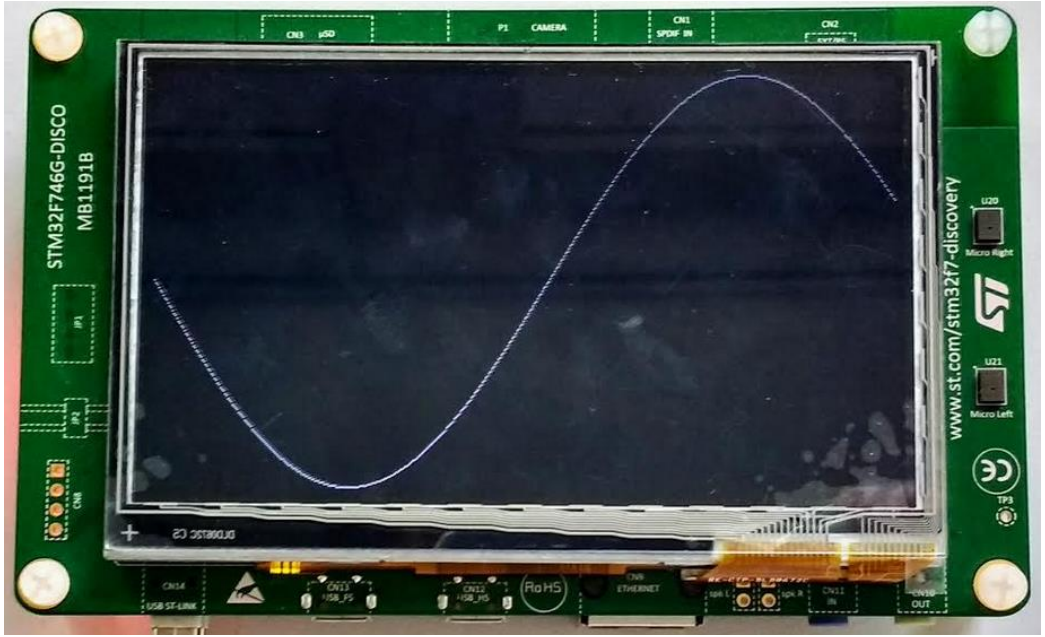
Let's Practice



Let's Practice

Task 1:

Generate one period of a sine wave on the display of the STM32F7 without using the maths library



Let's Practice

- To generate the sine wave without using any library
  - LookUp Table
  - Taylor series
  - CORDIC algorithm...

- To generate a LUT

http://www.daycounter.com/Calculators/Sine-Generator-Calculator.phtml

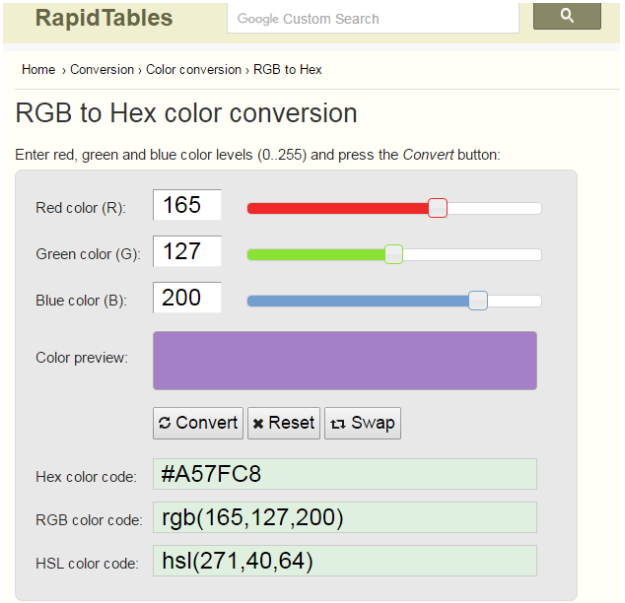
Let's Practice

Extra Tasks:

- Generate more periods of a sine wave on the display of the STM32F7
- Control the frequency of the sine wave

What about adding some colors

What about adding some colors



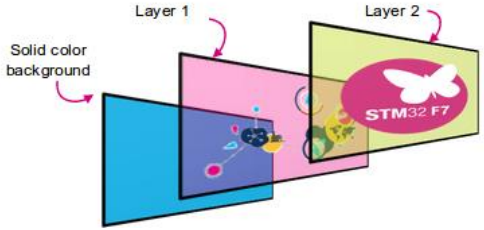
- RGB (red, green, blue) color values are used
- Each parameter (Red, Green,Blue)
  - defines the intensity of the color
  - can be an integer between 0..255 or hexadecimal between #000000 and #FFFFFF
  - http://www.rapidtables.com/convert/color/rgb-to-hex.htm
- The parameter alpha
  - Blending coefficient

What about adding some colors

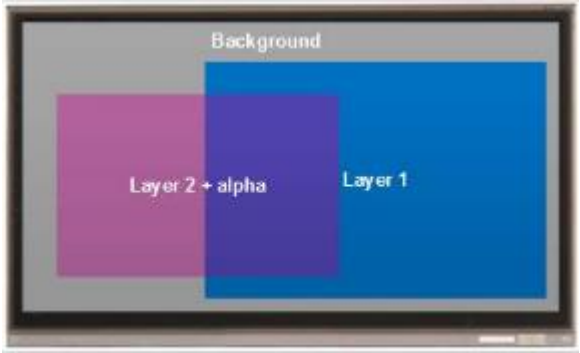
- Definition of the structure Color in Rust

```
pub struct Color {
    pub red: u8,
    pub green: u8,
    pub blue: u8,
    pub alpha: u8,
}
```

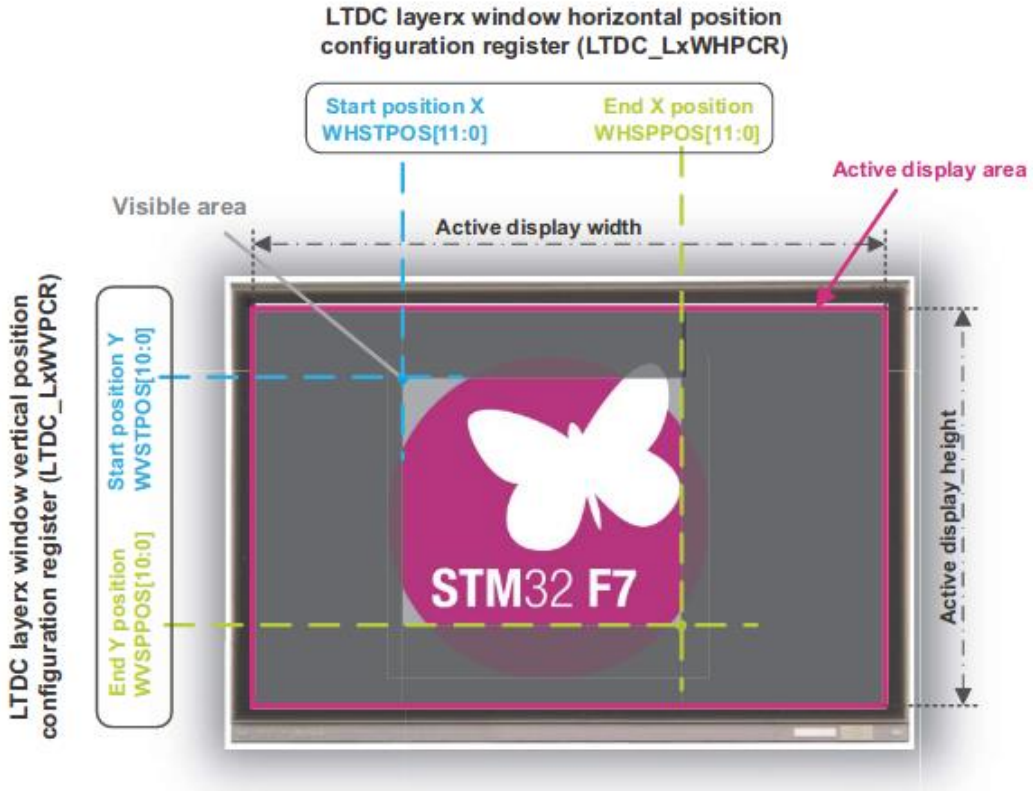
Programmable LTDC Layers



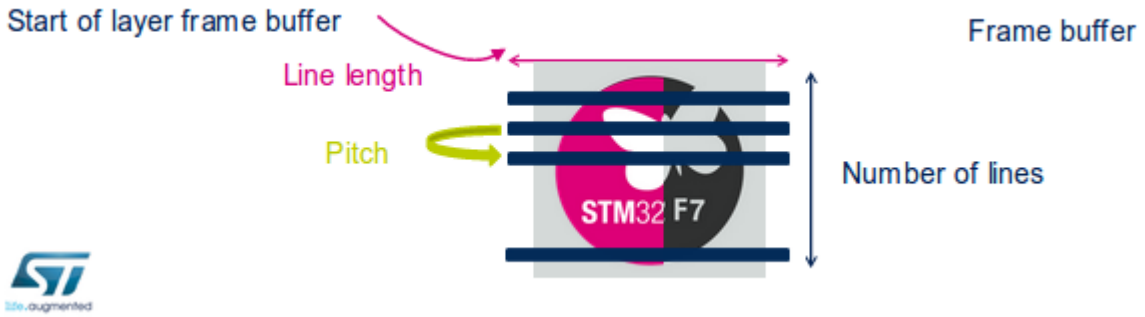
- LTCD has 3 layers (background + 2layers)
  - The layers can be enabled, disabled and configured separately
  - They can be blended according to the alpha coefficient
  - The blending order is fixed (bottom-up)



Flexible Window Position and Size Configuration

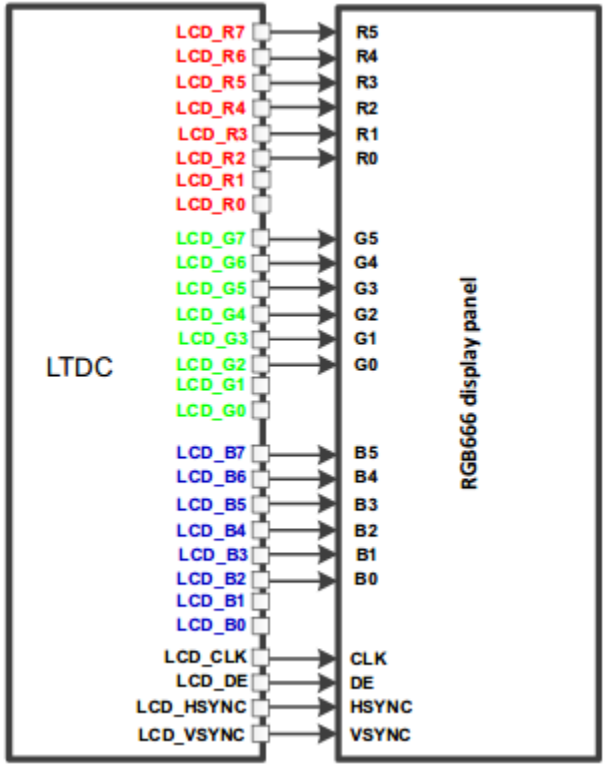


Color Frame Buffer



Registers	Description
LTDC_LxCFBAR	The start address for the color framebuffer
LTDC_LxCFBLR	The line length (in bytes)
LTDC_LxCFBLNR	The number of lines (in bytes)
LTDC_LxCFBLR	The pitch is the distance between the start of one line and the beginning of the next line in bytes

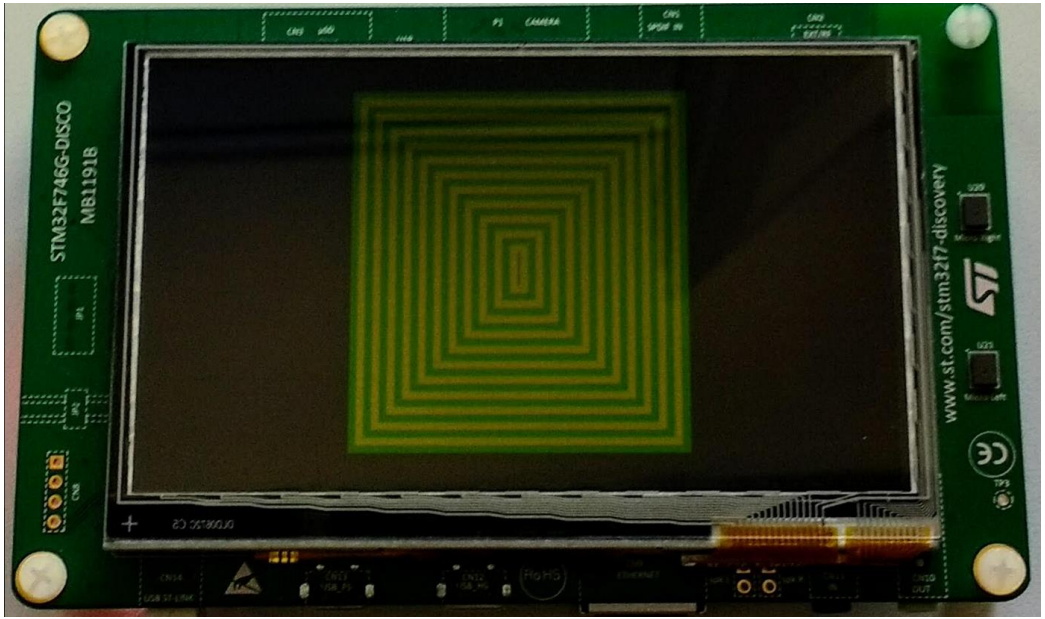
Display Panel Connection



Let's Practice

Task 2:

Generate concentric squares of different colors on the display in a loop without using the graphics library



Using the touch screen

LCD-TFT Touch Panel

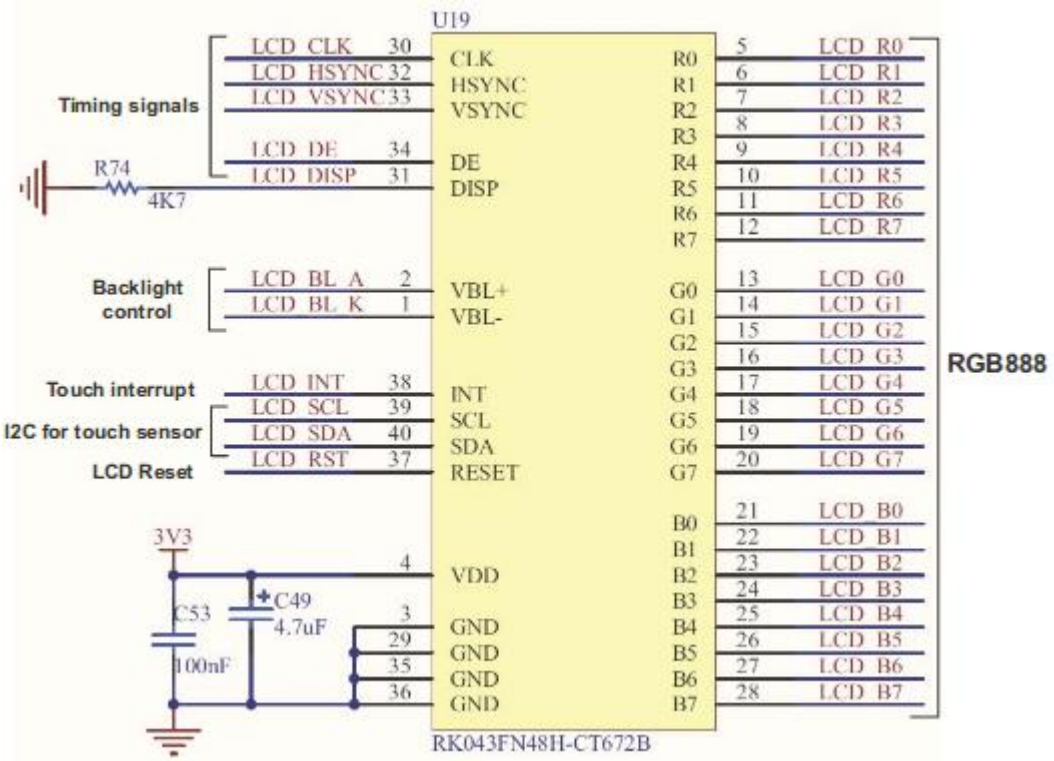
- Capacitive touch panel
- A serial interface I2C (Inter-Integrated Circuit) connects the display panel to the touch sensor

LTDC Pins and Signal Interface specific to the touch sensor

Other specific pins to the touch sensor are :

LCD-TFT Signals	Description
LCD_INT	allows the touch sensor to generate interrupts
LCD_SCL & LCD_SDA	control the touch sensor

LTDC Pins and Signal Interface specific to the touch sensor (2)



Configuration in Rust

- Hardware register structure

```
// hardware register structs with accessor methods
use stm32f7::{system_clock, sdram, lcd, i2c, touch, board, embedded};
```

Configuration in Rust

- Hardware extraction in the main function

```
let board::Hardware {
    rcc,
    pwr,
    flash,
    fmc,
    ltdc,
    gpio_a,
    gpio_b,
    gpio_c,
    gpio_d,
    gpio_e,
    gpio_f,
    gpio_g,
    gpio_h,
    gpio_i,
    gpio_j,
    gpio_k,
    i2c_3,
    ..
} = hw;
```

Configuration in Rust

- Initialisation of the I2C interface in the main function

```
// i2c
i2c::init_pins_and_clocks(rcc, &mut gpio);
let mut i2c_3 = i2c::init(i2c_3);
```

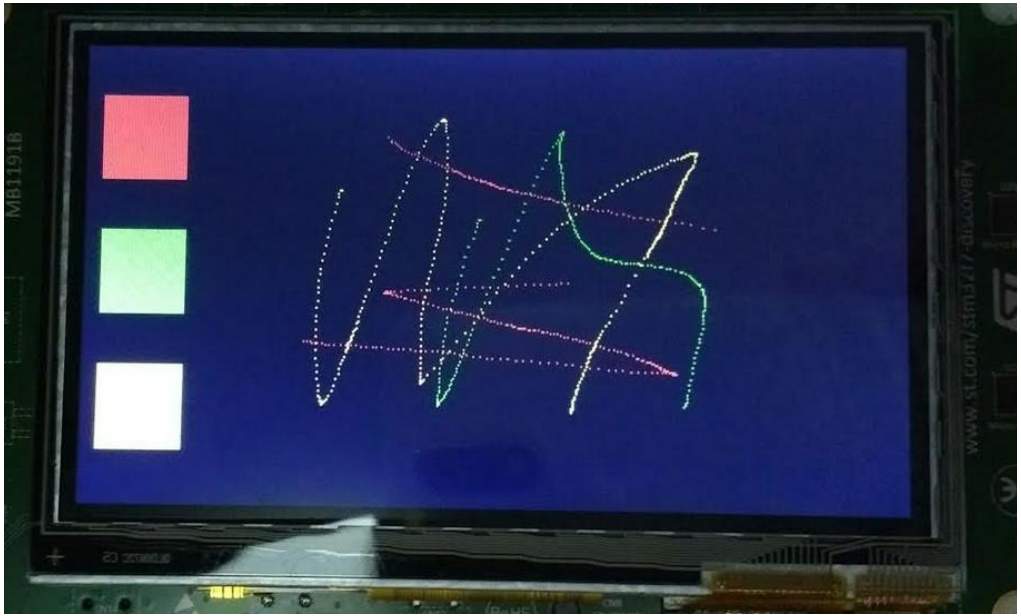
- Connecting the touch screen via the I2C interface

```
touch::check_family_id(&mut i2c_3).unwrap();
```

Let's Practice

Task 3:

Write on the touch screen of the STM32F7 using different colors



Let's Practice

Extra Tasks:

- Modify the size of the drawing on the display
- Erase some lines from your drawing...


That's all Folks!

Let's Practice: Task 1

```
loop {
    //Parameters to generate the
    //LUT (Nbre of pts:480 Max amplitude: 271)
    let y ; // y = LUT of sine
    for x in 1..480 {
        lcd.print_point_at(x, y[x as usize]);
    }
}
```

Let's Practice: Task 2

```
loop {
    let color = [0xff00, 0x0f00]; //yellow;green
    for c in 1..24 {
        let i1 = 124 + 5 * c;
        let i2 = 356 - 5 * c;
        let j1 = 10 + 5 * c;
        let j2 = 262 - 5 * c;
        for i in i1..i2 {
            for j in j1..j2 {
                lcd.print_point_color_at(i, j, color[c as usize & 1]);
            }
        }
    }
    lcd.clear_screen();
}
```

Let's Practice: Task 3

```
let color = [0xf000, 0x0f00, 0xff00, 0xffff];
let w = 80;
for i in 10..60 {
    for j in 30..80 {
        for c in 0..3 {
            lcd.print_point_color_at(i, j + w * c, color[c as usize]);
        }
    }
}
let mut c = 3;
loop {
    for touch in &touch::touches(&mut i2c_3).unwrap() {
        let x = touch.x;
        let y = touch.y;
        if x > 10 && x < 60 {
            if y > 30 && y < 80 {
                c = 0;
            } else if y > 30 && y < (80 + w) {
                c = 1;
            } else if y > 30 && y < (80 + 2 * w) {
                c = 2;
            }
        }
    }
    for touch in &touch::touches(&mut i2c_3).unwrap() {
        lcd.print_point_color_at(touch.x, touch.y, color[c as usize]);
    }
}
```