General Purpose Input/Output (GPIO)

ENCE361 Embedded Systems 1

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Department of Electrical and Computer Engineering

Where we're going today

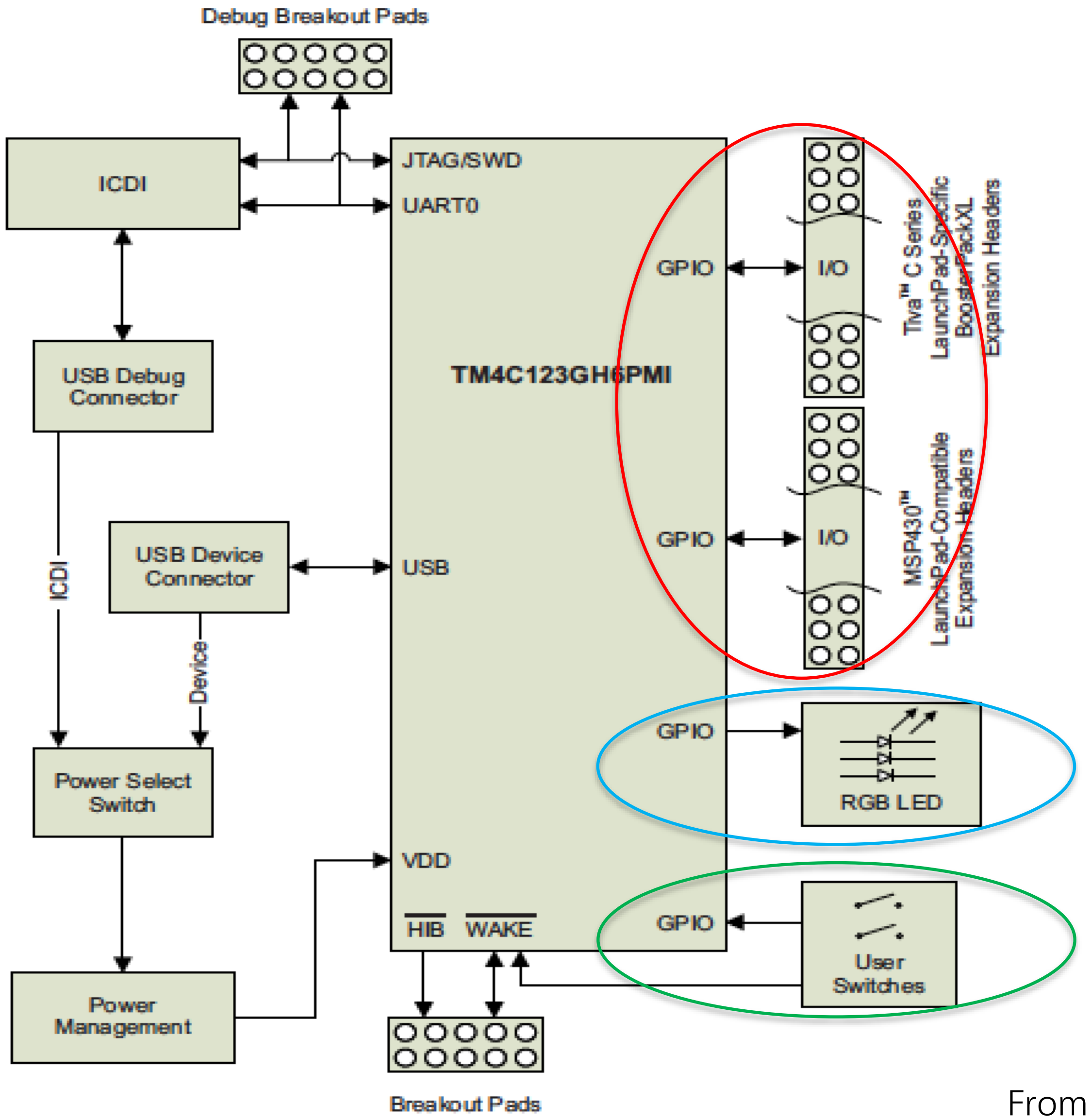
- **GPIO overview**
- Output LEDs and input switches
- Multiplexing and programmable control
- Example program in C

GPIO Overview

- A GPIO = An signal pin on an integrated circuit (IC) or circuit board
  - Basic I/O interface of a MCU
  - Programmable behavior (input or output, analog or digital, serial communications, …)
- Tiva C-series TM4C123x MCU provides up to 43 GPIOs

- 40 GPIO pins on Tiva C-Series launchpad
  - 4 (physical) single-in-line headers (J1 - J4), each having 10 pins
  - Accessible via 7 ports (PA – PG), each having up to 8 pins (0-7)
    - ‘P’ stands for port
    - “PF0”, “PA7”, “PE4” …

Tiva C-Series Launchpad Block Diagram



4 single-in-line headers (see next slide)

Output LEDs (see next slide & slide 6)

Input switches (see next slide & slide 7)

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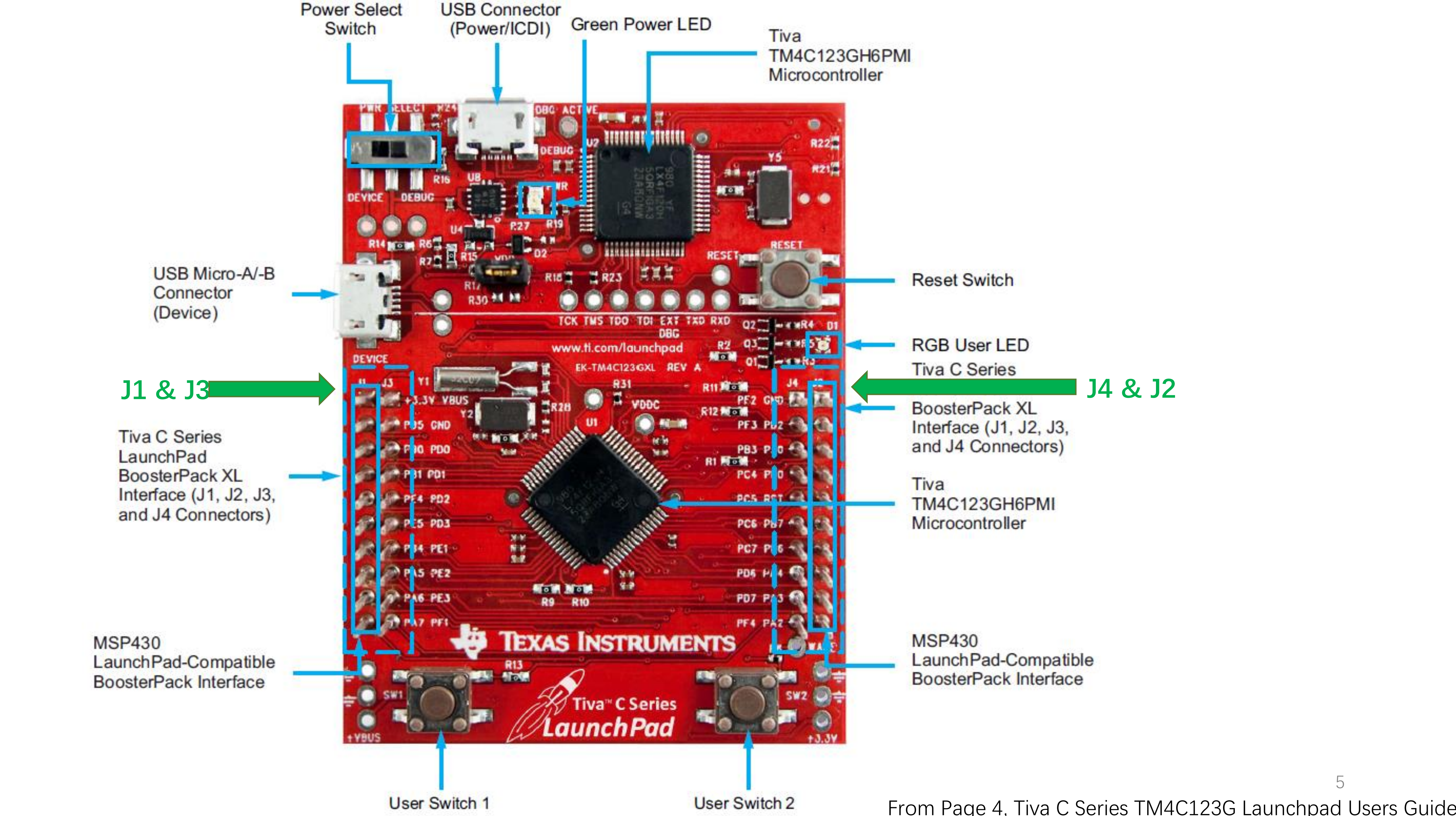
Power Select Switch
USB Connector (Power/ICDI)
Green Power LED
Tiva TM4C123GH6PMI Microcontroller
USB Micro-A/-B Connector (Device)
Reset Switch
RGB User LED
Tiva C Series
J1 & J3
J4 & J2
BoosterPack XL Interface (J1, J2, J3, and J4 Connectors)
Tiva C Series LaunchPad BoosterPack XL Interface (J1, J2, J3, and J4 Connectors)
Tiva TM4C123GH6PMI Microcontroller
MSP430 LaunchPad-Compatible BoosterPack Interface
MSP430 LaunchPad-Compatible BoosterPack Interface
User Switch 1
User Switch 2

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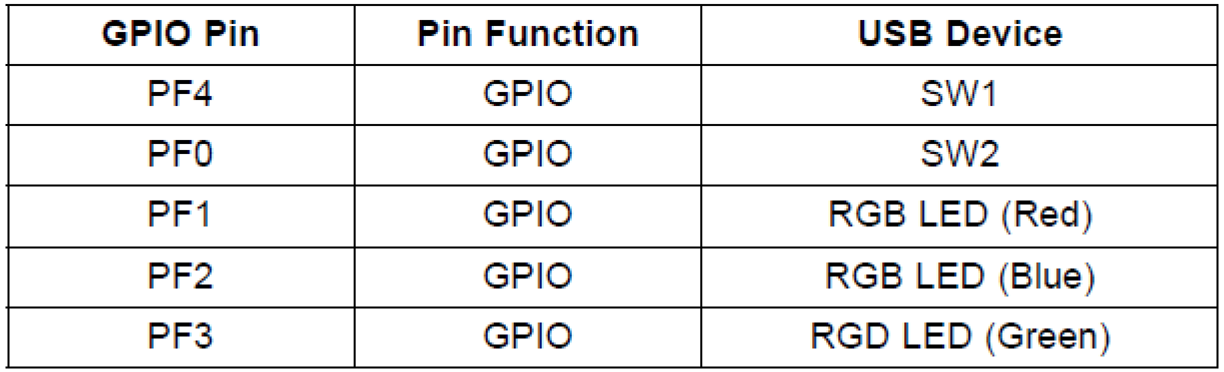
Output LEDs and Input Switches

- Tiva C-Series Launchpad comes with
  - 3 LEDs: red, green and blue
  - 2 user buttons (switches SW1 and SW2)

- They are wired to the following GPIO pins:

Table 2-2. User Switches and RGB LED Signals



GPIO Pin	Pin Function	USB Device
PF4	GPIO	SW1
PF0	GPIO	SW2
PF1	GPIO	RGB LED (Red)
PF2	GPIO	RGB LED (Blue)
PF3	GPIO	RGD LED (Green)

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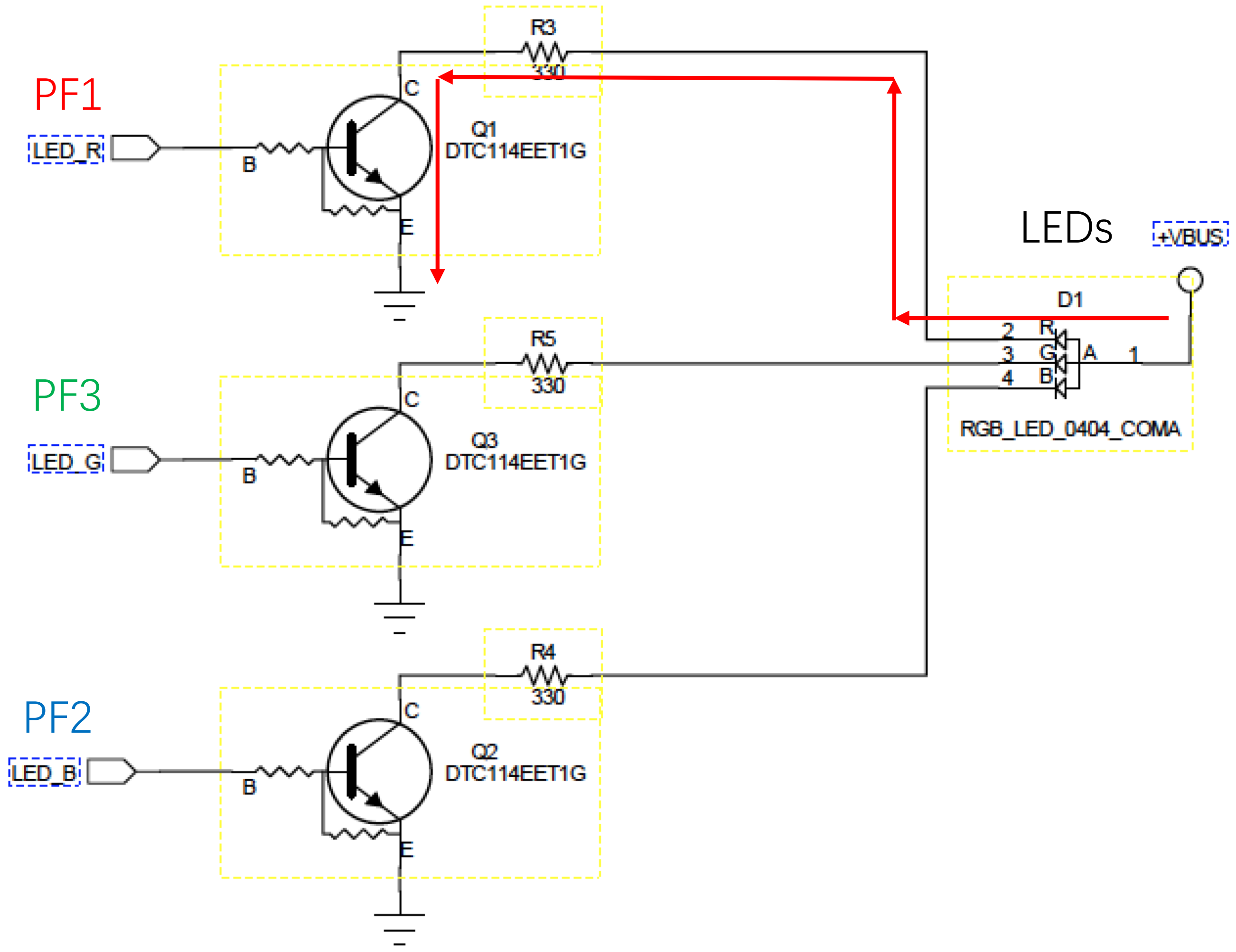
Output LEDs

- Support three output LEDs
- Transistors used as <u>switches</u>
  - V_{BE} greater than, say, 0.7V
    - Transistors in saturate state
    - V_{CE} smaller than, say, 0.2V, equivalent to closed circuits from +VBUS to GND
- LEDs configured as <u>active high</u>



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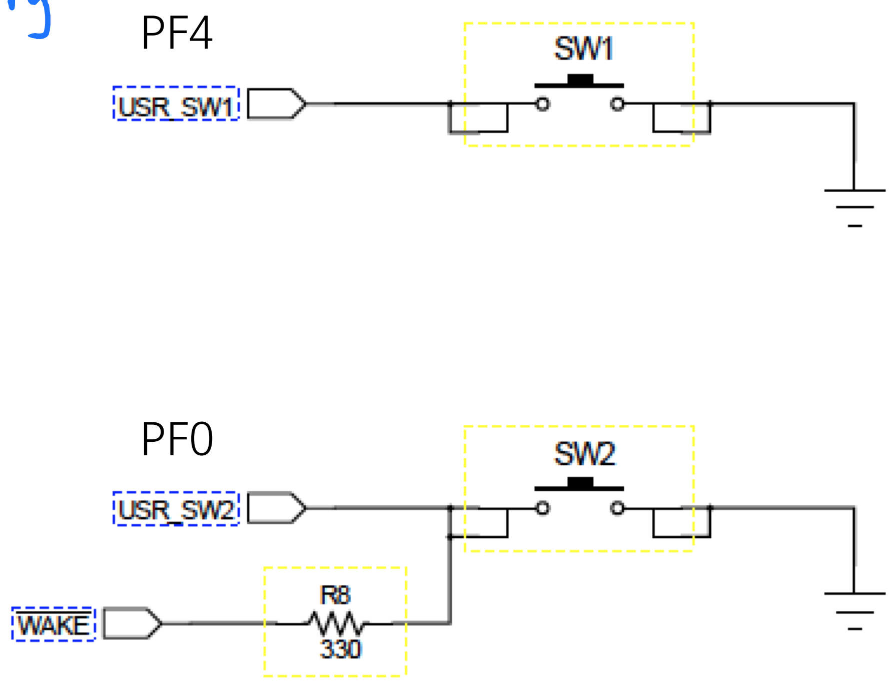
Input Switches

• Tivo board does not have debouncing circuitry (have to do it in software)

- Can be used for GUI
  - Steps/distance traveled
- Does not have debouncing circuitry
- Pushing a button connects a pin to GND
  - How to detect a switch being closed?
  - Configure the GPIO pin as weak pull-up (WPU), instead of weak pull-down (WPD)



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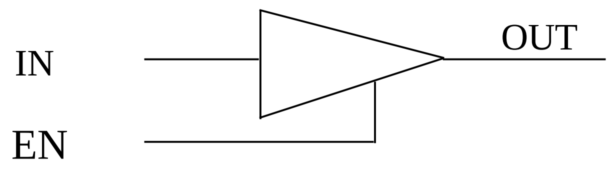
GPIO Pin Multiplexing

- Highly flexible pin multiplexing
  - Pin behavior programmable as a GPIO input/output or e.g., an ADC input
  - Most pins doubled-up with specialized functions
- Building blocks for pin multiplexing: tri-state (3-state) buffer
  - Hi-Z: high impedance (open circuit)
  - Allow selection of multiple inputs

tri-state buffer



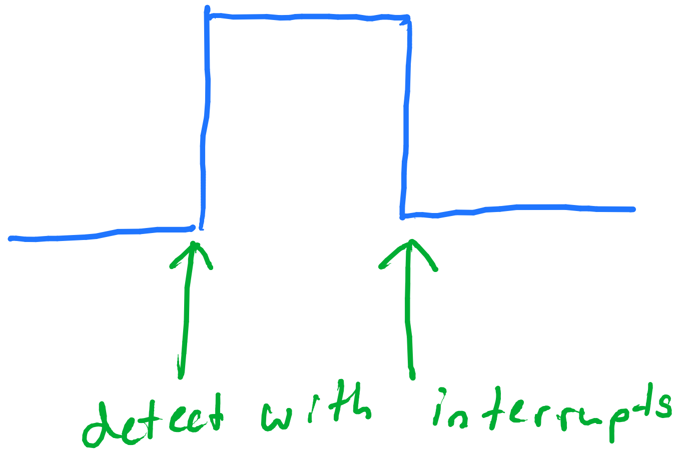
True Table

EN	IN	OUT
0	X	Hi-Z
1	0	0
1	1	1

- See more on Slide 18

Programmable Control for GPIO Pins

- Programmable control for GPIO pad configuration
  - Weak pull-up (WPU) vs. weak pull-down (WPD)
  - Input vs. output
  - 2-mA, 4-mA or 8-mA pad drive
- Programmable control for GPIO interrupts
  - Edge-triggered on rising, falling or both
  - Level-sensitive on High or Low voltage

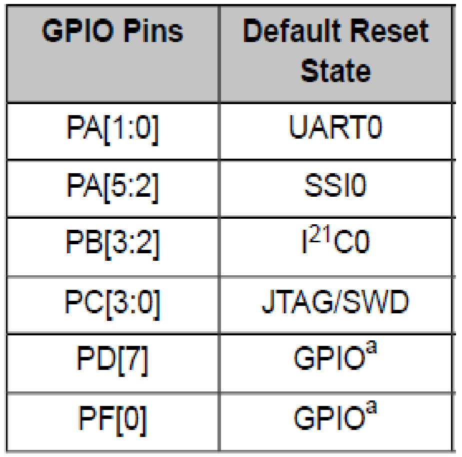


Using GPIO Pins

- Initialization
  - GPIO ports are system peripherals required to be enabled before use
    - e.g., SysCtlPeripheralEnable(SYSCTL_PERIPH_GPIOF)
    - GPIO pins with special considerations needed to be unlocked before being reprogrammed
- Configuration
  - Set GPIO pin as WPU or WPD
    - void GPIOPadConfigSet (ui32Port, ui8Pins, ui32Strength, ui32PinType)
  - Set GPIO pin as input or output
    - void GPIODirModeSet (ui32Port, ui8Pins, ui32PinIO)
    - void GPIOPinTypeGPIOInput (ui32Port, ui8Pins)
    - void GPIOPinTypeGPIOOutput (ui32Port, ui8Pins)

• look on slide 8

Table 10-1. GPIO Pins With Special Considerations



GPIO Pins	Default Reset State
PA[1:0]	UART0
PA[5:2]	SSI0
PB[3:2]	I^2C0
PC[3:0]	JTAG/SWD
PD[7]	GPIO[a]
PF[0]	GPIO[a]

From Page 650, TM4C123GH6PM Data Sheet.pdf

Using GPIO Pins (Continued)

- Access
  - GPIO pin read and write
    - int32_t GPIOPinRead (ui32Port, ui8Pins)
    - void GPIOPinWrite (ui32Port, ui8Pins, ui8Val)
- Alternative function configuration

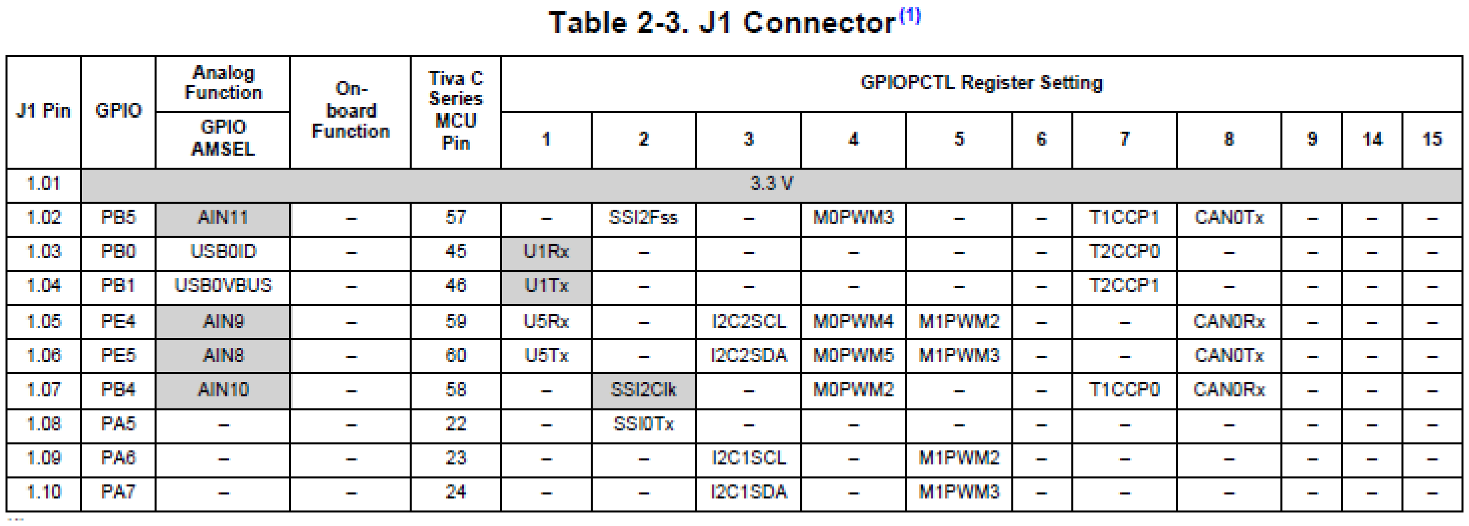


Table 2-3. J1 Connector[1]

J1 Pin	GPIO	Analog Function / GPIO AMSEL	On-board Function	Tiva C Series MCU Pin	GPIOPCTL Register Setting 1	2	3	4	5	6	7	8	9	14	15
1.01	3.3 V														
1.02	PB5	AIN11	–	57	–	SSI2Fss	–	M0PWM3	–	–	T1CCP1	CAN0Tx	–	–	–
1.03	PB0	USB0ID	–	45	U1Rx	–	–	–	–	–	T2CCP0	–	–	–	–
1.04	PB1	USB0VBUS	–	46	U1Tx	–	–	–	–	–	T2CCP1	–	–	–	–
1.05	PE4	AIN9	–	59	U5Rx	–	I2C2SCL	M0PWM4	M1PWM2	–	–	CAN0Rx	–	–	–
1.06	PE5	AIN8	–	60	U5Tx	–	I2C2SDA	M0PWM5	M1PWM3	–	–	CAN0Tx	–	–	–
1.07	PB4	AIN10	–	58	–	SSI2Clk	–	M0PWM2	–	–	T1CCP0	CAN0Rx	–	–	–
1.08	PA5	–	–	22	–	SSI0Tx	–	–	–	–	–	–	–	–	–
1.09	PA6	–	–	23	–	–	I2C1SCL	–	M1PWM2	–	–	–	–	–	–
1.10	PA7	–	–	24	–	–	I2C1SDA	–	M1PWM3	–	–	–	–	–	–

void GPIOPinTypeADC (ui32Port, ui8Pins)
void GPIOPinTypePWM (ui32Port, ui8Pins)
void GPIOPinConfigure (ui32PinConfig)

Reference to TivaWare Peripheral Driver Library Users Manual. Pdf

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Example GPIO use – “week2_blink.c” used in Week 2 lab

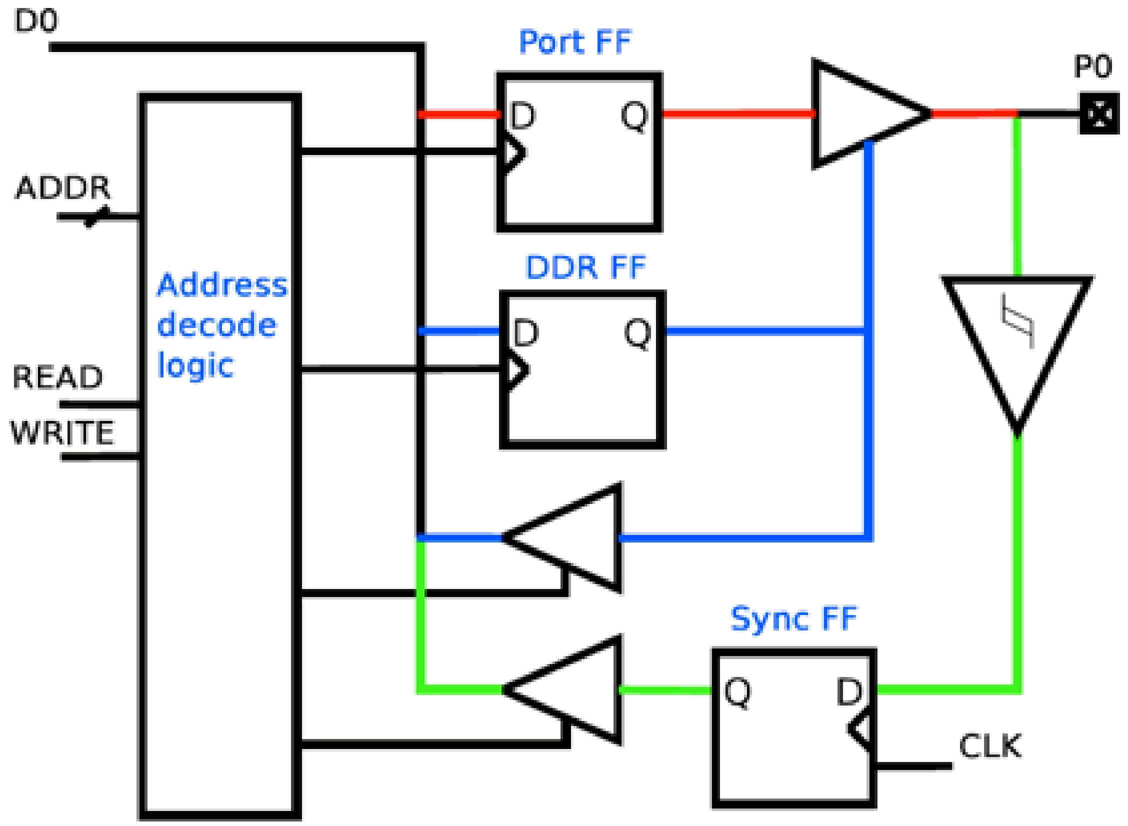
```
#define RED_LED   GPIO_PIN_1
#define BLUE_LED  GPIO_PIN_2
#define GREEN_LED GPIO_PIN_3

int main(void) {
     uint32_t clock_rate;
     // Set up the system clock rate to 20 MHz
     SysCtlClockSet(SYSCTL_USE_PLL | SYSCTL_OSC_MAIN |
                              SYSCTL_XTAL_16MHZ | SYSCTL_SYSDIV_10);

    SysCtlDelay(100);  // Allow oscillator to settle down
    clock_rate = SysCtlClockGet();  // Clock rate in pulses/s

    SysCtlPeripheralEnable(SYSCTL_PERIPH_GPIOF);       // Enable Port F

    GPIOPadConfigSet(GPIO_PORTF_BASE, GREEN_LED,
                              GPIO_STRENGTH_4MA, GPIO_PIN_TYPE_STD_WPD);     // Configure PF3, 4mA, WPD

   GPIODirModeSet(GPIO_PORTF_BASE, GREEN_LED, GPIO_DIR_MODE_OUT); //  Set PF3 as output
```

Example GPIO use – “week2_blink.c” used in Week 2 lab (continued)

```
    // Write a zero to the output pin 3 on port F
    GPIOPinWrite(GPIO_PORTF_BASE, GREEN_LED, 0x00);                // Turn off Green LED

    // Enter a gadfly loop (kernel) to make the LED blink
    while (1)
    {
      // Delay (passing the argument value clock_rate /3 gives a delay of 1 sec)
      SysCtlDelay(clock_rate /12);
                                                GPIO-Pin 3
      // Turn on the LED                                ↑
      GPIOPinWrite(GPIO_PORTF_BASE,  GREEN_LED, GREEN_LED);

     // Delay
     SysCtlDelay(clock_rate /12);

     // Turn off the LED
     GPIOPinWrite(GPIO_PORTF_BASE,  GREEN_LED, 0x00);
    }
}
```

Simplified 1-bit Bidirectional I/O

- Output:
  - D0 - port FF - tri-state buffer - P0
- Input:
  - P0 - Schmitt trigger - tri-state buffer - D0
- Control logic:
  - Address decode logic using ADDR (address), READ/WRITE
  - Double data rate (DDR) flip-flop (FF)


D0
Port FF
P0
D
Q
ADDR
DDR FF
Address decode logic
D
Q
READ
WRITE
Sync FF
Q
D
CLK