香港中文大學
The Chinese University of Hong Kong

CENG2400 Embedded System Design

Lecture 01: Introduction

Ming-Chang YANG

mcyang@cse.cuhk.edu.hk

Thanks to Prof. Q. Xu and Drs. K. H. Wong, Philip Leong, Y.S. Moon, O. Mencer, N. Dulay, P. Cheung for some of the slides used in this course!

Outline

- **Preface: Control a System**
- **Basics of Embedded System**
  - Embedded System (ES): Concepts and Examples
  - Typical ES Software Operations
  - Typical ES Attributes
- **Target Platform: Tiva™ LaunchPad**
  - ARM® Cortex™-M4F-based microcontrollers

Outline

- **Preface: Control a System**

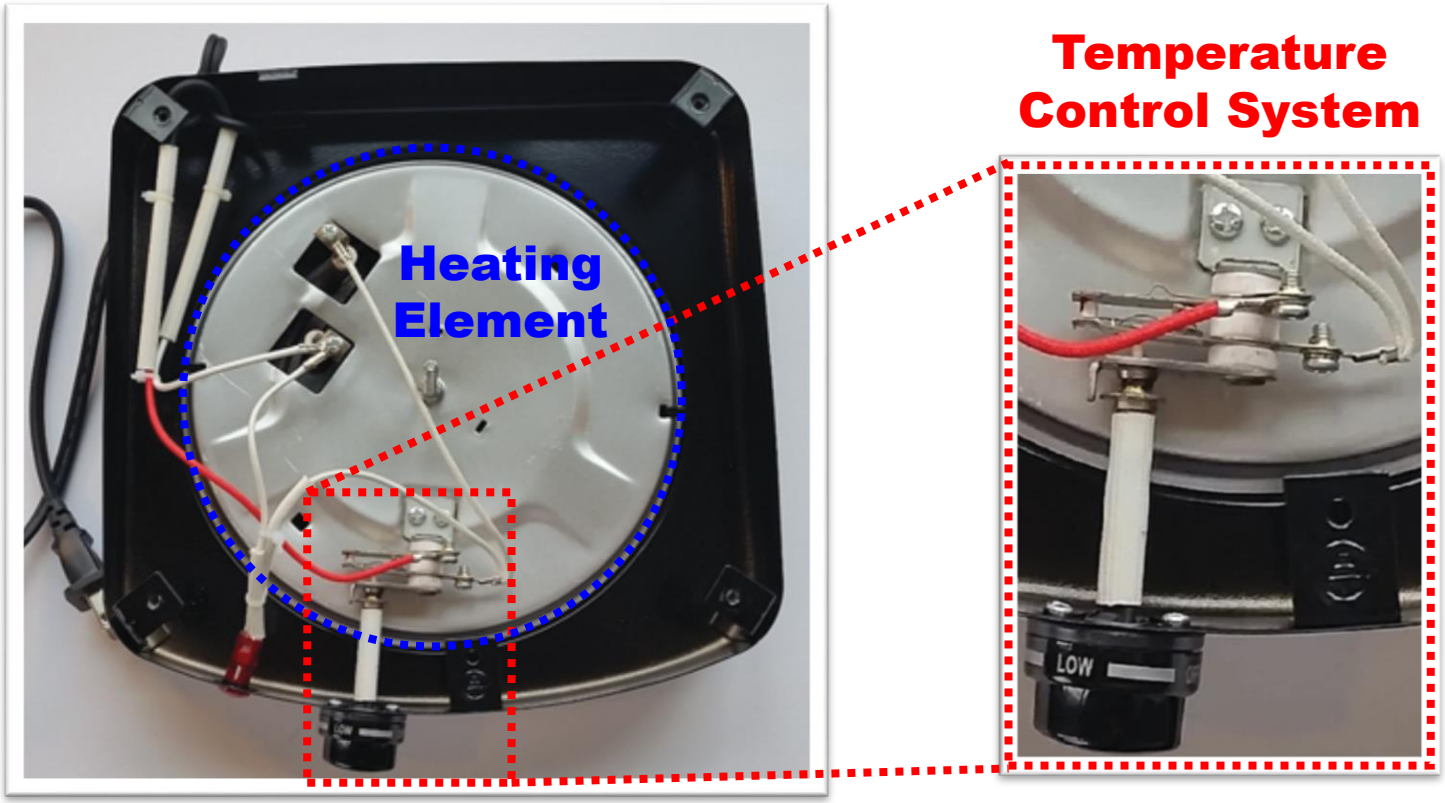
- **Basics of Embedded System**
  - Embedded System (ES): Concepts and Examples
  - Typical ES Software Operations
  - Typical ES Attributes

- **Target Platform: Tiva™ LaunchPad**
  - ARM® Cortex™-M4F-based microcontrollers

An Electric Hot Plate

- This is an **electric hot plate** that is used to cook food.
  - The **control knob** on the front is for **turning on/off** the hot plate and **setting the temperature** (to low/med/high).

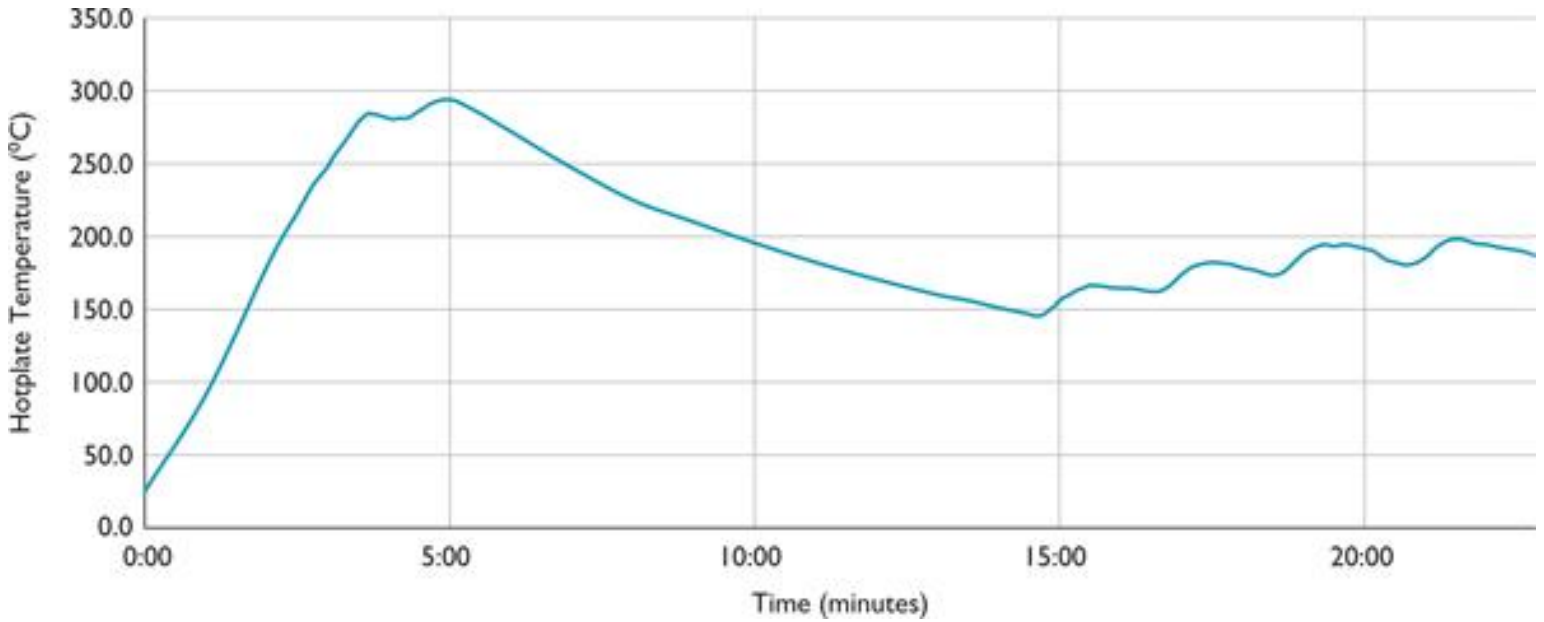
How Does It Work?



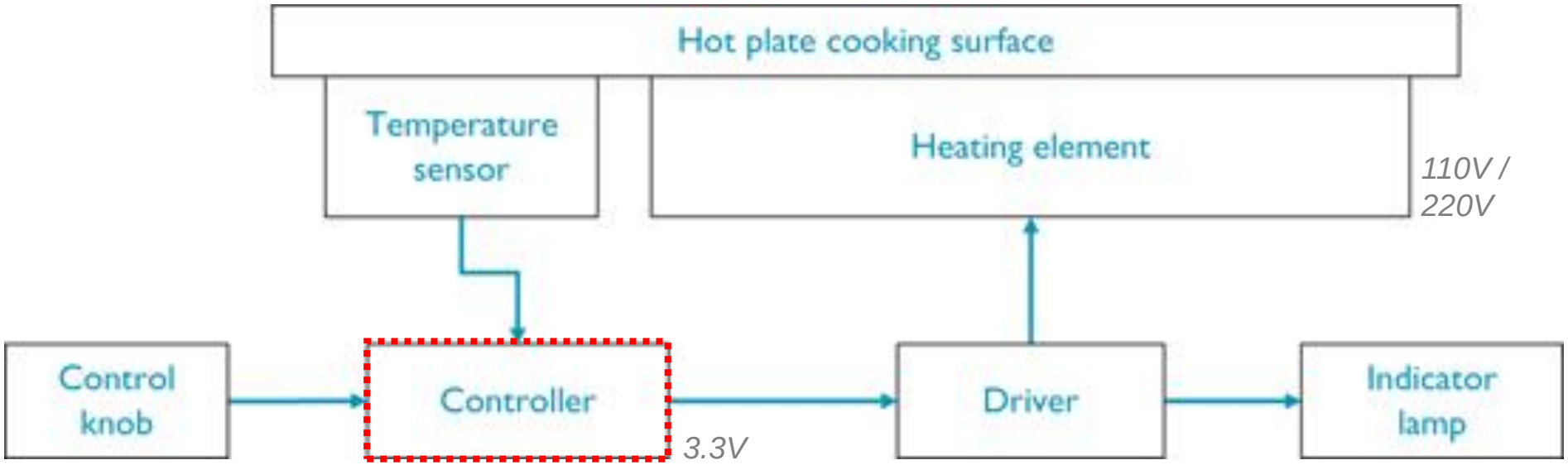
- The **temperature control system** is based on:
  - A **thermostatic switch**, which **bends** as it grows hotter to connect or disconnect the **heating element** from the power.
  - A **control knob**, which **adjusts** the distance between the switch contacts to set the temperatures.

Class Exercise 1.1

- The below figure shows the temperature over time, which is measured using a thermocouple, a type of electric thermometer.
- How good is its temperature control? Point out all possible issues you have observed.



Embedded Computer for Better Control



- Embedded computers use **microcontrollers** to simplify the system's monitoring/control at low cost.
  - The microcontroller reads the desired and actual temperatures and decides on how to control the system.
  - The outputs from microcontroller are low voltage/current (incapable of powering the heating element): a **driver** and a **power supply** (not shown) are needed.

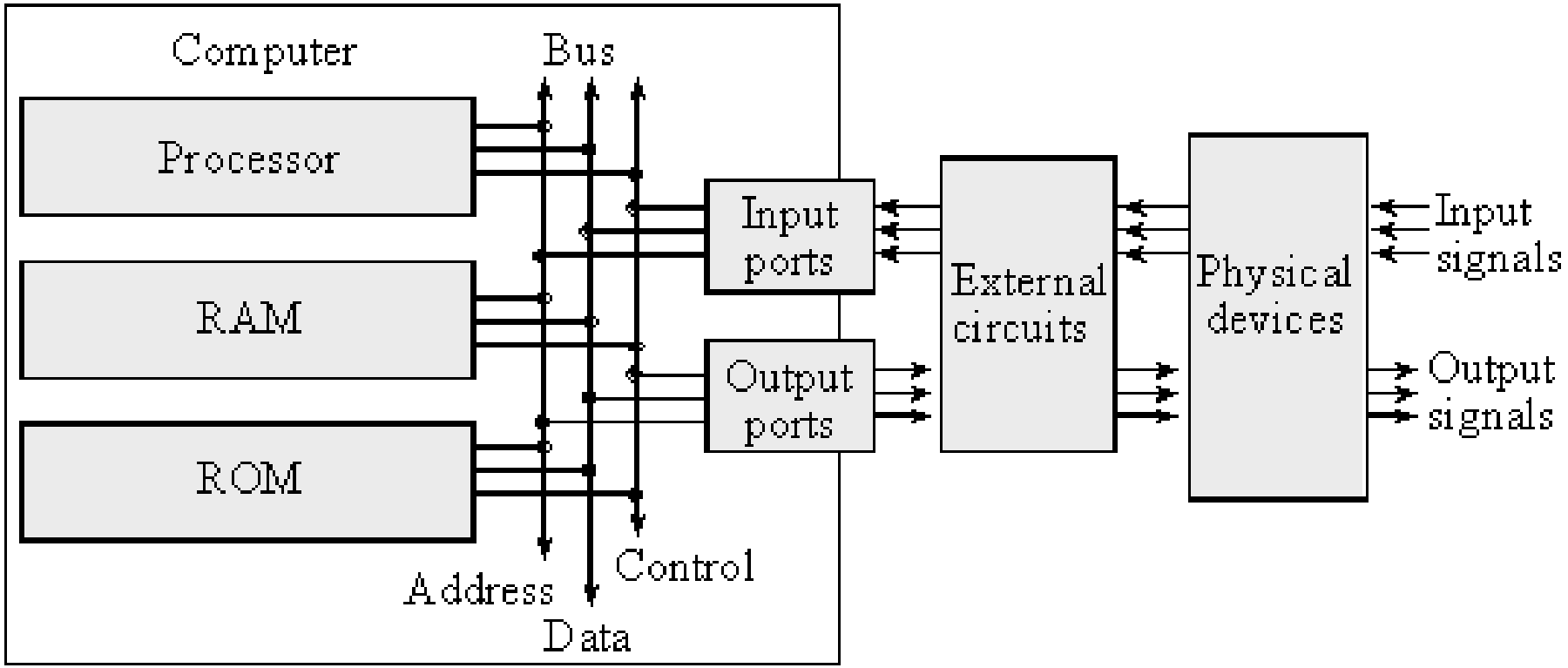
Outline

- Preface: Control a System

- **Basics of Embedded System**
  - Embedded System (ES): Concepts and Examples
  - Typical ES Software Operations
  - Typical ES Attributes

- Target Platform: Tiva™ LaunchPad
  - ARM® Cortex™-M4F-based microcontrollers

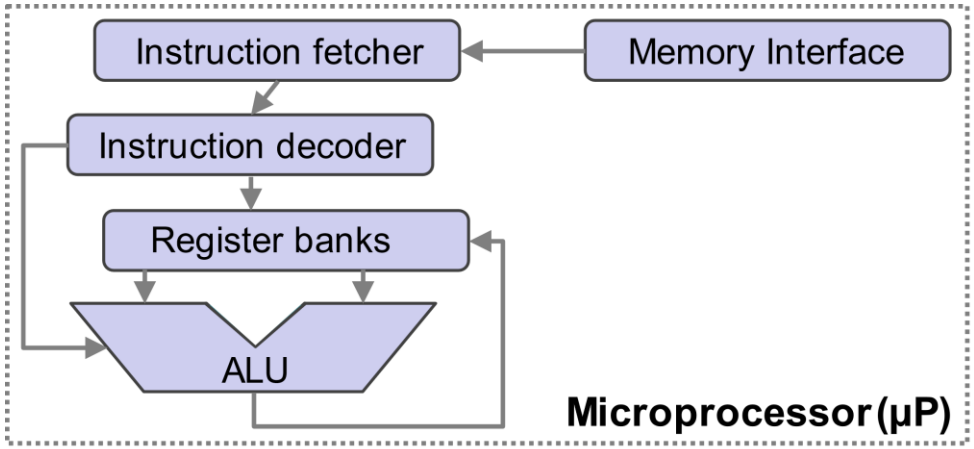
Major Components of a Computer

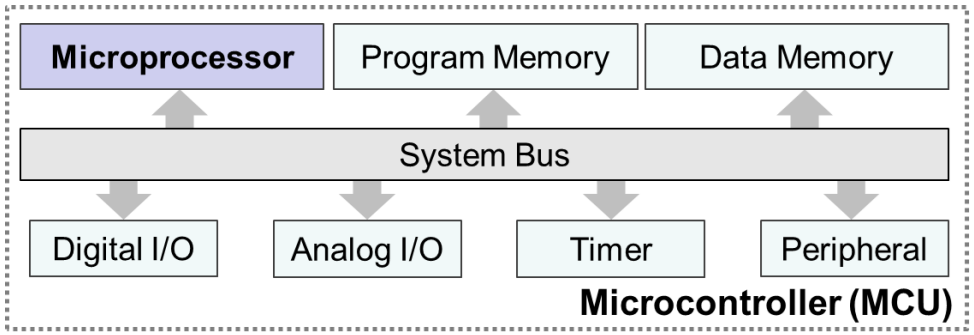


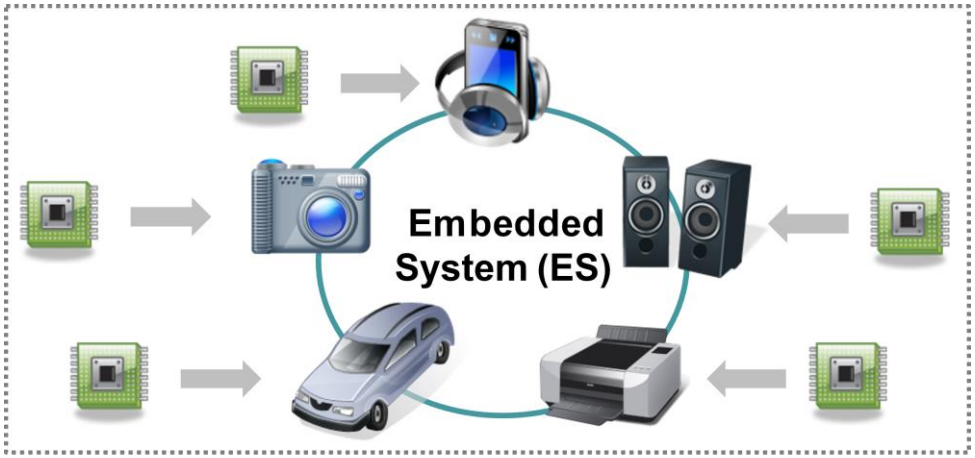
General Purpose vs. Embedded Computers

Versatility	**vs.**	**Specialization**
Powerful Hardware **(e.g., Central Processing Unit (CPU))**	**vs.**	**Limited Resources** **(e.g., Microprocessor)**
Upgradability	**vs.**	**Integration**

µP → MCU → Embedded System (ES)







- **Microprocessor (µP)**
  - As a compact form of CPU implemented on an IC.
- **Microcontroller (MCU)**
  - Has the microprocessor;
  - Integrated with other components including memory, digital/analog IOs, and other peripherals.
- **Embedded System (ES)**
  - Typically implemented using MCUs;
  - Often integrated into a larger mechanical or electrical system.

An Example: Smartband from Xiao Mi

Mi Band

Fitness monitor & sleep tracker

Sleep-cycle smart alarm

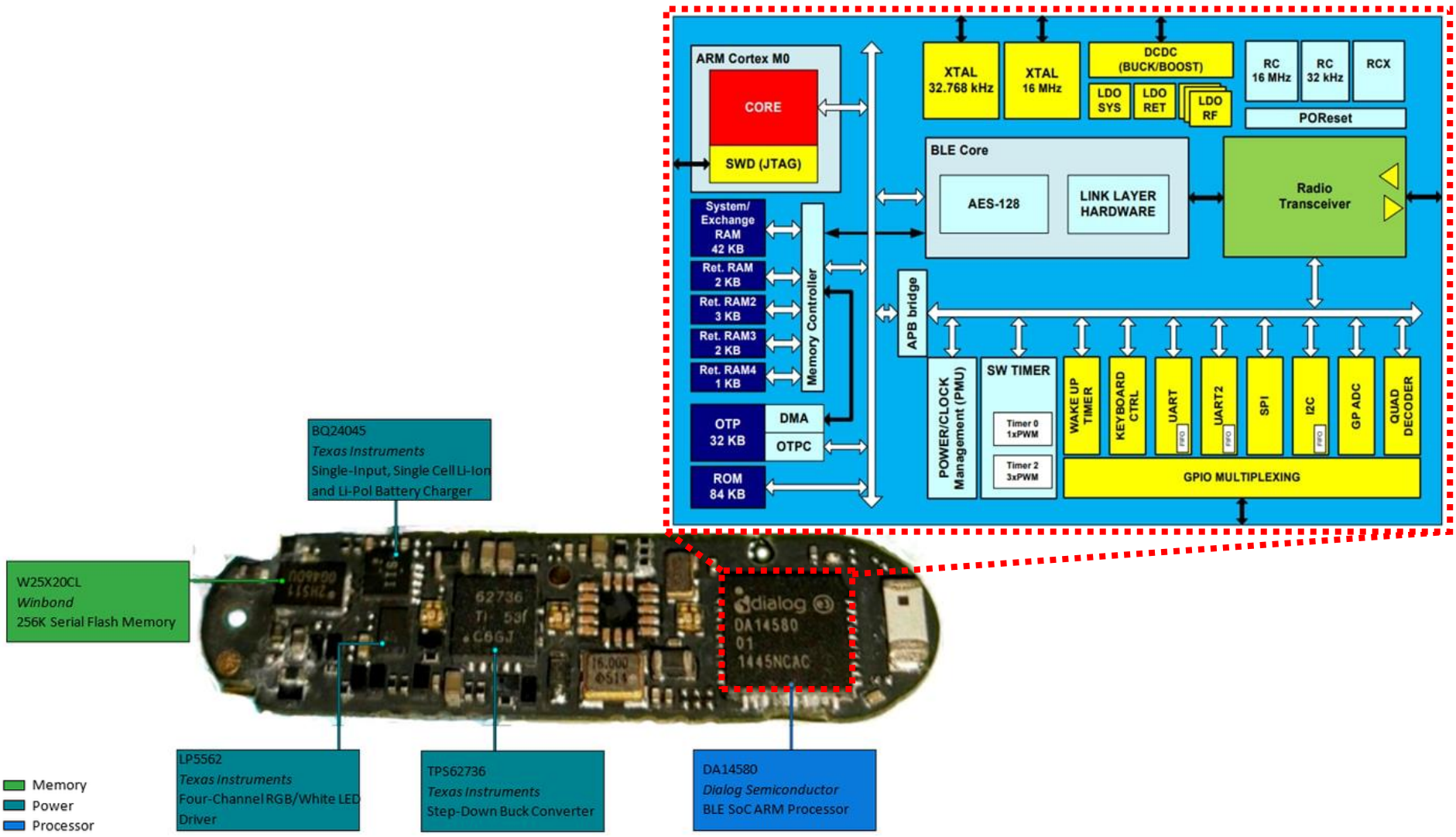
Unlock your phone without a password

30-day standby power

Water resistant (IP67)

Teardown the Mi Band

The Main Board of Mi Band



- **Printed Circuit Board (PCB)**: A board which holds electronic components and conductive traces for interconnection.

Typical ES Software Operations

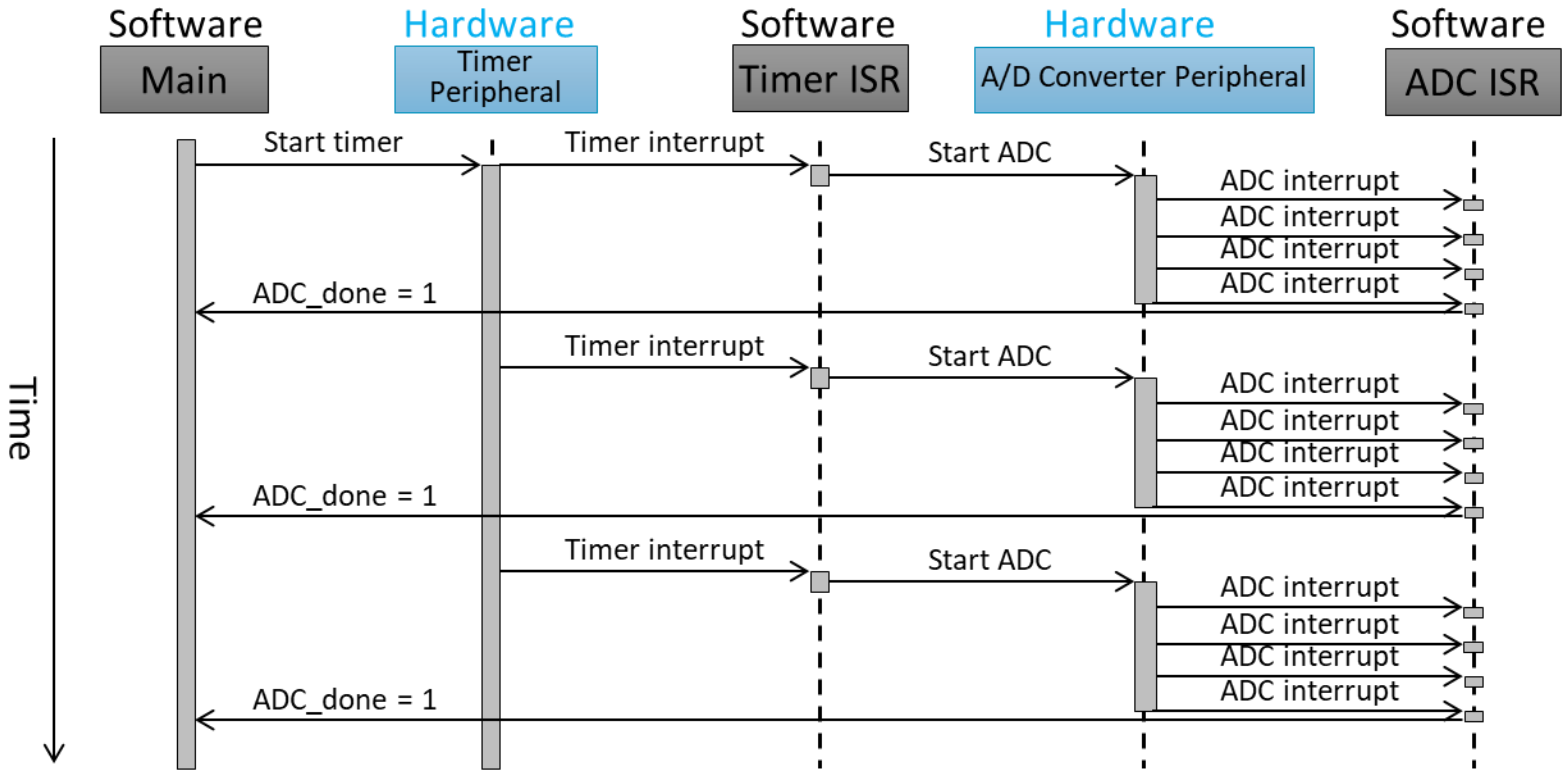
- **Closed-loop control**
  - Control an output variable based on one or more input measurements.
- **Sequencing**
  - Control an output through a sequence of steps.
- **Signal conditioning**
  - Average together multiple sensor readings or filter out noise from motors or other devices for better accuracy.
- **Communication and networking**
  - Interact with subsystems or other systems.

Typical ES Attributes

- **Interfacing with I/Os**
  - Sense the environment and control devices in response with specialized peripheral hardware circuits.
- **Concurrency**
  - Manage multiple activities concurrently by sharing the microprocessor or processing in hardware independently;
- **Responsiveness**
  - There are two aspects to making a system responsive: raw processing speed and task scheduling.
- **Reliability**, **Fault Handling**, and **Diagnostics**
  - Work correctly and reliably with quick and easy repair.
- **Constraints**
  - Cost, energy, weight, size, working temperatures, etc.

Concurrency with Software & Hardware?

- ESs rely on both MCU hardware peripherals and software to get everything done on time!
  - Hardware peripherals add dedicated concurrent processing;
  - Peripherals use interrupts to notify CPU of events.



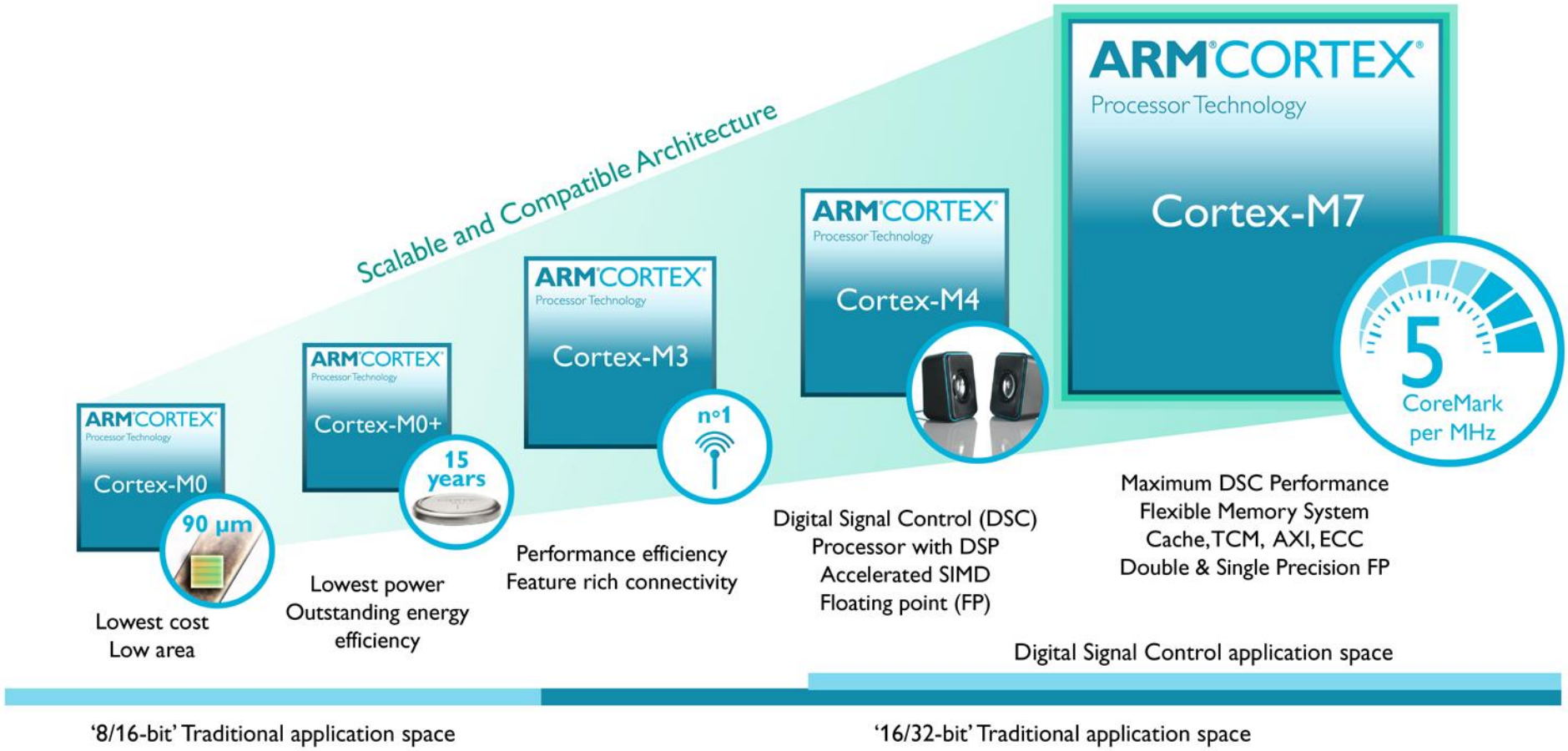
Outline

- **Preface: Control a System**

- **Basics of Embedded System**
  - Embedded System (ES): Concepts and Examples
  - Typical ES Software Operations
  - Typical ES Attributes

- **Target Platform: Tiva™ LaunchPad**
  - ARM® Cortex™-M4F-based microcontrollers

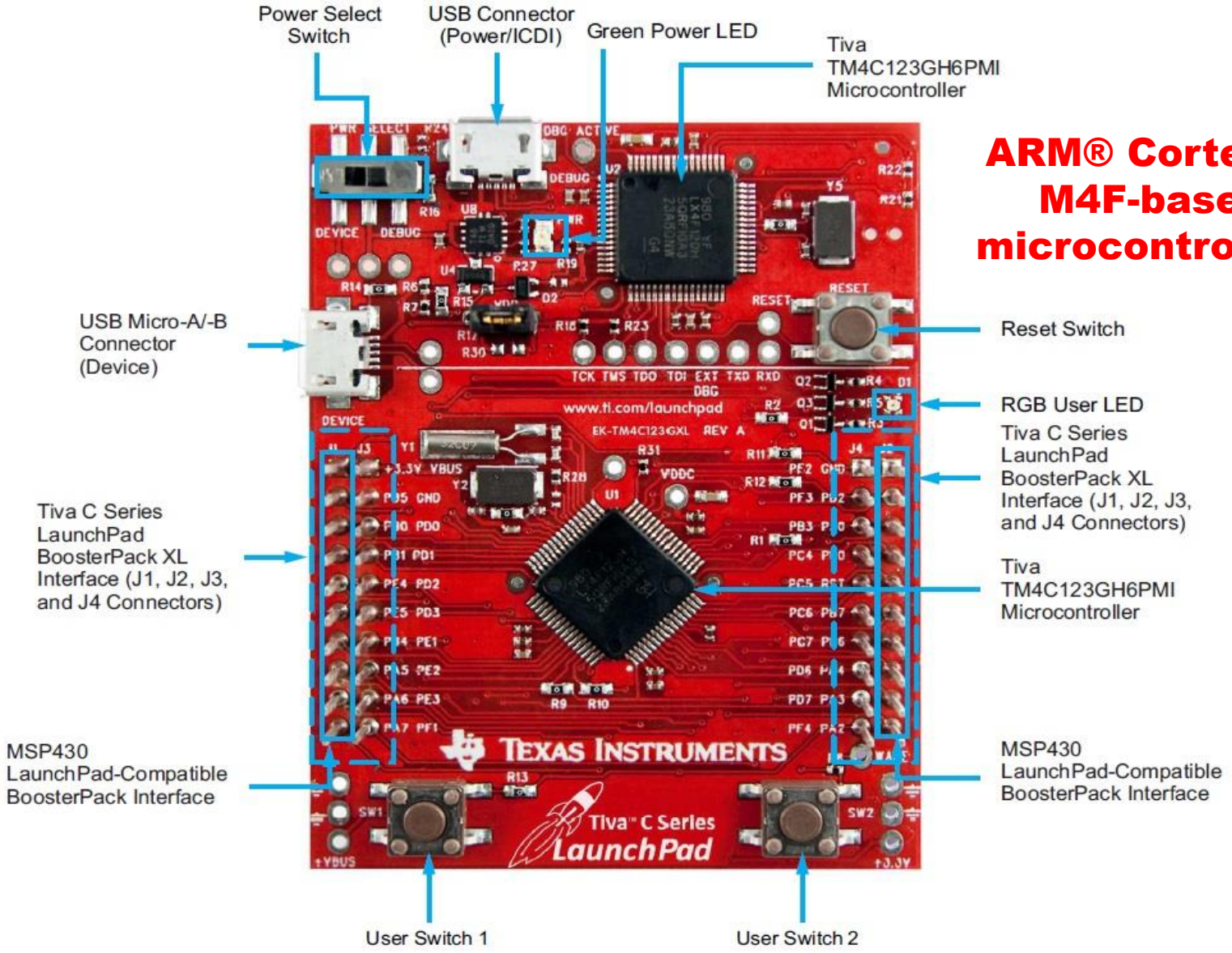
ARM Cortex-M Family



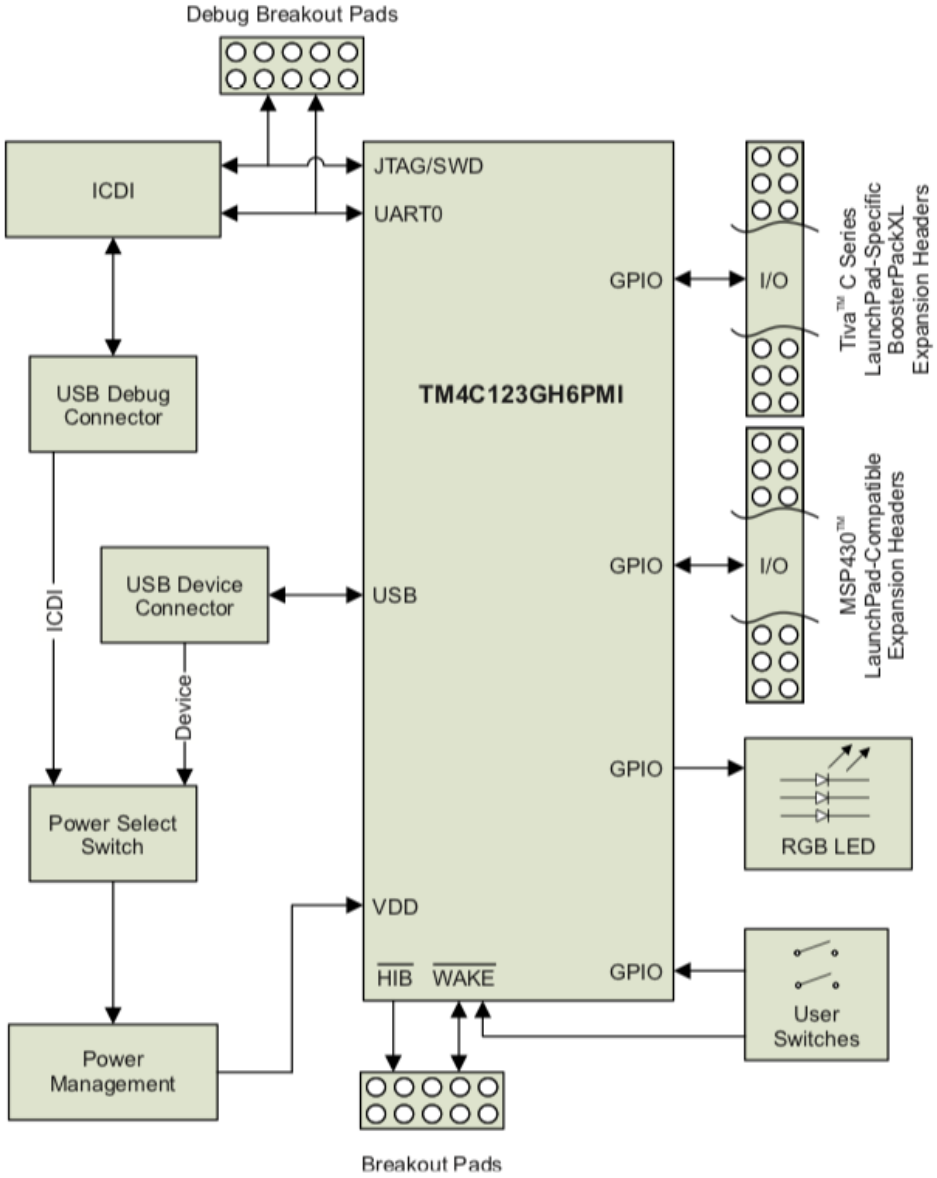
Target Applications

Cortex-M0	Cortex-M3	Cortex-M4
iBeacons (Blue Cat, Blue Sense, Estimote...) 	**Misfit Shine** 	**Withings Pulse** 
Well Cow sensor 	**Pebble Watch** 	**Whistle Dog Activity Monitor** 
Netatmo June UV sensor 	**Qualcomm TOQ** 	**Thalmic Lab MYO** 
August Smart Lock 	**FitBit Flex** 	**GoPro Hero3+** 

Tiva™ C Series LaunchPad (EK-TM4C123GXL)

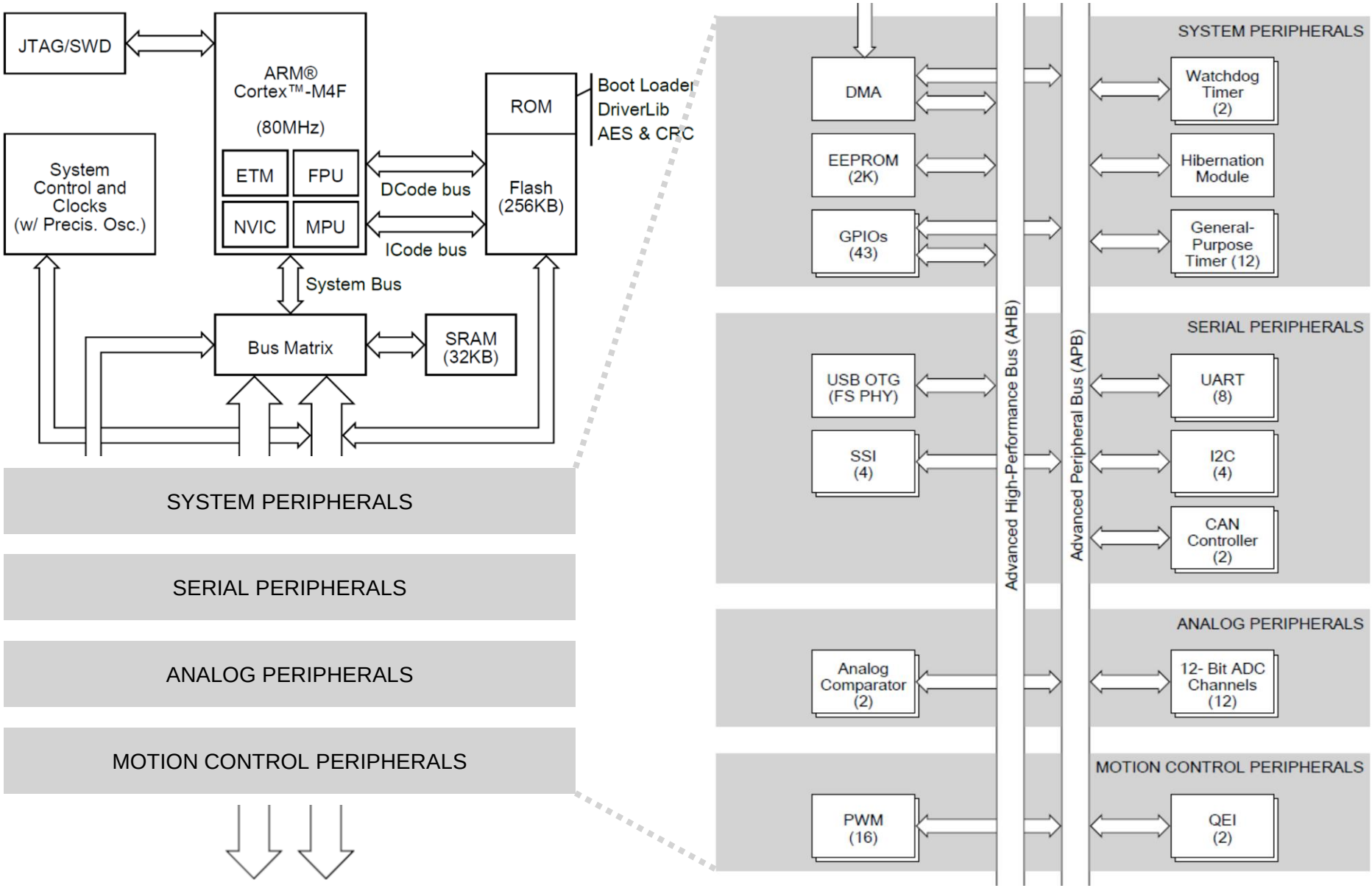


Tiva™ LaunchPad: Block Diagram

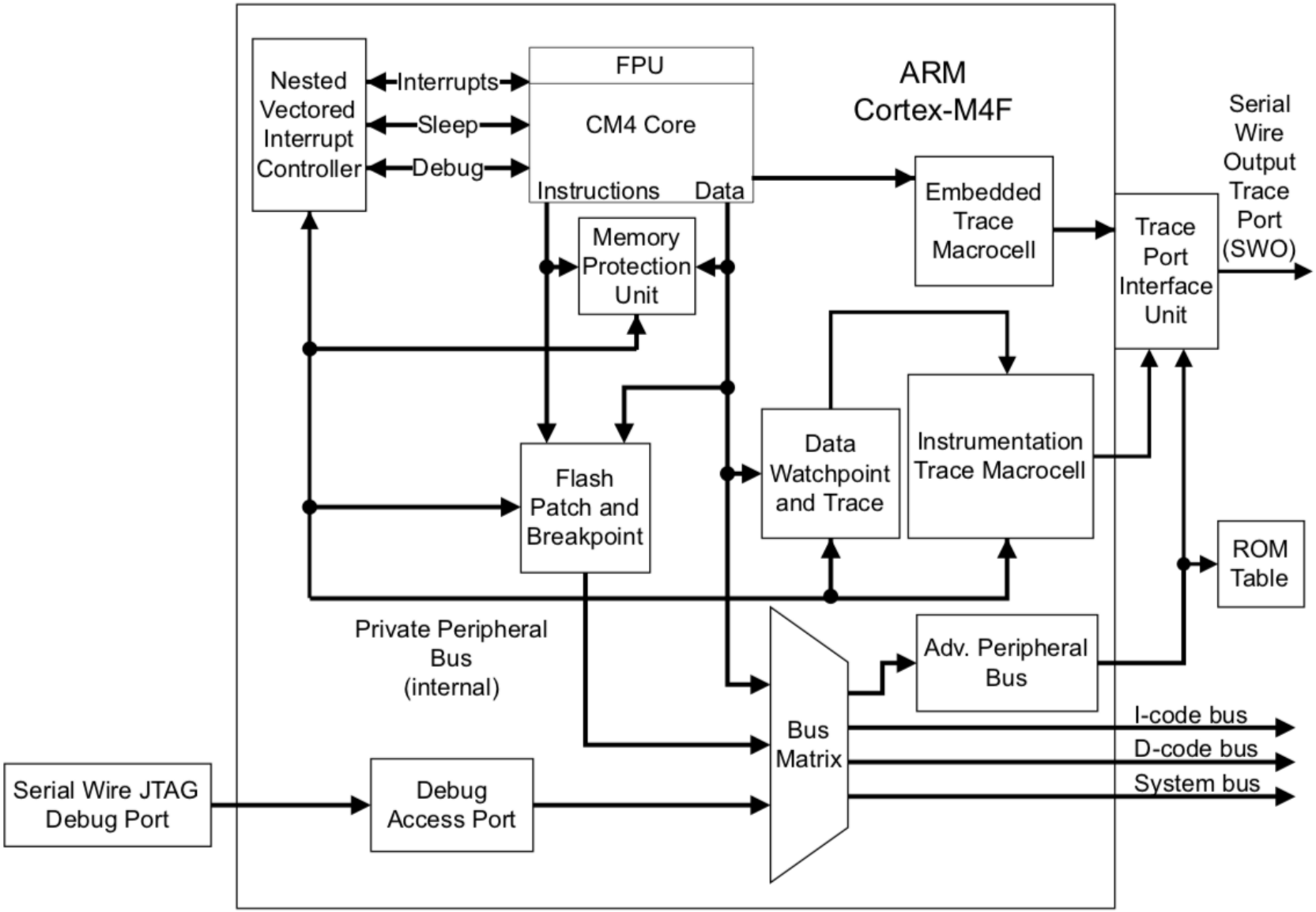


- **Microcontroller (MCU)**
  - Has a 32-bit ARM Cortex-M4-based microcontroller (**TM4C123GH6PM**).
- **USB Connectivity**
  - Functions as a USB device without hardware modifications.
- **Motion Control**
  - Includes the pulse-width modulation (PWM) technology.
- **User Switches/LED**
- **Headers/BoosterPacks**
  - Interfaces with other peripherals/devices esily.
- **Power Management**
- **In-Circuit Debug Interface**

MCU: TM4C123GH6PM



Microprocessor: ARM Cortex-M4F

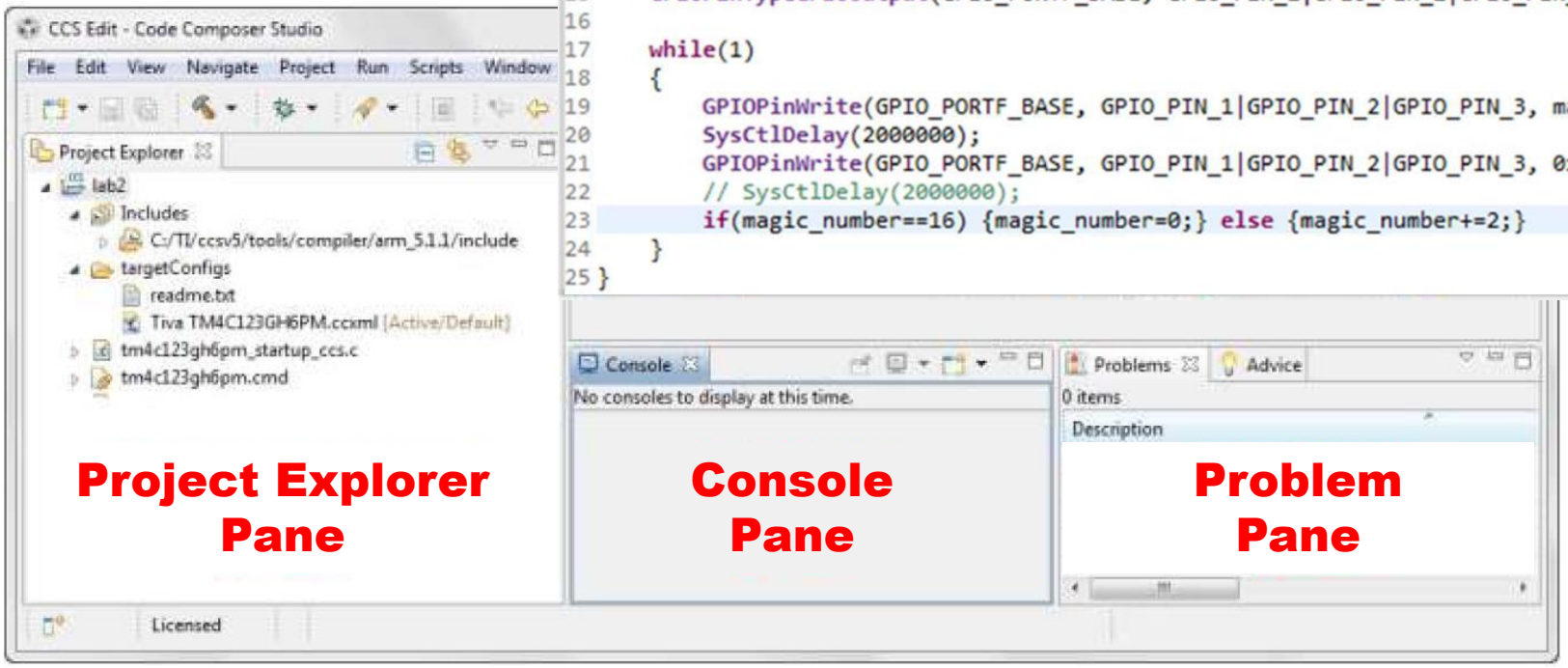


Code Composer Studio™ IDE

- Attend our labs to **learn from scratch**!

```c
#include <stdint.h>
#include <stdbool.h>
#include "inc/hw_memmap.h"
#include "inc/hw_types.h"
#include "driverlib/sysctl.h"
#include "driverlib/gpio.h"

uint8_t magic_number=0;

int main(void)
{
    SysCtlClockSet(SYSCTL_SYSDIV_5|SYSCTL_USE_PLL|SYSCTL_XTAL_16MHZ|SYSCTL_OSC_MAIN);

    SysCtlPeripheralEnable(SYSCTL_PERIPH_GPIOF);
    GPIOPinTypeGPIOOutput(GPIO_PORTF_BASE, GPIO_PIN_1|GPIO_PIN_2|GPIO_PIN_3);

    while(1)
    {
        GPIOPinWrite(GPIO_PORTF_BASE, GPIO_PIN_1|GPIO_PIN_2|GPIO_PIN_3, magic_number);
        SysCtlDelay(2000000);
        GPIOPinWrite(GPIO_PORTF_BASE, GPIO_PIN_1|GPIO_PIN_2|GPIO_PIN_3, 0x00);
        // SysCtlDelay(2000000);
        if(magic_number==16) {magic_number=0;} else {magic_number+=2;}
    }
}
```

C/C++ Programming

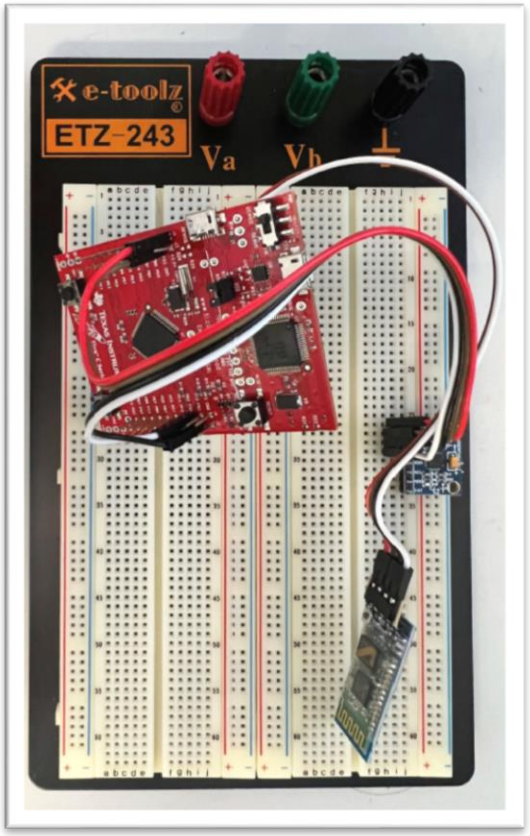


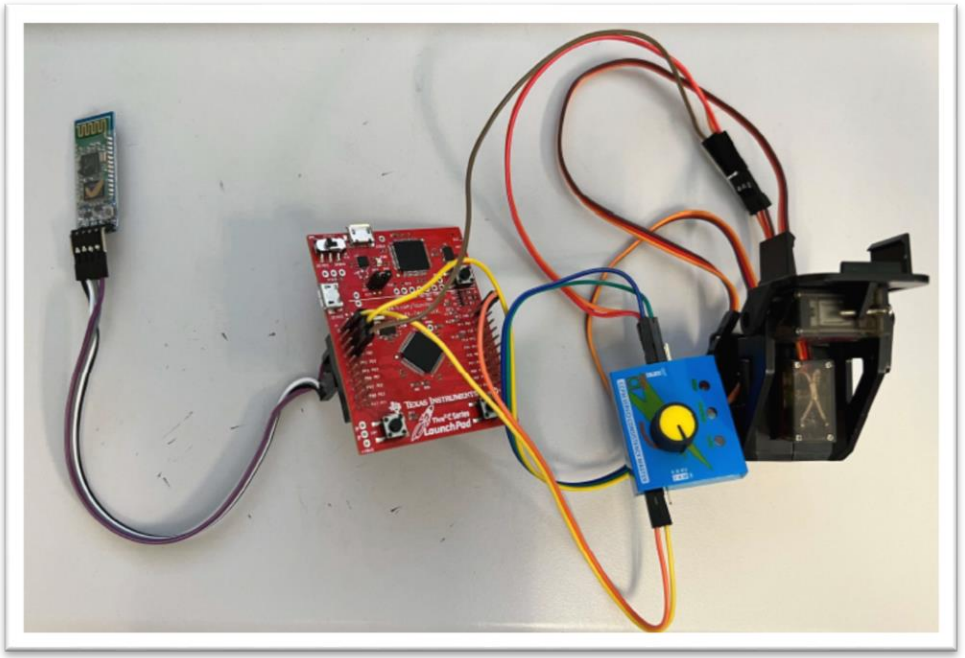
Project Explorer Pane

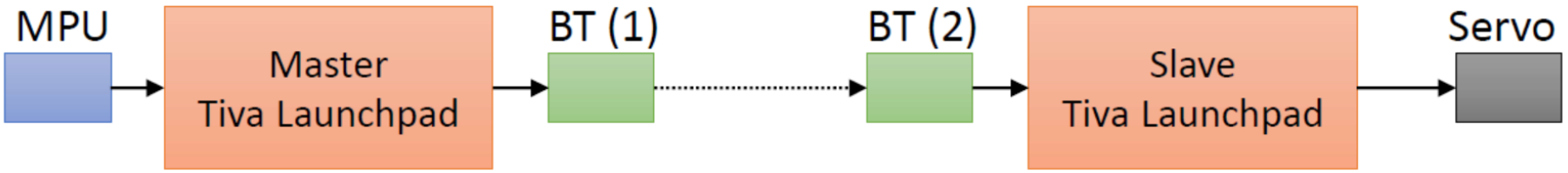
Console Pane

Problem Pane

Past Project: Motion-Controlled Laser Turret







Summary

- **Preface: Control a System**

- **Basics of Embedded System**
  - Embedded System (ES): Concepts and Examples
  - Typical ES Software Operations
  - Typical ES Attributes

- **Target Platform: Tiva™ LaunchPad**
  - ARM® Cortex™-M4F-based microcontrollers