



EEL4744


$\mu$ P2

EEL 4745C

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## Course Overview

- Expansion of  $\mu$ P ( $\mu$ P 1) with a focus on embedded systems, building an RTOS, IoT concepts, and some machine learning
- In fall 2022 and fall 2023, it was taught by Dr. Jahidul Islam  
    > Previously taught by Dr. Yier Jin
- Use new hardware to implement peripherals with a scheduler in interesting ways
- 6 labs that take about 2-3 weeks each.
- Develop various components of an RTOS over the semester (scheduling, threading, sleeping, semaphores, periodic threads, aperiodic events)
- In fall 2023
  - > Using a TI Tiva and TI Beaglebone Black embedded systems
  - > Using camera and OpenCV (and machine learning)
  - > End-of-semester project are mostly games

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## Old Hardware (pre-Fall 2022)

- TI MSP432
  - > 32-bit ARM microcontroller
  - > w/ Floating Point Unit (FPU)
  - > 256 kB Flash
  - > 64 kB RAM
  - > 48 MHz Clock
- Daughterboard w/ 16 RGB LEDs, Joystick, 4 tactile button switches, LCD resistive touch screen
- Sensor boosterpack- temperature, IMU, light, etc.
- WiFi boosterpack



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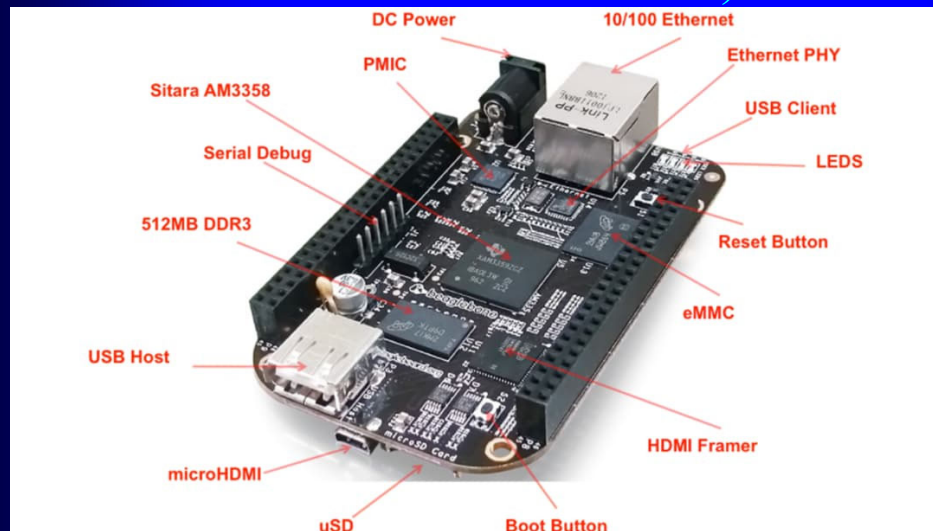
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## Beaglebone Black (used in Fall 23)



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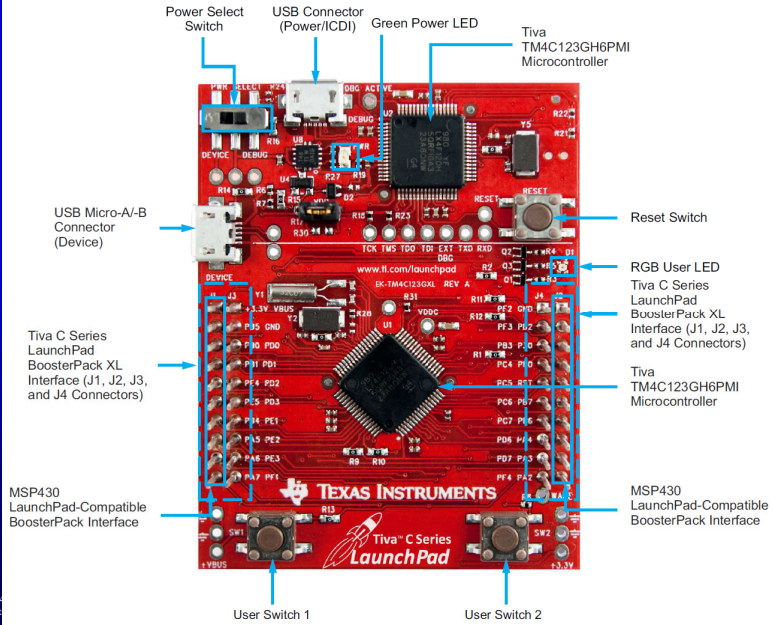
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## EEL4744


# Tiva C Series TM4C123G LaunchPad Evaluation Board



Labels in the diagram include: 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 LaunchPad BoosterPack XL Interface (J1, J2, J3, and J4 Connectors), Tiva TM4C123GH6PMI Microcontroller, MSP430 LaunchPad-Compatible BoosterPack Interface, User Switch 1, and User Switch 2.

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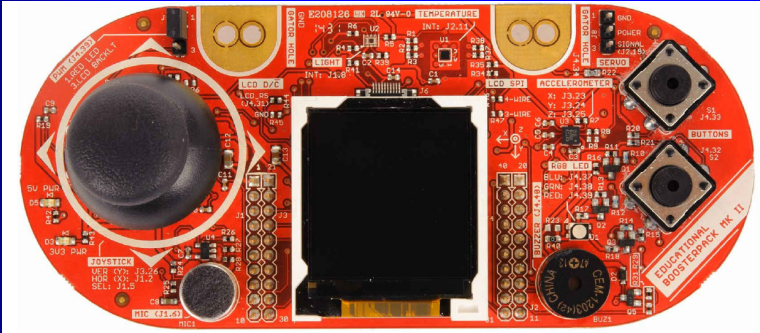
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## EEL4744

# OLD TI SENSOR Booster Pack (pre Fall 2023)



- TI OPT3001 light sensor
- Color 128x128 TFT LCD display
- TI TMP006 temperature sensor
- Microphone
- Servo motor connector
- 2-axis joystick with pushbutton
- 3-axis accelerometer
- User push buttons
- RGB multicolor LED
- Piezo buzzer

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**EEL4744 New Hardware (Fall 2023-)**

- **TI BOOSTXL-SENSORS** (SLAU666B)
  - TI OPT3001 light sensor
  - TI TMP007 temperature sensor
  - BMI160 6-axis IMU
    - 3-axis accelerometer, 3-axis gyroscope
  - BMM150 3-axis magnetometer
- LCD screen
- Radio, Bluetooth modules
- Joystick, tactile buttons, LEDs

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**EEL4744 Task Scheduling**

- Multiple tasks (threads) run “simultaneously”
- Each task (thread) gets its own section of memory (stack)
- Linked lists and queues
- Threads, semaphores, IPC (inter-process communication)
- Creating Linked lists for scheduled tasks
- Context switching using scheduler

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## Task scheduling (cont.)


- Round robin - tasks being run in circular order, Each for fixed amount of time
- Priority scheduler - run tasks depending on priority
- Blocked threads (using semaphores)
- Sleeping threads
- Adding/Killing threads in Real Time



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## Other Concepts

- Using I2C to communicate with external peripherals
- Build/Use FIFO queues to transfer data between tasks
- Using SPI to communicate with LCD display and touch screen
- Use WIFI/Bluetooth to communicate between boards
- Very good discussion of operating systems (OS)
- Some digital signal processing (DSP)

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### Labs (before Project)

- Lab 1: GPIO, UART
- Lab 2: I2C, Timer Interrupts, read from sensor backpack which has a light sensor, accelerometer, gyroscope, etc.
- Lab 3: Begin building RTOS, display thread outputs via PWM
- Lab 4: Add to RTOS (i.e, FIFOs, inter process communication [IPC]), switch debouncing, visually display threads on an LCD screen

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### Demo program

- Using G8RTOS to generate/delete squares of random color and speed
- Uses threads for: accelerometer read, screen touch ISR, screen touch thread, square physics thread
- Add/Delete threads in Real Time

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**EEL4744 Software**

- Code Composer Studio
- > Similar to Microchip/Atmel Studio

```

114 // and be responsible for handling sleeping and periodic threads
115 //
116 void SysTick_Handler()
117 {
118     SystemTime++;
119     tcb_t *pt = CurrentlyRunningThread;
120     tcb_t *p_ptr = &tcbthread[0];
121     int ii;
122     for(ii = 0; ii < NumberOfThreads; ii++){
123         if(p_ptr->execute_time == SystemTime){
124             p_ptr->execute_time = p_ptr->Period + SystemTime;
125             (*(p_ptr->Handler))();
126         }
127         // else{
128             p_ptr = p_ptr->Next_tcb;
129         // }
130     }
131     for(ii = 0; ii < NumberOfThreads; ii++){
132         if(pt->Asleep == true){
133             if(pt->Sleep_Count == SystemTime){
134                 pt->Asleep = false;
135             }
136         }
137         pt = pt->Next_tcb;
138     }
139 }
140 ICSR |= ICSR_PENDSVSET;
  
```

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**EEL4744 Things to Know**

- μP2 (EEL4745) is a very code intensive course
- Some Assembly
- Should be very familiar with C
- Will also use some Python
- 2-3 weeks to complete each labs
- Project for last lab
- 1 midterm exam (no final)

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