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MCU3121
16-bit Standard Peripherals and Programming using C30

Lab Manual

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MPLAB Navigation

- **Quick ways to find functions or variables in MPLAB**
  - Source Locator
    - **To Enable**
      - Right-click on editor and go to "Properties…"
      - Check "Enable Source Locator"
      - On the Project window, click on the "Symbols" tab. Right click and check "Enable Tag Locators"
    - **Use this feature to quickly navigate through large applications**
      - Right-click on a function or variable in code and select "Goto Locator" to jump its definition
      - In the project window under the symbols tab, you can browse through and double click items to jump there in code
  - Edit->Find in Files (ctrl+shift+F)
    - **Use this to search all files in the project for a variable, function name, or anything else**

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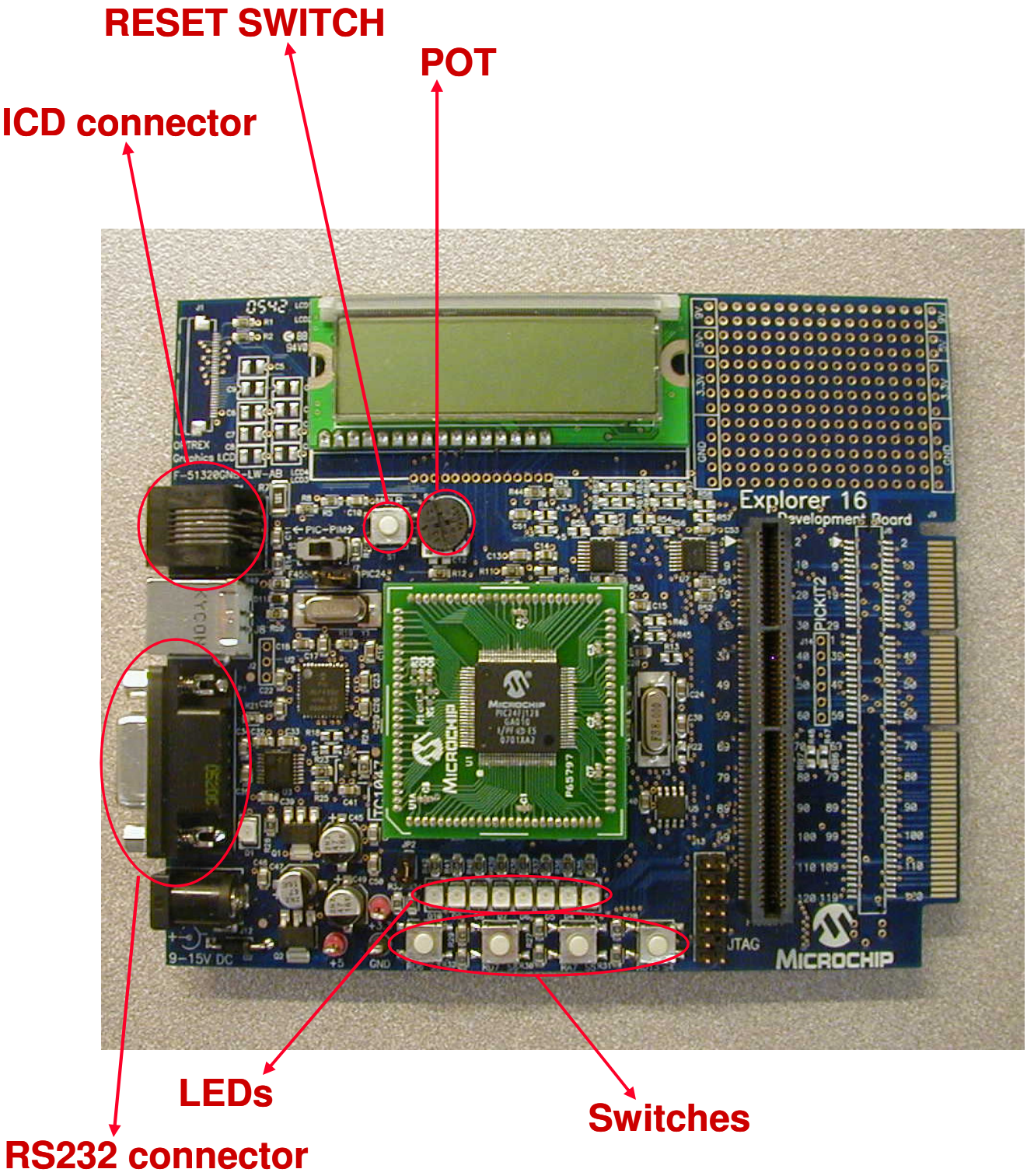
Explorer 16



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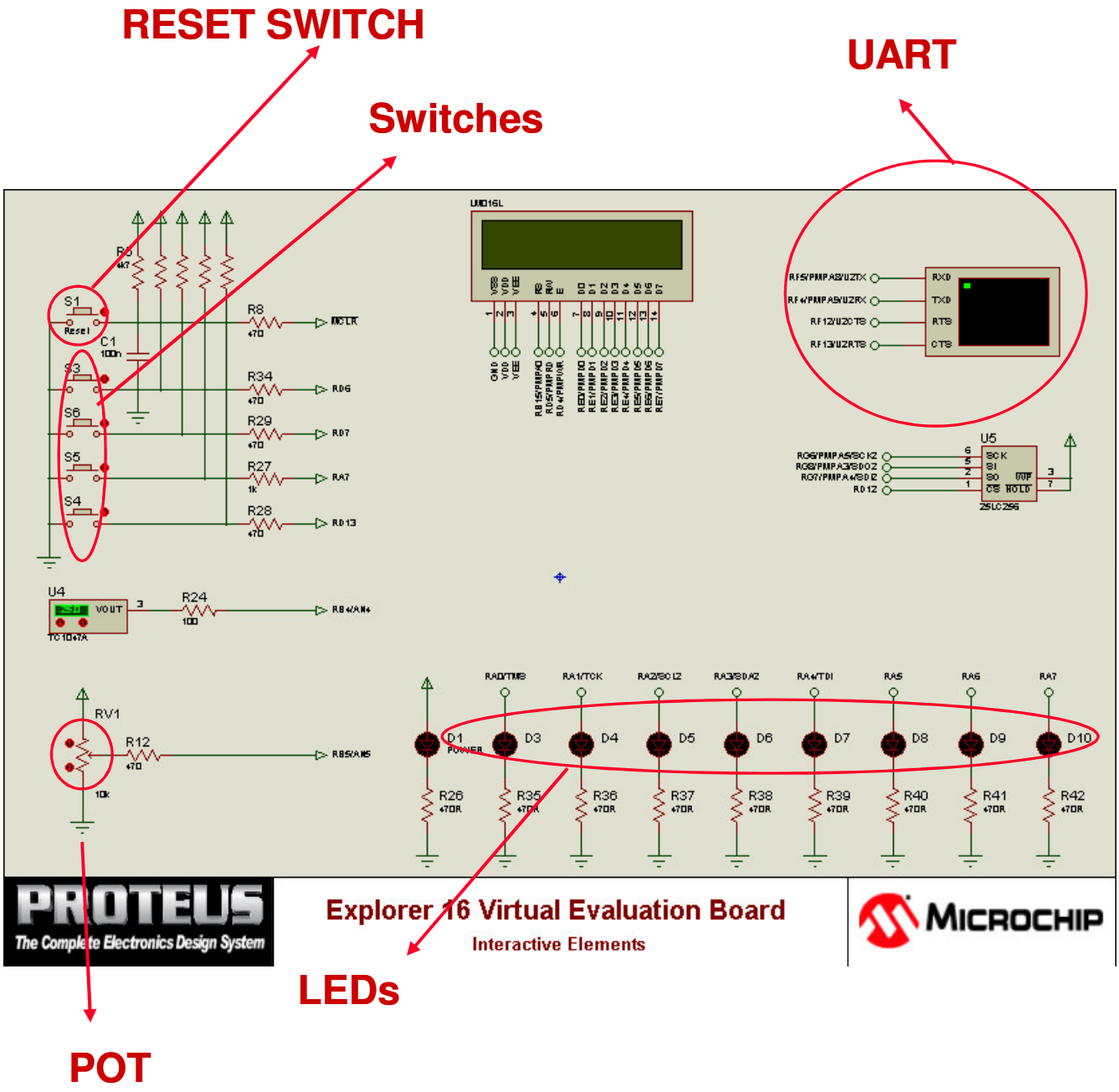
Explorer 16 in Proteus



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Lab 1

My First C30 Project

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LAB 1 Goals

- **To work with MPLAB® IDE environment**
- **To Do:**
  - Follow the presenter
- **Expected Result:**
  - Successfully build the project and program the device
  - LED D3 should blink

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LAB 1 Solution

MPLAB IDE Editor

Lab1_solution.c

```
136   /************* START OF MAIN FUNCTION ********************************/
137
138   int main ( void )
139   {
140
141       TRISAbits.TRISA0 = 0; //setup for LED output
142
143       while(1){
144
145           __builtin_btg((unsigned int*)&LATA,0x0); //toggle the LED pin
146
147           delay(); //wait for some time
148
149       }
150   }
151
152
153   void delay(void)
154   {
155       unsigned int i;
156
157       //delay for a while
158       for(i = 0; i < 0xFFFF; i++);
159
160
161   }
162   /************* END OF MAIN FUNCTION **********************************/
```

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Lab 2

PSV Configuration and Usage

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LAB 2 Goals

- To initialize PSV
- To store a “Hello World” string in PSV space
- To read and display this string on the LCD

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LAB 2 To Do

- **Open the project**
  - `C:\RTC\MCU3121\Lab2\Lab2.mcp`
- **Open the file**
  - `C:\RTC\MCU3121\Lab2\Lab2.c`
- **Step 1**
  - Use Space attribute and define a array “MyString” and place it in PSV space.
    - `__attribute__ ((space(psv)))`
- **Step 2**
  - In the `PSVInit()` function use the built-in function of C30 to load PSVPAG register with the page of PSV space where the array is placed.
    - `__builtin_psvpage(variable)`
- **Build the Project ,Run Proteus and Run the program**

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LAB 2 Solution

```
//##########################################
//  STEP 1:
//  Define an array "MyString" placing
//  in PSV space and assign a string ("Hello World") to it.
//##########################################

const unsigned char __attribute__ ((space(psv))) MyString[] = "Hello World";


main()
{
    LCDInit();
    PSVInit();

int i = 0;
    while(MyString[i]!=0)
    {
      LCDPut(MyString[i]);
      i++;
    }
    while(1);
}



PSVInit()
{

    //##########################################
    //  STEP 2:
    //  using built-in function load PSVPAG with the page address where the
    //  array MyString is placed.
    //##########################################

    PSVPAG = __builtin_psvpage(MyString);       // ###

    CORCONbits.PSV = 1;
}
```

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LAB 2 Expected Result

- Compare the content of the LCD display with the array defined.
- Both should match

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Lab 3

Working with Interrupts

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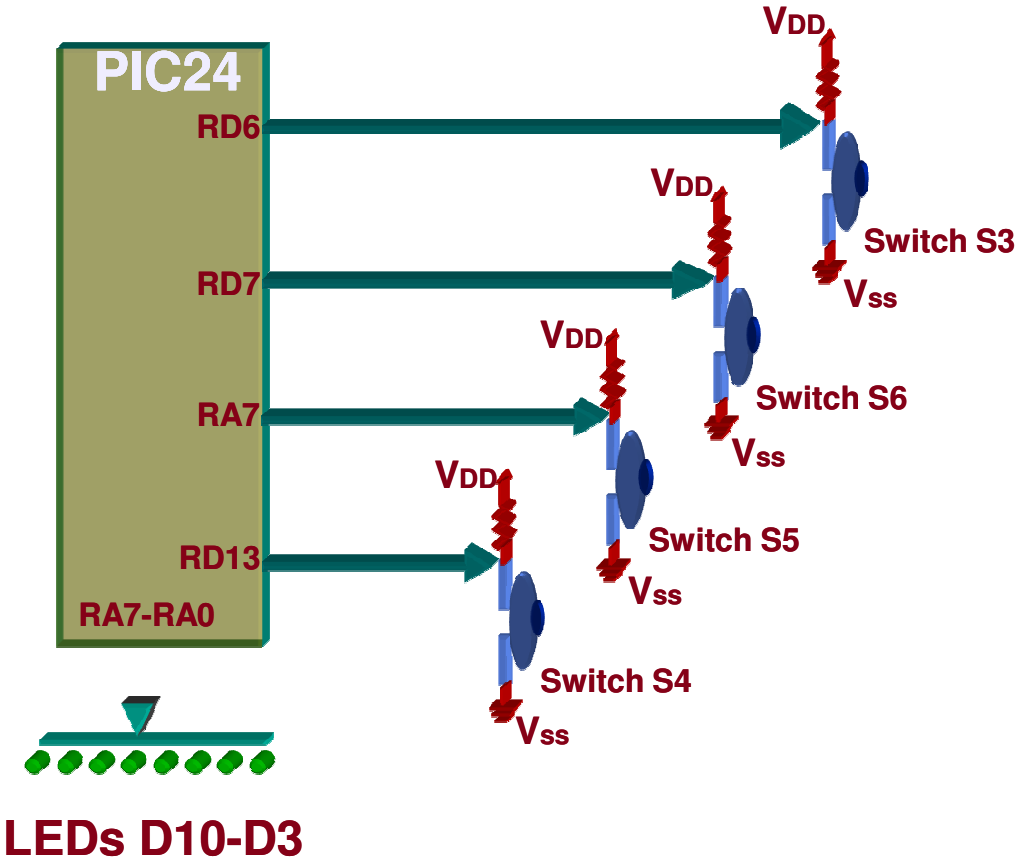
LAB 3 Goals

- Understand Interrupt configuration
- Understand Interrupt priority
- Writing Interrupt handler for a given Interrupt vector



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LAB 3 To Do

- Open the project
  - C:\RTC\MCU3121\Lab3\Lab3.mcp
- Open the file
  - C:\RTC\MCU3121\Lab3\Lab3.c
- Here Timer 3 is configured to give 4 sec ticks and Timer 5 is configured to give 1 Sec ticks.
- LED D3 indicates CPU is in T3 ISR and LED D4 indicates CPU is in T5 ISR.
- Look at TMR3Init and TMR5Init to see how timer interrupts are enabled.

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LAB 3 To Do

- **Step 1: Case 1 – S3**
  - Look for Switch Case1 and configure T3 priority to be higher than T5 priority. **NOTE: T3 & T5 interrupts must be disabled before modifying IPR bits, then re-enabled afterwards!**
  - By pressing S3 Case 1 will be executed.
- **Step 2: Case 2 – S6**
  - Look for Switch Case2 and configure T5 priority to be higher than T3 priority. **NOTE: T3 & T5 interrupts must be disabled before modifying IPR bits, then re-enabled afterwards!**
  - By pressing S6 Case 2 will be executed.
- **Step 3: Case 3 – S5**
  - Look for Switch Case3 and configure CPU priority to be higher than T5 priority and lower than T3 priority. **NOTE: T3 & T5 interrupts must be disabled before modifying IPR bits, then re-enabled afterwards!**
  - By pressing S5 Case 3 will be executed.
- **Step 4: Case 4 – S4**
  - Look for Switch Case4 and configure CPU priority to be higher than both T3 and T5 priority. **NOTE: T3 & T5 interrupts must be disabled before modifying IPR bits, then re-enabled afterwards!**
  - By pressing S4 Case 4 will be executed.

- **Watch what switch you are pressing!**
  - They are not in ascending order on the board
- **To configure the priority levels you require to write into some registers, IPC2, IPC7 and SR. The details are given in following pages**
- **Build the project and program the device**

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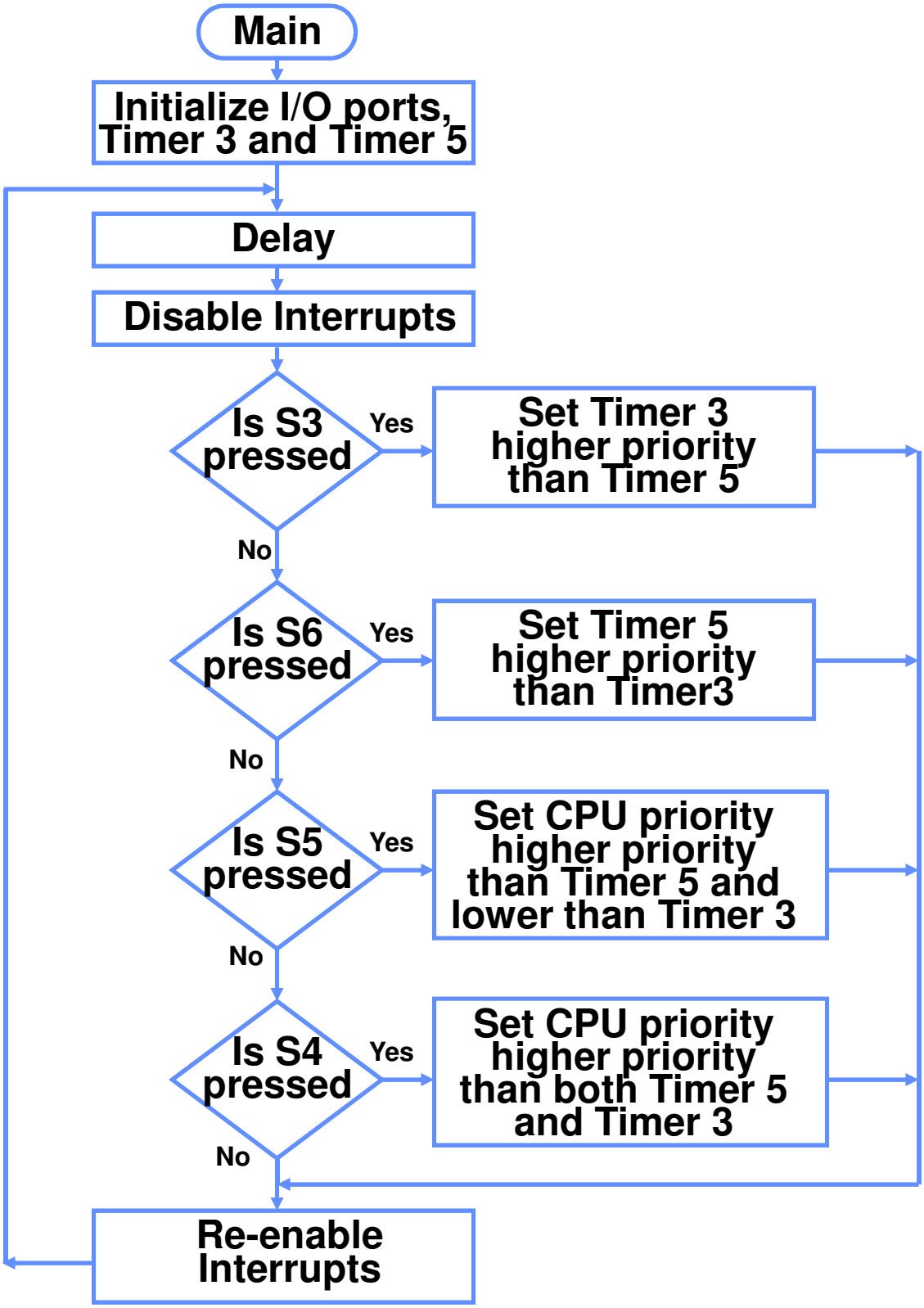
LAB 3 Flow Chart (`main()`)



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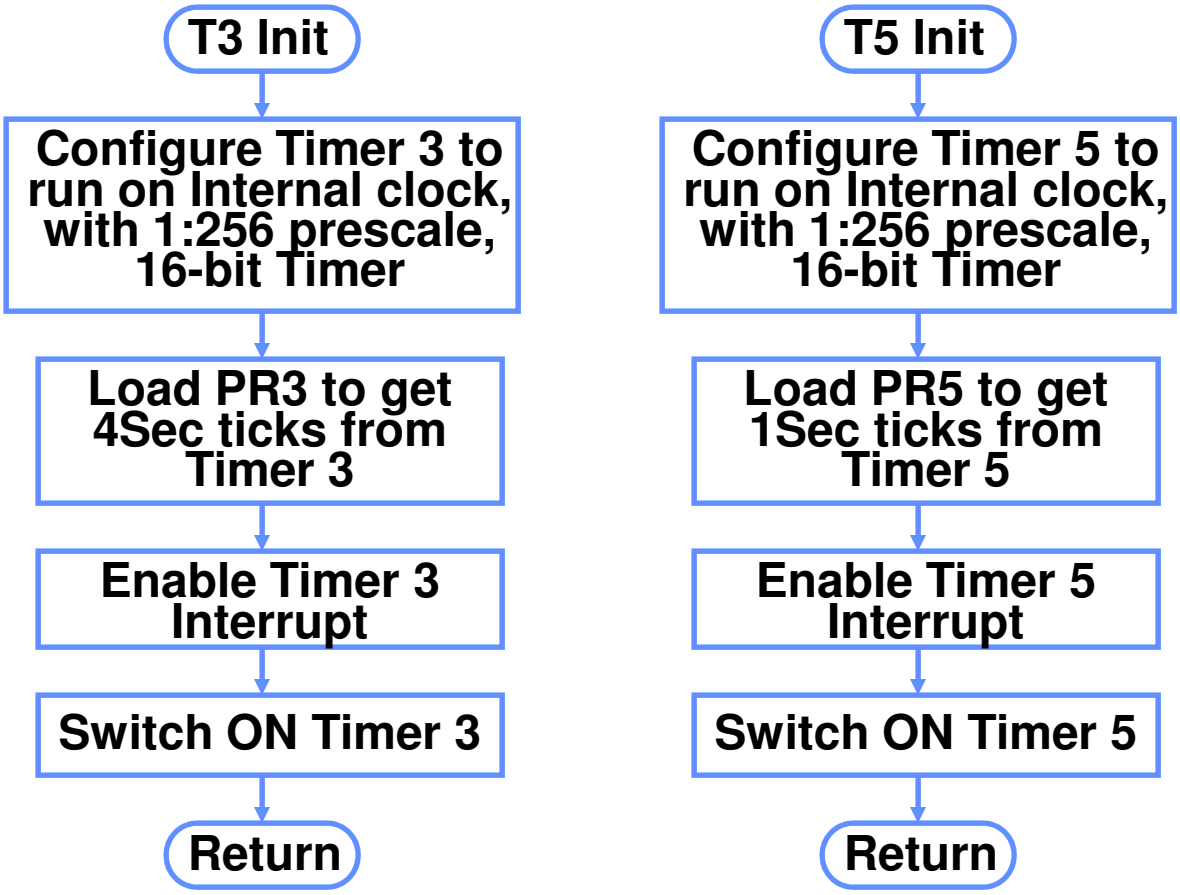
LAB 3 Flow Charts

(T3 Init() & T5 Init())



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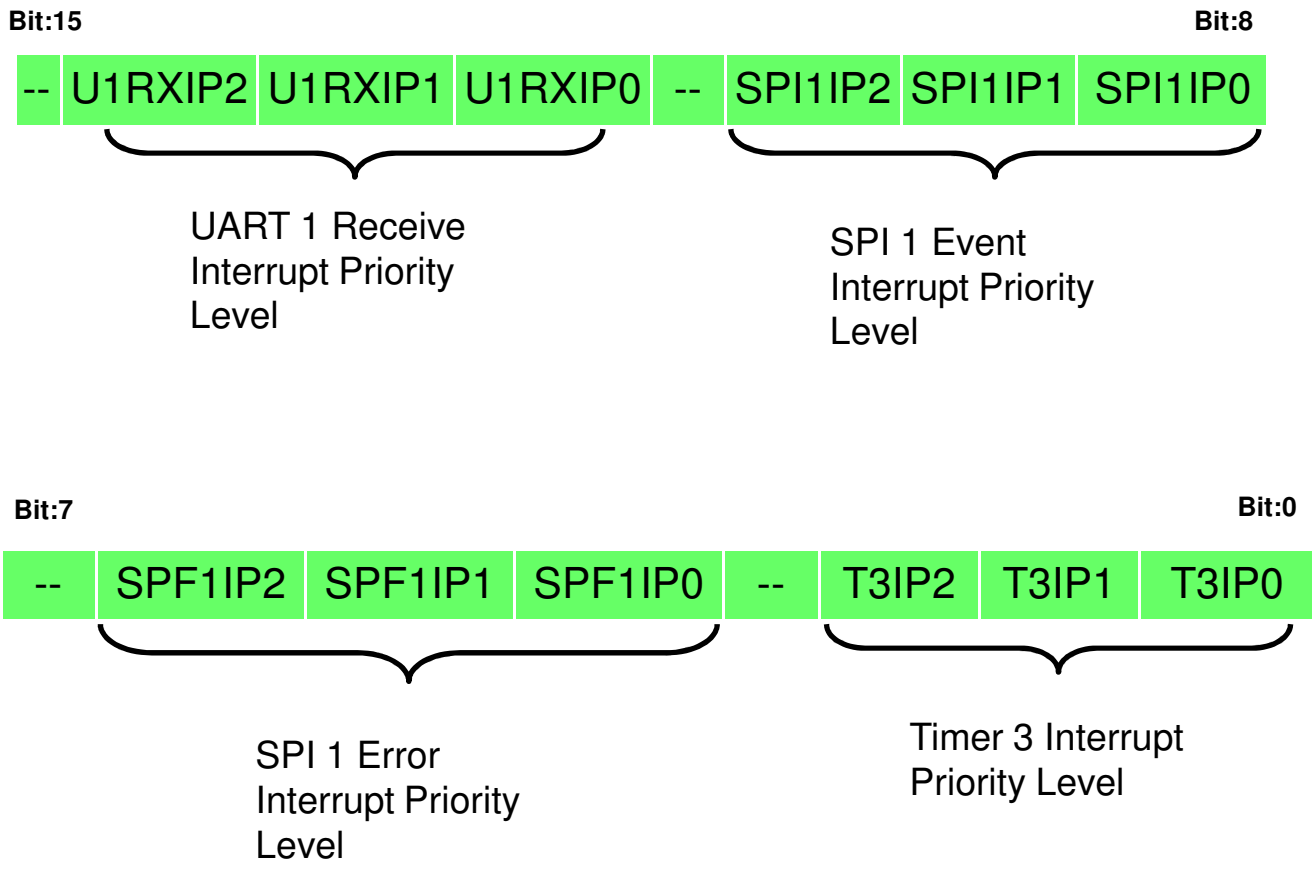
LAB 3 Interrupt Registers

IPC2: Interrupt priority control Register 2



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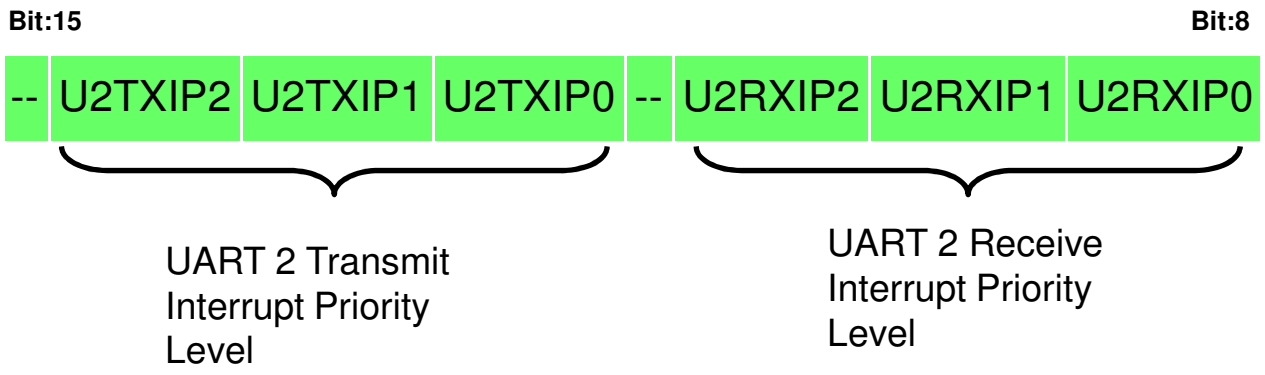
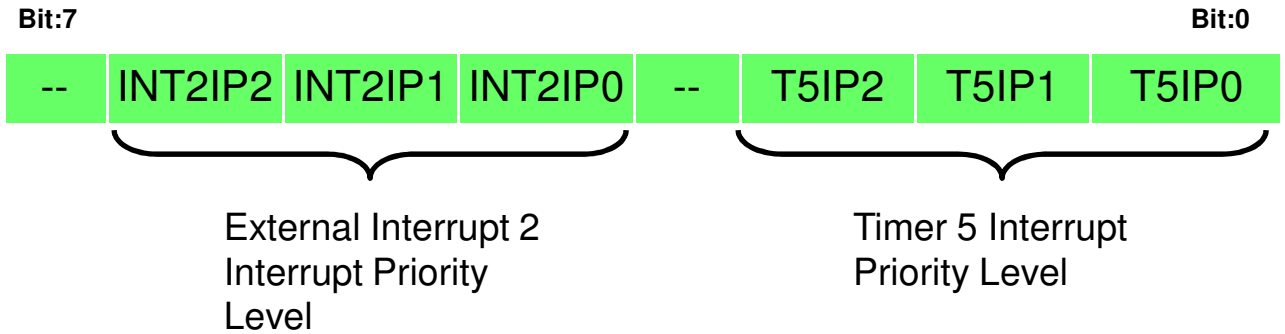
LAB 3 Interrupt Registers

IPC7: Interrupt priority control Register 7





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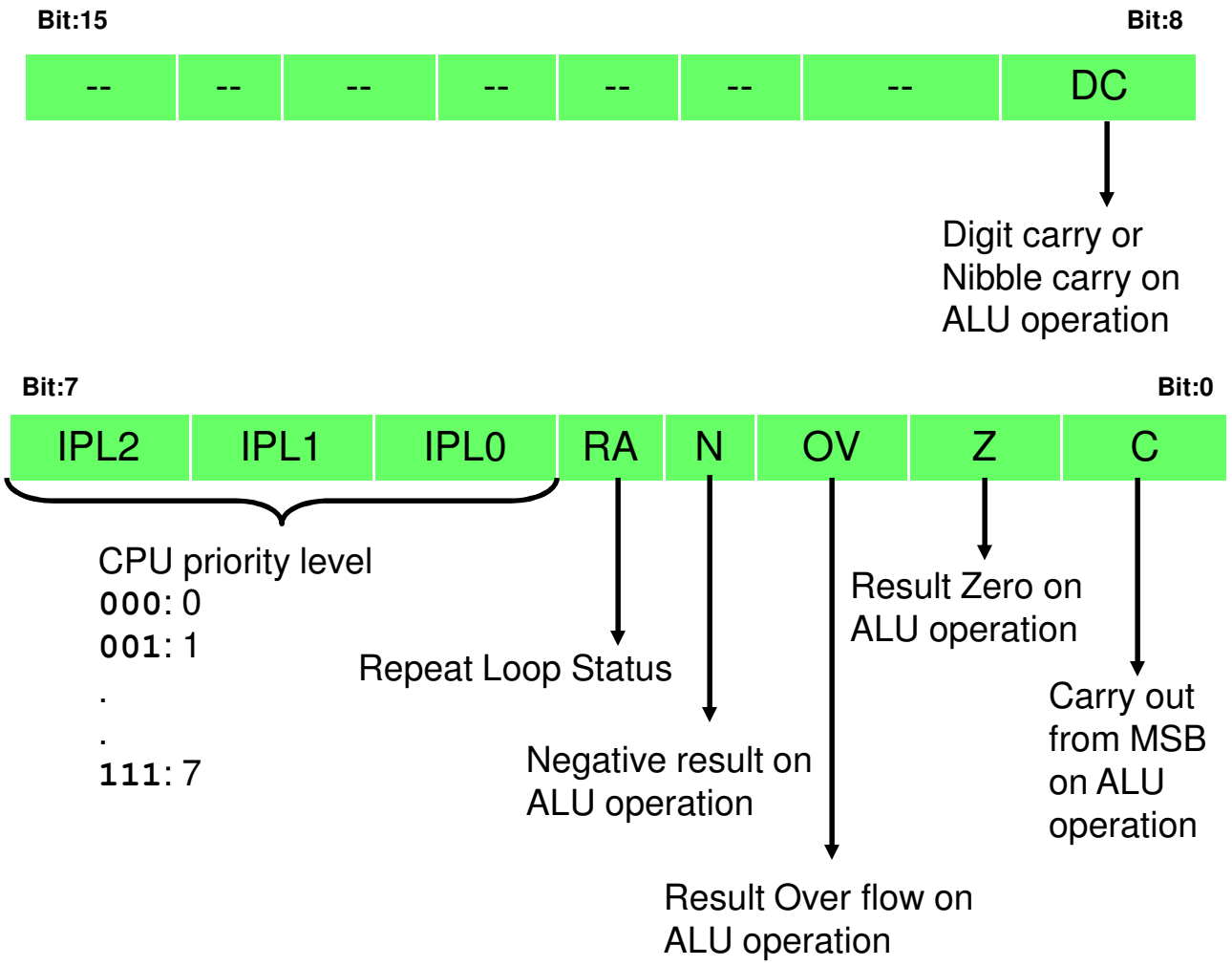
LAB 3 CPU Registers

SR: CPU Status Register



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LAB 3 Solution

```
case 1:
SRbits.IPL = 0;

//*****************************************************************************
//  STEP 1:
//  add the code to set Timer 3 higher priority level than Timer 5
//*****************************************************************************/
IPC2bits.T3IP = 4;
IPC7bits.T5IP = 2;


break;


case 2:
SRbits.IPL = 0;

//*****************************************************************************
//  STEP 2:
//add the code to set Timer 5 higher priority level than Timer 3
//*****************************************************************************/
IPC2bits.T3IP = 2;
IPC7bits.T5IP = 4;

break;


case 3:
SRbits.IPL = 3;

//*****************************************************************************
//  STEP 3:
//add the code to set the CPU priority level higher than Timer 5 and lower than Timer3
//*****************************************************************************/
IPC2bits.T3IP = 4;
IPC7bits.T5IP = 2;

break;


case 4:

//*****************************************************************************
//  STEP 4:
//add the code to set the CPU priority higher than both the Timers
//*****************************************************************************/
SRbits.IPL = 5;

break;
```

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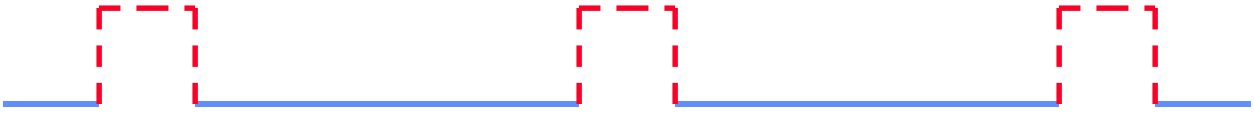
LAB 3 Expected Result

T5 ISR
T3 ISR
CPU Idle

- **Case 1**
  - The LEDs D3 and D4 will be flashing but one after the other
  - D4 will never be ON when D3 is ON as T5 cannot preempt T3 ISR.

- **Case 2**
  - The LEDs D3 and D4 will be flashing at the same time
  - D4 becomes ON even when D3 is ON as T5 can preempt T3 ISR

- **Case 3**
  - The LED D3 will be flashing but not D4 as T5 cannot interrupt the CPU



- **Case 4**
  - Both the LEDs D3 and D4 stops flashing as both T3 and T5 cannot interrupt the CPU

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Lab 4

ADC Configuration and Usage

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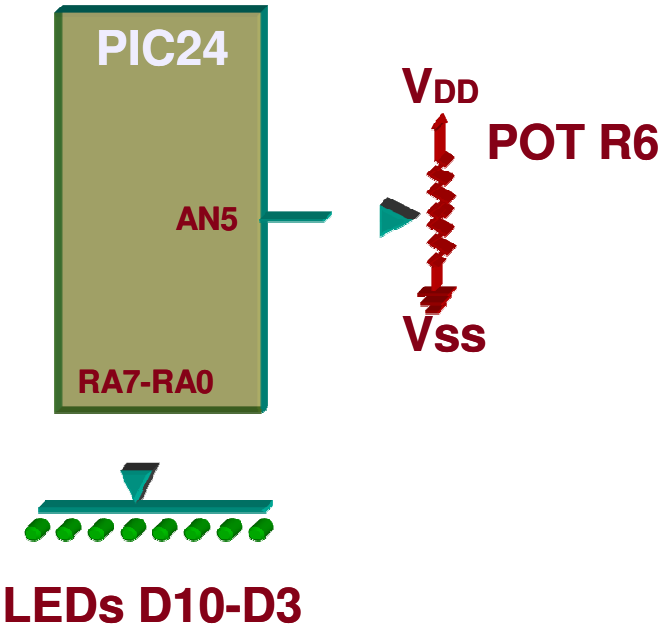
LAB 4 Goals

- To configure ADC
- To configure I/O ports
- To read ADC and display on LEDs



Hint :

Tconversion_total = Tsample + Tconversion

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LAB 4 To Do

- **Open the project**
  - `C:\RTC\MCU3121\Lab4\Lab4.mcp`
- **Open the file**
  - `C:\RTC\MCU3121\Lab4\Lab4.c`
- **Look for `ADCInit()` function and configure ADC by initializing the registers AD1CON1, AD1CON2, and AD1CON3 looking into the Register details on the next few pages.**
  - STEP 1: AD1CON1
    - **Select Integer Format Result**
    - **Auto Conversion Start**
    - **Sample after conversion**
  - STEP 2: AD1CON2
    - **Select AVDD and AVSS as references**
    - **Disable Scan mode**
    - **Interrupt at 16th sample/Convert sequence**
    - **16*1 level buffer**
    - **Always use Mux A**
  - STEP 3: AD1CON3
    - **Select Sample Time = 13TAD**
    - **Conversion Time is always 12TAD**
    - **Select AD Clock Source (ADCS) such that you get 16 samples in 1 mSec (16 ksps)**
    - **Assume 1TCY =.25 uS (FCY = 4 MHz)**

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LAB 4 To Do

- **Continue to configure ADC by initializing the registers AD1CHS, AD1PCFG, and AD1CSSL looking into the Register details on the next few pages.**
  - STEP 4: AD1CHS
    - **Set the positive sample input channel for MUX A to use AN5**
    - **Set the negative input channel for MUX A to use VR-**
  - STEP 5: AD1PCFG
    - **Set AD1PCFG so that the only pin using analog functionality is AN5**
  - STEP 6: AD1CSSL
    - **Channel scanning is not enabled, so no input channels should be selected for scanning**
- **Build the Project ,Run Proteus and Run the program**
- **Procedure to Test**
  - Vary the POT and observe LEDs

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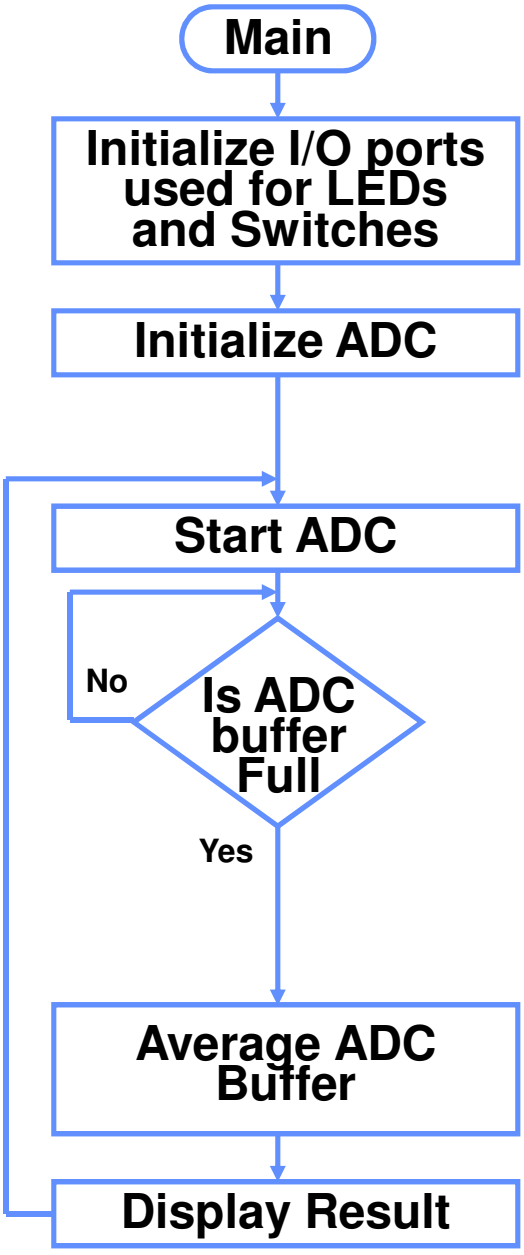
LAB 4 Flow Chart (`main()`)



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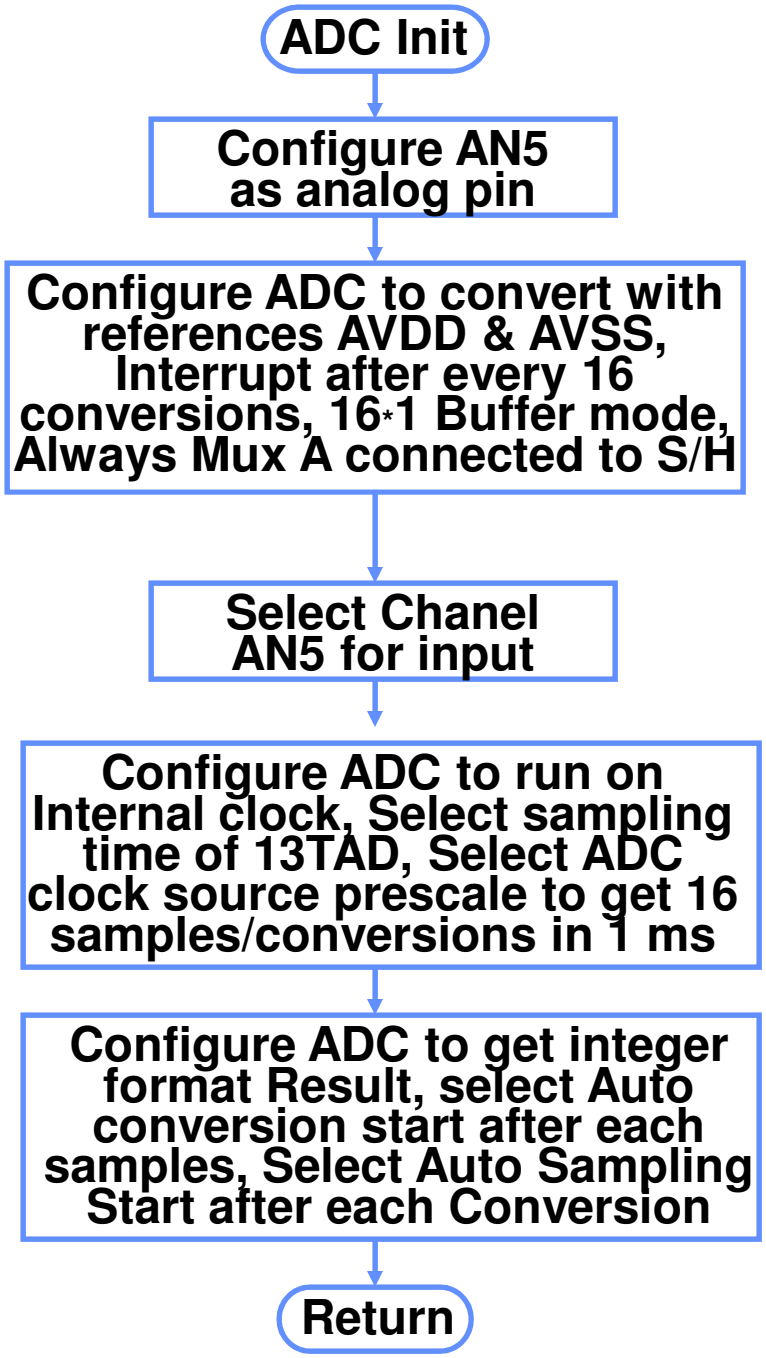
LAB 4 Flow Chart (ADCInit())



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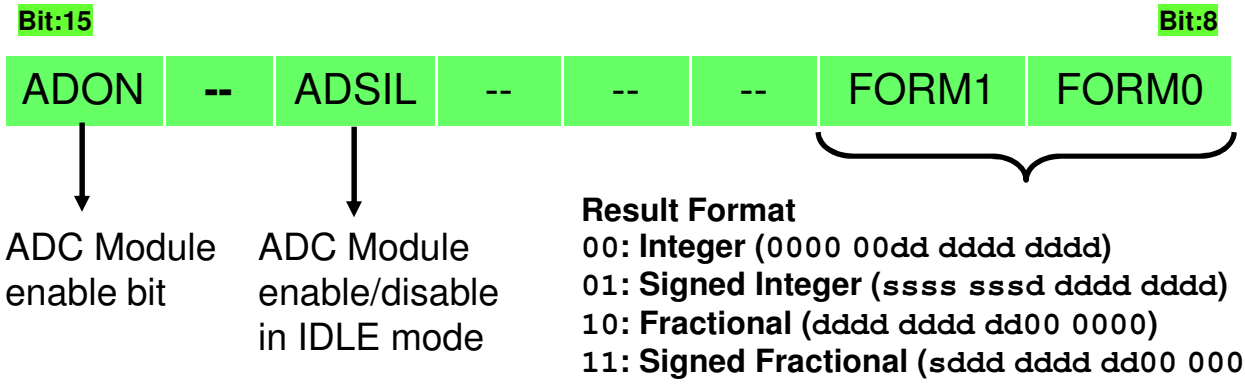
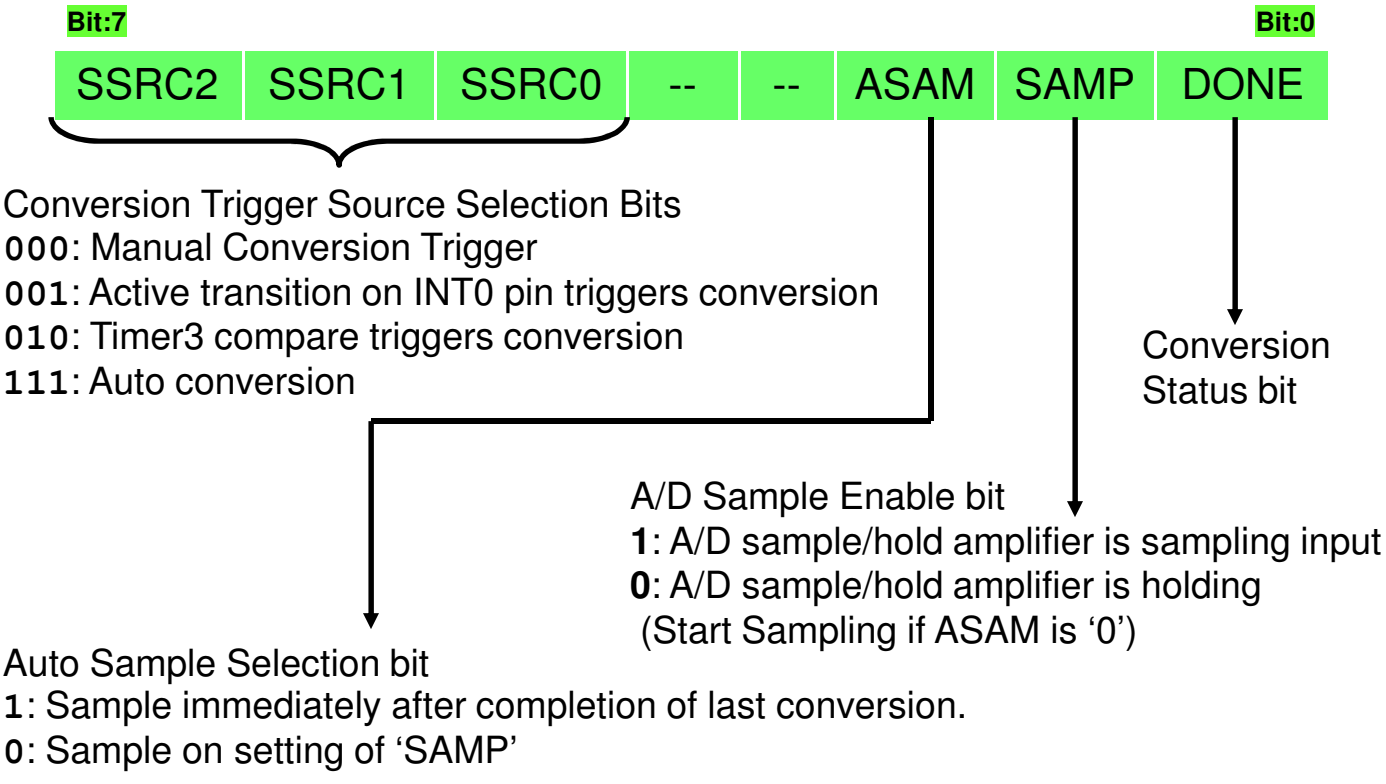
LAB 4 ADC Registers

AD1CON1: A/D CONTROL REGISTER 1





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LAB 4 ADC Registers

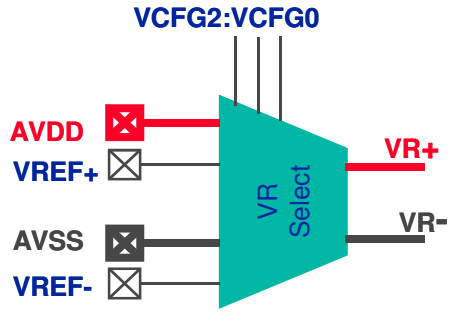
AD1CON2: A/D CONTROL REGISTER 2

Bit:15 Bit:8

VCFG2	VCFG2	VCFG0	--	--	CSCNA	--	--

1: Scan CH0+ Mux A Input

VCFG2:VCFG0	VR+	VR-
000	AVDD	AVSS
001	VREF+	AVSS
010	AVDD	VREF-
011	VREF+	VREF-
1xx	AVDD	AVSS



Bit:7 Bit:0

BUFS	--	SMPI3	SMPI2	SMPI1	SMPI0	BUFM	ALTS

SMPI3:SMPI0	Interrupt Event (Sample/convert sequence)
0000	each
0001	alternate
....	....
1110	Every 15th
1111	Every 16th

Sample alternatively MUX-A & MUX-B

Buffer Status bit, is valid only when BUFM = '1'
1: Buffer 8-F is being filled, can access Buffer 0-7
0: Buffer 0-7 is being filled, can access Buffer 8-F

Buffer Mode Select bit
1: Buffer configured as two 8-words buffers
0: Buffer configured as one 16-words buffers

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LAB 4 ADC Registers

AD1CON3: A/D CONTROL REGISTER 3

Bit:15							Bit:8
ADRC	--	--	SAMC4	SAMC3	SAMC2	SAMC1	SAMC0

A/D conversion Clock Source is ADRC OR system clock

A/D Sample Time Selection bits

SAMC4:SAMC0	Sampling Time
00000	0 T_{AD}
00001	1 T_{AD}
....	....
11110	30 T_{AD}
11111	31 T_{AD}

Bit:7							Bit:0
--	--	ADCS5	ADCS4	ADCS3	ADCS2	ADCS1	ADCS0

*Note: PIC24H & dsPIC implement ADSC7:ADSC0 (1-256*Tcy)*

$ADCS = (T_{AD}/T_{CY}) - 1$

A/D Conversion Clock Selection bits

ADCS5:ADCS0	Conversion Clock
000000	T_{CY} (F_{CY})
000001	2*T_{CY} (F_{CY} / 2)
....	....
111110	63*T_{CY} (F_{CY} / 255)
111111	64*T_{CY} (F_{CY} / 256)

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LAB 4 ADC Registers

AD1CHS : A/D Input Select Register

Bit:15 Bit:8

CH0NB	--	--	--	CH0SB3	CH0SB2	CH0SB1	CH0SB0

CH0 Negative input for MUX B
1: AN1
0: VR-

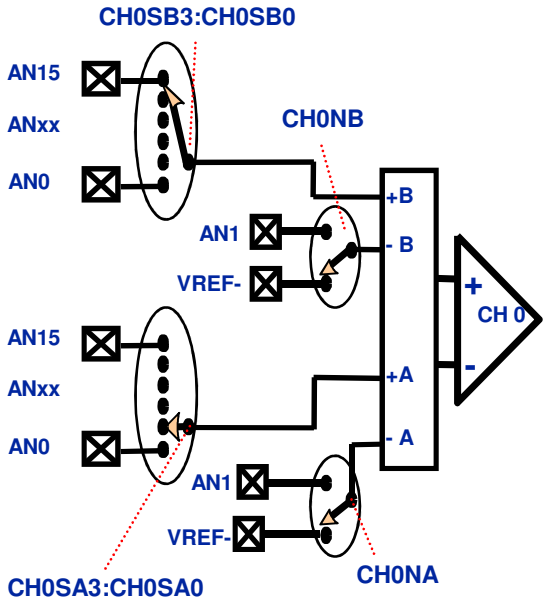
CH0SB3:CH0SB0	CH0 Positive Input for MUX B
0000	AN0
0001	AN1
....	....
1110	AN14
1111	AN15

Bit:7 Bit:0

CH0NA	--	--	--	CH0SA3	CH0SA2	CH0SA1	CH0SA0

CH0 Negative input for MUX A
1: AN1
0: VR-

CH0SA3:CH0SA0	CH0 Positive Input for MUX A
0000	AN0
0001	AN1
....	....
1110	AN14
1111	AN15



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LAB 4 ADC Registers

AD1PCFG : A/D Port Configuration Register

Bit:15							Bit:8
PCFG15	PCFG14	PCFG13	PCFG12	PCFG11	PCFG10	PCFG9	PCFG8
Bit:7							**Bit:0**
PCFG7	PCFG6	PCFG5	PCFG4	PCFG3	PCFG2	PCFG1	PCFG0

Analog Input Pin Configuration Control bits 0 to 15

1: Pin for corresponding analog channel (ANxx) is in digital mode

0: Pin for corresponding analog channel (ANxx) is in analog mode

AD1CSSL : A/D Input Scan Select Regsiter

Bit:15							Bit:8
CSSL15	CSSL14	CSSL13	CSSL12	CSSL11	CSSL10	CSSL9	CSSL8
Bit:7							**Bit:0**
CSSL7	CSSL6	CSSL5	CSSL4	CSSL3	CSSL2	CSSL1	CSSL0

A/D Input Channel Scan Selection bits 0 to 15

1: Corresponding analog channel (ANxx) is selected for sequential scanning

0: Corresponding analog channel (ANxx) is ignored for sequential scanning

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LAB 4 Solution

```
ADCInit()
{

    //##############################################
    //  STEP 1:
    //  Select integer format result,
    //  Select auto conversion start
    //  Select Sample after conversion ends
    //##############################################
    AD1CON1 = 0x00E4;

    //##############################################
    //  STEP 2:
    //  Select AVDD & AVSS as references,
    //  Disable Scan Mode for Ch0 input,
    //  Select interrupt after 16 sample/convert sequence,
    //  Select 16*1 buffer levels
    //  Always use MUX A
    //##############################################
    AD1CON2 = 0x003C;

    //##############################################
    //  STEP 3:
    //  Select AD Clock as derivative of system clock source,
    //  Select 13TAD sampling time,
    //  Select AD clcok frequency such that 16 samples are collected in 1 mSec
    //  Assume FCY = 4 MHz or 1TCY = .25 uS
    //##############################################
    AD1CON3 = 0x0D09;

    //##############################################
    //  STEP 4:
    //  Set the positive sample input channel for MUX A to use AN5
    //  Set the negative input channel for MUX A to use VR-
    //##############################################
    AD1CHS = 0x0005;

    //##############################################
    //  STEP 5:
    //  Set AD1PCFG so that the only pin using analog functionality is AN5
    //##############################################
    AD1PCFG = 0xFFDF;

    //##############################################
    //  STEP 6:
    //  Channel scanning is not enabled, so no input
    //  channels should be selected for scanning
    //##############################################
    AD1CSSL = 0x0000;

}
```

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LAB 4 Expected Result

- POT value is averaged for 16 samples over 1 ms.
- POT value is displayed on LEDs as a binary value from 0 to 255
- Pin RB2 toggles each time 16 samples are taken (a frequency of 500 Hz)

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Lab 5

Configuration of 32-Bit Timers

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LAB 5 Goals

- Understand working of Timers in 32bit mode
- Configure the Timer 2/3 pair for 32 bit mode
- Implement a stop watch

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LAB 5 To Do

- **Open the project**
  - `C:\RTC\MCU3121\Lab5\Lab5.mcp`
- **Open the file**
  - `C:\RTC\MCU3121\Lab5\Lab5.c`
- **Look for `Timer23Init()` function and configure Timer 2 & 3 by initializing the registers T2CON, PR2 and PR3.**
  - STEP 1: T2CON
    - **Select Internal clock as clock source (Fosc/2)**
    - **1:1 Pre-scale**
    - **No Gated time accumulation**
    - **32-bit Timer mode**
  - STEP 2: PR3 & PR2
    - **Load the count to get 1 tenth of a second ticks**
    - **PR = (Fosc/2) / (# Ticks per second)**
- **Build the Project ,Run Proteus and Run the program**

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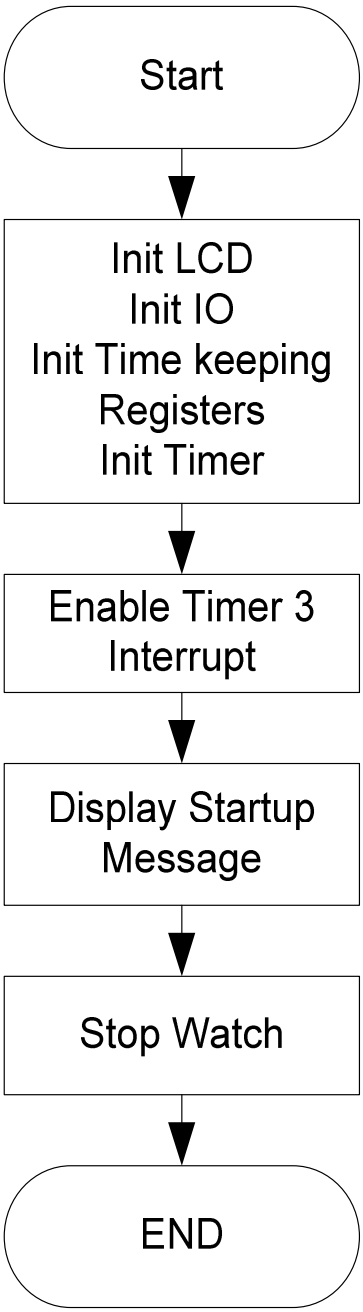
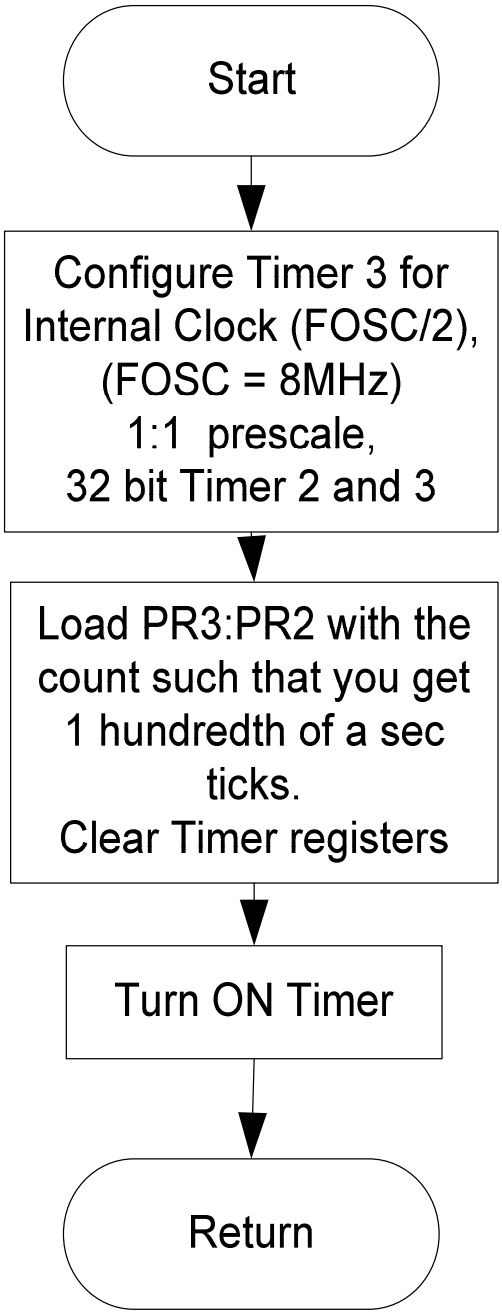
LAB 5 Flow Charts

Main Routine



Timer 3 Init Routine



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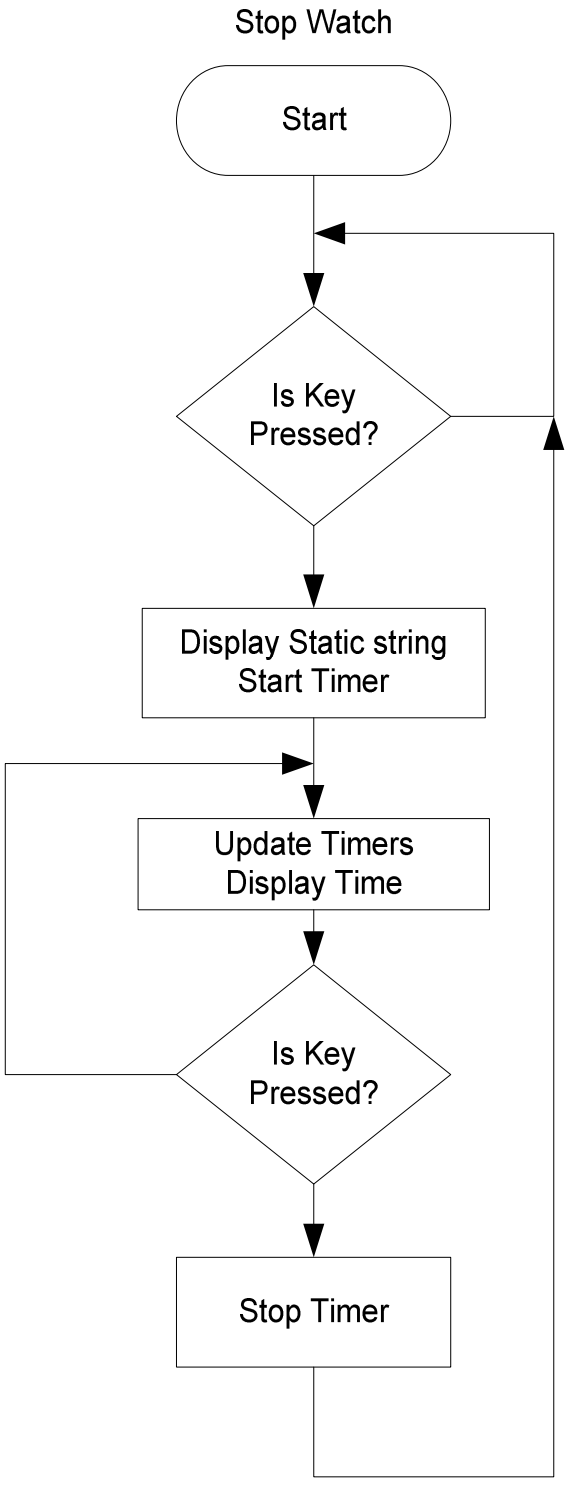
LAB 5 Flow Charts



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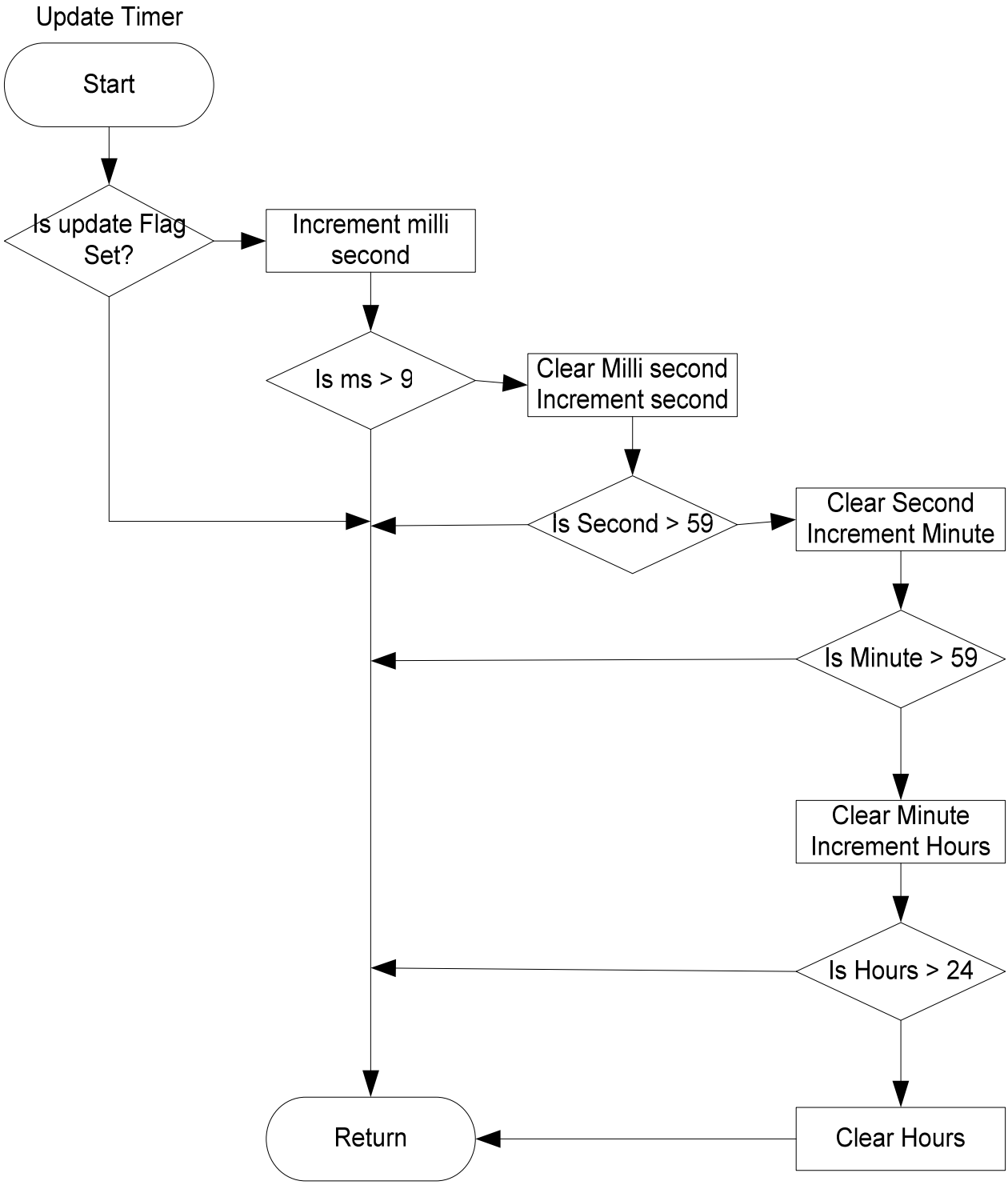
LAB 5 Flow Charts



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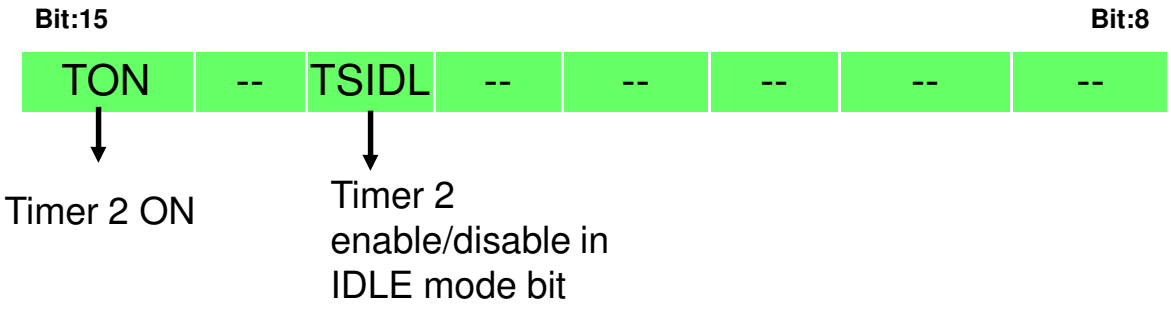
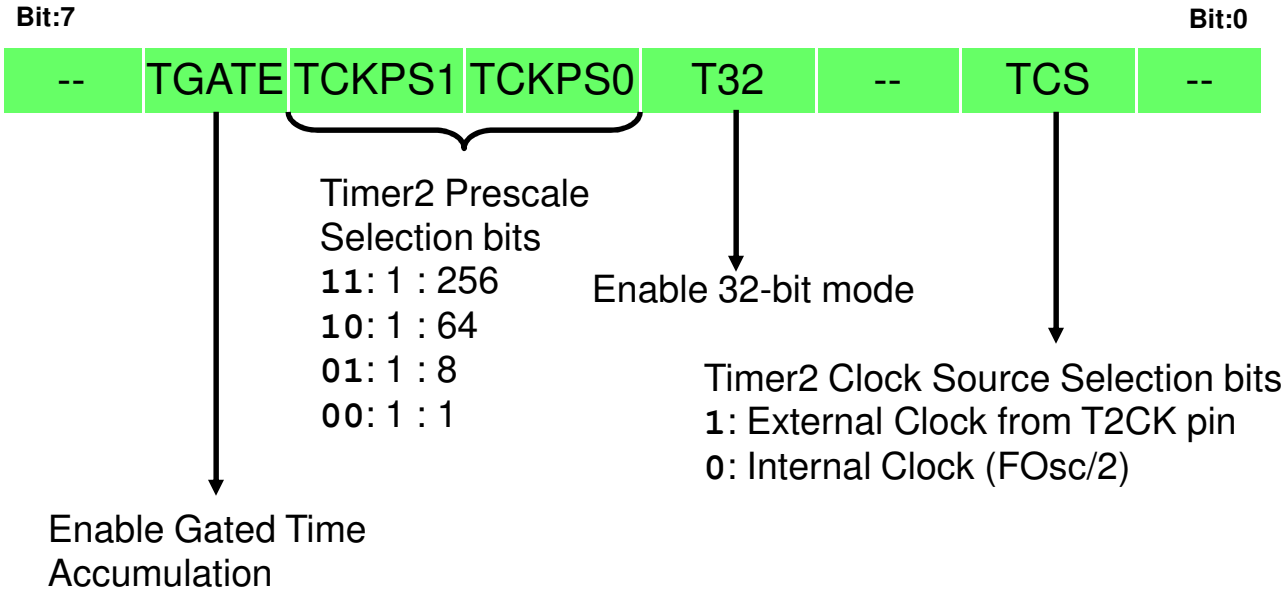
LAB 5 Timer Registers

T2CON: Timer 2 Control Register





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LAB 5 Solution

```
Timer23Init()
{

    //*****************************************************************************
    //  STEP 1:
    //  Internal Clock (FOSC/2) (FOSC = 8MHz)
    //  1:1 prescale
    //  32 bit Timer2 and 3
    //*****************************************************************************/
    T2CON = 0x8008;

    //*****************************************************************************
    //  STEP 2:
    //  Load PR3 & PR2 with the count such that you get 1 tenth of a sec ticks.
    //  Equation for PR calculation:  PR = (Fosc/2) / (# Ticks per second)
    //*****************************************************************************/
    PR3 = 0x0006;
    PR2 = 0x1A80;


    TMR3 = 0x0000;
    TMR2 = 0x0000;

    T2CONbits.TON = 1;      // Start Timer
}
```

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LAB 5 Expected Result

- The On-Board LCD will be Displaying
  - Press S3 - Start
- Press the Switch S3 to start timer
- Again press the Switch S3 to stop timer and LCD displays the Time elapsed between the start and stop

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Lab 6

UART Configuration and Usage of FIFO

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LAB 6 Goals

- **Understand Configuration of UART module**
- **Understand Transmit and Receive interrupts**
- **Understand the advantages of the FIFO**
  - A slow baud rate is used to make this more easily visible
- **Write a software to Transmit and Receive data using UART**

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LAB 6 To Do

- **Open the project**
  - `C:\RTC\MCU3121\Lab6\Lab6.mcp`
- **Open the file**
  - `C:\RTC\MCU3121\Lab6\Lab6.c`
- **Look for `UARTInit()` function and configure UART by initializing the registers U2MODE, U2STA and U2BRG.**
  - STEP 1: U2BRG
    - **Load the count to get 300 baudrate**
    - **BRG = Fcy/(16*BaudRate)-1 where Fcy = 4MHz**
  - STEP 2: U2MODE
    - **Select No IrDA**
    - **Select Flow Control Mode**
    - **Enable RTS and CTS**
    - **No Wake-Up**
    - **No Loop-back mode**
    - **No Auto baud**
    - **No Rx Inversion**
    - **Low Baudrate**
    - **1 Stop-bit**
    - **8-bit data with parity of your choice**
  - STEP 3: U2STA
    - **No Tx Inversion**
    - **Disable Sync Break**
    - **Enable Transmit**
    - **Disable Address Detect**
    - **Interrupt on every receive.**
- **Build the Project ,Run Proteus and Run the program**
- **In the Terminal window of Proteus**
  - Type characters into the HyperTerminal window
- **Make sure the settings of UART window are: 300 baud, 8-bit data, Parity of your choice, 1 Stop bit, Hardware Flow Control**

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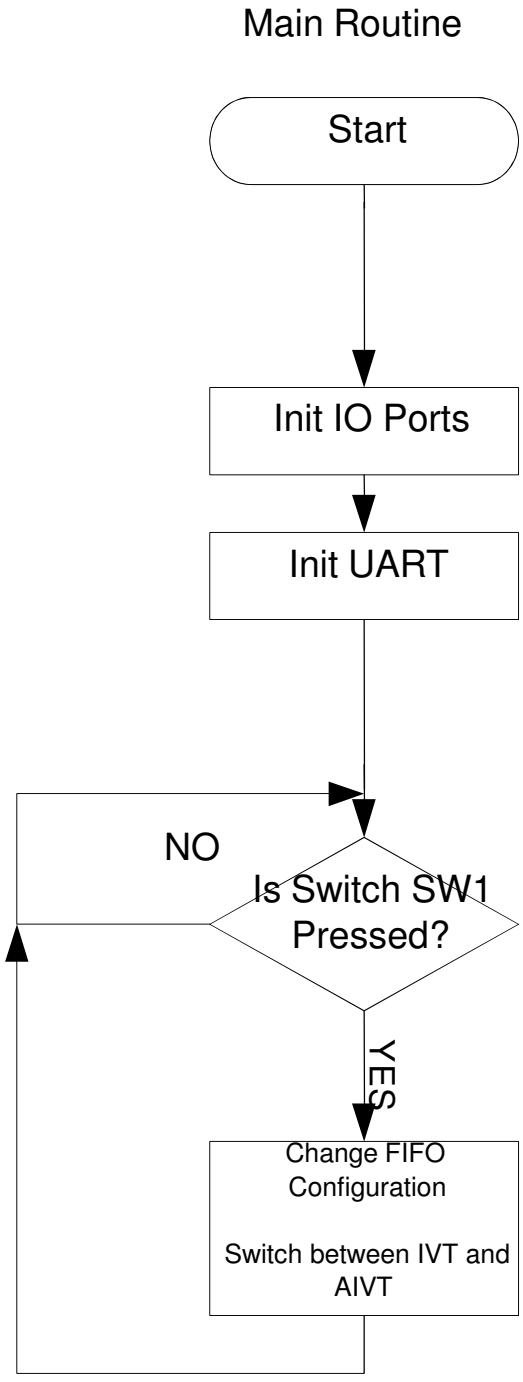
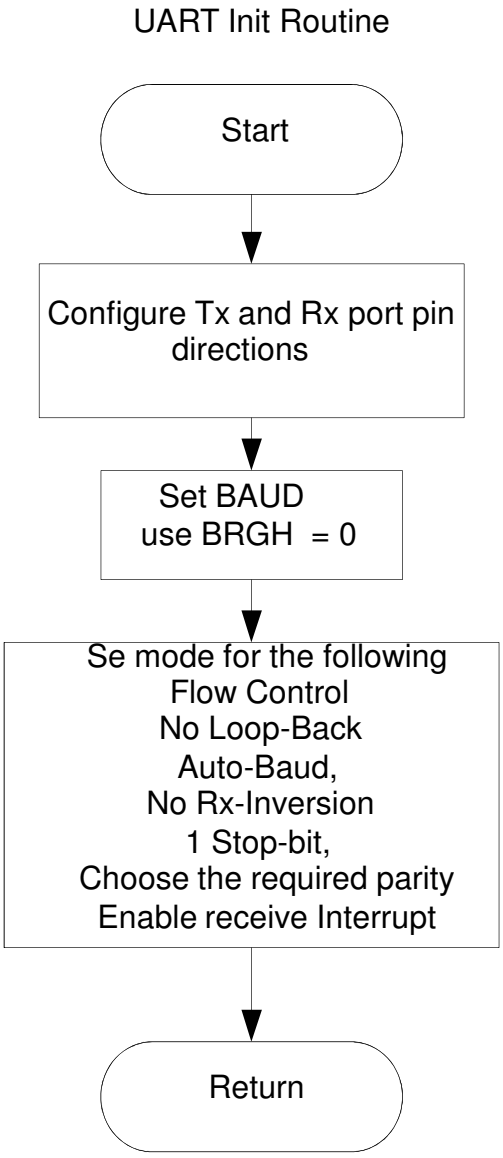
LAB 6 Flow Charts





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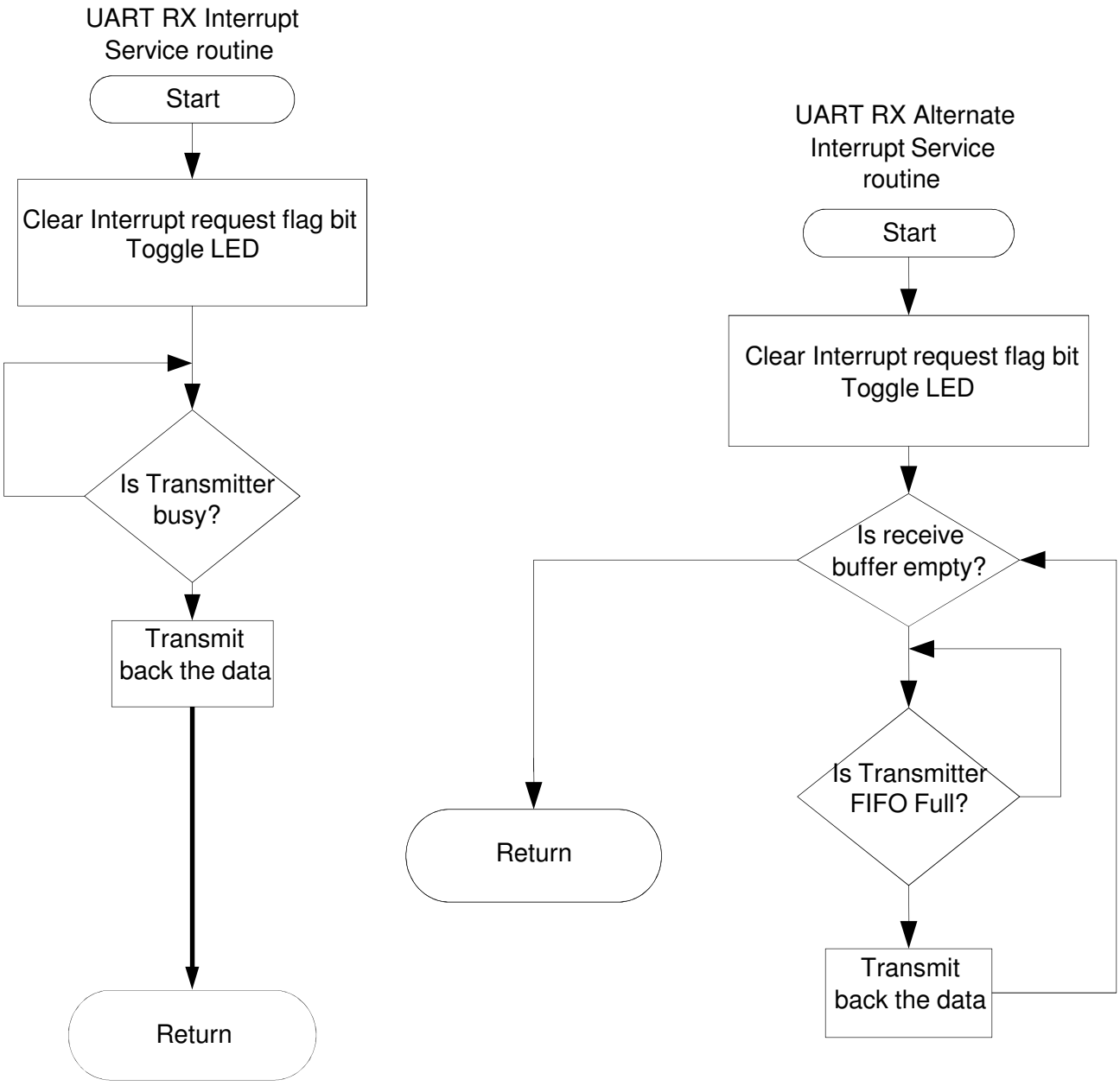
LAB 6 Flow Charts



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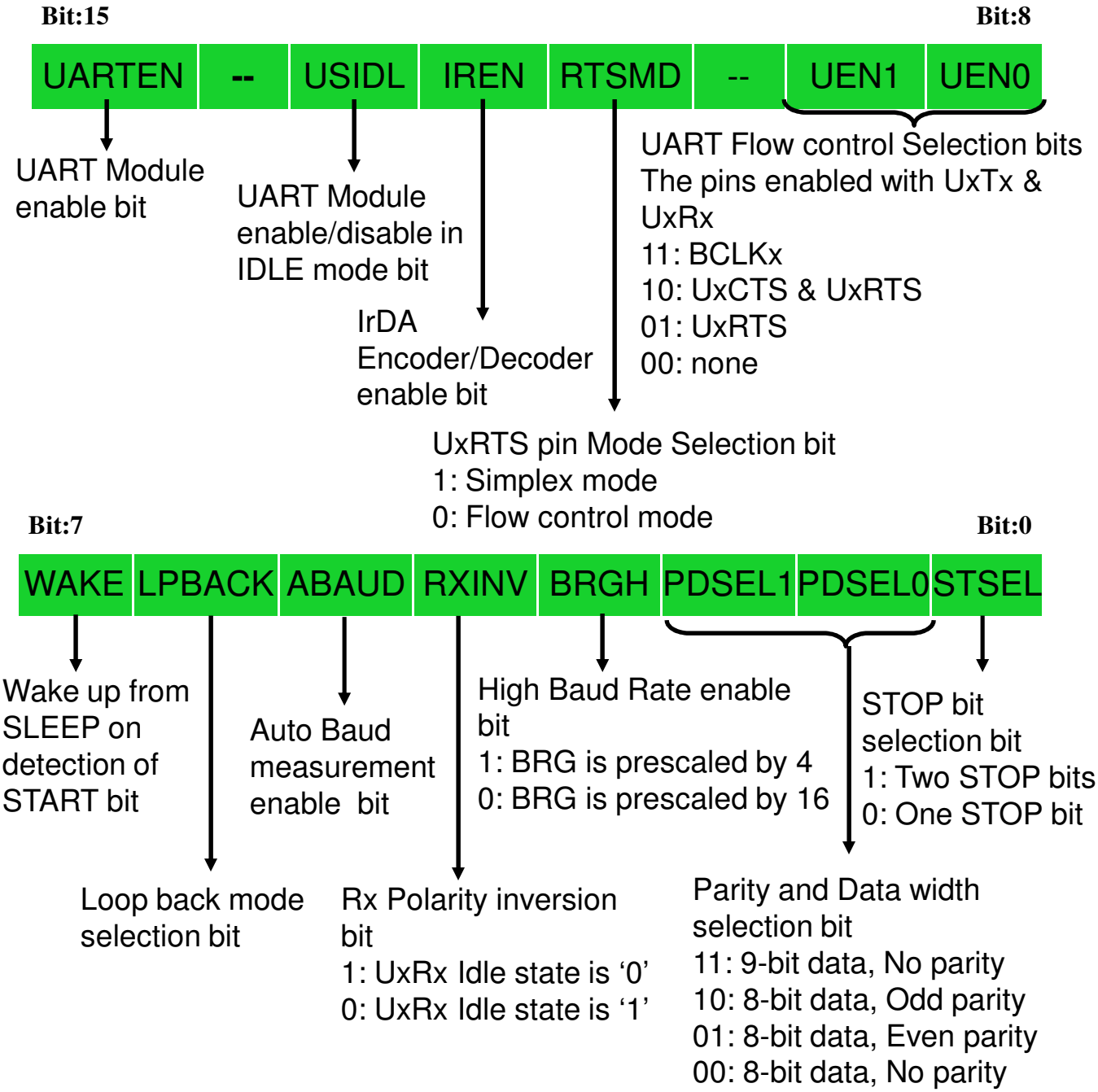
LAB 6 UART Registers

UxMODE: UART Mode register



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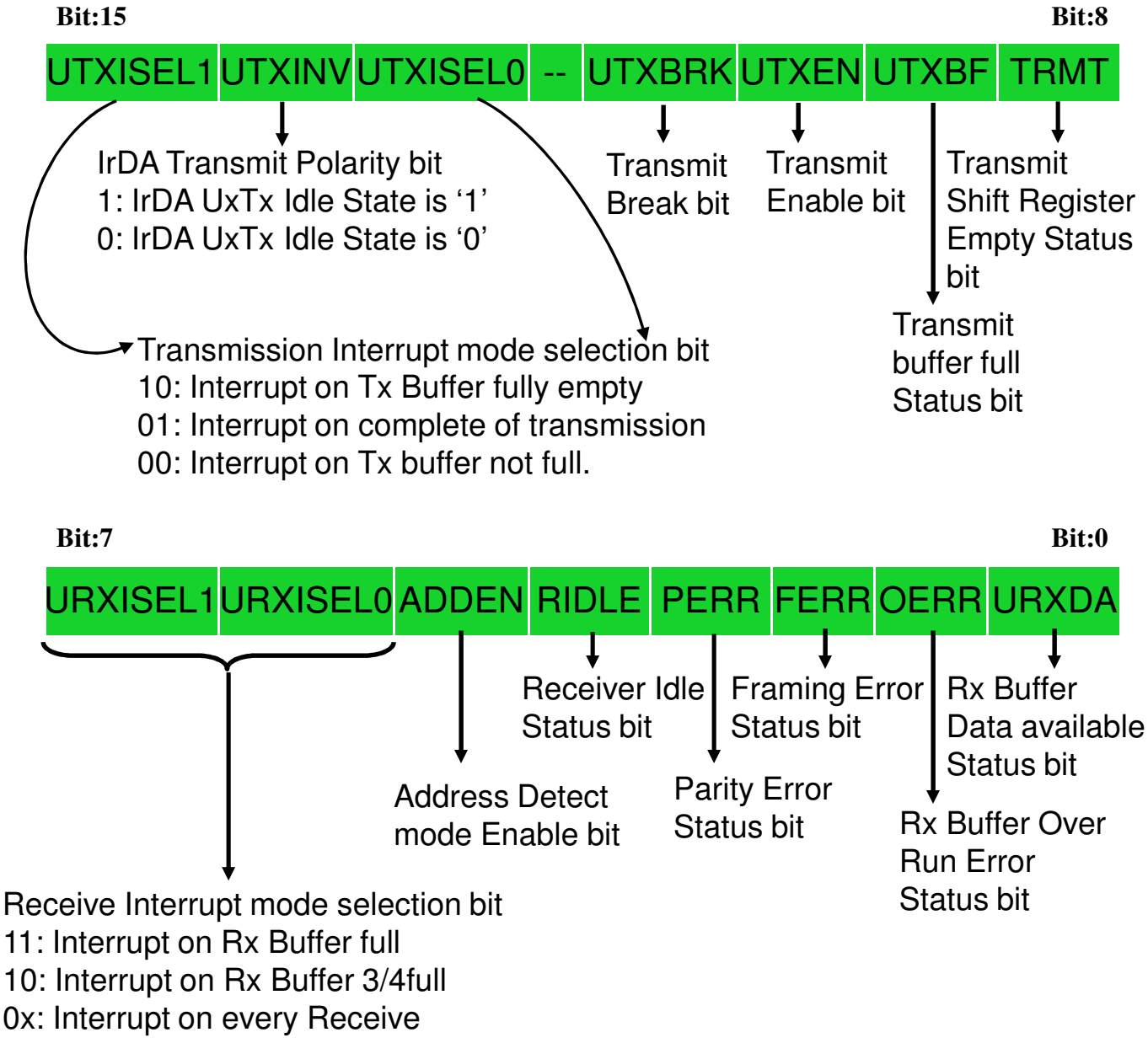
LAB 6 UART Registers

UxSTA: UART Status and Control register



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LAB 6 Solution

```
UARTInit()
{
    TRISFbits.TRISF5 = 0;

    //*****************************************************************************
    //  STEP 1:
    //  Load the count to get 300 baudrate
    //  BRG = Fcy/(16*BaudRate)-1  where Fcy = Fosc/2 = 4MHz
    //*****************************************************************************/
    U2BRG = 0x320;  //0xC8; //0x19;

    //*****************************************************************************
    //  STEP 2:
    //  Flow Control Mode, No Loop-Back
    //  No Auto-Baud, No Rx-Inversion
    //  Low BaudRate, 1 Stop-bit,
    //  8-bit with parity of your choice
    //*****************************************************************************/
    U2MODE = 0x8200;

    //*****************************************************************************
    //  STEP 3:
    //  Tx Interrupt to interrupt when at least one location is free in Tx buffer
    //  No Tx Inversion, Disable Sync Break
    //  Enable Transmit, Disable Address Detect
    //  Interrupt on every receive.
    //*****************************************************************************/
    U2STA = 0x0400;


    IFS1bits.U2RXIF = 0;
    IEC1bits.U2RXIE = 1;

}
```

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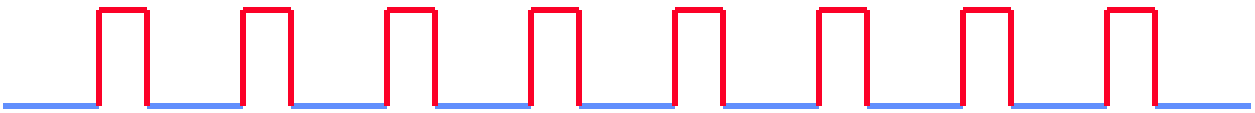
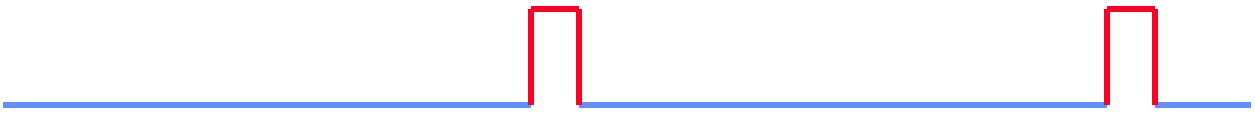
LAB 6 Expected Result

- **LED D3 indicates amount of CPU time spent processing UART data. Slower blinking means indicates less time spent servicing UART interrupt routine.**
- **Press Switch S4, the rate at which LED flashes decreases as now UART is using the RxBuffer and interrupting only on Buffer.**



Normal LED pattern – blink each receive



S4 Pressed – blink each full buffer, 4 characters received

- **The transmitted data can be observed on the screen as the received Data is transmitted back**
  - Without S4, the data comes back as you enter it
  - With S4 pressed, the data will come back in packets of 4

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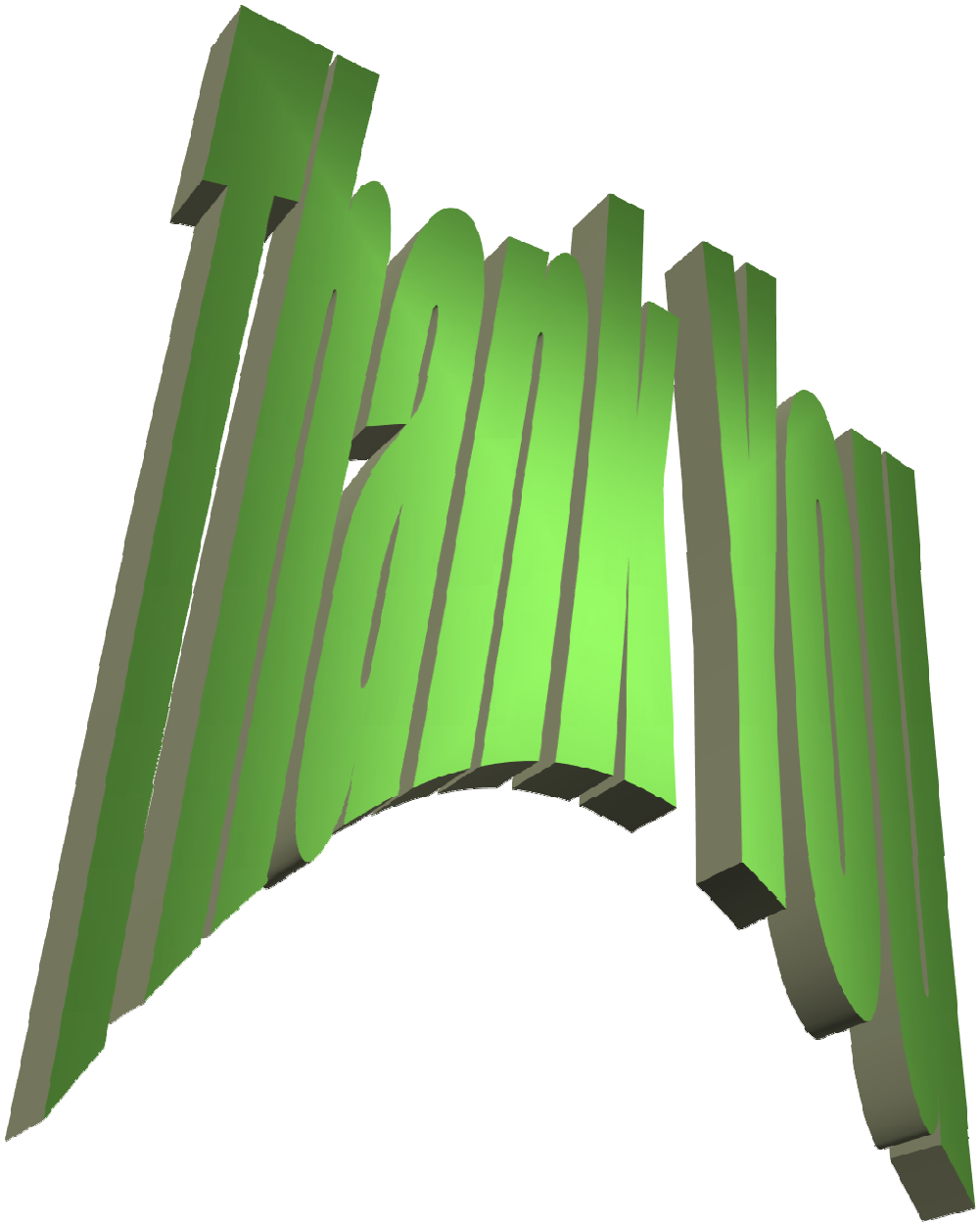

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