# Today:

- Announcement –lab notes marking
- Announcement –lecture test
- General info finding strategy
- Compering results of C and assembler code
- Activity 2
- Programing in C continuation – interrupts
- ADC introduction

# Announcement:

Please submit on Canvas lab notes and annotated programs as a pdf file before the beginning of lab 3.

Labs Marking scheme:

Completeness and quality of procedure/circuits/code etc.
used to perform all the completed activities 5
General Report Structure:
objectives defined, clear enough statements of what is
being done and why, what the results were.
General clarity of the notes 2
Above and beyond. Evidence of exploration above and beyond
the specific tasks requested in the manual. 1

Labs 1&2 will be worth 4 points, labs 3&4 and 5&6 8 points each pair.

# Lecture test on February 27th

Write a program in C doing ….

You will be using your computer with all the programs you want as well as any notes or texts. You will submit your program as a text file – just email it to me when the time is up (no later). 10% penalty per minute!

Its all on the honor system, you will be expected not to communicate with anybody.

# General info finding strategy

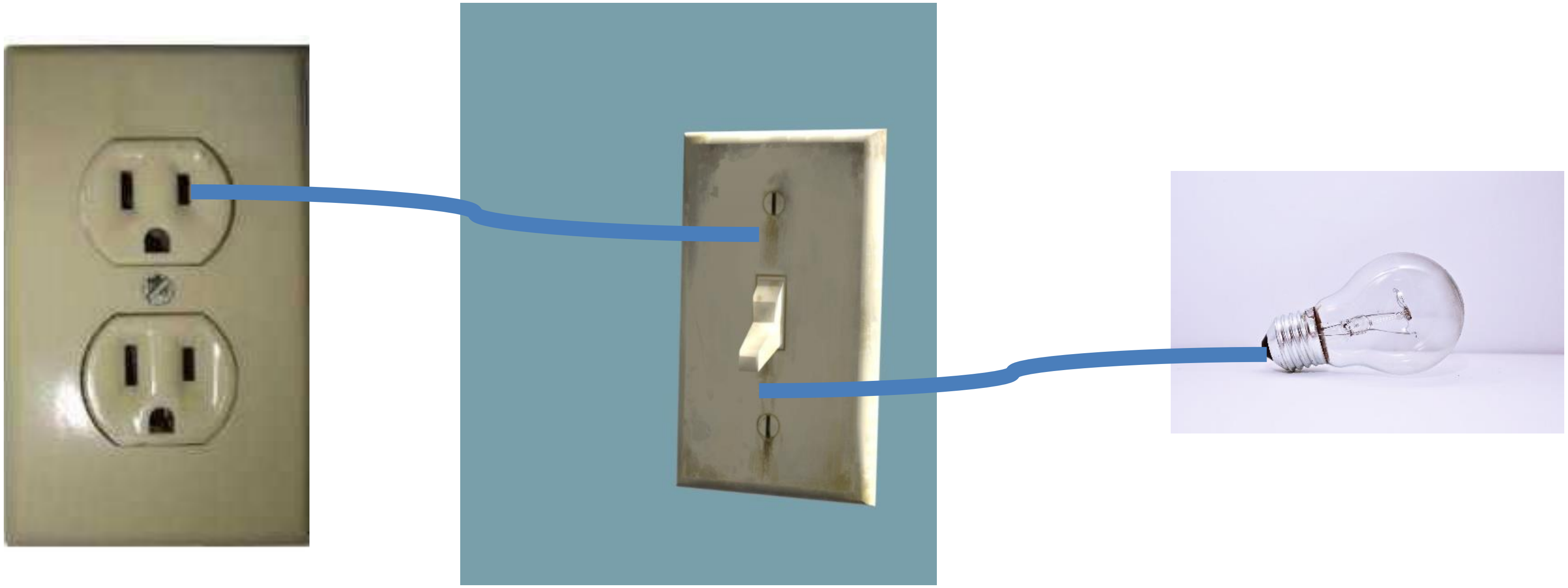
Documentation: read the manual!
 - not always so easy. Which manual?

There are two major documents relevant for the microcontroller:
 - Family reference guide [eg cpu instructions]
 - chip data sheet [eg what pin can do what]
Both contain much more info than we need!

Use:
-Table of contents
-Keyword searching

Also:
- Course lab manual – general instruction, what tasks are required

# Ground



# C compared to assembler

- Why do we program in C?
- Why you might to have to use assembler in the future

## Assembler program compiled from C

```
.include "msp430g2553.inc"
MOV.W   #0x5a80,&Watchdog_Timer_WDTCTL
MOV.B   #0x0041,&Port_1_2_P1DIR
MOV.B   #0x0040,&Port_1_2_P1OUT
PUSH    R13
PUSH    R14
MOV.W   #0x2844,R13
MOV.W   #1,R14
DEC.W   R13
SBC.W   R14
JNE     ($1_$2)
TST.W   R13
JNE     ($1_$2)
POP.W   R14
POP.W   R13
JMP     (0xc02c)
NOP
XOR.B   #0x0041,&Port_1_2_P1OUT
JMP     ($C$L1)
MOV.W   #0x0400,SP
CALL    #_system_pre_init
CLR.W   R12
CALL    #main
MOV.W   #1,R12
CALL    #C$$EXIT
 BIS.W  #0x0010,SR
JMP __TI_ISR_TRAP
JMP     (__TI_ISR_TRAP)
NOP
NOP
NOP
JMP     ($C$L1)
NOP
MOV.W   #1,R12
RET
AND.B   @R15+,0xffff(R15)
AND.B   @R15+,0xffff(R15)
```

## The same program just written in Assembler

```
.include "msp430g2553.inc"
start:
        mov.w #WDTPW|WDTHOLD, &WDTCTL
        mov.b #0x41, &P1DIR
        mov.w #0x01, r8
repeat:
        mov.b r8, &P1OUT
        xor.b #0x41, r8
        mov.w #60000, r9
waiter:
        dec r9
        jnz waiter
        jmp repeat
```

# Activity 2

Pin 1.3 is connected to 3.3 V and pin 1.0 is connected to ground. Other pins are open.

What will be the decimal value of m after the following commands are executed:

```
char m;

P1DIR = 0;

P1REN = 0b11111111;

P1OUT = 0b00000111;

m = P1IN;
```

Data types:

char, unsigned char – 8 bit integer (0 to 255 or -128 to 127) It can also be interpreted as character depending on the context.

int, unsigned int – usually an integer of the native word size: 16 bits (-32768 to 32767 or 0 to 65536)

long, unsigned long – 32 bit integer (~ $-2x10^9$ to ~$2x10^9$ or 0 to ~$4x10^9$)

long long , unsigned long long – 64 bit integer (~ $-9x10^{18}$ to ~ 9 x $10^{18}$ or 0 to ~2 x $10^{19}$)

float – floating point number (32 bits) (floating point operations are very expensive on a processor like the msp430 that lacks a dedicated fpu - avoid if possible).

# Program with interrupt: enable

```
#include <msp430.h>
void main(void)
{
WDTCTL = WDTPW + WDTHOLD; // Stop watchdog timer
P1DIR = 0b00000001; //set P1.0 pin for output rest including P1.1 are inputs
P4DIR = 0b10000000; //set P4.7 pin for output
P1OUT = 0b00000011; // set Pin P1.0 to high and P1.1 to pullup
P4OUT = 0b10000000; // set Pin P4.7 to high
P1REN = 0b00000010; //enable pull up/down resistor on P1.1
P1IE = 0b00000010; //Enable input at P1.1 as an interrupt
P1IES= 0b00000010; //Interrupt occurs when input voltage goes from High to Low
_BIS_SR (LPM4_bits + GIE); //Turn on interrupts and go into the lowest
//power mode (the program stops here)
//Notice the strange format of the function, it is an "intrinsic"
//ie. not part of C; it is specific to this microprocessor
}
//Port 1 interrupt service routine starts below
void __attribute__ ((interrupt(PORT1_VECTOR))) PORT1_ISR(void) {
//code of the interrupt routine goes here
P1OUT ^= 0b00000001;
P4OUT ^= 0b10000000; // toggle the LEDs
P1IFG &= ~0b00000010; // Clear P1.3 IFG. If you don't, it just happens again.
}
```

# Setting the bits

We want to set bit 3 in a P2REN register which contains a number 0b11000000.

If we do:

```
P2REN = 0b00001000;
```

We clear the other 2 bits

Instead we do:

```
P2REN |= 0b00001000;
```

11000000 |00001000=11001000

# Clearing the bits

P1OUT = 0b00000011; // set Pin P1.0 to high and P1.1 to pullup
I want to set P1.0 to low

If I do

P1OUT = 0b00000000; // I also cancelled the pullup!

Instead we do:

P1OUT &= ~0b00000001;

Which is the same as

P1OUT &= P1OUT &(~0b00000001);

0b00000011&11111110=000000010

# Program with interrupt: general enable

```
#include <msp430.h>
void main(void)
{
WDTCTL = WDTPW + WDTHOLD; // Stop watchdog timer
P1DIR = 0b00000001; //set P1.0 pin for output rest including P1.1 are outputs
P4DIR = 0b10000000; //set P4.7 pin for output
P1OUT = 0b00000011; // set Pin P1.0 to high and P1.1 to pullup
P4OUT = 0b10000000; // set Pin P4.7 to high
P1REN = 0b00000010; //enable pull up/down resistor on P1.1
P1IE = 0b00000010; //Enable input at P1.1 as an interrupt
P1IES= 0b00000010; //Interrupt occures when input voltage goes from High to Low
_BIS_SR (LPM4_bits + GIE); //Turn on interrupts and go into the lowest
       //power mode (the program stops here)
       //Notice the strange format of the function, it is an "intrinsic"
        //ie. not part of C; it is specific to this microprocessor
}
//Port 1 interrupt service routine starts below
void __attribute__ ((interrupt(PORT1_VECTOR))) PORT1_ISR(void) {
//code of the interrupt routine goes here
P1OUT ^= 0b00000001;
P4OUT ^= 0b10000000; // toggle the LEDS is
P1IFG &= ~0b00000010; // Clear P1.3 IFG. If you don't, it just happens again.
}
```

# rogram with interrupt:interrupt routine

```
#include <msp430.h>
void main(void)
{
WDTCTL = WDTPW + WDTHOLD; // Stop watchdog timer
P1DIR = 0b00000001; //set P1.0 pin for output rest including P1.1 are outputs
P4DIR = 0b10000000; //set P4.7 pin for output
P1OUT = 0b00000011; // set Pin P1.0 to high and P1.1 to pullup
P4OUT = 0b10000000; // set Pin P4.7 to high
P1REN = 0b00000010; //enable pull up/down resistor on P1.1
P1IE = 0b00000010; //Enable input at P1.1 as an interrupt
P1IES= 0b00000010; //Interrupt occures when input voltage goes from High to Low
_BIS_SR (LPM4_bits + GIE); //Turn on interrupts and go into the lowest
        //power mode (the program stops here)
        //Notice the strange format of the function, it is an "intrinsic"
         //ie. not part of C; it is specific to this microprocessor
}
//Port 1 interrupt service routine starts below
void __attribute__ ((interrupt(PORT1_VECTOR))) PORT1_ISR(void) {
//code of the interrupt routine goes here
P1OUT ^= 0b00000001;
P4OUT ^= 0b10000000; // toggle the LEDS is
P1IFG &= ~0b00000010; // Clear P1.3 IFG. If you don't, it just happens again.
}
```

# Program with interrupt: clear the flag

```
#include <msp430.h>
void main(void)
{
WDTCTL = WDTPW + WDTHOLD;       // Stop watchdog timer
P1DIR = 0b11110111;            //set all P1 pins for output except P1.3
P1OUT = 0b01001001;             // set Pins P1.0 and P1.6 to high and P1.3 to pullup
P1REN = 0b00001000;             //enable pull up/down resistor on P1.3
P1IE =     0b00001000;          //Enable input at P1.3 as an interrupt
_BIS_SR (LPM4_bits + GIE);     //Turn on interrupts and go into the lowest
                               //power mode (the program stops here)
                                //Notice the strange format of the function, it is an "intrinsic
                               //ie. not part of C; it is specific to this chipset
}
                               // Port 1 interrupt service routine
void __attribute__ ((interrupt(PORT1_VECTOR))) PORT1_ISR(void)
   {                           //code of the interrupt routine goes here
      P1OUT ^=0b01000001;       // toggle the LEDS
P1IFG &= ~0b00001000;         // Clear P1.3 IFG. If you don't, it just happens again.
   }
```

# Interrupts

When interrupt occurs the current microprocessor’s activity stops and the interrupt service routine (ISR) is started. It is like a function with a microcontroller specific format.

The event setting an interrupt is in fact setting a bit in a specific register. This bit is called an interrupt flag The ISR must clear this flag (some commands like the ones accessing an output communication buffer clear the specific flags automatically)!

# Programming in C

Libraries:
there are some “standard” libraries available that extend the operations you can easily use.

eg:
the math library gives access to functions like:
sin(x), cos(x), tan(x), sqrt(x), ln(x), log(x) etc...

To use math functions, you need to:
`#include <math.h>` at the top of the file

Other libraries provide routines for string manipulations and many other things...

These libraries tend to take up a substantial amount of flash and consume (precious) ram.  You should try to avoid these on the MSP430 if at all possible!

# Programming in C: functions

```
int multiply_together(int x, int y)
{
       return x*y;
}
```

You can define other functions that can take arguments and return values.

```
...

y = multiply_together(4,8);
...
```

The function definition either needs to come in the file before you call it, or you need to supply a *function prototype* before you call it.

A prototype for this function would simply be:

```
int multiply_together(int x, int y);
```

# Indentation.

Please use proper indentation of your C code to make it readable!

There are tools that can help. Many text editors can help you indent properly.

See

http://www.cprogramming.com/tutorial/style.html

For more details than you care about, see:
http://en.wikipedia.org/wiki/Indent_style

# Some Resources for C programming:

## Operators and Operator Precedence:

http://en.wikipedia.org/wiki/Operators_in_C_and_C%2B%2B#Operator_precedence

## C reference guide:

https://www.gnu.org/software/gnu-c-manual/gnu-c-manual.html

## Textbook: Introduction to Embedded Systems Using Microcontrollers and the MSP430

http://webcat2.library.ubc.ca/vwebv/holdingsInfo?bibId=7372090

# Analog to digital converter

Function: take an analog value (voltage in this case) and convert it to a number.

Resolution (from number of bits)

Our analog to digital converter has 12 bits

Range (by default a power supply voltage, 3.3V, but can be set up differently)

# Using peripherals: Analog to digital converter

READING THE DATASHEET IS ESSENTIAL!

```
#include <msp430f5529.h>
#include<stdio.h>

int main(void)
{
 WDTCTL = WDTPW + WDTHOLD;
 ADC12CTL0 = ADC12SHT02 + ADC12ON;        // Sampling time, ADC12 on
 ADC12CTL1 = ADC12SHP;                    // sampling timer
 ADC12CTL0 |= ADC12ENC;                   // ADC enable
 P6SEL |= 0b00000001;                     // P6.0 allow ADC on pin 6.0
 P1DIR |= 0b00000001;                     // set pin P1.0 as output

 while (1)
 {

  ADC12CTL0 |= ADC12SC;                  // Start sampling
  while (ADC12CTL1 & ADC12BUSY);//while bit ADC12BUSY in register ADC12CTL1 is high wait

  if(ADC12MEM0>=3072)    //This value depends on the input voltage
     P1OUT |= BIT0;
  else
    P1OUT &= ~BIT0;
 }
```

# Using peripherals: Analog to digital converter

READING THE DATASHEET of the family IS ESS

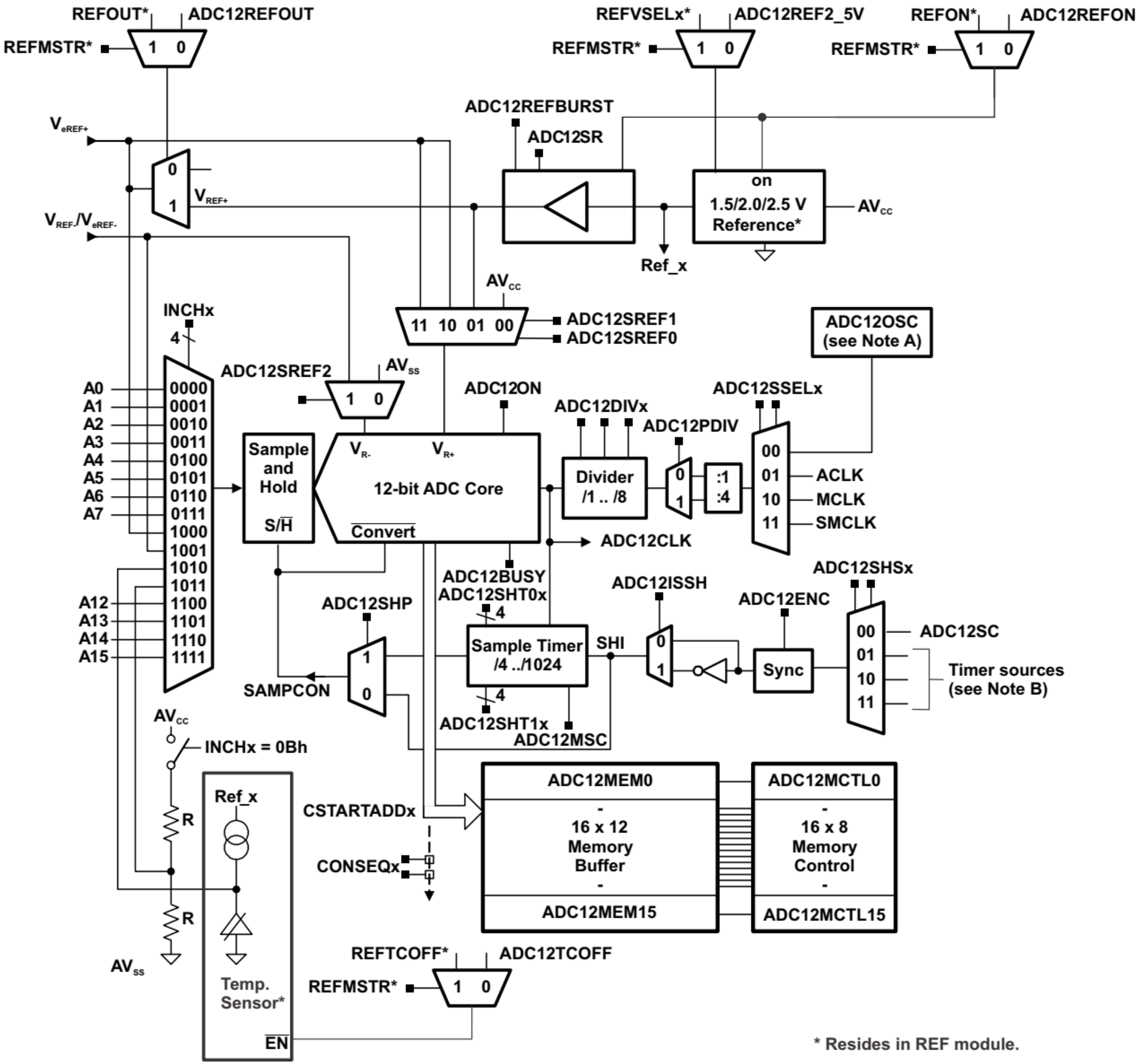
```
#include <msp430f5529.h>
#include<stdio.h>

int main(void)
{
  WDTCTL = WDTPW + WDTHOLD;
  ADC12CTL0 = ADC12SHT02 + ADC12ON;        // Sampling time 16 cycles, ADC12 on
  ADC12CTL1 = ADC12SHP;                    // sampling timer
  ADC12CTL0 |= ADC12ENC;                   // ADC enable
  P6SEL |= 0x01;                           // P6.0 allow ADC on pin 6.0
  P1DIR |= 0x01;                           // set pin P1.0 as output

  while (1)
  {

    ADC12CTL0 |= ADC12SC;                  // Start sampling
    while (ADC12CTL1 & ADC12BUSY);//while bit ADC12BUSY in register ADC12CTL1 is high wait

    if(ADC12MEM0>=3072)    //This value depends on the input voltage
       P1OUT |= BIT0;
    else
      P1OUT &= ~BIT0;
  }
```

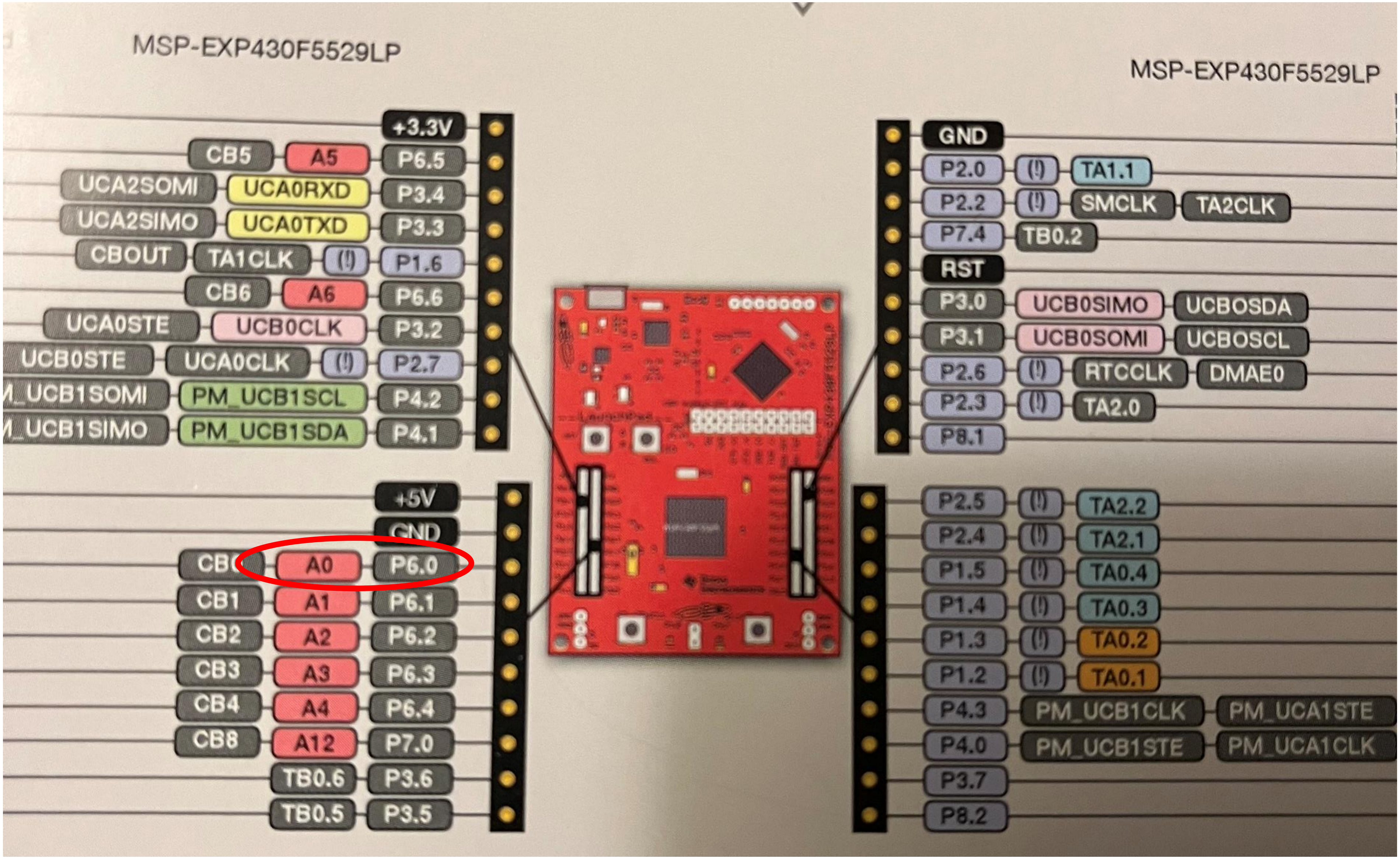


* Resides in REF module.

A ADC12OSC refers to the MODCLK from the UCS. See the UCS chapter for more information.

B See the device-specific data sheet for timer sources available.

**Figure 28-1. ADC12_A Block Diagram (Devices With REF Module)**


MSP-EXP430F5529LP
MSP-EXP430F5529LP
+3.3V
CB5 A5 P6.5
UCA2SOMI UCA0RXD P3.4
UCA2SIMO UCA0TXD P3.3
CBOUT TA1CLK (!) P1.6
CB6 A6 P6.6
UCA0STE UCB0CLK P3.2
UCB0STE UCA0CLK (!) P2.7
M_UCB1SOMI PM_UCB1SCL P4.2
M_UCB1SIMO PM_UCB1SDA P4.1
+5V
GND
CB0 A0 P6.0
CB1 A1 P6.1
CB2 A2 P6.2
CB3 A3 P6.3
CB4 A4 P6.4
CB8 A12 P7.0
TB0.6 P3.6
TB0.5 P3.5
GND
P2.0 (!) TA1.1
P2.2 (!) SMCLK TA2CLK
P7.4 TB0.2
RST
P3.0 UCB0SIMO UCB0SDA
P3.1 UCB0SOMI UCB0SCL
P2.6 (!) RTCCLK DMAE0
P2.3 (!) TA2.0
P8.1
P2.5 (!) TA2.2
P2.4 (!) TA2.1
P1.5 (!) TA0.4
P1.4 (!) TA0.3
P1.3 (!) TA0.2
P1.2 (!) TA0.1
P4.3 PM_UCB1CLK PM_UCA1STE
P4.0 PM_UCB1STE PM_UCA1CLK
P3.7
P8.2