

Today::

- Input – output ports
- Whirlwind tour of the MSP430 CPU and its assembly language
- Activity 1.
- Please read up on binary and hexadecimal if you're not familiar with them.

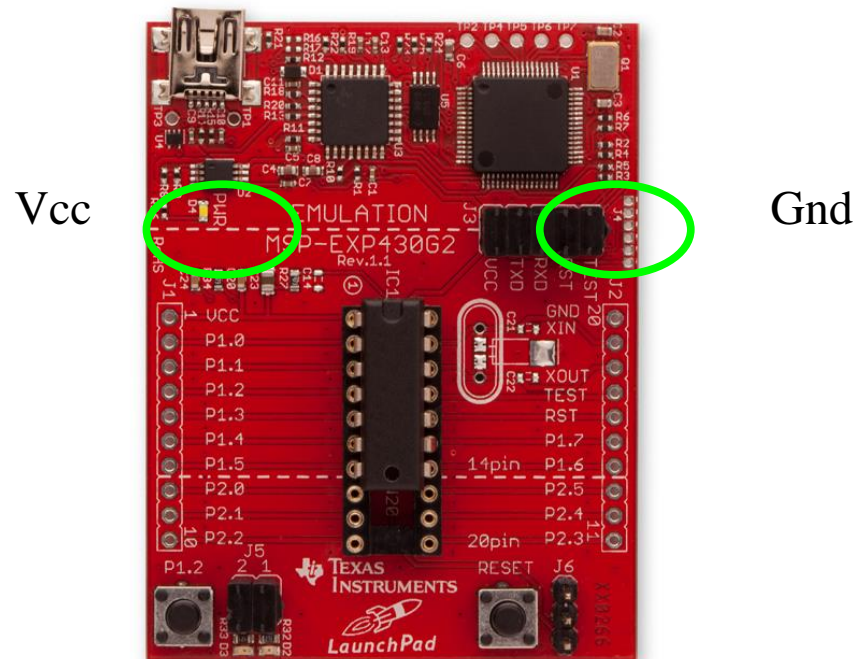
## Board Safety:

When Launchpad board is connected to USB:

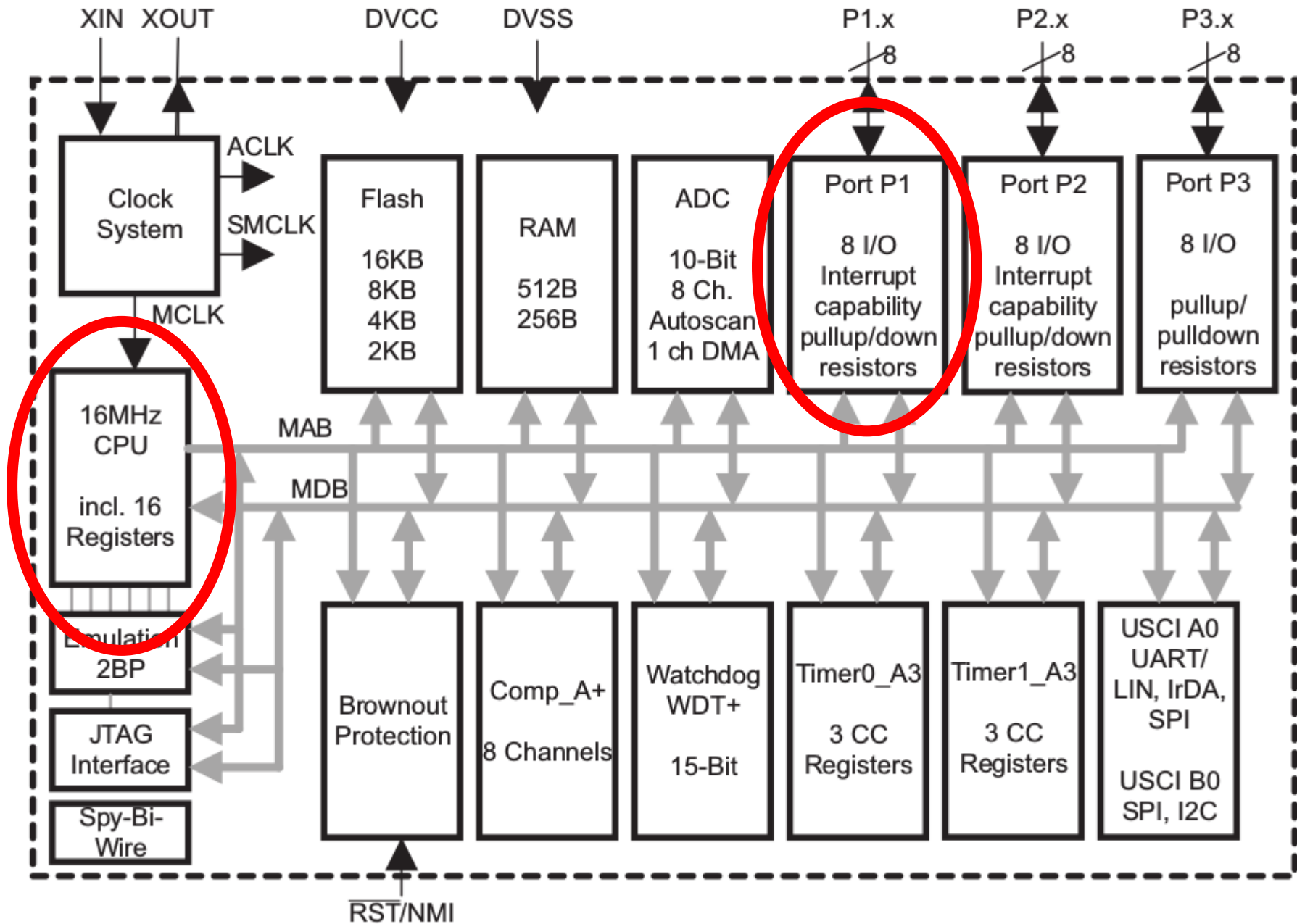
- **don't** connect VCC pin to anything (chip is USB powered)
- **do** connect GND pin to your circuit (no floating ground)
- **do** always connect P1.x pins to your circuit through resistors

**Any voltage higher than 3.6V or any negative voltage has the potential to damage the Launchpad board.**

**Any voltage higher than 5V or any negative voltage has the potential to damage the USB controller in your computer.** Resistors in series with the 5V power supply make the likelihood of damage **much smaller!**



# Functional Block Diagram, MSP430G2x53



# General Purpose Input/Output (GPIO) Ports

Several registers control the configuration and operation of sets of pins. In these registers, the different bits in the register control different pins.

P1DIR – sets the pin directions. Bit = 0 = input, Bit = 1 = output.

P1IN – input register. When configured for input, this register contains the digital input values

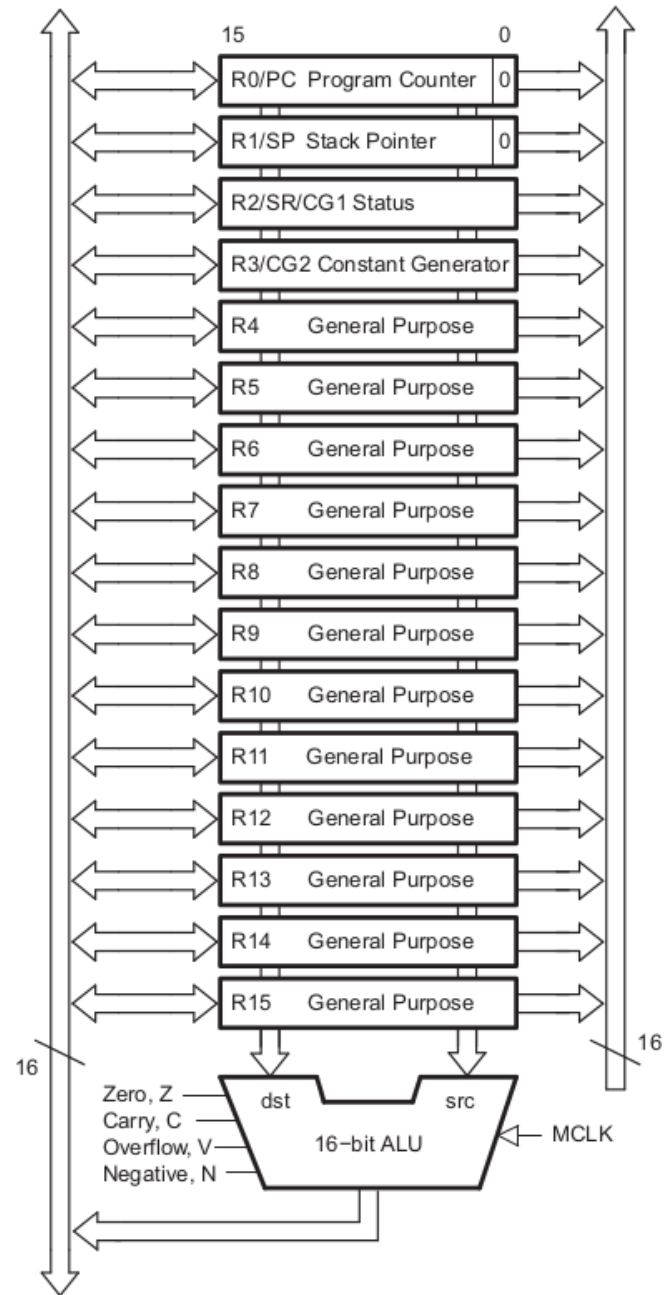
P1OUT – output register. When configured for output, writing to this register sets the outputs. When configured as input sets the pullup (1) or down (0)

P1REN – pullup/pulldown enable. Bit = 1, enable resistor (P1OUT sets whether pullup or down).

P1SEL/P1SEL2 – alternate function enable – both 0 means GPIO.

eg setting P1DIR = 3 (00000011b) configures pins P1.0 and P1.1 as outputs, P1.2-P1.7 as inputs

MDB – Memory Data Bus      Memory Address Bus – MAB



## **Registers:**

PC – program counter

SP – stack pointer

SR – status register

CG2 – constant generator

R4-R15 -general purpose registers

blink.asm:

```
.include "msp430g2553.inc"

    org 0xc000
start:
;mov.w #0x5a80, &WDTCTL
    mov.w #WDTPW|WDTHOLD, &WDTCTL
    mov.b #0x41, &P1DIR
    mov.w #0x01, r8
repeat:
    mov.b r8, &P1OUT
    xor.b #0x41, r8
    mov.w #40000, r9
waiter:
    dec r9
    jnz waiter
    jmp repeat

    org 0xfffe
    dw start        ; set reset vector to 'start' label
```

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    jmp repeat

    org 0xfffe
    dw start           ; set reset vector to 'init' label
```



# Assembler Commands:

- `.include`
- **Example:** `.include "msp430g2553.inc"`
- Instructs the assembler to include the contents of the file `msp430g2553.inc` into the program. This particular file contains definitions of registers and other names, but any other file, for example containing part of the program, can be included

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    dec r9
    jnz waiter
    jmp repeat

    org 0xfffe
    dw start           ; set reset vector to 'init' label
```

# Assembler Commands:

- `org`
- Example `org 0xc000`
- To define the address where the next lines of the program or data are going to be stored.
- Example `org 0xFFFFE`
- To store the address pointing to where the program should start after a reset

# Memory map

- Interrupt vector table                    ffe0 - ffff
- Flash memory (program)                c000 –ffdf (16 kB)
- Information memory (flash)            1000 -10ff
- RAM (variables)                        0200 - 03ff (512 bytes)
- 16-bit peripherals (registers)        0100-10ff
- 8-bit peripherals (port registers) 0010-00ff
- Special function registers            0000-000f

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```

# Assembler Commands:

```
;mov.w
```

lines beginning with ; are comments  
and are ignored by the assembler

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```

# Assembler Commands:

- `dw`
- Define word
- Example:  
`dw start`
- Will put a 16 bit number into the next memory location
- Word `start` is defined as hexadecimal number `c000` (beginning of the flash memory) because it is a label immediately following the command  
`org 0xc000`



# Assembler Commands:

- `equ`
- definition of a name for a number
- Example  

```
P1OUT equ 0x0021
```
- This command is used in the file `msp430g2553.inc` to call hexadecimal number 0021 “P1OUT”

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    dec r9
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    jmp repeat

    org 0xfffe
    dw start          ; set reset vector to 'init' label
```

# Microprocessor Commands:

- Move Byte

- Example:

```
mov.b #0x41, &P1DIR
```

- P1DIR is an address of the port control register defined in the file msp430g2553.inc

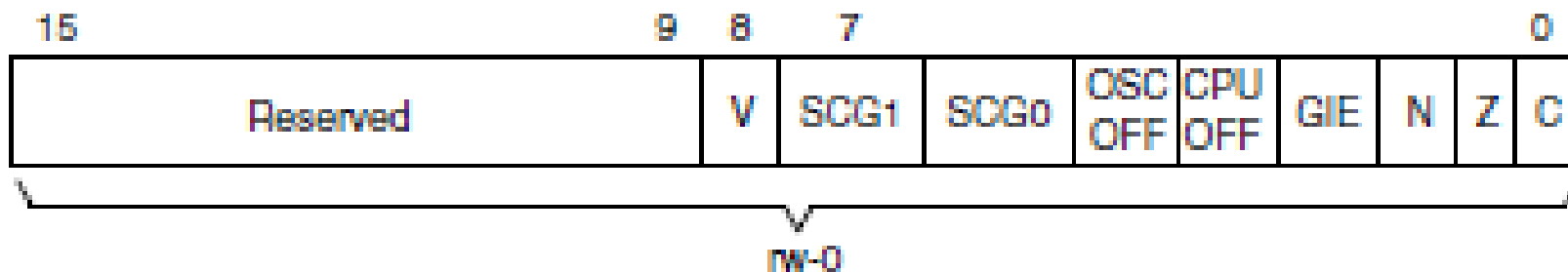
# Microprocessor Commands:

- `bis.w`
- Set a bit in a 16 bit register
- Example:  
`bis.w #CPUOFF, SR`
- Sets a particular bit in the Status Register
- The symbol `CPUOFF` must be defined earlier (eg in `msp430g2553.inc`)

# Status Register bits

- N Negative bit. This bit is set when the result of a byte or word operation is negative and cleared when the result is not negative.
  - Word operation: N is set to the value of bit 15 of the result
  - Byte operation: N is set to the value of bit 7 of the result
- Z Zero bit. This bit is set when the result of a byte or word operation is 0 and cleared when the result is not 0.
- C Carry bit. This bit is set when the result of a byte or word operation produced a carry and cleared when no carry occurred.
- V Overflow bit. Set if an operation overflows the signed variable range

*Status Register Bits*



# Microprocessor Commands:

## Two operand instructions:

mov.b, mov - move a byte or a word from src to dst

add.b/add – add source and destination

addc.b/addc - add with carry

sub.b/sub - subtract byte or word

subc.b/subc - subtract with carry

cmp.b/cmp - compare (dst-src), discard result

dadd.b/dadd - decimal (BCD) addition

bit.b/bit – test bits in destination, set status bits

bic.b/bic – clear bits in destination, **dst &= ~src**

bis.b/bis – set bits in destination, **dst |= src**

xor.b/xor – **dst ^= src**

and.b/and – **dst &= src**

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xor.b/xor – **dst ^= src**

and.b/and – **dst &= src**

eg, xor:

src: 01100101

dst: 11010001

-----

dst: 10110100

# Microprocessor Commands:

## Jump instructions and program flow

JEQ/JZ	Jump to label if zero bit is set
JNE/JNZ	Jump to label if zero bit is reset
JC	Jump to label if carry bit is set
JNC	Jump to label if carry bit is reset
JN	Jump to label if negative bit is set
JGE	Jump to label if $(N \text{ .XOR. } V) = 0$
JL	Jump to label if $(N \text{ .XOR. } V) = 1$
JMP	Jump to label



# Microprocessor Commands:

## **Single operand instructions:**

rrc.b/rrc – rotate right through carry

swpb - swap bytes

rra.b/rra – rotate right arithmetic

sxt – sign extend byte to word

push.b/push – push value onto stack

call – push PC on stack and move source to PC

reti – return from interrupt – pop SR, then pop PC

# Microprocessor Commands:

That's it! That is all the instructions the CPU understands.

In the manual, there are some additional instructions, referred to as 'emulated instructions' which are really just convenient abbreviations.

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    org 0xfffe
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```

# Addressing Modes

As/Ad	Addressing Mode	Syntax	Description
00/0	Register mode	Rn	Register direct. Register contents are operand
01/1	Indexed mode	X(Rn)	Indexed mode. The operand is in memory at address Rn+X.
01/1	Symbolic mode	ADDR	Symbolic mode. (PC + X) points to the operand. X is stored in the next word. Indexed mode X(PC) is used.
01/1	Absolute mode	&ADDR	Absolute Mode. The word following the instruction contains the absolute address. X is stored in the next word. Indexed mode X(SR) is used.
10/-	Indirect register mode	@Rn	Register indirect. Rn is used as a pointer to the operand. (same as 0(Rn) )
11/-	Indirect autoincrement	@Rn+	Register autoincrment. Rn is used as a pointer to the operand. Rn is incremented afterwards by 1 for .B instructions and by 2 for .W instructions.
11/-	Immediate mode	#N	Immediate Mode. The word following the instruction contains the immediate constant N. Indirect autoincrementmode @PC+ is used.

# Addressing Modes

- Immediate mode
- Syntax:            #N
- The word following the instruction contains the immediate constant N.
- Examples:  
  mov.b #01000001b, & P1DIR  
  mov.b #65, & P1DIR  
  mov.b #0x41, & P1DIR
- Source address can use this format (destination cannot)

# Addressing Modes

- Absolute mode
- Syntax:           &ADDR
- The word following the instruction contains the absolute address.
- Example:

```
mov.b #11110111b, &P1DIR
```

The destination address uses this format

# Addressing Modes

- Register mode
- Syntax Rn
- Register contents are operand
- Rn can be PC, SP, SR, CG2, R4 ...R16
- Example

bis.w #CPUOFF,SR

Destination address is the CPU status register  
SR

# Addressing Modes

- Indexed mode
- Syntax  $X(Rn)$
- Memory location pointed to by  $Rn+X$  are operand
- $Rn$  can be PC, SP, SR, CG2, R4 ...R16

Example

```
mov #27,4(R4)
```

Destination address is the memory location 4 bytes after the address pointed to by R4.



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00/0	<u>Register mode</u>	Rn	Register direct. Register contents are operand
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