Bit Clear, Bitwise *Logic Instructions(Continuing)*

`bic(.B or .W) src,dst;` dst←(NOTsrc)ANDdst, clear bits in dst with mask src. **Flag is not effected.**

Ex. For the initial conditions, R12=25A3H, R15= 8B94H and [25A5H]= 6CH, what will be the content of R15 after the execution of the following program?

```
bic.b 2(R12),R15; R15←(R12+2)'AND R15
```

Operation:
1001 0011 ($\overline{Memory}$) AND
1001 0100 (LowByteR15) =
1001 0000 (new Low Byte R15)

New Contents: R15 = 0090
Flags: not affected

Bit Set

`bis(.B or .W) src,dst;` dst←srcORdst, set bits in dst with mask src. **Flag is not effected.**

Ex. For the initial conditions, R12=25A3H, R15= 8B94H and [25A5H]= 6CH, what will be the content of R12 after the execution of the following program?

```
bis R15,R12; R12←R12 OR R15
```

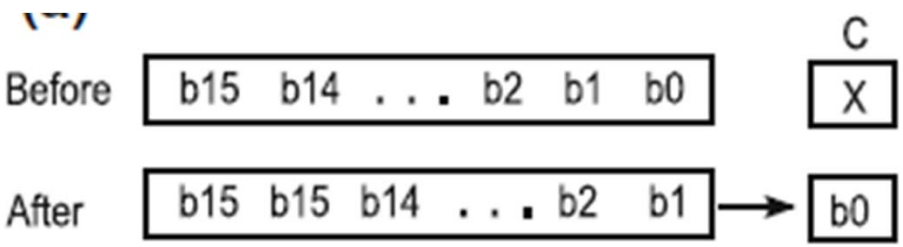
Operation:
1000 1011 1001 0100 (R15) OR
0010 0101 1010 0011 (R12) =
1010 1111 1011 0111

New Contents: R12 = AFB7

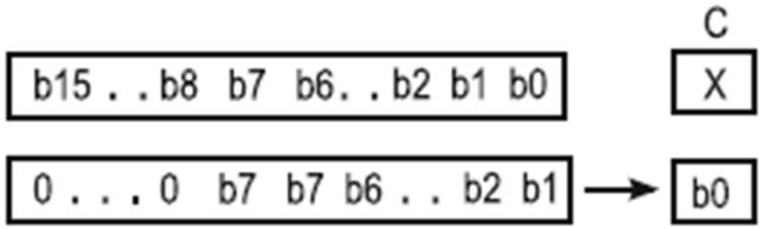
Flags: not affected.

Roll Right Arithmetically

`rra(.B or .W) dst;` Shift all bits to the right, C←LSB



`rra.w`; C=LSB



`rra.b`; C=LSB

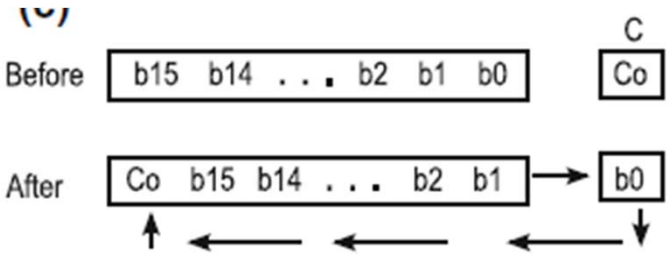
Ex. If the initial content of R5 is 8EF5H. What will be the content of R5 and the Carry value after the following codes individually?

`rra.w` R5; R5= C77AH, C=1

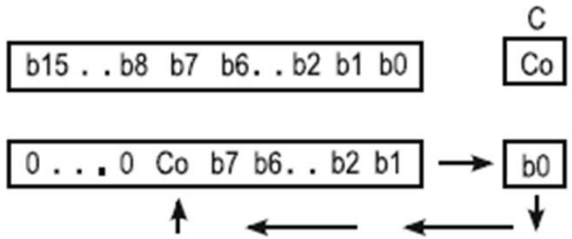
`rra.b` R5; R5= 00FAH, C=1

Rotate Right through Carry

`rrc(.B or .W) dst;` Shift all bits to the right, C←LSB



`rrc.w`; C=LSB



`rrc.b`; C=LSB

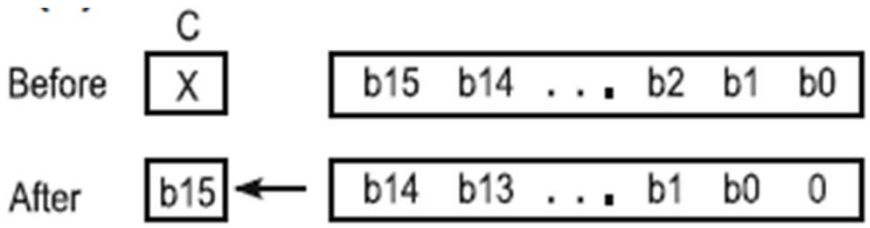
Ex. If the initial content of R5 is 8EF5H and C=0. What will the content of R5 and the new Carry value be after the following codes individually?

`rrc.w` R5; R5= 477AH, C=1

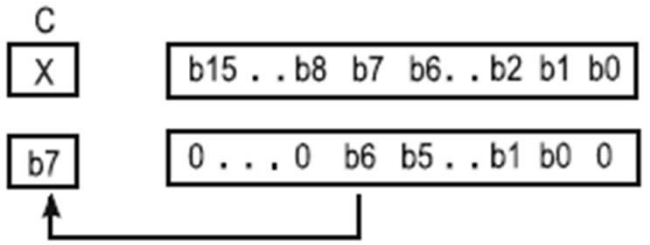
`rrc.b` R5; R5= 007AH, C=1

Roll Left Arithmetically

`rla(.B or .W) dst;` Shift all bits to the left



`rla.w`; C=b15



`rla.b`; C=b7

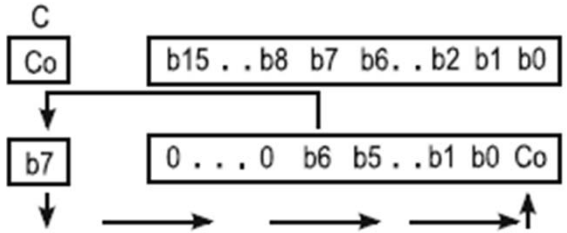
Ex. If the initial content of R5 is 8EF5H. What will the content of R5 and the new values of C, Z, N and V bits be after the following codes individually?

`rla.w` R5; R5= 1DEAH, C=1,Z=0,N=0,V=1 **`rla.b`** R5; R5= 00EAH, C=1,Z=0, N=1,V=0

Rotate Left through Carry

`rlc(.B or .W) dst;` Shift all bits to the left

`rlc.w`; C=b15



`rlc.b`; C=b7

Ex. If the initial content of R5 is 8EF5H and C=0. What will the content of R5 and the new values of C be after the following codes individually?

`rlc.w` R5; R5= 1DEAH, C=1

`rlc.b` R5; R5= 00EAH, C=1

Program Flow Instructions, Unconditional Jump

Unconditional jumps are realized with the jump instruction **`jmp label`**.

- When the program flow sees the **`jmp label`** instruction. Program flow will continue from the point the label indicates.
- Text for the label may be anything in English characters such as abc, xyz, etc**.**

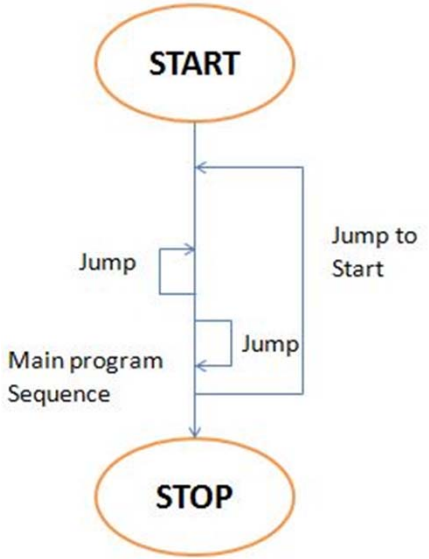


Figure. Unconditional jump

Conditional Jump

Conditional jumps are realized with different types of the jump instructions such as

`jz label`, `jnz label`, `jc label`, `jnc label`, `jl label`,

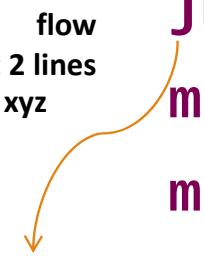
`jge label` and `jn label`.

- When the program flow sees the “jump” instruction and also the specific condition is satisfied, program flow will continue from the point the label indicates otherwise program will continue.
- Text for the label may be anything in English characters such as abc, xyz, etc.

Unconditional Jump

JMP dst; Program flow jumps to destination label without any condition.

```
Ex.   mov.w #0x1234, r5; load R5 with 1234H
      mov.w #0x5678, r6; load R6 with 5678H
      jmp xyz; jump to label xyz
      mov.w #0xEEEE, r7; skip this line
      mov.w #0x2222, r8; skip this line
xyz   mov.w #0x9999, r9 ; load R9 with 9999H
      mov.w #0xABCD, r10 ; load R10 with ABCDH
```



Unconditional Jump

Jumping procedure may also be nested…

```
Ex.   mov.w #0x1234, r5; load R5 with 1234H
      mov.w #0x5678, r6; load R6 with 5678H
      jmp xyz; jump to label xyz
      mov.w #0xEEEE, r7; skip this line
      mov.w #0x2222, r8; skip this line
xyz   mov.w #0x9999, r9 ; load R9 with 9999H
      mov.w #0xABCD, r10 ; load R10 with ABCDH
      jmp abc; jump to label abc
      mov.w #0xABCD, r3 ; skip this line
abc   mov.w #0x3333, r14; load R14 with 3333H
```

Unconditional Jump

Jumping direction can also be backward…

```
Ex.   mov.w #0x1234, r5 ;load R5 with 1234H
      mov.w #0x5678, r6 ;load R6 with 5678H
      jmp abc ;jump to label abc
      mov.w #0xEEEE, r7 ;skip this line
      mov.w #0x2222, r8 ;skip this line
 xyz  mov.w #0x9999, r9 ;load R9 with 9999H, skipped at first jump
      mov.w #0xABCD, r10 ;load R10 with ABCDH, skipped at first jump
      mov.w #0xABCD, r3 ;load R3 with ABCDH, skipped at first jump
 abc  mov.w #0x3333, r14 ;load R14 with 3333H
      jmp xyz ;jump to label xyz
```

Conditional Jump

JZ dst, JEQ dst; Jumps to destination label if Z=1.

```
Ex.    mov.w #0x1234, r5 ;load R5 with 1234H
       mov.w #0x1234, r6 ;load R6 with 1234H
       sub.w r6,r5 ;subtract R6 from R5, save to R5
       jz zero ;Z=1, jump to label zero
       mov.w #0xEEEE, r7 ;skip this line
       mov.w #0x2222, r8 ;skip this line
zero   mov.w  #0x1111, r9 ;load R9 with 1111H
       add.w #0x2222, r9 ;add 2222H to R9 and save in R9
```

Conditional Jump

JNZ dst, JNE dst; Jumps to destination label if Z=0.

```
Ex.     mov.w #0x1234, r5 ;load R5 with 1234H
        mov.w #0x4567, r6 ;load R6 with 4567H
        sub.w r5, r6 ;subtract R5 from R6, save to R6
        jnz nzero ;Z=0, jump to label nzero
        mov.w #0xEEEE, r7 ;skip this line
        mov.w #0x2222, r8 ;skip this line
nzero   mov.w #0x1111, r9 ;load R9 with 1111H
        xor.w #0x2222, r9 ;XOR 2222H with R9 and save in R9
```

Conditional Jump

JN dst; Jumps to destination label if N=1.

Ex.

```
        mov.w #0x1234, r5 ;load R5 with 1234H
        mov.w #0x4567, r6 ;load R6 with 4567H
        sub.w r6,r5 ;subtract R6 from R5, save to R5
        jn negative ;N=1, jump to label negative
        mov.w #0xEEEE, r7 ;skip this line
        mov.w #0x2222, r8 ;skip this line
negative mov.w  #0x1111, r9 ;load R9 with 1111H
        and.w #0x2222, r9 ;AND 2222H with R9 and save in R9
```

Conditional Jump

JC dst; Jumps to destination label if C=1.

```
Ex.      mov.w #0xA234, r5 ;load R5 with A234H
         mov.w #0xB567, r6 ;load R6 with B567H
         add.w r6,r5 ;add R6 to R5, save to R5
         jc carry ;C=1, jump to label carry
         mov.w #0xEEEE, r7 ;skip this line
         mov.w #0x2222, r8 ;skip this line
carry    mov.w  #0x1111, r9 ;load R9 with 1111H
         and.w #0x2222, r9 ;AND 2222H with R9 and save in R9
```

Conditional Jump

JNC dst; Jumps to destination label if C=0.

```
Ex.       mov.w #0x1234, r5 ;load R5 with 1234H
          mov.w #0x2567, r6 ;load R6 with 2567H
          add.w r6,r5 ;add R6 to R5, save to R5
          jnc ncarry ;C=0, jump to label ncarry
          mov.w #0xEEEE, r7 ;skip this line
          mov.w #0x2222, r8 ;skip this line
ncarry    mov.w  #0x1111, r9 ;load R9 with 1111H
          and.w #0x2222, r9 ;AND 2222H with R9 and save in R9
```

Conditional Jump

What if the jump condition is not satisfied…

```
Ex:         mov.w #0x1234, r5 ;load R5 with 1234H
            mov.w #0x4567, r6 ;load R6 with 4567H
            sub.w r5,r6 ;subtract R5 from R6, save to R6
            jn negative ;N=0, DO NOT jump to label negative, just continue!
            mov.w #0xEEEE, r7 ;load R7 with EEEEH
            mov.w #0x2222, r8 ;load R8 with 2222H
negative    mov.w  #0x1111, r9 ;load R9 with 1111H
            or.b #0x33, r9 ;OR 33H with R9 and save in R9
```

Conditional Jump

JL dst; Jumps to destination label if N and V bits are different.

```
Ex.  mov.w #0xABCD, r5 ;load R5 with ABCDH
     mov.w #0x9876, r6 ;load R6 with 9876H
     add.w r6,r5 ;R5=4443H, V=1, N=0
     jl bjk ;jump to label bjk
     mov.w #0xEEEE, r7 ;skip this line
     mov.w #0x2222, r8 ;skip this line
bjk  mov.w  #0xAAAA, r9 ;load R9 with AAAAH
     and.b #0x44, r9 ;AND 44H with R9 and save in R9
```

Conditional Jump

JGE dst; Jumps to destination label if N and V bits are same.

```
Ex.   mov.w #0x2345, r5 ;load R5 with ABCDH
      mov.w #0x6789, r6 ;load R6 with 6789H
      add.w r6,r5 ;V=1, N=1
      jge bjk ;jump to label bjk
      mov.w #0xEEEE, r7 ;skip this line
      mov.w #0x2222, r8 ;skip this line
bjk   mov.w  #0xAAAA, r9 ;load R9 with AAAAH
      and.b #0x44, r9 ;AND 44H with the content of R9, save to R9
```

GPIO
General Purpose Input Output

Pinout

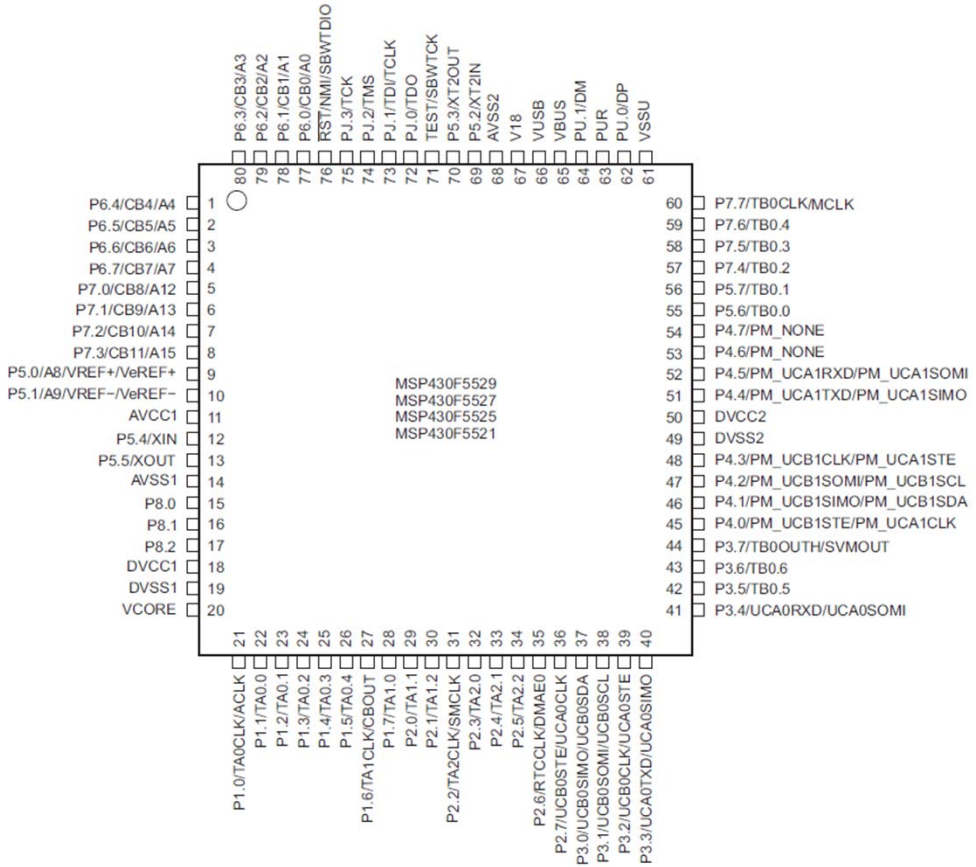


Figure. Pinout of MSP430F5529

* As can be seen from the figure, some pins of the microcontroller has multiple functions, these functions can be set through the software!
* Our MCU has totally 8 ports (P1,…P7, each port is 8-bit but P8 is 3-bit) that can be configured for different purposes.

MSP430 LaunchPad Evaluation Kit

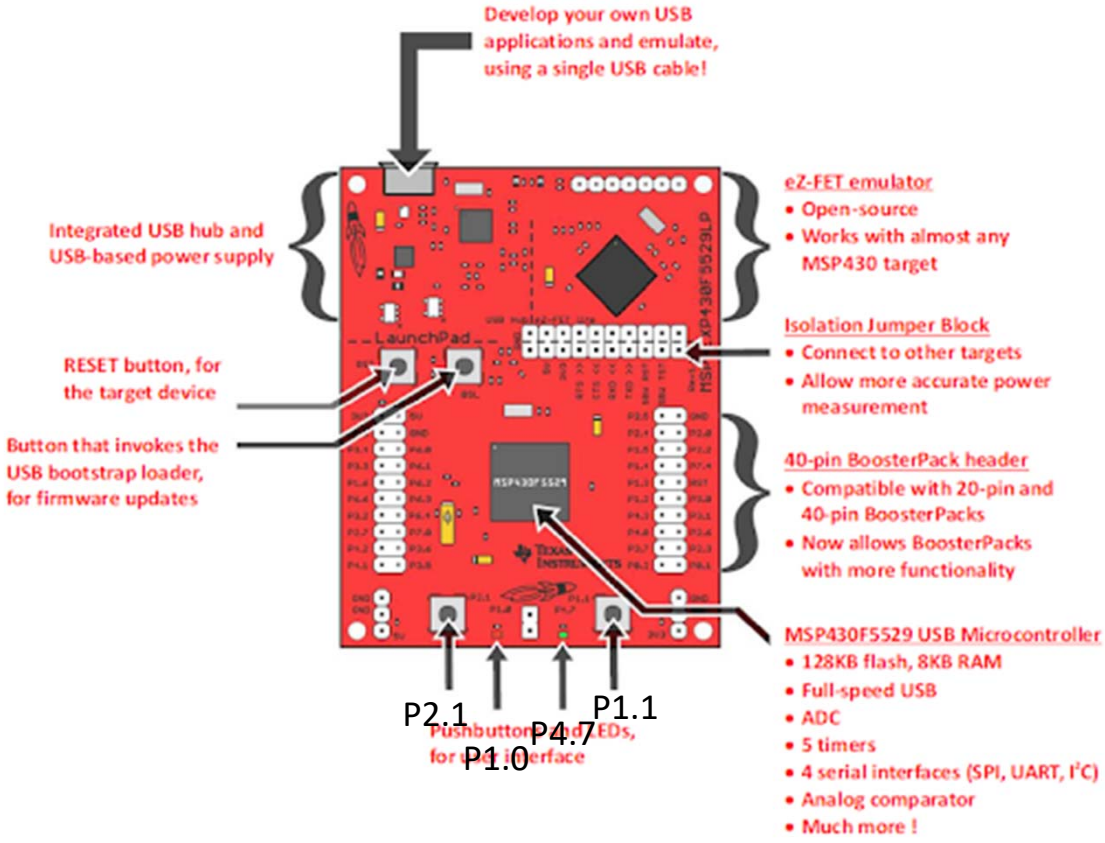
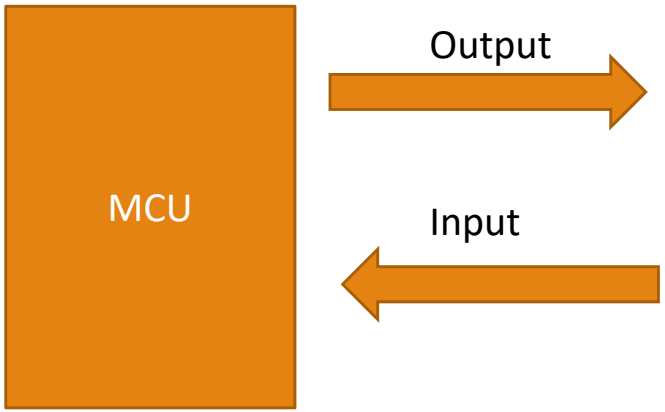


Figure. MSP430F5529 LaunchPad

Input and Output



Input refers the data transfer **TO** the microcontroller(MCU)
Output refers the data transfer **FROM** the microcontroller(MCU)

* There are special function registers that allow the Ports to be configured as input and/or output
* Moreover, while some pins of a port can be configured as inputs others can be configured as outputs.

Port Registers

Direction Registers, PxDIR

It allows the user to configure the target port as an Input and/or Output. It is 8-bit register.

'x' is the port number (from 1 to 8)

Bit = 1: The port pin is set up as an output;

Bit = 0: The port pin is set up as an input.

Ex. Write the program that configures the Port 1's all bits as output

```
mov.b #0xff, r5 ;load R5's LSB with FFH
mov.b r5, P1DIR ;PIDIR=FFH
```

** Therefore, all pins of Port 1 are outputs

(P1.0, P1.1, P1.2, P1.3, P1.4, P1.5, P1.6, P1.7)

While the number before '.' shows port number, the one after '.' shows bit(pin) number.

Port Registers

Output Registers, PxOUT

It allows the user to send the desired data to the output port. Its width is 8-bit.

'x' is the port number (from 1 to 8)

Ex. Write the program that turns on the LED on P4.7

```
mov.b #0x80, r5 ;load R5's LSB with 80H (10000000)
mov.b r5, P4DIR ;P4DIR=80H, Only P4.7 is output, others are inputs
mov.b #0x80, P4OUT ;Turn ON P4.7, 10000000.
```

Port Registers

Output Registers, PxOUT

Ex. Write the program that toggles (ON and OFF) the P1.0 continuously.

```
     mov.b #0x01, r5 ;load R5's LSB with 01H
     mov.b r5, P1DIR ;P1DIR=01H, Only P1.0 is output, others are inputs
OFF  mov.b #0x00, P1OUT ;Turn OFF P1.0
     mov.b #0x01, P1OUT ;Turn ON P1.0
     jmp OFF ;jump to label OFF
```

Port Registers

Input Registers, PxIN

It allows the user to receive the desired data from the input port. Its width is 8-bit.

'x' is the port number (from 1 to 8)

It is read-only register, which means data inside the registers can be read but not written.

PxIN configuration:

Bit = 1: The input is high;

Bit = 0: The input is low;

Port Registers

Ex. Run the following program and discuss about the sense.

```
        mov.b #0xFF, P1DIR ;Entire Port1 is output
        mov.b #0xFF, P4DIR ;Entire Port4 is output
        mov.b #0x00, P4OUT ;Clear Port4, recommended to clear at start
        mov.b #0x00, P1OUT ;Clear Port1
        mov.b #0x00, P2DIR ;Entire Port2 is input
        mov.b P2IN, r9
        cmp  #0xFD, r9
        jz zero
        mov.b #0xFF, P4OUT
        jmp Done
zero    mov.b #0xFF, P1OUT
Done
```

MSP430F5529 LaunchPad has logic 1 at its input pins (P2.1, P1.0, P4.7 and P1.1) as default.

Therefore, if no button pressed at P2, the data that is read in P2IN is **FFH.**

If the button at P2.1 is pressed (logic 0), the data that is read in P2IN is **FDH**

Program flow is controlled by the state of the button at P2.1 on the board

Port Registers

Port Function Select Registers (PxSEL1 and PxSEL0)

We use the Port Function Select (PxSEL) registers to tell the MCU which function to use, including whether to make the signal pin a digital input/output. The MSP430F5529 has more than two functions assigned to most of its pins, so it requires two bits to control the function selection.

PxSEL1	PxSEL0	Function
0	0	Digital I/O (Default)
0	1	Primary Function
1	0	Reserved
1	1	Secondary Function

Since PxSEL registers have 0 default value, we don't have to configure them for GPIO applications.