

# Microcontroller Interrupts

4/16/2007

BAE 5413

# Interrupt functions

- Interrupt – Function provided in most micro-controllers to allow an “external” event to cause a branch in program execution
- Events associated to interrupts
  - External port lines
    - Level and edge triggered
  - Peripherals
    - Serial I/O
      - Asynchronous
      - I<sup>2</sup>C, SPI
    - Timers time-out
    - A/D end of conversion
  - Software instruction
- Typical structural elements of interrupt functions
  - Control or indication functions
    - Specific interrupt enable function (bits/flags)
    - Global interrupt enable function (bits/flags)
    - Interrupt source indication (bits/flags)
  - Triggering mechanisms (level change or edge)

# Interrupt functions

- Typical structural elements of interrupt functions – continued –
  - Automatic clearing of source flags
  - Prioritization
    - May have one to many levels
    - Same level interrupts do not pre-empt, higher level pre-empts
- Latency in servicing interrupts
  - Critical factor in task overhead
  - Composed of
    - Time to complete current instruction
    - Time to save current context
- RISC strategy
  - Single interrupt
  - Processor must poll to determine interrupt source.
    - Hardware may be added to provide sources (PIC) or sources may be available in internal source related registers
- Low power strategy
  - Allow the processor to sleep and wakeup only to process interrupts

## Interrupts / Watchdog

```
#include <msp430x20x3.h>

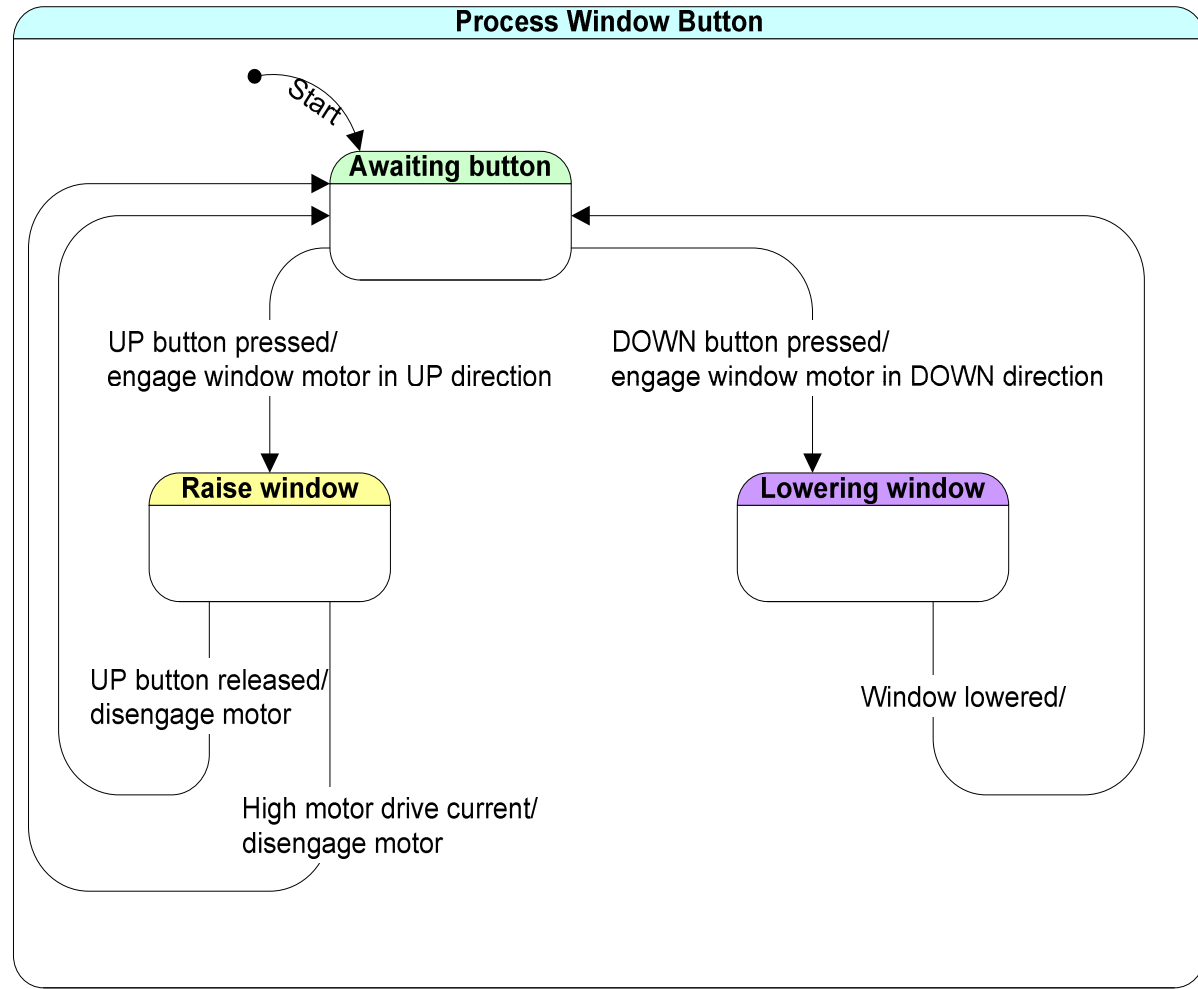
void main(void)
{
    WDTCTL = WDTPW + WDTHOLD;           // Stop watchdog timer
    P1DIR |= 0x01;                      // Set P1.0 to output direction
    SD16CTL = SD16REFON + SD16SSEL_1;   // 1.2V ref, SMCLK
    SD16INCTL0 = SD16INCH_1;           // A1+/-
    SD16CCTL0 = SD16UNI + SD16IE;      // 256OSR, unipolar, interrupt enable
    SD16AE = SD16AE2;                  // P1.1 A1+, A1- = VSS
    SD16CCTL0 |= SD16SC;                // Set bit to start conversion

    _BIS_SR(LPM0_bits + GIE);          // Enable interrupts and then sleep
}
```

```
// A to D interrupt service routine
#pragma vector = SD16_VECTOR
__interrupt void SD16ISR(void)
{
    if (SD16MEM0 < 0x7FFF)              // SD16MEM0 > 0.3V?, clears IFG
        P1OUT &= ~0x01;
    else
        P1OUT |= 0x01;
}
```

# Statechart Interrupt Example

- Interrupt may be generated by button event



# TI MSP430F20xx Demo – P1.4 Interrupt

- How it looks in code

```
#include <msp430x20x3.h>

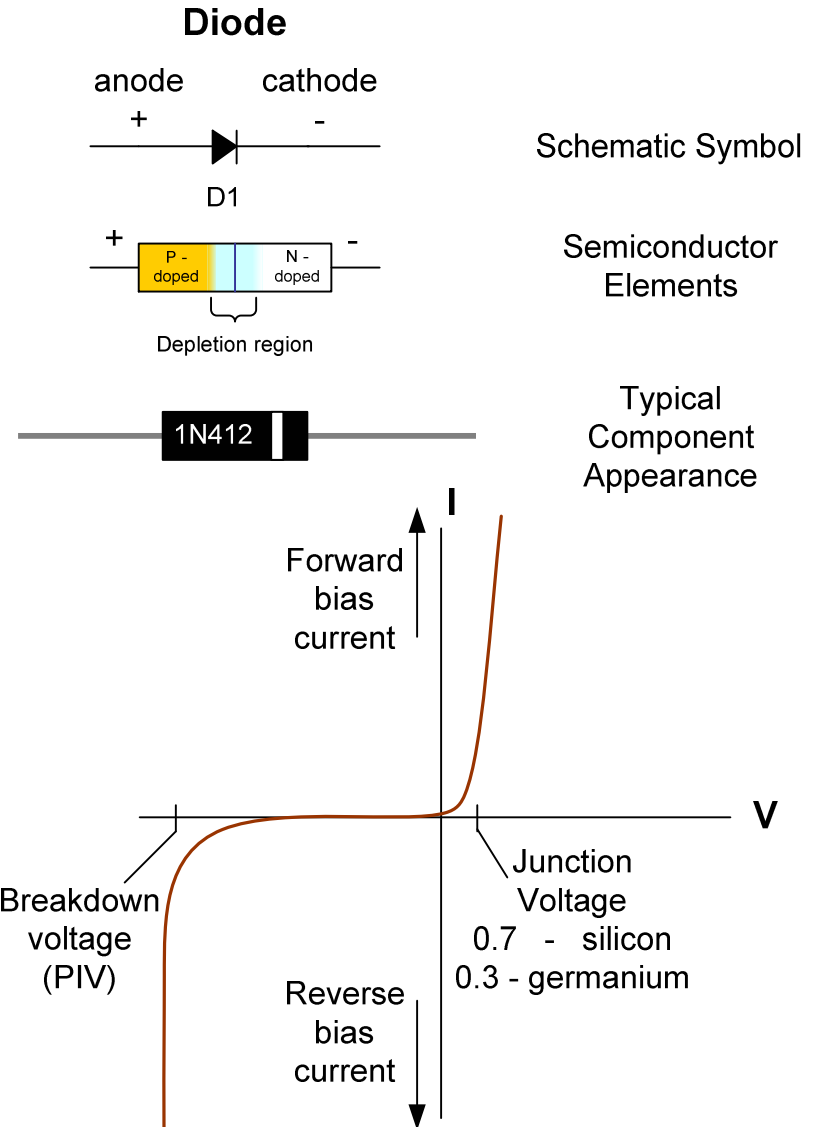
void main(void)
{
    WDTCTL = WDTPW + WDTHOLD;           // Stop watchdog timer
    P1DIR = 0x01;                       // P1.0 output, else input
    P1OUT = 0x10;                       // P1.4 set, else reset
    P1REN |= 0x10;                      // P1.4 pullup
    P1IE |= 0x10;                       // P1.4 interrupt enabled
    P1IES |= 0x10;                      // P1.4 Hi/lo edge
    P1IFG &= ~0x10;                    // P1.4 IFG cleared

    __BIS_SR(LPM4_bits + GIE);         // Enter LPM4 w/interrupt
}

// Port 1 interrupt service routine
#pragma vector=PORT1_VECTOR
__interrupt void Port_1(void)
{
    P1OUT ^= 0x01;                     // P1.0 = toggle
    P1IFG &= ~0x10;                   // P1.4 Interrupt Flag cleared
}
```

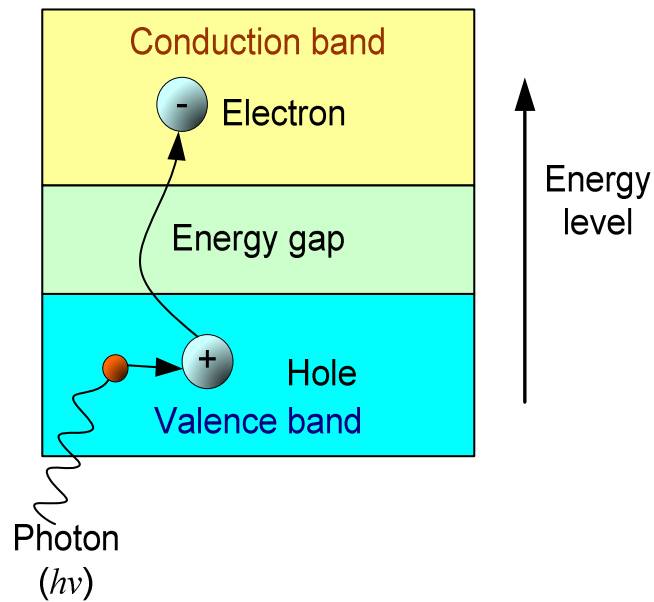
# Diode devices

- Check valve behavior
  - Diffusion at the PN junction of P into N and N into P causes a depleted non-conductive region
  - Depletion is enhanced by reverse bias
  - Depletion is broken down by forward bias
- When forward biased
  - High current flow junction voltage
- When reverse biased
  - Very low current flow unless above peak inverse voltage (PIV) (damaging to rectifying diodes, OK for zeners)

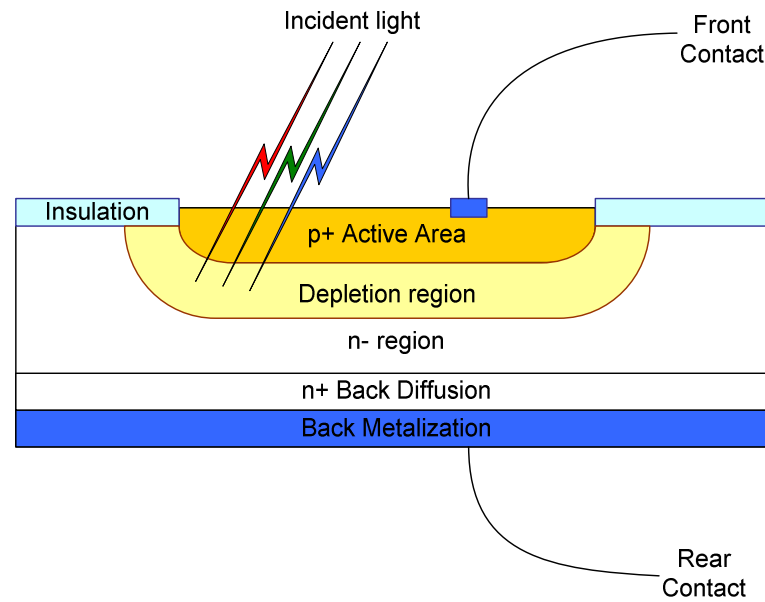


## Quantum devices (photodiode)

- Absorption of a photon of sufficient energy elevates an electron into the conduction band and leaves a hole in the valence band.
- Conductivity of semi-conductor is increased.
- Current flow in the semi-conductor is induced.

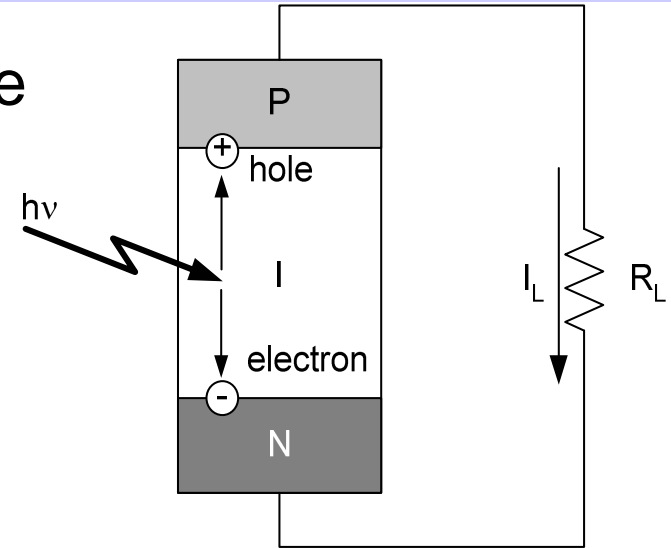


# Photodiode structure



## Photodiode fundamentals

- Based on PN or PIN junction diode
  - photon absorption in the depletion region induces current flow



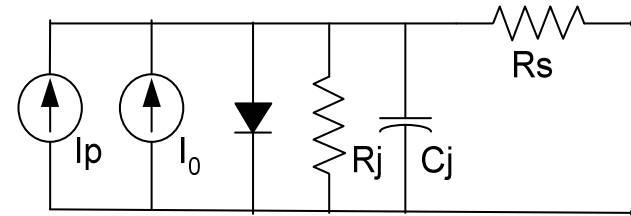
- Spectral sensitivity

Material	Band gap (eV)	Spectral sensitivity
silicon (Si)	1.12	250 to 1100 nm
indium arsenide (InGaAs)	~0.35	1000 to 2200 nm
Germanium (Ge)	.67	900 to 1600 nm

# Photodiode characteristics

- Circuit model

- $I_0$  Dark current (thermal)
- $I_p$  Photon flux related current



- Noise characterization

- Shot noise (signal current related)

- $q = 1.602 \times 10^{-19}$  coulombs
- $I$  = bias (or signal) current (A)
- $i_s$  = noise current (A rms)

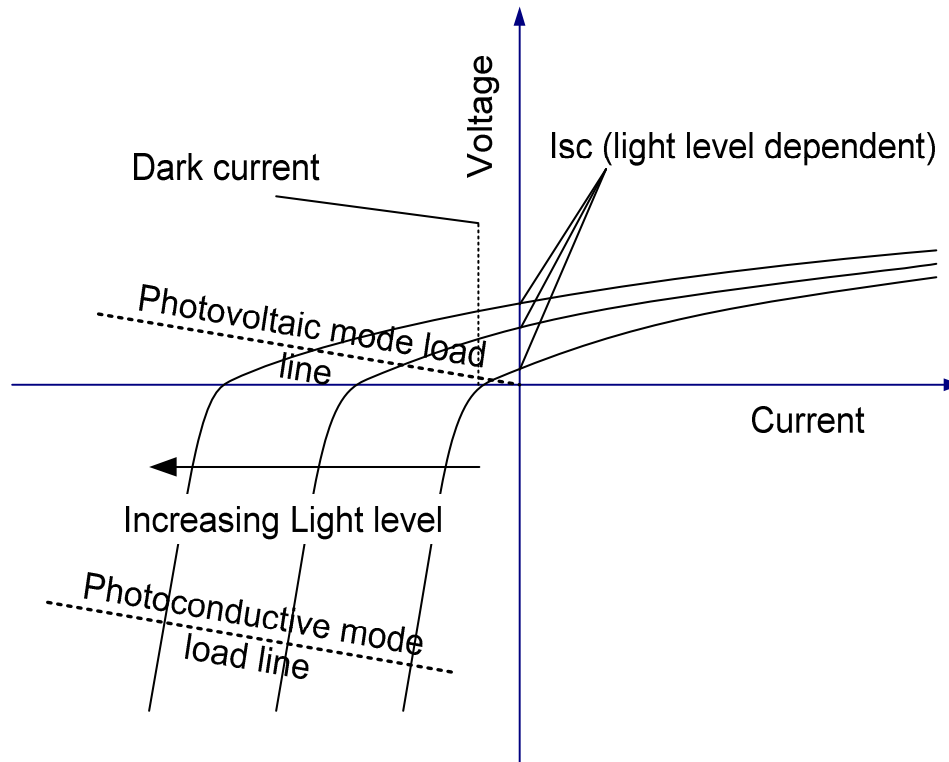
$$i_s = \sqrt{2qi}$$

- Johnson noise (Temperature related)

- $k$  = Boltzman's constant =  $1.38 \times 10^{-23}$  J/K
- $T$  = temperature (°K)
- $B$  = noise bandwidth (Hz)
- $R$  = feedback resistor (W)
- $e_{OUT}$  = noise voltage (Vrms)

$$e_{out} = \sqrt{4kTBR}$$

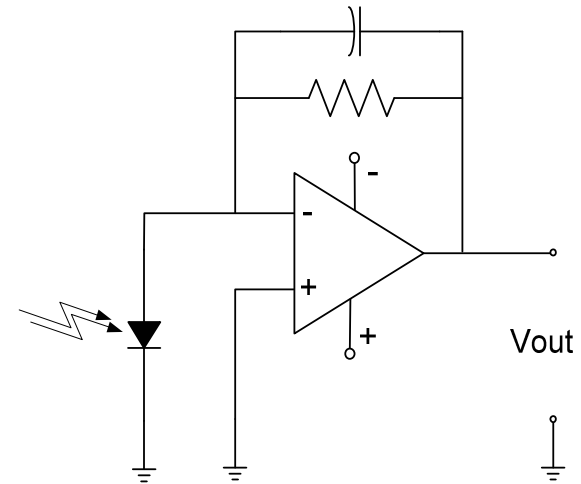
# Photodiode current/voltage characteristics



## Diode operating modes

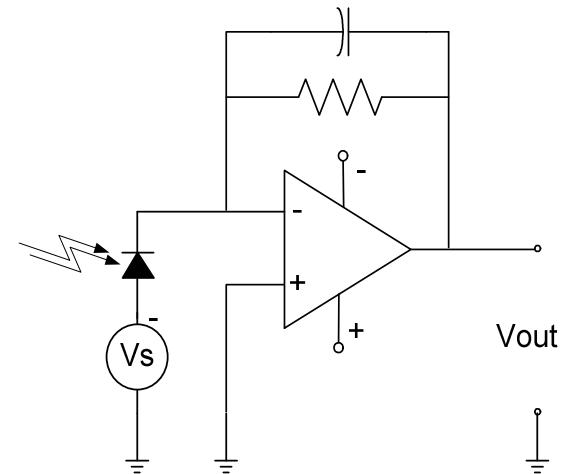
- Photovoltaic mode

- Photodiode has no bias voltage
- Lower noise
- Lower bandwidth
- Logarithmic output with light intensity



- Photoconductive mode

- Higher bandwidth
- Higher noise
- Linear output with light intensity



# ez430 Target Circuit

