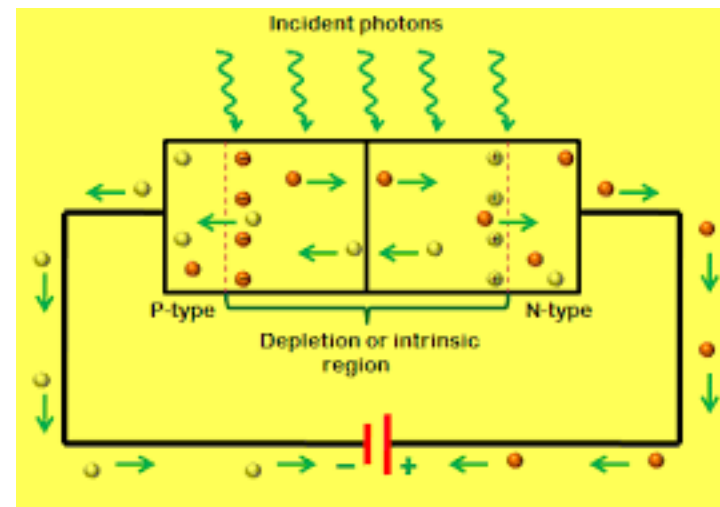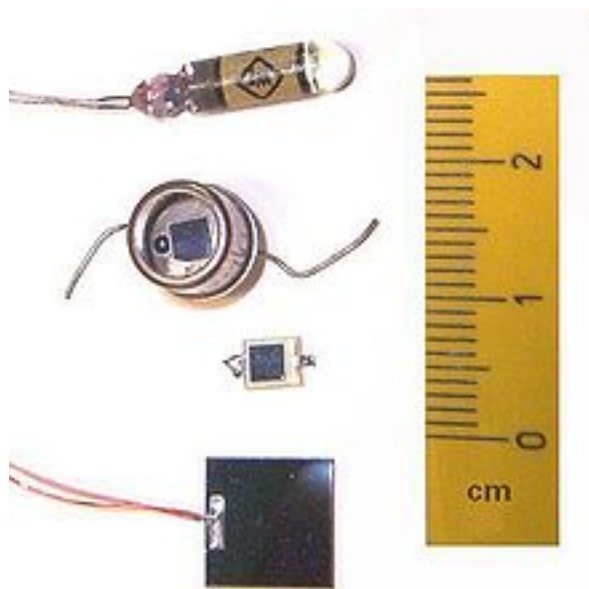# Electromechanical Systems
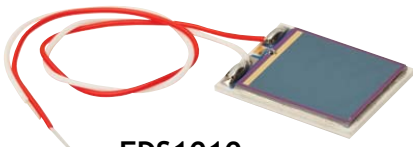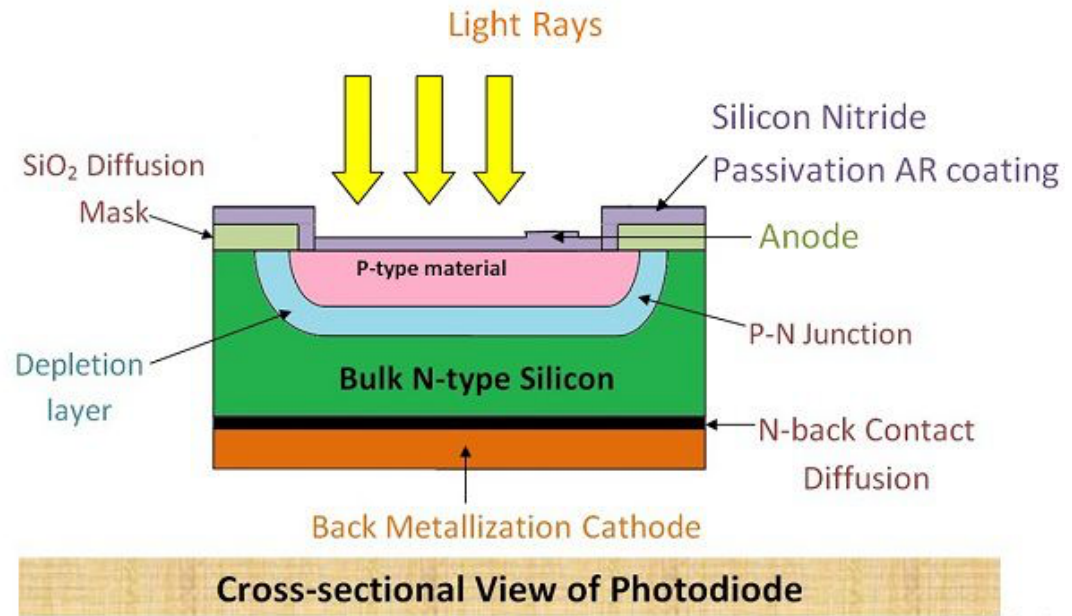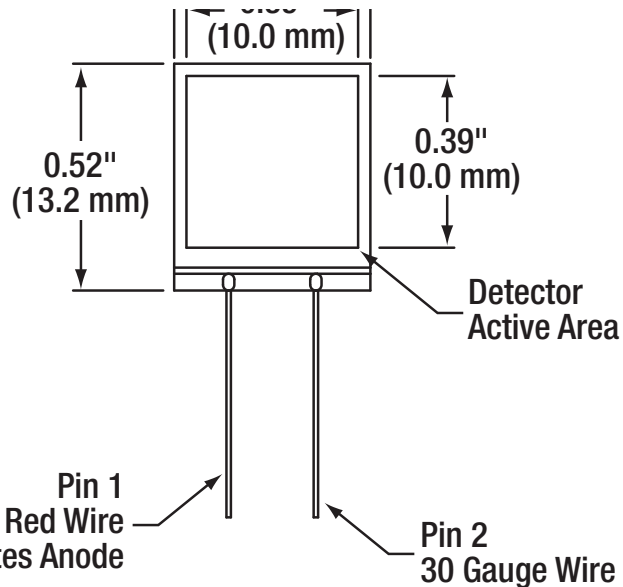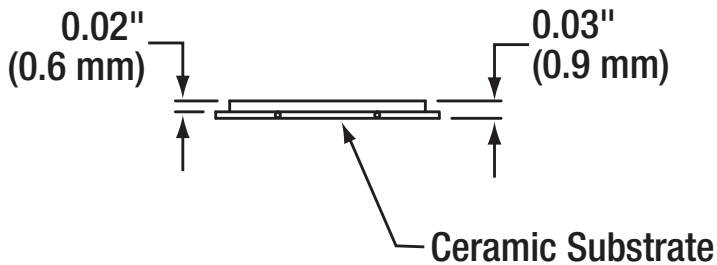# ASE 375

## Triggered Data Acquisition

# Photodiodes



- Photodiodes are semiconductor light sensors that generate a current or voltage when the P-N junction in the semiconductor is illuminated by light
- When a photon of sufficient energy strikes the diode, it creates an electron-hole pair. This mechanism is also known as the inner photoelectric effect.
- If the absorption occurs in the junction's depletion region, or one diffusion length away from it, these carriers are swept from the junction by the built-in electric field of the depletion region.
- Thus holes move toward the anode, and electrons toward the cathode, and a photocurrent is produced.
- The common, traditional solar cell used to generate electric solar power is a large area photodiode.
- Properties of photodiodes
  - Excellent linearity with respect to incident light
  - Low noise
  - Wide spectral response
  - Mechanically rugged
  - Compact and lightweight
  - Long life

# ThorLabs Si PhotoDiode FDS1010

FDS1010

0.02" (0.6 mm)    0.03" (0.9 mm)

Ceramic Substrate

(10.0 mm)

0.52" (13.2 mm)    0.39" (10.0 mm)

Detector Active Area

Pin 1 Red Wire Denotes Anode

Pin 2 30 Gauge Wire (2X)

Light Rays

SiO₂ Diffusion Mask

Silicon Nitride Passivation AR coating

P-type material    Anode

Depletion layer    P-N Junction

Bulk N-type Silicon

N-back Contact Diffusion

Back Metallization Cathode

**Cross-sectional View of Photodiode**

Electronics Coach

- The Thorlabs FDS1010 photodiode converts the optical power to an electrical current.
- The detector is on an un-housed ceramic wafer with an anode and cathode lead wires.
- The photodiode anode produces a current, which is a function of the incident light power and the wavelength.
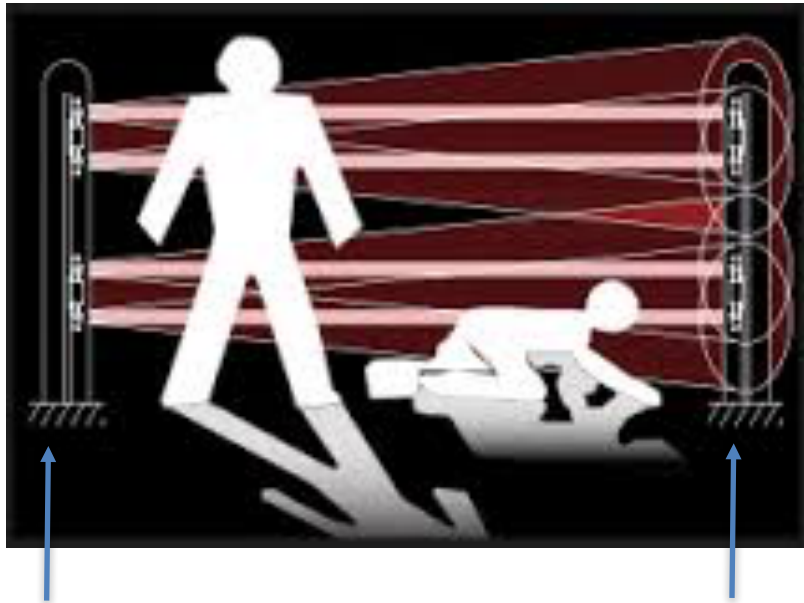
https://electronicscoach.com/photodiode.html

# Spectral Response



**Spectral Response**
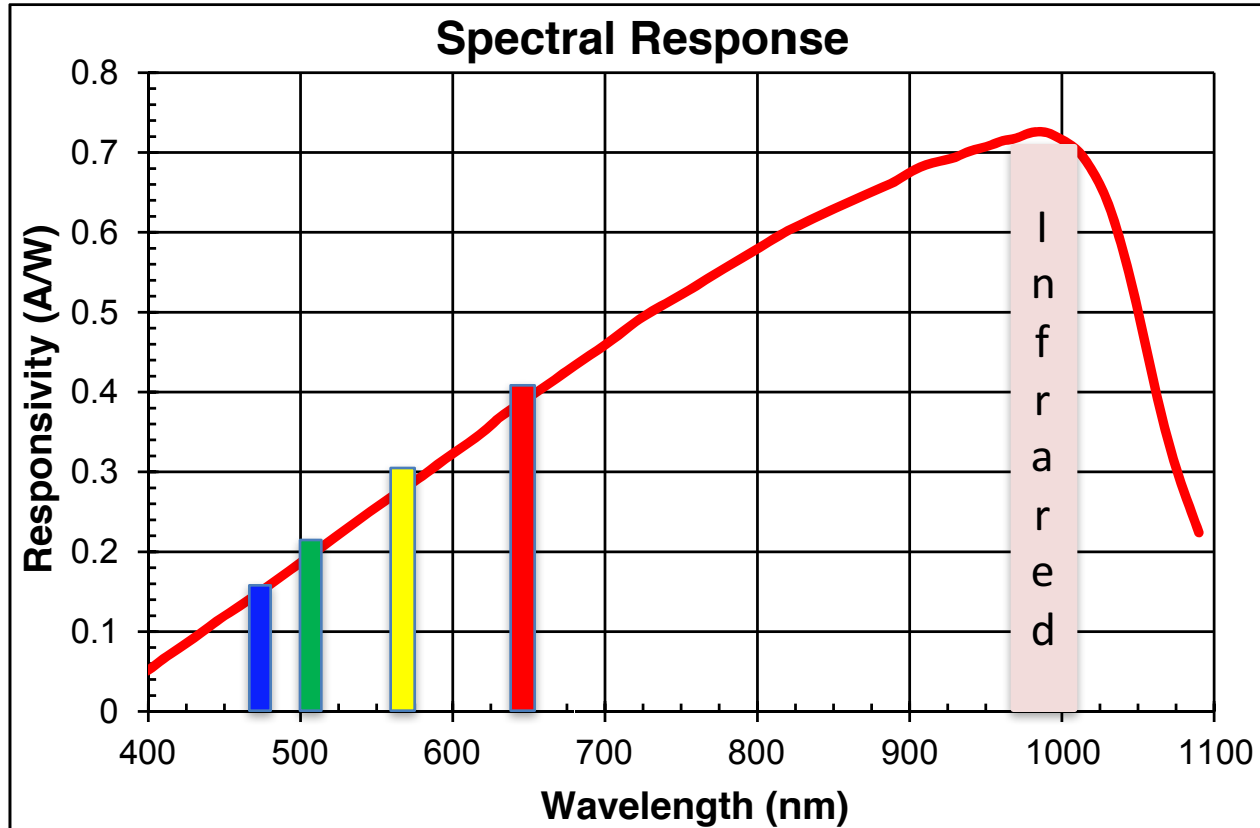
- The responsivity of a photodiode is a measure of its sensitivity to light and is defined as the ratio of the photo-current $I_P$ to the incident light power P at a given wavelength

$$R_\lambda = \frac{I_P}{P}$$

# Photoelectric Beam Detectors

- Security systems
- Automatic light, HVAC systems
- Triggers for experiments involving motion

Incident infra-red beam          Photodetector

- When the beam is not interrupted the photodetector circuit reads a high voltage
- As soon as the beam is interrupted the photodetector circuit voltage drops
- This falling voltage edge is called a trigger

High

Low

Voltage output

Time

Beam interruption event
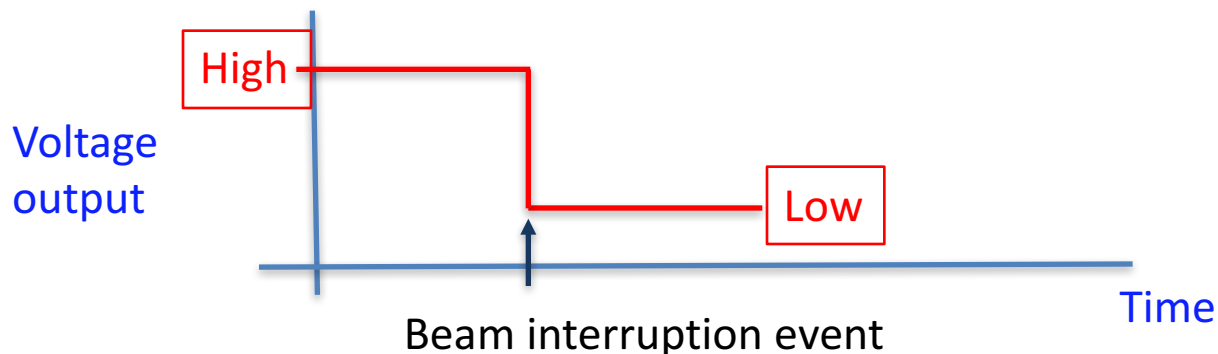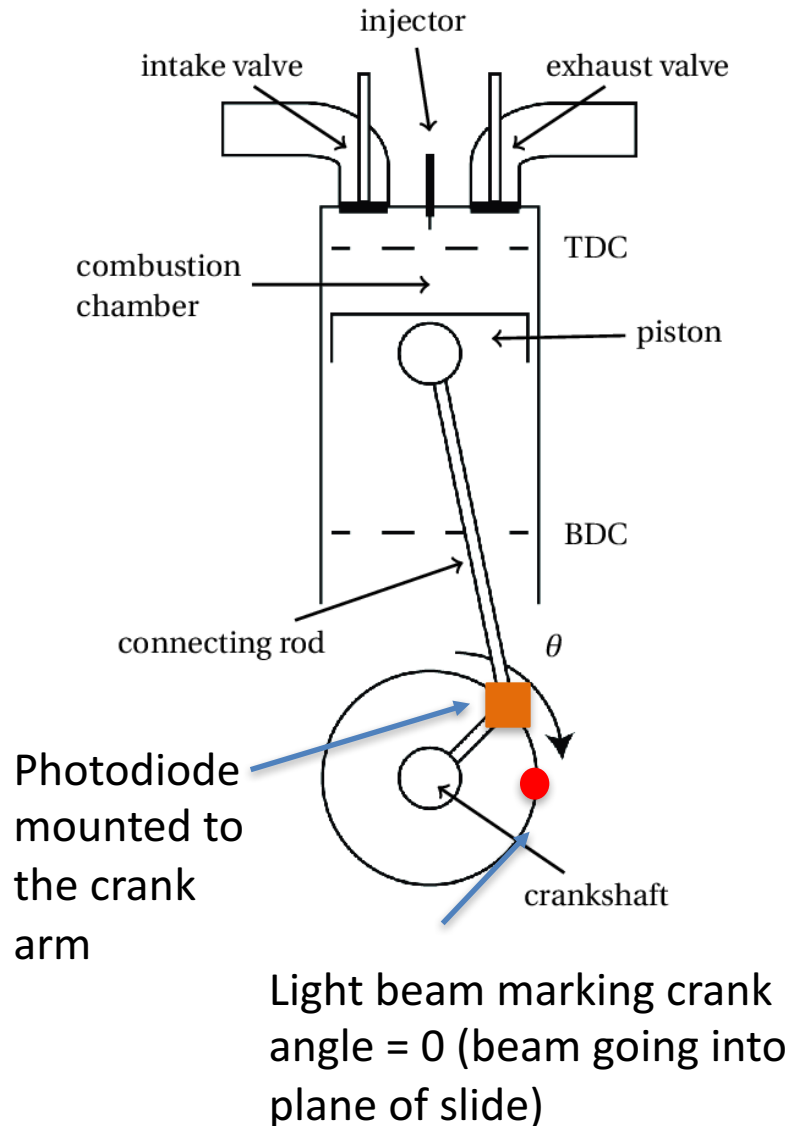
# Digital Data Acquisition System
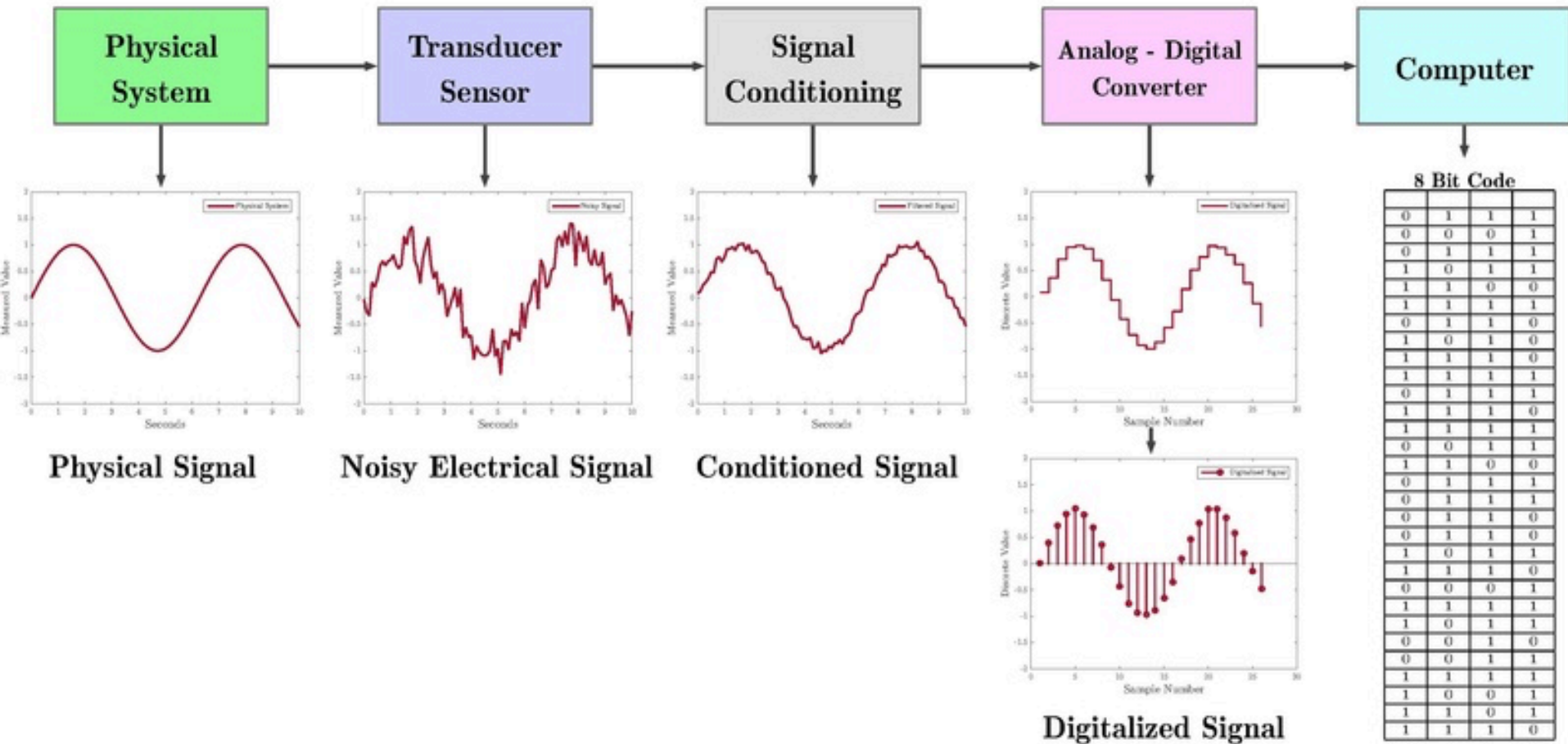


- Nowadays, all data acquisition is done digitally
- Signal conditioning can include amplification, filtering, converting, range matching, isolation etc.
- The most basic building elements are diodes, transistors and operational amplifiers

# Triggered Data Acquisition

- Synchronization of the data acquisition (DAQ) process relative to an external event is an important criterion in many DAQ applications.
- In such instances, the DAQ system has to be set up to start or stop the analog-to-digital (A/D) conversions as soon as the external event, or trigger, occurs.
  - Ex. Collect data when the temperature of a chamber exceeds a critical value. The temperature measuring device produces the trigger
  - When periodic signals are being acquired, a trigger is used to mark the cycle starting point, which can then be used to get cycle-averaged data

# Example: Measuring pressure in an IC Engine



injector

intake valve

exhaust valve

combustion chamber

TDC

piston

BDC

connecting rod

$\theta$

Photodiode mounted to the crank arm

crankshaft

Light beam marking crank angle = 0 (beam going into plane of slide)

- A photodiode is mounted to the crank arm
- A beam of light marks where the crank angle is 0 degrees.
- Everytime the diode passes through 0 degrees, it registers the light and outputs a voltage (like Slide 5)
- This marks each cycle in the data, when the acquisition is triggered using this signal.

# Timing Requirements for Data Acquisition

- Data acquisition of unsteady signals requires a timing device (clock) that sets and records the time of each acquired data point.

- Usually, these are clocks within the chip, using some type of an electronic oscillator

- Like any timing system, data acquisition clocks are characterized their resolution and accuracy.

- Timing resolution is defined as the smallest time interval that you can accurately measure.

- The timing accuracy is affected by clock *jitter*. Jitter arises when a clock produces slightly different values for a given time interval.

# Pre-triggering vs Post-triggering

- Post-triggered Acquisition – In a post-triggered acquisition, the hardware starts the A/D conversions after the trigger is received

- Pre-triggered Acquisition – In a pre-triggered acquisition, the hardware starts acquiring data before the trigger signal is received

  – With this type of acquisition, the user can view the signal before the trigger event.

  – The trigger signal in this case is referred to as the "stop trigger."
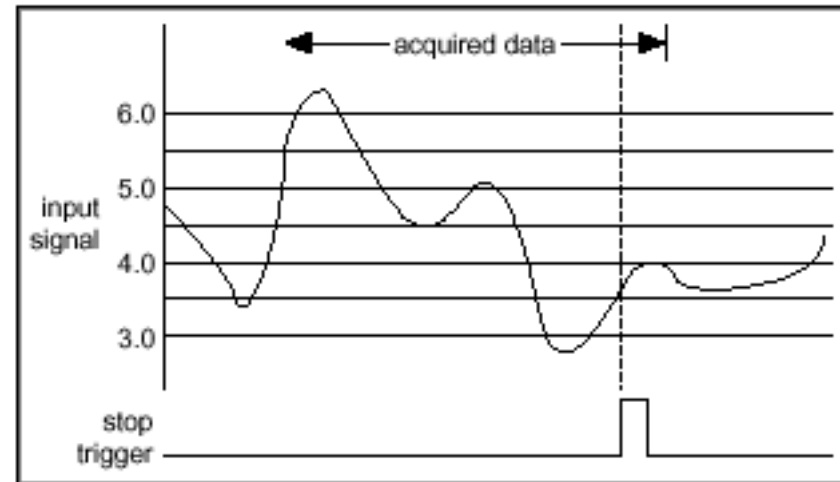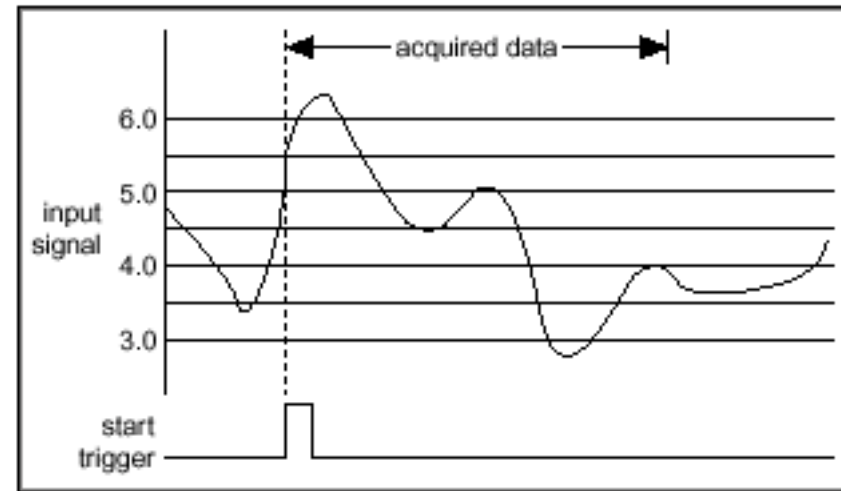
# Analog vs Digital Trigger

- Analog Trigger- The level and slope of an analog signal triggers the acquisition

- In such a system, analog trigger circuitry (ATC) on the DAQ hardware continuously monitors the analog signal to determine if it satisfies the trigger conditions.
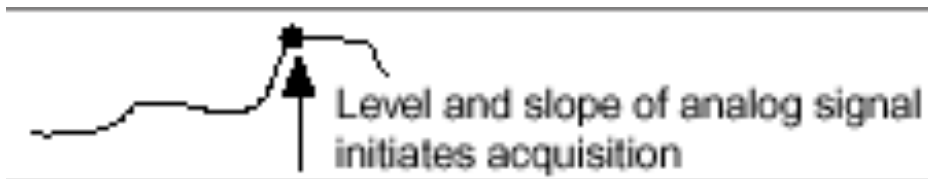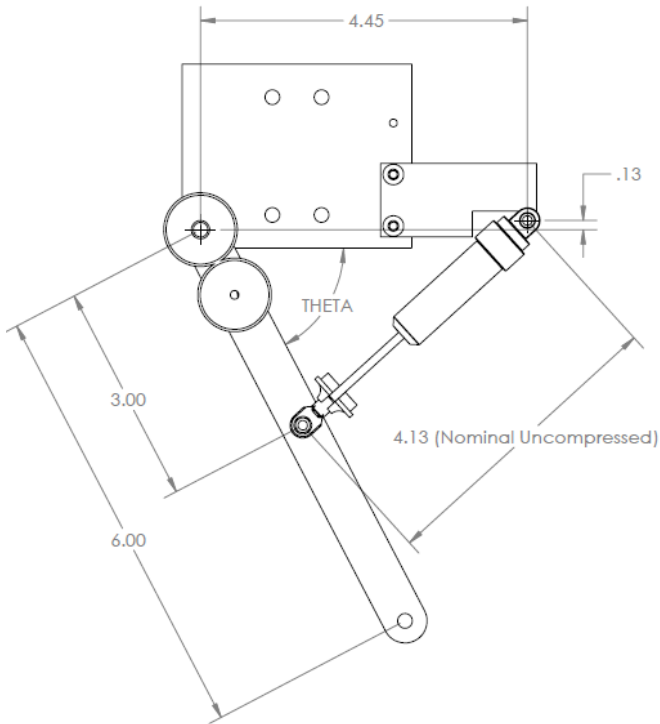
- Digital Trigger – The rising or falling edge of a TTL signal initiates the data acquisition.

- TTL stands for Transistor-Transistor Logic

TTL Signal ——▶ Trigger input of board

Edge initiates acquisition

Level and slope of analog signal initiates acquisition

Triggerevent        Triggerevent
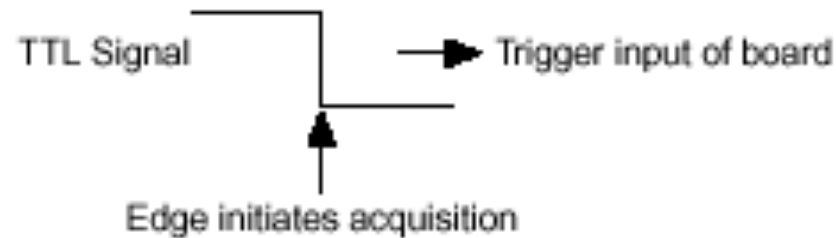
# Lab 8

In this lab you will measure the acceleration and stroke of a landing gear undergoing a vertical drop. The goal is to learn how to make triggered, time-resolved measurements.

1. Drop the landing gear from several heights (at least three) and record the transient acceleration as well as stroke. You will have to choose an appropriate accelerometer and sampling frequency to properly trigger the data acquisition and capture the transient.

2. Plot the transient acceleration and landing gear stroke for each test. Discuss the results (in terms of transient force and total energy disspation) and the sources of error.
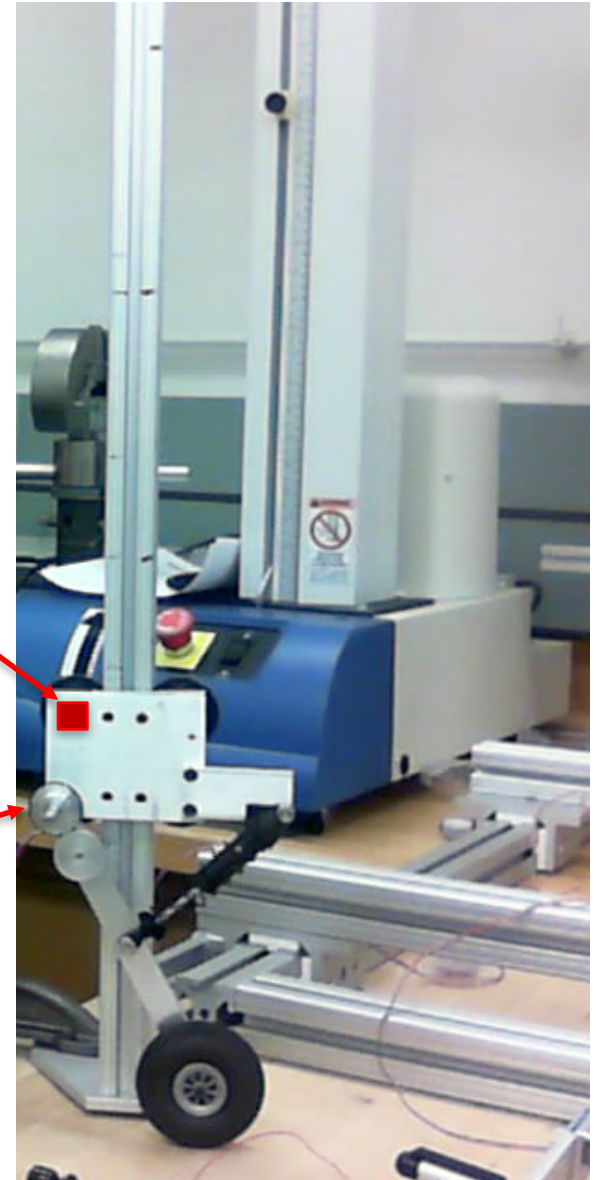


Data collection will be triggered by breaking a light beam, creating a falling edge trigger