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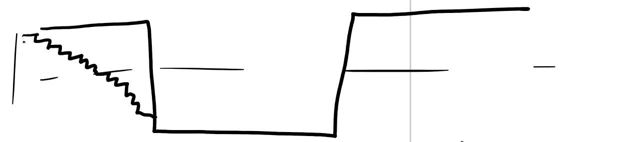


Overview of Sensors

physic

A sensor is a device that converts a physical phenomena into a signal that can be measured or processed. voltage.
It consists of two parts

Transducer → **Interface / Signal conditioning unit**

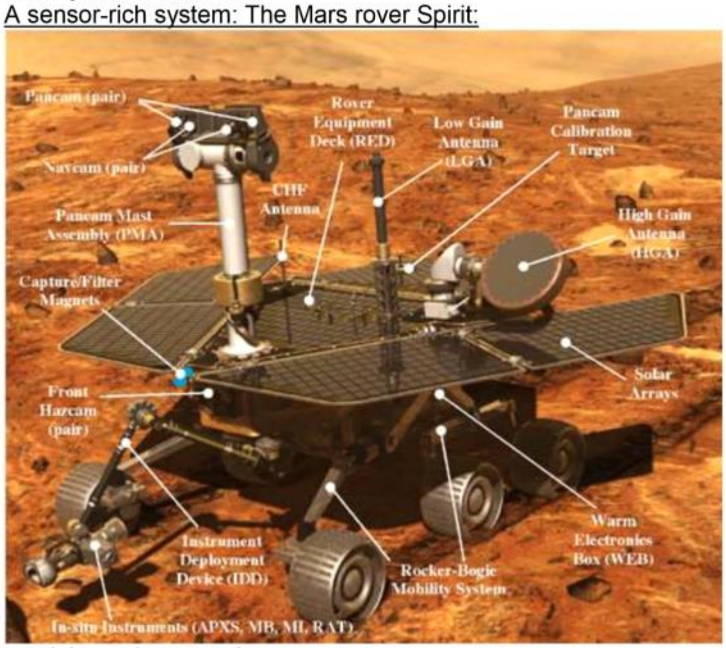
...verts energ... ...ther (e.g., pressure to

Signal Conditioning Unit: Amplify, filter, “condition” signal into a meaningful and easily interfaced source

Note: Research in developing new sensors is enormous. The dollar amount spent on new sensors each year is very large. This drives many fields such as MEMS, etc. At this point however we are interested in using COTS (commercial off-the-shelf) sensors.

Examples of Sensors:

A sensor-rich system: The Mars rover Spirit:



A Minimum Sensory robot system:

1

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Considerations for Sensor Performance

1) Range or span
2) Error / Accuracy / Resolution
3) Hysteresis
4) Nonlinearity
5) Repeatibility
6) Stability / drift
7) Bandwidth, speed
8) Cost
9) Reliability
10) Ease of application

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Categorizing Commercial Sensors
We could categorize sensors in several fashions, for ex., based on theory of operation or on type of application.

Commercial Navigation and Control Sensors

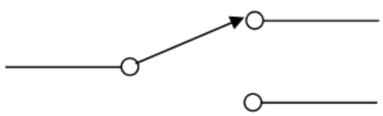
Sensor Type	Method of operation	COTS sensors of this type	Approx. cost ($)
Bump/Proximity	Contact	Momentary/toggle switch	1
Gyro (angular rate)	Inertial	Piezo RC gyro	80
Accelerometers	Inertial	Analog devices MEMES accel.	10
Compass	Magnetic	Precision Navigation Vector 2X	40
Encoder	Optical	US Digital Encoder	35
Laser Ranger	Time of flight	Leica and Sick	1-3k
Ultrasonic Ranger	TOF	Polaroid 6500 / Devantech	70 / 35
IR Ranger	PSD	Sharp GP2D12	12
Camera	CCD array + image processing	CMU Cam	125

DPDT
PMDC:

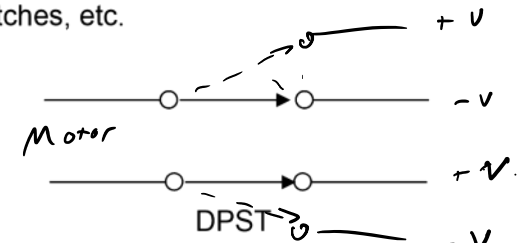
Catagorize Based on Theory of Application:
Cat. 1: Contact (proximity)
<u>C1 - 1) 2 state, Contact (mechanical)</u>

a) requires contact and small amount of force
b) can be used as proximity, limit switches, etc.
c) comes in many forms;

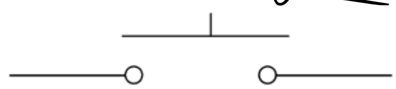
SPST



SPDT



DPST



NO Pushbutton

SPST, SPDT, DPDT, momentary, toggle, etc
DPDT Equivalent to two SPDTs with a common input
d) cheap, reliable, versatile

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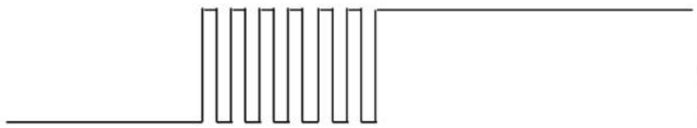
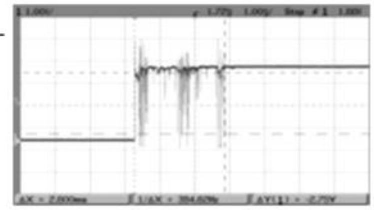
mechanical.

e) One common problem is switch “bounce” making the signal look like;



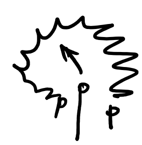


f) Another problem is low switching frequency and relatively short life.

Cat 1 - 2) Multi-state Analog (contact, Mechanical movement of an input)

Rotation (Rotary or angular) and translation (linear)

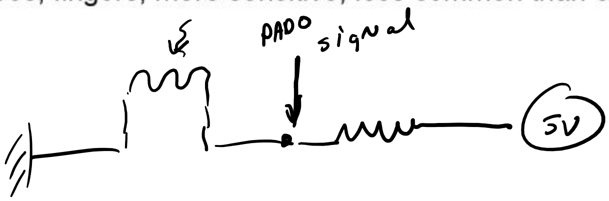
a) Vary voltage; Potentiometer



Available in many forms, cheap, absolute measurement, low to medium accuracy

Cat 1: Vary resistance:

Examples: Potentiometer, switches, resistive touchscreens – generally work with stylus, gloves, fingers, more sensitive, less common than capacitive.



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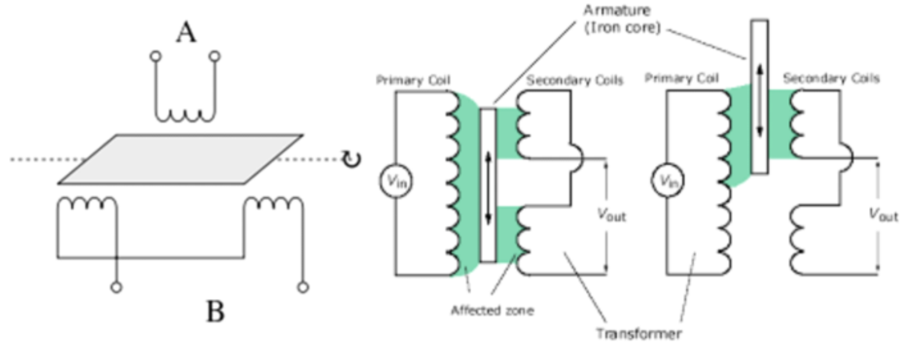
Cat 2: Vary inductance; LVDT / RVDT
(linear variable differential transformer)
Iron rod connects primary to secondary coil, its movement changes transmitted signal.

1. 

Cat 3: Vary capacitance
Capacitive sensing based on capacitive coupling, commonly uses human body capacitance as input.

Mutual capacitance (alter capacitance between two electrodes)

Self capacitance: (object causes a parasitic capacitance).

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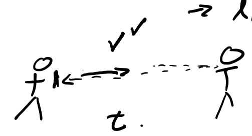
Acoustic-based → sonar
EM-based (light, RF.)
→ lidar. GPS.
radar



Cat. 2: (non contact) Time of Flight Sensors TOF
sensors used to measure distance

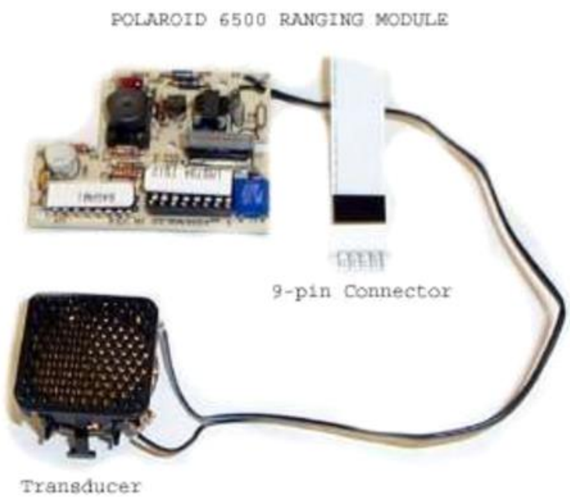
$$v = \frac{ds}{dt}$$

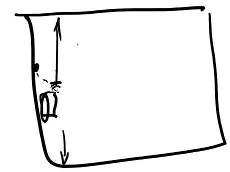
a) Acoustic-based
Examples include Polaroid, Devantech

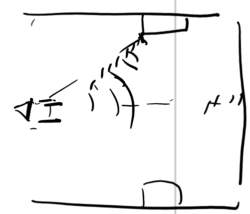
$$\int ds = \int v\,dt$$

$$s = \int v\,dt.$$

$$s = vt + c$$







30cm min.

100m.

speaker.

$V \rightarrow \epsilon$

~300m/s.

*d= t/(2*v(T,M)*
v = 343 m/s
Ultrasonics for NDE

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b) EM waves

1) Radar (RAdio Detection and Ranging) – radio waves (adds Doppler shift to measure velocity)

2) Lidar – IR waves

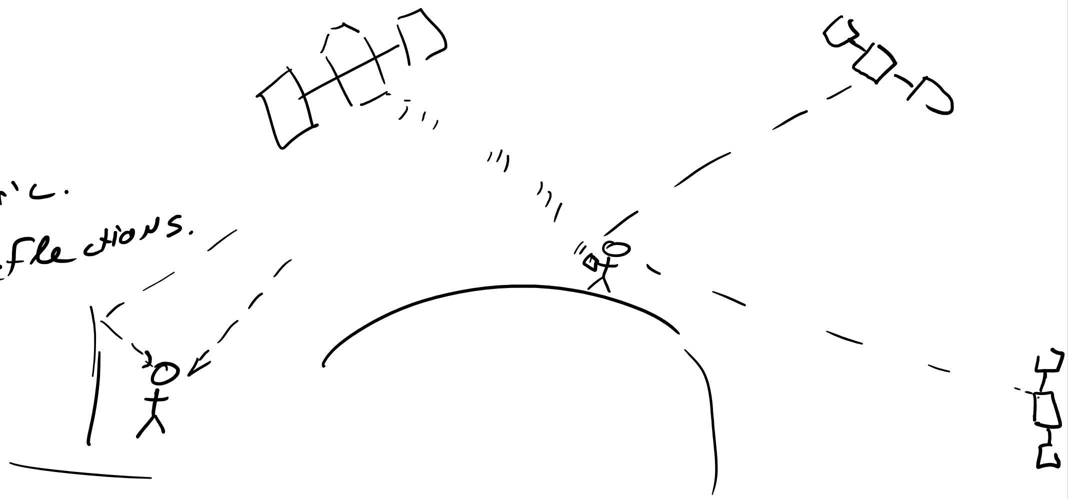
3) GPS: Sends a signal encoded with time, use multiple to “triangulate”

c~=300e6 m/s

Calculate time for an acoustic wave to travel 2 m in air, EM wave

1. atmospheric.

2. reflections.



Triangulation:

Process of determining absolute position based on multiple measurements from known locations

1 – 1D

2 - 2D

3 – 3D

6 – Pose

Why 5-6 typical in GPS?

1-5m.

~1m. WAAS.

1cm. ← pay $.

Other means to navigate;

- Active beacon
- Landmarks

US / IR.

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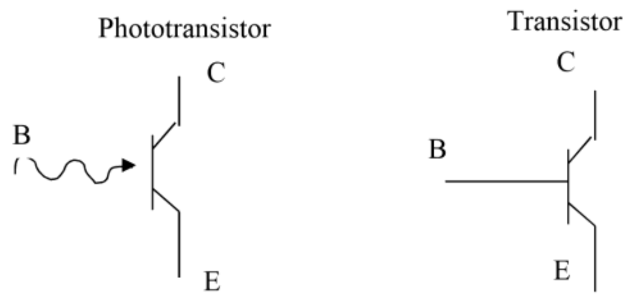
Cat 3: Optical Sensors

a) light sensitive devices

1) photodiodes
2) phototransisters – transistor that is forward biased by light – the emitter

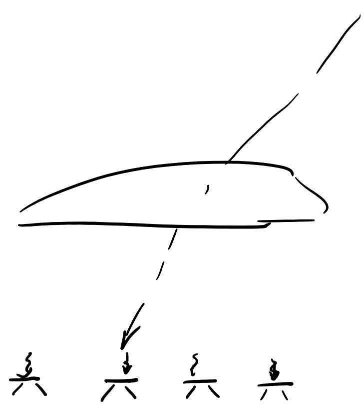


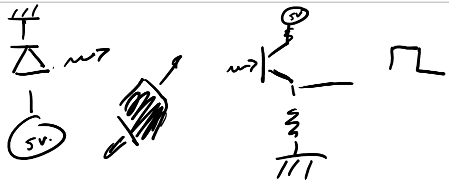
For Saturation;
$V_{BE} = 0.7V$ and
$I_{Bmin} = I_C/\beta$

Can be sensitive to various wavelengths
Used to measure proximity, beam-break, opto-isolators, remote controllers, encoders (discussed later)

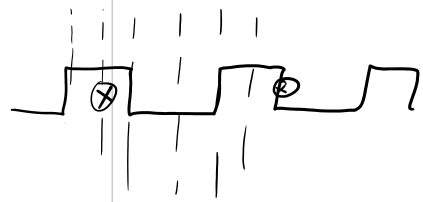
3) Photoresistor – varies resistance w.r.t. light

4) PSD (position sensitive device)



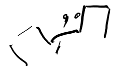


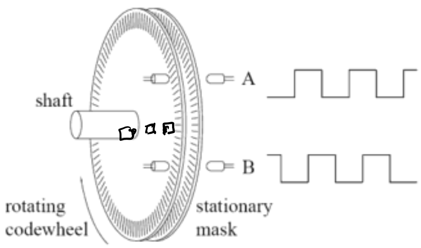
Cat 3 – 2 state



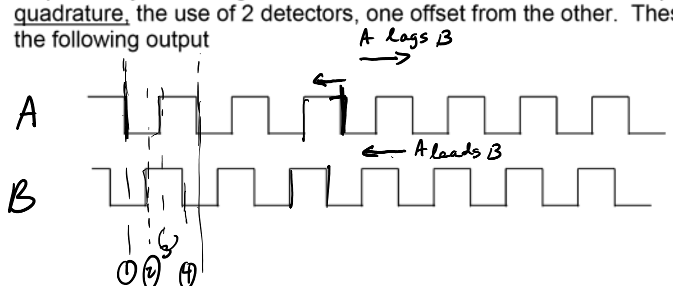
Encoders: Used to measure rotational rate – very common, basic component in servo motors

1) Optical incremental encoder: Uses an emitter-detector (phototransistor) pair + a banded disk:





Resolution is a function of the disk. Typical disks are 100 ppr or 500 ppr. This output tells you the degree of rotation, but not direction. That requires <u>quadrature,</u> the use of 2 detectors, one offset from the other. These would give the following output



A lagging B

look For a rising edge on A.
if B hi
CW
else CCW.

A D flip-flop could be used to give direction. The quadrature output can be used to increase resolution by a factor of four. One combination: HP 2020 IC will perform quadrature counting and output a 16bit “count” when queried.

```
TOF  int. 4. {
 ↳   rising edge
      if (ch B is Hi){
          count = count+1
      }
      else {
          count = count-1
      }
     }
```

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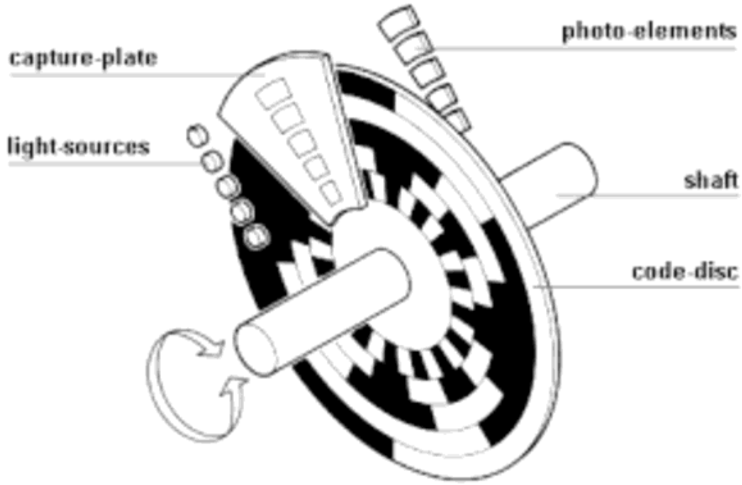
2) Absolute optical encoder

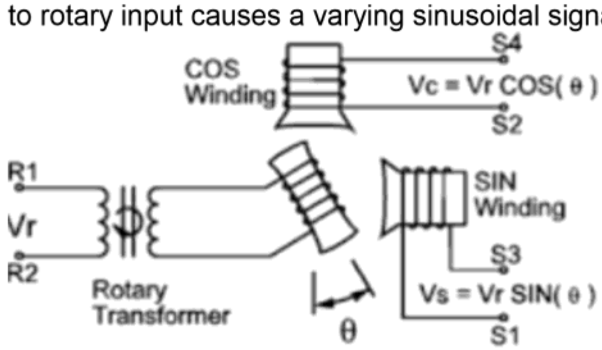
Unique coding signal for each location



Much lower resolution, but absolute position information

Much less common

3) Resolver: (based on RVDT) sinusoidal signal flowing through a loop attached to rotary input causes a varying sinusoidal signal on a fixed loop.



4) Other encoders use hall-effect sensor, magnetic sensor, etc.

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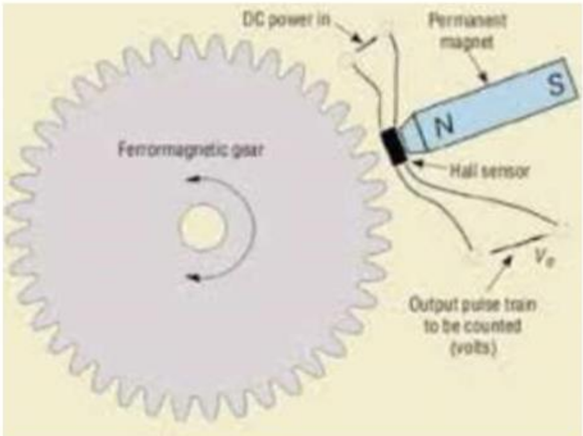
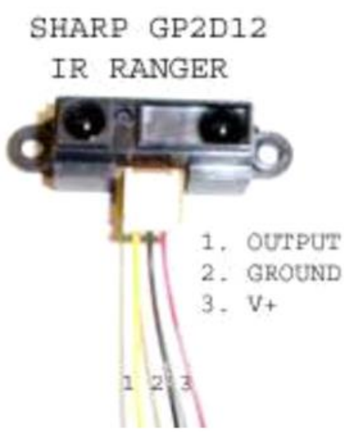


Tachometer: electrical generator produces a voltage proportional to rotary speed (back emf).

Cat 3 – multi-state

Example: Sharpe GP12   The PSD returns the position on the cell the light is received.



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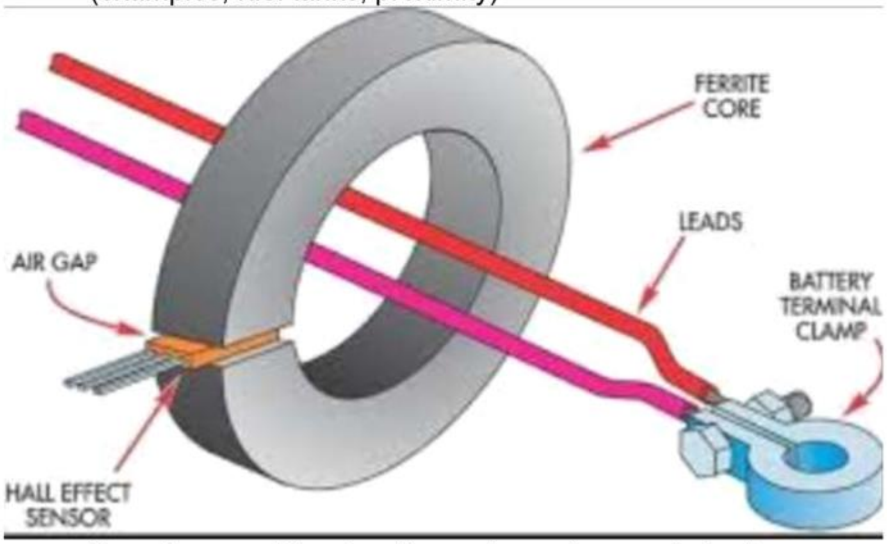
5) CCD

Cat 4: Current sensing

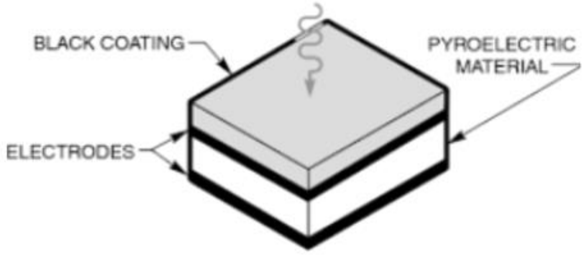
Hall effect sensors; A current flowing through a magnetic field is deflected (examples, fuel tanks, proximity)



Transformer – Resolver (type of encoder, see below)

Cat 5: Pyroelectric sensors: Based on pyroelectric materials which generate charge in response to heat flow $\Delta q = kp^*\Delta t$

PIR: One that senses IR radiation



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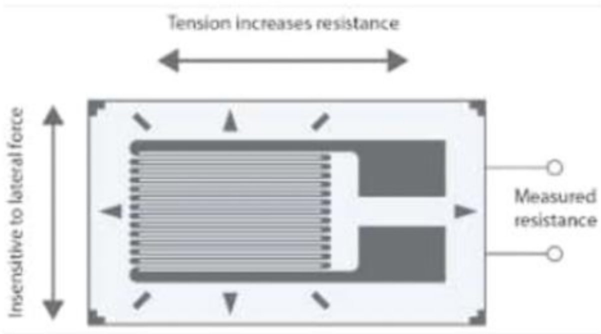
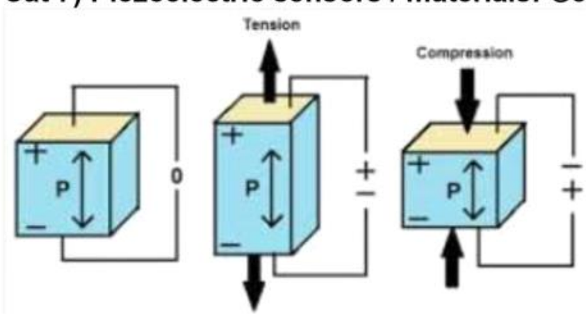
Cat 6: Resistance change due to strain: Strain gauges ∆proportional to strain
- Metal and semiconductor type
- Guage factor
- Problem -> temp also affects resistance
- Used in many types of sensors; pressure, load cell, etc.



Cat 7) Piezoelectric sensors / materials: Generate a voltage when strained



1 form used in tactile sensors, e.g., a PVDF film (piezoelectric polyvinylidene fluoride)

Materials for piezo electrics;
- Lead Zirconate (PZT), common
- Lead titante
- Lead metaniobate
- Barium titanate

(these are all ferro electric ceramics)

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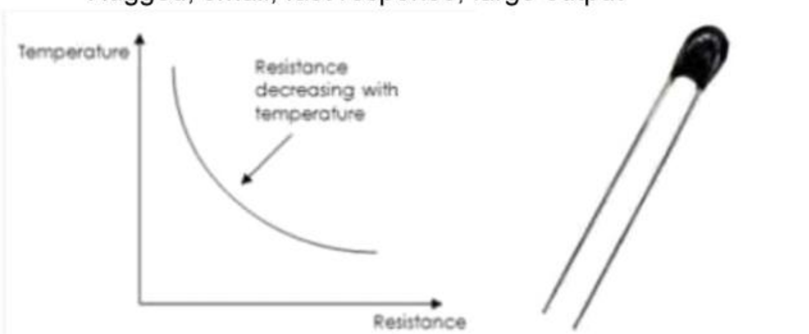
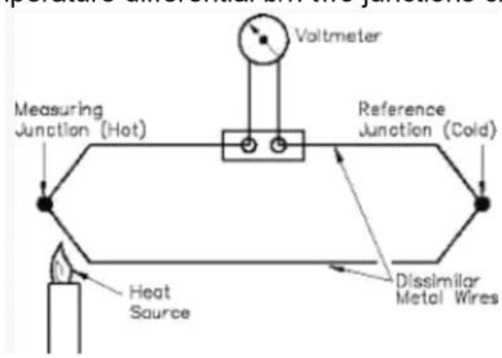
Cat. 8) Thermisters: Materials (metal oxides, semiconductors) whose resistance changes with temperature

typically nonlinear change

Rugged, small, fast response, large output



Cat 9) Thermocouples: Two dissimilair metals combined to form a junction. A temperature differential b/n two junctions creates a voltage



J type – Iron/contantan

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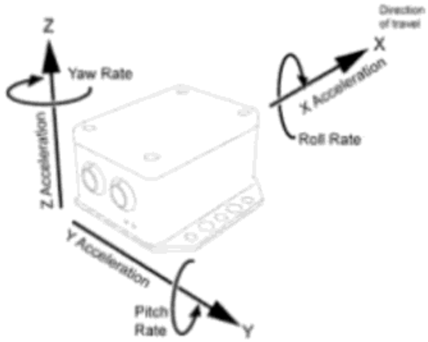
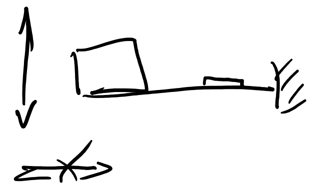
Cat. 10) Inertial Measurement

Accelerometers: Use a mass for inertia and strain gauge or PZT for sensing element





Gyroscope

Uses angular momentum and Euler's equation:

$$T = I\alpha + \omega \times I\omega$$

Or with three linear mass accelerometers

Or with a RLG

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Questions and exercises

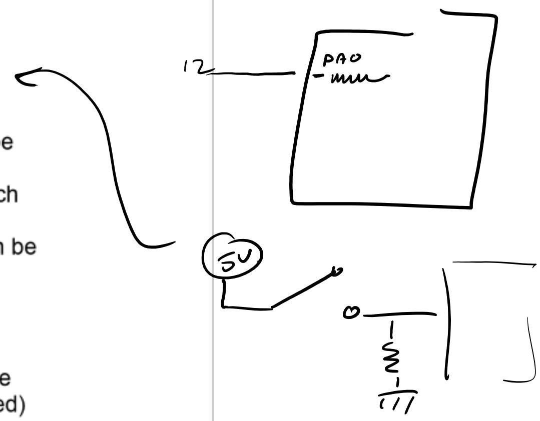
1) Show how an SPST switch can be wired with a 5V supply and resistors to provide a digital signal to a high impedance input (MCU) that is low when the switch is open and high when it is closed.

2) Show how a NO pushbutton switch can be wired with a 5 V supply and resistors to provide an active low reset signal to a MCU. (The signal should be low only while the button is held down)

3) Draw a schematic for a DPDT switch and show how it can be wired to switch two separate circuits on and off.

4) Draw a schematic for a DPDT switch with center open and show how it can be wired to drive a PM DC motor forward, off or reverse.

5) What is the angular resolution of a two-channel incremental encoder with quadrature encoder and a disk that has 100 radial slots. ← 4 × 100



6) given the speed of sound as 350 m/s, find the shortest distance that can be measured using and ultrasonic ranger on the S12 with PLL (24 MHz bus speed) and assume 100 clock cycles required for initiating, receiving echo and doing necessary calculations.

7) given the speed of light as 3e8 m/s, find the shortest distance that can be measured using a lidar ranger (bsed on time of flight) on the S12 with PLL (24 MHz bus speed) and assume 100 clock cycles required for initiating, receiving echo and doing necessary calculations.

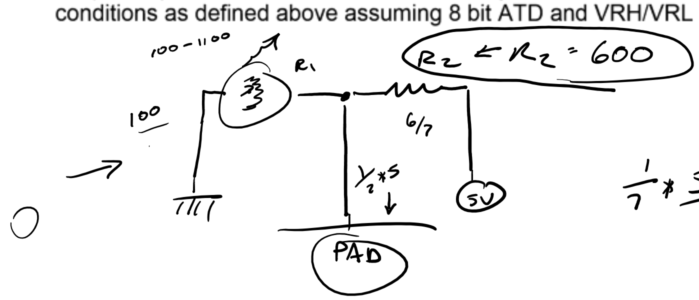
8) draw a circuit diagram to connect an optical incremental encoder to the S12, to capture on one channel and check the direction on the second channel.

9) Define the registers on the S12 needed to implement the problem described in no. 8.

10) draw a circuit diagram to connect an optical incremental encoder to the S12, using quadrature encoding (capture on all rising and falling edges).

11) Define the registers on the S12 needed to implement the problem described in no. 10.

12) a photo resister records 100 ohms at dark room conditions, 1100 ohms at bright room conditions, and a linear relationship to light in between. Draw a desirable circuit to connect the photo resister to the S12 (maximize resolution, etc.). For your circuit, show the ATD reading at dark room and bright room conditions as defined above assuming 8 bit ATD and VRH/VRL = 5/0 V.



$\frac{1}{7} * \frac{5}{5} * 255 =$

16