CENG4480
Lecture 05: Sensors

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Overview

Overview

1-1. Accelerometer

- ▶ Electromechanical devices that sense
  - ▶ Static acceleration (gravity)
  - ▶ Dynamic acceleration (vibrations & movement)
- ▶ Functions:
  - ▶ measure acceleration in one or more directions, position can be deduced by integration.
  - ▶ Orientation sensing: tilt sensor
  - ▶ Vibration sensing
  - ▶ measure acceleration in one or more directions, position can be deduced by integration.
- ▶ Methods:
  - ▶ Mass spring method ADXL78 (from Analog Device)
  - ▶ Air pocket method (MX2125)

ADXL78 (Mass Spring Method)

- ► Click this online document
- ► Measure the capacitance to create output
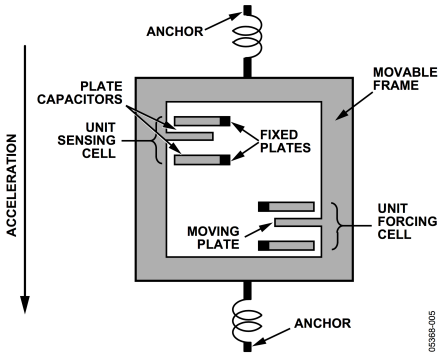- ► Measure both dynamic & static acceleration

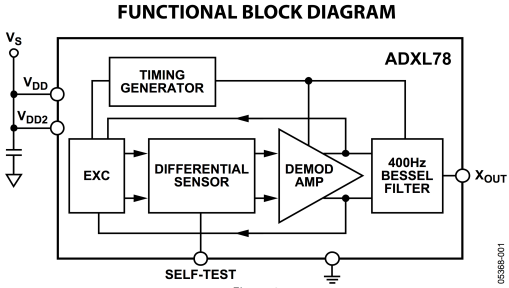

Figure 5. Simplified View of Sensor Under Acceleration

FUNCTIONAL BLOCK DIAGRAM

Figure 1.

`ADXL330` Accelerometer for (X, Y, Z) Directions

▶ Clik this online document
▶ 3D

Figure 1.

05677-001
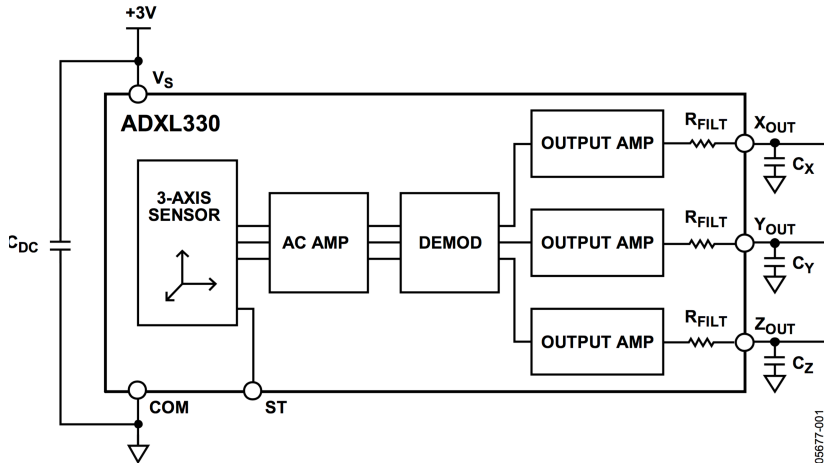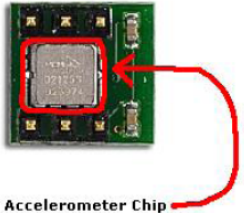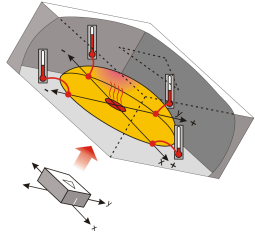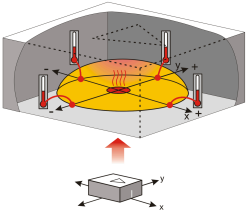
2D Translational Accelerometer `MX2125`
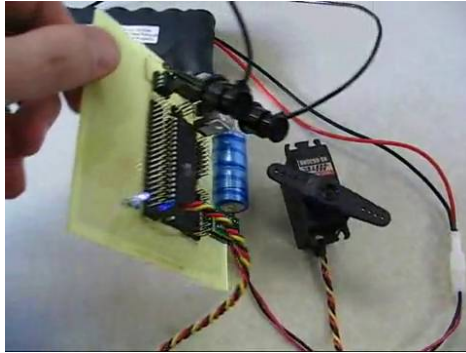

Accelerometer Module **Accelerometer Chip**

- ▶ Clik this online document
- ▶ Gas pocket type

▶ When the sensor moves, the temperatures of the 4 sensors are used to evaluate the 2D accelerations
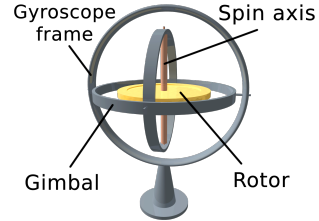
Demo: orientation sensing

(http://www.youtube.com/watch?v=9NEiBDBXFEQ)

1-2. Gyroscopes

- ▶ wiki page
- ▶ Measure rotational angle

Gyroscope frame — Spin axis
Gimbal — Rotor

Rate Gyroscope

- ▶ Measure the rate of rotation along 3-axes of X (pitch), Y (roll), and Z (yaw).
- ▶ Modern implementations are using Microelectromechanical systems (MEMS) technologies.
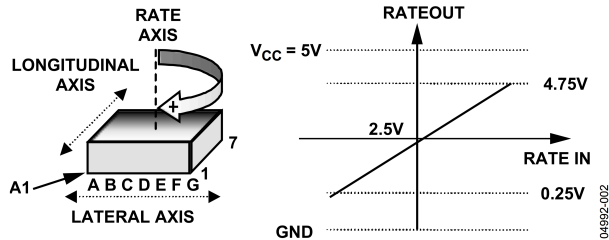
Gyroscope to Measure Rational acceleration

Figure 2. RATEOUT Signal Increases with Clockwise Rotation

Features

▶ Complete rate gyroscope on a single chip Microelectromechanical systems (MEMS)
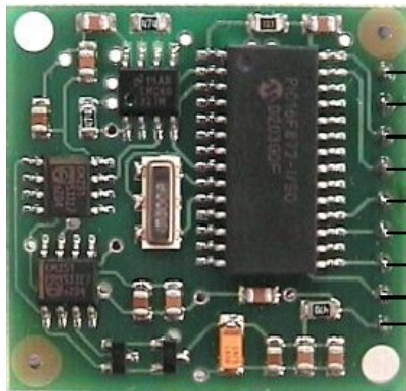
▶ Z-axis (yaw-rate) response

Applications

▶ GPS navigation systems

▶ Image stabilization

▶ Inertial measurement units

▶ Platform stabilization

1-3. Compass

▶ Philips `KMZ51` magnetic field sensor
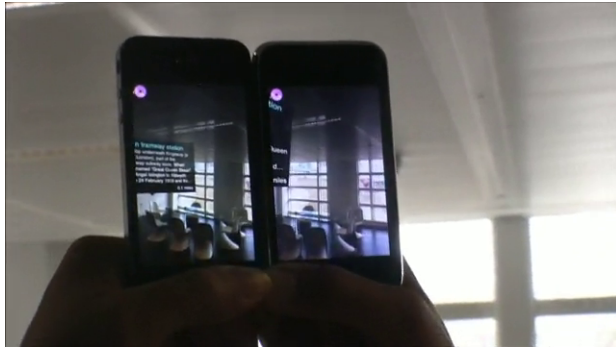▶ 50/60Hz (high) operation, a jitter of around $1.5°$

Pin 9 - 0v Ground
Pin 8 - No Connect
Pin 7 - 50/60Hz
Pin 6 - Calibrate
Pin 5 - No Connect
Pin 4 - PWM
Pin 3 - SDA
Pin 2 - SCL
Pin 1 - +5v

Rate gyroscope demo

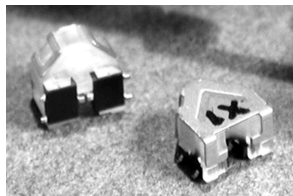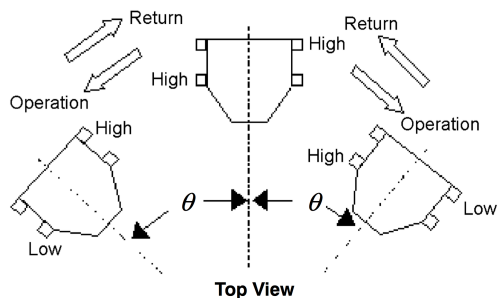Using Gyroscope compass for virtual reality application in an iphone

(http://www.youtube.com/watch?v=VP4-wdMMLFo)

1-4. Tilt Sensor by OMRON

► Click this online document

► Detect tilting $35 \sim 65$ degrees in right-and-left inclination

Top View

⇩

Gravity
direction

Note: 1. Operation angle: Output goes from High to Low
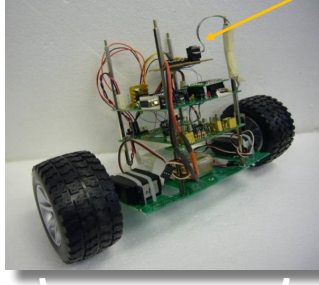2. Return angle: Output goes from Low to High

Demo: Tilt Sensing

(http://www.youtube.com/watch?v=C6uVrYz-j70)

One more reference: https://www.youtube.com/watch?v=KZVgKu6v808.

Application – Self Balancing Robot

Motion sensors: gyroscope and accelerometer

20cm

35cm

by Kelvin Ko (http://hk.youtube.com/watch?v=2u-EO2FDFG0)

Complementary Filter

- Since

Gyroscope	Accelerometer
High frequency	Low frequency
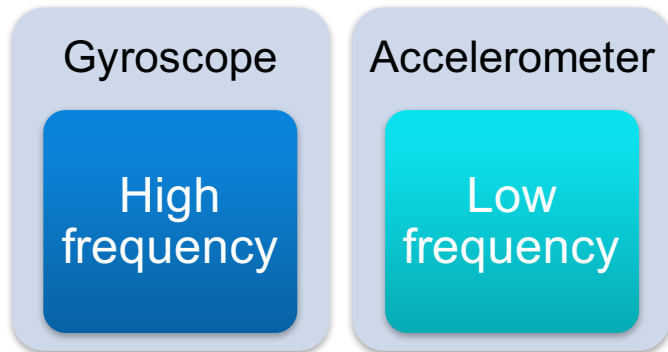
- Combine two sensors to find output

Complementary Filter (cont.)

High Pass Filter $\left(= \dfrac{\tau s}{\tau s + 1}, \text{ for example} \right)$

Low Pass Filter $\left(= \dfrac{1}{\tau s + 1} \right)$

θ_{est}
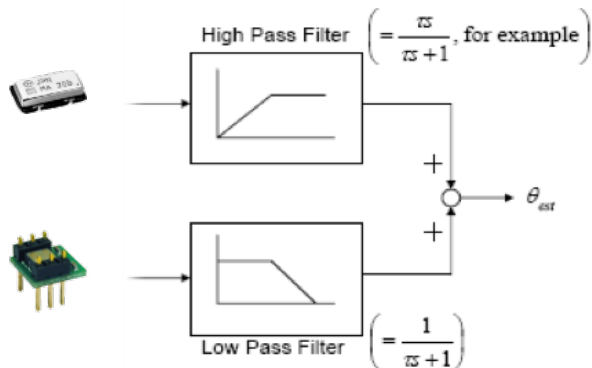
- ▶ θ: rotation angle
- ▶ τ: filter time constant
- ▶ s: Laplance operator

Overview

2-1. Force Sensing Resistors

▶ `FSR402`

▶ **Click** this online document
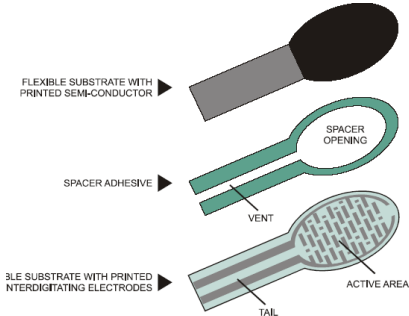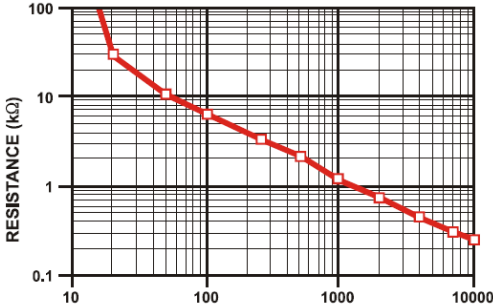
Figure 1: FSR Construction

Force Sensing Resistor Demo

(http://www.youtube.com/watch?v=LQ21lXr6egs)
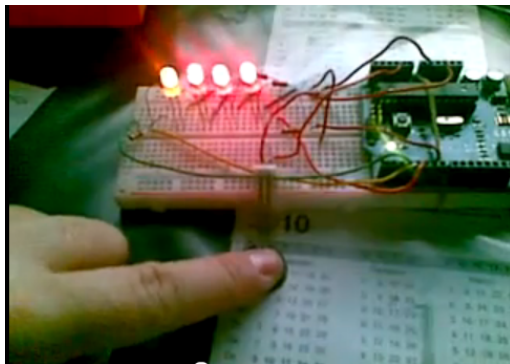
Application 1: Walking Robot
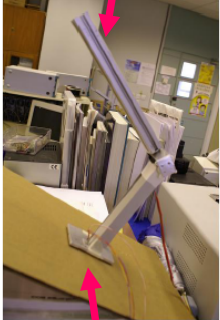
▶ Balancing

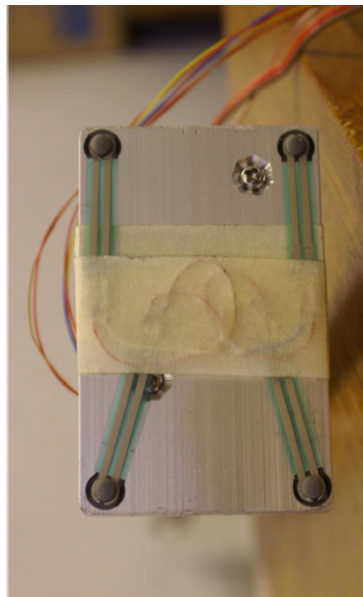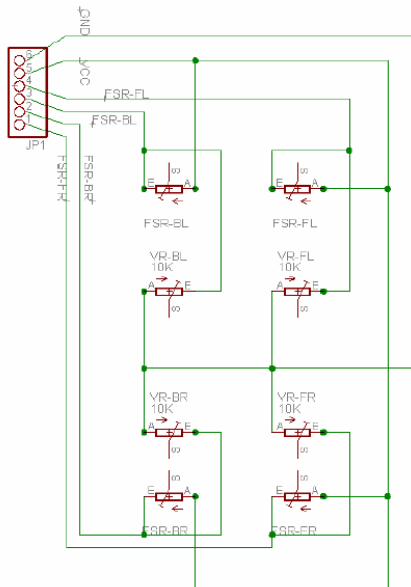Neutral position

Floor tilled left
upper leg bend right

Floor tilled right
upper leg bend left

Four sensors under the foot

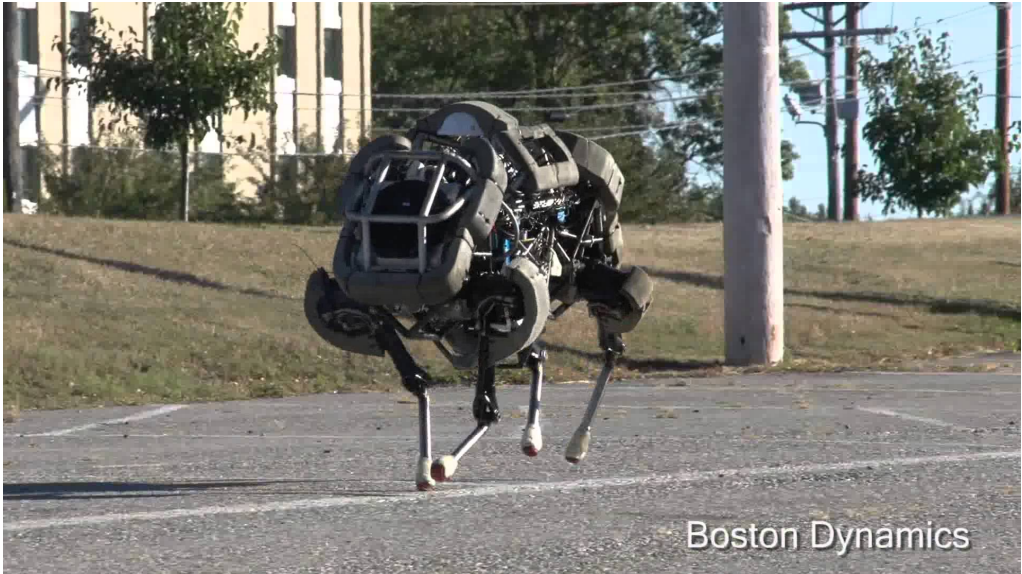# Four Force sensors under the foot

Application 2: The Nao Robot

▶ uses force feedback at its feet

▶ wiki page

(https://www.youtube.com/watch?v=2STTNYNF4lk)

Application 3: Robot Dog from Boston Dynamics

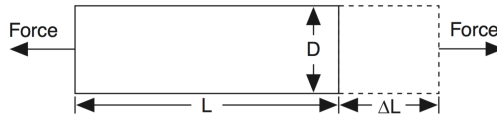(https://www.youtube.com/watch?v=NtU9p1VYtcQ)

2-2. Strain Gauge

What's Strain?

Amount of deformation of a body due to an applied force.
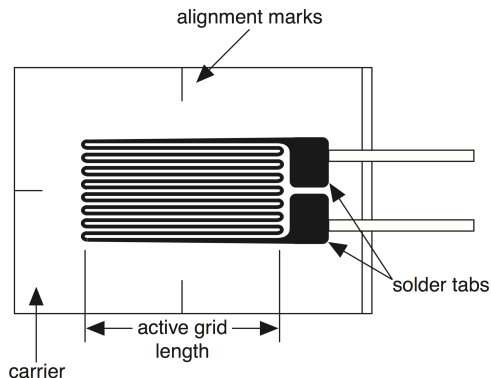

$$\varepsilon = \frac{\Delta L}{L}$$

Figure 1. Definition of Strain

Strain Gauge (cont.)
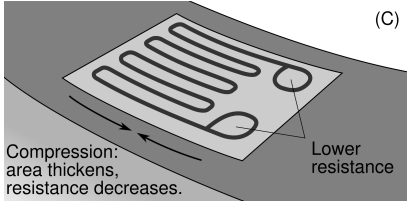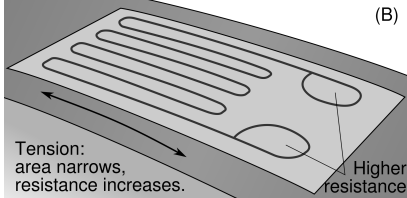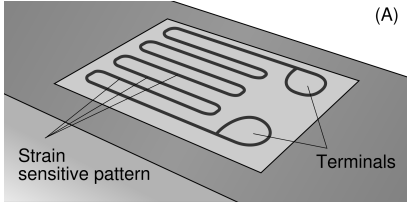
▶ Piezoelectric crystal: produces a voltage that is proportional to force applied

▶ Strain gauge: cemented on a rod. One end of the rod is fixed, force is applied to the other end. The resistance of the gauge will change with the force.
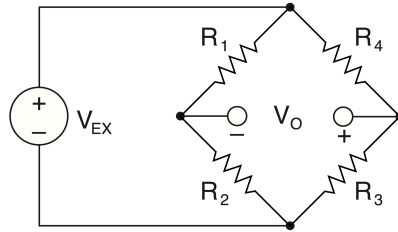
Strain Gauge (cont.)

Ex: mechanical strain gauge used to measure the growth of a crack in a masonry foundation.

(A)

Strain sensitive pattern

Terminals

(B)

Tension: area narrows, resistance increases.

Higher resistance

(C)

Compression: area thickens, resistance decreases.

Lower resistance

Wheatstone Bridge

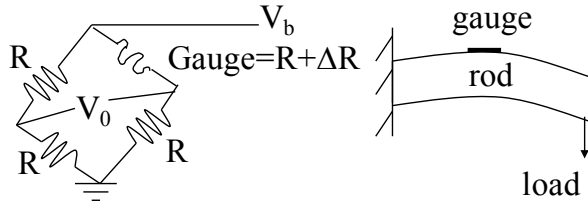**Wheatstone Bridge**

$$V_O = \left[\frac{R2}{R1 + R2} - \frac{R3}{R3 + R4}\right] \cdot V_{EX}$$

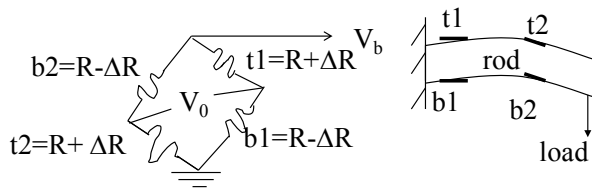# Single Element Strain Gauge

Sensitive to temperature change.

Out Voltage

$$V_O = [\frac{R}{2R} - \frac{R}{2R + \Delta R}] \cdot V_b = [\frac{\Delta R}{4R + 2\Delta R}] \cdot V_b$$
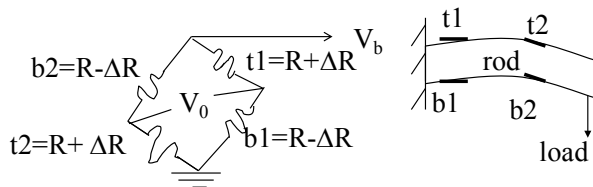
$$\approx \frac{\Delta R}{4R} \cdot V_b$$

Four-Element Strain Gauge

▶ Four times more sensitive than single gauge system

▶ NOT sensitive to temperature change.

▶ All gauges have unstrained resistance R.

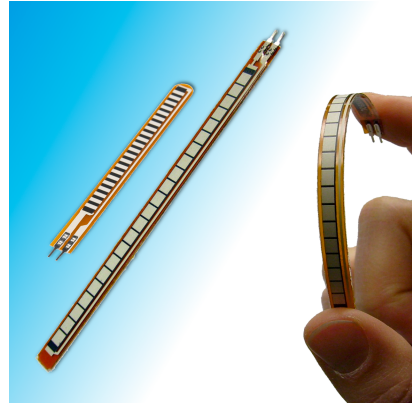For four-element strain gauge, calculate $\dfrac{V_O}{V_b}$.

$$b2 = R - \Delta R \qquad t1 = R + \Delta R \qquad V_b$$
$$V_0$$
$$t2 = R + \Delta R \qquad b1 = R - \Delta R$$

t1   t2
rod
b1   b2
load

2-3. Flexion (bend) sensors

Resistance:

- 10 KΩ (0°);
- 30–40 KΩ (90°)

`https://www.youtube.com/watch?v=lEUVlSsAhCg`
Click this online document

Felixon resistance Demo

(http://www.youtube.com/watch?v=m4E5SP7HCnk&feature=related)
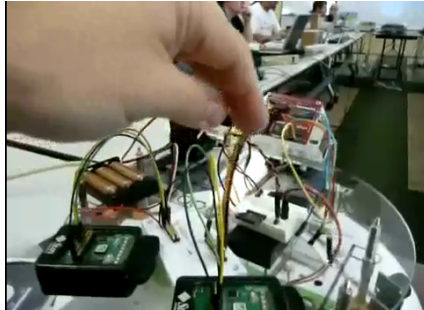
2-4. Air Pressure Sensor

► Measure up to 150 psi (pressure per square inch).

Overview

Infra-red Range detectors

- by SHARP (4 to 30 cm)
- An emitter sends out light pulses. A small linear CCD array receives reflected light.
- The distance corresponds to the triangle formed.

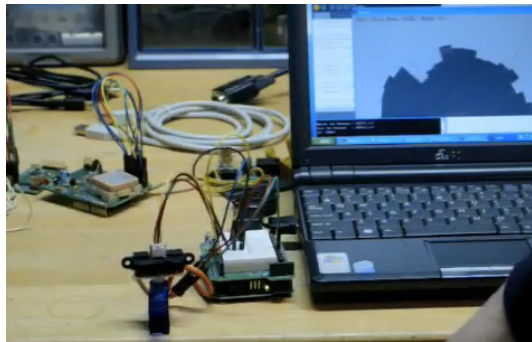http://www.acroname.com/robotics/info/articles/sharp/sharp.html
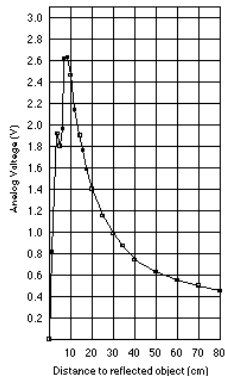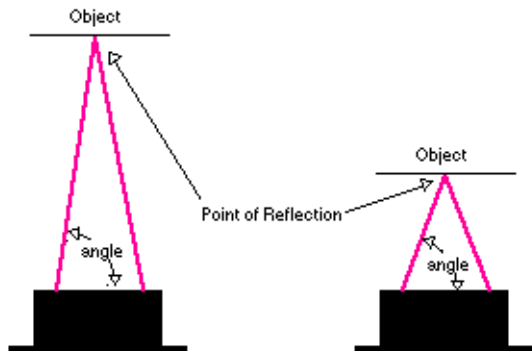
IR radar using the Sharp range detector

http://www.youtube.com/watch?v=tStBLAiQaC8&feature=related

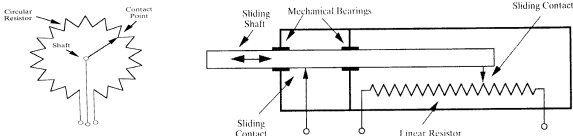# Position Sensors

▶ Rotary

▶ Rotary Encoder
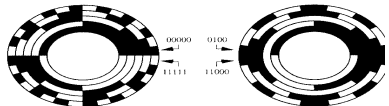
▶ Digital Linear Encoder

Optical Rotary Encoder

- wiki page
- https://www.youtube.com/watch?v=RuIislTGOwA
- The light received (on or off) will tell the rotation angle)

3 light receivers

Light paths

Rotation shaft

3 light emitters

Crank shaft sensor
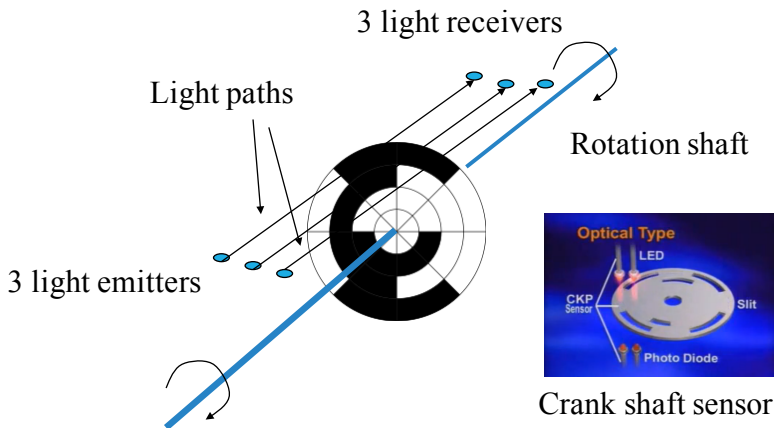
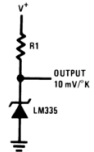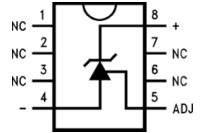# Magnetic rotary encoder

- ▶ Check the online info
- ▶ Non touch sensing

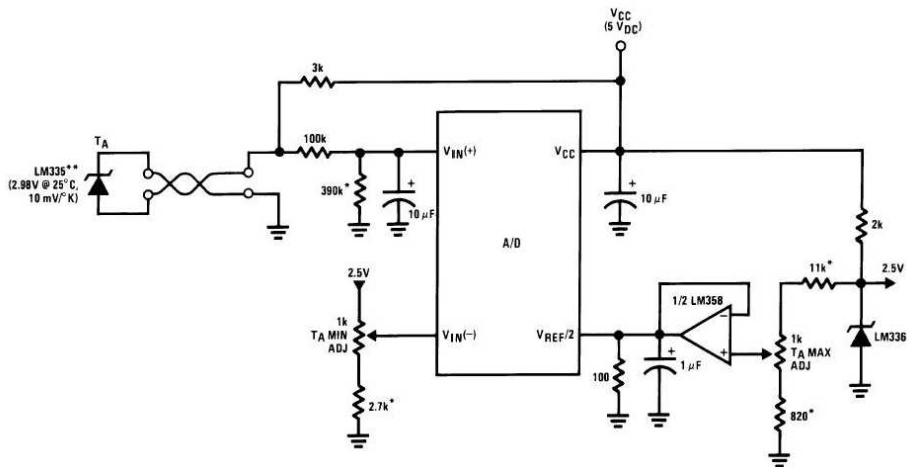# Temperature sensors

- Click the online document
- Directly calibrated in ° Kelvin
- $1°C$ initial accuracy available
- Operates from 400 μA to 5 mA
- Less than 1 Ohm dynamic impedance
- Easily calibrated
- Wide operating temperature range
- $200°C$ over range
- Low cost

Application note

µP Interfaced Temperature-to-Digital Converter

connecting to an ADC e.g. `ADC0820` or `ADC0801`

Humidity Sensor

► Check the online document

► Humidity range (RH) -> Capacitance

► `BCcomponents 2322 691 90001`: 10–90%RH Dc

QUICK REFERENCE DATA

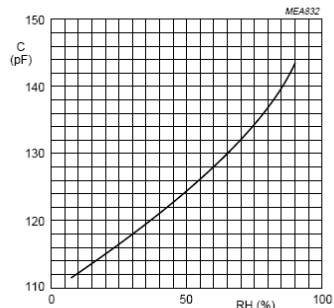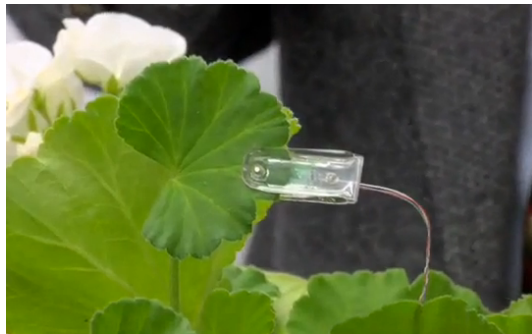| PARAMETER	VALUE	U
Humidity range (RH)	10 to 90	%
Capacitance at +25 °C; 43% RH; 100 kHz	122 ±15%	pF
Sensitivity between 12 and 75% RH	0.4 ±0.05	pF/%
Frequency	1 to 1000	kHz
Maximum AC or DC voltage	15	V

Fig.2 Typical capacitance as a function of relative humidity.
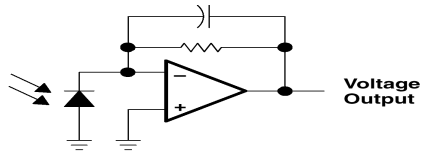
Leaf Sensor Alerts When Plants Are Thirsty

http://www.youtube.com/watch?v=VM4X_fqPPco

Light-to-voltage Optical Sensors

▶ Click the online document
▶ Light-to-voltage optical sensors, each combining a photodiode and an amplifier (feedback resistor = 16 MW, 8 MW, and 2 MW respectively).
▶ The output voltage is directly proportional to the light intensity on the photodiode.

CdS Photoconductive Photocells

- Click the online document
- Cadmium Sulfoselenide (CdS)
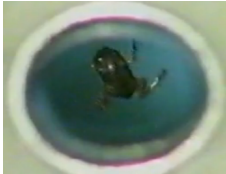- Light sensing using CdS
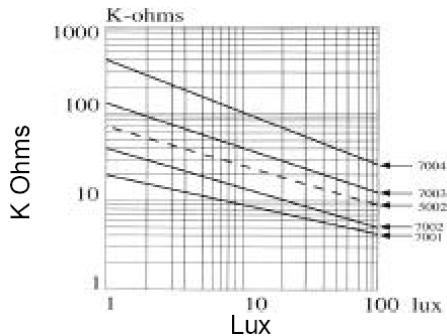
3-4. Hall effect Sensors

▶ voltage difference across an electrical conductor, transverse to an electric current
▶ A wheel containing two magnets passing by a Hall effect sensor
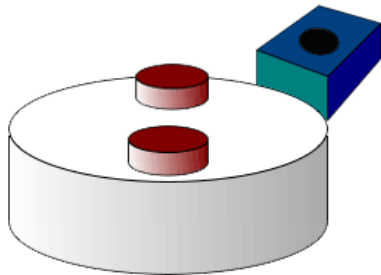
Application on Magnetic levitation

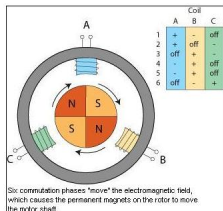Magnetic levitation Train Model: http://www.youtube.com/watch?v=TeS_U9qFg7Y

frog levitation

http://www.youtube.com/watch?v=A1vyB-O5i6E

http://www.youtube.com/watch?v=XjjBqzilkIc

Hall effect sensors and brushless DC motors

Brushless DC motor

Six commutation phases "move" the electromagnetic field, which causes the permanent magnets on the rotor to move the motor shaft.

https://www.youtube.com/watch?v=bCEiOnuODac

Is it using Hall effect sensor? Don't known.

http://www.youtube.com/watch?v=cm0h2Qf3upQ

http://www.youtube.com/watch?v=JmRkxZT4XhY

3-5. Kinect Sensors

https://learn.adafruit.com/hacking-the-kinect

https://www.youtube.com/watch?v=p2qlHoxPioM

http://www.youtube.com/watch?v=nvvQJxgykcU
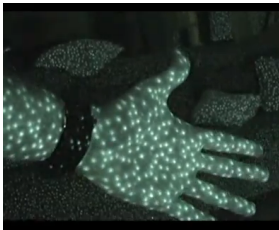

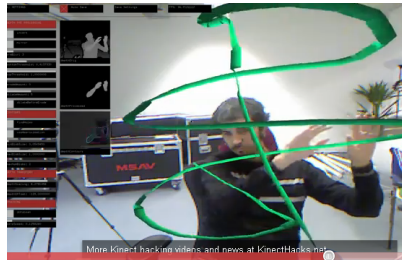http://www.youtube.com/watch?v=Brpu30vjCa4&feature=related
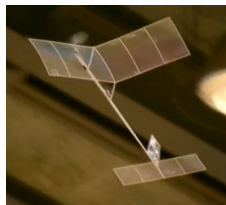
Summary

- Studied the characteristics of various sensors
- and their applications