# Robot Sensors
## An Overview

# Robot Sensors

- Why do Robots Need Sensors?
- What can be Sensed?
- What Sensors are Out There?
- What can They do?
- How Much do They Cost?
- How Easy are They to Use?

# Why Do Robots Need Sensors?

- Provides “awareness” of surroundings
  - What’s ahead, around, “out there”?
- Allows interaction with environment
  - Robot lawn mower can “see” cut grass
- Protection & Self-Preservation
  - Safety, Damage Prevention, Stairwell sensor
- Gives the robot capability to goal-seek
  - Find colorful objects, seek goals
- Makes robots “interesting”

# Sensors - What Can Be Sensed?

- Light
  - Presence, color, intensity, content (mod), direction
- Sound
  - Presence, frequency, intensity, content (mod), direction
- Heat
  - Temperature, wavelength, magnitude, direction
- Chemicals
  - Presence, concentration, identity, etc.
- Object Proximity
  - Presence/absence, distance, bearing, color, etc.
- Physical orientation/attitude/position
  - Magnitude, pitch, roll, yaw, coordinates, etc.

# Sensors - What Can Be Sensed?

- Magnetic & Electric Fields
  - Presence, magnitude, orientation, content (mod)
- Resistance (electrical, indirectly via V/I)
  - Presence, magnitude, etc.
- Capacitance (via excitation/oscillation)
  - Presence, magnitude, etc.
- Inductance (via excitation/oscillation)
  - Presence, magnitude, etc.
- Other Things?

# What Sensors Are Out There?

- Feelers (Whiskers, Bumpers) – Mechanical
- Photoelectric (Visible) – Active & Passive
- Infrared (light) – Active & Passive
- Ultrasonic (sound) – Active & Passive
- Sonic – Active & Passive
- Resistive/Capacitive/Inductive – Active & Passive

# What Sensors Are Out There?

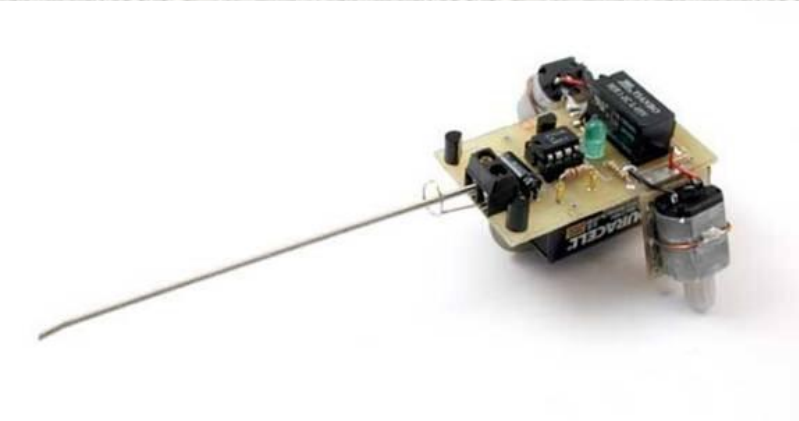
- Visual – Cameras & Arrays (Active & Passive)
- Color Sensors (Active & Passive)
- Magnetic (Active & Passive)
- Orientation (Pitch & Roll)
- GPS (location, altitude)
- Compass (orientation, bearing)
- Voltage – Electric Field Sensors
- Current – Magnetic Field Sensors
- Chemical – Smoke Detectors, Gas Sensors

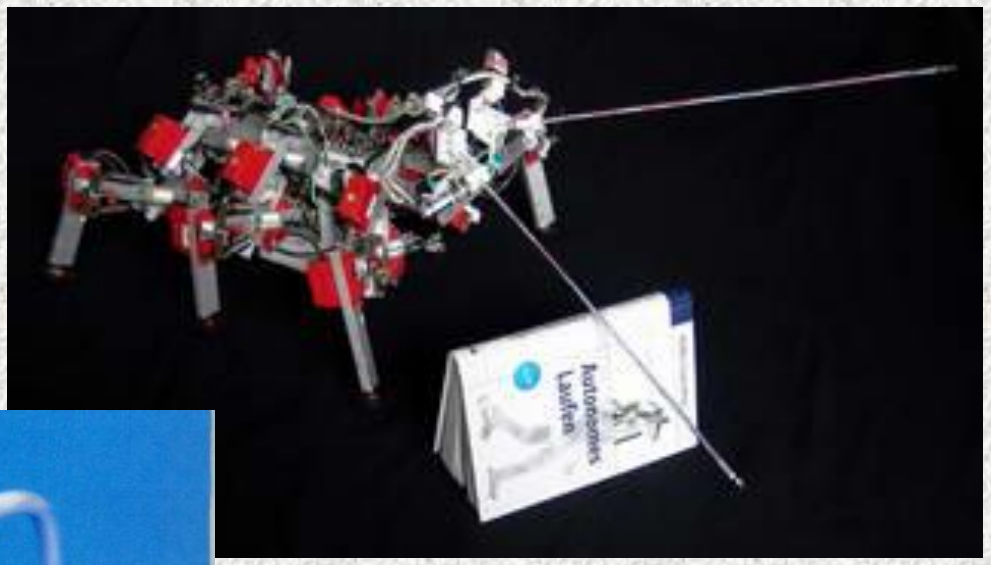
# A Closer Look

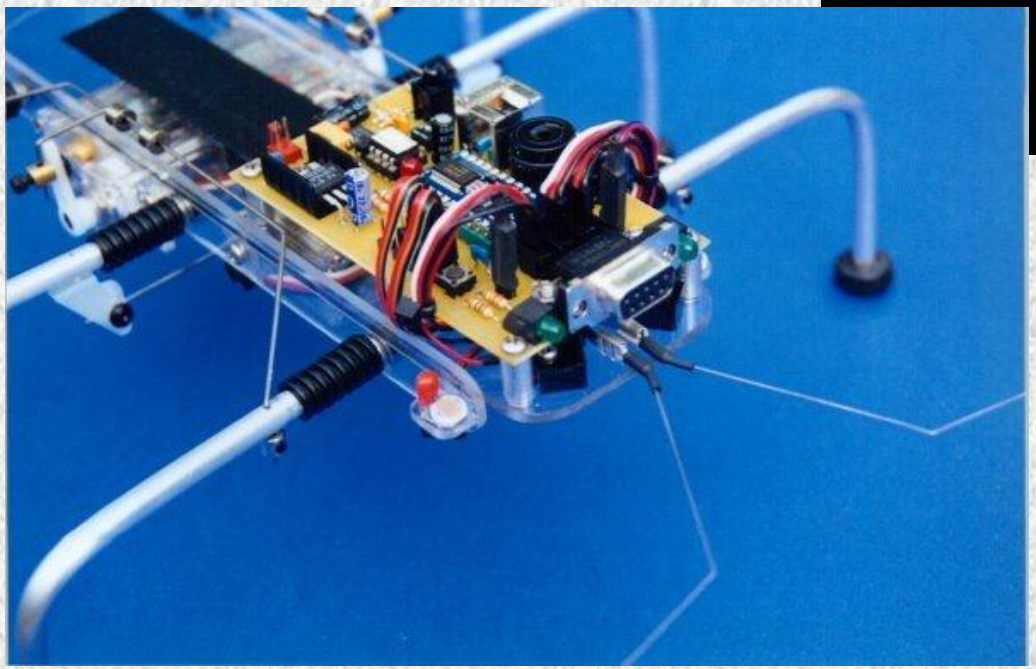
# Sensors – Feelers

- Whiskers
  - Piano wire suspended through conductive “hoop”
  - Deflection causes contact with “hoop”
  - Springy wire that touches studs when deflected
  - Reaches beyond robot a few inches
  - Simple, cheap, binary output
- Bumpers & Guards
  - Impact/Collision sensor, senses pressure/contact
  - Microswitches & wires or framework that moves
  - Simple, cheap, binary output, easy to read

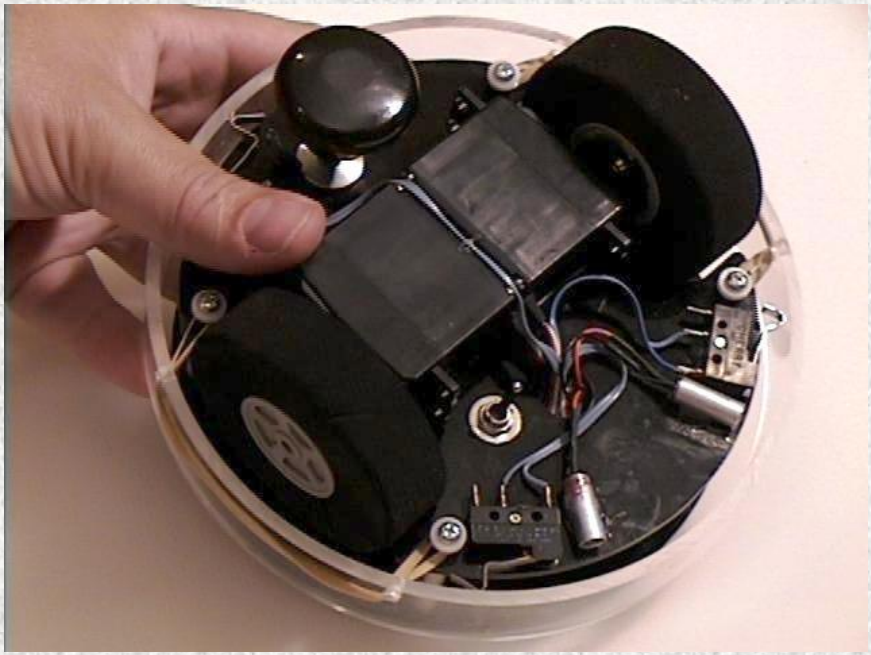
# Feelers - Whiskers

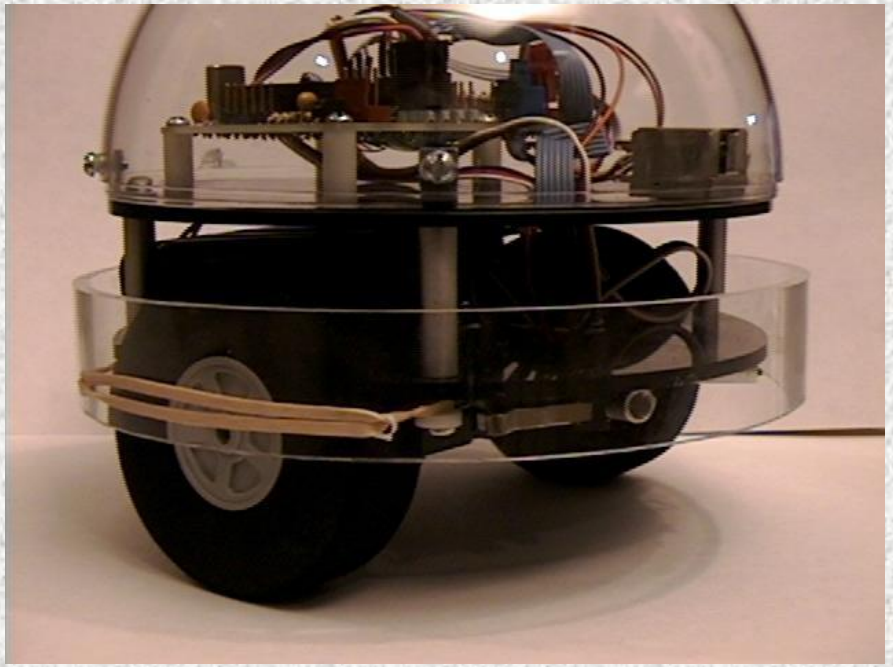






# Feelers - Bumpers & Guards



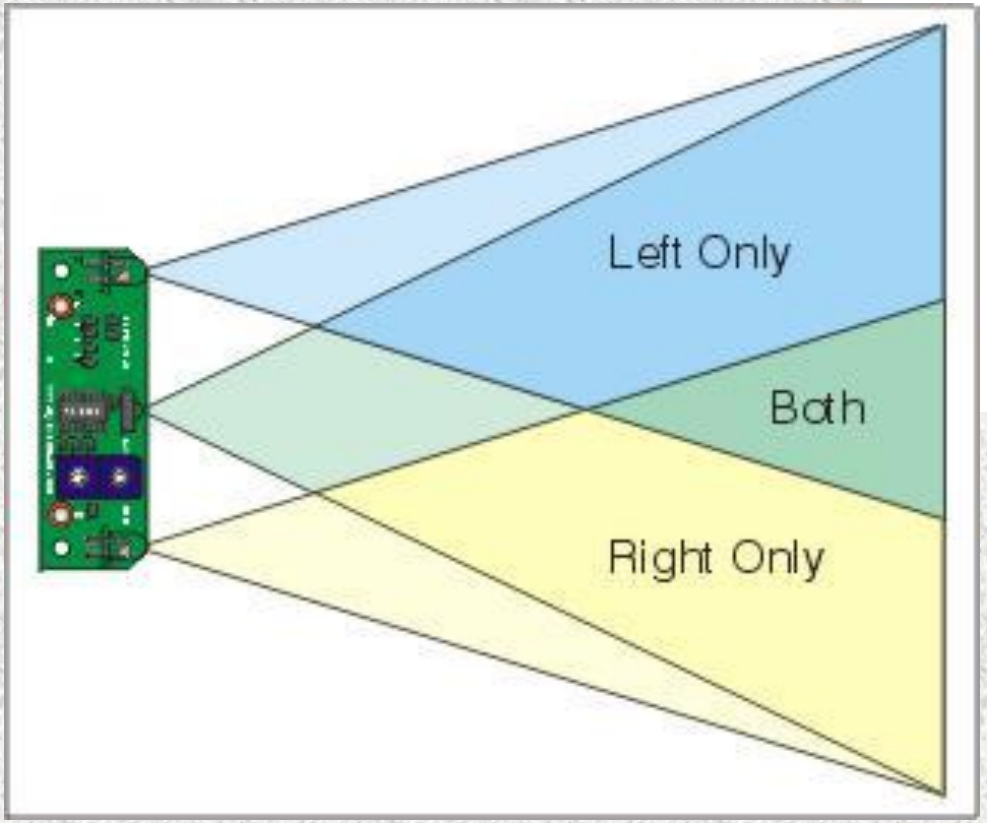


From Kevin Ross's "Getting Started Article (SRS Website)

# Sensors – IR

- Active (emitting)
  - Oscillator generates IR reflections off objects
  - Filtered receiver looks for “reflections”
  - Pulses may be encoded for better discrimination
  - Typically frequencies around 40KHz
  - Doesn’t work well with dark, flat colored objects
- Passive (sensor only)
  - Pyro-electric (heat sensor)
  - Look for IR emissions from people & animals
  - Used in security systems & motion detectors

# Infrared - Active




$30 from Lynxmotion

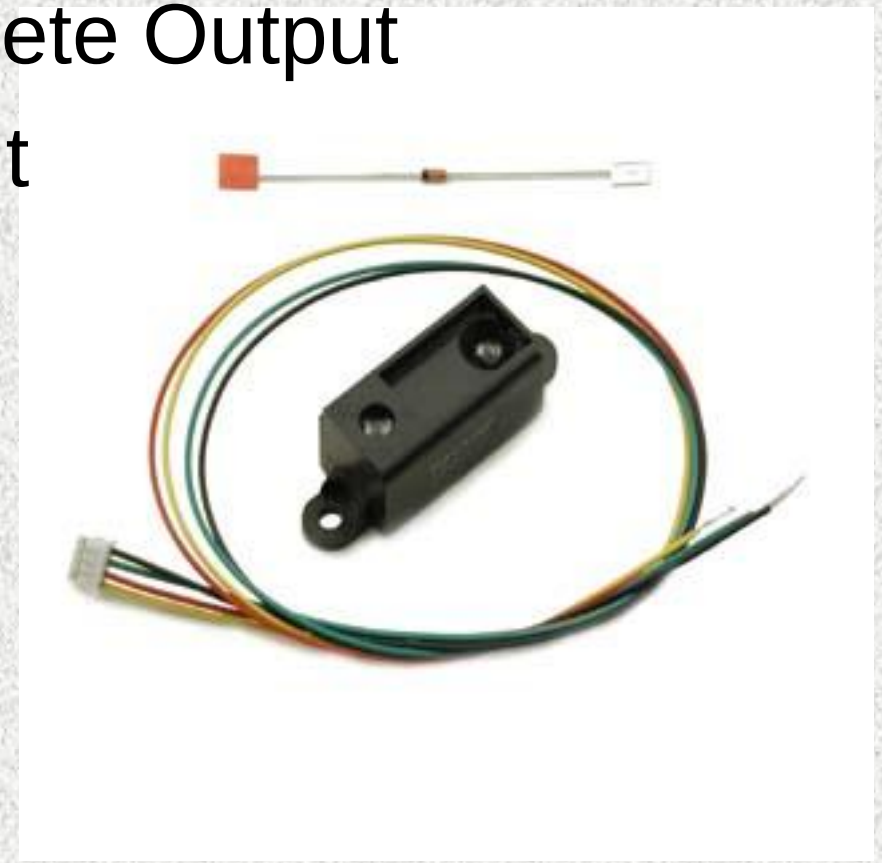
July 99 Encoder

# Active IR Sensor Specs

- Sensor type = Reflective IR
- IR detector = Panasonic PNA4602M
- IR LED type = Narrow focus 10º
- I/O required = 3 digital lines: 2 outputs, 1 input
- Range = Approximately 4“ to 26"
- Input voltage = 5vdc regulated @ 8mA
- PC board size = 2.3" x .75"

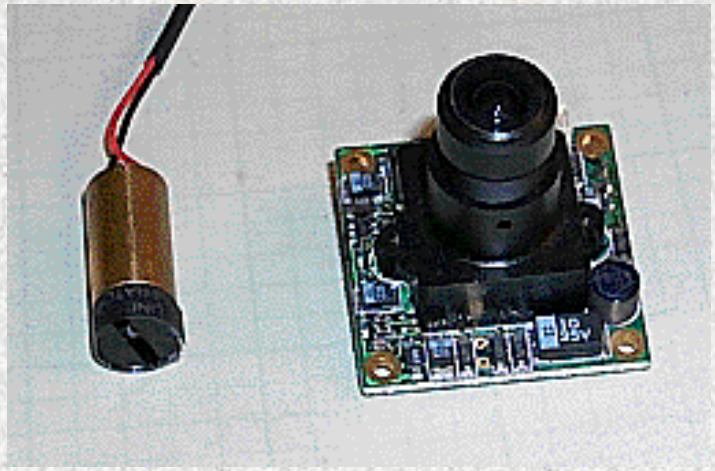
# Linear Array IR Range Sensors

- Sharp GP2Dxx (one of many)
- ~4 to 30cm Range
- Fixed Range with Discrete Output
- Analog or Digital Output
- Easy to Use

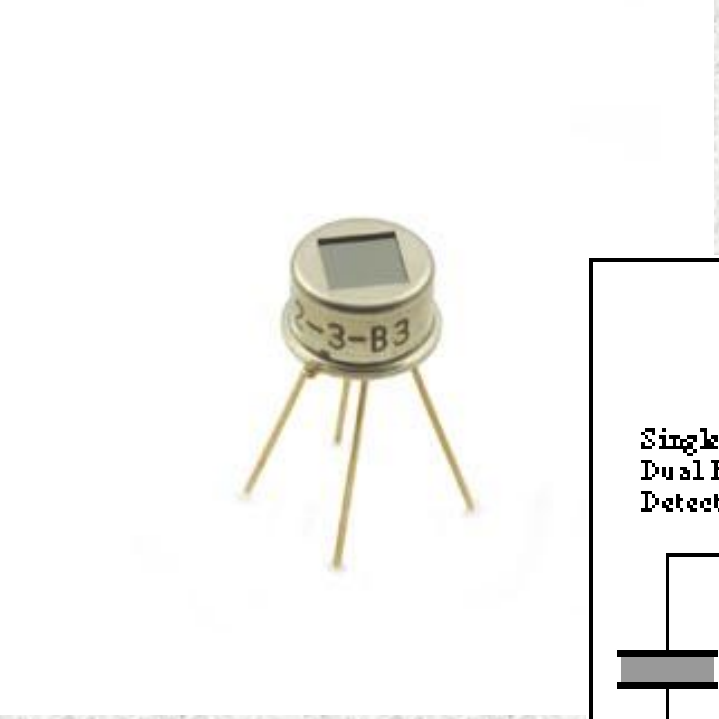


# Laser Range Sensors

- USB Interface
- 240º Field of View
- 0.36º Angular Resolution
- 10Hz Refresh Rate
- 20mm to 4m
- $2695 (cool but pricey)
- Also See:
  - Oct 2001 Encoder
  - Kenneth Maxon

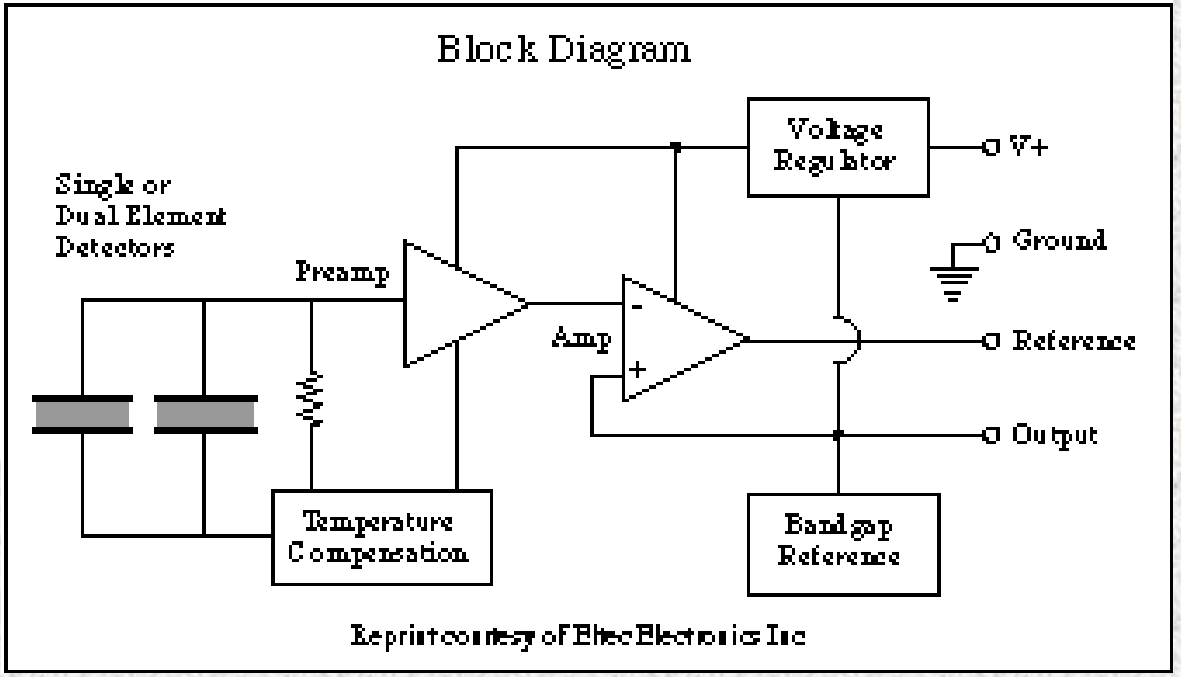



# Passive IR – Pyro-Electric




$66 from Acroname

Dec 2000, Sept 2001 Encoder




The Model 442-3 IR-EYE is a Lithium Tantalate pyroelectric parallel opposed dual-element high-gain detector with complete integral analog signal processing.

# Sensors – Ultrasonic

- Active
  - Emit pulses & listen for echos
  - Times round trip sound travel (~1ft/mS)
  - Reaches far fairly beyond robot (inches to 30-50’)
  - Relatively simple, not cheap, analog output
  - Directional; not everything reflects sound well
- Passive (listens only)
  - Sensor listens for ultrasonic sounds
  - Electronics may translate frequency or modulation
  - Software may perform signal analysis (FFTs, etc.)

# Ultrasonic - Active

$27


$49


$134


Visit http://www.acroname.com for more information about these & other products.

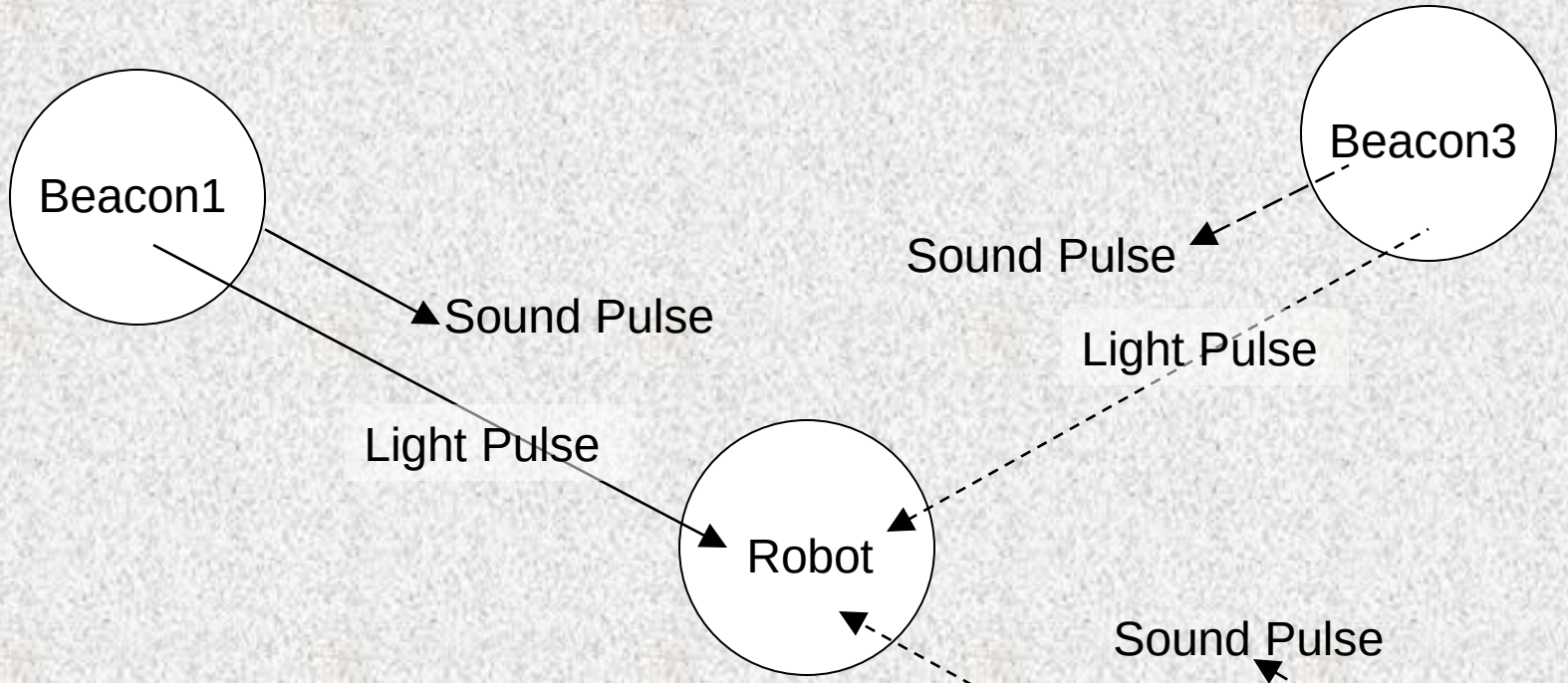
Search the web for “polaroid ultrasonic sensor”

# Sensors – Ultrasonic (cont.)

- Passive - Beacons & Sensors
  - Beacons listen: RF command to broadcast
    - Send light & sound pulses
    - Robot looks & listens for each beacon
    - Light pulse starts timer, sound pulse stops it
  - Robot knows location of each beacon
  - Compass on robot provides its orientation
    - Robot computes distance, measures bearing
  - Robot can then compute its location

(Speed of Light=1 ft/nS, Speed of Sound=1ft/mS)

# Ultrasonic - Passive




**BEACON**

RF Receiver

IR Emitter

Ultrasonic Emitter

**ROBOT**

RF Transmitter

IR Receiver

Ultrasonic Receiver

# Sensors – Sonic (Acoustic)

- Active
  - Emit pulses & listen for echos
  - Times round trip sound travel (~1ft/mS)
  - Reaches far fairly beyond robot (30-50 ft)
  - Relatively simple, not cheap, analog output
  - Directional, not everything reflects sound
  - Noisy!!!!
- Passive (sensor only)
  - Sensor listens to ambient sounds
  - Filters or scans selected frequencies
  - ADC measures conditioned signal amplitude
  - CPU performs signal analysis on what it hears

# Sonic (Acoustic) - Passive

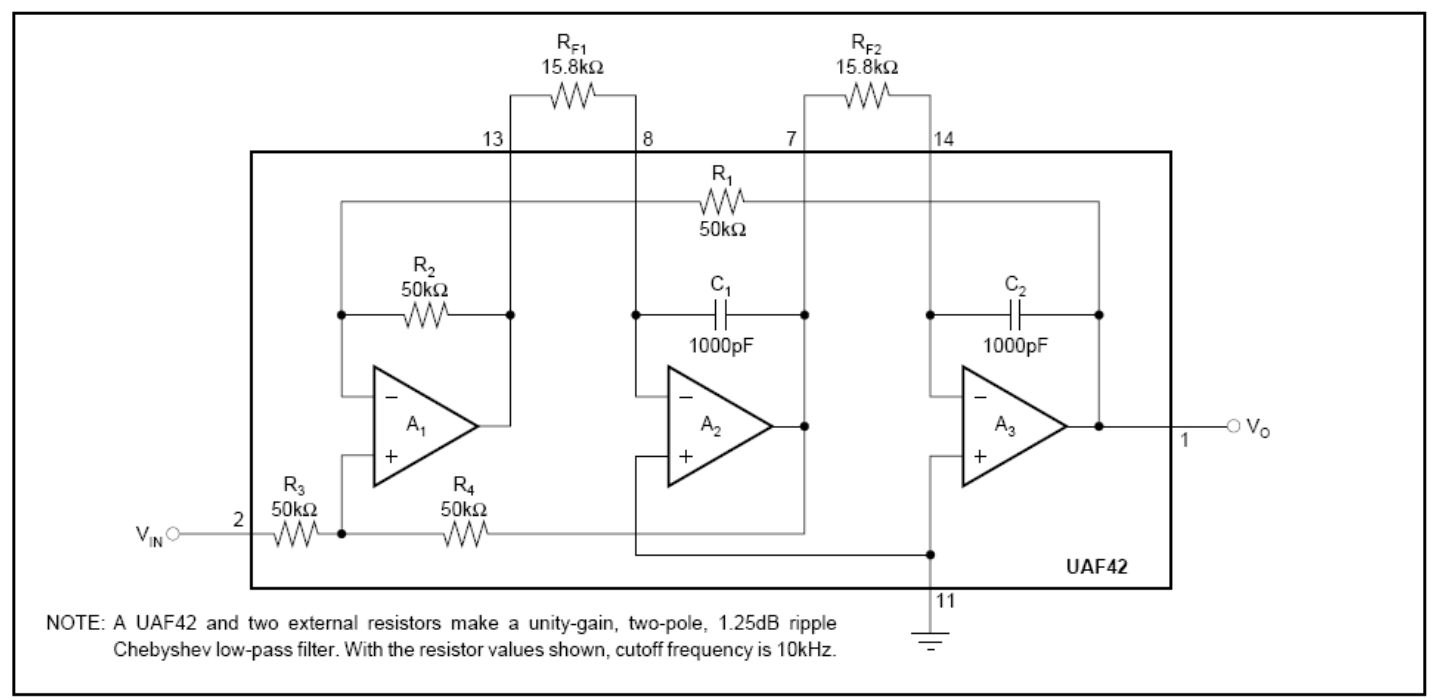



FIGURE 1. Two-Pole Low-Pass Filter Using UAF42.

TI (Burr-Brown) UAF42 Universal Active Filter

http://focus.ti.com/lit/an/sbfa002/sbfa002.pdf

# Sensors – Resistance

- Passive (sensor only)
  - Measures elec. resistance between objects
  - Measure sensor that varies resistance
  - Use absolute or differential readings
  - Other ideas?

# Sensors – Capacitive

- Passive
  - Really doesn’t work (Needs excitation)
- Active (emitting)
  - Generate AC or DC voltage
  - Apply to external environment
  - Measure current to determine Resistance
  - Short range applications

# Sensors - Capacitive

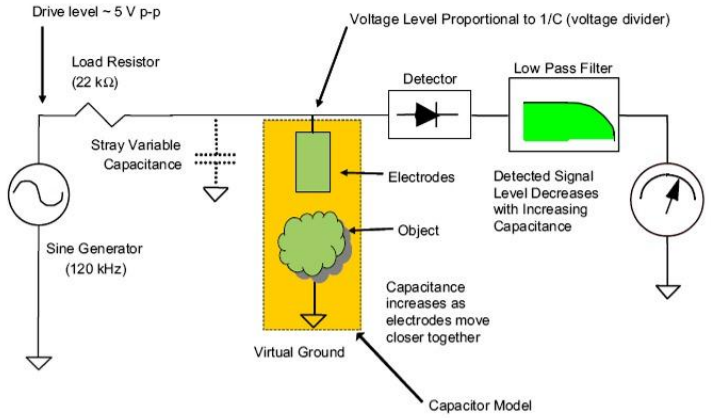


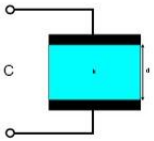

**Figure 3. Conceptual Block Diagram**

**CAPACITOR MODEL**

The capacitance measured by the E-Field IC is:

- Proportional to the area of the electrode
- Proportional to the dielectric constant of the material between the electrodes
- Inversely proportional to the distance between the objects

$$C = \frac{k\varepsilon_0 A}{d}$$




C = The Capacitance in Farads (F)
A = The area of the plates in square meters (m2)
d = The distance between the plates in meters (m)
k = The dielectric constant of the material separating the plates
0 = Is the permittivity of free space (8.85 x 10-12 F/m)

**Figure 4. Capacitor Model**

**Table 4. Dielectric Constants of Various Materials**

| Dielectric Material | Thickness (mil) | *k* |
|---|---|---|
| Acrylic | 84.5 | 2.4-4.5 |
| Glass | 74.5 | 7.5 |
| Nylon Plastic | 68 | 3.0-5.0 |
| Polyester Film | 10 | 3.2 |
| Flexible Vinyl Film | 9 | 2.8-4.5 |
| Air | - | 1.0 |
| Water | - | 80 |
| Ice | - | 3.2 |
| Automotive Oil | - | 2.1 |

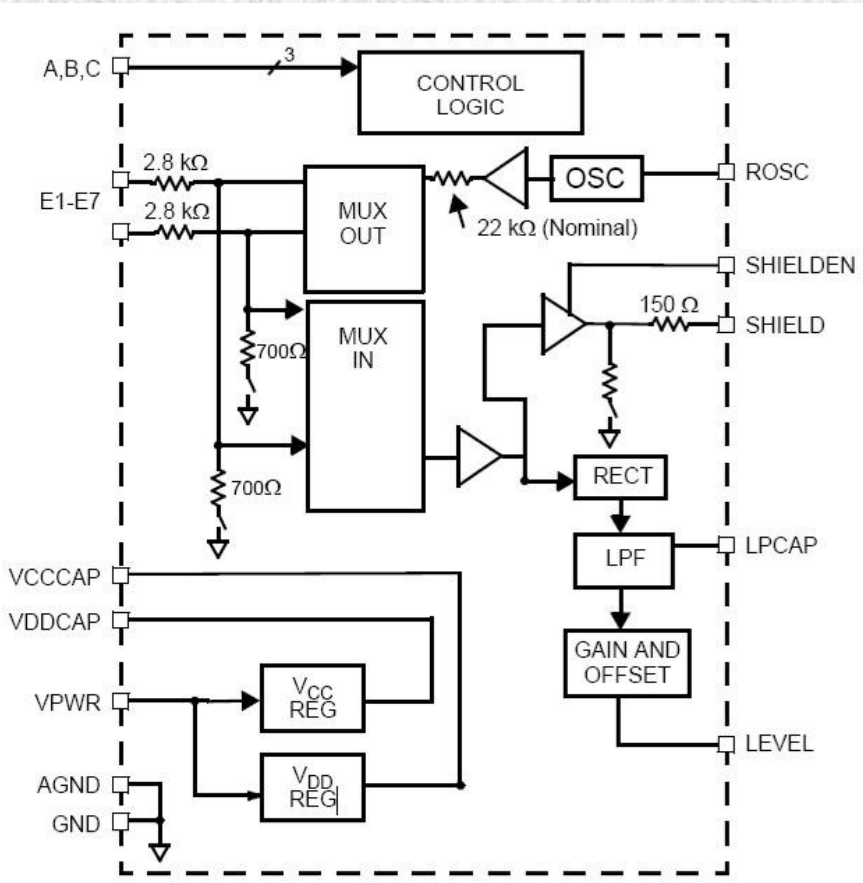



**Figure 2. Simplified Functional Block Diagram**

# Sensors - Capacitive

- Emit an electric field below the sensor.
- Nulled to a known “void” wall area.
- Detect capacitance difference due to underlying material density.


# Sensors – Inductive

- Passive
  - Really doesn't work (Needs excitation)
- Active (emitting)
  - Current flows through inductor
  - Magnetic field mostly ignores non-metals
  - Inductance changes with metallic proximity
  - Short range applications

# Sensors - Inductive

- Passive
  - Really doesn't work (Needs excitation)

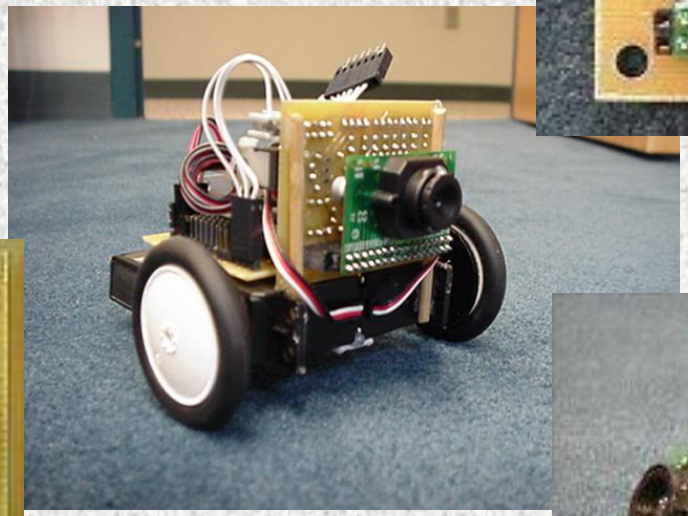
- Active (emitting)
  - Metals affect sensor
  - Current flows through inductor
  - Magnetic field mostly ignores non-metals
  - Inductance changes with metallic proximity
  - Short range applications (~cm or mm)

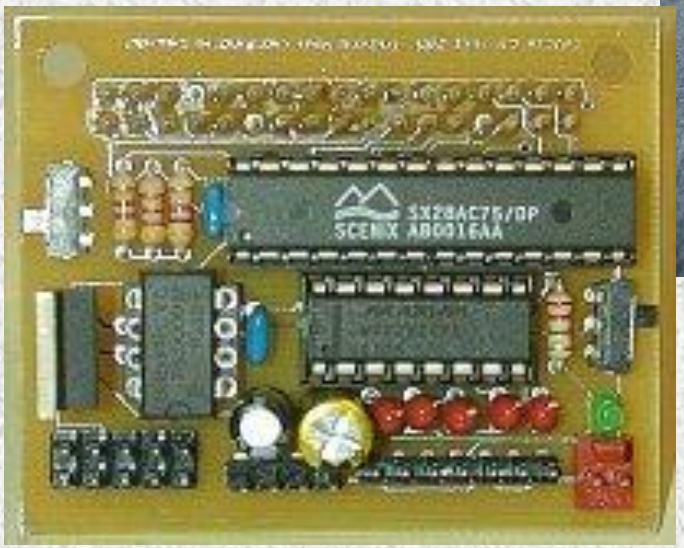
# Sensors – Visual

- Active (emitting)
  - Camera with field of view illumination
  - Looks for particular reflections
  - Filter removes non-significant light sources
  - Linear array senses single axis of motion
- Passive (camera only)
  - Scans field of interest
  - Looks for objects, artifacts, features of interest
  - Processes digital data to simplified interpretation

# Sensors – Visual

- CMUCam
- Linear Optical Array



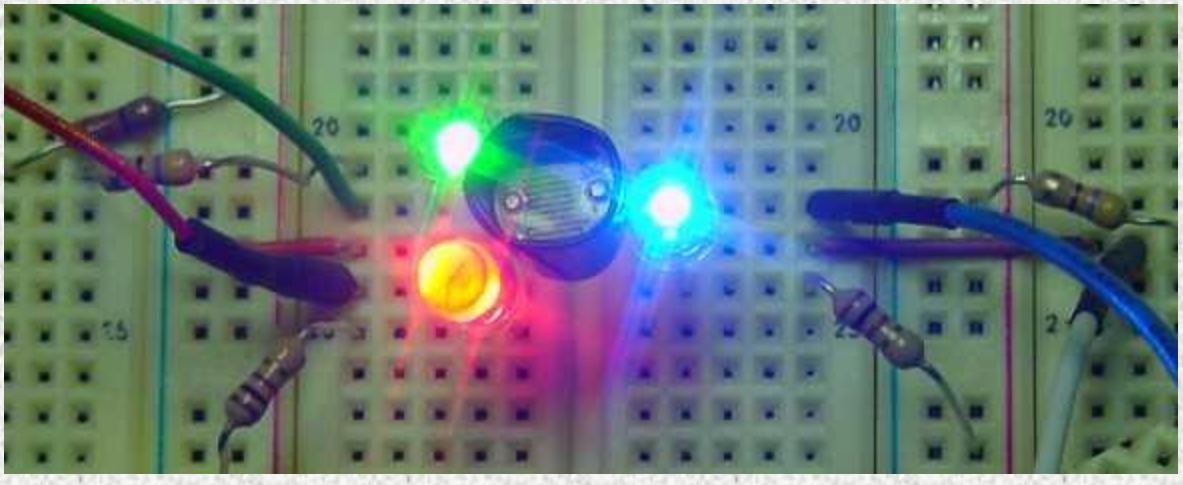



# Sensors – Color

- Active (emitting)
  - Selective field illumination (specific color(s))
  - Sensor filter removes extraneous light sources
  - Output can be analog (prop.) or digital (on/off)
- Passive (sensors only)
  - Different sensors for different colors
  - Color filter removes extraneous light sources
  - Output can be analog (prop.) or digital (on/off)

# Sensors – Color

http://robotroom.com/ColorSensor.html

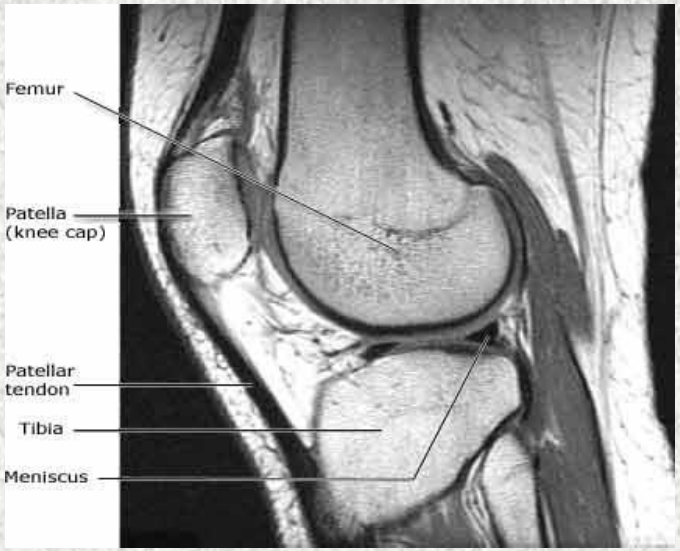


# Sensors – Magnetic

- Active (emitting)
  - Metal detectors
  - Follows metallic strips on or under the floor
  - Magnetometer
  - Magnetic Resonance Imaging (MRI)
- Passive (sensors only)
  - Compass
  - Magnetic field sensor (→oscillating current)

# Sensors – Magnetic

From HowStuffWorks.com & RadiologyInfo.org



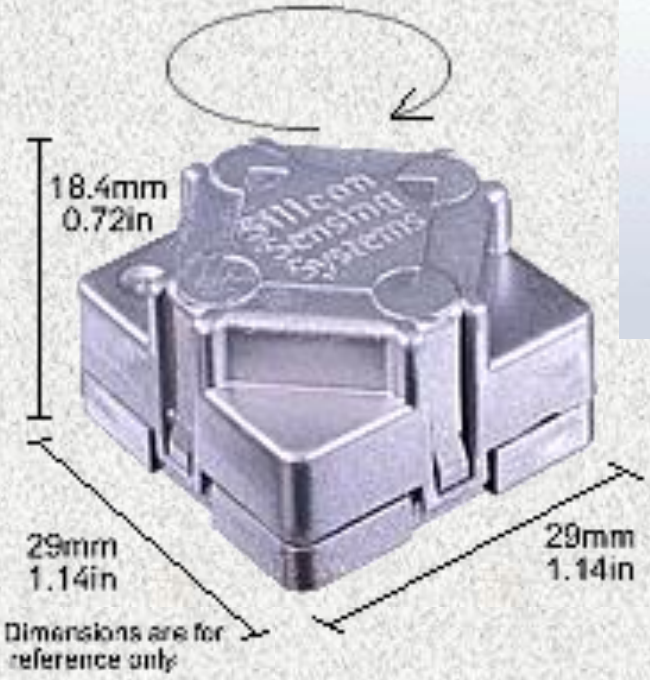

# Sensors – Orientation

- Rate Gyros
  - Output proportional to angular rotation speed
  - Integrate to get position
  - Differentiate to get acceleration
- DC Accelerometer
  - Output proportional to sine of vertical angle

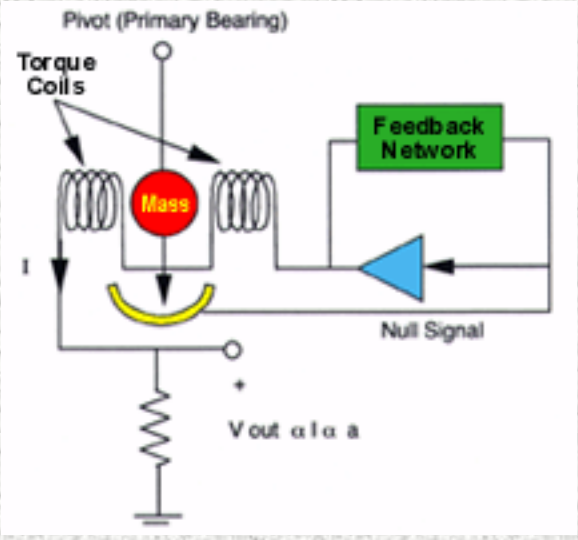
# Sensors – Motion

Rate Gyro – Silicon Sensing Systems

Servo Accel – Sensorland.com





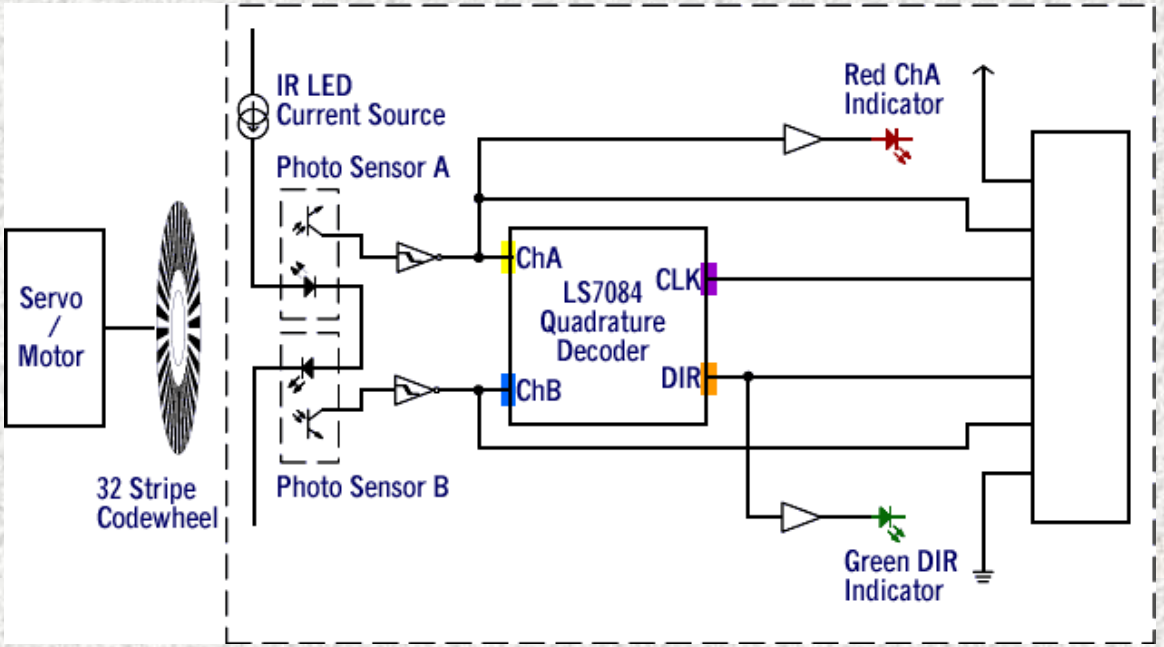


# Sensors – Position/Location

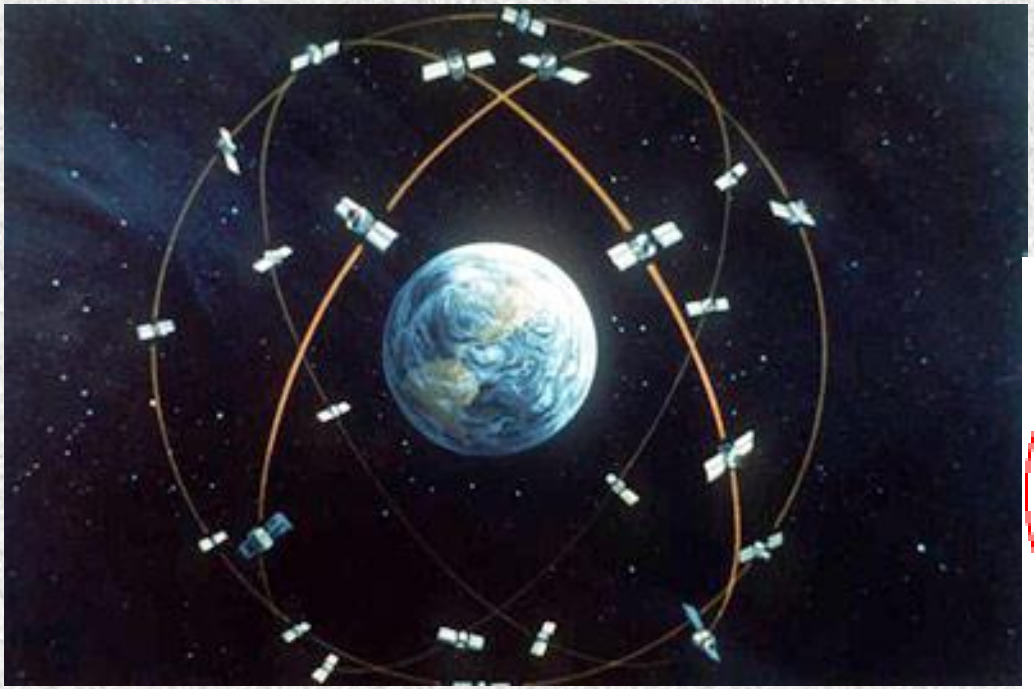
- Wheel Encoders
  - Relative position & motion
  - Integrate/Differentiate for other parameters
- Global Positioning System
  - Absolute position/location on earth
  - Local differential error correction
  - Integrate/Differentiate for other parameters

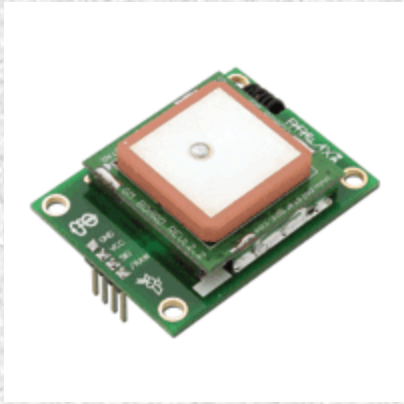
# Wheel Encoders

- Nubotics.com, $27
- Jun 98, Oct 2000 Encoder

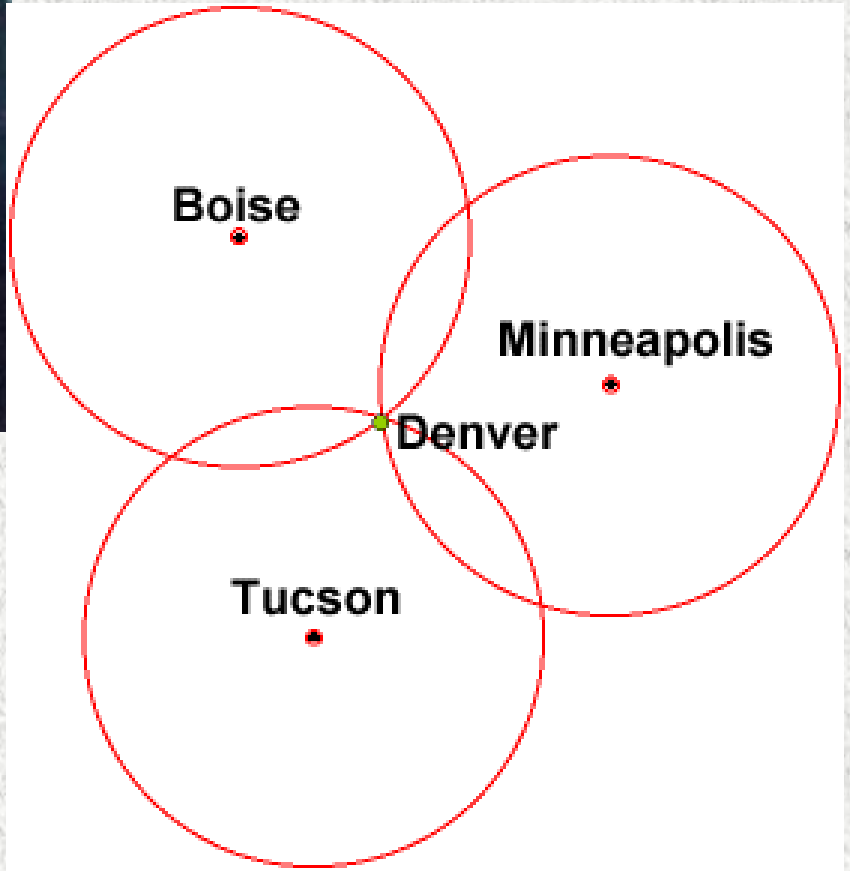


# Sensors – Position/Location

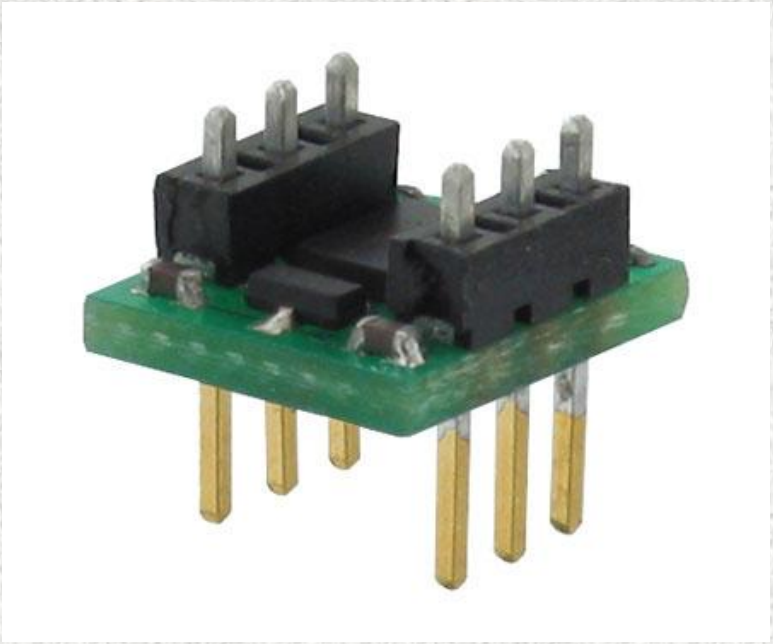


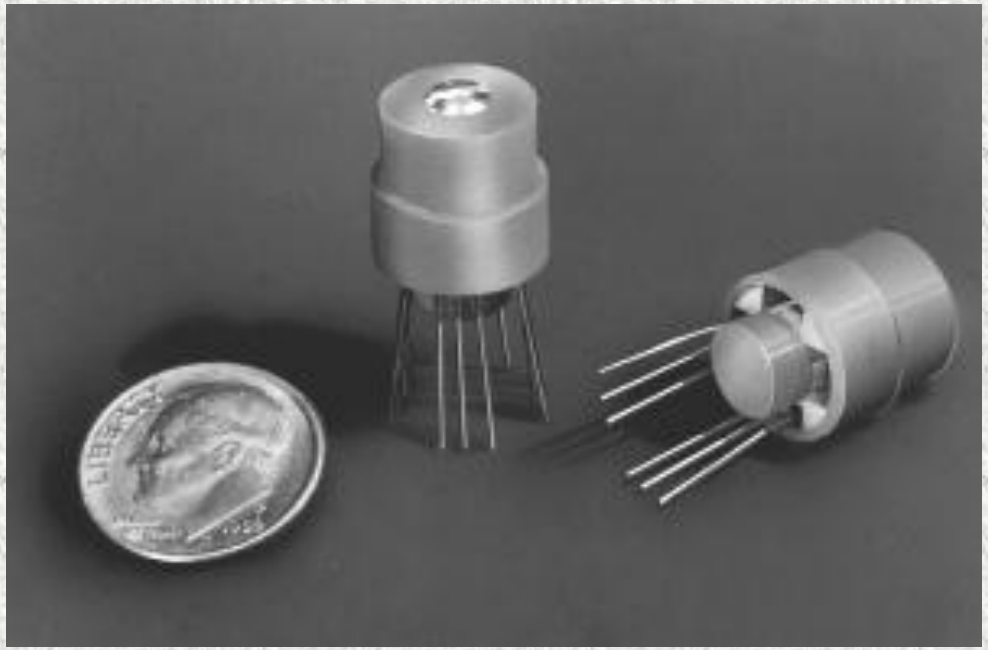


- Parallax.com
- $80



# Sensors – Compass (Orientation)





- Track bearing & distance to determine position
- L: Parallax.com, $30
- R: Dinsmoresensors.com, $13-$37

# Sensors – Voltage

- Passive – Senses electric field
- Fluke Electric Field Sensors

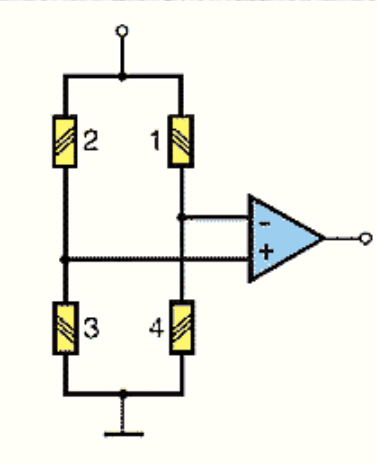
$23

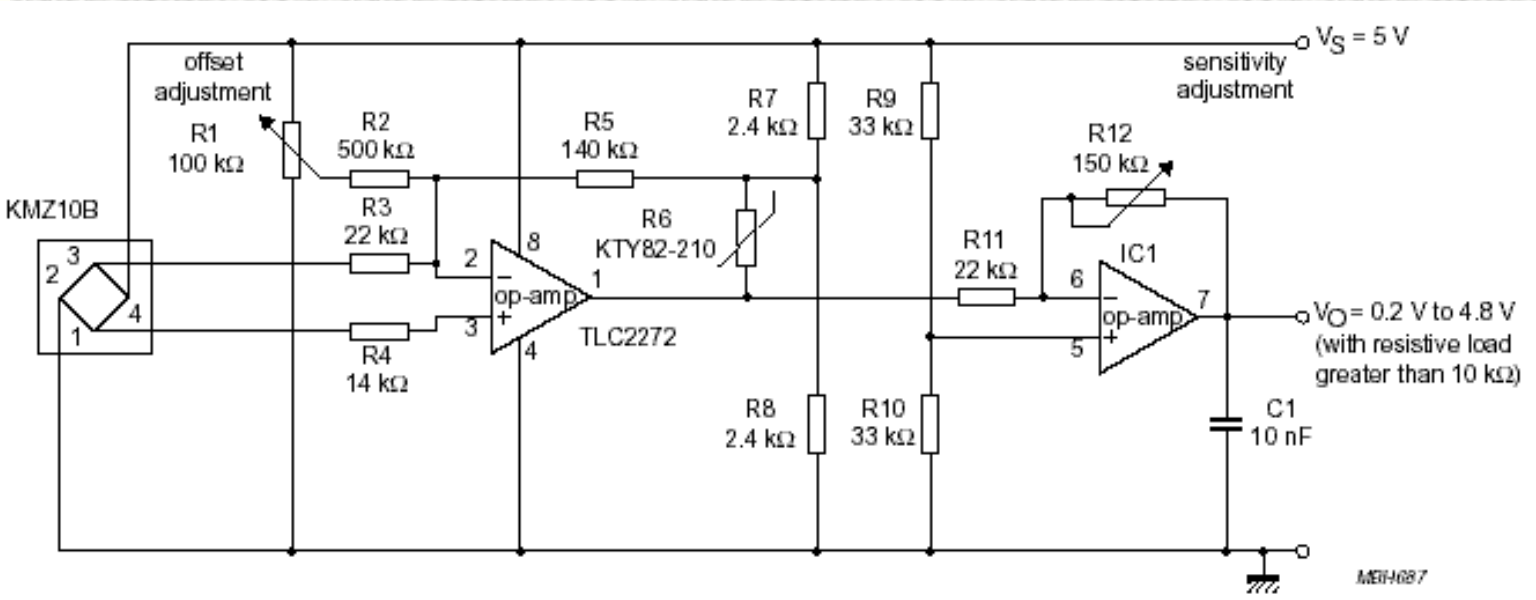
$25


$24

# Sensors – Current

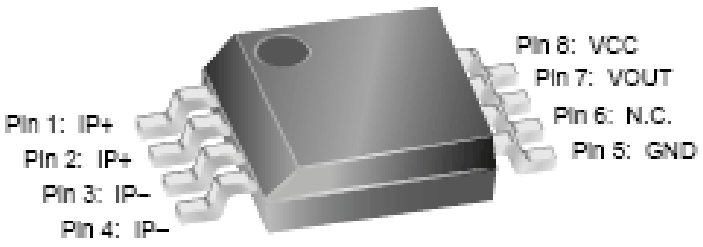
- Series measurement with Hall Effect device
- Current loop (coil), then amplified
- Magnetoresistive (Wheatstone bridge)



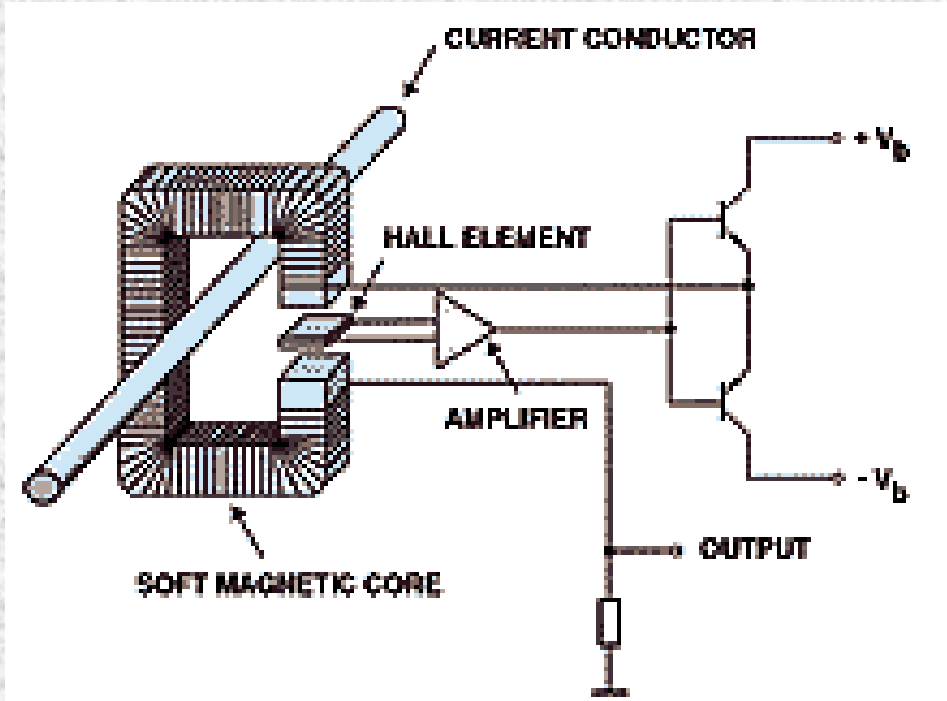



# Sensors – Current

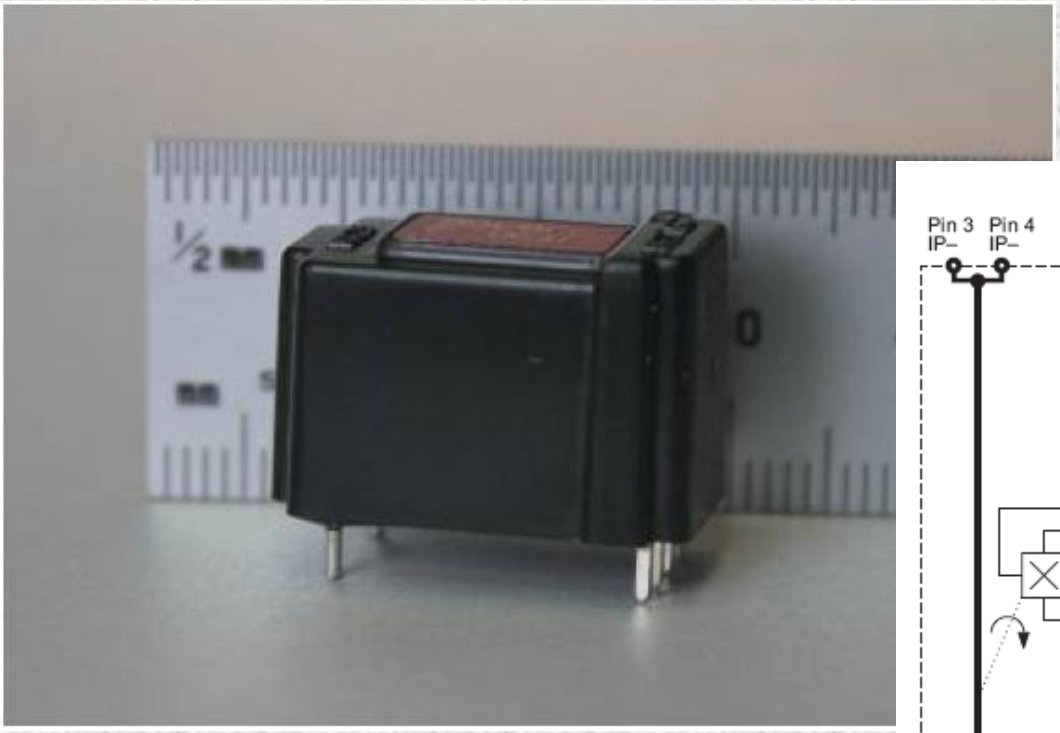
Package LC

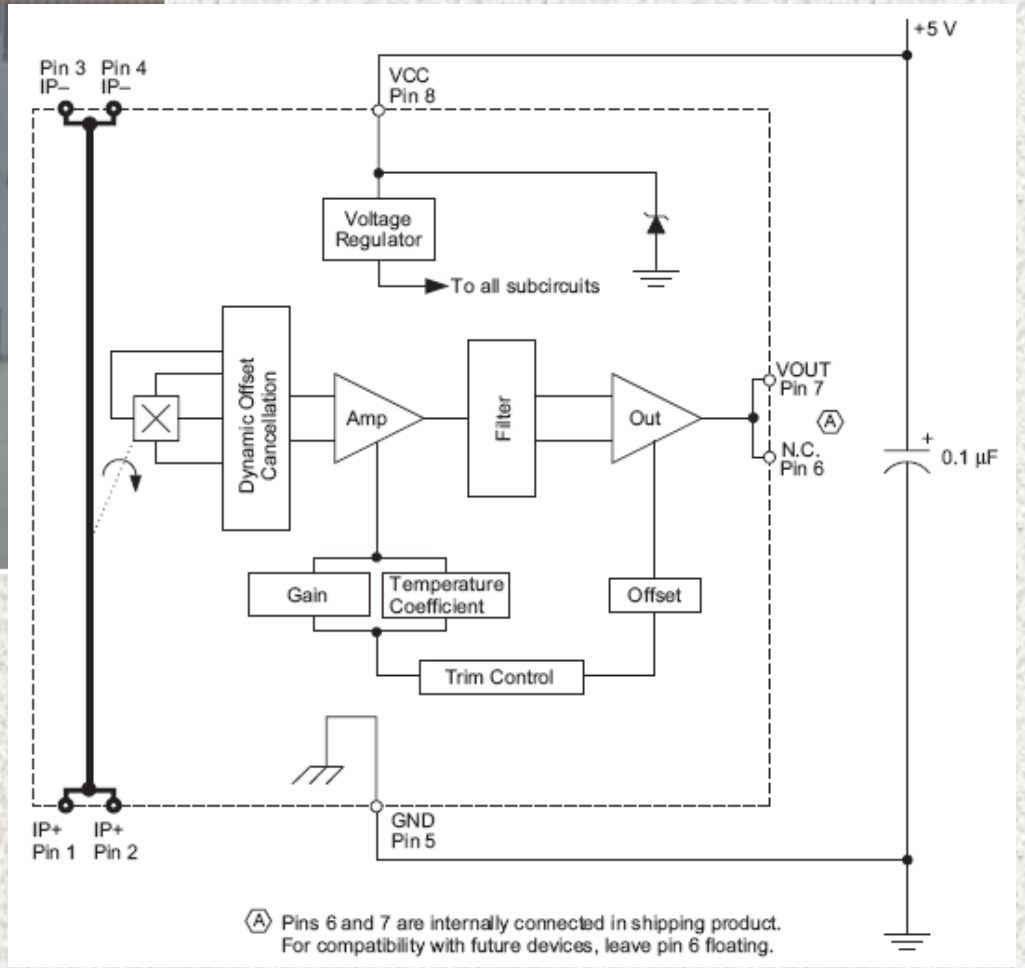



Pins 6 and 7 are internally connected in shipping product. For compatibility with future devices, leave pin 6 floating.



# Sensors – Current



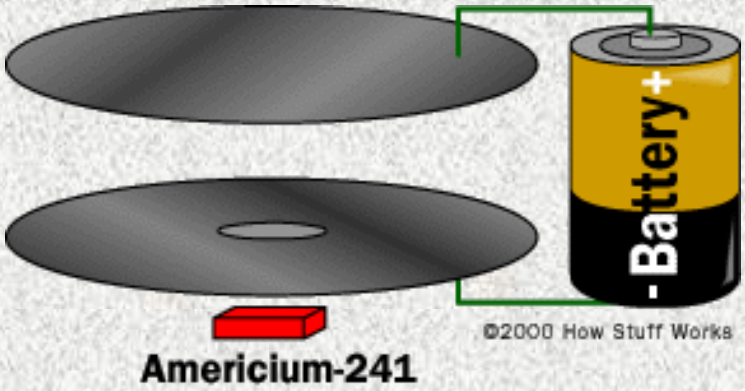


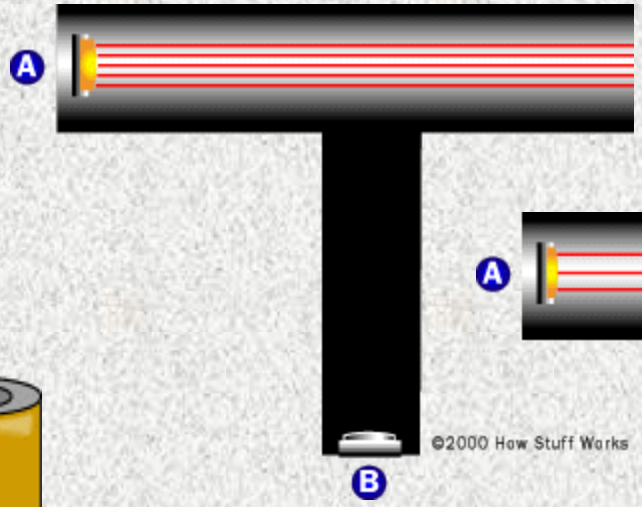
# Sensors – Chemical

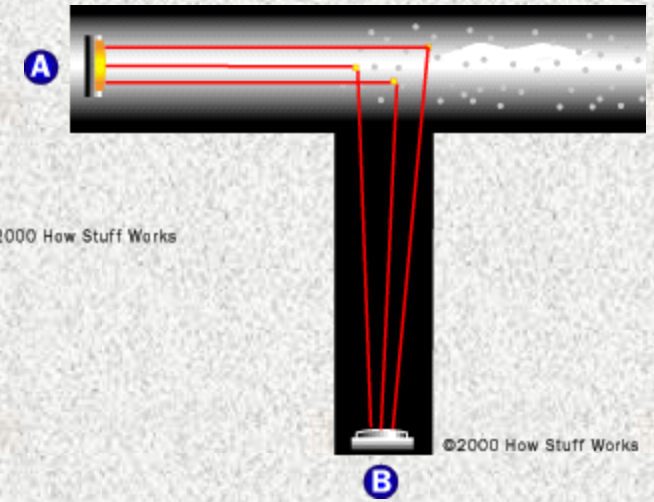
- Passive (sensors only)
- Active (optical emitter/photo sensor)

# Sensors – Chemical

- Smoke Detectors - Cheap, readily available, $5
- Oxygen concentration sensors - CO, $H_4S$, $CH_4$, pricey
- See HowStuffWorks.com



# Sensors – Conclusion

- Sensors provide a way of simulating “aliveness”
- Sensors give robots environmental awareness
- Sensors provide of means of human protection
- Sensors help robot preserve itself
- Sensors enable goal seeking
- Sensors enable closed-loop interaction
- Sensors make robots interesting
- Sensors can make programming “challenging”

Sensors

Q&A
Comments
Discussion

# Backup Slides

# Parallax Sensor Sampler - $165

- Memsic 2125 Accelerometer
- Sensirion Temperature and Humidity Sensor
- Flexiforce Demo Kit
- PING))) Ultrasonic Sensor
- PIR Sensor
- Hitachi HM55B Compass Module
- Hitachi H48C Tri-Axis Accelerometer Module
- Piezo Film Vibra Tab Mass
- QTI Sensor (IR Surface Color)

# Sensor Vendor/Info Links

http://www.dinsmoresensors.com
http://www.fluke.com
http://www.howstuffworks.com
http:// www.lynxmotion.com
http://www.magnetometer.org
http:// www.nubotics.com
http:// www.parallax.com
http://www.raztec.co.nz
http:// www.robotics.com
http:// www.robotroom.com
http://www.sensorland.com
http://www.seattlerobotics.org/encoder
http:// www.solarbotics.com

# Demo Equipment

- ✓ Fluke E-Field Detectors (big+small)
- ✓ Stud finder
- ✓ Light Chaser Robots
- ✓ Sharp IR Distance Sensor
- ✓ Polaroid Camera (Ultrasonic Sensor)
- ✓ Rate Gyro
- ✓ IR Detector (TV Remote)
- ✓ Motion detector
- ✓ Smoke detector
- ✓ Electronic compasses
- ✓ Ask people to bring in their sensory stuff
- ✓ Laser pointer, video camera+tripod, light, cables