Introduction

- Industrial robot requires sensory feedback to:
  1. Locate randomly placed object;
  2. Allow for variations in shape of objects;
  3. Protect against dangerous and unexpected situations. Especially if the robot must work close to humans:
  4. Allow “intelligent” recovery form error conditions;
  5. Perform quality control.
- The main objective of incorporating sensors in robotic system is to enable robots to work in nonstructural and random environments.
- Sensors will make robots more intelligent. But the associated robotic software must have the ability to receive data from the sensors and to process the necessary real time information and commands needed for the decision making.

What is Sensing ?

- Collect information about the world
- Sensor - an electrical/mechanical/chemical device that maps an environmental attribute to a quantitative measurement
- Each sensor is based on a *transduction principle -* conversion of energy from one form to another

Transduction to electronics

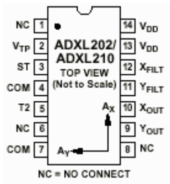
- Thermistor: temperature-to-resistance
- Electrochemical: chemistry-to-voltage
- Photocurrent: light intensity-to-current
- Pyroelectric: thermal radiation-to-voltage
- Humidity: humidity-to-capacitance
- Length (LVDT: Linear variable differential transformers) : position-to-inductance
- Microphone: sound pressure-to-<anything>

Human sensing and organs

- Vision: eyes (optics, light)
- Hearing: ears (acoustics, sound)
- Touch: skin (mechanics, heat)
- Odor: nose (vapor-phase chemistry)
- Taste: tongue (liquid-phase chemistry)

Counterpart?

Sensors Used in Robot



Accelerometer

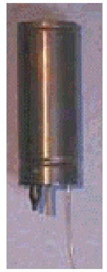
Gyro

Pendulum Resistive Tilt Sensors

Piezo Bend Sensor

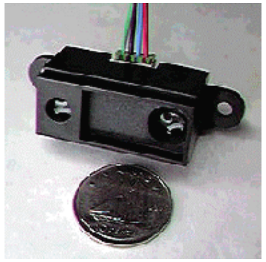
Metal Detector

Gas Sensor

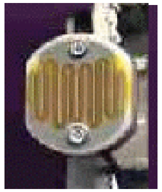


Gieger-Muller Radiation Sensor

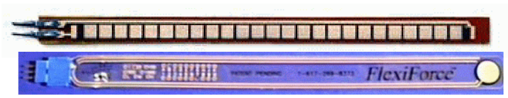
Pyroelectric Detector



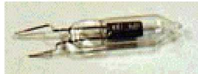
Digital Infrared Ranging



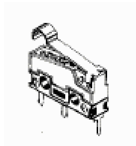
CDS Cell Resistive Light Sensor



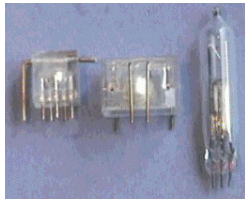
Resistive Bend Sensors



UV Detector

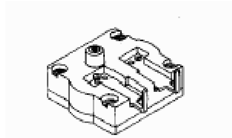


Limit Switch

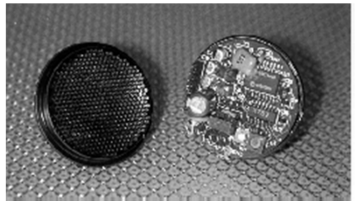


Mechanical Tilt Sensors

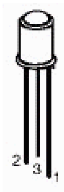
Touch Switch

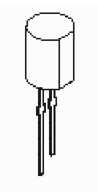


Pressure Switch

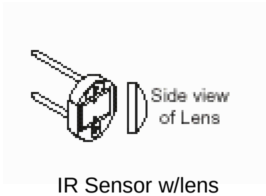


Miniature Polaroid Sensor

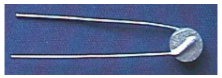




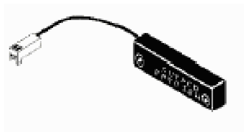
IR Pin Diode



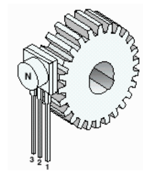
IR Sensor w/lens



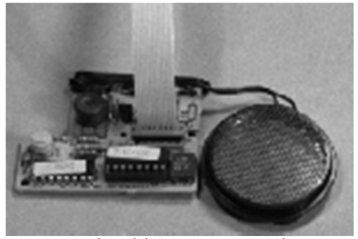
Thyristor



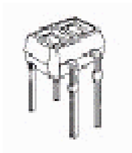
Magnetic Sensor



Hall Effect Magnetic Field Sensors



Polaroid Sensor Board

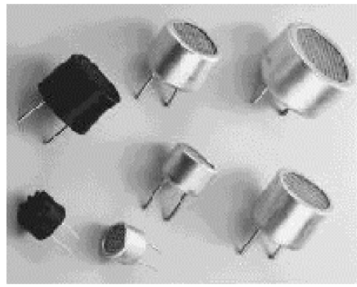


IR Reflection Sensor

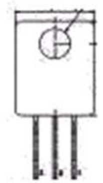
IR Amplifier Sensor

IRDA Transceiver

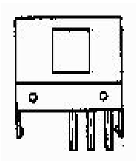
Magnetic Reed Switch



Piezo Ultrasonic Transducers



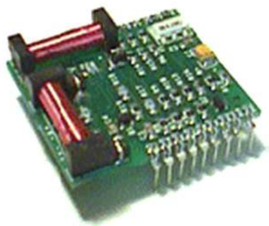
Lite-On IR Remote Receiver



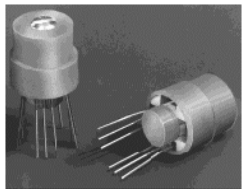
Radio Shack Remote Receiver

IR Modulator Receiver

Solar Cell



Compass



Compass

Sensors used in robot navigation

- Resistive sensors
  - bend sensors, potentiometer, resistive photocells, ...
- Tactile sensors
  - contact switch, bumpers…
- Infrared sensors
  - Reflective, proximity, distance sensors…
- Ultrasonic Distance Sensor
- Inertial Sensors (measure the second derivatives of position)
  - Accelerometer, Gyroscopes,
- Orientation Sensors
  - Compass, Inclinometer
- Laser range sensors
- Vision
- Global Positioning System

Classification of Sensors

- Internal state (proprioception) v.s. external state (exteroceptive)
  - feedback of robot internal parameters, e.g. battery level, wheel position, joint angle, etc,
  - observation of environments, objects
- Active v.s. non-active
  - emitting energy into the environment, e.g., radar, sonar
  - passively receive energy to make observation, e.g., camera
- Contact v.s. non-contact
- Visual v.s. non-visual
  - vision-based sensing, image processing, video camera

Robotic Sensor Classification

- In general, robotic sensors can be divided into two classes:

  i. **Internal state sensors** - device being used to measure the position, velocity and acceleration of the robot joint and/or end-effector. These devices are potentiometer, tachometers, synchros, resolvers, differential transformers, optical interrupters, optical encoders and accelerometer.

  ii. **External state sensors** – device being used to monitor the relationship between the robot kinematics and/or dynamics with its task, surrounding, or the object being manipulated.

•Some tasks requirements features:

•Insertion Monitoring
•Assembly Verification
•Detection of Reject Parts
•Recognition of Part Types
•Assembly Test Operations
•Check Gripper/Tool Operation
•Location & Orientation of Parts
•Workspace Intrusion Detection
•Check Correct Manipulation of Parts
•Analysis of Spatial Relations Between Parts

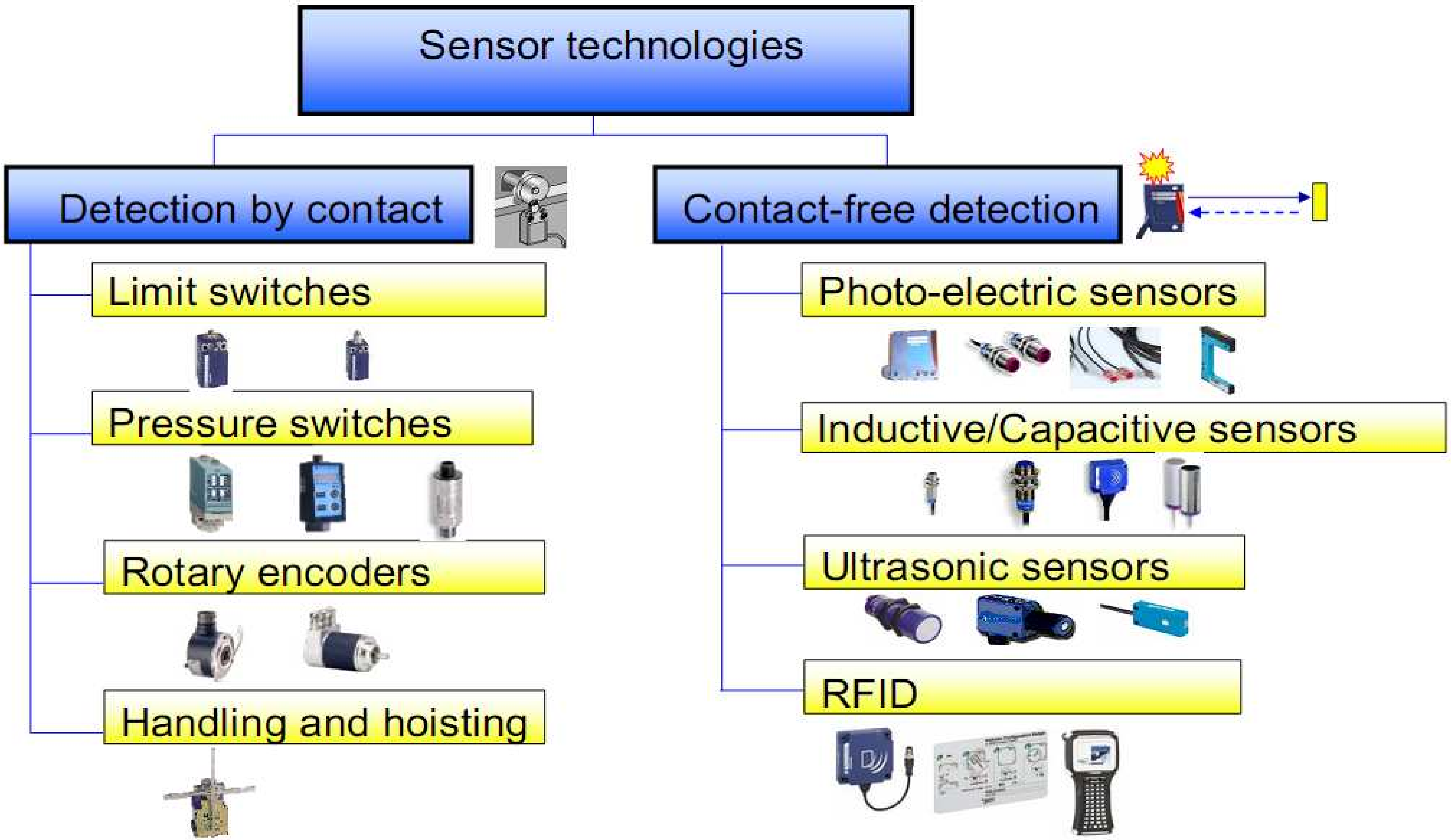
Some typical sensor operational data:

- Ultrasonics
- Resistive Effects
- Capacitive Efects
- Piezo-Electric Effects
- Visible Light Imaging
- Photo-Electric & Infrared
- Mechanical Switching
- Inductive Effects
- Thermal Effects
- Hall Effect

Primary physical mechanisms employed in sensors:

Cost
Range
Accuracy
Repeatability
Power Requirements
Output Signal Specification
Processing Reuirements
Sensitivity
Reliability
Weight
Seze

Sensors technologies :



SENSORS FOR INDUSTRIAL ROBOTS

Proximity and Range Sensors

Tactile Sensors

Vision Sensors

Miscellaneous Sensors

PROXIMITY AND RANGE SENSORS

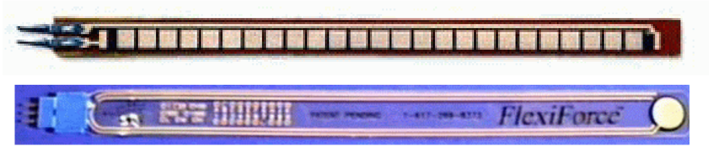
PROXIMITY & RANGE SENSORS

- It is a technique of detecting the presence or absence of an object with electronic noncontact sensors.
- Typical application of proximity sensors includes:
  - Object detection
  - Collision avoidance
  - Object verification & counting
- Commonly available proximity sensors are:

1. Photoelectric/optical sensors
2. Inductive proximity sensors
3. Capacitive proximity sensors
4. Ultrasonic proximity sensors

Resistive Sensors

Bend Sensors
- Resistance = 10k to 35k
- As the strip is bent, resistance increases



Resistive Bend Sensor

Potentiometers
- Can be used as position sensors for sliding mechanisms or rotating shafts
- Easy to find, easy to mount

Potentiometer

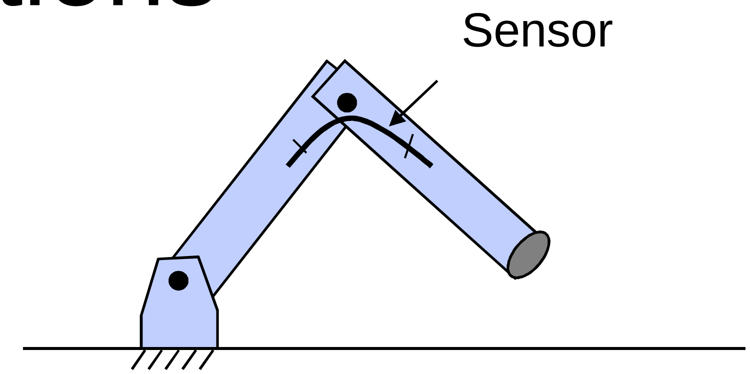
Light Sensor (Photocell)
- Good for detecting direction/presence of light
- Non-linear resistance
- Slow response to light changes

Photocell

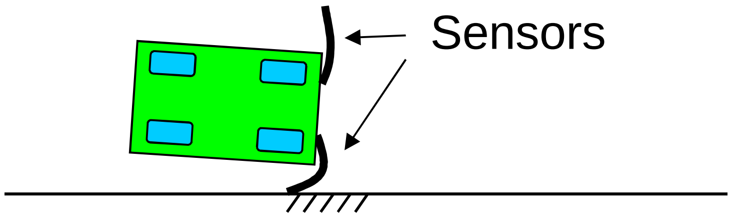
R is small when brightly illuminated

Applications

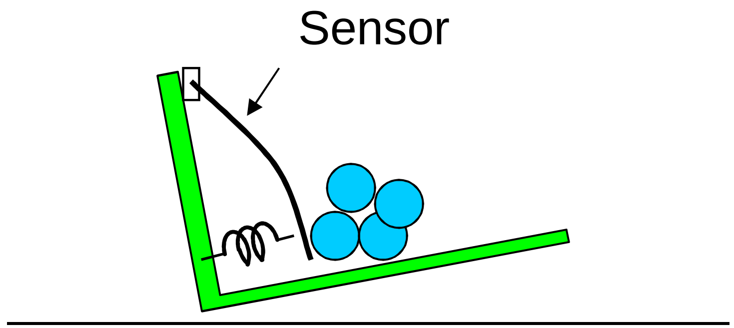
- Measure bend of a joint



- Wall Following/Collision Detection



- Weight Sensor

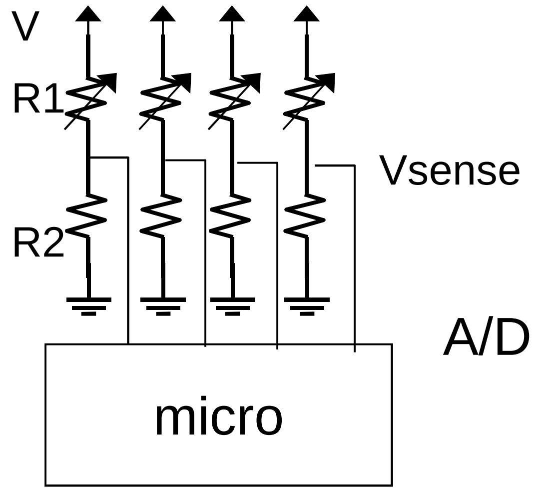


Inputs for Resistive Sensors

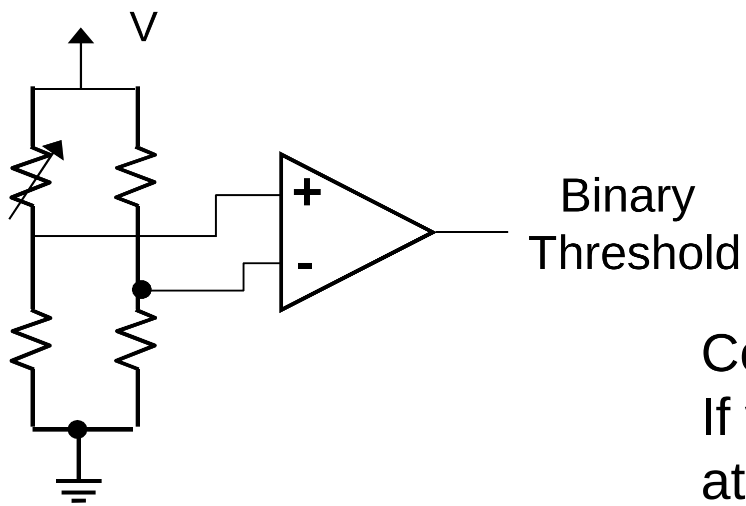
Voltage divider:

You have two resisters, one is fixed and the other varies,
as well as a constant voltage

$$V_{sense} = \frac{R_2}{R_1 + R_2} V$$



A/D converter



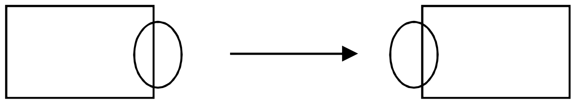
Digital I/O

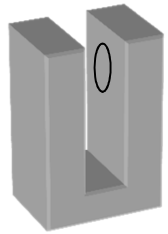
Comparator:
If voltage at + is greater than at -, digital high out

Infrared Sensors

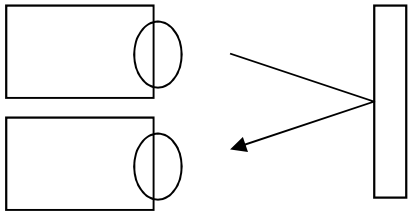
- Intensity based infrared
  - Reflective sensors
  - Easy to implement
  - susceptible to ambient light
- Modulated Infrared
  - Proximity sensors
  - Requires modulated IR signal
  - Insensitive to ambient light
- Infrared Ranging
  - Distance sensors
  - Short range distance measurement
  - Impervious to ambient light, color and reflectivity of object

Intensity Based Infrared

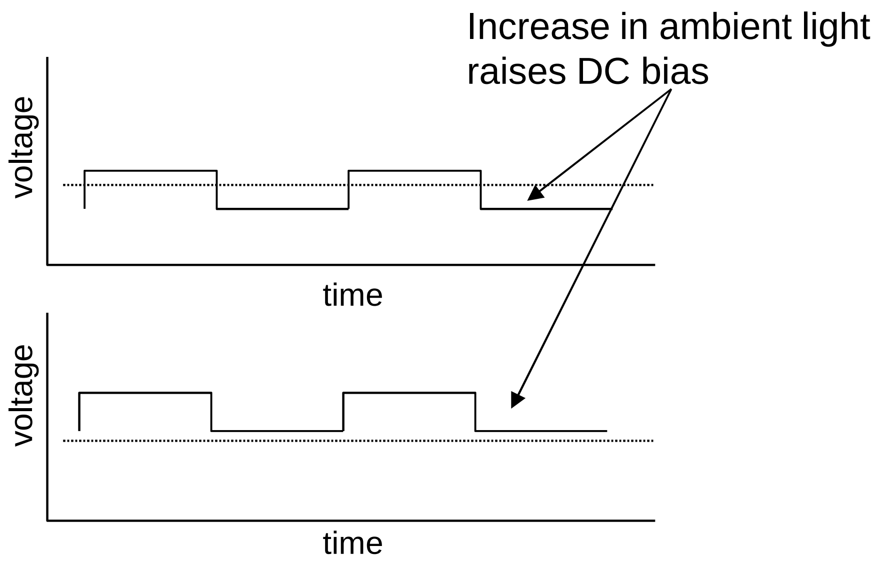




Break-Beam sensor



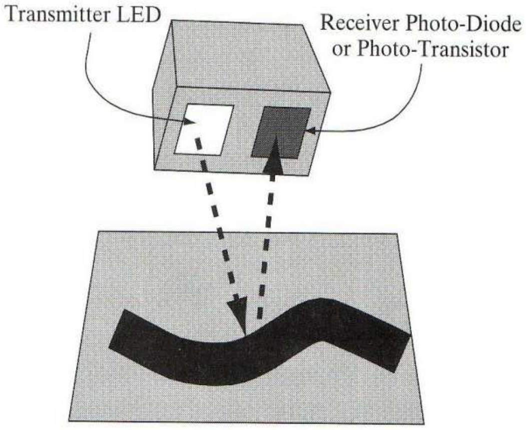
Reflective Sensor



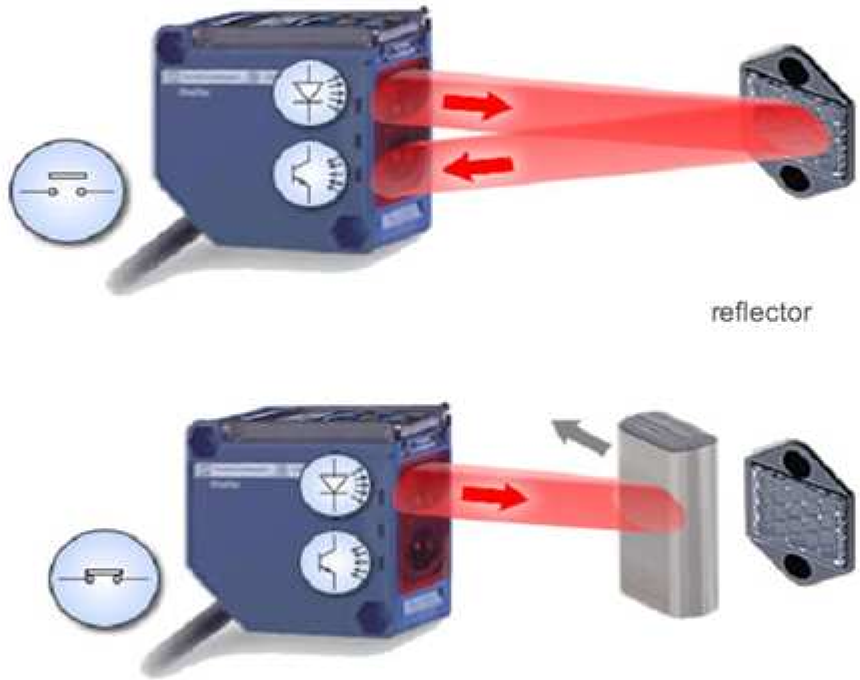
- Easy to implement (few components)
- Works very well in controlled environments
- Sensitive to ambient light

IR Reflective Sensors

- Reflective Sensor:
  - Emitter IR LED + detector photodiode/phototransistor
  - Phototransistor: the more light reaching the phototransistor, the more current passes through it
  - A beam of light is reflected off a surface and into a detector
  - Light usually in infrared spectrum, IR light is invisible

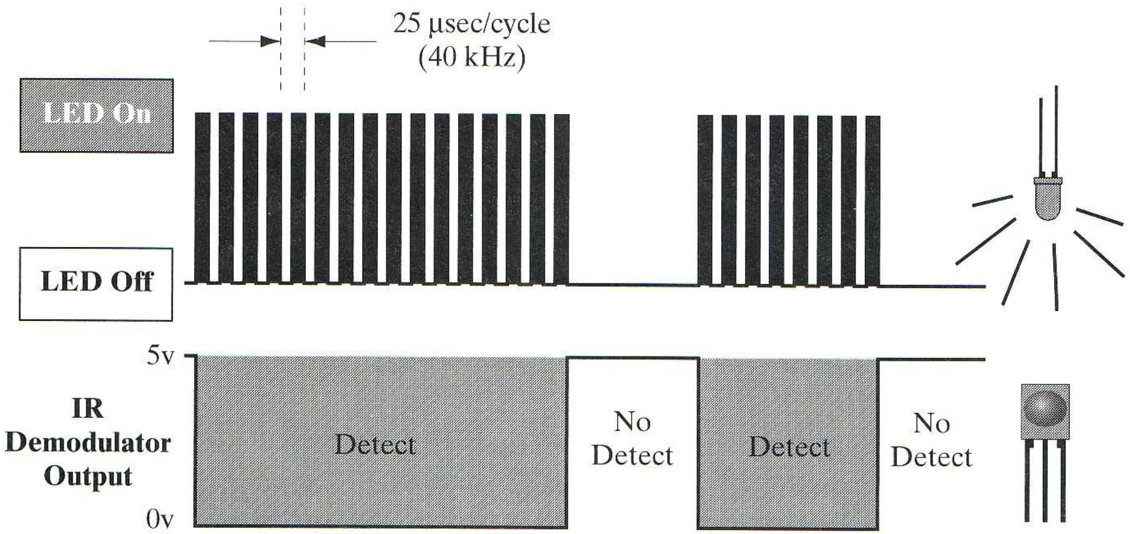


- Applications:
  - Object detection,
  - Line following, Wall tracking
  - Optical encoder (Break-Beam sensor)
- Drawbacks:
  - Susceptible to ambient lighting
    - Provide sheath to insulate the device from outside lighting
  - Susceptible to reflectivity of objects
  - Susceptible to the distance between sensor and the object


reflector

Modulated Infrared

- Modulation and Demodulation
  - Flashing a light source at a particular frequency
  - Demodulator is tuned to the specific frequency of light flashes. (32kHz~45kHz)
  - Flashes of light can be detected even if they are very week
  - Less susceptible to ambient lighting and reflectivity of objects
  - Used in most IR remote control units, proximity sensors

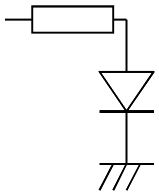


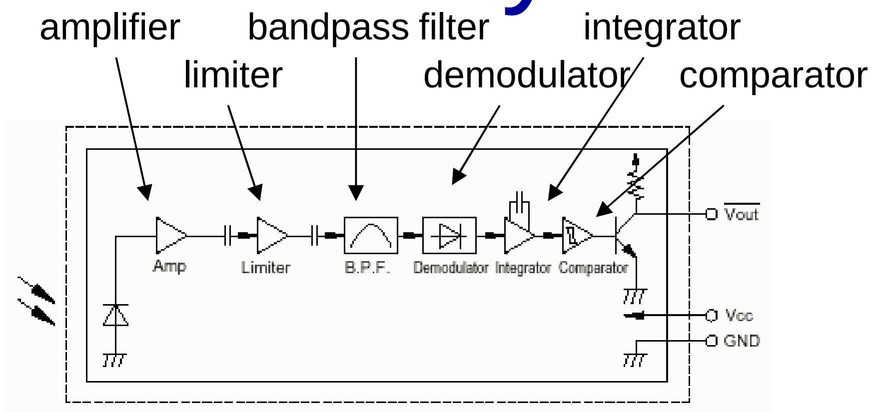
Negative true logic:

Detect = 0v

No detect = 5v

IR Proximity Sensors

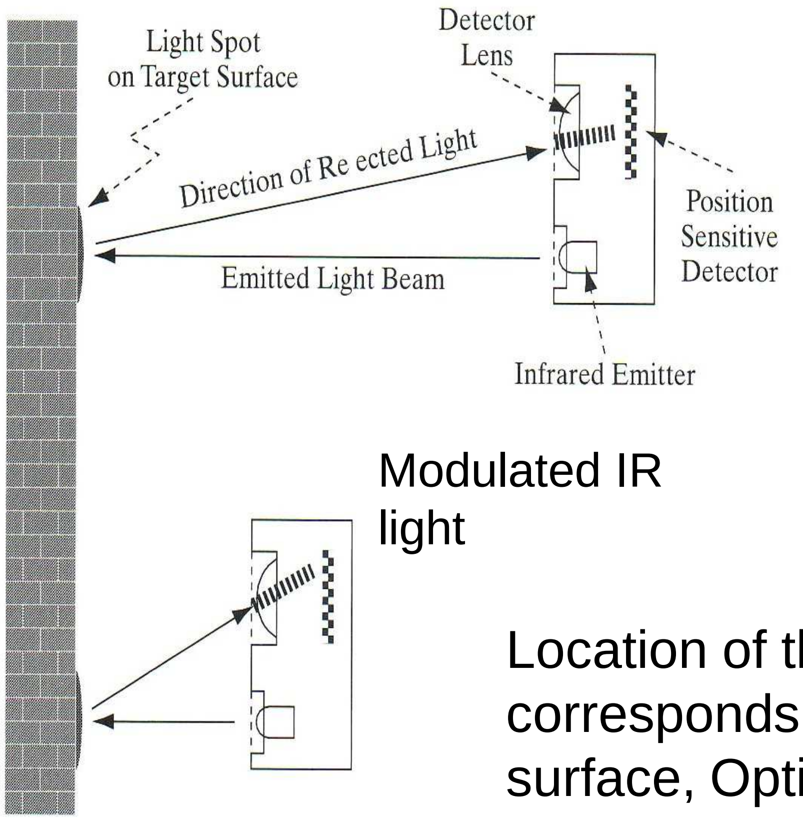




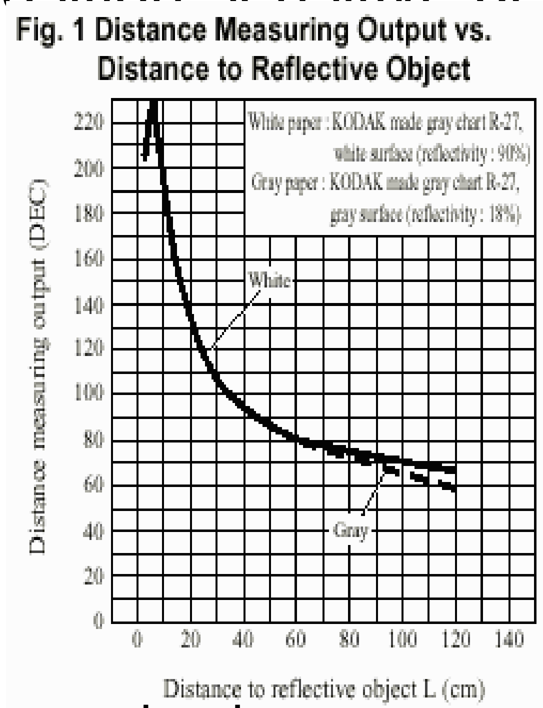
- Proximity Sensors:
  - Requires a modulated IR LED, a detector module with built-in modulation decoder
  - Current through the IR LED should be limited: adding a series resistor in LED driver circuit
  - Detection range: varies with different objects (shiny white card vs. dull black object)
  - Insensitive to ambient light
- Applications:
  - Rough distance measurement
  - Obstacle avoidance
  - Wall following, line following

IR Distance Sensors

- Basic principle of operation:
  - IR emitter + focusing lens + position-sensitive detector



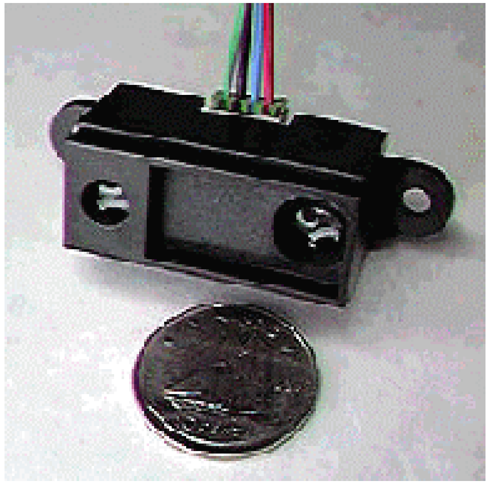
Modulated IR light



Location of the spot on the detector corresponds to the distance to the target surface, Optics to covert horizontal distance to vertical distance

IR Distance Sensors

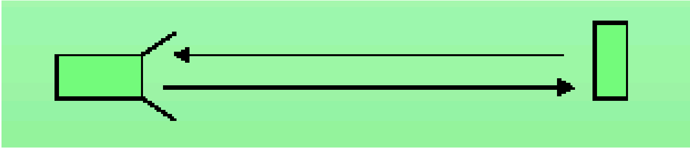
- Sharp GP2D02 IR Ranger
  - Distance range: 10cm (4") ~ 80cm (30").
  - Moderately reliable for distance measurement
  - Immune to ambient light
  - Impervious to color and reflectivity of object
  - Applications: distance measurement, wall following, …



Range Finder

(Ultrasonic, Laser)

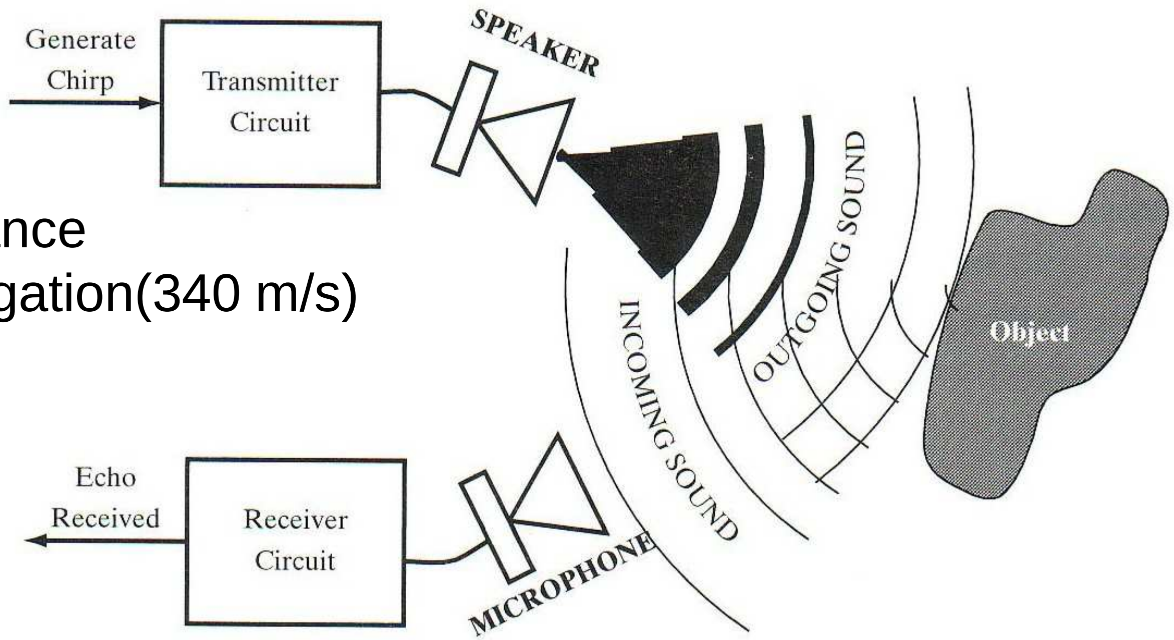
Range Finder



- Time of Flight
- The measured pulses typically come form ultrasonic, RF and optical energy sources.
  - **D = v * t**
  - D = round-trip distance
  - v = speed of wave propagation
  - t = elapsed time
- Sound = 0.3 meters/msec
- RF/light = 0.3 meters / ns (Very difficult to measure short distances 1-100 meters)

Ultrasonic Sensors

- Basic principle of operation:
  - Emit a quick burst of ultrasound (50kHz), (human hearing: 20Hz to 20kHz)
  - Measure the elapsed time until the receiver indicates that an echo is detected.
  - Determine how

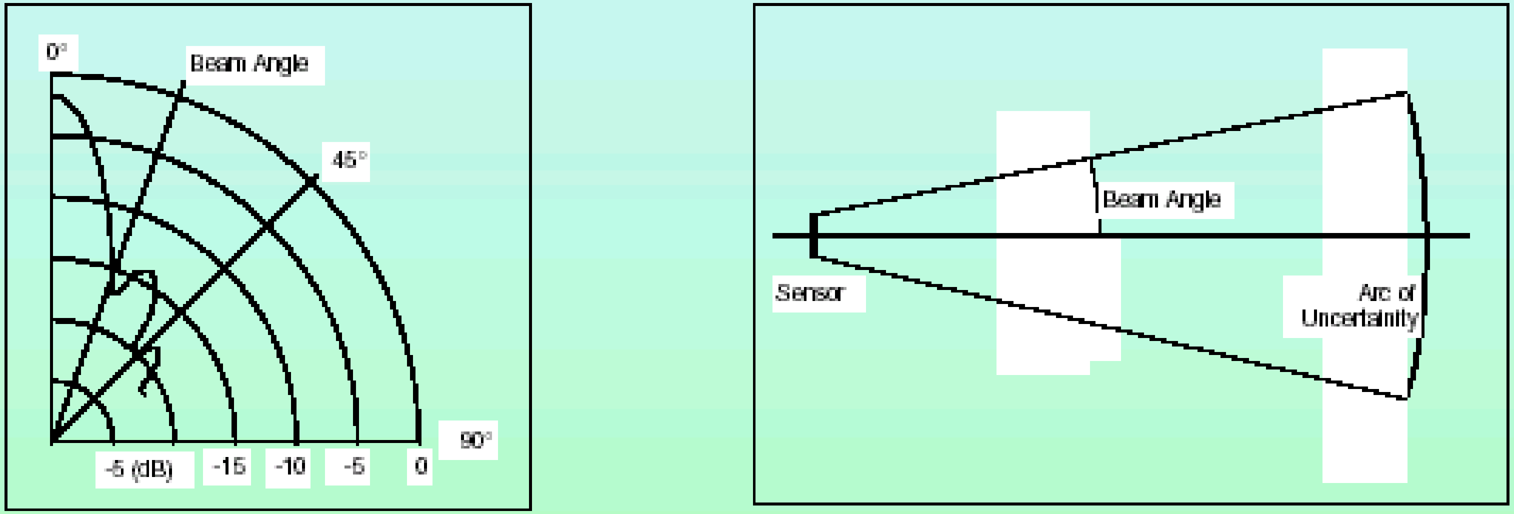


- **D = v * t**

D = round-trip distance
v = speed of propagation(340 m/s)
t = elapsed time

Bat, dolphin, …

Ultrasonic Sensors



Sensor Specification

Sensor Model, angle = 15 degrees

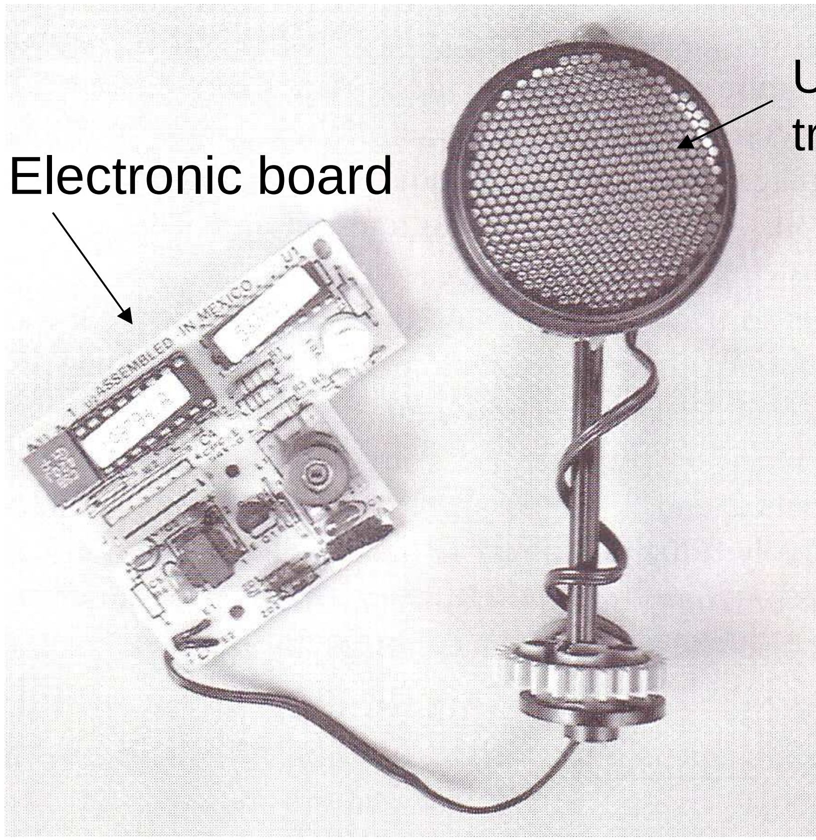
- Ranging is accurate but bearing has a 30 degree uncertainty. The object can be located anywhere in the arc.
- Typical ranges are of the order of several centimeters to 30 meters.
- Another problem is the propagation time. The ultrasonic signal will take 200 msec to travel 60 meters. (30 meters roundtrip @ 340 m/s)

Ultrasonic Sensors

- Polaroid ultrasonic ranging system
  - It was developed for auto-focus of cameras.
  - Range: 6 inches to 35 feet

Transducer Ringing:

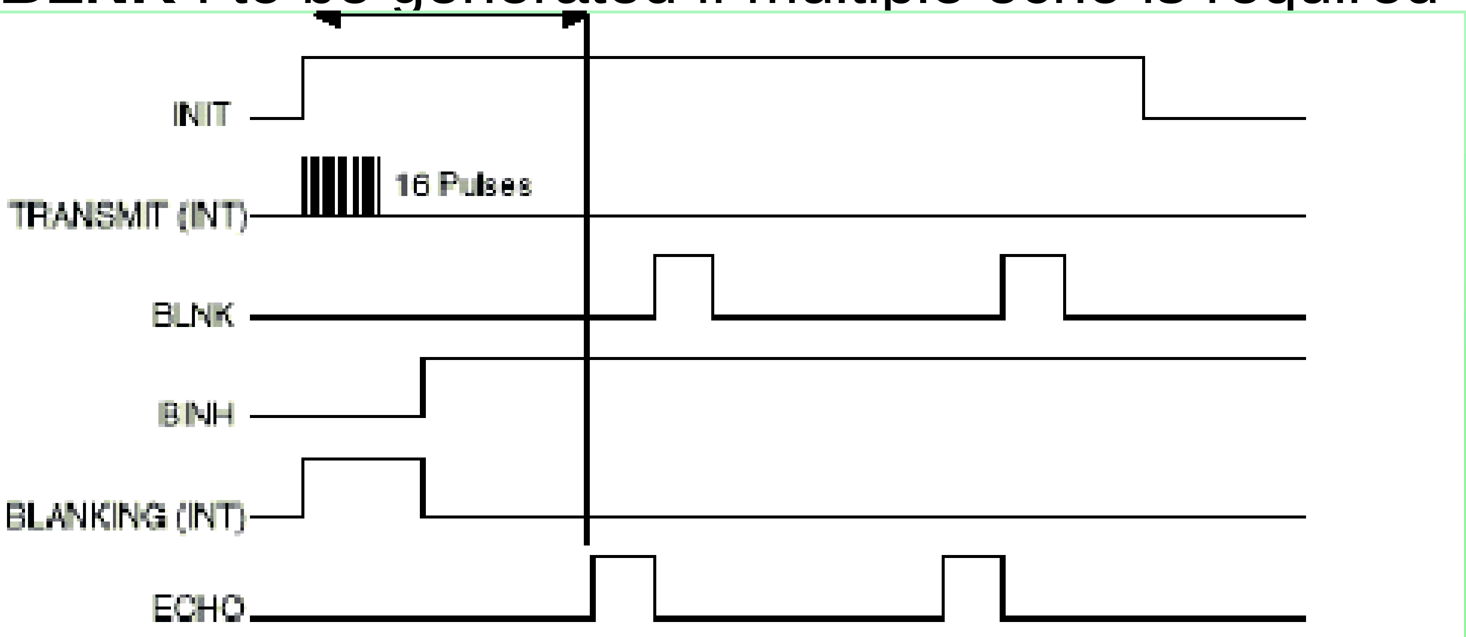
- transmitter + receiver @ 50 KHz
- Residual vibrations or ringing may be interpreted as the echo signal
- Blanking signal to block any return signals for the first 2.38ms after transmission



http://www.acroname.com/robotics/info/articles/sonar/sonar.html

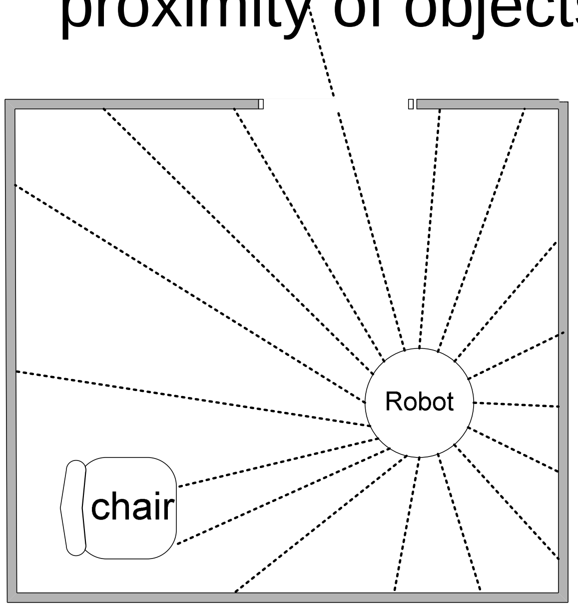
Operation with Polaroid Ultrasonic

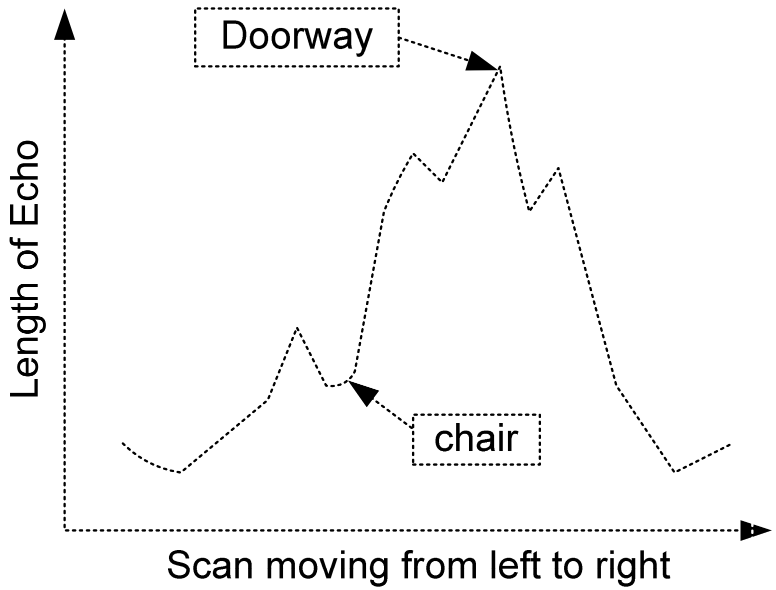
- The Electronic board supplied has the following I/0
  - **INIT** : trigger the sensor, (16 pulses are transmitted)
  - **BLANKING** : goes high to avoid detection of own signal
  - **ECHO** : echo was detected.
  - **BINH** : goes high to end the blanking (reduce blanking time < 2.38 ms)
  - **BLNK** : to be generated if multiple echo is required



Ultrasonic Sensors

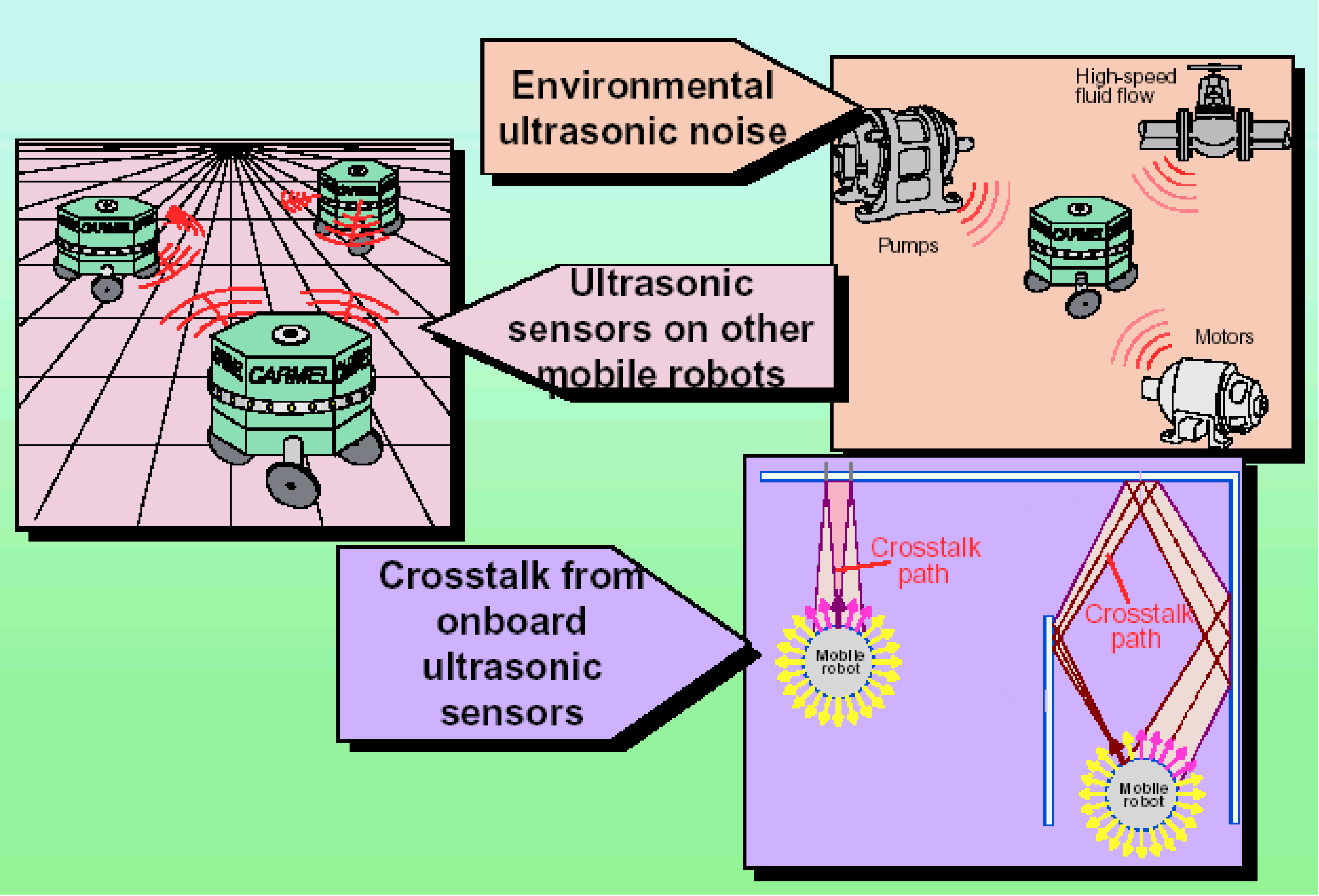
- Applications:
  - Distance Measurement
  - Mapping: Rotating proximity scans (maps the proximity of objects surrounding the robot)





Scanning at an angle of 15º apart can achieve best results

Noise Issues



Laser Ranger Finder

- Range 2-500 meters
- Resolution : 10 mm
- Field of view : 100 - 180 degrees
- Angular resolution : 0.25 degrees
- Scan time : 13 - 40 msec.
- These lasers are more immune to Dust and Fog

http://www.sick.de/de/products/categories/safety/

Thank you!