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Introduction to Sensors

Workshop

TIM THE BEAVER

Department of Mechanical Engineering
Massachusetts Institute of Technology

Outline

- Introduction
- Overview of Sensors
  - Position Encoders
  - Inertial Units
  - Pressure and Force Sensors
  - Electrical and Magnetic Sensors
  - Optical Sensors
  - Additional Sensors
- Arduino Sensor Kit
- Demo

Introduction

Definition:

Sensor is a device that detects or measures a physical property and records, indicates, or otherwise responds.

In most engineering applications, sensors output analog voltage signal for circuit or micro-controllers to process.

An instrument (i.e. scanning electron microscope) may contain multiple sensors.

1 Acoustic, sound, vibration
2 Automotive, transportation
3 Chemical
4 Electric current, electric potential, magnetic, radio
5 Environment, weather, moisture, humidity
6 Flow, fluid velocity
7 Ionizing radiation, subatomic particles
8 Navigation instruments
9 Position, angle, displacement, distance, speed, acceleration
10 Optical, light, imaging, photon
11 Pressure
12 Force, density, level
13 Thermal, heat, temperature
14 Proximity, presence
15 Sensor technology
16 Other sensors and sensor related properties and concepts
17 References

Wikipedia Sensor Category List

Position Encoders

Displacement
- Rotary or Linear Potentiometer
- Linear encoder
  - Optical
  - Magneto
- Shaft encoders
  - Rotary into Linear w. screw

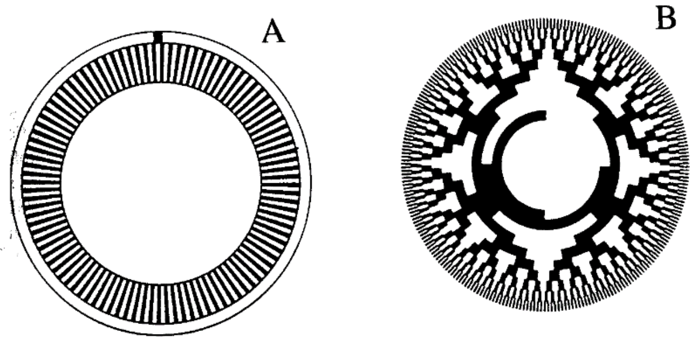
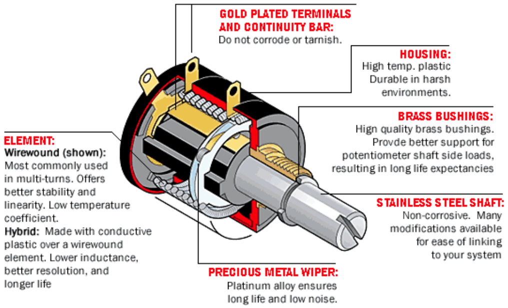


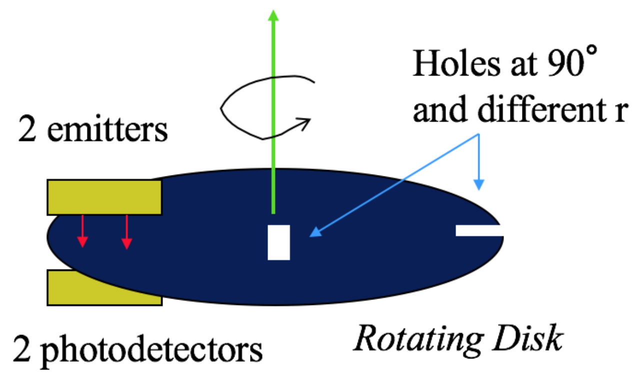
FIGURE 5.34. Incremental (A) and absolute (B) optical encoding disks.

Interface:	CANopen
Resolution/Revolution:	16 Bit = 65,536 steps
Revolutions:	up to 14 Bit = 16,384
Code	Binary
Housing Diameter:	58 mm
Shaft:	Full shaft 6 or 10 mm ø / hollow shaft 15 mm ø

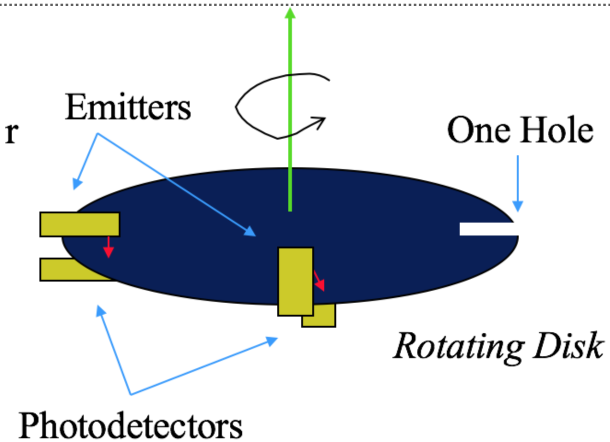


Position Encoders

Quadrature Encoder



2 Holes and 1 dual optical sensor



1 hole and 2 single optical sensors

One sensor measures “I” and the other measures “Q”
-> Direction determined by whether I leads Q in time or vice-versa

Can be spaced more closely, for rapid direction determination

Position Encoders

Linear Encoder


HEIDENHAIN Linear Encoders

Click Here

Products & Specs

Sealed Linear Encoders

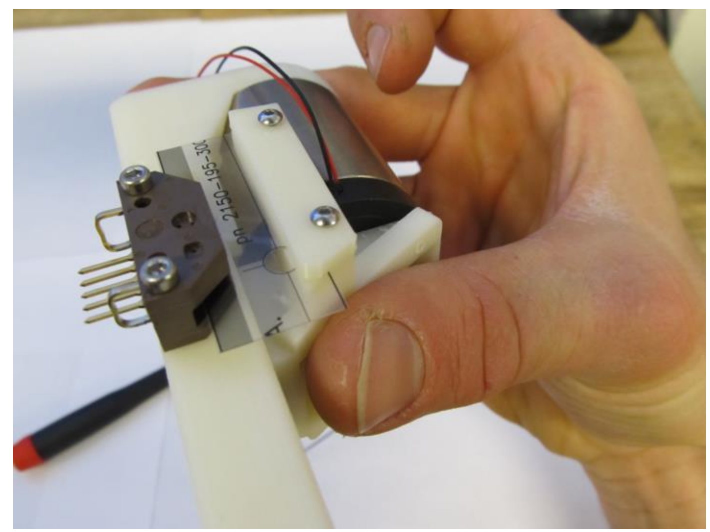
The scale and scanning unit of sealed linear encoders are protected against harsh machine shop environments by an aluminum housing with flexible sealing lips. These linear encoders are ideal for all manual and NC machine applications as well as all metal forming and wood working machines. The sealed linear scales come in several size configurations as well as lengths (over 30 meters for a single axis). Accuracy ranges from ± 10 µm to ±2 µm. Reference marks come in standard or distance-coded versions.

Exposed Linear Encoders

Exposed linear encoders operate with no mechanical contact between the scanning head and the scale. This eliminates any mechanical backlash or hysteresis. The measuring standard for all exposed linear encoders is a phase grating applied to a carrier of steel or glass. Applications include high accuracy test and measurement machines, manufacturing machines related to the electronics industry, and ultra precision machines such as diamond lathes, and facing lathes. Several accuracy grades (to ±0.1 µm) and size configurations (lengths to over 30 meters) as well as standard or distance-coded reference marks are available.

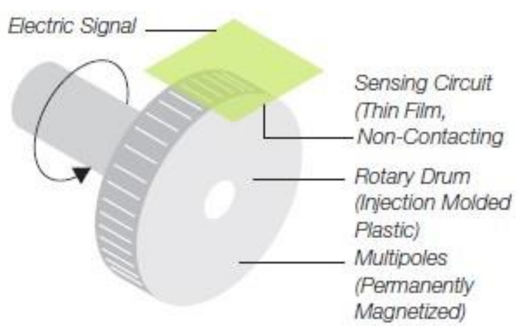
Optical encoders

- Track micro marks
- 100 nm accuracy!
- Film encoders are in cheap printers



Position Encoders

Magnetic Encoder



ELECTROSWITCH
ELECTRONIC PRODUCTS
UNIT OF ELECTRO SWITCH CORP.

500 SERIES MAGNETIC ENCODERS NEW

The Electroswitch 500 Series Magnetic Encoders are built upon a contact free integrated circuit design. This encoder integrates Hall Effect sensing and digital signal processing to provide high-resolution angular measurement solutions.

An important advantage of the 500 Series is the dramatic reduction in package size to ½ inch, while still incorporating the performance and output options required to support the widest range of industrial and motion sensing applications.

The 500 Series design leverages its reduced part count and simplified construction to provide extremely robust, high shock and vibration resistant performance, excelling in harsh and dirty environments.

FEATURES

- Compact, Robust, 1/2" package
- High Resolution Encoding up to 1024 PPR
- Widest Temperature Range
- Absolute and Incremental Outputs
- Zero Reference Positioning
- Tachometer with Direction Sensing
- Quadrature Code Output
- RoHS Compliant
- Contact Free Magnetic Design
- 3.3 or 5.0 VDC Options

BENEFITS

- Compact Size
- Multiple Output Codes Allowing Simpler Integration With a Wider Variety of Receiving Devices
- Best Encoder Reliability
  - Longest Life
  - Excellent Performance in Harsh Environments
- Low Power Consumption

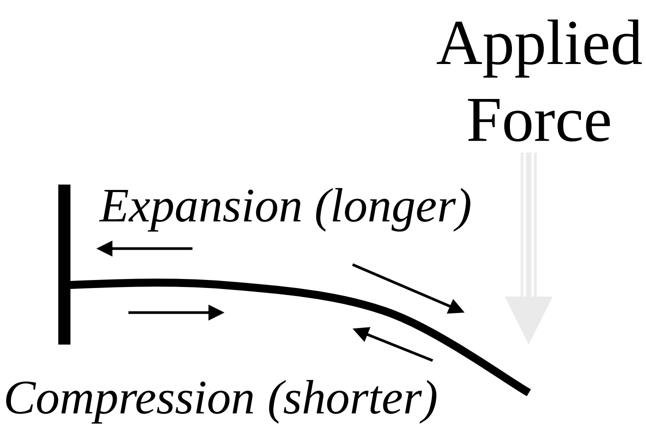
Inertial Sensors

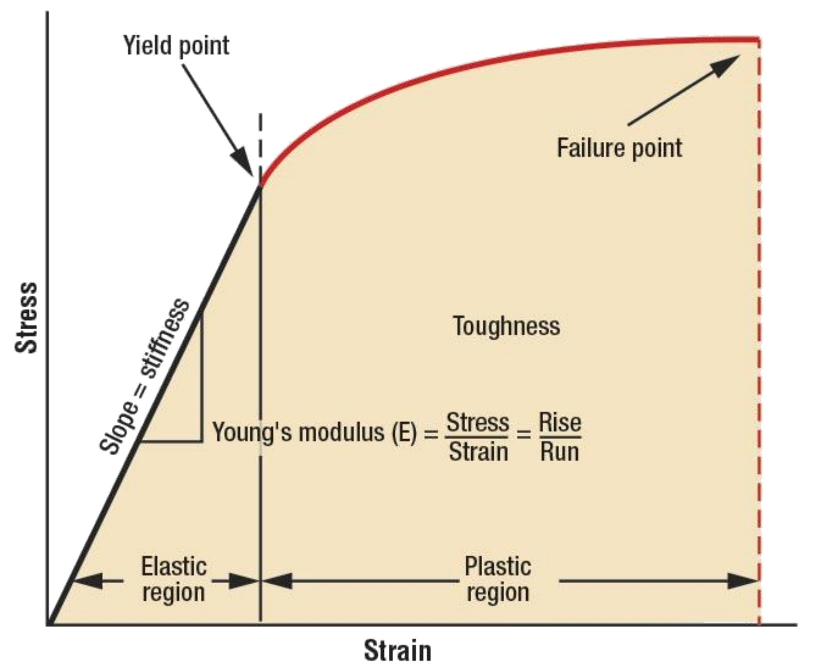
- An inertial measurement unit (IMU) is a sensor package containing three orthogonal axes of rotation sensors (gyros) and three orthogonal axes of acceleration sensors (accelerometers)
- Historically used for inertial navigation or tracking –until recently, out of price range for HCI
- Made by:
  - Intersense (now Thales) http://www.isense.com
  - Crossbow http://www.xbow.com
  - Many Others…. (e.g., Sparkfun)
  - Us http://www.media.mit.edu/resenv/Stack (and Sensemble)

- Was about $1000 and under 10 cm^3 - chips now!

Pressure and Force Sensors

- Strain: s = ΔL/L
- Force is proportional to displacement F = -kx
- Pressure is defined as P = F/A





Pressure and Force Sensors

Optical Pressure Sensor

Figure 3: Camera view of membrane: (a) undeformed (b) in contact with an object.

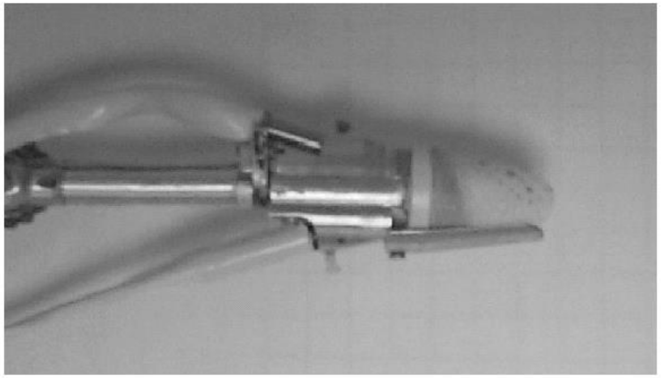
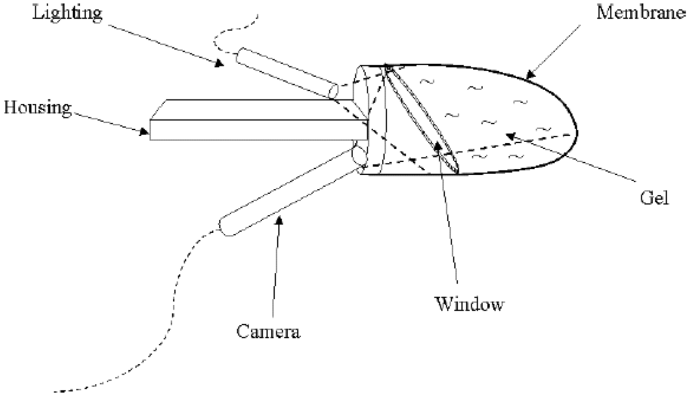


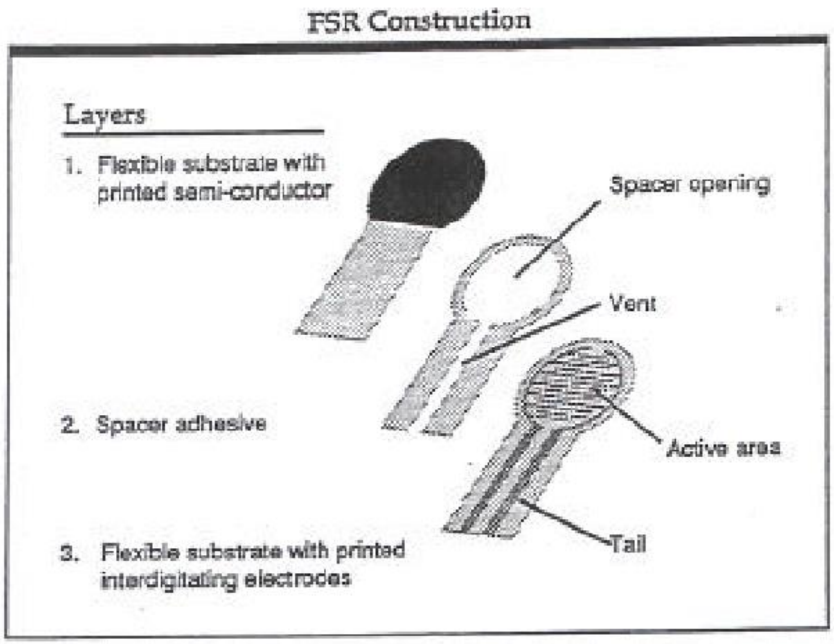
Figure 1: The tactile sensor.



Pressure Profile of deformable dot-matrix fingertip (Hristu, Ferrier & Brockett)

Pressure and Force Sensors

Force Sensitive Resistors (FSR)



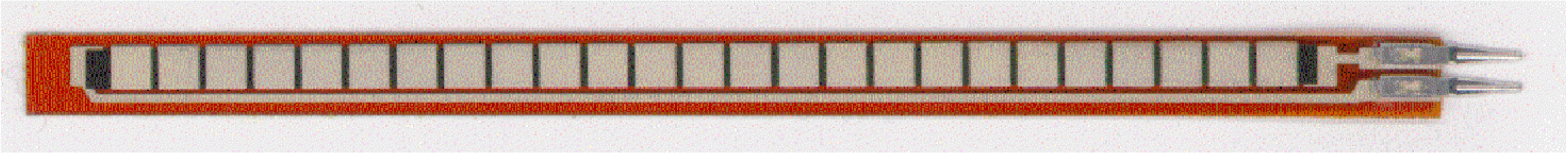
- Composite structure
  - Top, ink, electrodes
    - Flat, but can be fragile to shear force (delamination) and sensitive to bend

Pressure and Force Sensors

Bending Sensor

The Flex Sensor is a unique component that changes resistence when bent. An unflexed sensor has a nominal resistance of 10,000 ohms (10 K). As the flex sensor is bent the resistance gradually increases. When the sensor is bent at 90 degress its resistance will range between 30-40 K ohms.

The sensor measures 1/4 inch wide, 4 1/2 inches long and only .019 inches thick!



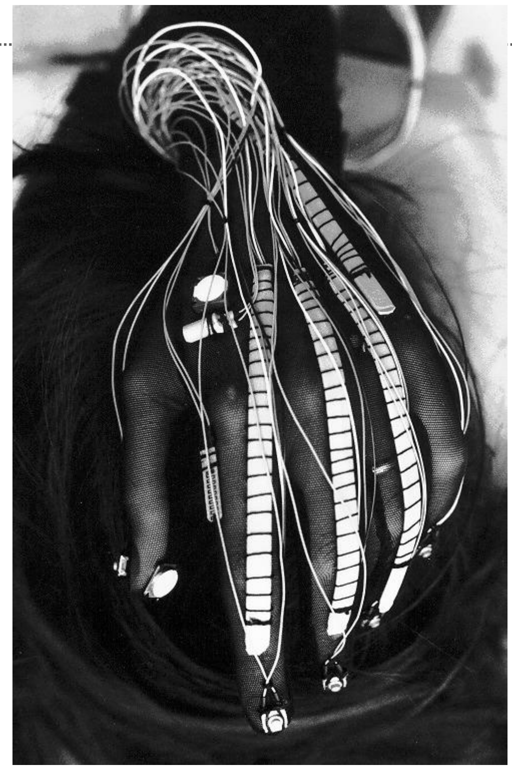
Available from the Images Co. (for PowerGlove - made by “Abrams-Gentile)
High-end versions made by Immersion for their CyberGlove
- 0.5° resolution, 1° repeatability, 0.6% max nonlinearity, 2-cm min bend radius

These only measure bend in one dimension (expanding the FSR’s on surface)
- *Conduction saturates quickly when contracted*
- *Can measure bidirectional bend with 2 FSR’s back-to-back (and diff amp)*

Pressure and Force Sensors

Bending Sensor

Mattel's Power Glove
1989



Laetitia Sonami's Lady's Glove
(STEIM, 1997)

[redacted]

The 22-sensor CyberGlove has three flexion sensors per finger, four abduction sensors, a palm-arch sensor, and sensors to measure flexion and abduction. Each sensor is extremely thin and flexible being virtually undetectable in the lightweight elastic glove.

Immersion's Cyber Glove

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Pressure and Force Sensors

Fiber-Optic Pressure Sensor

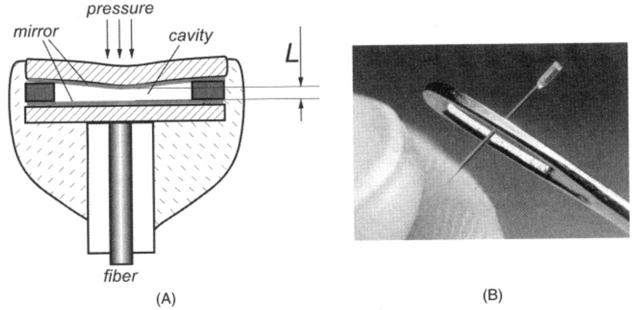


Fig. 7.31. Construction of a Fabry–Perot pressure sensor (A) and view of FISO FOP-M pressure sensor (B).

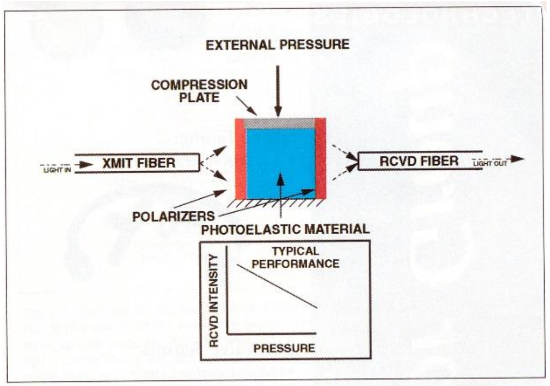


Figure 11. In an extrinsic fiber-optic pressure sensor based on polarization, pressure is applied to a plate that compresses a compliant photoelastic material. Polarized light is sent into the photoelastic material, which then rotates the polarization state of the light as the pressure changes. Another bulk polarizer (when used in this configuration it is called an analyzer) only transmits light of a certain polarization rotation. The sensor works in the following manner: with no pressure applied, there is no polarization rotation, hence the maximum field intensity emerges from the analyzer. As the pressure increases, more and more polarization rotation happens, resulting in decreasing intensity emerging from the analyzer.

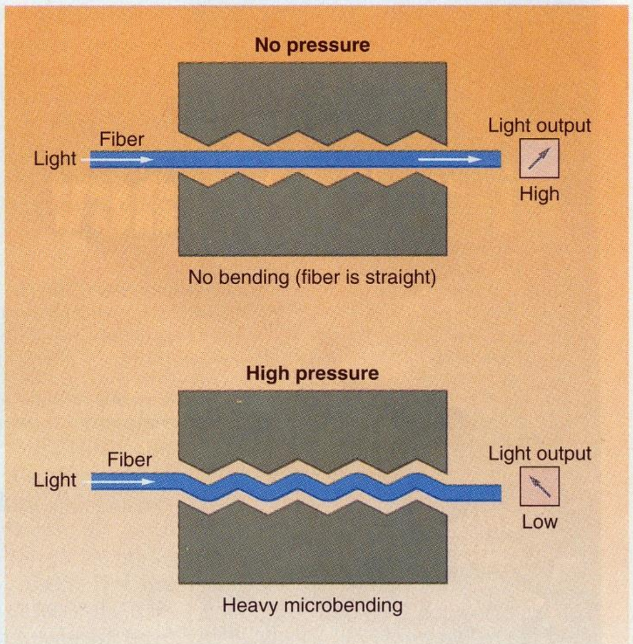


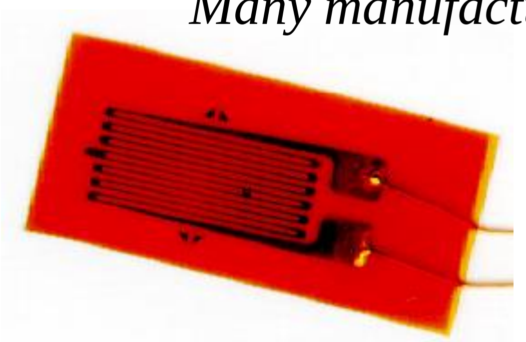
FIGURE 1. Fiber pressure sensor depends on microbending in a fiber mounted between two grooved plates. Increasing the pressure increases microbending losses, so pressure can be inferred from measurements of transmitted optical power.

Pressure and Force Sensors

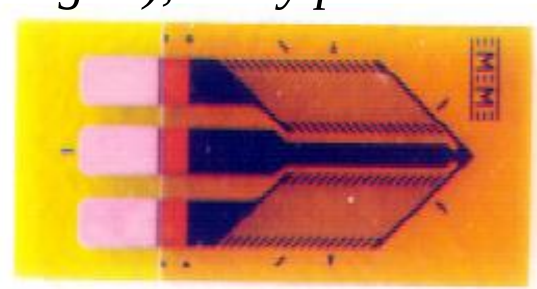
Strain Gauge

A wire strain gauge is composed of a resistor bonded with an elastic carrier (backing). The backing, in turn, is applied to the object for which stress or force should be measured. Obviously, that strain from the object must be reliably coupled to the gauge wire, whereas the wire must be electrically isolated from the object. The coefficient of thermal expansion of the backing should be matched to that of the wire. Many metals can be used to fabricate strain gauges. The most common materials are alloys *constantan, nichrome, advance,* and *karma*. Typical resistances vary from 100 Ω to several thousand ohms. To possess good sensitivity, the sensor should have long longitudinal and short transverse segments (Fig. 9.2), so that transverse sensitivity is no more than a couple of percent of the longitudinal. The gauges may be arranged in many ways to measure strains in different axes. Typically, they are connected into Wheatstone bridge circuits (Section 5.7 of Chapter 5). It should be noted that semiconductive strain gauges are quite sensitive to temperature variations. Therefore, interface circuits or the gauges must contain temperature-compensating networks.

Many manufacturers (e.g., JP Technologies), many patterns...



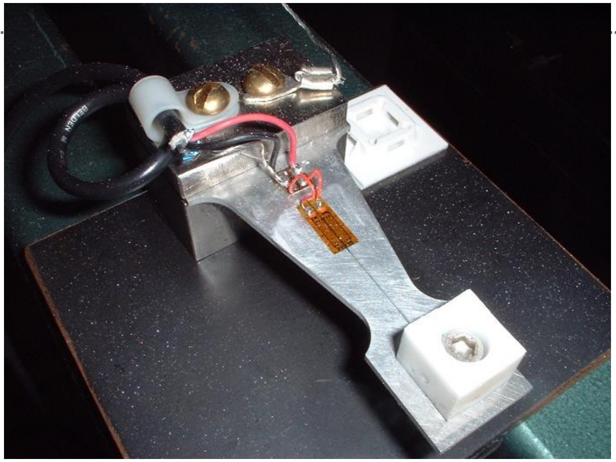
Simple strain gauge



Torsional strain gauge

Pressure and Force Sensors

Load Cell



Simple, "naked" load cell from Ohio State

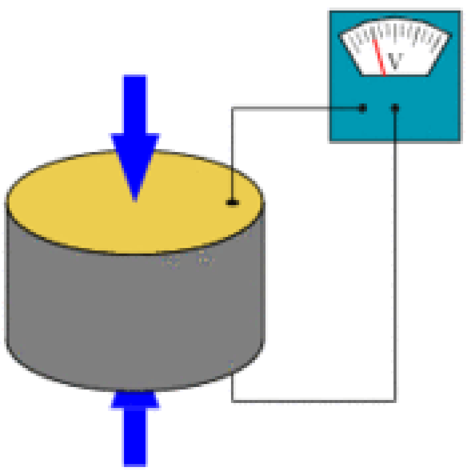
20 Ton load cell for truck weight

Load Cell assortment from DHS

- Bond strain gauge to cantilevered beam
  - Force deflects beam, bends strain gauge, creates signal
- Can be quite accurate
  - Compensate temperature effects

Pressure and Force Sensors

Piezoelectric Sensors



Piezo Foil
(PVDF)

http://www.meas-spec.com/myMeas/sensors/piezo.asp

EM Sensors

Electric Field Sensing

Pros:
- Cheap
- Not affected by light, sound, etc.
- Not “really” line-of-sight
- Easy to do and easy to configure
  - Range scales with size and spacing of the electrodes
- Can get extremely high resolution (e.g., angstroms) if appropriately configured and shielded

Cons:
- Hard to get detailed information
  - e.g., can’t (maybe) tell if you’re smiling, but can easily tell that your hand moves near a point.
  - Doesn’t deal well with ambiguity
- Sensing field can be self-shielded
  - Can’t see through skin, metal, etc.
- Sensitive range is limited (e.g., 1-3 meters max)
- Nearby metal can perturb and attenuate sensitive range
- Although synchronous filtering helps, some sensitivity to external EMI

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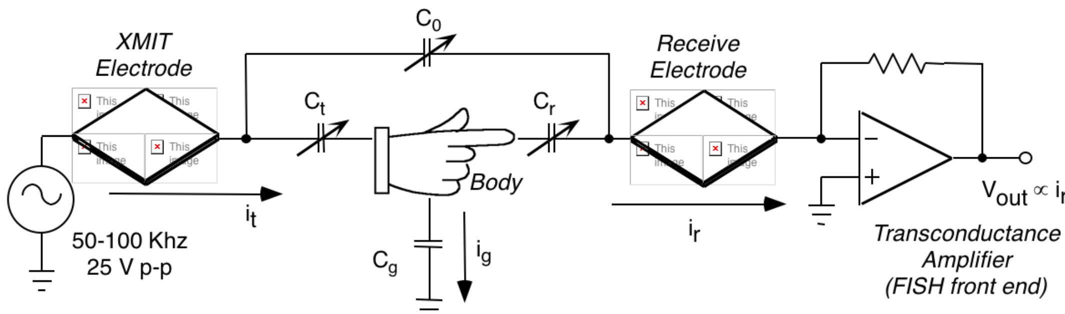
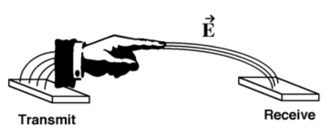
EM Sensors

Electric Field Sensing

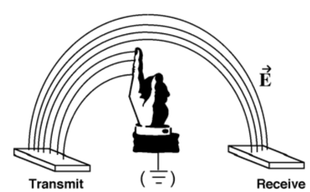


Equivalent circuit for all modes of electric field sensing



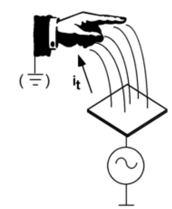
Transmit mode ($C_t >> C_g$)

- User must contact transmitter
- User uniquely tagged
- Can use multiple frequencies; multiple users
- 2-object geometry
  => Best for accurate tracking
- Industrial (short range) proximity



Shunt mode ($C_g >> C_t$)

- No contact with electrode
- 3-object geometry
  => Hard to do tracking
- Can “focus” w. tomograpy
  => Add more transceivers

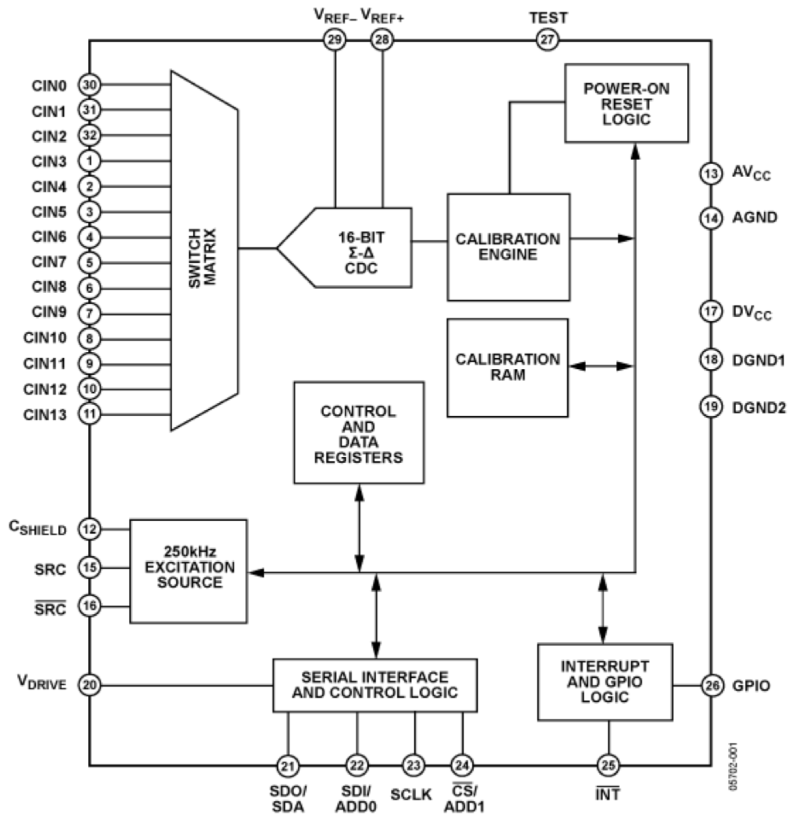


Loading Mode (measure I)

- Single Electrode
- No cable to electrode
- Couples to everything
- Hard to adjust sens. area
- Used for everything
  - Stud finders (pre MIR)
    Theremins, buttons...

EM Sensors

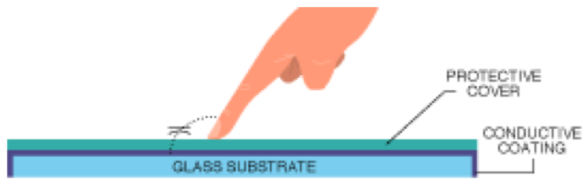
AD7142

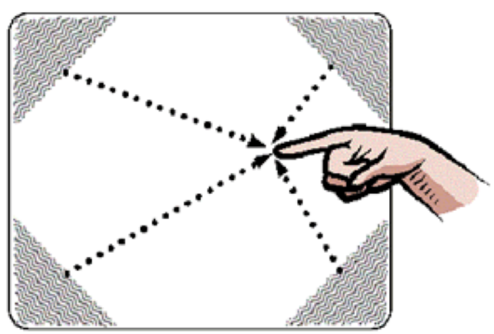


- AD7142 (14-channel) and several others
- T/R mode
- Calibrates out external signals when sensors idle
- Low power - aimed at touch controllers and sensors (e.g., humidity)
- SPI output

EM Sensors

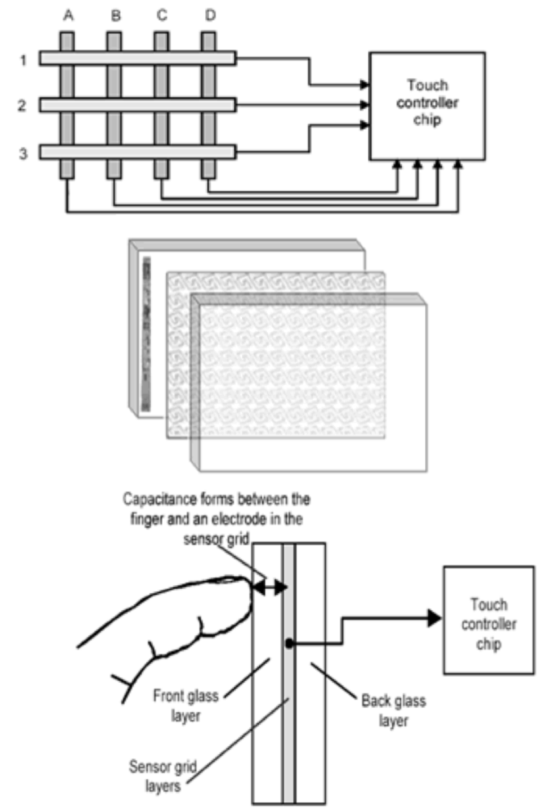
Capacitive Touch Screen





Surface Capacitance

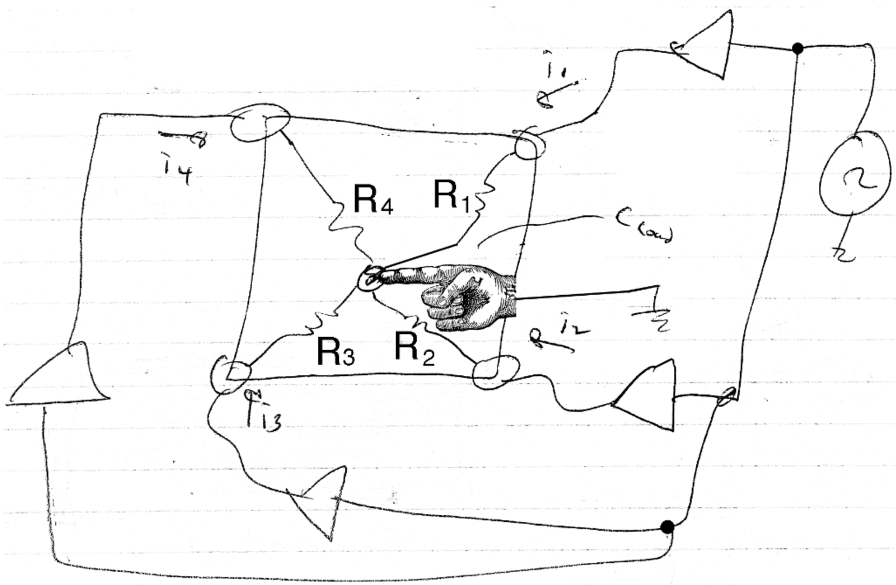
Transmit from 4 corners
Receive around screen.
Or vice-versa…,

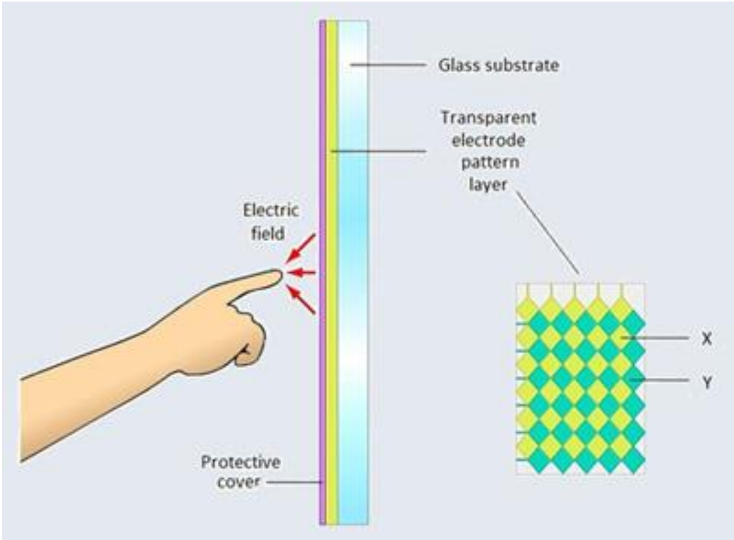


Pixellated or grid capacitance

EM Sensors

Resistive Versus Capacitive Touch Screen





- Current splits - Measure Capacitive loading as sourced @ 4 corners
  - Sum/Difference across x,y can locate touch in plane

EM Sensors

Magnetic Sensor

ANALOG DEVICES

Linear Output Magnetic Field Sensor

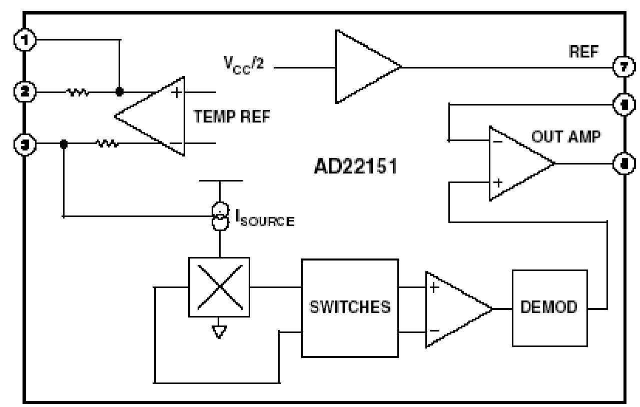
AD22151

FEATURES
Adjustable Offset to Unipolar or Bipolar Operation
Low Offset Drift over Temperature Range
Gain Adjustable over Wide Range
Low Gain Drift over Temperature Range
Adjustable First Order Temperature Compensation
Ratiometric to V_{CC}

APPLICATIONS
Automotive
- Throttle Position Sensing
- Pedal Position Sensing
- Suspension Position Sensing
- Valve Position Sensing

Industrial
- Absolute Position Sensing
- Proximity Sensing

FUNCTIONAL BLOCK DIAGRAM

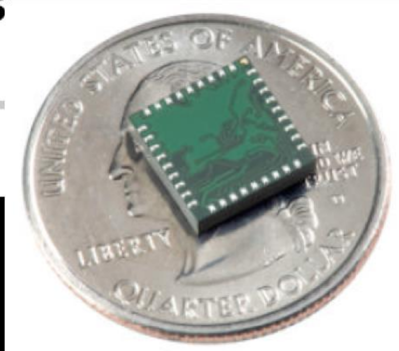


EM Sensors

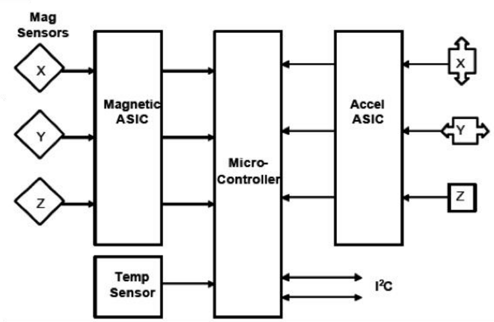
Compass

3-Axis Compass with Algorithms HMC6343

The Honeywell HMC6343 is a fully integrated compass module that includes firmware for heading computation and calibration for magnetic distortions. The module combines 3-axis magneto-resistive sensors and 3-axis MEMS accelerometers, analog and digital support circuits, microprocessor and algorithms required for heading computation. By combining the sensor elements, processing electronics, and firmware into a 9.0mm by 9.0mm by 1.9mm LCC package, Honeywell offers a complete, ready to use tilt-compensated electronic compass. This provides design engineers with the simplest solution to integrate high volume, cost effective compasses into binoculars, cameras, night vision optics, laser ranger finders, antenna positioning, and other industrial compassing applications.



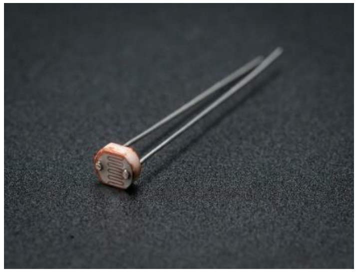
FEATURES	BENEFITS
Compass with Heading/Tilt Outputs	A complete compass solution including compass firmware
3-axis MR Sensors, Accelerometers and a Microprocessor in a Single Package	A digital compass solution with heading and tilt angle outputs in a chip-scale package
Compass Algorithms	For computation of heading, and magnetic calibration for hard-iron
9 x 9 x 1.9mm LCC Surface Mount Package	Small size, easy to assemble and compatible with high speed surface mount technology assembly
Low Voltage Operations	Compatible with battery powered applications
EEPROM Memory	To store compass data for processor routines
Digital Serial Data Interface	I^2C Interface, easy to use 2-wire communication for heading output
Moderate Precision Outputs	Typical 2° Heading Accuracy with 1° Pitch and Roll Accuracy
Lead Free Package Construction	Complies with RoHS environmental standards
Flexible Mounting	Can be mounted on horizontal or vertical circuit boards



Now commonly integrated into IMUs

Optical Sensors

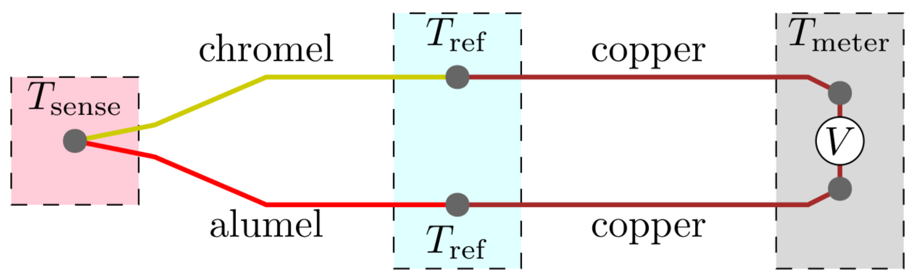
- Photoresistor
- Photodiode
- Phototransistor
- Color detector
- Camera
- Stereo Camera-Depth

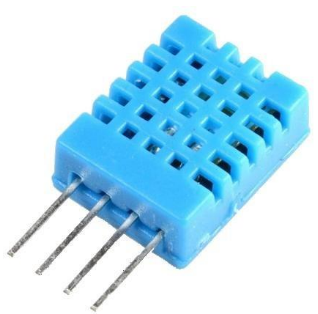




Additional Sensors

- Temperature
- Humidity
- Acoustic
- Ultrasonic





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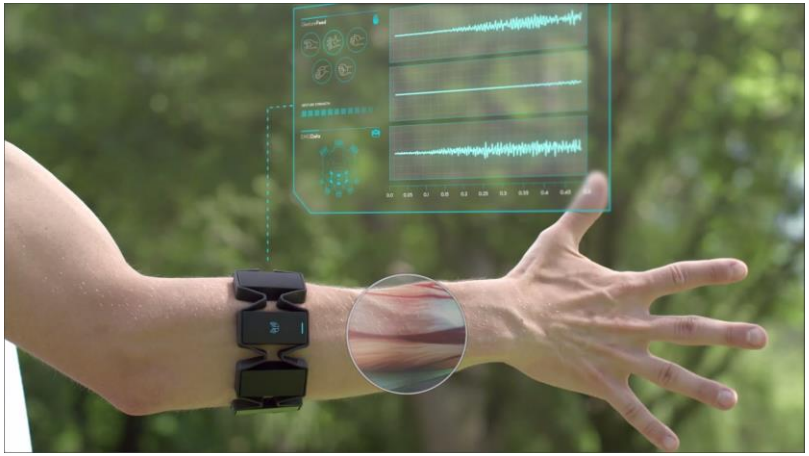
AsiaUS Business Connection

Workshop TIM THE BEAVER

Arduino Sensor Kit

Demo: Advanced Sensors

Leap Motion Gesture Sensor



Myo Electromyopgraphy Sensor

Demo

- Interface force sensing resistor (FSR) with Arduino
- Interface inertia measurement unit (IMU) with Arduino
- Use 1 FSR and IMU to build an inertia based mouse with left button only
- (Bonus) Use only 1 FSR with additional coding to enable left click and right click (through force level)

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Thank You!