Physics 120B: Lecture 7

Sensors

(bit incomplete, still)

Sensing Categories

- Voltage
  - starting easy: analog in
- Distance
  - acoustic or light
- Speed
  - hard; usu. via distance
- Acceleration
  - accelerometers
- Light Level
  - phototransistors, photodiodes
- Object Passage
  - photogate (light source/sense)
- Sound Level
  - microphone to rectifier?
- Temperature
  - RTD, thermistor, AD-590
- Magnetic Flux
  - coil and EMF
- Pressure
  - pads?
- Mass
  - spring stretch?
- Strain
  - strain gauge

http://en.wikipedia.org/wiki/List_of_sensors for overwhelming list

Voltage

- Crudest version is digital: HIGH or LOW: 1-bit resolution
  - lots of digital inputs to handle this
  - option for internal pull-up resistor to V_{cc}
- Analog in provides 10-bit (0–1023) on Arduino
  - considered on crude-to-modest side: 50 mV in 5 V
  - high-end is 16-bit (65536 values)
    - seldom meaningful to carry more precision than this
  - 12-bit is also common, and 4× improvement over 10-bit
  - 8-bit is painful: 0.2 V in 5 V
    - but fine for some applications
- Voltage is seldom what you fundamentally want to know, but is often the electronic analog of a physical quantity of greater interest
  - generally, "converter" can be termed *transducer*

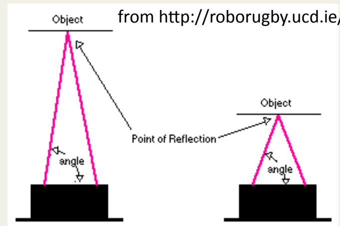
Distance

- Popular 120B metric
  - collision avoidance; parallel park; target approach
- Acoustic variety
  - ultrasound burst and time-of-flight measurement
  - Parallax Ping unit is integrated unit, $30
    - 2 cm to 3 m (dep. on surface type)
  - must send 2 μs pulse on SIG pin
  - then listen for return pulse
    - duration of pulse is round-trip time
  - must switch same pin between input/output
  - use `pulseIn()` to measure input duration
- Other modules in lab to roll your own acoustic sensor

Distance via Light?

- Not time-of-flight; forget about it! Leave that to pros
- Clever sensing of angle between emitter and receiver

from http://roborugby.ucd.ie/distsensor.html



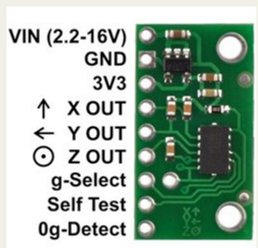
- Detector is linear array behind lens
  - angle maps to position, indicating distance
- Smarts on board, so GND, +5 V in; analog voltage out proportional to distance, though not linearly so
- Also a proximity version: logic out dep. on "too close"

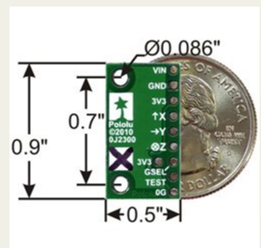
Measure Speed?

- Galileo and Einstein would both agree that this is hard to directly sense
- Options
  - measure distance and rate of change
    - noise in distance measurement can make for ratty/spiky velocity
  - Doppler?
  - measure rotation rate of wheel or axle engaged in motion
    - what speedometers do
    - can use photogate for once/revolution knowledge

Acceleration

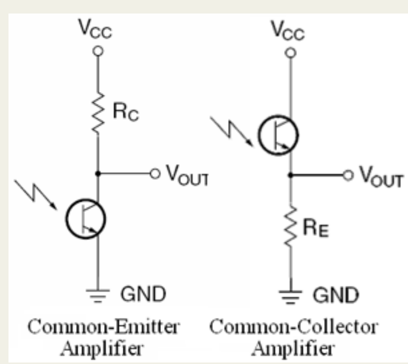
- This is something we *can* directly sense
- Recent rapid advances; driven by MEMs and smartphones
  - 3-axis accelerometer based on micro-cantilevers capacitively sensed
  - bitty MMA7361L unit, $15
    - centers output on ½ of 3.3 V
    - default roughly ±1.5g, but can config. for ±6g
    - zero-g detection and digital flag





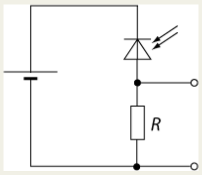
Light Level

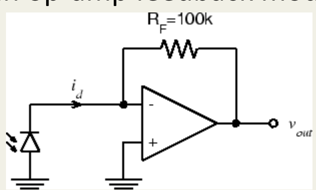
- Lots of options: phototransistor, photodiode most common
  - photons knock electrons loose, which either constitute a base current (phototransistor) or direct into current (photodiode)
- Phototransistor (right) effectively has some gain already
  - 10 kΩ usually about right

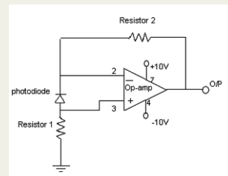


Photodiode Read Out

- Many options for photodiode
  - reverse bias, developing voltage across resistor
  - zero bias, in op-amp feedback mode

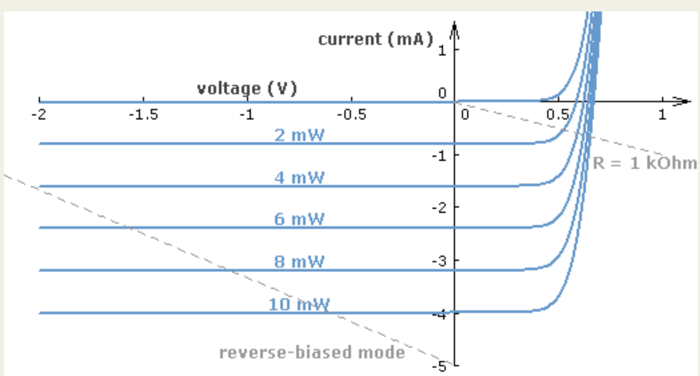






- Typically < 0.4 A per Watt incident
  - stream of photons at 550 nm → 0.447 A at 100% Q.E.
  - so 1 mm^2 detector in full sun (1000 W/m^2) is 1 mW
  - thus at best 0.5 mA current (puny)
  - tend to want pretty large resistor to build up voltage

Photodiode IV Curve



- At zero or reverse bias, current is proportional to incident light power
  - note approximate relation: $I \approx 0.4P$
  - matches quantum expectations

Object Passage

- We often need to know if something is physically present, has passed through, count rotations, etc.
- Can have simple scheme of light source and light detector, where the something of interest passes between
  - termed a *photogate*
  - interruption of light level pretty unmistakably sensed
  - pulse duration, via `pulseIn()`, may even speak to velocity
- Magnetic

Temperature

- Exploit temperature dependence of materials
  - RTD: resistive temperature device
    - usually laser-etched platinum spiral, often 1000 Ω + 3.85×(T °C)Ω
    - linear, good absolute calibration
    - but a resistor: need to fashion accurate current source and read off voltage (make ohmmeter)
  - thermistor: exploits conduction electron density as e^T
    - nonlinear, due to exponential dependence on T
  - AD-590: Analog Devices
    - supply 5 V and a route for current (resistor), and output current is proportional to temperature
    - measure current as voltage across provided resistor
- Caution: resistors often 200 ppm per °C
  - for accuracy, may want low "tempco" resistors

Sound Level

- Microphone is transducer for acoustic vibrations into voltage
  - usually membrane that vibrates is part of capacitor
  - can rectify resulting waveform, low-pass, and measure level

Magnetic Flux

- A loop of wire (or many loops) will develop EMF according to changing magnetic field
  - can amplify, rectify, etc.
- A Hall sensor can measure DC magnetic field

Pressure

- Pressure pads: 2 conductors separated by carbon film, squeezes out; so more conductivity: bite pads
- Capacitive pressure deflects membrane (lab pressure meter)
- Party-roller paper tube

Mass/Weight

- "Spring" stretch plus flexometer (strain gauge)

Strain

- Strain gauge can tell you about minute flexing of a structural beam/material

Other Sensors

- Direction
  - HM55B Compass Module from Parallax ($30)
- Motion
  - infrared motion sensor