12 - Sensors

CEG 4330/6330 - Microprocessor-Based Embedded Systems

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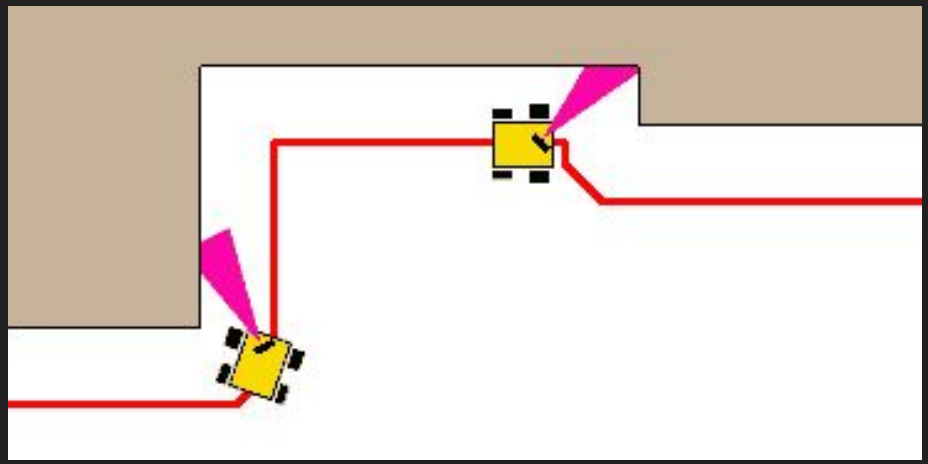
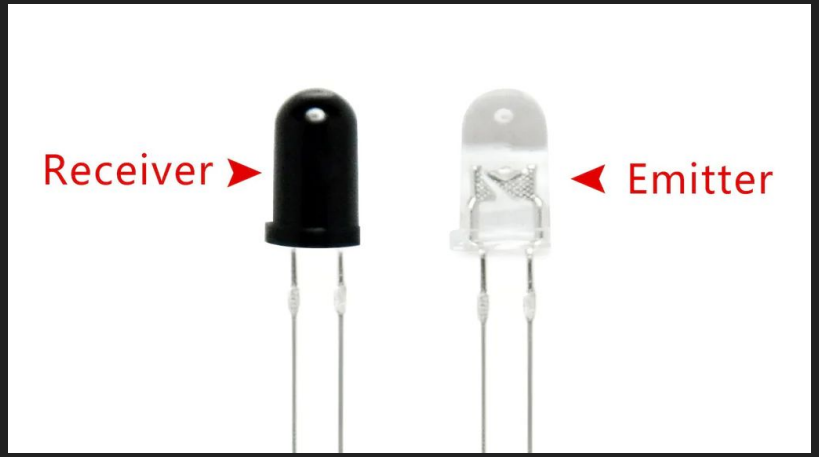
Wall-Following Mobile Robot System

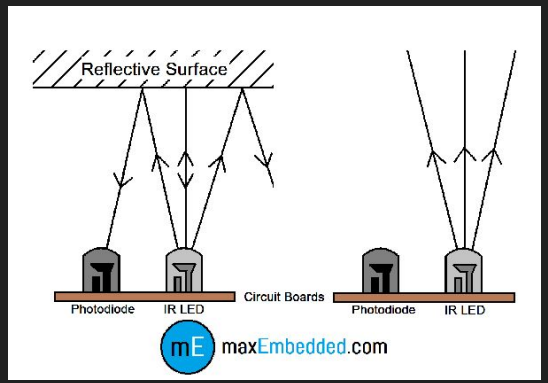
- IR Emitter and Detector
  - Uses ADC
  - Measures distance from walls
- Hall Effect Sensor
  - Uses ADC
  - Detects mines or magnets
- DC Motors
  - Flyback diode, opto-isolator, H-bridge, and PWM
  - Allows the robot to move

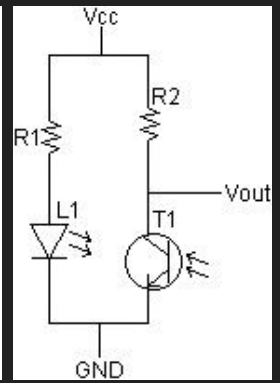


Infrared Emitter and Detector

- IR emitters and detectors come in a similar size/shape as an LED
- As the name suggests, the emitter emits IR light
- The receiver acts like a switch
  - Closed when IR light is detected
  - Opened when no IR light is detected
  - Somewhere in between when the IR light is not as strong or is reflected off of surface
- The signal from the receiver can be connected to an ADC to measure the distance from the wall

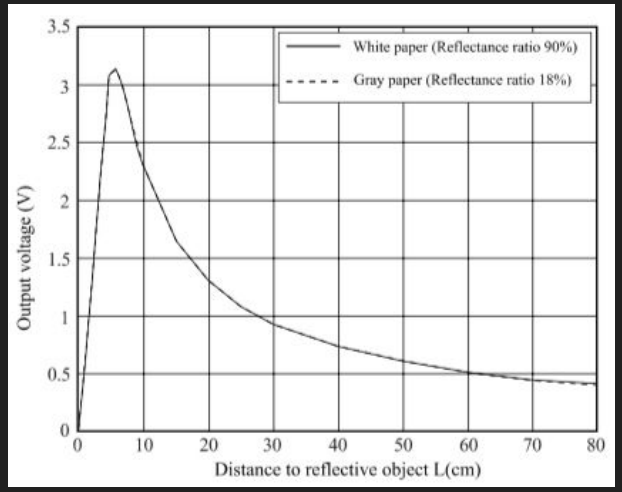


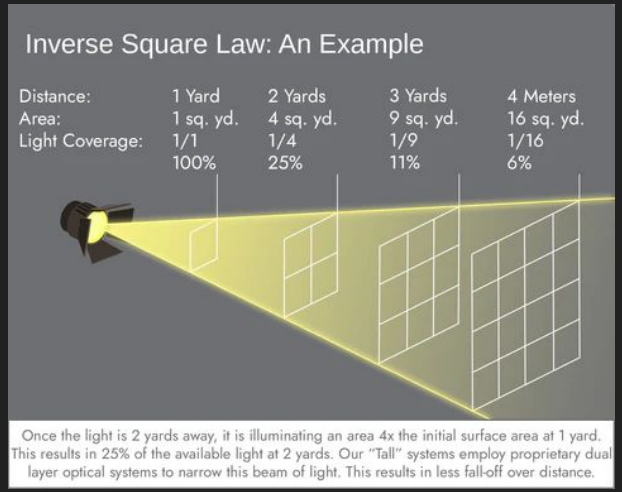




Inverse Square Law

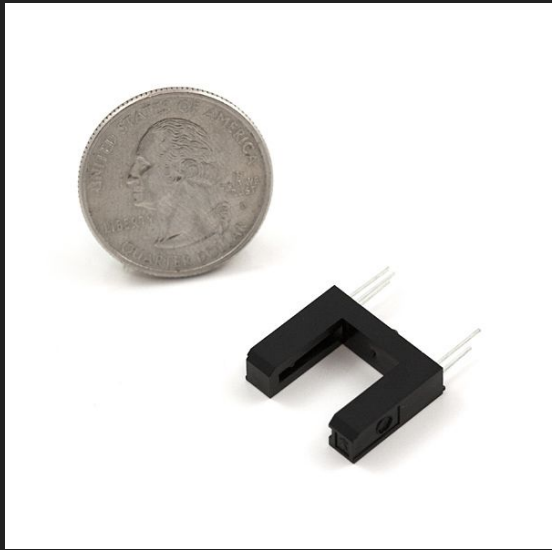
- The intensity of light over distance is reduced by 1/x^2 where x is a unit of distance
- Due to this, the light measured by the IR sensor is not linear with respect to distance
- In order to properly calculate the distance measured, the output voltage must be linearized
  - Linearization will result in a constant rate of change for distance when a constant rate of change of the output voltage is measured





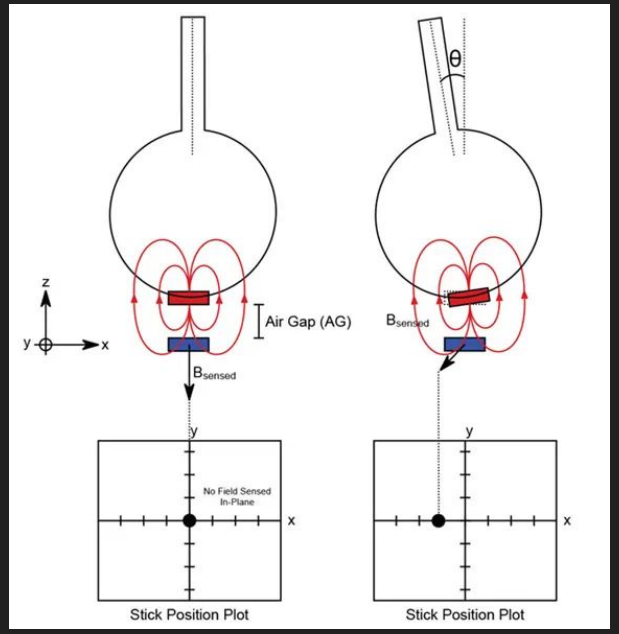
Other IR Devices

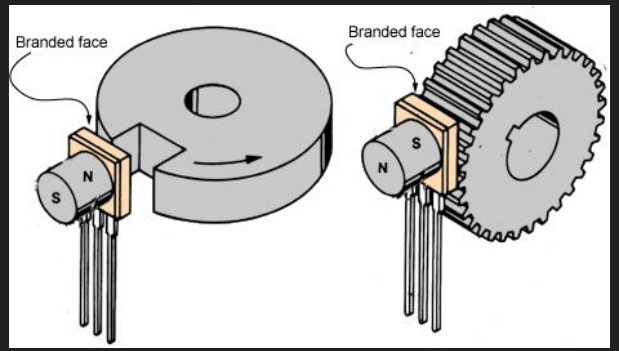
- Some devices combine both emitter and receiver into the same device
  - Can be used for a more compact or simpler design
- An IR interrupter can be used to detect a moving part, door, or conveyor belt



Hall Effect Sensor

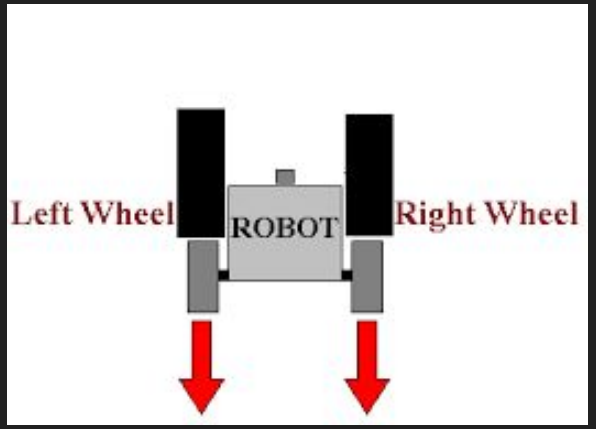
- Hall effect sensors detects the magnitude of a magnetic field using the Hall effect
- Used in driftless joysticks, gear position measurement, ABS anti-lock brakes, steering wheels, or contactless switches
- Bipolar vs Unipolar
  - Magnets have a north and south pole
  - A bipolar sensor can detect both north and south poles
  - A unipolar sensor can only detect one pole

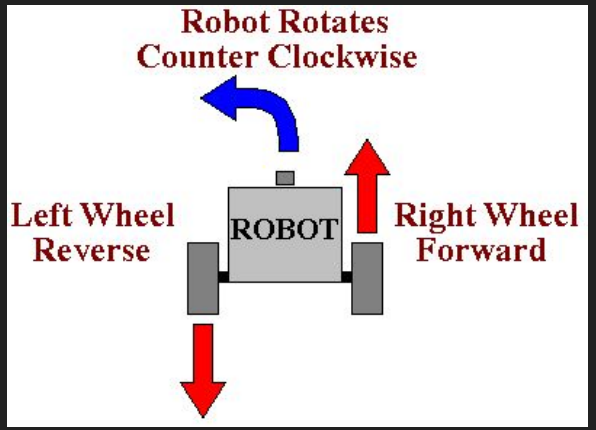




DC Motor

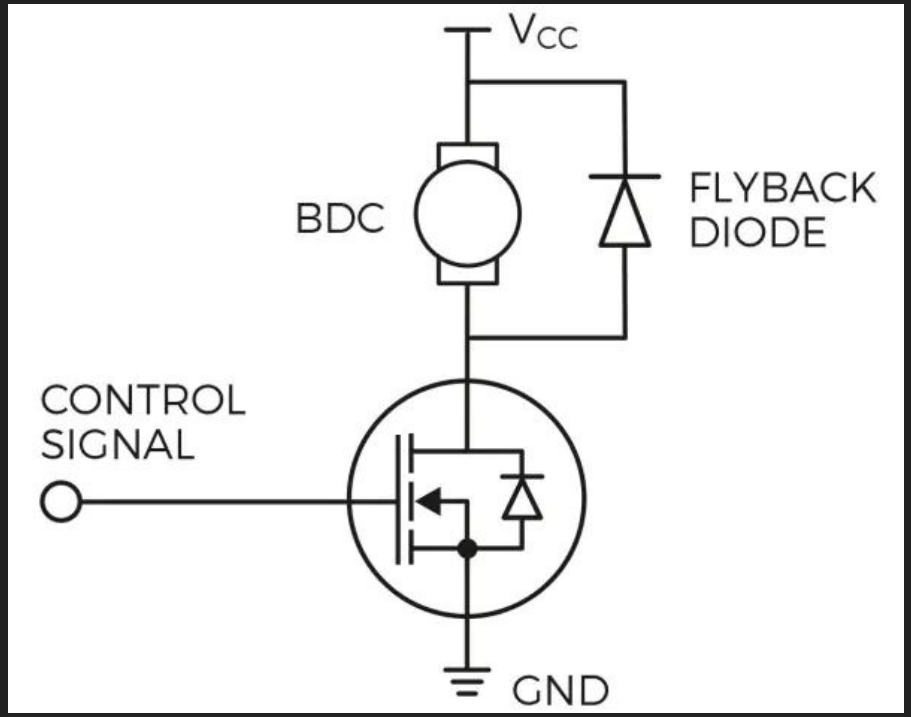
- Assume a robot has 2 wheels
  - If both wheels are rotating at the same angular velocity in the same direction, the robot will move in that direction
  - Turning the robot requires more angular velocity on one wheel compared to the other
  - Rotating in place can be achieved by rotating both wheels at the same angular velocity and opposite directions





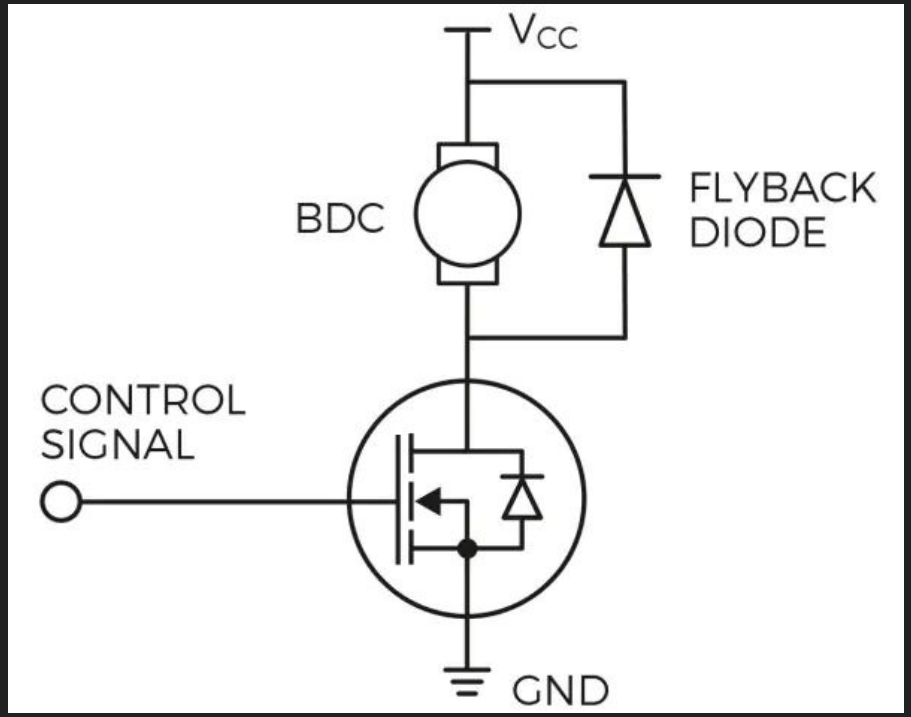
DC Motor (cont.)

- To achieve this movement and rotation a power MOSFET and a flyback diode can be used to control the DC motor
- The power MOSFET receives a PWM signal from a microcontroller
- By changing the duty cycle of the PWM signal, the speed of the motor can be controlled
  - 0% for no movement
  - 100% for full speed
- This system is necessary because the microcontroller is not capable of delivering enough current to power the motor by itself



DC Motor (cont.)

- The motor must be driven at a high enough frequency to smooth out or average the duty cycle
- Here is an example where you can change the duty cycle and frequency for an equivalent DC motor circuit: link

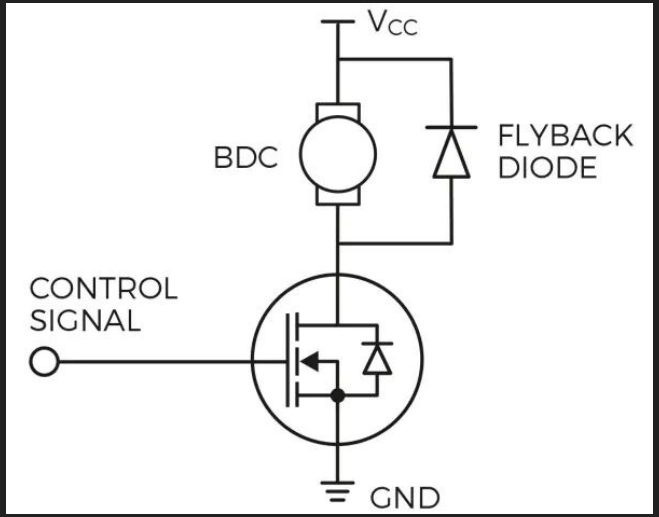


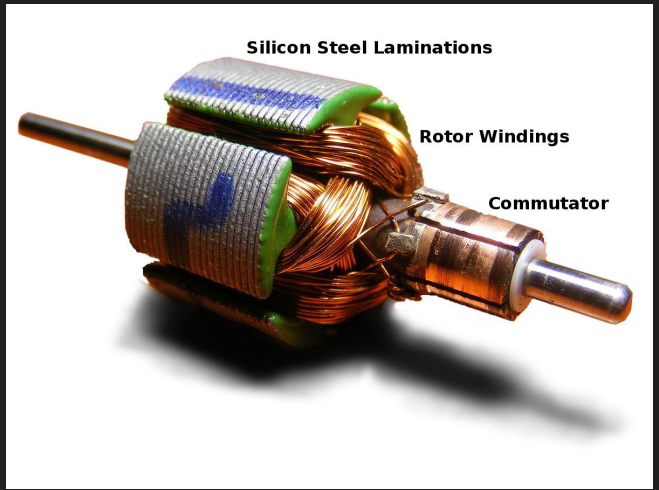
DC Motor (cont.)

- A motor is a bundle of wires that is actually an inductor
- The voltage across and inductor:

$$V = L\frac{dI}{dt}$$

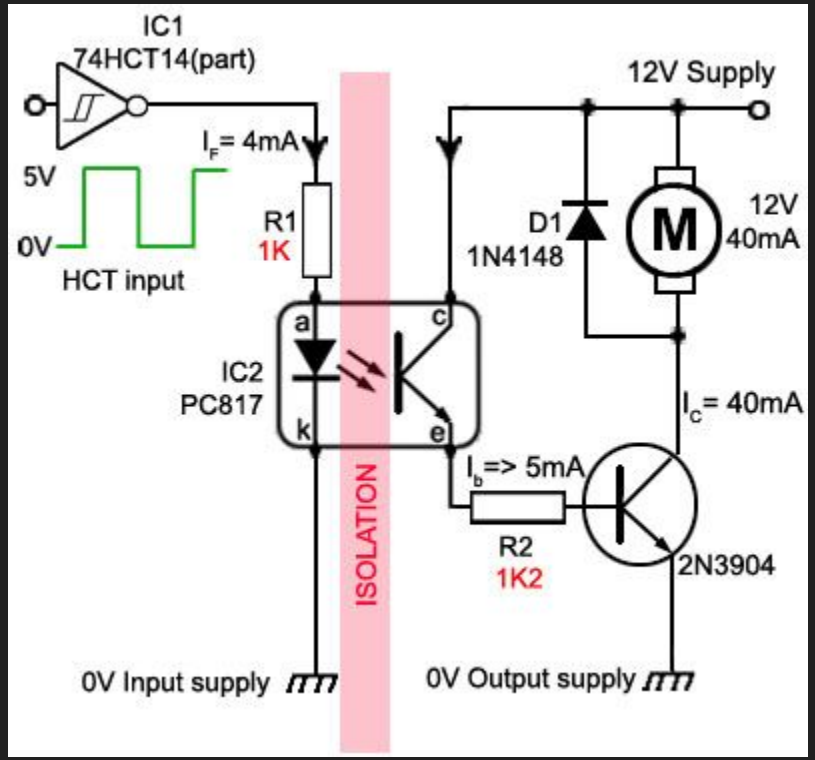
- When the rate of change in current is high, the voltage across the inductor (motor) will spike
- To prevent damaging the MOSFET or the power supply, a flyback diode is used to feed excess current back into the motor when the MOSFET is off





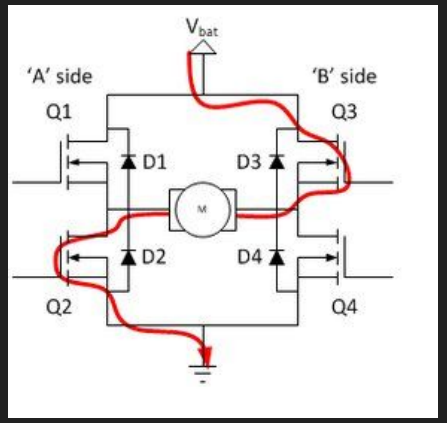
DC Motor (cont.)

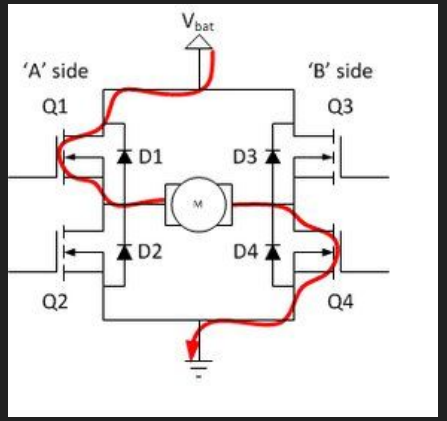
- To remove all direct electrical contact between the microcontroller and the motor drive circuit, sometimes an opto-isolator is used
- The opto-isolator is an IR transmitter and receiver, used to transmit the PWM signal using light instead of electricity
- Since the motor drive circuit usually has high voltage, high current, and high noise, the opto-isolator can be used to protect the microcontroller



DC Motor (cont.)

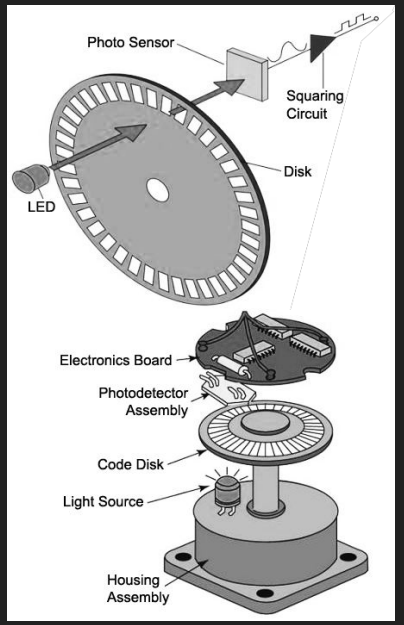
- To allow a motor to rotate in two directions, an H bridge can be used
- 4 MOSFETS are used to switch the direction of current for the motor
- This switching allows for rotating the motor in both directions

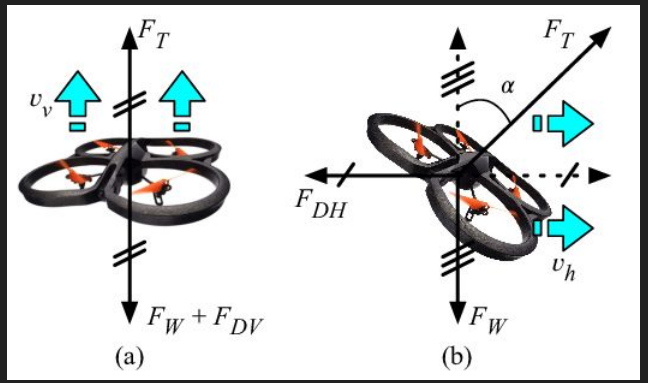




Other Examples

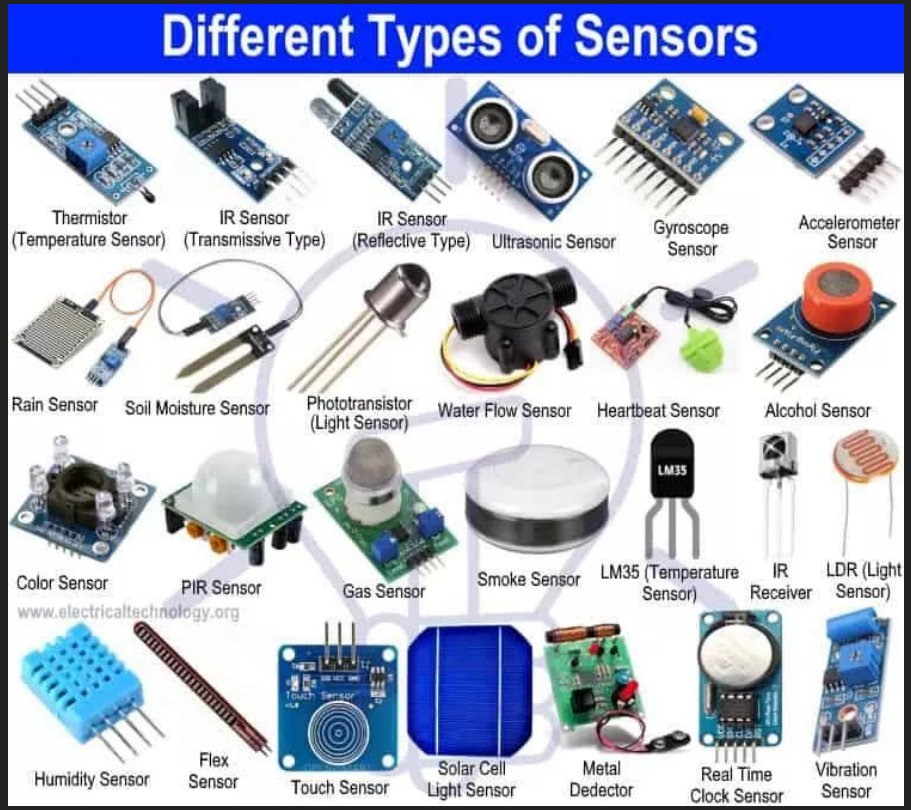
- Motor speed control using optical tachometer
  - Same as conveyor belt example we did earlier in the semester
- Flying robot or drone
  - Gyroscope and accelerometer sensors used to measure the orientation of the drone
  - Depending on the orientation of the drone, the microcontroller can speed up/down the propellers attached to motors





Other Types of Sensors

- Motion
  - PIR (passive infrared), optical, radar
- Temperature
- Pressure
- Acceleration/Orientation
  - Accelerometer, gyroscope, magnetometer
- Distance
- Sound
- Camera
- Proximity
  - Capacitive, optical, inductive, magnetic (reed switch)
- Water
  - Presence, level
- Touch
  - Resistive, capacitive



Other Types of Sensors

- Sensor interfaces
  - Analog:
    - Analog voltage
    - PWM
  - Digital:
    - SCI
    - SPI
    - I2C
    - Parallel
- Many sensors are sold on break out boards
  - You can buy the sensor individually
  - You can buy the sensor soldered to a board with all necessary components
    - Much easier to connect to microcontroller