# The Artemis Project

Lunar Regolith Excavator Student Competition
ME Team #8 / ECE Team #1


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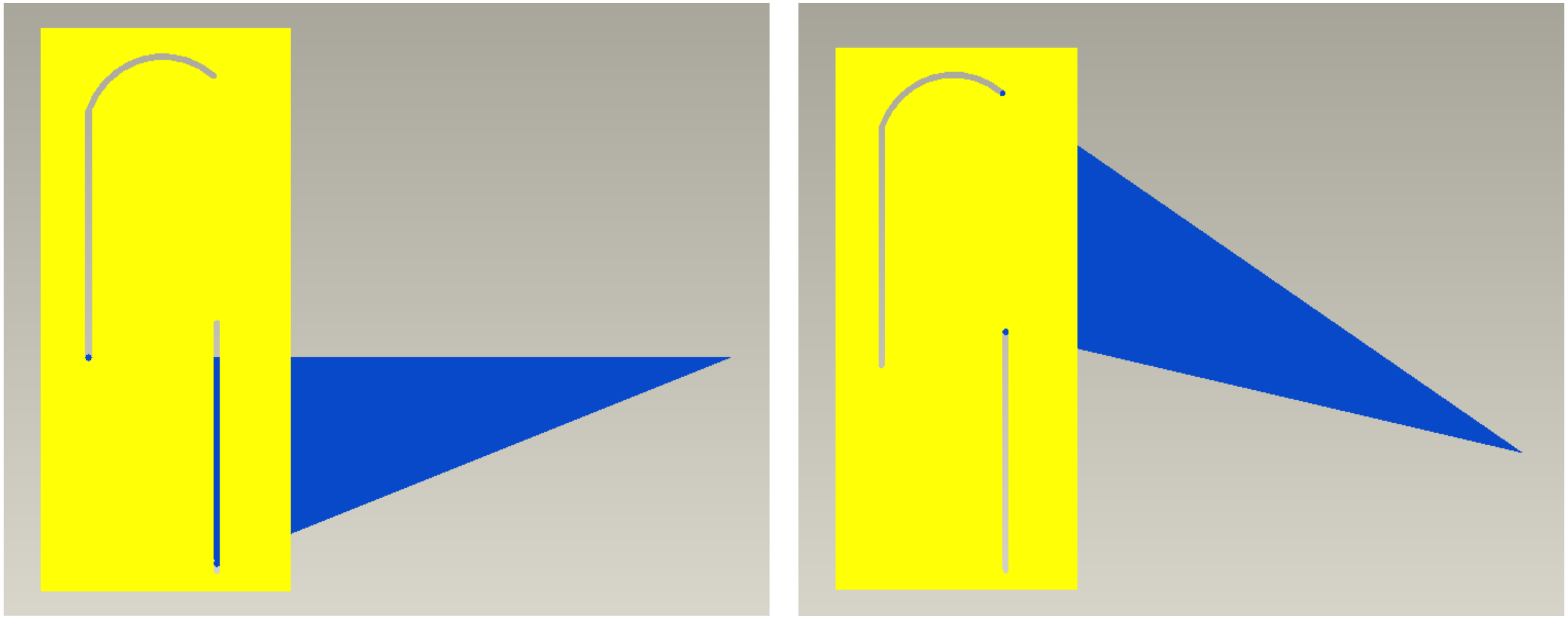
# NASA's Lunabotics Mining Competition

- Overview
  - Excavation Subsystem
    - Bucket
    - Conveyor
    - Plow/Bumper
  - Locomotion Subsystem
    - Chassis
    - Tracks
  - Power Subsystem
  - Control Subsystem
  - Navigation Subsystem
  - Sensors Subsystem

# Bucket Design

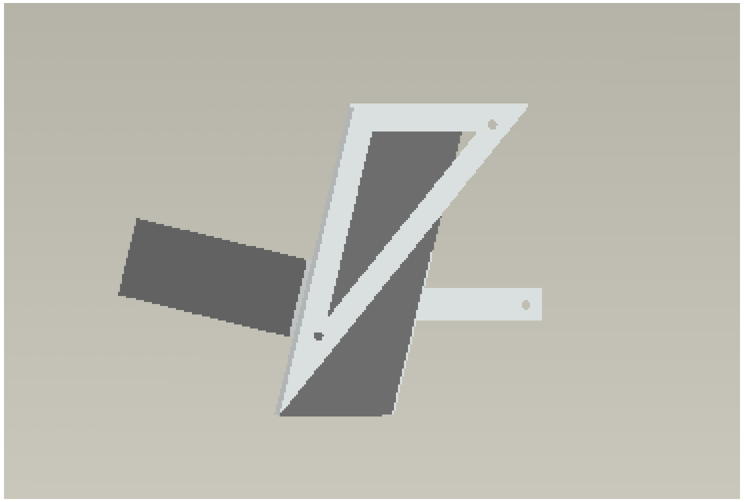
- Density of Regolith – 1.5 g/cm$^3$
- Desired capacity – 100 kg
- Required Volume – 0.066 m$^3$
- Our Bucket
  - Capacity 0.075 m$^3$
  - Height 0.3 m
  - Length 1.0 m
  - Width 0.6 m
  - Material Al 6061
  - Weight 9 kgs

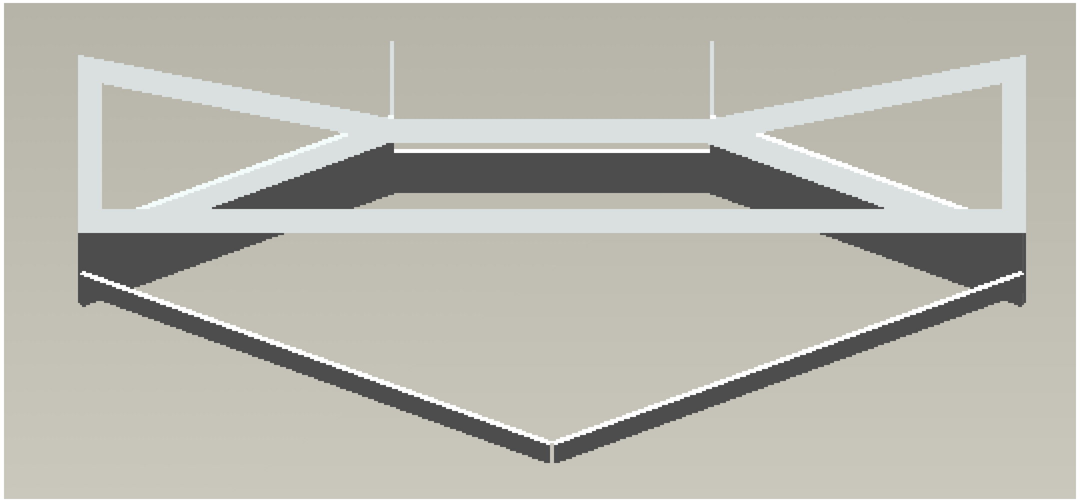
# Bucket Unloading



# Plow and Bumper

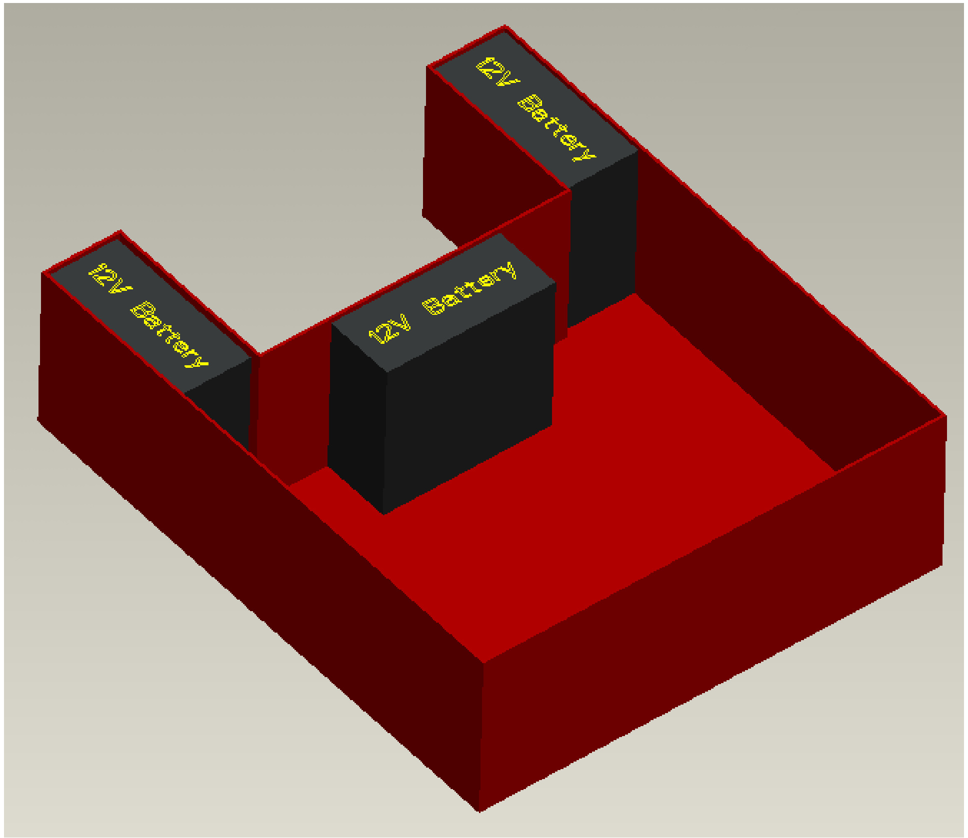
- Integrated regolith channeling and rock deflection
- Coupled to conveyor for maximum efficiency
- Linearly actuated engagement
- Constrained angle using parallel 4-bar





# Chassis

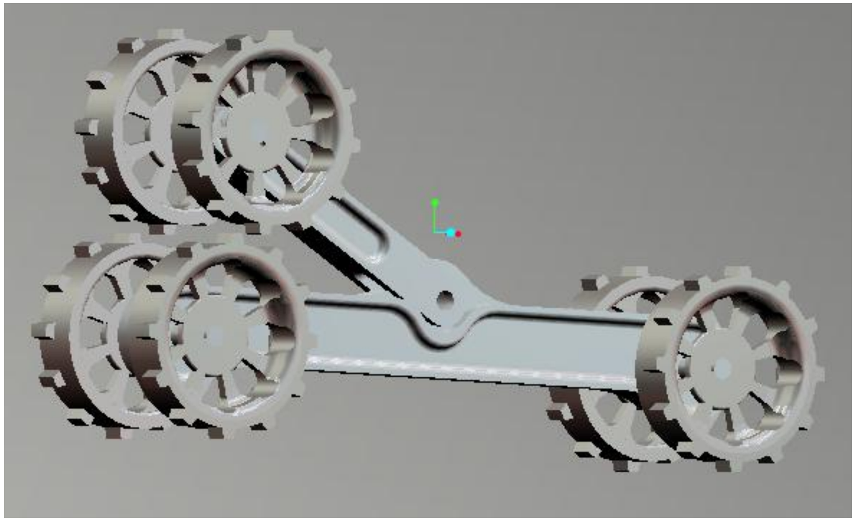
- Triangulated space frame
- Enclosure of dust sensitive systems
- Heatsink for protected components
- Ensure weight balance



# Plow/Chassis Optimization

- Plow/Bumper
  - Reduce complexity
  - Determine best angle of attack
  - Test control of regolith collection
- Chassis
  - Reduce weight
  - Increase stiffness
  - Lower center of mass
  - Ease component access

# Tracked Locomotion System

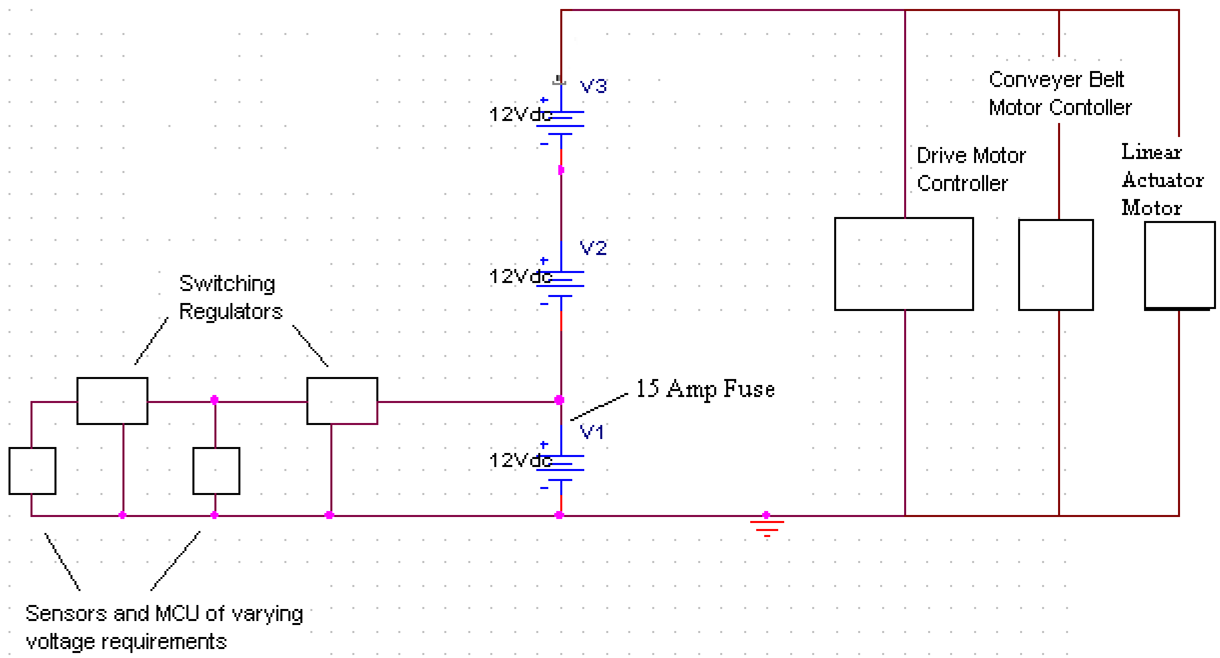


- Center Frame with torsion arm for tension
  - k=150 (Nm/deg)
- Motor housed in main body
  - Drive shaft to sprockets
- Total mass of each track
  - ~12 kg with tread

# Chain and Sprocket Assembly

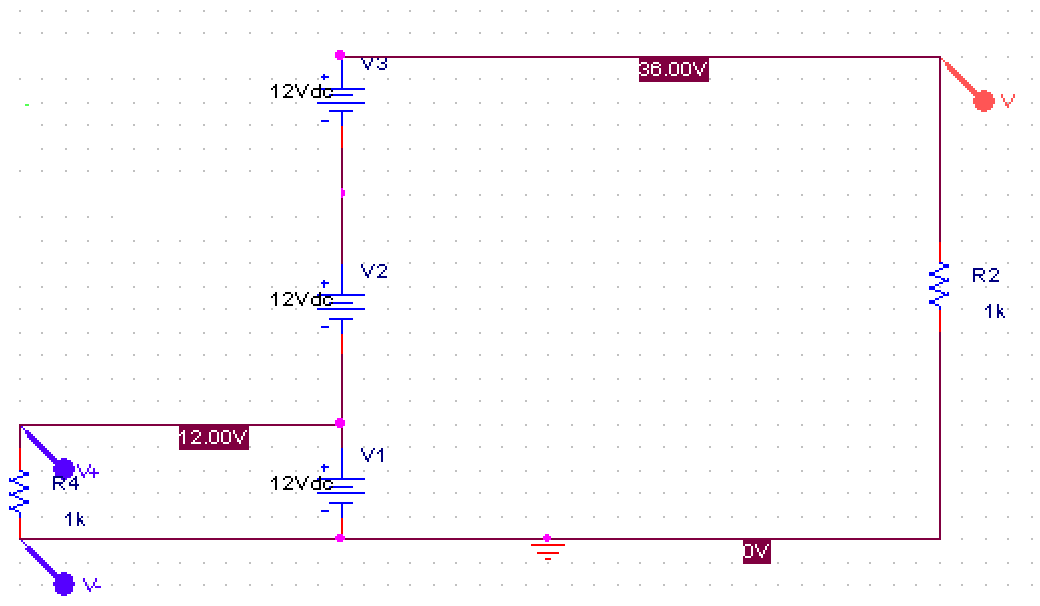
- Chain Assembly
  - Variation of a bike chain
  - 15 cm tread surface at center
  - Individually adjustable connector links
  - Pin Joint allows large circular deformations

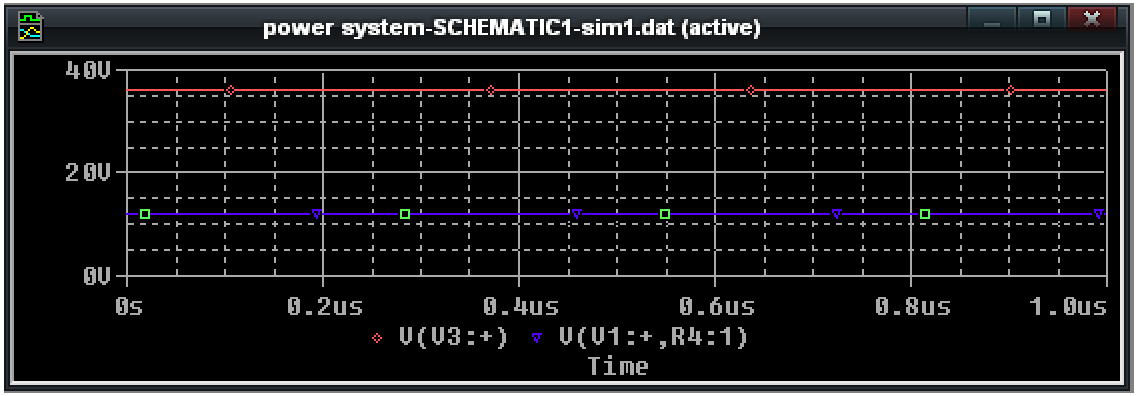
# Power System Schematic




| Artemis Power System Specifications | | | |
|---|---|---|---|
| | | | |
| **Part** | **Type** | **Weight** | **Price** |
| Switching Regulator | DE-SWADJ | N/A | $12 x2 |
| Lead-Acid Batteries | Powersonic 12V 18AH | 13.10 LBS x3 | $51.95 x3 |
| Accessories | Wires/Fuses/Switches/Capacitors | N/A | $50.00 |
| | | | |
| | **Total:** | ~40 LBS | $229.85 |

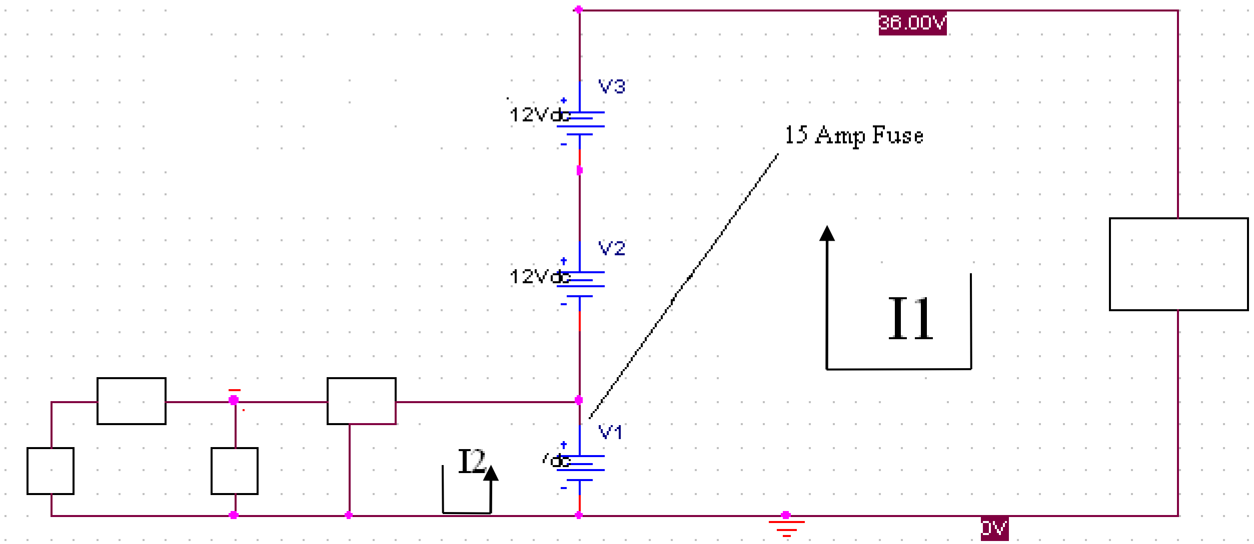
# Power System Simulation



# Maximum Current Analysis

The combined current of I1 and I2 must never exceed 15A, at any given time.




**Current Restrictions:** $I1+I2 < 15A$

# Power System Operation

**PHASE 1**: Plow Engage
**PHASE 2**: Regolith Collection
**PHASE 3**: Regolith Deposit into Collector

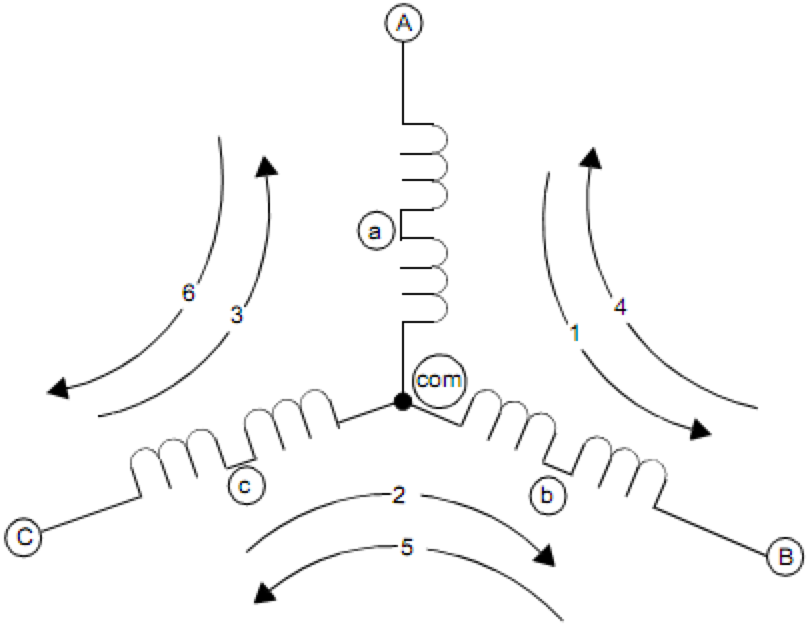
| Device | PHASE 1 | PHASE 2 | PHASE 3 |
|---|---|---|---|
| Drive motor 1 | ON | ON | OFF |
| Drive motor 2 | ON | ON | OFF |
| Conveyor Motor | OFF | ON | OFF |
| Linear Actuator 1 (Plow Lift) | ON | OFF | OFF |
| Linear Actuator 2 (Bucket Lift) | OFF | OFF | ON |
| MCU/Sensors | ON | ON | ON |

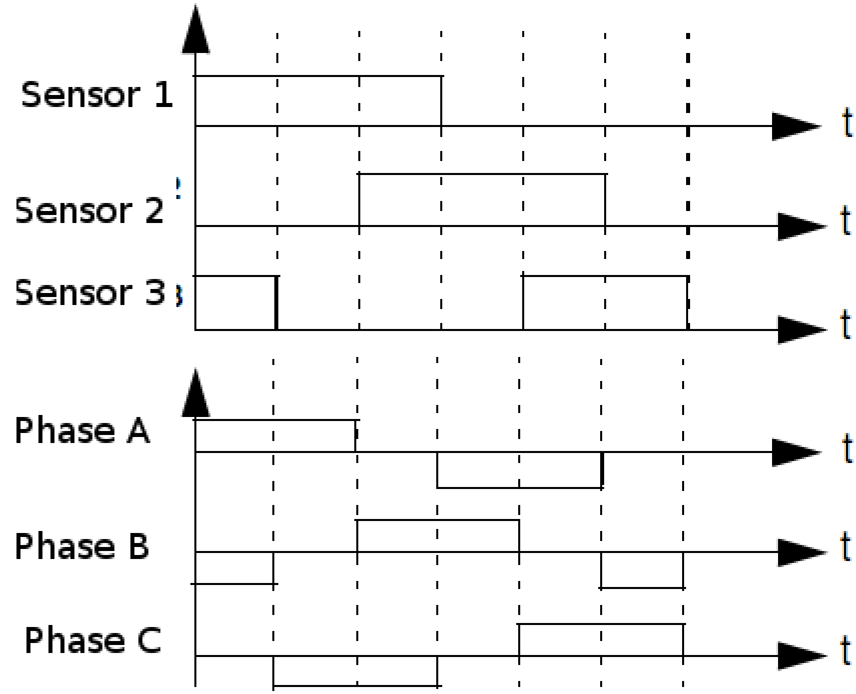
**Maximum Device Specifications in accordance to phase and 15A draw limit:**

| Device | Maximum Allowable Current Draw | Maximum Power Draw |
|---|---|---|
| Drive Motor 1 | 5A | 180W |
| Drive Motor 2 | 5A | 180W |
| Conveyor Motor | 2A | 72W |
| Linear Actuator 1 | 2A | 72W |
| Linear Actuator 2 | 10A | 360W |
| MCU/Sensors | 2A | 12W |

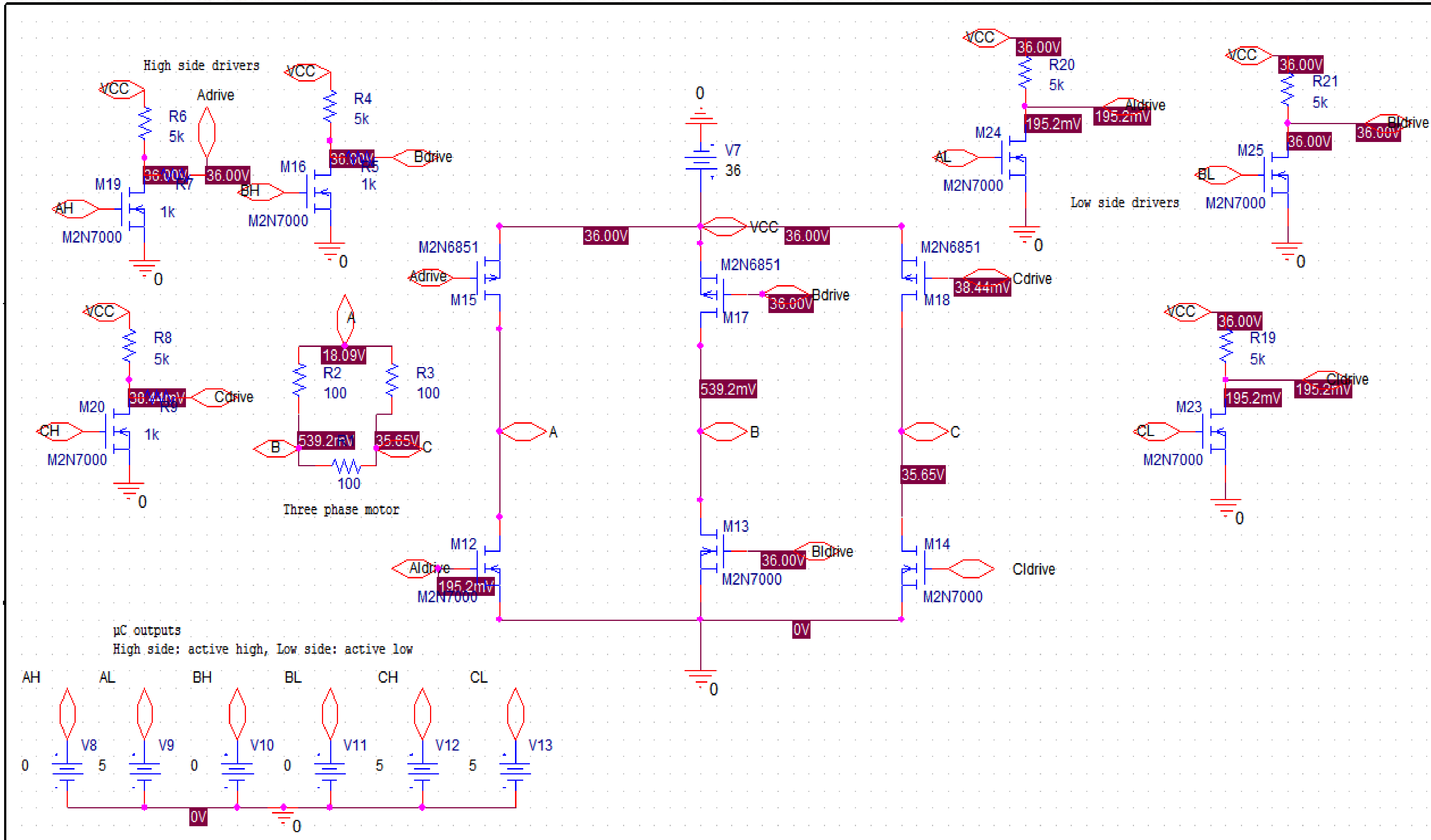
# Brushless DC Motor Control

- Brushed motors are more efficient but are harder to control
  - Commutation needs to be done manually
- Generally three phase with three position sensors that monitor rotor position
  - Clockwise Example:



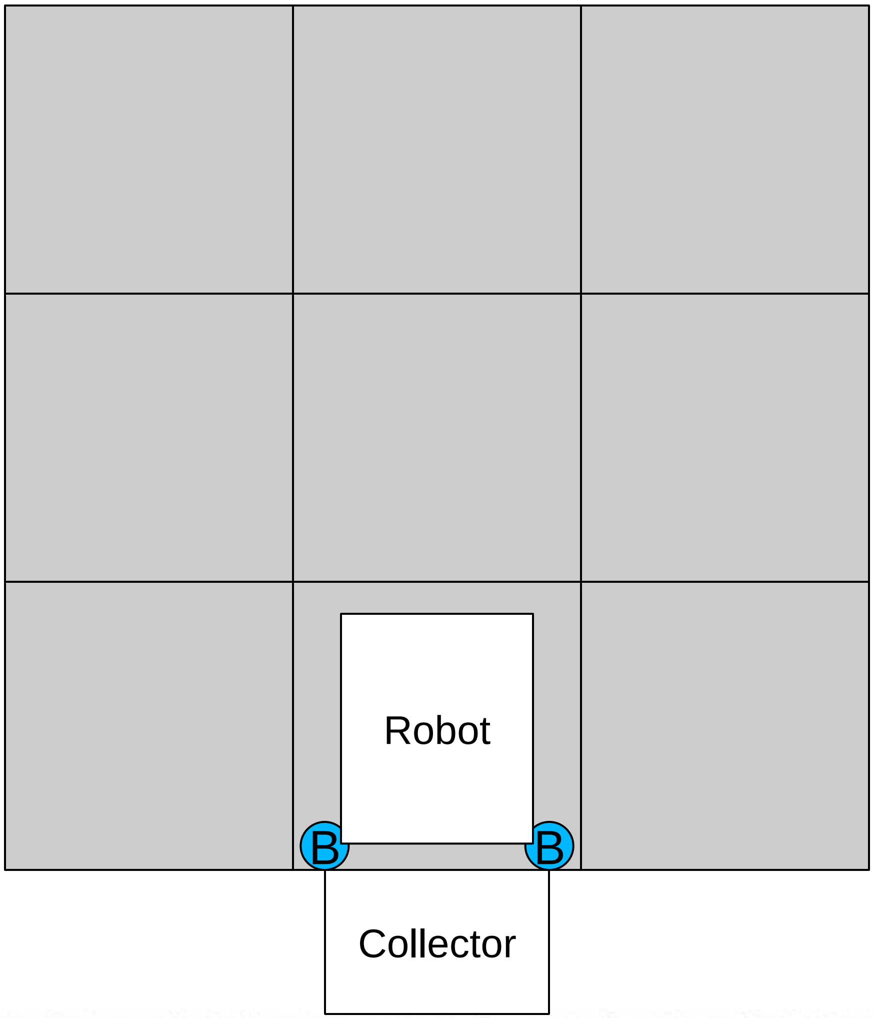



# MOSFET Motor Driver



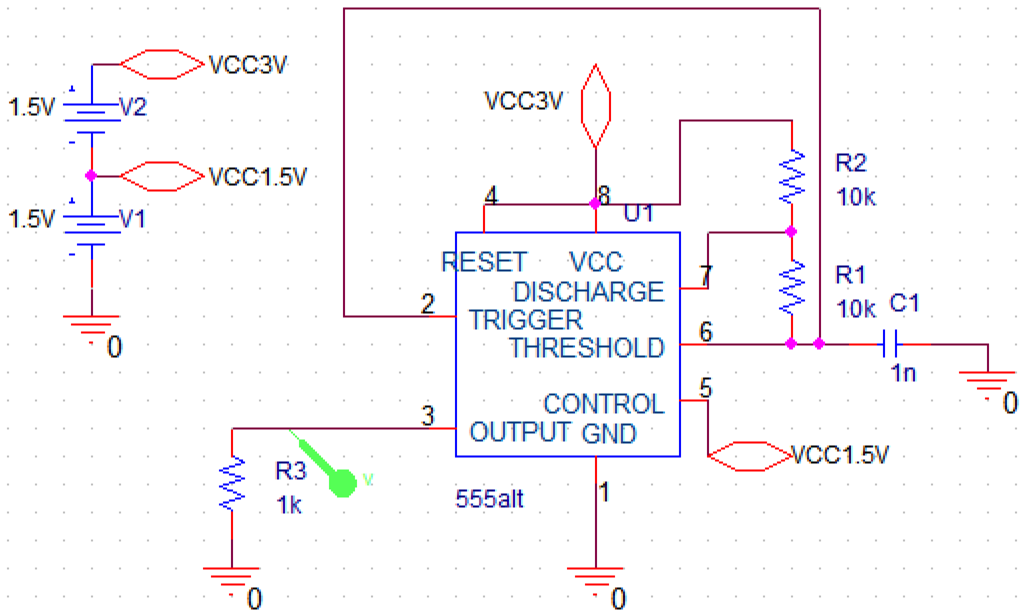
# Navigation Procedure

- From start, proceed on random or preset course
- Once out of starting square, start digging
- When bin is full, move to center of area and face collector
- Move towards collector using beacons for alignment
- When at wall of collector, dump regolith
- Reset inertial navigation and repeat

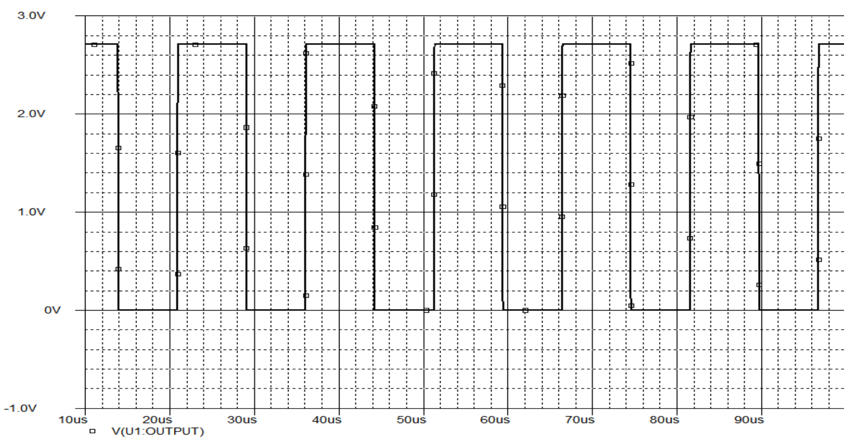


# IR Beacons

- Self-contained beacons running IR LEDs off normal batteries
- Used to allow robot to find and align with collector using infrared detectors
- Need to modulate LEDs
- Use a 555timer to generate a square wave




Frequency and duty cycle are changed by changing R and C

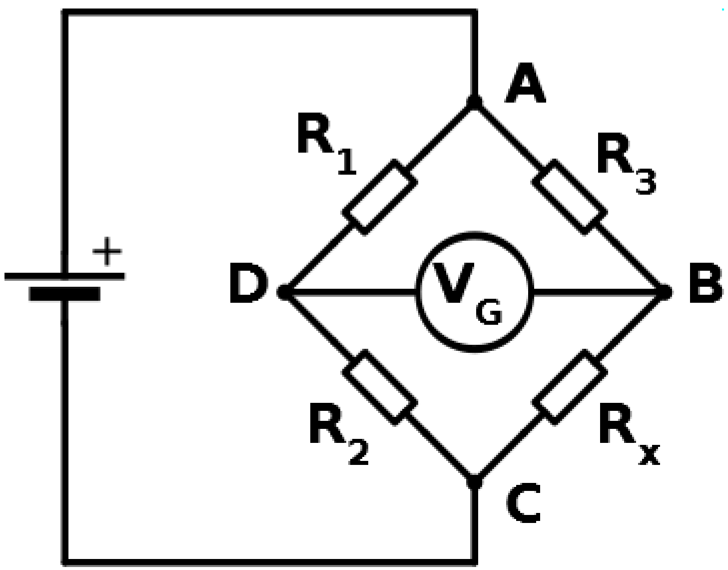


# Inertial Navigation Sensors

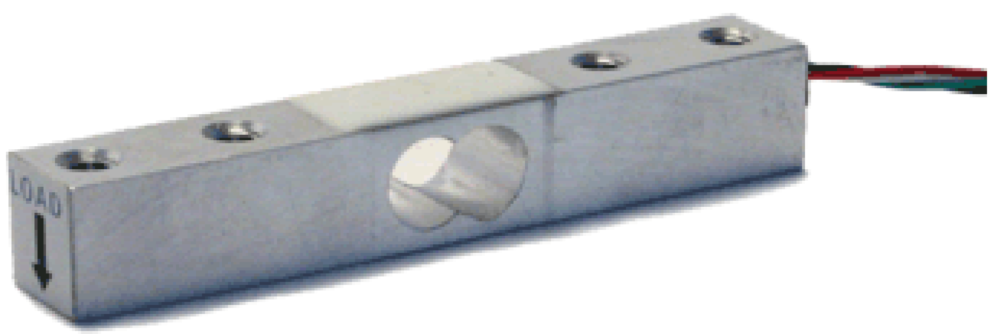
- Accelerometer and gyroscope provide position and direction sensing independent of the robots environment
  - Accelerometers measure acceleration in X Y and Z axises
  - Gyroscopes measure pitch, yaw, and roll
- Accelerometer pseudocode running once per second:
- Xvelocity = (Xacc – prv_Xacc)
- Xposition = (Xvelocity – prv_Xvelocity)
- prvXacc = Xacc
- prv_Xvelocity = Xvelocity
  - Essentially integrate acceleration twice to get position
- Use yaw for steering, pitch and roll not needed

# Weight Sensor

- The robot needs to know when its bin is full and to return to dump
  - Taking apart a cheap digital scale gives a force sensor so the robot can know the weight of the regolith it has
  - The scale works as a wheatstone bridge, one resistor varies with the weight(deformation) and changes the voltage Vg



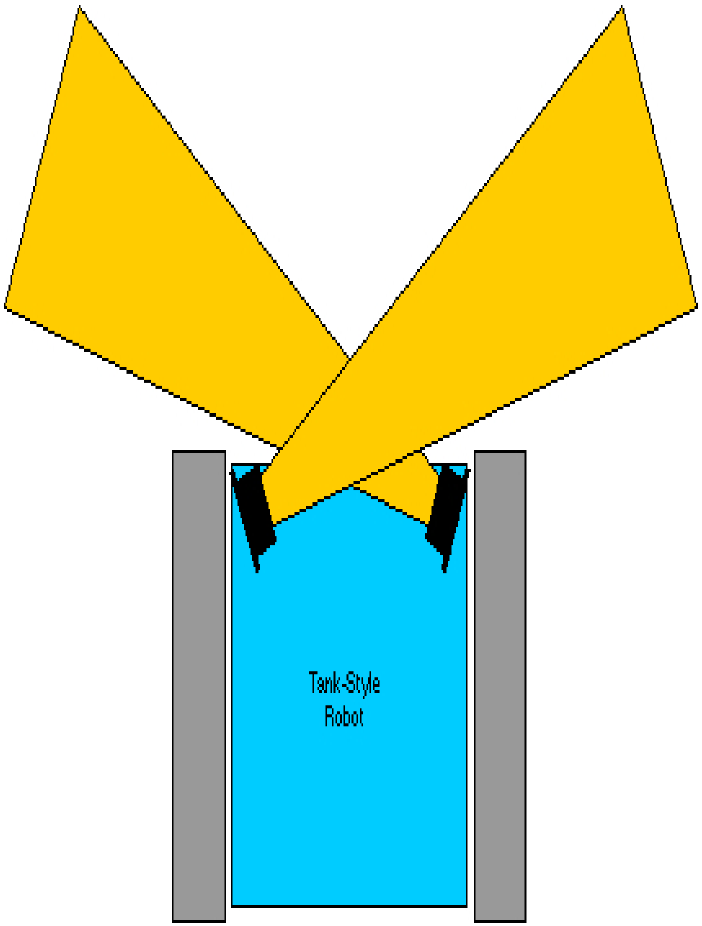

» This is a small voltage and needs to be amplified so the controller can read it



# Sensors

- Navigational Sensors
  - IR Sharp Sensor
  - IR Beacon Sensor
  - Inertial Measurement Unit (IMU)
- Current Senor
- Pressure Senor
  - Bumper Sensor
  - Weight Sensor

# IR Sharp Sensor



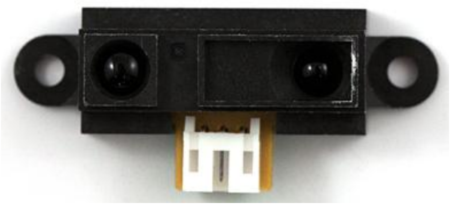
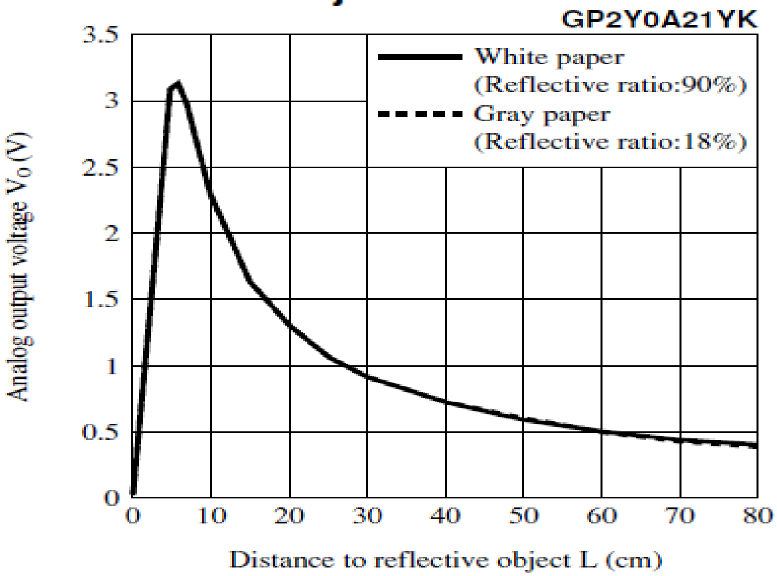
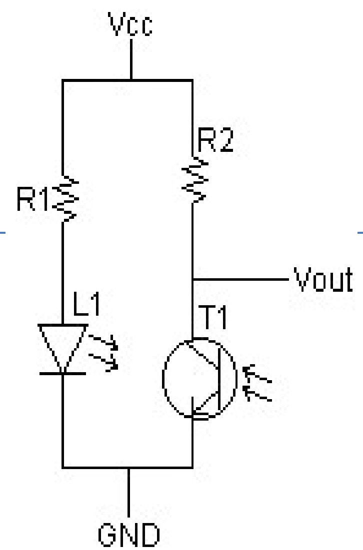



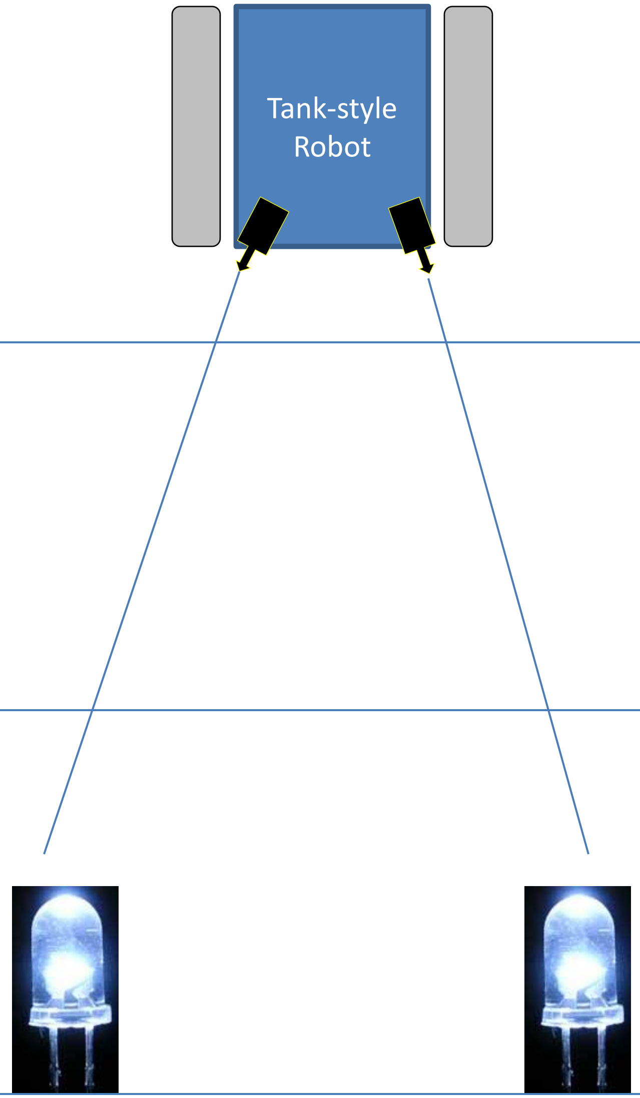
Fig.5 Analog Output Voltage vs. Distance to Reflective Object



# IR Beacon Sensor

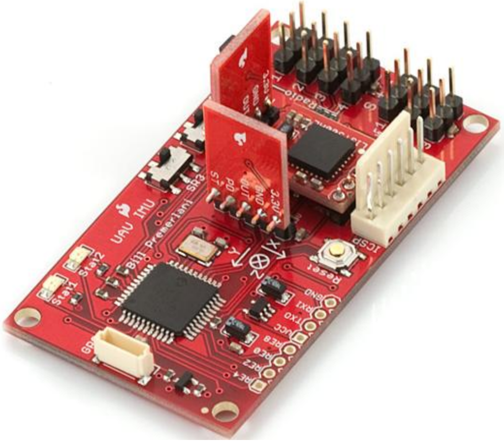
IR Emitter Circuit



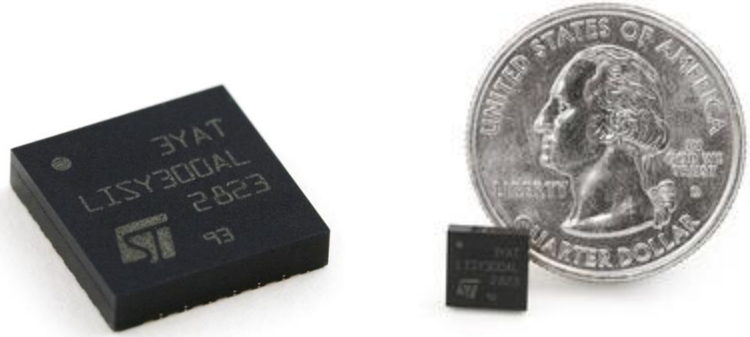



# Inertial Measurement Unit

- Three axis inertial navigation sensor

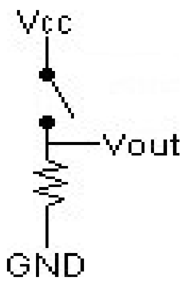


- Single Gyroscope

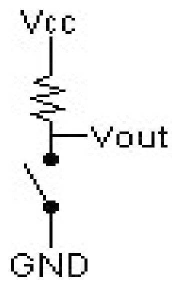


# Bumper and Weight Sensor

- **Tactile Bump Sensor Circuits**

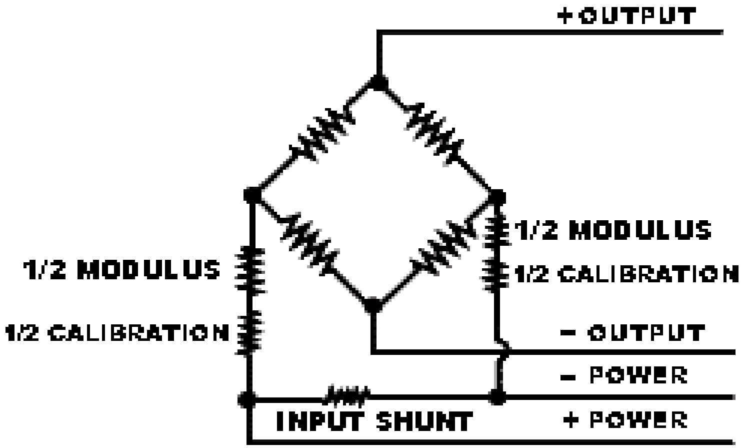


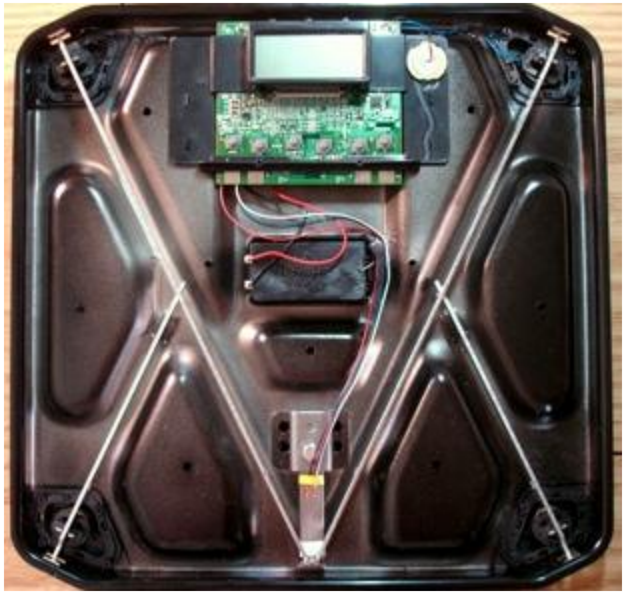

Voltage
goes high
with contact




Voltage
goes low
with contact

- **Weight Sensor Circuit**



# Cost Analysis

| | |
|---|---|
| • IR Sharp  Sensor | $9.95 |
| • IR Beacon Detector | $14.95 |
| • IR LEDs (850 nm 100pcs) | $7.00 |
| • IR LEDs (940 nm 100pcs) | $6.00 |
| • IMU | $149.95 |
| • Gyroscope | $11.95 |
| • Bumper Senor | $1.50 |
| • Weight Sensor | $40.00 |

# Questions