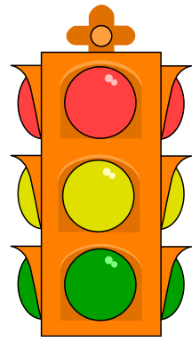
EGN1935: ECE (Ad)Ventures

Today's Menu

- Resistors (Review), Voltage, Current
- Power, batteries
- Switches
- Simple Circuits
  - >Voltage divider, pull up/down resistors, variable resistors, resistor ladder network
- A/D System
- Sensors
  - >Bump sensors, battery-level Sensor, CdS cells



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Resistors

- **Resistors** (Physics 2 & EEL 3111) are a good example of a non-polarized component, i.e., they don't care in which direction electricity flows in them.
  - > However, SIP resistor packages have non-symmetric internal wiring configurations, making them polarized from a mounting point of view.
- **Resistors** (Review)

  Ohm's Law: $V = I \times R$, where
  - I = current in Amps (A)
  - V = voltage in Volts (V)
  - R = resistance in Ohms (Ω)

Named for Georg Ohm, from his 1827 publication

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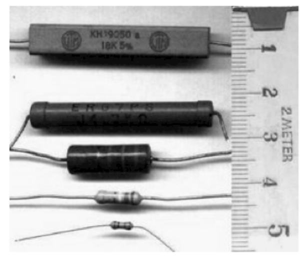
Resistor Power and Packages

- **Resistors** (Review)
  - > Resistors are small cylindrical devices with
  - > color-coded bands indicating their value.
  - > Most of the resistors in small robots are rated for 1/8 watts, which is a very low power rating. They are generally very small.
  - > A few resistors are much larger
    - – A 2W [Watt] resistor is a large cylindrical device, a 5W resistor has a large, rectangular package.
  - > **Resistor Packs**
    - – Resistor packs are flat, rectangular packages with anywhere from six to twenty leads. There are two basic types of packs:
      - Isolated Element (DIP)
      - Common Terminal (SIP)



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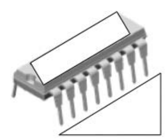
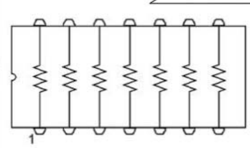
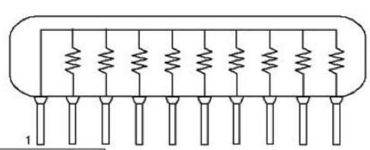
Resistor Packages

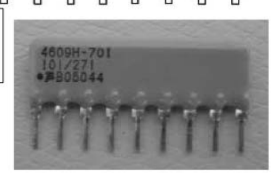


- **Resistors** (Review)
  - > **Resistor Packs**
    - – **Isolated Element**: Discrete resistors; usually three to ten package. (Usually in a **DIP**.)
    - – **Common Terminal**: Resistors with one pin tied together and the other pin free. Any number from three to nine resistors per package. (Usually in a **SIP**.)





Vcc or Gnd



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Component Types & Polarity

Device	Polarized?	Effect of Mounting Incorrectly
Resistor	no	
Isolated R-Pack	no	
Common R-Pack	yes	circuit doesn't work
Diode	yes	circuit doesn't work
LED	yes	device doesn't work
Monolithic capacitor	no	
Tantalum capacitor	yes	explodes
Electrolytic capacitor	yes	explodes
DIP socket	yes	user confusion
PLCC socket	yes	52-pin severe frustration
Integrated circuit	yes	overheating; permanent damage
Inductor	no	
Transistor	yes	circuit doesn't work

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Component Values

- **Component Value Marking**
  - >Various electronic components have their values marked on them in different ways.
    - – For the same type of component, say, a resistor, there could be several different ways that its value would be marked.
  - >We'll concentrate on how to read the markings on resistors and capacitors.
    - – Other devices, such as transistors and integrated circuits, have their part number printed clearly on the device package.
  - >**Resistors**
    - – The largest resistors (in terms of wattage, not resistive value), simply have their value

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Resistor Color Code

- **Component Value Marking**
  - **Resistors**
    - Other resistors are labeled using a standard color code.
    - This color code consists of three value bands plus a tolerance band. The first two of the three value bands form the value mantissa. The final band is an exponent.
      - It's easiest to locate the tolerance band first. This is a metallic silver- or gold-colored band.
        - If it is silver, the resistor has a tolerance of 10%; if it is gold, the resistor has a tolerance of 5%.
        - If the tolerance band is missing, the tolerance is 20%.
      - The more significant mantissa band begins opposite the tolerance band. If there is no tolerance band, the more significant band is the one nearer to an end of the resistor.

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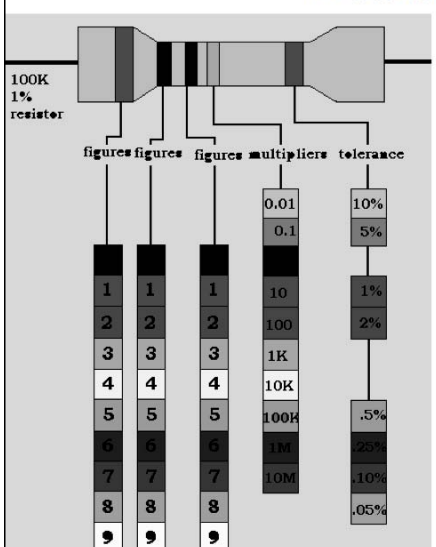
Resistor Color Code



Color	Mantissa Value	Multiplier Value
Black	0	1
Brown	1	10
Red	2	100
Orange	3	1000
Yellow	4	10,000
Green	5	100,000
Blue	6	1,000,000
Violet	7	
Grey	8	
White	9	

Bad **b**eer **r**ots **o**ur **y**oung **g**uts **b**ut **v**odka **g**oes **w**ell – **g**et **s**ome **n**ow

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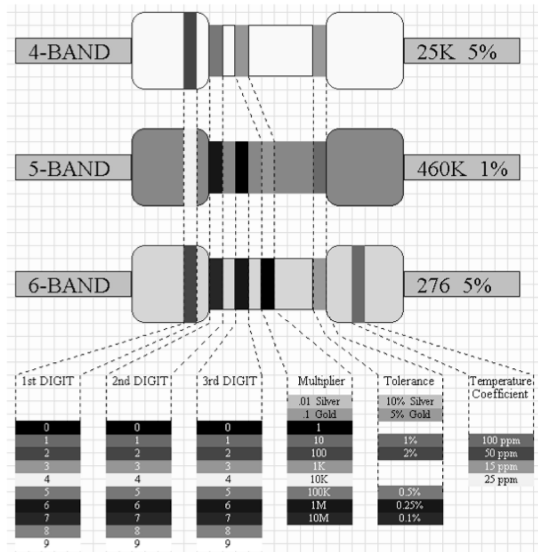
Resistor Color Code Examples

- Resistor Examples
  - >Brown, Black, Black: 10Ω (= 10 * 10^0)
  - >Brown, Black, Brown: 100Ω = 0.1kΩ. (101)
  - >Brown, Black, Red: 1,000Ω = 1kΩ. (102)
  - >Yellow, Violet, Orange: 47,000Ω = 47kΩ (473)
  - >Brown, Black, Orange: 10,000Ω =10k. (103)



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Power & Batteries

- Power is the amount of voltage & current delivered to an electronic device, usually measured in watts.
  - >A simple way to view power is that it is the product of voltage and current, that is,
    - Power (watts) = voltage (volts) × current (amperes) that is, $P = V \times I$
    - For a resistor, since Ohm's Law is $V = I \times R$, or alternatively $I = V / R$ then we have $P_{Resistor} = I^2 \times R = V^2 / R$

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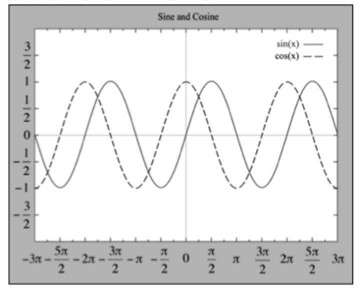
Power & Batteries

- Power from the wall socket is said to be AC or "alternating current."
  - >The voltage delivered to the socket is 120 V which varies sinusoidally at a frequency of 60 Hz.



  - >The current delivered to the socket is limited by a fuse or circuit breaker (usually 15-20 Amps).
  - >The round plug is connected to ground.
  - >In Europe the frequency is usually 50 Hz and the voltage is 240 V.

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Power & Batteries

- Power from batteries is said to be DC or "direct current."
  - > Batteries store chemical energy.
  - > The electricity produced by a battery is generated by a chemical reaction.
  - > The voltage delivered by a common automotive (**lead acid**) battery is 12 V.
  - > The current delivered by a battery is limited by the technology used in constructing the battery.
  - > Typical values for small car batteries are 50-60 amps and 100-150 amps for large tractor/diesel truck batteries. (Cold-cranking amps are much higher 450-1100 amps.)
    - **Battery book: http://www.buchmann.ca/**
    - **See also Wikipedia: Batteries, Rechargeable Batteries**

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Power & Batteries

- Robots may be powered by a variety of methods.
  - >For our small robots we previously used **Ni-Cad** battery packs. We now use **NiMH** batteries.
  - >Battery power offers a number of advantages over any other method in our robotic applications.
  - >Batteries are cheap, relatively safe (at least Ni-Cads and NiMH are), small, and easy to use.
  - >DC motors convert electrical power into mechanical power with relatively good efficiency.
- There are many different types of batteries, each with its own "positives and negatives" (LOL).

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Power & Batteries

- Most small batteries come in one of the following voltages: 1.2, 1.5, 3, 3.6, or 9.
- Common battery technologies include:
  - >Alkaline: (like those used in radios & flashlights)
  - >NiCad [Nichol Cadmium]: used in hobby cars and our small robots
  - >NiMH [Nickel Metal Hydride]: used also in toys
  - >Lithium Ion or Lithium Polymer: used in cameras, laptop computers, and cardiac pacemakers
- A cell is the unit that houses a single chemical reaction to produce electricity.
- A battery is a bank of cells.

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Power & Batteries

- **Voltage**
  - >Cells use chemical reactions to produce electricity.
    - – Depending on what materials are used to create the reaction, a different voltage will be produced.
    - – This voltage is called the nominal cell voltage and is different for different battery technologies.
  - >For example, some standard flashlight batteries have cells that use a carbon-zinc chemical reaction yielding a nominal cell voltage of ≈ 1.5 volts.
  - >Car batteries have six lead-acid cells, each with a nominal cell voltage of ≈ 2.0 volts, (6 × 2 = 12V battery).

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Power & Batteries

- **Capacity**
  - >In general, the larger a cell is, the more electricity it can supply. This cell capacity is measured in **ampere-hours**, which are the number of hours that the cell can supply a certain amount of current before its voltage drops below a predetermined threshold value.
  - >For example, 9 V alkaline batteries (which consist internally of six 1.5 V alkaline cells) are generally rated at about 1 **ampere hour**. This means that the battery can continuously supply one ampere of current for one hour before discharging, i.e., "dying."

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Power & Batteries

- **Capacity**
  - >In the capacity measurement, the 9 V alkaline battery "dies" when the battery voltage drops below 5.4 V. However, the amp-hour measurement is usually taken to assume a twenty hour discharge time.
  - >A 9-volt battery would need to be tested by having the battery supply 1/20th of its rated capacity for twenty hours (that is 1A÷20 = 0.05A = 50 mA for 20 hours).
    - – If the battery were drained more quickly, as in the one-hour test, the capacity would turn out to be quite a bit less.

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Power & Batteries

- **Power Density**
  - >There are large differences in capacity per unit weight (the cell's power density) across battery types. This is one of the cell's most important rating.
  - >Inexpensive carbon-zinc cells have the lowest power density of all types.
  - >Alkaline cells have about ten times the power density of carbon-zinc cells.
  - >Ni-Cad cells have less power density than alkaline cells, but they are rechargeable.

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Power & Batteries

- **Discharge Curve**
  - >When a cell discharges, its voltage lessens over the course of the cell life. The characteristic discharge curve varies considerably over different types of cell.
  - >For example, alkaline cells have a fairly linear drop from full cell voltage to zero volts. This makes it easy to tell when the cell is weakening.
  - >NiCad cells have a linear voltage drop region that drops off sharply at some point. For this reason, when consumer products use NiCad cells, the device will suddenly "die" with no warning from the cells. One minute, they are fine, the next, they are dead. For a Ni-Cad cell, this is normal, but it can be annoying.

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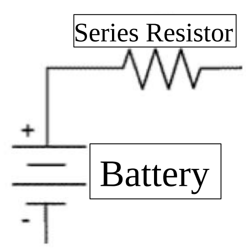
Power & Batteries

- **Internal Resistance**
  - >A cell can be modeled as a perfect voltage source in series with a resistor. When current is drawn out of the cell, its output voltage drops as voltage is lost across the resistor.
  - >This cell characteristic, called the **internal resistance**, is important because it determines the maximum rate at which power can be drawn out of the cell.



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Power & Batteries

- **Internal Resistance**
  - >For example, lead acid cells have very low internal resistance. This makes them well suited for the application of being a car battery — large currents can be draw from the cells to operate the car's starter motor.
  - >The rate of power delivery is limited largely by the cells' internal resistance. Alkaline cells have higher internal resistance than NiCad cells.
    - For example, a flash unit takes longer to recycle when alkaline cells are used.

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Power & Batteries

- **Internal Resistance**
  - >Cells that have low internal resistance, in particular, lead acid and NiCad cells, can be dangerous to work with, because if the cell is shorted, large currents can flow.
    - These currents will heat the metal wire they are flowing through to very high temperatures, easily melting the insulation from them. The cells will also become very hot and potentially may explode.
  - >For this reason it is very important **not to short** a lead acid or NiCad cell
    - Alkaline cells and carbon zinc cells, with their high internal resistances, will still deliver quite a bit of current when shorted, but nowhere near the amounts of the other above types of cells.
  - >Example: 9 V battery in your pocket.

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Power & Batteries

- **Rechargeablility**
  - >Another important cell characteristic is whether or not they are rechargeable, and if so, **how many times**. Since rechargeable cells are often, environmentally speaking, highly toxic, the use of rechargeable battery technology is a hotly debated political issue.
  - >Unfortunately, the cells with the highest (pre-lithium) power densities (alkaline and carbon) are not rechargeable. However, advances in rechargeable technologies are catching up. For example, lithium ion and lithium polymer cells can now be charged with specially designed (smart) chargers.

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Power & Batteries

- **Memory Effect**
  - >The term “memory effect” refers to a phenomenon observed in rechargeable NiCad cells in which cells that are only partially discharged before being recharged have a tendency to “remember” the level of discharge, and, over time, only become usable to that discharge level. There is disagreement as to whether or not this phenomenon actually exists, but most concur that NiCad cells should be discharged fully before being recharged.
  - >Lead acid cells and the NiMH technology, do not exhibit this effect. Lead acid cells typically last for several hundred cycles of full discharge, and thousand of cycles of partial discharge.

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Power & Batteries

- **Cost**
  - >It would be wonderful if the best cells did not cost substantially more than the cells with worst performance, but this is not the case.
    - – For consumer purposes, it is generally agreed that NiCad cells, which cost several times more than alkaline cells, are much less expensive over the cells' lifetimes.
    - – NiCad cells can be recharged several hundred times while alkaline cells are one-use devices.
    - – But, NiCad cells exhibit the "sudden death" discussed earlier.
  - >NiMH cells are more expensive, but offer twice the capacity of either lead acid or Ni-Cad cells.

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Power & Batteries

- **Cost**
  - >**Lithium-Ion** and **Lithium-Ion Polymer** (**LiPo** or **Li-poly**) offer higher power density than NiMH
  - >Probably the worst thing one can say about all types of batteries is that "they never last long enough."
    - – Unfortunately this is more or less true, but things in the battery technology field are improving. Tablets, laptop computers, and electric cars have created a real market need for improved batteries.
    - – For example, the batteries in laptops can last 3 to 7 hours. They have a micro-processor circuit inside to monitor their usage and charging. They often cost near $50-$100. In 2000, they probably cost $100-$150.

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Power & Batteries

- When cells are connected in series, their voltages add but their amp-hour capacity does not. Series batteries should be composed of cells of equal capacities.
- When cells are connected in parallel, their voltages remain the same, but their capacities add. This can be **dangerous** for certain types of batteries, so research this prior to use.

Cell Type	Voltage	Power Density	Internal Resistance	Rechargeable	Cost
Carbon-Zinc	1.5 volts	low	high	no	low
Alkaline	1.5 volts	high	high	no	moderate
Lithium	1.5 volts	very high	low	no	high
NiCd	1.2 volts	moderate	low	yes	moderate
Lead-Acid	2.0 volts	moderate	low	yes	moderate
Nickel-Hydride	1.2 volts	high	low	yes	high
Lithium-Ion	3.6 volts	higher	low	yes	higher
LiPo	3.7 volts	highest	low	yes	highest

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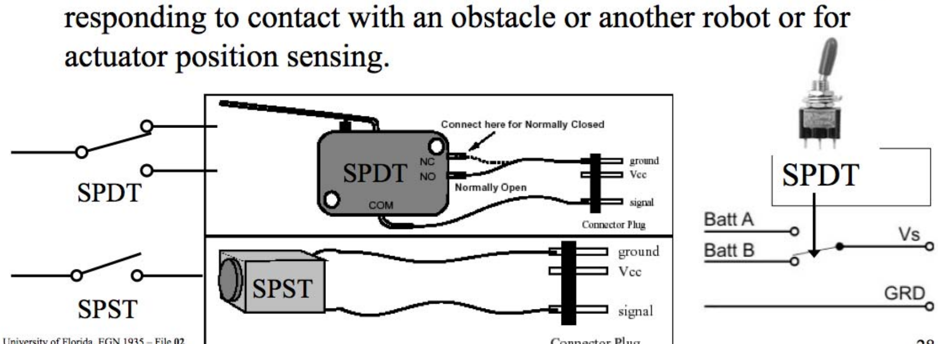
Switches

- **Simple Switches** (EEL-3111 and EEL-3701)
  - > Simple small switches include micro switches and a small push button types. These make great object detectors, so long as you are only interested in answering the question, "Am I touching something right now?" with a yes or no. This is often enough for responding to contact with an obstacle or another robot or for actuator position sensing.



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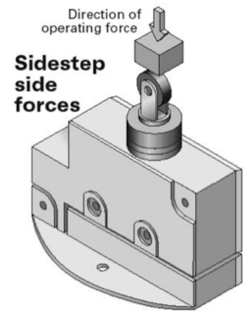
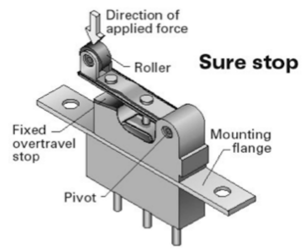
Switches

- Simple Switches
  - >A **limit switch** can be a good way to protect drive mechanisms which self destruct when overdriven.
    - – This could be handy for limiting the motion of hinged joints or linear actuators by requiring that a switch be open (or closed, depending upon the situation) before running the motor and monitoring it while things are moving.
    - – They could also be used for extended user interface for testing and development purposes





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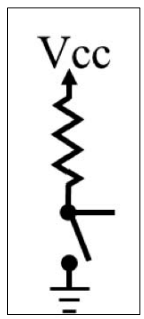
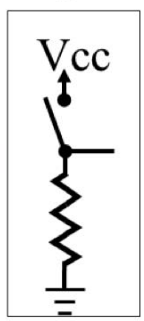
Switches





- Simple Switches for **digital inputs**
  - >Some micro switches are **pulled up or pulled down**, which means they can be wired so that they return a high (one) or a low (zero) when not depressed.
    - – The only major difference is how you think about the device in your code.
      - Reading a particular sensor can be thought of as asking a question. The question could be, "Are you open?" or "Are you closed?"
      - Opened and closed mean different things for these switches.
      - What are the voltages for each if the switches are open?
      - What are the voltages for each if the switches are closed?

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Switches

- Simple Switches
  - >Touch switches with a pull up resistor should be wired in a normally open configuration, so that the signal line is brought to ground only when the switch is depressed.
  - >**Bouncing** is a problem found in many switches.
    - – At the point where the switch goes from open to close or vice versa, the output from the switch is very glitchy. The switch may output several transitions. Bounciness occurs especially when the switch is used in a sensitive mode.
    - – One way to debounce the switch is to add a delay between samples of the digital input. If the sampling is sparse enough, the bouncing section of the data will not be collected.

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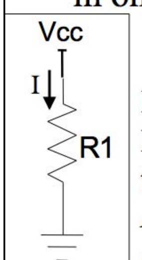
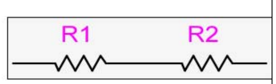
Resistors

- **Ohm's Law** (EEL-3111)
  - >The voltage across a resistor is proportional to the product of the current and its resistance.
  - >$V = I \times R$, where V is measured in volts (v), I is measured in amperes (amps, A or a) and R is measured in ohms (Ω). Note: $I = V / R$

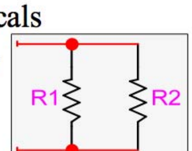


If V_{cc} = 5v &
R_1 = 100 Ω,
then (I=V/R)
I = 0.05 A
I = 50 mA

Resistors in series add
$\mathbf{R_T = R_1 + R_2 + \ldots + R_n}$



Resistors in parallel add reciprocals
$\mathbf{1/R_T = 1/R_1 + 1/R_2 + \ldots + 1/R_N}$



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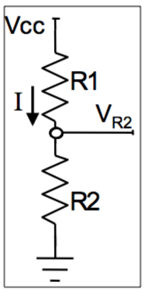
Resistors

- **Voltage Divider** (EEL-3111)
  - > If two resistors are connected in series, then the current flowing through both is the same. But the voltage they dissipate is different depending on their resistance. What is the voltage on each of the resistors? This is called the 'voltage divider' equation.



- Since $R_T = R_1 + R_2$ and
  $I = V_{CC} / R_T$, then
  $V_{R2} = I \times R_2 = (V_{CC} / R_T) \times R_2$
  $V_{R2} = V_{CC} / (R_1 + R_2) \times R_2$
  $V_{R2} = V_{CC} \times [R_2 / (R_1 + R_2)]$

$$V_{R2} = \frac{R_2}{R_1 + R_2} V_{CC}$$

- What is V_{R1}? $V_{R1} = V_{CC} \times [R_1 / (R_1 + R_2)]$

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Sensors

- **Sensors** (EEL-4665/EEL-5666)
  - > Sensors convert information about the environment into a form that can be used by a computer. The sensors that are on the robot are related to sensors found in humans.
    - – Touch sensors embedded in your skin, visual sensors in your retina, and hair cells in your ears convert information about the environment into a neural code that your brain can understand.
    - – Your brain needs to understand the neural code so you can react. In order to program our robots, you'll need to understand the output of the sensors before you can program a robot to react to different stimuli.

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Sensors

- **Analog Signals** and A-to-D (EEL-3135)
  - >Without sensors, a robot is just a (dumb) machine.
  - >Robots need sensors to deduce what is happening and be able to react to changing situations.
  - >An analog signal is any variable signal continuous in both time and amplitude.
    - – It differs from a digital signal in that small fluctuations in the signal are meaningful.
    - – Analog is usually thought of in an electrical context, however mechanical and other systems may also convey analog signals.

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Sensors

- **Analog Signals** and A-to-D (EEL-3135)
  - >Digital signals are the subset of discrete-time signals that are also discrete in level. They may be divided into two categories:
    - – Some are inherently both discrete and quantized (e.g., the number of people who visit the Swamp every day.)
    - – Some describe phenomena that are actually continuous in one way or another. The signal must be made discrete, quantized, or both, in order to make it digital. This "digitization" is required if the signal is to be processed in a computer or other digital device. (e.g., a song on a CD)
  - >In most applications, digital signals are represented as binary numbers, so their quantization is measured in bits.

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Sensors

- **Sensor Types**
  - >Sensors come in two basic types: analog and digital.
    - – Analog sensors are connected into the ADC input ports in a μC
    - – The analog to digital converter (ADC) in the robot (μC) convert the input voltage to a *n*-bit value, where *n* is usually 8, 10, or 12
      - Usually the input voltage is between 0 and 5V or (0 and 3.3V)
      - For 8-bit analog ports (n=8), 0v → 0 and 5V → 255 (=2^8-1)
      - For 10-bit analog ports (n=10), 0v → 0 and 5V → 1023 (=2^{10}-1)
    - – Digital sensors can be plugged into either the digital ports or the analog ports, but will always return either "0" or "1."
    - – **Analog to Digital**: (8-bits): $0 \le x \le 255$ (10-bits): $0 \le x \le 1023$
    - – **Digital**: "0" or LOW or 0V or 0 and "1" or HIGH or 5V or 255

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Sensors

- **Sensor Types**
  - >Each type of sensor has its own unique uses.
    - –Digital sensors, such as pushbuttons, can tell you when you've hit a wall.
    - –Digital sensors always answer a question about the environment with a YES (1) or NO (0).
      e.g., "Have I hit the wall?"
      - Yes if the switch is closed.
      - No if the switch is still open.

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Sensors

- **Analog Sensors**
  - >Bend sensors detect how far the sensor has bent.
  - >Photo-resistors (CdS [cadmium sulfide] cells) can detect the amount of light hitting the sensor.
  - >Analog sensors answer questions with more detail than digital sensors.
  - >Analog sensors can be converted to digital sensors using thresholds.
    - – Instead of asking the question “How much is the sensor bent?” you can ask the question: “Is the sensor bent more than half way?” The threshold can be determined by playing around with the specific sensor.
    - – For example, if value ≤ threshold, then No, else Yes.

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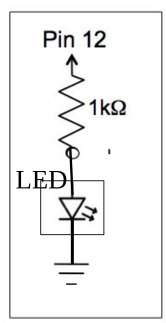
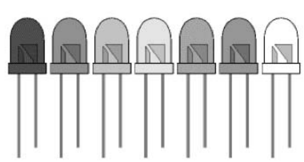
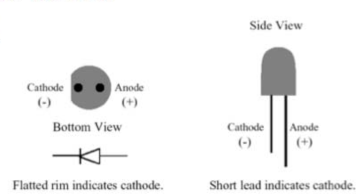
Sensors

- **Digital Sensors** (EEL-3701)
  - >Digital outputs often have resistors connected to them to limit the current flow.
  - >We can connect an LED through a current-limiting resistor to test Digital Output Pins.
  - >LED is a diode that emits light when on. An LED's cathode is marked either by a small flat edge along the circumference of the diode casing, or the shorter of two leads.







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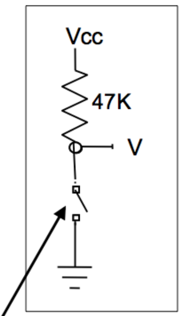
Sensors

- **Digital Sensors** (EEL-3701)
  > Digital inputs usually have pull-up resistors connected to them as shown below.
  > Digital switches are often wired such that the sensor is wired across the signal pin and ground. This means that when the digital sensors is closed, the signal is grounded or LOW. When the switch is open, the signal pin outputs HIGH (Vcc, often 5 V or 3.3 V).
  – The switch is wired with a "pull-up" resistor.

- $V \approx Vcc$, if switch open
- $V = 0$, if switch closed



Single Pole Single Throw (SPST) Switch

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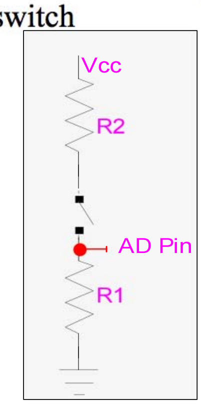
Sensors

- **Analog Sensors** (EEL-3111 & EEL-4744)
  > Switches can also be connected to the analog input pins on a robot. If the resistor values are carefully selected, e.g., 10kΩ each, the value of the signal will be either near 0V when the switch is open or near 1/2 V_{CC} , i.e., 127 (1/2 of 255) when the switch is closed. A threshold of, anything under 127 would work, but 20 will do the job nicely.
  > If Signal > 20 then "switch closed" else "switch open"
  - Analog value of V_{CC} is 255
  - V_{R1}= 0, if switch is open
  - V_{R1}=255 x $R_1/(R_1+R_2)$, if the switch is closed



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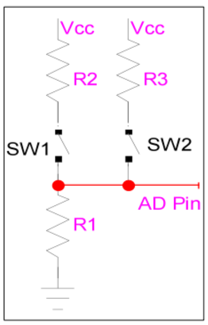
Sensors

- **Analog Sensors**
  - > We can use many resistor-switch pairs in parallel with R2 to construct a so-called resistor bridge circuit and a single A/D signal distinguishes between the switches. Standard values of 10kΩ, 20kΩ, 30kΩ, 47kΩ and 100kΩ work nicely



- The value on the analog pin (signal) will be given by:
  - > $V_a = V_{R1} = 0$, if both switches are open
  - > $V_b = 255 \times R_1/(R_1+R_2)$, if **SW1** is closed
  - > $V_c = 255 \times R_1/(R_1+R_3)$, if **SW2** is closed
  - > $V_d = 255 \times R_1/(R_1 + R_2//R_3)$, if **both** closed
- Suppose $R_1=R_2=10k\Omega$ and $R_3= 20k\Omega$ ➔ $R_2//R_3 = 6.67k\Omega$
- $V_b=0.5*255 \approx 127$, $V_c=0.33*255 \approx 85$, $V_d=0.6*255 \approx 153$
- If Signal < 85, then **NO** bump, else
- If 85 < Signal < 137, then **SW2** bumped, else
- If 137 < Signal < 153, then **SW1** bumped, else **both** bumped

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Sensors

- **Analog Sensors**
  - > There are typically 8 pins (inputs) on a micro-controller for the A/D system. Each pin (channel) is a separate (independent) device.
  - > Many A/D systems are 8-bit which yield a value between 0 and 255, but some are 10-bit which yield a value between 0 and 1023.
  - > Reading the value of an analog port without a sensor will return a value above 250. With the sensor plugged in, the value should be less. This is one good way to check if one sensor fell out: write a piece of code that checks the values of the analog ports that you have sensors plugged into. If that value is above 250 or so, have it tell you to check the sensor.
  - > We could use this scheme to create a battery level sensor. If the value falls below a certain voltage, tell the user to charge the batteries.

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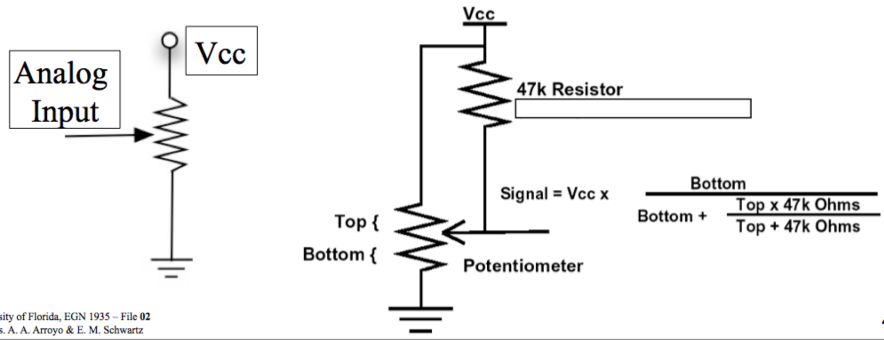
Sensors

- **Potentiometers**
  - > Potentiometers are variable resistors.
  - > There are several sizes of potentiometers (aka pots). Some are controlled by turning a knob, other by sliding a knob linearly.
  - > Turning the knob or sliding the handle increases/decreases the resistance, producing different analog values.



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Sensors

- **Potentiometers**
  - >Potentiometers should be wired with Vcc and ground on the two outside pins, and the signal wire on the center tap. This places the resistance of the potentiometer in parallel with the 47kΩ pull-up resistor and is more stable than using one side and the center to make a plain variable resistor.
  - >"Pots" have a variety of uses. They have been used in angle measurement for various rotating mechanisms.
  - >Pots are not designed to turn more than about 270°. Forcing them farther is likely to break them.

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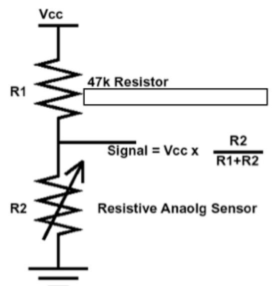
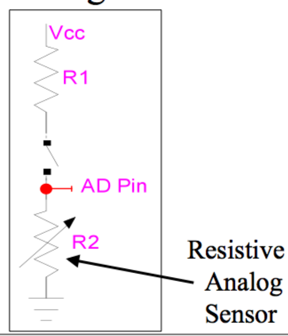
Sensors

- **Analog Sensors**
  - > The resistance of resistive analog sensors, like the bend sensors or photo-resistors, change with changes in the environment, either an increase in light, or a physical deformation. The change in resistance causes a change in the voltage at the signal input by the voltage divider relation.

$$V_{AD} = \frac{R_2}{R_1 + R_2} V_{CC}$$





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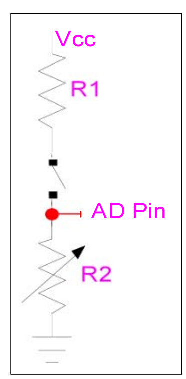
Sensors

- **Bend Sensors**

  - > The bend sensor element is a resistive device that changes in resistance when it is deformed.
    - – The sensors are only sensitive to being bent in one direction—the one that stretches the silver material.
    - – Bending them in this direction increases their resistance.
    - – Bending them in the opposite direction does not change the resistance.



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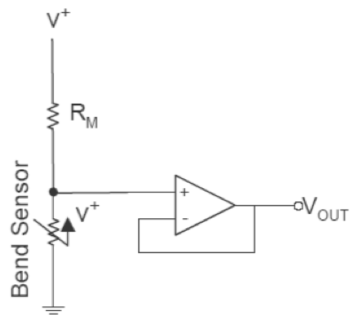
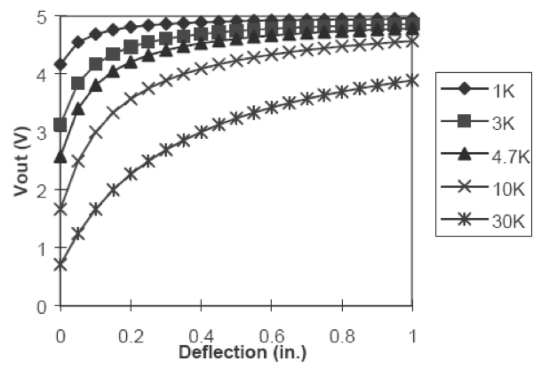
Sensors

- **Bend Sensors**





Deflection vs. Voltage

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Sensors

- Photocells (EEL-3304)
  - >The photocell (CdS cell) is a special type of resistor which responds to light. The more light hitting the photocell, the lower its resistance.
  - >A photo-resistor (CdS cell) changes its resistive value based on the amount of light that strikes it. As the light hitting it increases, the resistive value decreases. They are somewhat sensitive to heat, but stand up to abuse well. Try not to over heat when soldering wires to them.

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Sensors

- **Photocells**
  - >As with all the light-sensing devices, shielding is **VERY** important.
    - A properly shielded sensor can make the difference between valid/invalid values reported by that sensor.
    - The idea is simple: restrict the amount of light striking the sensor to the direction you expect the light to be coming from.
    - You do not want light from external sources (i.e., windows or lights) to interfere with your robot.
    - Black heat shrink tubing often works well to shield the CdS cells from external light sources.

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Sensors

- **Photocells**
  - >One good way to get a feel for how these sensors work, and how your robot and software interact, is to make a light-sniffer.
    - With two or more CdS cells, try to create a simple robot that can move around a room, either avoiding light or avoiding shadows in a controlled manner.
    - Ambient light conditions play a major role in how to interpret the data from any light sensors.
    - A combination of photocells, one pointed up and one pointed down, may be used to adjust for ambient light levels, which may be useful in some applications.

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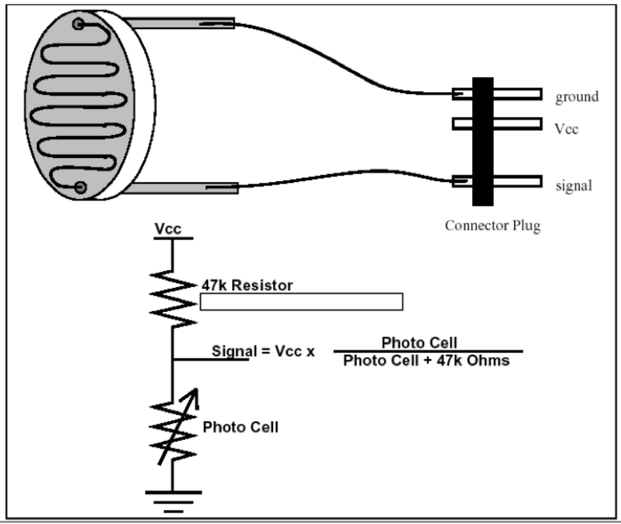
Sensors

- **CdS Cells**



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"Learning is an important part of autonomy. A system is autonomous to the extent that its behaviour is determined by its immediate inputs and past experience, rather by its designer's. Agents are usually designed for a class of environments, where each member of the class is consistent with what the designer knows about what the real environment might hold in store for the agent. Truly autonomous systems should be able to operate successfully in any environment, given sufficient time to adapt. The system's internal knowledge structures should therefore be constructible, in principle, from its experience of the world…"

The End!

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