

Conductors and Insulators Tutorial

Cornerstone Electronics Technology and Robotics I Week 6

- Administration:
 - Prayer
 - Turn in quiz
- Electricity and Electronics, **Section 3.1**, Conductors and Insulators:
 - Resistivity: Resistivity is the resistance (in ohms) to the flow of current exhibited by a certain length of material.

Resistance in Ohms Per Cubic Centimeter		
Material	Approximate Resistance in Ohms	Approximate Resistance in Ohms
Conductors:		
Silver	0.000001	1 $\mu\Omega$
Copper	0.000005	5 $\mu\Omega$
Aluminum	0.00001	10 $\mu\Omega$
Semi-conductors:		
Carbon	0.003	3 m Ω
Pure Silicon	60,000	60 k Ω
Transistor Silicon	5	5 Ω
Pure Germanium	10	10 Ω
Transistor Germanium	6	6 Ω
Insulators:		
Wood	500,000,000	500 M Ω
Glass	50,000,000,000	50 G Ω
Polystyrene	50,000,000,000,000,000	50,000 T Ω

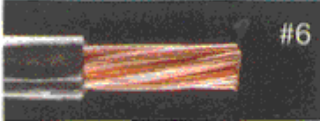
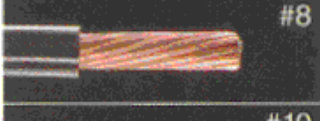
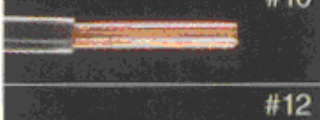
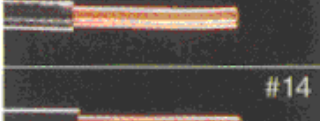
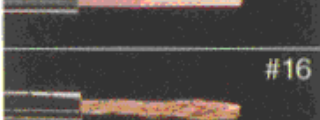
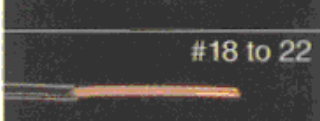
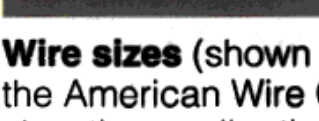
- Conductors: A low resistance material through which electrical electrons can easily flow. The conduction of electricity is done by transferring electrons from one atom to the next atom in the conductor. The speed of this transfer approaches the speed of light, 186,000 miles/second. The electrons themselves are not traveling at the speed of light, but the effect of all of the electrons from one end of a conductor to the other end appears to approach the speed of light.
 - Electricity is always looking for a conductor!
 - The body as a conductor: Do not allow electrical current to pass through from one hand to another or from one hand to your feet. This current will pass through your heart which may prove fatal. (Stoneridge nail story).

- Common Conductors:
 - See electron affinity vs. electrical conductivity:
http://www.chem.uoa.gr/Applets/AppletPerTable/Appl_PerTable2.html
 - Silver-- Best
 - <http://www.germane-software.com/~dcaley/atom/Atom.html>
 - Precious metal
 - High cost
 - Not practical for wire
 - Corrosive problems (such as silver tarnishes)
 - Copper -- 2nd
 - Used in many wiring applications
 - Reasonable cost
 - Flexible
 - Easy to make into wire
 - Good corrosion resistance
 - Gold-- 3rd
 - Precious Metal
 - Very expensive
 - Does not corrode
 - Seldom used as a wire
 - Used to plate (coat) connectors in electronic devices
 - Aluminum-- 4th
 - Abundant metal
 - Reasonable cost
 - Flexible
 - Light weight
 - Corrosion problems / reacts with other metals
 - Used in large wire sizes - power lines and service entrance cable
 - Electrical wire # 4 and larger is usually aluminum and stranded.
 - Pound for pound aluminum is a better conductor than copper.
 - Tungsten-- Poor
 - Rare metal
 - Used to make light-bulb filaments
 - High melting point
 - Poor conductor
- Types of Conductors:
 - Hookup wire
 - Ribbon wire
 - GRU wire samples
- Solid vs Stranded:
 - When electricity flows through a wire, it mostly flows on the surface of the wire, not through the middle. This means that a "wire" of a given size that made up of many smaller strands can carry more power than a solid wire - simply because the stranded wire has more surface area. This is why battery cables in your car and welding cables are made up of many very fine strands of smaller

wire - it allows them to safely carry more power with less of that power being dissipated as heat. Almost all automotive wiring is stranded while almost all house wiring is solid.

- Burn #30 ga in series with # 18 ga wire using three motors in parallel.
- Conductor Sizes:
 - American Wire Gauge (AWG): A system of wire sizes developed over 100 years ago.
 - Demonstrate wire gauge.
 - The larger the wire size, the smaller the AWG number.
 - Common wire sizes we'll be using are #14 through #28

Wire Size Chart

Wire gauge	Wire capacity & use
 #6	60 amps, 240 volts; central air conditioner, electric furnace.
 #8	40 amps, 240 volts; electric range, central air conditioner.
 #10	30 amps, 240 volts; window air conditioner, clothes dryer.
 #12	20 amps, 120 volts; light fixtures, receptacles, microwave oven.
 #14	15 amps, 120 volts; light fixtures, receptacles.
 #16	Light-duty extension cords.
 #18 to 22	Thermostats, doorbells, security systems.

Wire sizes (shown actual size) are categorized by the American Wire Gauge system. The larger the wire size, the smaller the AWG number.

- Wire Identification:
 - Example: 12/3 G or 12-3 w/G
 - 12 is the gauge of the conductor wire
 - 3 is the number of conductors
 - G or w/G means there is a safety ground wire
- Electrical Cables:
 - A group of two or more wires enclosed in a metal, rubber, or plastic sheath is called a cable.
 - The sheath protects the wire from damage.
 - Metal conduit also protects wires, but is not considered a cable.



Flexible armored cable, sometimes called "Greenfield" or "BX," was used extensively from the 1920s to the 1940s. It was an improvement over knob and tube wiring because it provided a shield for the wires. Armored cable is grounded through the metal coils of the cable itself: there is no separate ground wire.

Metal conduit protects wires and was installed from the 1940s until 1970. Individual wires are inserted into a rigid tubing. The metal walls of the conduit provide the grounding path: no separate grounding wire is present. Conduit is still recommended by codes for some installations, like exposed wiring in a basement or garage.

Early NM (nonmetallic) cable was used from 1930 until about 1965. It features a flexible rubberized fabric sheathing that protects the individual wires. NM cable greatly simplified wiring installations because separate wires no longer had to be pulled by hand through a metal conduit or armored cable. Early NM cable had no separate grounding wire.

Modern NM (nonmetallic) cable came into use in 1965. It includes a bare copper grounding wire. Wire insulation and outer sheathing are both made of plastic vinyl, which is more durable and moisture-resistant than the rubber materials used in older NM cable. Modern NM cable is inexpensive and easy to install, and is preferred for most installations.

UF (underground feeder) cable has wires that are embedded in a solid-core plastic vinyl sheathing and includes a bare copper grounding wire. It is designed for installations in damp conditions, such as buried circuits that supply power to a detached garage, shed, or yard light.

Knob and tube wiring, so called because of the shape of its porcelain insulating brackets, was common in wiring systems installed before 1940. Wires are covered with a layer of rubberized cloth fabric, called "loom," but have no sheath for additional protection.

- Four factors that affect conductor resistance (Know these):
 - Cross section area of a conductor; the larger the cross-section area, the lower the resistance.
 - See table below
 - Type of material; resistance varies for different conductor materials. See table above
 - Length of the conductor; the longer the conductor, the higher the resistance.
 - Verify with demonstration
 - Temperature of the conductor material; the higher the conductor temperature, the higher the resistance.
 - Verify with demonstration
- Resistances per 1000': Using the table below, determine the voltage drop in a 300' extension cord of #22 copper wire if a saw is pulling 10 amps. Do the calculation if the wire is copper.

Resistance per 1000' @ 25° Celsius

Gauge	Material	Resistance/1000' (in Ohms)
10	Copper	1.018
10	Aluminum	1.616
14	Copper	2.575
14	Aluminum	4.08
18	Copper	6.51
18	Aluminum	10.3
22	Copper	16.46
22	Aluminum	26.2
26	Copper	41.62
26	Aluminum	66.4

- For a complete listing of AWG wire gauges and copper wire, see: <http://www.daycounter.com/Calculators/AWG.phtml>
- Insulators: A material with few or no free electrons which will not let electrons flow freely. Insulators provide a protective coating around a conductor.
 - Types of Insulators:
 - H Heat
 - HH High Heat
 - M Oil Resistant
 - UF Underground
 - C Corrosive resistant
- Semi-conductors, materials that have conductivity between conductors and insulators.
- Is air a conductor or an insulator?

- Related Web Sites:
 - http://www.allaboutcircuits.com/vol_1/chpt_12/index.html
 - http://www.ieee.org/portal/cms_docs_iportals/iportals/education/preuniversity/tisp/pdf/lessons/condinsul.pdf#search=%22conductor%20insulator%20lesson%22
- Electricity and Electronics, **Section 3.2**, Special Conductor Pathways Continued:
 - Breadboards were covered in Week 2.
 - Printed Circuit Boards (PCB): A printed circuit board is an insulated board where copper foil paths and connection pads provide electrical paths for current to flow.
 - Demonstrate difference between general purpose and custom PCB.
 - Complete Printed Circuit Boards Lab 1 – Photofabrication of PCB
 - Chassis: Components mounted on a metallic surface uses the metal as a pathway for circuits.
 - Use vehicle as an example.

Electronics Technology and Robotics I Week 6
Printed Circuit Boards Lab 1 – Photofabrication of PCB

- **Purpose:** The purpose of this lab is to acquaint the student with:
 - PCB layout using dry transfers, and
 - The process of chemical photofabrication.

- **Apparatus and Materials:**
 - 1 – Solderless Breadboard
 - 1 – 1/32" Pre-etched Copper-Clad Single Sided Circuit Board (Allied Electronics #661-0595 (18"x12" x 1/32"))
 - PC Transfers
 - 1 – M.G. Chemicals Etchant Process Kit M.G. Cat #416-E (Electronix Express # 03416E); (<http://www.mgchemicals.com/products/416e.html>)
 - 1 – M.G. Chemicals Exposure Kit M.G. Cat #416-X (Electronix Express # 03416X); (<http://www.mgchemicals.com/products/416x.html>)
 - M.G. Chemicals Developer M.G. Cat #418 (Electronix Express # 03418500ML); (<http://www.mgchemicals.com/products/418.html>)
 - M.G. Chemicals Ferric Chloride Etchant, M.G. Cat #415 (Electronix Express #03151L(1Liter) or #034154L(4 Liter)); (<http://www.mgchemicals.com/products/415.html>)
 - 6 – Red LED's
 - 1 – SPDT 0.1" Center Mini Slide Switch (Electronix Express #17SLDH251)

- **Procedure:**
 - Wire the circuit in the schematic below.
 - Measure the voltage drop across the battery and each LED. Record the results in Table 1.
 - In the conclusions, compare the total voltage drop of the LEDs with the battery.
 - Add another LED to the series and observe the results. Now add a sixth LED to the series and observe the results. What does this reveal about LEDs?
 - Photofabrication of the printed circuit board (PCB):
 - Using dry transfers, layout the circuit on a copper-clad PC board.



- Use the MG Chemical process guide to etch a presentized copper-clad single sided circuit board:
 - MG Chemicals instructions for complete prototyping process website:
http://www.mgchemicals.com/techsupport/photo_inst.html **Pay special attention to the warnings listed on this website.**
 - Use the Exposure Kit to expose the PC board for a minimum of 5 minutes, preferably 10 minutes.
 - Develop the board in one part developer to ten parts tepid water. Lightly brush the resist with a foam brush. Development should be completed within one to two minutes.
 - Immediately neutralize development action by rinsing the board with water.
 - Etch your board using the Etching Kit and the ferric chloride etchant. An ideal etching temperature is 50°C (120°F).
 - See illustrated process at:
http://www.mgchemicals.com/techsupport/photo_demo.html

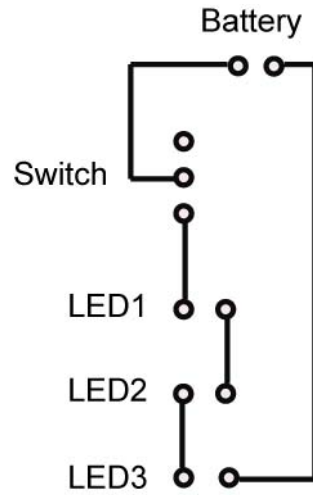
- **Results:**

Part	Voltage Drop	Source Voltage
LED1		
LED2		
LED3		
LED4		
Total:		
Battery		

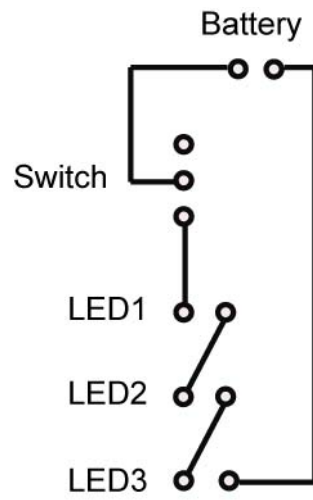
Table 1

- **Conclusions:**

- **Sample PCB Artwork Layouts:**



Layout 1



Layout 2