Applied Basic Electricity
Never touch a downed wire

Stay clear of power lines

Don’t bring appliances near water

NO power tools on wet grass or wet surfaces

Ground Fault Circuit Interruptors on ALL outdoor electrical outlets (GFCI)
Pull the plug not the cord

Keep cords away from heat and water

Never run under carpets

Electricity and water don’t mix

Check cords and plugs for wear

Never remove the ground prong

Eliminate octopus connections

Don’t use cords as permanent wiring

Don’t pry toast from a plugged-in toaster
Wear appropriate attire

- Hard hat
- Goggles
- Tight clothing
- No rings or metal jewelry
- Safety shoes

Breathing Protection

- Wear earmuffs in noisy areas
- Lockout
- Tagout
- Confine long hair or keep it trimmed when working around machinery

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Less than 1 ampere can cause death

- **Severe burns**
- **Breathing stops**
- **Severe shock**
- **Mild shock**

1 milliampere = 1/1000 of an ampere

- Lights a 100-watt bulb
- Heart stops pumping
Body Resistance and Shock

- Electrical resistance is defined as the opposition to flow of current in a circuit
- Resistance is measured in OHMS
- The lower the body resistance, the greater the potential shock hazard
- Body resistance can be measured with an ohm meter
- Any current flow above 5 milli-amperes is considered dangerous
Skin Conditions and Resistance

- Dry skin resistance: 100,000 to 600,000 Ohms
- Wet skin resistance: 1,000 Ohms
- Internal body….hand to foot: 400 to 600 Ohms
- Ear to ear: about 100 Ohms
- **Burns and neurological** damage are the most common injuries caused by electrical shock

**THE DANGER OF HARMFUL SHOCK INCREASES AS THE VOLTAGE INCREASE**

**VOLTAGES AS LOW AS 30V CAN BE DANGEROUS!!**
First Aid For Electrical Shock

- Turn power OFF & remove victim from electric contact.
- Do Not touch victim until power is removed.
- Apply artificial respiration if not breathing. Keep victim warm.
- Keep victim head low so blood can flow to brain. Avoid placing victim where breathing obstruction may occur.
- Cold water or ice pack for first degree and minor second degree.
- Don’t break blisters! For open blisters…no water or cold packs…use thick clean bandages to avoid infection.
- Do not remove charred clothing..let a medical pro do it.
Know where the fire extinguisher is and how to use it

CLASS A
WOOD

CLASS B
Gas

CLASS C
MOTOR

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HAZARDOUS PROPERTIES

Corrosive
Ignitable
Toxic
Reactive
Trip Requirements:
• 10 millisecond response time
• 5 milliamp difference in outgoing and returning current
AFCI Circuit Example

Reference: www.iaei.org
Arc Fault Circuit Interrupter (AFCI)

- AFCI is expected to provide enhanced protection from arcing and sparking
- AFCIs are intended to address fire hazards; GFCIs address shock hazards
- NEC 2002 will require AFCIs for bedroom circuits in new residential construction, effective January 2002
Static Electricity

- **STATIC:**
  - Having no motion; at rest

- **STATIC ELECTRICITY:**
  - Electrical charge at rest.

- **FYI**
  - Electrical charges are caused by an imbalance of electrons on the surface atoms of materials.
  - Primarily due to *triboelectric* charging between materials where electrons from surface atoms are transferred between materials creating an electrostatic potential.
  - *Electrostatic field* surrounds electrostatically charged objects.

ESD: A hare raising experience
Producing Static Electricity by *Friction*

Fur and rubber rod rubbed together

Charge accumulates at end of rod only

Negative charge produced on the rod

Electrons move from the fur to the rod
Law of Electric Charges
(Law of Electrostatics)

Like charges repel

Unlike charges attract
Electrostatic Discharge (ESD)

Lightning: a mega ESD event

Lightning strikes somewhere on Earth about 100 times each second!

**DEFINITION:**
A transfer of electrostatic charge between bodies at different electrostatic potentials caused by direct contact or induced by an electrostatic field.
ESD Damage

- Can damage electronic components at any time
  - During shipping, should use special bags (pink)
  - During component installation
  - During board installation
  - During handling (ex. Storage area to workbench)
  - During storage
Wrist Straps

ANY EXCUSE FOR STATIC-CAUSED DAMAGE IS GROUNDLESS.

WEAR YOUR WRISTSTRAP. GROUND IT CORRECTLY.
Electrostatic Protection

• Electronic parts can be easily destroyed by electrostatic discharge
• Wearing a wrist strap tied to the local ground is the most important thing you can do to control electrostatic discharge (ESD)
• Wrist straps need to be checked once a week
• A static meter can be used to detect and measure electrostatic charge
• Follow the ESD procedures used by your employer
Basic Electrical Formulas

&

Calculations
The Powers of Ten and Scientific Notation. It is often used in electronics to express very large numbers and very small numbers. Very small numbers are expressed by using negative powers of ten. For example, $3.2 \times 10^{-8}$ is a scientific notation for the number 0.000000032. Here, “ten to the minus eight power” means “move the decimal place in 3.2 eight places to the left.”

\[
\begin{align*}
7.9 \times 10^4 &= 79,000 \\
9.1 \times 10^8 &= 910,000,000 \\
7.9 \times 10^{-4} &= 0.00079
\end{align*}
\]
### Metric and Prefix Notations

<table>
<thead>
<tr>
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<th>Prefix</th>
<th>Symbol</th>
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<td>deka-</td>
<td>da</td>
</tr>
<tr>
<td>10^2</td>
<td>hecto-</td>
<td>h</td>
</tr>
<tr>
<td>10^3</td>
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<td>k</td>
</tr>
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<td>G</td>
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<td>tera-</td>
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<tr>
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<tr>
<td>10^{18}</td>
<td>exa-</td>
<td>E</td>
</tr>
<tr>
<td>10^{21}</td>
<td>zeta-</td>
<td>Z</td>
</tr>
<tr>
<td>10^{24}</td>
<td>yotta-</td>
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<th>Number</th>
<th>Prefix</th>
<th>Symbol</th>
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<tr>
<td>10^{-1}</td>
<td>deci-</td>
<td>d</td>
</tr>
<tr>
<td>10^{-2}</td>
<td>centi-</td>
<td>c</td>
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<tr>
<td>10^{-3}</td>
<td>milli-</td>
<td>m</td>
</tr>
<tr>
<td>10^{-6}</td>
<td>micro-</td>
<td>μ (greek mu)</td>
</tr>
<tr>
<td>10^{-9}</td>
<td>nano-</td>
<td>n</td>
</tr>
<tr>
<td>10^{-12}</td>
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<td>atto-</td>
<td>a</td>
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<td>10^{-21}</td>
<td>zepto-</td>
<td>z</td>
</tr>
<tr>
<td>10^{-24}</td>
<td>yocto-</td>
<td>y</td>
</tr>
</tbody>
</table>

Note: Symbols in red are most used... know them

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Prefix Examples

0.002A = 2 \times 10^{-3}A = 2mA

100kV = 100 \times 10^{3}V = 1 \times 10^{5}V = 100,000V

100µs = 100 \times 10^{-6}s = 1 \times 10^{-4}s = 0.0001s
Most of the mass of an atom is located in its nucleus
Electron Configuration

- The Electron Configuration is the orbital description of the locations of the electrons in an unexcited atom.
- Electrons orbit in "SHELLS" or "Energy Levels".
- The higher the orbit, the higher the "Energy Level".
- Atoms react based on the Electron Configuration.
- The outermost electron shell is the most important as far as conductivity properties are concerned.
Bohr model of the aluminum atom

Protons = Electrons
13 = 13
Net charge is neutral or zero

Electrically Neutral

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Placement of electrons in a copper atom

Complete with 2
Complete with 8
Complete with 18
Incomplete with 1
Electricity—the flow of free electrons

Valance electron

Positive source

Negative source

Bound electron

Free electron
Atomic structure of conductors, insulators, and semiconductors

Conductor - 1 to 3 valence electrons

Insulator - full valence shell

Semiconductor - 4 valence electrons
Instruments

Multimeter
- voltage
- current
- resistance

Voltage tester
- voltage level
- rugged construction

Clip-on ammeter
measures current
without direct connection

Digital circuit probe
measures digital logic levels

Oscilloscope
used to measure and examine voltage waveforms

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Meter Safety

- Never use an ohmmeter on a live circuit
- Never connect an ammeter in parallel with a voltage source
- Use proper range settings: Do NOT overload a meter
- Do not short terminals using meter probes
- Never measure unknown high voltages: find out the range before attaching a meter
- Check for frayed or broken meter leads
- Avoid touching exposed meter probes
- If possible, connect meter before applying power to circuit
- When connecting a meter to a live circuit work with one hand at your side to lessen the danger of shock
- To reduce the danger of accidental shock, disconnect meter test leads immediately after completing a measurement
Megger Safety Precautions

When you use a megger, you could be injured or damage equipment you are working on if the following MINIMUM safety precautions are not observed.

- Use meggers on high-resistance measurements only (such as insulation measurements or to check two separate conductors on a cable).
- Never touch the test leads while the handle is being cranked.
- Deenergize and discharge the circuit completely before connecting a megger.
- Disconnect the item being checked from other circuitry, if possible, before using a megger.
For maximum safety, most meggers are equipped with hand-crank generators for producing the high DC voltage (up to 1000 volts). If the operator of the meter receives a shock from the high voltage, the condition will be self-correcting, as he or she will naturally stop cranking the generator! A simple hand-crank megger is shown in this photograph:

Some meggers are battery-powered to provide greater precision in output voltage. For safety reasons these meggers are activated by a momentary-contact pushbutton switch, so the switch cannot be left in the "on" position and pose a significant shock hazard to the meter operator.

Real meggers are equipped with three connection terminals, labeled Line, Earth, and Guard.
Megger Use

• Meggers are field instruments: that is, they are designed to be portable and operated by a technician on the job site with as much ease as a regular ohmmeter. They are very useful for checking high-resistance "short" failures between wires caused by wet or degraded insulation. Because they utilize such high voltages, they are not as affected by stray voltages (voltages less than 1 volt produced by electrochemical reactions between conductors, or "induced" by neighboring magnetic fields) as ordinary ohmmeters.

• For a more thorough test of wire insulation, another high-voltage ohmmeter commonly called a hi-pot tester is used. These specialized instruments produce voltages in excess of 1 kV, and may be used for testing the insulating effectiveness of oil, ceramic insulators, and even the integrity of other high-voltage instruments. Because they are capable of producing such high voltages, they must be operated with the utmost care, and only by trained personnel.

• It should be noted that hi-pot testers and even meggers (in certain conditions) are capable of damaging wire insulation if incorrectly used. Once an insulating material has been subjected to breakdown by the application of an excessive voltage, its ability to electrically insulate will be compromised. Again, these instruments are to be used only by trained personnel.
GENERIC CIRCUIT

Control Device

Power Source

Load Device

Conductor

Electron current flow

Protective Device
VOLTAGE - The difference in electric charge between two points.

1 Volt - Difference in Electric Charge

1 Ohm of Resistance

Produces 1 Ampere of Current Flow.
Voltage, also called electromotive force, is a quantitative expression of the potential difference in charge between two points in an electrical field.

For electrons to flow, there must be a source of electromotive force (emf), or voltage.

Electromotive force can be produced by a variety of different primary energy sources.
**Current** - The rate of flow of electrons

One Coulomb Per Second = One Ampere

Measurement Point

One Coulomb = One Coulomb

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CURRENT MEASUREMENT

Connected in Series

Circuit Schematic

AMMETER
- Connected in parallel to measure lamp voltage.

- Connected in parallel to measure battery voltage.
RESISTANCE MEASUREMENT

Measured with an Ohmmeter
(multimeter used as an ohmmeter)

Ohmmeters should never be connected to live circuits!
Resistors Oppose & Control The Flow of Current in a Circuit

- Series
- Parallel
- Units: Ohm
- Symbol
- R1, R2, etc schematic representation

![Series Circuit Diagram]

![Parallel Circuit Diagram]
OHM’S LAW FORMULAS

Find Current

\[ I = \frac{V}{R} \]

Current equals voltage divided by resistance

Find Voltage

\[ V = I \times R \]

Voltage equals current multiplied by resistance

Find Resistance

\[ R = \frac{V}{I} \]

Resistance equals voltage divided by current
## Voltage - Current - Resistance

<table>
<thead>
<tr>
<th>Quantity</th>
<th>Unit of Measure</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Voltage</td>
<td>V, emf or E</td>
<td>Pressure which makes current flow</td>
</tr>
<tr>
<td>Current</td>
<td>I</td>
<td>Rate of flow of electrons</td>
</tr>
<tr>
<td>Resistance</td>
<td>R</td>
<td>Opposition to current flow</td>
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### Table

<table>
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<th>Symbol</th>
<th>Unit</th>
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<td>V, emf or E</td>
<td>V</td>
<td>Voltage</td>
<td>V</td>
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<tr>
<td>Current</td>
<td>I</td>
<td>A</td>
<td>Ampere</td>
<td>A</td>
</tr>
<tr>
<td>Resistance</td>
<td>R</td>
<td>Ω</td>
<td>Ohm</td>
<td>Ω</td>
</tr>
</tbody>
</table>
POWER

-The amount of electric energy converted to another form in a given length of time.

Power = Voltage x Current

Watts = Volts x Amperes

\[ P = V \times I \]
Power loss in cable: \( P = I^2 \times R_{\text{Wire}} \)

Recall:
\[
V = I \times R
\]
\[
P = V \times I
\]
\[
= (I \times R) \times I
\]
\[
= I^2 \times R
\]

\( P \) = power in watts (W)
\( I \) = current in amperes (A)
\( R \) = resistance in Ohms (Ω)
ENERGY IS THE ABILITY TO DO WORK

- Energy is measured in Joules or kWh
- Energy is stored in a battery or a gallon of gasoline
- .......Or stored in water behind a dam
- .......Or stored in a body in motion
- Energy can be converted from one form to another
- We pay for electricity based on energy used: example $0.10 per kWh
- We buy gasoline by the gallon (126MJ/gallon)
- Power is the RATE at which Energy is transferred or consumed
- Power is measured in Watts or Horsepower
- 1 Watt = 1 Joule/second
- 1 Joule = (1 Watt) x (1 second)
Energy Example

Energy = Power $\times$ Time

$E = (100 \, \text{W}) \times (300 \, \text{s})$

$E = 30,000 \, \text{J}$

$E = 30 \, \text{kJ}$
ENERGY - Electric energy refers to the energy of moving electrons

Energy = Power x Time

kWh = kilowatts x hours

Measured with a kilowatthour energy meter
Energy Cost EXAMPLE

Energy = Power \times Time

= (4.2 \text{kW}) \times (20 \text{ h})

= 84 \text{kWh}

Cost = Energy \times \text{rate per kWh}

= (84 \text{kWh}) \times ($0.12)

= $10.08

Rated for 4.2 kW
Used 20 h/month
Cost of 12¢ per kWh

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Series Circuit

- Same current through each component
- Sum of voltage drops = supply voltage (Kirchoff Voltage Law)
- Largest resistance has the largest voltage drop.
- Add resistance
  - Lowers current
- One open the circuit fails.
- The total resistance is the sum of all resistors:
  \[ R_T = R_1 + R_2 + R_3 \]
SOLVING A SERIES CIRCUIT PROBLEM

\[ V_T = 60 \text{ V} \]
\[ R_1 = 4 \text{ k}\Omega \]
\[ R_2 = 2 \text{ k}\Omega \]
\[ R_3 = 14 \text{ k}\Omega \]
Parallel Resistor Network

From Kirchoff’s Current Law: \( I_T = I_1 + I_2 + I_3 + \cdots + I_N \)

From Ohm’s Law: \( I = \frac{V}{R} \) and \( R = \frac{V}{I} \)

\[
I_T = \frac{V_T}{R_1} + \frac{V_T}{R_2} + \frac{V_T}{R_3} + \cdots + \frac{V_T}{R_N}
\]

\[
= \left( \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \cdots + \frac{1}{R_N} \right) V_T
\]

\[
R_T = \frac{V_T}{I_T} = \frac{1}{\left( \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \cdots + \frac{1}{R_N} \right)}
\]

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Time for Lab #1 & Lab #2
Troubleshooting
Troubleshooting

• Series Circuit
  – Open:
    • No current
    • Source voltage at the open
    • Rest are zeros
  – Short
    • Current Increase
    • \( V \) is zero at the short
SOLVING A OPEN CIRCUIT

\[ V_T = 24 \text{ V} \]
\[ R_1 = 12 \Omega \]
\[ R_2 = 4 \Omega \]
SOLVING SHORT CIRCUIT

<table>
<thead>
<tr>
<th></th>
<th>Voltage</th>
<th>Current</th>
<th>Resistance</th>
<th>Power</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>R₁</strong></td>
<td>40 V</td>
<td>10 mA</td>
<td>4 kΩ</td>
<td>400 mW</td>
</tr>
<tr>
<td><strong>R₂</strong></td>
<td>20 V</td>
<td>10 mA</td>
<td>2 kΩ</td>
<td>200 mW</td>
</tr>
<tr>
<td><strong>R₃</strong></td>
<td>0</td>
<td>10 mA</td>
<td>0 (Short)</td>
<td>0 mW</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>60 V</td>
<td>10 mA</td>
<td>6 kΩ</td>
<td>600 mW</td>
</tr>
</tbody>
</table>
Troubleshooting

- Parallel
  - Short: Fuse blows
  - Open: Less current
Parallel Circuit

- Same Voltage across all components
- Smallest resistance, most current.
- Add a branch:
  - Increase Current
  - Decrease Overall Resistance
- One branch opens, current is smaller than normal.
- Resistance of Network is less than smallest resistor
SOLVING A PARALLEL CIRCUIT

$I_T = 5.5 \text{ A}$

$R_1 \quad V_2 = 24 \text{ V} \quad R_2 = 16 \text{ Ω} \quad R_3 = 24 \text{ Ω}$
EFFECT OF A SHORT CIRCUIT ACROSS PARALLEL BRANCHES

Voltage drops

Circuit breaker closed

Breaker opens

Current jumps to max value

Switch closed

$R_1 = 60 \text{ k}\Omega$

$R_2 = 30 \text{ k}\Omega$

$R_3 = 40 \text{ k}\Omega$

120 V

Short

$R_1 = 60 \text{ k}\Omega$
Kirchhoff's Voltage Law

\[ V_T = V_1 + V_2 + V_3 \]

\[ V_T = 24V \]

\[ V_T - V_1 - V_2 - V_3 = 0 \]

\[ +24V - 4V - 8V - 12V = 0 \]
KIRCHHOFF’S CURRENT LAW

\[ I_T = I_1 + I_2 + I_3 \]

\[ I_{IN} = I_{OUT} \]
Direct Current vs. Alternating Current
TYPES OF DIRECT CURRENT

- Pure or Constant DC
- Pulsating DC
- Varying or Analog DC
- Digital DC
• The purpose of a battery is to store chemical energy and to convert this chemical energy into electrical energy when the need arises

• Battery safety concerns
  – Exposure to chemicals (acid)
  – Potential for electrical shock
  – Lifting hazard, some batteries in excess of 150 lbs
Battery Characteristics

- When connecting batteries in Series you are doubling the voltage while maintaining the same capacity rating (amp hours).

- When connecting in Parallel you are doubling the capacity (amp hours) of the battery while maintaining the voltage of one of the individual batteries.
Installing Batteries

- Dependant on battery style, below are the general rules
  - Perform a load test
  - Verify condition (physical)
  - Service with electrolyte, if required
AC WAVEFORMS

Sine wave

Square wave

Sawtooth wave

Current

Time
GENERATOR PRINCIPLE

Magnetic field  Moving conductor

Induced voltage
One complete wave of alternating current or voltage
PERIOD

The time required to produce one complete cycle
The number of cycles produced per second

Frequency = \frac{1}{\text{Period}}

F = \frac{1}{T} = \frac{1}{0.25 \text{ s}} = 4 \text{ Hz}
PEAK VALUE

The maximum voltage or current value
SOLVING AC CIRCUIT RMS

\[ I_{\text{rms}} = I_{\text{peak}} \times 0.707 \]

\[ I_{\text{rms}} = (10 \text{ A}) \times (0.707) \]

\[ I_{\text{rms}} = 7.07 \text{ A} \]
SOLVING AC PEAK & PEAK-PEAK VALUES

\[ V_{\text{peak}} = V_{\text{rms}} \times 1.414 \]

\[ V_{\text{peak}} = (120 \text{ V}) \times (1.414) \]

\[ V_{\text{peak}} = 170 \text{ V} \]

\[ V_{\text{p-p}} = V_{\text{peak}} \times 2 \]

\[ V_{\text{p-p}} = (170 \text{ V}) \times (2) \]

\[ V_{\text{p-p}} = 340 \text{ V} \]
Time for Lab #3 & Lab #4
Common AC Circuit Components

- Resistors
- Capacitors
- Inductors
- Transformers
- AC Power Source

R, Resistance in Ohms
C, Capacitance in Farads
L, Inductance in Henry’s
Ohm’s Law

Inductive Reactance = \( X_L = 2\pi fL \)

Capacitive Reactance = \( X_C = \frac{1}{2\pi fC} \)

Impedance, \( Z = \sqrt{R^2 + (X_L - X_C)^2} \)

\[ I = \frac{V}{Z} \]

\[ V_C = I \cdot X_C \]

\[ V_L = I \cdot X_L \]

\[ V_R = I \cdot R \]
DIODE CHARACTERISTIC CURVE

Forward bias current

Reverse bias voltage

Reverse breakdown voltage

Avalanche current

Forward bias voltage

0.7 V (silicon)

Reverse bias current
BRIDGE RECTIFIER

Circuit simplified using common ground connections

First half cycle

Positive pulse across load (conducted by $D_1$ and $D_2$)

Voltage output from full-wave rectifier
Circuit Protection

- Fuses
- Circuit breakers
- Overload
- Thermal shunt
OVERLOADED CIRCUIT

Branch circuit rating:
15 A / 120 V
1500 W

Total power = 2640 W
Total current = 22 A
Fuses

Ferrule-contact cartridge fuse

Knife-blade cartridge fuse

Glass cartridge fuse

Fuse symbol

OR

Plug fuse
CIRCUIT BREAKERS

Light duty

Heavy duty

Circuit breaker symbol

High-voltage
CURRENT RATINGS

Plastic automotive fuse
Rated current: 20

Household circuit breaker
Rated current: 15
USING AN OHMMETER TO TEST FUSES

Zero resistance reading

Good
THERMAL OVERLOAD PROTECTION

Fuse protects wiring

Overload = Excessive temperature

Thermal overload switch protects motor
AUTO STARTER MOTOR CIRCUIT

Low-current wiring

High-current wiring

Battery

Electromagnetic Switch or Solenoid Or Starter Relay

Starter motor
TRANSISTOR CONTROLLED RELAY

20 mA of control current controls 10 A of load current

DC supply
Transistor
Electromagnetic Relay
Motor
To power line

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RELAY CONTACTS

Single-pole, double-throw (SPDT)

Double-pole, single-throw (DPST)

Double-pole, double-throw (DPDT)
TYPES
of
CONNECTIONS
Connections

• High Resistance Connections
• Strip
• Crimp
• Solder (tin lead, 63/37)
• Screw terminal Type
• Heat shrink
• Cable splicing and bending
NASA Standards for Connections

- NASA Technical Standard 8739.3 “Soldered Electrical Connections”
- NASA Technical Standard 8739.2 “Workmanship Standards for Surface Mount Technology”
- NASA Technical Standard 8739.4 “Crimping, Interconnection Cables, Harnesses, Connectors”
- NASA Technical Standard 8739.7 Electrostatic Discharge
- NASA Technical Standard 8739.5 Fiber Optics
HIGH-RESISTANCE CONNECTIONS

Lost Heat Energy

Loose Connection

Corroded Connection
CONNECTING TO TERMINAL SCREWS

Bend wire into a loop

Hook wire over the screw

Tighten in clockwise direction
The Crimp-on is also called a Compression Connector.
Crimp-Terminal Lugs

Remember: The size of the connector Must be matched to the Wire gauge size
Crimping Tools Specifications

• Must meet standards set by organization

• ex. NASA-STD-8739.4 section 12.3 states:
  – Calibration Intervals based on type of tool and it’s records, if tool does not perform correctly in between calibration periods, tool will be sent out for re-calibration
  – Indenter blades, tool shall have a minimum of 4
  – Ratcheting mechanism will prevent indenter from releasing before crimp cycle is complete
  – Pull tests required for each crimp is a minimum of 3
Splicing Wires
Heat Shrink

Do it yourself Bike Generator

Use heat gun to shrink the heat shrink tubing

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• Solder is an alloy of tin and lead
• Lead/tin ratio determines strength and melting point
• Wire type 60/40 tin/lead is recommended for most electrical/electronic work
• Item being soldered must be cleaned of dirt and oxide…..otherwise solder will not adhere to the splice
Solder Flux

- Soldering flux prevents oxidation of the copper surfaces by insulating the surface from air.
- Acid and resin based solders are available.
- Acid based solder SHOULD NOT be used for electrical work as it corrodes copper wire.
- Resin flux is available in paste form or as a continuous core inside solder wire and should be used in electrical work.
Splices should be distributed in a cable to avoid a large bulge in the cable.
SOLDERING TO A TERMINAL

Make a loop around the terminal

Bend the wire through and around the terminal hole

Apply heat

Apply solder

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CONDUCTOR FORMS

- Solid wire
- Stranded wire
- Large stranded cable
- Multiconductor cable
- Lamp cord
The larger the gauge number the smaller the actual diameter of the conductor.

The primary cable selection criteria are current rating and allowable voltage drop.
Wiring Color Codes

• Basic Electrical Color Coding
  – DC Black –, Red +
  – Ac 120v Black Hot, White Neutral, Green Ground, Red is switched Hot
  – Ac 277 3 Phase Black Phase A, Red Phase B, Blue Phase C, Ground Green
  – Ac 480 3 Phase Brown Phase A, Orange Phase B, Yellow Phase C, Ground Green
Grounding/Bonding

• Bonding is what is done to prevent you from being shocked/electrocuted when your left hand touches one metal component, and your right hand touches another metal component. By running a wire (bonding wire) from one metal component to another, stray electricity (from a short for example) will equalize through the wire and one metal component will NOT have a greater voltage in it than another metal component.

• Grounding is to give stray electrical current a place to go, other than through you.
• A cable bend radius of at least **10 times the diameter** should be maintained
• True for wire and fiber cable
• Fiber cable can suffer increased attenuation from too sharp a bend
Tools
Tool Pouch

Screwdrivers

- Slot
- Phillips
- Torx
- Square
Basic Tools
Tools for Connections
Strippers
Crimp-Terminal Lugs

Remember:
The size of the connector must be matched to the wire gauge size.
Crimping Tools Specifications

• Must meet standards set by organization
• ex. NASA-STD-8739.4 section 12.3 states:
  – Calibration Intervals based on type of tool and it’s records, if tool does not perform correctly in between calibration periods, tool will be sent out for re-calibration
  – Indenter blades, tool shall have a minimum of 4
  – Ratcheting mechanism will prevent indenter from releasing before crimp cycle is complete
  – Pull tests required for each crimp is a minimum of 3
Wire Benders

- NASA – STD – 8739.3

Section 8.1.6.d states any wire bending tools shall not show evidence of nicks or deformations.
Digital Circuits
The world is moving from the industrial revolution to an information and communications revolution based on digital electronics.
This chapter serves as an introduction to digital technology. It focuses on the devices and circuits used to build computers and other digital equipment.
All voltages above this level are considered to be ON (1).

All voltages below this level are considered to be OFF (0).
BINARY DATA

USING SWITCHES TO ENTER BINARY DATA
DISPLAY BINARY DATA

16-BIT WORD MADE UP OF TWO BYTES

Decimal 197
(128 + 64 + 4 + 1 = 197)
(64 + 8 + 4 + 1 = 77)
THE AND GATE

CIRCUIT SCHEMATIC

Truth table
Timing diagram

5 V

H (1)  Input B
L (0)

H (1)  Input A
L (0)

330 Ω

7408

LED Output

(Combinations possible = 8)

is controlled by the length of time that the output is HIGH)

= YES = 1 = HIGH
THE OR GATE

Circuit schematic

OR truth table

Typical quad two-input OR gate IC chip

Timing diagram
THE NOT (INVERTER) GATE

Circuit schematic

INVERTER symb

INVERTER IC chip

+5V

7404

14 13 12 11 10 9 8

1 2 3 4 5 6 7

330 Ω

Input

H (1) A

L (0)

Output

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THE NAND GATE

Circuit schematic

B

5 V

NAND

A

B

+5 V

Input B

L (0)

Input A

L (0)

14

7400

330 Ω

Output

Typical quad two-input NAND gate IC chip
THE NOR GATE

Circuit schematic

Typical quad two-input NOR gate IC chip
DIGITAL SIGNAL CODING

INPUTS

- Signal goes high to activate circuit
- This pin must be high for the chip to operate
- Enable

OUTPUTS

- Signal goes low to activate circuit
- Bar over word indicates this pin must be low for the chip to operate
- Enable

- Active high output
- Active low output
COMBINATION LOGIC CIRCUIT

Circuit symbol

A + B

Inputs

Output

Equivalent circuit wired using switches

Truth table

<table>
<thead>
<tr>
<th>Input Switches</th>
<th>Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>C  B  A</td>
<td>Y</td>
</tr>
<tr>
<td>0  0  0</td>
<td>0</td>
</tr>
<tr>
<td>0  0  1</td>
<td>0</td>
</tr>
<tr>
<td>0  1  0</td>
<td>0</td>
</tr>
<tr>
<td>0  1  1</td>
<td>0</td>
</tr>
<tr>
<td>1  0  0</td>
<td>0</td>
</tr>
<tr>
<td>1  0  1</td>
<td>1</td>
</tr>
<tr>
<td>1  1  0</td>
<td>1</td>
</tr>
<tr>
<td>1  1  1</td>
<td>1</td>
</tr>
</tbody>
</table>

Boolean equation: \((A + B)C = Y\)
EXCLUSIVE-OR (XOR) FUNCTION

USED FOR THE COMPARISON OF TWO BINARY NUMBERS

Comparison output register

| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

Input from sensor

0 0 0 1 0 1 0 1

XOR gate symbol

Equivalent combination of gates

A

Y

Binary number for temperature

| 0 0 0 1 0 1 0 0 |
| 0 0 0 1 0 1 0 1 |
| 0 0 0 1 0 1 1 0 |
| 0 0 0 1 0 1 1 1 |
| 0 0 0 1 1 0 0 0 |
| 0 0 0 1 1 0 0 1 |

Actual temperature

90°  92°  94°  96°  98°  100°

XOR gate IC chip

8  6  10  11  12  13  14  VCC

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ANALOG-TO-DIGITAL CONVERSION

**Sample** | **Analog input voltage**
--- | ---
1 | 4 V
2 | 5 V
3 | 7 V
4 | 6 V

**Binary output**

0100
0101
0111
0110

**A/D converter**
DIGITAL-TO-ANALOG CONVERSION

<table>
<thead>
<tr>
<th>Sample</th>
<th>Binary Input</th>
<th>DC analog voltage output</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0000</td>
<td>0.0 V</td>
</tr>
<tr>
<td>2</td>
<td>0001</td>
<td>0.1 V</td>
</tr>
<tr>
<td>3</td>
<td>0010</td>
<td>0.2 V</td>
</tr>
<tr>
<td>4</td>
<td>0011</td>
<td>0.3 V</td>
</tr>
<tr>
<td>5</td>
<td>0100</td>
<td>0.4 V</td>
</tr>
<tr>
<td>6</td>
<td>0101</td>
<td>0.5 V</td>
</tr>
</tbody>
</table>
DIGITAL LOGIC PROBE

TESTING A GATE

Logic probe

Logic probe

1 0
0 0

OH OL

OH OL

1
This Concludes Applied Basic Electricity
BACK UP SLIDES
APPLYING DC VOLTAGE TO A COIL

Magnetic field builds up

Current rise is gradual

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REMOVING THE DC VOLTAGE

Magnetic field collapses

Current drop is gradual

Time

Current
MUTUAL INDUCTANCE

Changing magnetic field created

Switch operated on and off

Core

Circuit A  Circuit B

Voltage produced

\[ V = N \frac{d\Phi}{dt} \]

\[ \Phi = \text{MMF/R} \]

MMF = Magneto Motive Force
In Amp-Turns
R = Reluctance
\( \Phi \) = Flux
EXAMPLE 30-4

\[ X_L = \frac{2\pi fL}{?} \]

\[ = (2)(3.14)(1000 \text{ Hz})(0.2 \text{ H}) \]

\[ = 1,256 \, \Omega \]
Power in = Power out

\[ V \times I \text{ primary} = V \times I \text{ secondary} \]

\[ (120 \text{ V}) \times (0.625 \text{ A}) = (15 \text{ V}) \times (5 \text{ A}) \]

\[ 75 \text{ VA} = 75 \text{ VA} \]

The basis for transformer operation is mutual inductance
EXAMPLE 31-2

Turns ratio \( = \frac{N_P}{N_S} = \frac{50}{100} = 1:2 \)

\( V_S = 2 \times 120 \text{ V} = 240 \text{ V} \)
EXAMPLE 31-3

\[ V_P = 240 \, \text{V} \]

\[ N_P = 100 \]

\[ V_S = ? \]

\[ N_S = 5 \]

Turns ratio = \( \frac{N_P}{N_S} = \frac{100}{5} = 20:1 \)

\[ V_S = \frac{240 \, \text{V}}{20} = 12 \, \text{V} \]
EXAMPLE 31-4

$$I_S = \frac{V_S}{R_L} = \frac{60 \text{ V}}{25 \Omega} = 2.4 \text{ A}$$

$$I_P = 5 \times I_S = 5 \times 2.4 \text{ A} = 12 \text{ A}$$