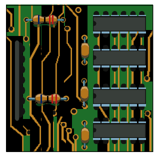
Basic Electronics

Well, basic to start…

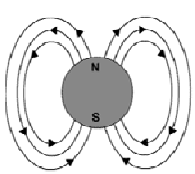


Charles Sekafetz
Chemeketa Community College

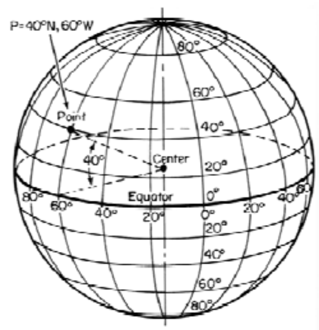
Areas of Focus

- Introductions
- Basic Fundamentals
- Lunch
- Communications
- Soldering

How this stuff works



Magnetics


P=40°N, 60°W
80°
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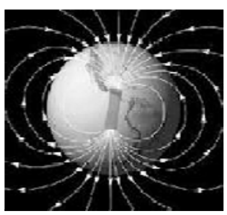
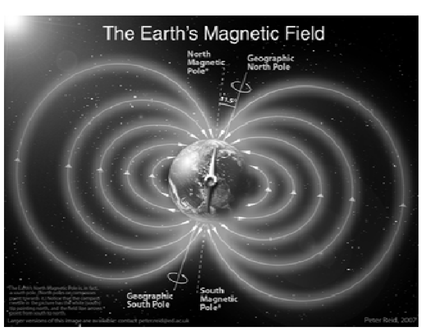
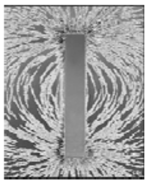
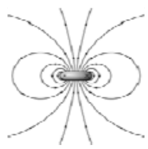
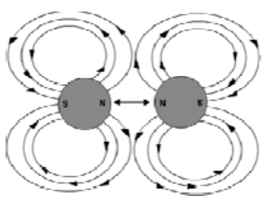



The Earth's Magnetic Field
North Magnetic Pole*
Geographic North Pole
Geographic South Pole
South Magnetic Pole*

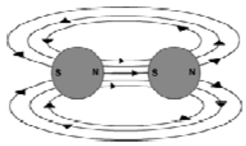




Charges – Like Charges Repel



Charges – Dissimilar Charges Attract



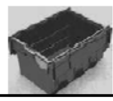
What creates this attaction?

- Atomic Structure
  - Protons
  - Electrons

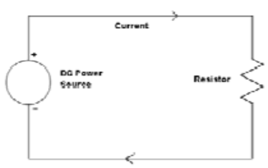
Conductors v Insulators








DC Theory



Voltage

- Electromotive Force (EMF)
- It is the force that “pushes” electrons through a wire
- Electrical Pressure or Potential
- Ohms Law Symbol fo Voltage is E or V
- The unit of voltage is V.

Current

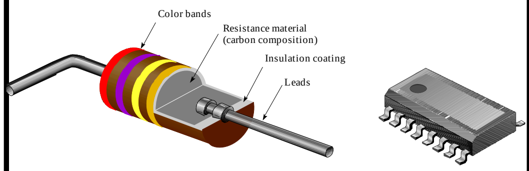
- The rate of charge flow measured in amperes (Amps).
- Milliamps or microamps are common within electronics

Resistance

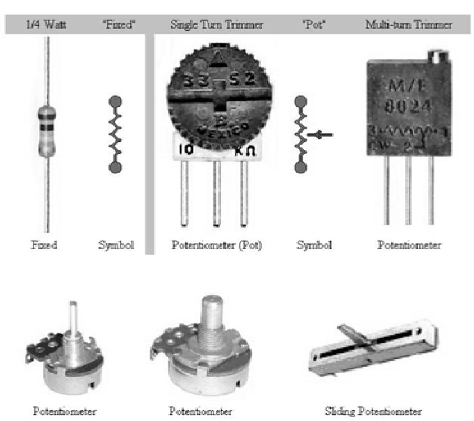
- The oposition to current flow measured in Ohms. (Ω)

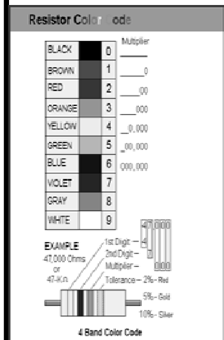
- **All materials have a resistance that is dependent on cross-sectional area, material type and temperature.**

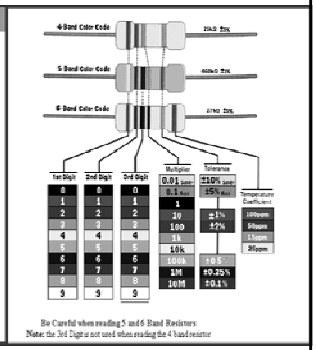
Resistors are devices that oppose the flow of electricity.



- A resistor dissipates power in the form of heat







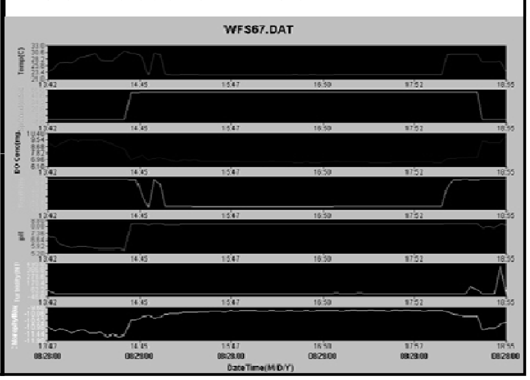
Conductance

- The inverse of resistance, it is the ability of a material to conduct electricity.

$$G = \frac{1}{R}$$

Unit is siemans (S)

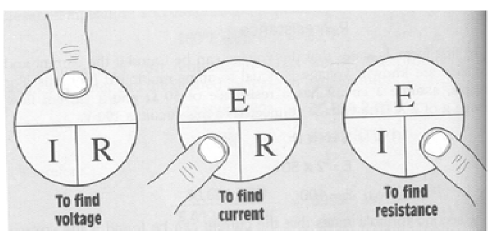
Conductance in Use



Ohms Law

- The most important fundamental law in electronics is Ohm's law, which relates voltage, current, and resistance.

$$I = \frac{V}{R}$$



It takes one volt to push one amp through one ohm.

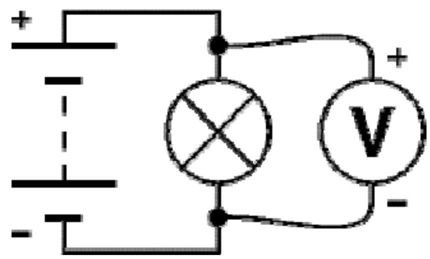
What is the current in from a 12V source if the resistance is 10 Ω?

Safety

Multimeters

Measuring Voltage

- Connect the **black** (negative -) voltmeter lead to 0V, normally the negative terminal of the battery or power supply.
- Connect the **red** (positive +) voltmeter lead to the point you where you need to measure the voltage.
- The **black** lead can be left permanently connected to 0V while you use the **red** lead as a probe to measure voltages at various points.



- Voltmeters measure voltage.
- Voltage is measured in volts, V.
- Voltmeters are connected in parallel across components.
- Voltmeters have a very high resistance.

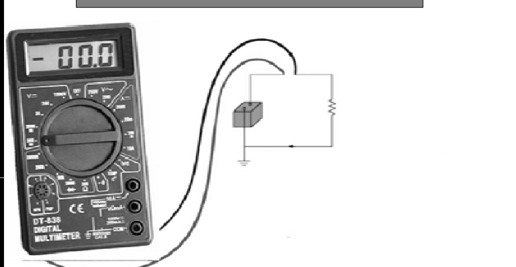
Measuring Current

- Ammeters measure current.
- Current is measured in amps (amperes), A.
- 1A is quite large, so mA (milliamps) and μA (microamps) are often used.
- 1000mA = 1A,
- 1000μA = 1mA,
- 1000000μA = 1A.
- To measure current, you must break circuit and install meter in line

- **Ammeters are connected in series.** ***To connect in series you must TURN OFF ALL POWER, break the circuit and put the ammeter across the gap***
-
- **Ammeters have a very low resistance.**

- The need to break the circuit to connect in series means that ammeters are difficult to use on soldered circuits.
- **Most** testing in electronics is done with voltmeters which can be easily connected without disturbing circuits.

Current Measurement



Measurement is imperfect because of voltage drop created by meter.

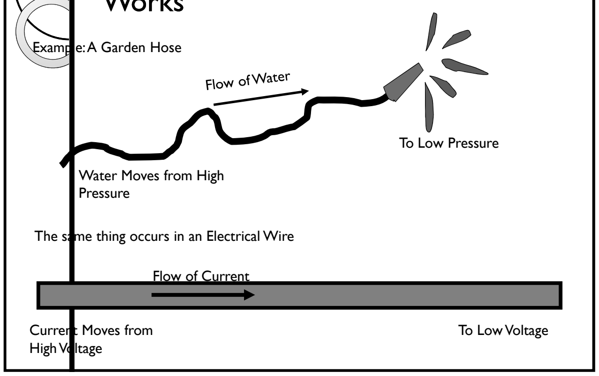
Safety

Electricity

- DC
- AC
- RF

General Electrical Safety

Basic Analogy of How Electricity Works



Electrical Shocks

- Electricity travels in closed circuits, normally through a conductor
- Shock results when the body becomes part of the electrical circuit
- Current enters the body at one point and leaves at another

Note: Ground circuits provide a path for stray current to pass directly to the ground, and greatly reduce the amount of current passing through the body of a person in contact with a tool or machine that has an electrical short. Properly installed, the grounding conductor provides protection from electric shock.

How DC Electrical Current Affects the Body

Current (Amps)	Human Reaction
0.001	Perception level. Just a faint tingle.
0.005	Slight shock felt; not painful but disturbing. Average individual can let go.
0.006-0.025 (Women)	Painful shock, muscular control is lost.
0.009-0.030 (Men)	This is called the freezing current or "let-go" range.
0.050-0.150	Extreme pain, respiratory arrest, severe muscular contractions.
.15 - .43	Ventricular fibrillation.
>.43	Cardiac arrest, severe burns and probable death.

Note: some smaller microwave ovens use 10.0 Amps (10,000 milliamps) and common florescent lights use 1 Amp (1,000 milliamps)

AC

"At currents as low as 60 to 100 milliamperes, low-voltage (110-220 volts), 60-hertz alternating current traveling through the chest for a split second can cause life-threatening irregular heart rhythms.

About 300-500 milliamperes of direct current is needed to have the same effect."

"Electrical Injuries." *The Merck Manual of Medical Information: Home Edition*. Pennsylvania: Merck, 1997.

RF

Current (Amps)	Human Reaction
0.001	Perception level. Just a faint tingle.
0.005	Slight shock felt; not painful but disturbing. Average individual can let go.
0.006-0.025 (Women)	Painful shock, muscular control is lost.
0.009-0.030 (Men)	This is called the freezing current or "let-go" range.
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Burns

The most common shock-related injury is a burn. Burns suffered in electrical incidents may be one or more of the following three types:

- **Electrical Burns** cause tissue damage, and are the result of heat generated by the flow of electric current through the body. *Electrical burns are one of the most serious injuries you can receive and need to receive immediate medical attention.*
- High temperatures near the body produced by an electric arc or explosion cause **Arc or Flash Burns** (also need prompt medical attention)
- **Thermal Contact Burns** occur when skin comes in contact with overheated electric equipment, or when clothing is ignited in an electrical incident.

Note: the graphic pictures were not included. But if you would like to view them click http://www.osha.gov/SLTC/etools/construction/electrical_incidents/burns.html

Internal Injuries

- Our bodies use small electrical currents to transmit signals through the nervous system and contract muscles, extra electrical current flowing through the body can cause serious damage.
- Medical problems can include internal bleeding, tissue destruction, and nerve or muscle damage.
- Internal injuries may not be immediately apparent to the victim or observers; however, left untreated, they can result in death

Involuntary Muscle Contraction

- Muscles violently contract when stimulated by excessive amounts of electricity
- These involuntary contractions can damage muscles, tendons, and ligaments, and may even cause broken bones.
- If the victim is holding an electrocuting object, hand muscles may contract, making it impossible to drop the object.

Note: injury or death may result from a fall due to muscle contractions.

Water and Conduction

Conductors- Substances with relatively little resistance to the flow of electrical current (e.g., metals).

Water- influences the conductive properties of some materials

Dry wood is a poor conductor
Wood saturated with water becomes a ready conductor

Use ***extreme caution*** when working with electricity where there is water in the environment or on the skin.

Human Skin & Resistance

Dry Conditions → Human Skin is Resistant

Current = Volts/Ohms = 120/100,000 = 1mA (0.001A)

-Barely perceptible level of current

Wet Conditions → Skin's Resistance drops dramatically

Current = Volts/Ohms = 120/1,000 = 120mA (0.12A)

-Sufficient current to cause ventricular fibrillation

A low voltage electrocution becomes much more hazardous in a wet condition

High voltage electrical energy greatly reduces the body's resistance by quickly breaking down human skin. Once the skin is punctured, the lowered resistance results in massive current flow.

Low Voltage = Hazardous

- Muscular contraction caused by stimulation does not allow a victim to free himself from a circuit
- The degree of injury increases with the **length of time** the body is in the circuit.
- Thus even relatively low voltages can be extremely dangerous.

LOW VOLTAGE
DOES NOT IMPLY
LOW HAZARD!

An exposure of 100mA for 3 seconds can cause the same amount of damage as an exposure of 900mA for .03 seconds

Ground-Faults

(The Most Common Form of Electrical Shock)

A ground-fault occurs when current flowing to the load (drill, saw, etc.) does not return by the prescribed route.

In a simple 120 volt circuit, current travels through the black (ungrounded) wire to the load and returns to the source through the white (grounded) wire. If some or all of the current does not travel back through the white wire then it has gone somewhere else, usually to ground.

A person's body can act as the path to ground when a fault occurs.

Ground-Fault Incidents

Use GFCI's for protection against ground-faults

1. A double insulated drill (no ground pin) was used in a wet location. Water entered the drill housing and current flowed through the water and user, and then back to its source.
2. An individual with moist hands was electrocuted while winding up a damaged extension cord when their skin contacted exposed wiring in the extension cord.

(This fatality occurred in Utah)

Ground-Fault Protection

The ground-fault circuit interrupter (GFCI) works by comparing the amount of current *going to* and *returning from* equipment along the circuit conductors. When the amount *going* differs from the amount *returning* by approximately 5 milliamperes, the GFCI interrupts the current within as little as 1/40 of a second.

Note: A GFCI will *not* protect you from line contact hazards (i.e. a person holding two "hot" wires, a hot and a neutral wire in each hand, or contacting an overhead power line). However, it protects against the most common form of electrical shock hazard, the ground-fault. It also protects against fires, overheating, and destruction of wire insulation.

Ground-Fault Protection

Use ground-fault circuit interrupters (GFCIs) on all 120-volt, single-phase, 15- and 20-ampere receptacles that will be used to supply temporary power (i.e. hand tools and other portable equipment).

-Portable GFCIs, like this one, are available for situations where GFCI protection is not otherwise provided-

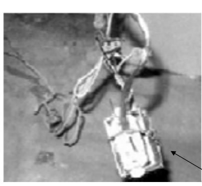
Follow manufacturers' recommended testing procedure to insure GFCIs are working correctly.

Important - Plug this end directly into the electrical source, not another flexible cord.

Grounding - How Do I Avoid Hazards

- Ground all power supply systems, electrical circuits, and electrical equipment
- Do not remove ground pins/prongs from cord- and plug-connected equipment or extension cords
- Use double-insulated tools
- Ground all exposed metal parts of equipment

Using Equipment in a Manner Not Prescribed By The Manufacturer



Shock, fire, loss of life and property?

If electrical equipment is used in ways for which it is not designed, you can no longer depend on safety features built in by the manufacturer. This may damage property and cause employee injuries or worse

Note: Junction boxes such as this one must be mounted properly.

Common Examples of Equipment Used in A Manner Not Prescribed

- Using multi-receptacle boxes designed to be *mounted* by fitting them with a power cord and placing them on the floor.
- Fabricating extension cords with ROMEX® wire.
- Using equipment outdoors that is labeled for use only in dry, indoor locations.
- Using circuit breakers or fuses with the wrong rating for over-current protection, e.g. using a 30-amp breaker in a system with 15- or 20-amp receptacles (protection is lost because it will not trip when the system's load has been exceeded).
- Using modified cords or tools, e.g., removing face plates, insulation, etc.
- Using cords or tools with worn insulation or exposed wires.

REMEMBER - ONLY USE EQUIPMENT IN A MANNER PRESCRIBED BY THE MANUFACTURER

Flexible Cords Not Used Properly

The following cords are improperly wired directly to the electrical circuit, are not protected by a GFCI, and are two-wire cords that are not grounded and not rated for hard- or extra-hard service.

Temporary (flexible wiring) must not be used in place of permanent wiring. Multioutlet surge protection such as this can be used to supply power to equipment that needs surge protection, but not used to provide more outlets due to the lack of permanent wiring.

Note: a common OSHA violation.

Extension type cords that are not 3-wire type, not designed for hard-usage, or that have been modified, increase your risk of contacting electrical current, and should not be used.

Flexible Cord Safe Practices

- Only use factory-assembled cord sets.
- Use only extension cords that have a ground wire (3-wire type).
- Use only cords, connection devices, and fittings that are equipped with strain relief.
- Remove cords from receptacles by pulling on the plugs, not the cords.
- Remove from service flexible cords that have been modified or damaged

Protect flexible cords from damage.

Remember



•Visually inspect all electrical equipment before use.

•Remove any equipment with frayed cords, missing ground prongs, cracked tool casings, etc. from service.

•Apply a warning tag to any defective tool and do not use it until it has been properly repaired.

New IEC Safety Standards

International Electrotechnical Commission

- IEC 61010 is the new standard for low voltage "test, measurement and control equipment".
- IEC 61010 provides much improved protection against "overvoltage impulse transients" - voltage spikes.
- IEC 61010 is the basis for:
  - ANSI/ISA-S82.01-94 (US)
  - CAN C22.2 No. 1010.1-92 (CAN)
  - EN61010-1:1993 (EUR)

Myths

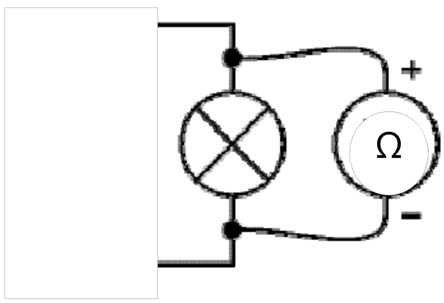
- Electricity takes the path of least resistance
  - Truth: It will take ALL paths that return to neutral.
- Electricity want to go to ground
  - Truth: It is only looking for a path that is different in potential.
- If an electric tool is in water it will short out
  - Truth: The water may not provide a return or path and may just become an energized potential.

Myths

- It takes a high voltage to kill
- Double insulated tools are safe to use in wet and damp locations

Measuring Resistance

- Power to device must be OFF
- Device must be isolated from the circuit.
- Connect the **black** (negative -) volt-ohm meter lead to one side of the device.
- Connect the **red** (positive +) volt-ohm meter lead to the point you where you need to measure the voltage.
- If the meter is not an auto scaling meter, then you must select the proper scale.



Measuring Resistance with a Multimeter

To measure the resistance of a component it must not be connected in a circuit. If you try to measure resistance of components in a circuit you will obtain false readings (even if the supply is disconnected) and you may damage the multimeter.

The techniques used for each type of meter are very different so they are treated separately.

An ohmmeter is used to measure resistance in ohms (Ω). Ohmmeters are rarely found as separate meters but all standard multimeters have an ohmmeter setting.

1 Ω is quite small so kΩ and MΩ are often used.
1kΩ = 1000Ω , 1MΩ = 1000kΩ = 1000000Ω .

Measuring Resistance with a Digital Multimeter

1. **Set the meter to a resistance range greater than you expect the resistance to be.**
   Notice that the meter display shows "off the scale" (usually blank except for a 1 or ! on the left). Don't worry, this is not a fault, it is correct - the resistance of air is very high!
2. **Touch the meter probes together and check that the meter reads zero.**
   If it doesn't read zero, turn the switch to 'Set Zero' if your meter has this and try again.
3. **Put the probes across the component.**
   Avoid touching more than one contact at a time or **your** resistance will upset the reading!

Measuring Resistance with a Analog Multimeter

The resistance scale on an analog meter is normally at the top, it is an unusual scale because it reads **backwards** and is **not linear** (evenly spaced). This is unfortunate, but it is due to the way the meter works.

1. **Set the meter to a suitable resistance range.**
   Choose a range so that the resistance you expect will be near the middle of the scale. For example: with the scale shown below and an expected resistance of about 50k choose the × 1k range.

2. **Hold the meter probes together and adjust the control on the front of the meter which is usually labeled** "0 ADJ" **until the pointer reads zero (on the RIGHT remember!).**
   If you can't adjust it to read zero, the battery inside the meter needs replacing.

3. **Put the probes across the component.**
   Avoid touching more than one contact at a time or **your** resistance will upset the reading!

Reading Analog Resistance Scales

For **resistance** use the **upper scale**, noting that it reads backwards and is not linear (evenly spaced).

Check the setting of the range switch so that you know by how much to multiply the reading.

Sample readings on the scales shown:
- × 10Ω range: 260 Ω
- × 1kΩ range: 26k Ω

Analog Multimeter Scales
The resistance scale is at the top, note that it reads backwards and is not linear (evenly spaced).

"Meggers"

- Nickname of high resistance measurement devices.
- Can measure very high resistances
  - >1M Ohm

Break

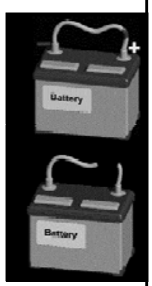
Open and Short Circuits

When the current path is closed but has little or no resistance, the result is a short circuit.

Short circuits can result in too much current.

When a current path is broken (incomplete) the circuit is said to be open. The resistance of an open circuit is infinitely high.

There is no current in an open circuit.

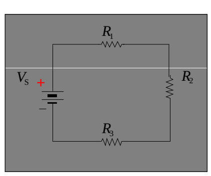


Series circuits

All circuits have three common attributes. These are:

1. A source of voltage.
2. A load.
3. A complete path.

A ***series circuit*** is one that has only one current path.

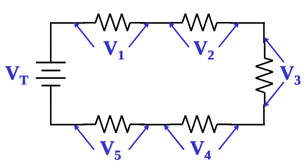


Total Resistance

- The total resistance of a series circuit is the summation of the resistances.

Series Resistances

The total voltage is equal to the sum of the drops.

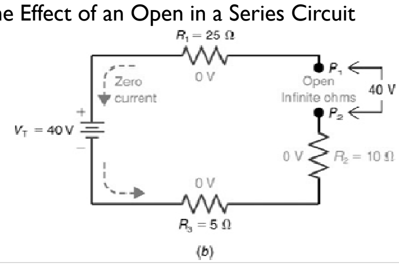


$V_T = V_1 + V_2 + V_3 + V_4 + V_5$

This is known as **Kirchhoff's voltage law (KVL).**

Troubleshooting: Opens in Series Circuits

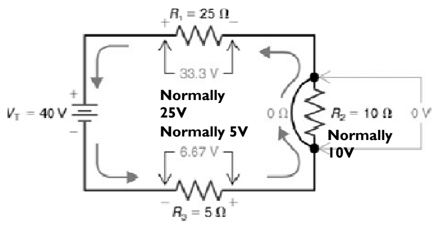
- The Effect of an Open in a Series Circuit



Effect of an open in a series circuit. Open path between points *P1* and *P2* results in zero current in all parts of the circuit.

Troubleshooting:
Shorts in Series Circuits

- The Effect of a Short in a Series Circuit



When R2 is shorted in a series circuit, the total current increases from 1A to 1.333A. This causes an increase in the IR drop of the other resistors as well as their power dissipation.

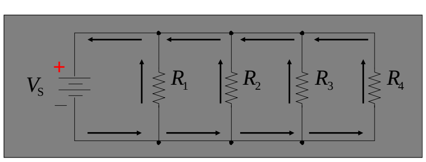
Current – Ohms Law

- The total current in a series circuit is the same as any individual current in any component in the series circuit.

Parallel Resistances

Resistors that are connected to the same two points are said to be in parallel.

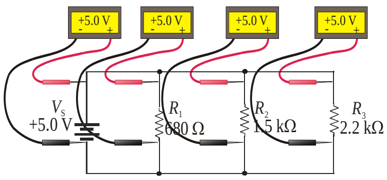
A ***parallel circuit*** is identified by the fact that it has more than one current path (branch) connected to a common voltage source.



Parallel Voltage

Because all components are connected across the same voltage source, the voltage across each is the same.

For example, the source voltage is 5.0 V. What will a volt- meter read if it is placed across each of the resistors?



Total Resistance

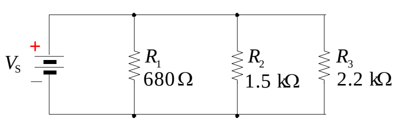
The total resistance of resistors in parallel is

the reciprocal of the sum of the reciprocals of the individual resistors.

$$R_T = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \ldots \frac{1}{R_N}}$$

For example, the resistors in a parallel circuit are 680 Ω, 1.5 kΩ, and 2.2 kΩ. What is the total resistance?

386 Ω

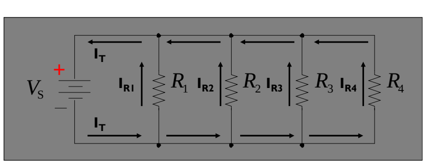


Current

In a ***parallel circuit,*** the total current I_T divides among parallel branches and recombines at the source.

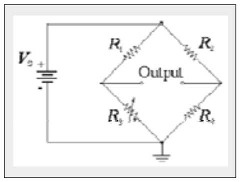
$$I_T = I_1 + I_2 + I_3 + \ldots + I_N$$

Kirchoff's Current Law, KCL, states that the sum of the currents flowing in parallel branches equals the total current.



Wheatstone Bridge

The Wheatstone bridge consists of four resistive arms forming two voltage dividers and a dc voltage source. The output is taken between the dividers. Frequently, one of the bridge resistors is adjustable.



When the bridge is balanced, the output voltage is zero, and the products of resistances in the opposite diagonal arms are equal.

$$R_1 = R_2,\ R_3 = R_4$$

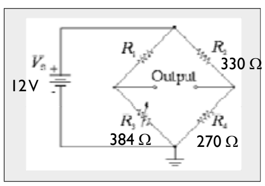
$$\frac{R_1}{R_3} = \frac{R_2}{R_4} = \frac{V_1}{V_3} = \frac{V_2}{V_4}$$

$$R_1 \bullet R_4 = R_2 \bullet R_3 = V_1 \bullet V_4 = V_2 \bullet V_3$$

Wheatstone Bridge

Example: What is the value of R_1 if the bridge is balanced when R_3 is adjusted to 384 Ω?

469.33 Ω

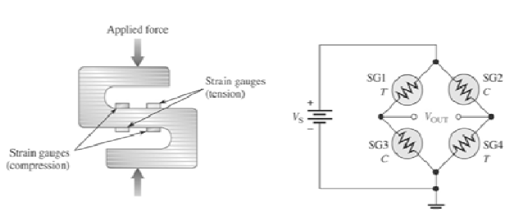


$$R_1 = R_3\left(\frac{R_2}{R_4}\right)$$

$$R_1 = 384\Omega\left(\frac{330\Omega}{270\Omega}\right) = 469.33\Omega$$

Wheatstone Bridge

Wheatstone Bridge with Strain-gauges



(a) A typical load cell with four active strain gauges

(b) Wheatstone bridge

Power Law

- Power is the *rate* energy is "used" (actually converted to heat or another form). Power is measured in watts (or kilowatts). Notice that *rate* always involves *time*.

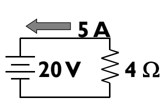
The symbol for Power is P

One watt = one joule/second

Three equations for power in circuits that are collectively known as Watt's law are:

$$P = IV \qquad P = I^2R \qquad P = \frac{V^2}{R}$$

Calculating Total Power



$P = VI = 20V \quad 5A = 100\ W$

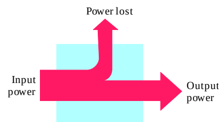
$P = I^2R = 25A \times 4\Omega = 100\ W$

$P = \frac{V^2}{R} = \frac{400V}{4\Omega} = 100\ W$

Efficiency

Efficiency of a power supply is a measure of how well it converts ac to dc. For all power supplies, some of the input power is wasted in the form of heat. As an equation,

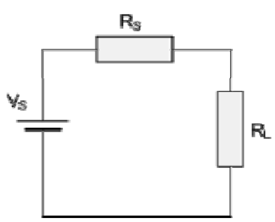
$$\text{Efficiency} = \frac{P_{OUT}}{P_{IN}}$$



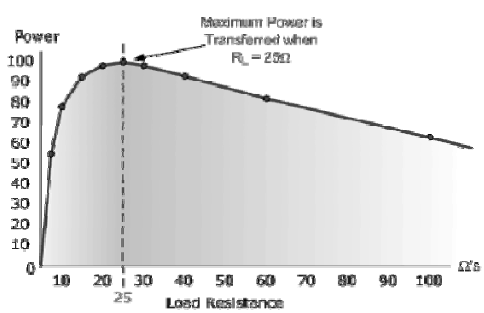
What is the efficiency of a power supply that converts 20 W of input power to 17 W of output power?

85%

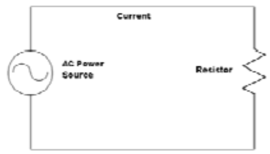
Maximum Power Transfer



Maximum Power Transfer

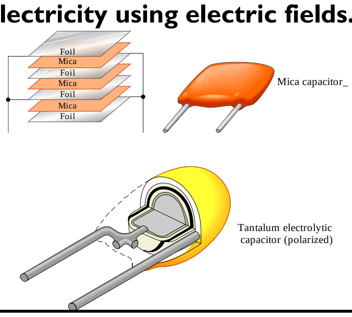


AC Theory



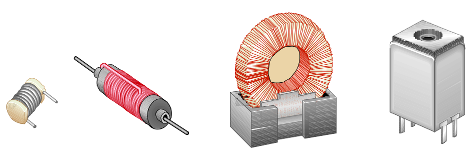
Capacitors

- **Capacitors are devices that store electricity using electric fields.**

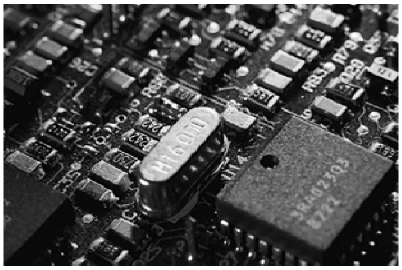


Inductors

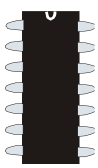
- **Inductors are devices that store electricity using magnetic fields.**

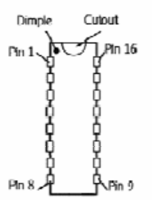


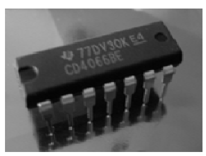
Integrated Circuits (IC's)

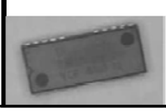


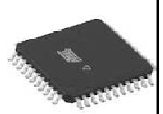
IC Orientation









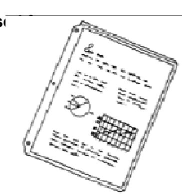


ESD

To feel an Electrical Discharge, the voltage must be approx. 3000 Volts

- ESD Class 0: Damage you can't feel: **0 to 199 Volts**
- ESD Class 1: Damage you can't feel: **200 to 1,999 Volts**
- ESD Class 2: Damage you might feel: **2,000 to 3,999 Volts**
- ESD Class 3: Damage you can probably detect as spark with your own body: **4,000 to 15,999 Volts**

- Vinyl envelope us
work instructions:
- 600 - 7,000 volts

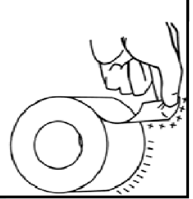


- Walking across a carpet:
- 1,500 - 35,000 volts

- Worker at a bench:
- 700 - 6,000 volts

- Walking over untreated vinyl floor:
- 250 - 12,000 volts

- Unwinding regular tape:
- 9,000 - 15,000 volts



TYPICAL ELECTROSTATIC VOLTAGES*

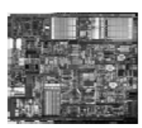
EVENT	RELATIVE HUMIDITY		
	10%	40%	55%
Walking across carpet	35,000	15,000	7,500
Walking across vinyl floor	12,000	5,000	3,000
Motions of bench worker	6,000	800	400
Remove DIPs from plastic tubes	2,000	700	400
Remove DIPs from vinyl trays	11,500	4,000	2,000
Remove DIPs from Styrofoam	14,500	5,000	3,500
Remove bubble pack from PCBs	26,000	20,000	7,000
Pack PCBs in foam-lined box	21,000	11,000	5,500

*Source: AT&T ESD Control Handbook-1989

Device Sensitivity

MOSFET EPROM	100 – 300 V
Schottky Diodes	300 – 2500 V
Schottky TTL	1000 – 2500 V
Film Resistors	300 – 3000 V
VMOS	30 – 1800 V
NMOS	60 – 100 V
CMOS	200 – 3000 V
JFET	140 – 7000 V
GaAsFET	25 – 50 V

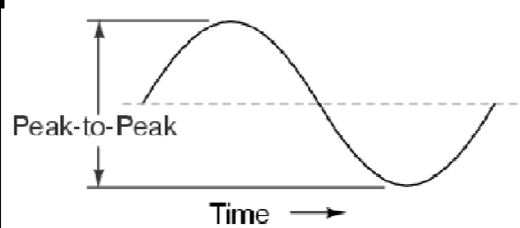
Technology Trends



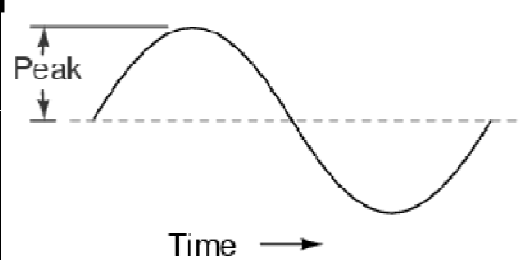
Year	**1995**	**1998**	**2001**	**2004**	**2007**
Feature size (μm)	0.35	0.25	0.13	0.10	0.09
Voltage (V)	3.5	2 - 3.5	1.0 – 1.5	0.9 – 1.0	0.7

AC Basics

Voltage Peak to Peak ($V_{p\text{-}p}$)

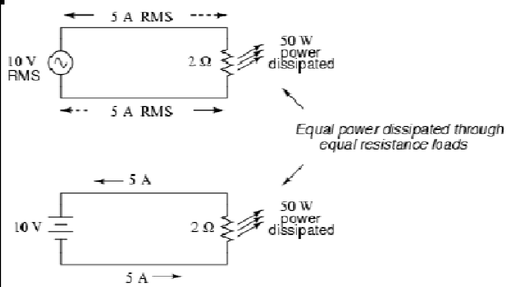


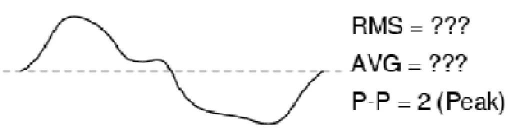
Voltage Peak (V_p)



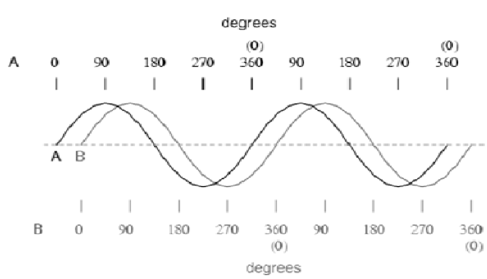
Voltage RMS(V_{RMS})

- DC Equivalent Voltage



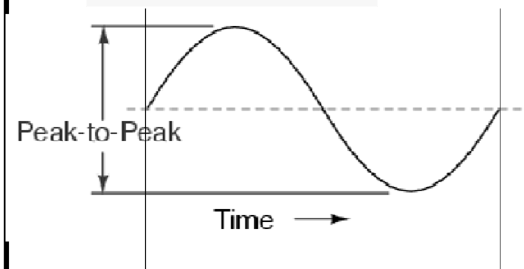


Phase



Period

$$\text{Period} = \frac{1}{\text{frequency}}$$



Frequency

$$\text{frequency} = \frac{\text{one cycle}}{\text{Period}}$$

Measurements

- Multimeter Limitations
- Oscilloscopes

Oscilloscopes

- Sinewaves
- Squarewaves

Oscilloscope Basics

- Probes
  - X
  - Y
  - 1X
  - 10X
  - Ground
- Amplitude
- Time Base
- Trigger
- Input Impedance

Sinewaves

- Amplitude
- Period
- Frequency

Squarewaves

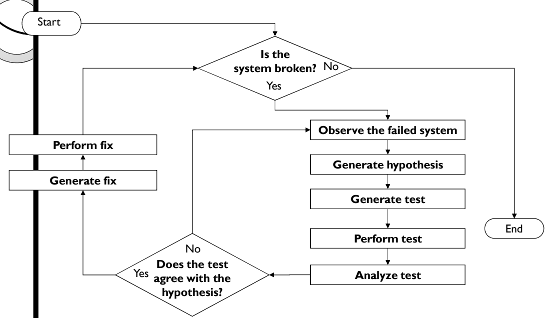
- Amplitude
- Period
- Duty Cycle

Making Measurements

- XYZ's of measurements

Lunch

Troubleshooting: A Flow Chart



Digital Logic

Why Digital?

Number Systems: The Basics

Decimal	Binary	Octal	Hexadecimal
0	0	0	0
1	1	1	1
2		2	2
3		3	3
4		4	4
5		5	5
6		6	6
7		7	7
8			8
9			9
10			A
11			B
12			C
13			D
14			E
15			F

Logic Families

- What are logic families?
  - Related groups of digital chips
  - Similar power requirements
  - Similar operating voltages
  - Similar speeds

TTL

- TTL = Transistor-Transistor Logic
  - Resistant to static discharge
  - Input Voltages
    - Low: -0.1V–0.8V, high: 2.0V–5.1V
  - Output Voltages
    - Low 0.0V–0.2V, high: 4.7V–5.0V

Logic Families

- TTL (Transistor-to-transistor logic)
  - 74: standard TTL
  - 74S: Schottky TTL
  - 74AS: Advanced Schottky
  - 74LS: Low power Schottky
  - 74ALS: Advanced Low power Schottky
  - 74F: Fast TTL

CMOS

- CMOS (Complementary Metal-Oxide semiconductor)
  - 74HC and 74HCT: High Speed CMOS
  - 74AV and 74ACT: Advanced CMOS
  - 74AHC and 74AHCT: Advanced High Speed CMOS
  - 74LV or 74LVC: Low Voltage CMOS
  - 74ALVC: Advanced Low Voltage CMOS

Logic Families

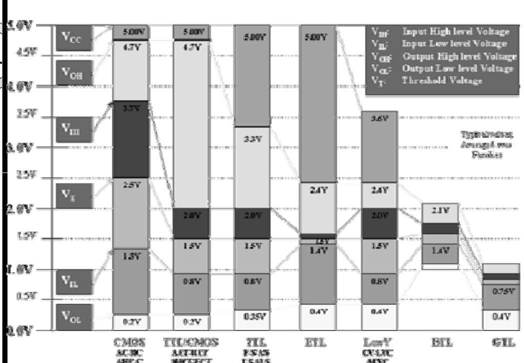
- Combined CMOS and TTL
  - 74BCT: BiCMOS
  - 74ABT: Advanced BiCMOS
  - 74LVT: Low Voltage BiCMOS
  - 74ALB: Advanced Low Voltage BiCMOS

CMOS vs TTL

- TTL
  - Faster switching speeds
  - Greater selection
- CMOS
  - –Lower Power Dissipation
  - –5Volt and 3.3 Volt Series

ECL

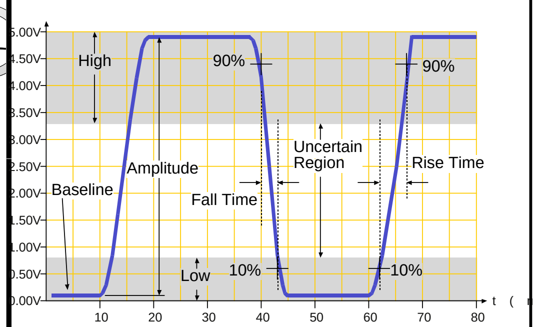
- ECL = Emitter-Collector Logic
  - The fastest room-temperature logic
  - Input Voltages
    - Low: -1.810 V – -1.475 V, high: -1.165 V – -0.880 V
  - Output Voltages
    - Low: -1.810 V – -1.620 V, high: -1.025 V – -0.880 V

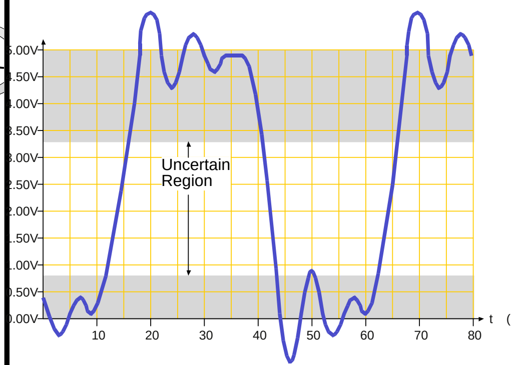


Drop in Voltages

- Speed, speed, speed
  - The lower the voltage swing, the faster you can swing it
- Power dissipation
  - Chips with $1 \cdot 10^8$ transistors get warm
  - $P = V_{cc} \cdot I_{transistor}$
- Battery powered systems
  - Run below 3V (two 'AA' cells in series)
  - Ideal: below 1.5V (one 'AA' cell)
- Reliability
- Any problems with lower voltages?
  - More sensitive to external noise

ESD Implications

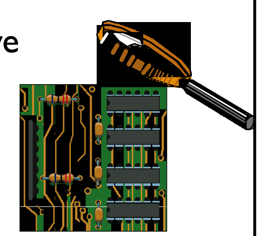




Basic Gates

- AND
- OR
- NOT
- NAND
- NOR
- EXOR
- EXNOR

Being A Detective



- Givens
  - A schematic
- Questions
  - How many inputs?
  - How many outputs?
  - Which inputs are data?
  - Which inputs are control?
  - Which inputs are global? Which are local?
  - Is the device synchronous?
  - <u>What does it do?</u>

References

- What makes a good reference?
  - Trustworthy information
  - Ease of access
  - Well organized
  - Familiarity
- When should you use a reference?
  - Whenever you need it
  - Always exercise your head first
- What kind of references are there?
  - People
  - Printed materials
  - On-line materials

On-line References

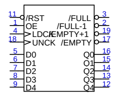
- Chips
  - By number
    - http://www.mitronet.com/chipdir/n/index.htm
  - By function
    - http://www.mitronet.com/chipdir/f/index.htm
- Datasheets
  - http://mwd.ee.qub.ac.uk/DataSheet/Down_Load
- Troubleshooting
  - http://www.ganssle.com/articles.htm
  - http://www.troubleshooters.com/tinterm.htm#top

Off-line References

- Common books
  - The Art of Electronics, 2nd Edition
    - Paul Horowitz & Winfield Hill
    - Best cook-book approach to electronics
  - Digital Fundamentals, >5th Edition
    - Thomas L. Floyd
    - Simple, well edited, clearly illustrated basic text

Example: A Tough MSI Chip

- The chip?
  - 74ALS233, almost on worksheet
- Where could I start?
  - Books are at home
  - People!
  - The web



- Where do I concentrate?
  - Texas Instruments: http://www.ti.com/
- Why?
  - Familiar
  - Accessible

The Actual Search: 74ALS233

- Step 1: search for '74ALS233'
  - Where? Top search opening
  - Result? Zilch
- Step 2: delve into ALS
  - How? Use the product tree
  - Where? Upper left hand side of web site
  - What? Choose 'Digital Logic'
  - Next? Choose 'Logic Family' --> 'ALS'
  - And then? D's & Q's…how about 'Buffers & Drivers'?
  - Hey! All these numbers have an 'SN' on the front!
- Step 3: search again: 'SN74ALS233'
  - Success! "16 x 5 asynchronous FIFO memory"

Analog to Digital Conversion

- Sensitivity
- Resolution!
- Impedance Matching

Analog to Digital Conversion

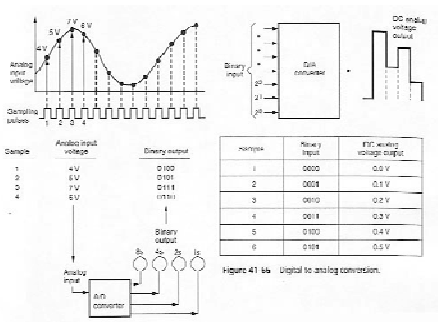
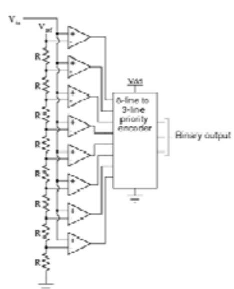
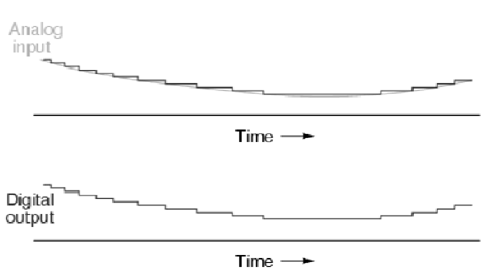


Figure 41-66 Digital-to-analog conversion.

Basic A/D Circuit



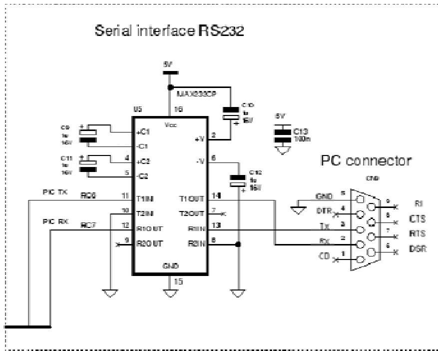


Communications

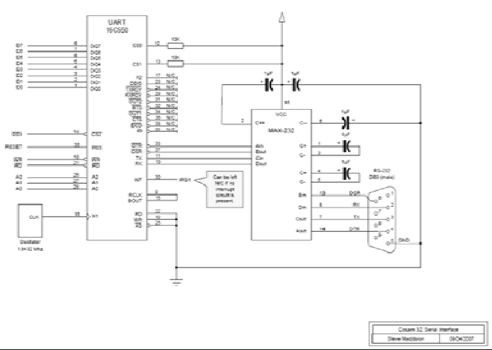
Serial v Parallel

Baudrate	Distance
19200bps	15m
9600bps	150m
4800bps	300m
2400bps	900m

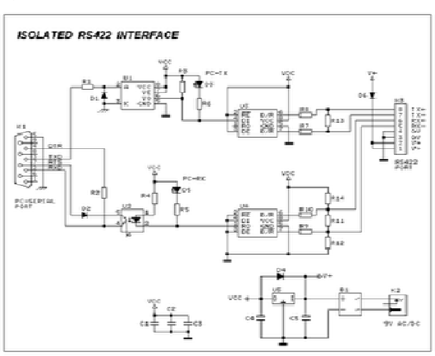
RS232



Serial Interface



RS422

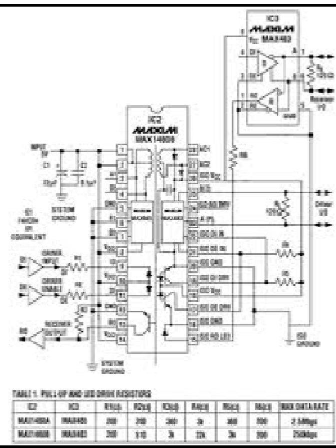


Serial, balanced and *differential*

- *Balanced differential*
  - Each signal line consists of two wires, preferably twisted to reduce noise.

- Voltage-*difference* between the two lines is an indication of the signal value, rather than the voltage-*level*.

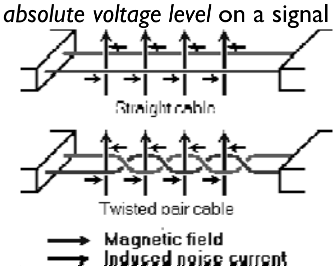
RS485

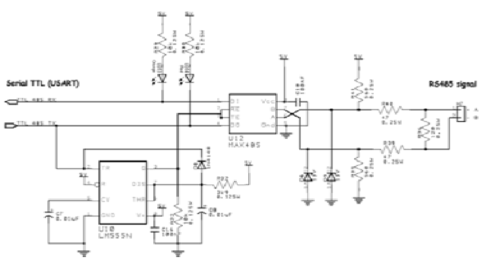


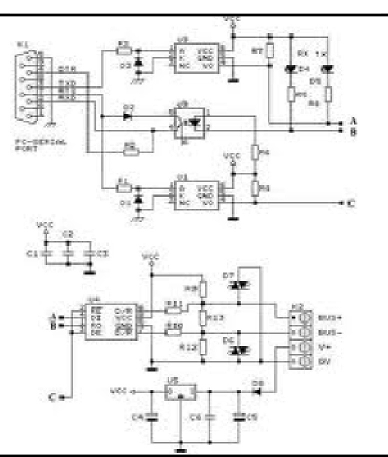
RS485

- Connect Data terminal Equipment (DTE's) directly without the need of modems
- Connect several DTE's in a network structure
- Ability to communicate over longer distances
- Ability to communicate at faster communication rates

- The **RS485** receiver compares the *voltage difference* between both lines, instead of the *absolute voltage level* on a signal line.

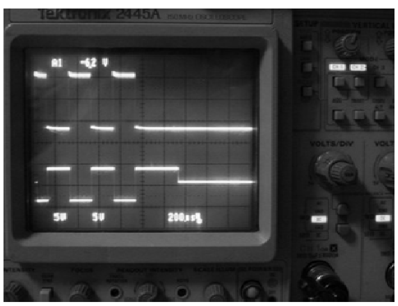




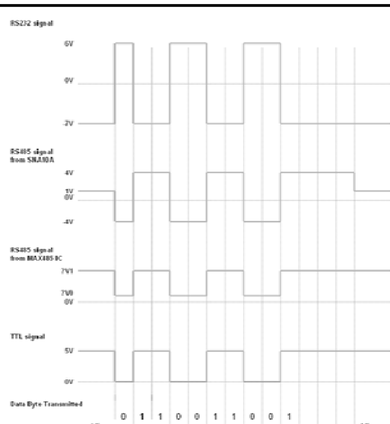


- All the senders on the **RS485** bus are in tri-state with high impedance.

232 - 485 Waveforms



0x33 or ASCII char '3'



Baud

Symbols per second or *pulses per second*

Parity

- Parity is a simple way to encode a data word to have a mechanism to detect an error in the information.

- Even Parity

- Odd Parity

Stop Bits

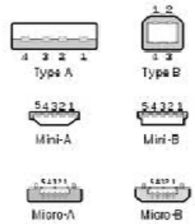
- A mechanism to resynchronize the communication, used when we "frame" our communications.
- The stop bit is always a mark value.
- If the receiver detects a value other than mark when the stop bit should be present on the line, it knows that there is a synchronization failure.

- Stop bit times are represented by the data word size associated with the system.
- While there are values of **1**, **1.5** or **2** these are minimum stop lengths.

	RS232	RS423	RS422	RS485
Differential	no	no	yes	yes
Max number of drivers	1	1	1	32
Max number of receivers	1	10	10	32
Modes of operation	half duplex full duplex	half duplex	half duplex	half duplex
Network topology	point-to-point	multidrop	multidrop	multipoint
Max distance (acc. standard)	15 m	1200 m	1200 m	1200 m
Max speed at 12 m Max speed at 1200 m	20 kbs (1 kbs)	100 kbs 1 kbs	10 Mbs 100 kbs	35 Mbs 100 kbs
Max slew rate	30V/µs	adjustable	n/a	n/a
Receiver input resistance	3..7 kΩ	≧ 4 kΩ	≧ 4 kΩ	≧ 12 kΩ
Driver load impedance	3..7 kΩ	≧ 450 Ω	100 Ω	54 Ω
Receiver input sensitivity	±3V	±200 mV	±200 mV	±200 mV
Receiver input range	±15V	±12V	±10V	–7..12V
Max driver output voltage	±25V	±6V	±6V	–7..12V
Min driver output voltage (with load)	±5V	±3.6V	±2.0V	±1.5V

USB

- Standards
  - Ver 1
  - Ver 2
- Connectors
  - A
  - B
  - Mini
- Camera Considerations



Cabling

- Network
- Shielded
- Coaxial
- Insulation Types

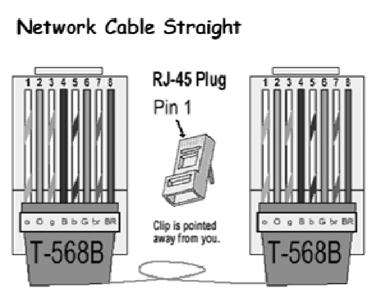
Cabling Safety

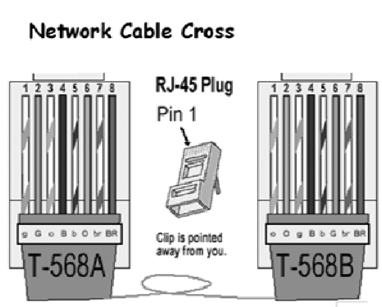
- Know where you are going with it
  - Plenum Cabling
- Know what you are doing with it
  - Speed
  - Bandwidth
  - Connector Requirements

Wire Type

- Solid
- Stranded

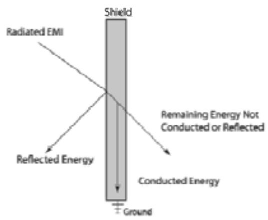
Network



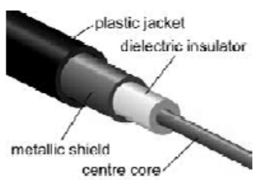


Shielding

- Reduce or eliminate EMI
  - Reflection
  - Conduction to ground



Coaxial



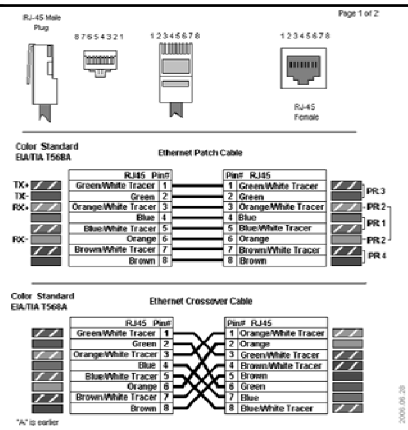
Insulation

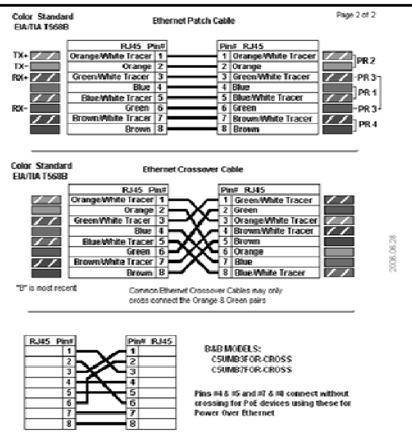
- **T: Thermoplastic insulation**
- **R: Thermoset insulation (rubber or synthetic rubber)**
- **X: Cross-linked synthetic polymer insulation**
- **H: High temperature (usually 75°C when dry or damp)**
- **HH: Higher temperature (usually 90°C when dry or**
- damp)
- **W: Moisture resistant (usually 60°C when wet)**
- **N: Nylon jacket**
- **-2: High temperature and moisture resistance (90°C**
- wet or dry)

Connectors

Computer Connections

Network Specific Connectors





RF Connectors

RCA – not really RF

BNC

UHF

N

TNC

Tools

Network Basics

NMEA 0183

- The data stream consists of a series of "sentences" delimited by a newline character.
- The first character of which is always "$".
- The standard defines dozens of sentences.

http://www.tronico.fi/OH6NT/docs/NMEA0183.pdf

BASIC FORMAT OF A TALKER SENTENCE

$ttsss,d1,d2,....<CR><LF>

The first two letters following the „$" are the *talker identifier.*

The next three characters (sss) are the sentence identifier, followed by a number of data fields separated by commas, followed by an optional checksum, and terminated by carriage return/line feed.

http://www.tronico.fi/OH6NT/docs/NMEA0183.pdf

A sentence may contain up to 80 characters plus "$" and CR/LF.

The standard allows individual manufacturers to define proprietary sentence formats. These sentences start with "$P", then a 3 letter manufacturer ID, followed by whatever data the manufacturer wishes, following the general format of the standard sentences.

http://www.tronico.fi/OH6NT/docs/NMEA0183.pdf

- EC Electronic Chart Display & Information System (ECDIS)
- II Integrated Instrumentation
- IN Integrated Navigation
- LC Loran C
- P Proprietary Code
- RA RADAR and/or ARPA
- SD Sounder, Depth
- SN Electronic Positioning System, other/general
- SS Sounder, Scanning
- TI Turn Rate Indicator
- VD Velocity Sensor, Doppler, other/general
- DM Velocity Sensor, Speed Log, Water, Magnetic
- VW Velocity Sensor, Speed Log, Water, Mechanical
- WI Weather Instruments
- YX Transducer

http://www.tronico.fi/OH6NT/docs/NMEA0183.pdf

MTW Water Temperature

```
        1   2 3
        |   | |
$--MTW,x.x,C*hh
```

- 1) Degrees
- 2) Unit of Measurement, Celcius
- 3) Checksum

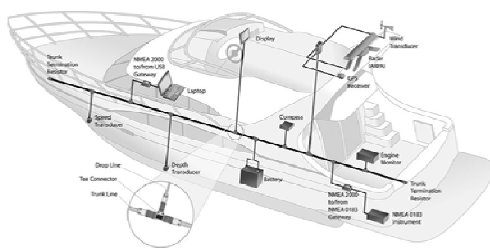
http://www.tronico.fi/OH6NT/docs/NMEA0183.pdf

DPT Heading – Deviation & Variation

```
          1  2 3
          |  | |
```
- $--DPT,x.x,x.x*hh
- 1) Depth, meters
- 2) Offset from transducer;
- positive means distance from transducer to water line,
- negative means distance from transducer to keel
- 3) Checksum

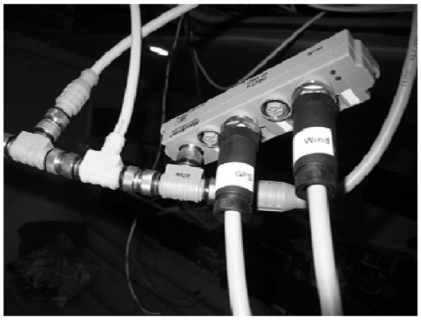
http://www.tronico.fi/OH6NT/docs/NMEA0183.pdf

NMEA 2000



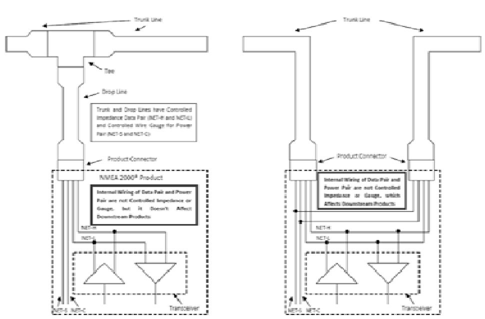
http://www.maretron.com/
http://en.wikipedia.org/wiki/File:NMEA2000_Modified_motor_yacht.jpg

- Higher data rate (250k bits/second vs. 4800 bits/second for NMEA 0183).
- Compact binary message format as opposed to the ASCII serial communications protocol used by NMEA 0183.
- Supports a disciplined multiple-talker, multiple-listener data network whereas NMEA 0183 requires a single-talker, multiple-listener (simplex) serial communications protocol.



- **The NMEA 2000® Standard does not allow daisy chaining for a number of reasons.**
- **Most importantly, daisy chaining can setup potential electrical and signal properties mismatches.**

http://www.nmea.org/content/technical_updat/nmea_tech_tips.asp



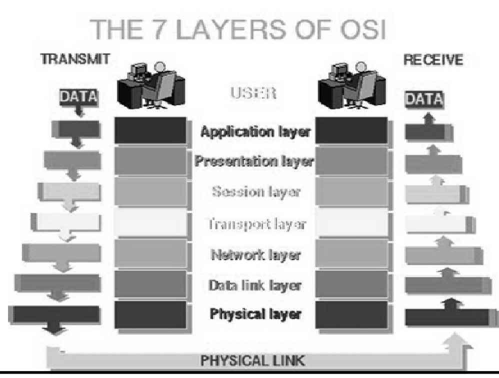
http://www.nmea.org/Assets/20100414%20daisychaining%20internal%20diagrams%20drawing%202.pdf

Other Networks for Marine Use?

OSI Model

- These are the 7 Layers of the OSI model:
  - 7. Application Layer (Top Layer)
  - 6. Presentation Layer
  - 5. Session Layer
  - 4. Transport Layer
  - 3. Network Layer
  - 2. Data Link Layer
  - 1. Physical Layer (Bottom Layer)

OSI Model



MAC Addresses

- The MAC address is a unique value associated with a network adapter.
- MAC addresses are also known as **hardware** addresses or **physical** addresses.
- MAC addresses are 12-digit hexadecimal numbers (48 bits in length).

- The first half of a MAC address contains the ID number of the adapter manufacturer.
- 00:A0:C9:14:C8:29
- The prefix 00A0C9 represent Intel Corp.
- Hardware specific

IP Addresses

- 142.110.237.1 is an IP address
- While we look at them as a decimal numbering system, it really goes to a bit level.
- Static
- Dynamic

Why address MAC over IP?

Subnets

- The subnet mask is used to determine which portion of the IP address is the network address, and which is the host address.
- The most common subnet mask is 255.255.255.0

Protocols

OSI Model	*DoD Model*	*TCP/IP Suite of Protocols*						
Application Presentation Session	Application (Port)	HTTP 80	SNMP 161 162	FTP 20 21	TFTP 69	SMTP 25	Telnet 23	NNTP 119
Transport	Host to Host	TCP				UDP		
Network	Internet	ICMP	IP			ARP		
Data Link Physical	Network Access	Network Devices						

Bridges

- Both hardware and software devices.
- They can be stand alone devices such as separate boxes specifically designed for bridging applications or they can be dedicated PCs (with 2 NICs and bridging software).
- Most server software will automatically act as a bridge when a second NIC card is installed.

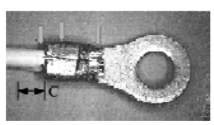
- The purposes of a Bridge are the following:
  - Isolates networks by MAC addresses
  - Manages network traffic by filtering packets
  - Translates from one protocol to another

Routers

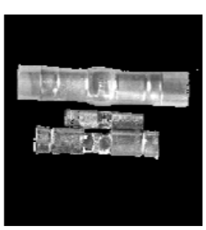
- The purpose of a router is to connect nodes across an Internetwork, regardless of the Physical Layer and Data Link Layer protocol that is used.
- Routers are hardware and topology-independent.
- Routers are not aware of the type of medium or frame that is being used (Ethernet, Token Ring, FDDI, X.25, etc.).

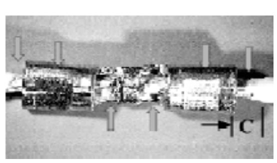
Break

Soldering Basics



http://workmanship.nasa.gov/lib/insp/2%20books/frameset.html





http://workmanship.nasa.gov/lib/insp/2%20books/frameset.html

Soldering Safety

- Heat
- Lead (if using lead solder)
- Flux (if using lead-free solder)

ESD

- Components
- False Readings

Lead Based Solder

Lead-Free Based Solder

Fluxes v Rosin Core

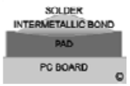
Soldering Irons

Resistive Heating Element

RF Heating Element

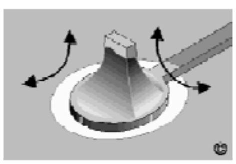
Hot Air Systems

Through Hole Soldering



http://www.circuitrework.com/guides/7-1-1.shtml

Concerns

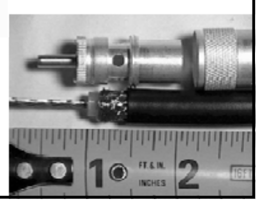


http://www.circuitrework.com/guides/7-1-1.shtml

Technique

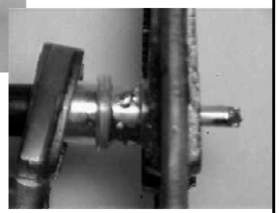
Practice

Cable End Soldering

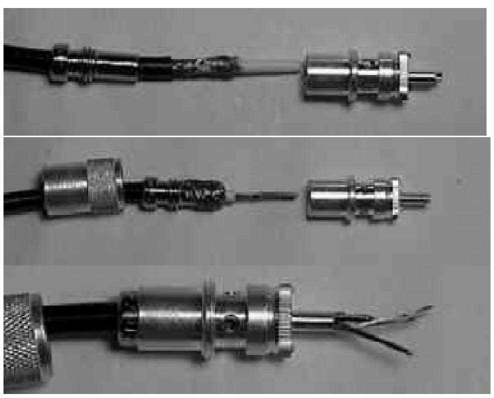


- **Step 1 Slide coupling ring onto cable. Cut end of cable even and** strip jacket, braid and dielectric. All cuts are to be sharp and square. Do not nick braid, dielectric or center conductor. Tin exposed center conductor and braid, avoiding excessive heat.
- **Step 2 Screw the plug sub-assembly on cable. Solder assembly to** braid through solder holes, making a good bond between braid and shell. Solder conductor to contact. Do not use excessive heat.
- **Step 3 For final assembly on straight plugs, move coupling ring forward** and screw in place on plug sub-assembly.

http://www.amphenolrf.com/products/AssemblyInstructions/uhf.pdf



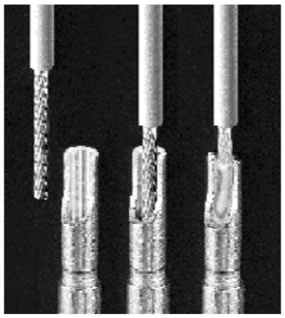
http://www.seed-solutions.com/gregordy/Amateur%20Radio/Experimentation/SolderCoax.htm



Heat Shrink

- Secure fit -
  - Be sure that the tubing's ***recovered*** diameter (the diameter after shrinking) is smaller than the diameter of the area you're going to insulate.
- Overlap –
  - allow for a minimum 1/4" overlap over any existing insulation or connectors

Bifuricated Connectors



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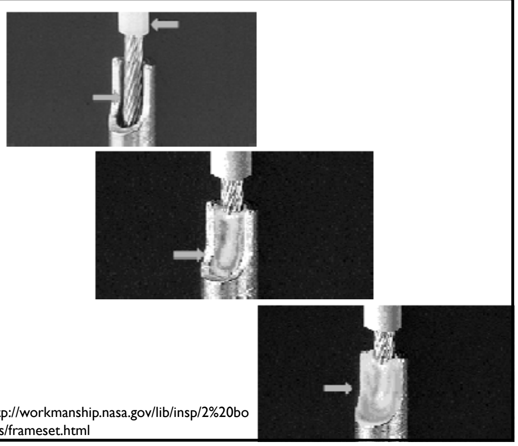

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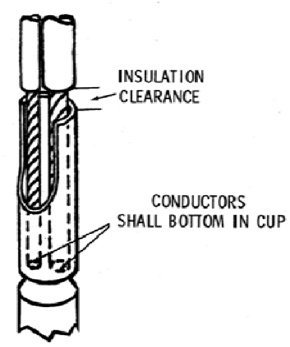
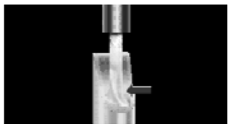
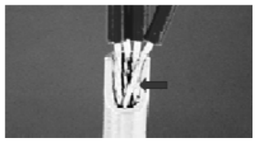


http://socrates.berkeley.edu/~phylabs/bsc/PDFFiles/Soldered.pdf

Concerns



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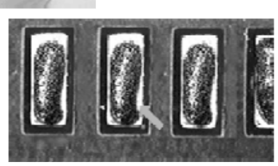
Surface Mount

Solder Paste





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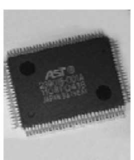
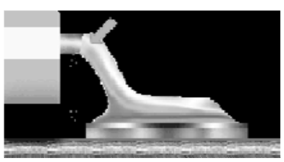
Technique

Gull Wing





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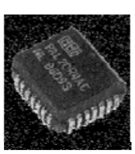
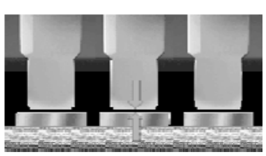
J Lead





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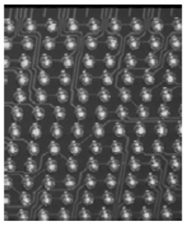
BGA



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Practice

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Fast and Furious Overview