General License Course
Chapter 4.5

Active Components

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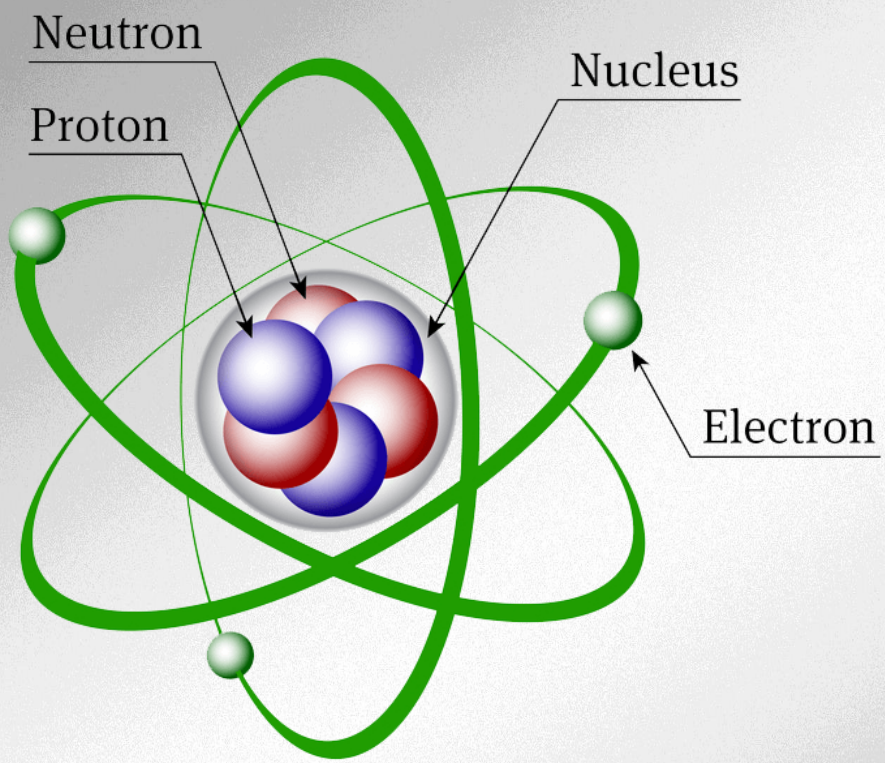
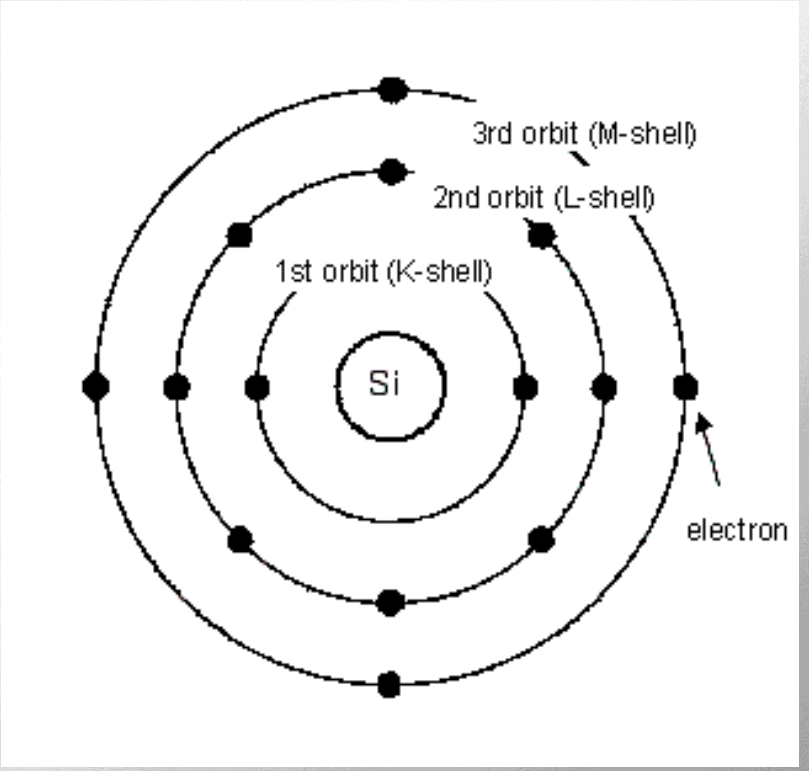
Atomic Structure





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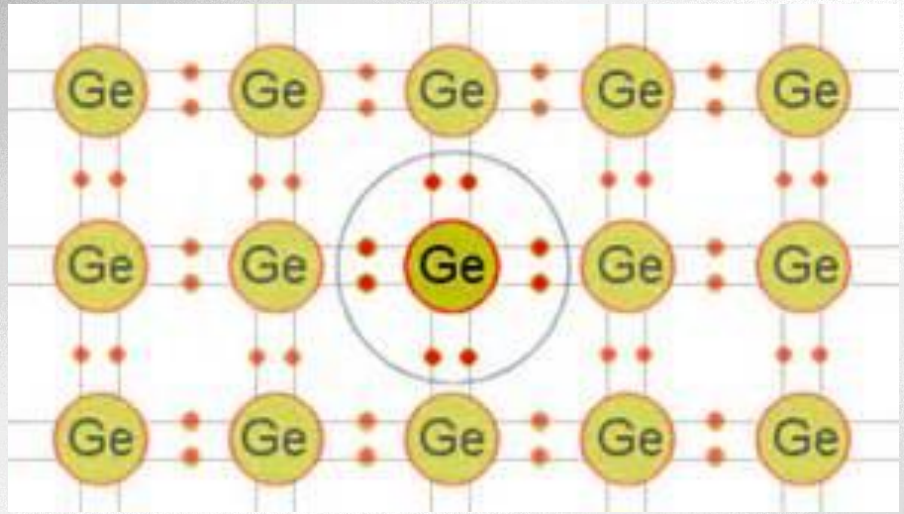
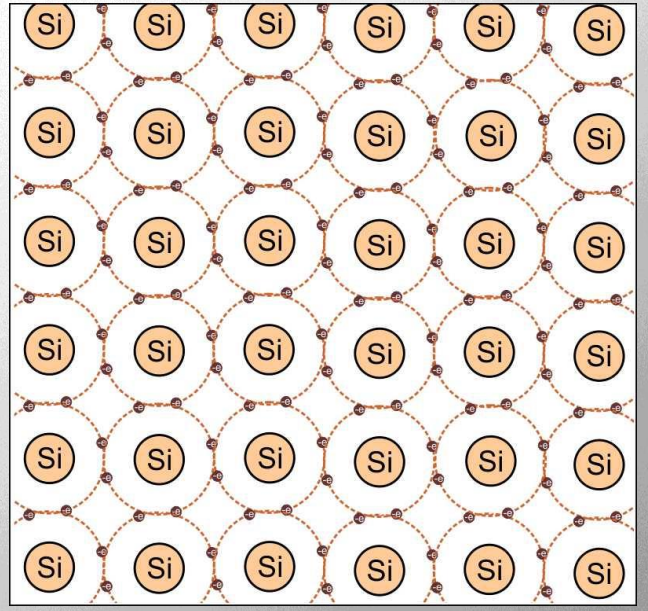
The number of Protons = the number of Electrons

Atomic Lattice

Germanium and Silicon are used in semiconductor devices.
Each has 4 electrons in their outermost valence electron shell

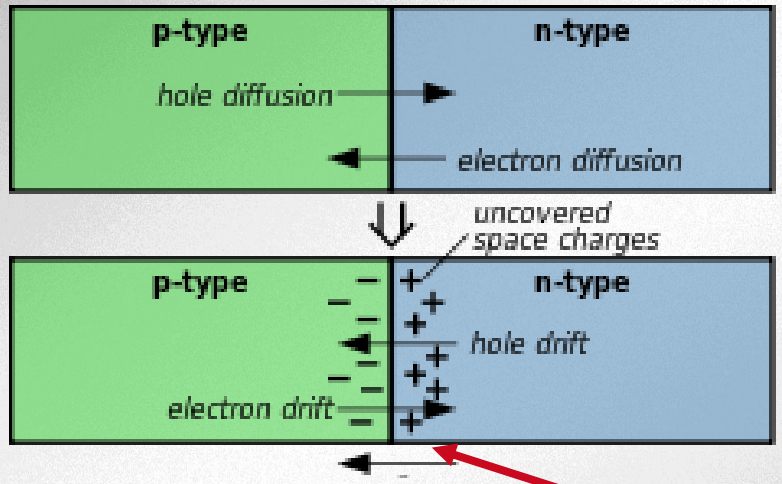
Covalent Bonding

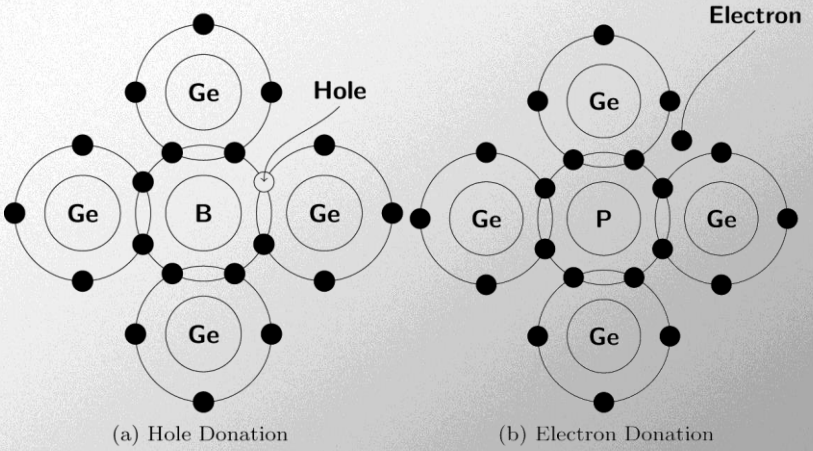




Semiconductor

Semiconductor material is created by “doping” crystalline (non-conducting) lattices with impurities to allow them to “semi-conduct”





Near the PN junction, electrons diffuse across to combine with holes, creating a "depletion region"

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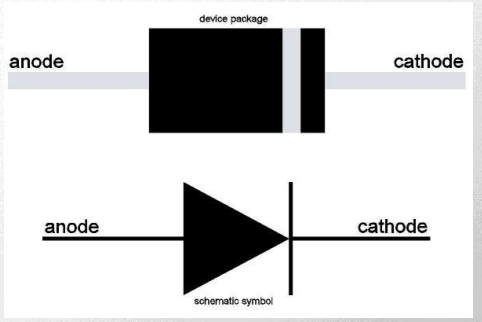
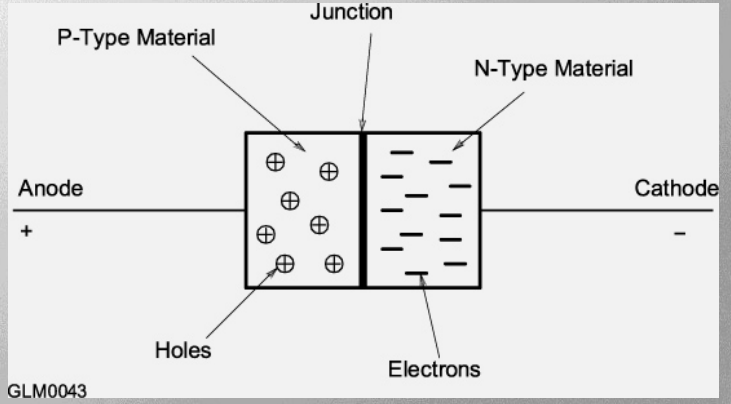
Semiconductor Components

- Diodes & Rectifiers
- Junction diode - PN semiconductor junction blocks flow of current in one direction
- Current flows when (+) voltage is applied to the P-type material and (-) voltage to the N-type material - **forward bias**

Diode forward voltage drop (or *junction threshold voltage,* to overcome the depletion region) : ***germanium 0.3 V - silicon 0.7 V***





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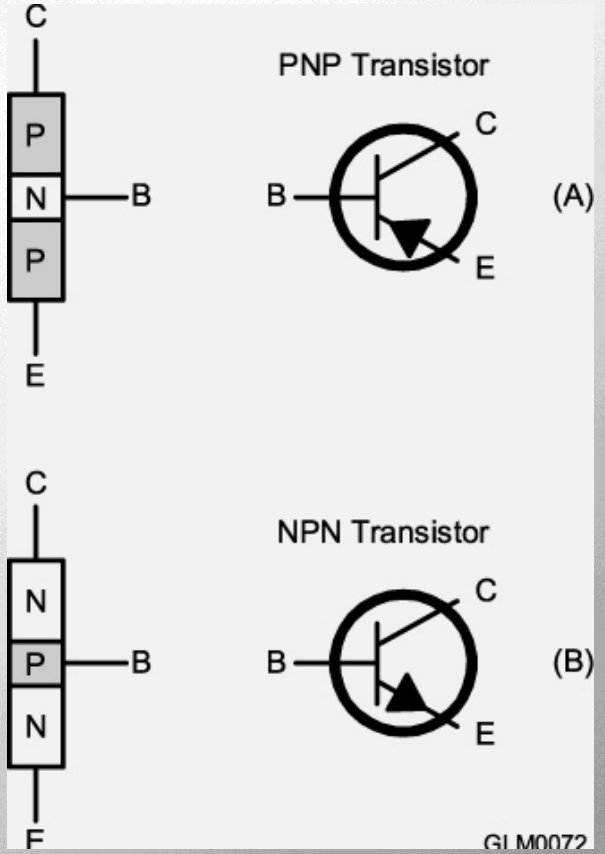
Bipolar Transistors

- Bipolar junction transistors have 3 electrodes:
  - Collector (C)
  - Base (B)
  - Emitter (E)
- Emitter-Collector *current* flow is controlled by the much smaller *current* flow between base and emitter



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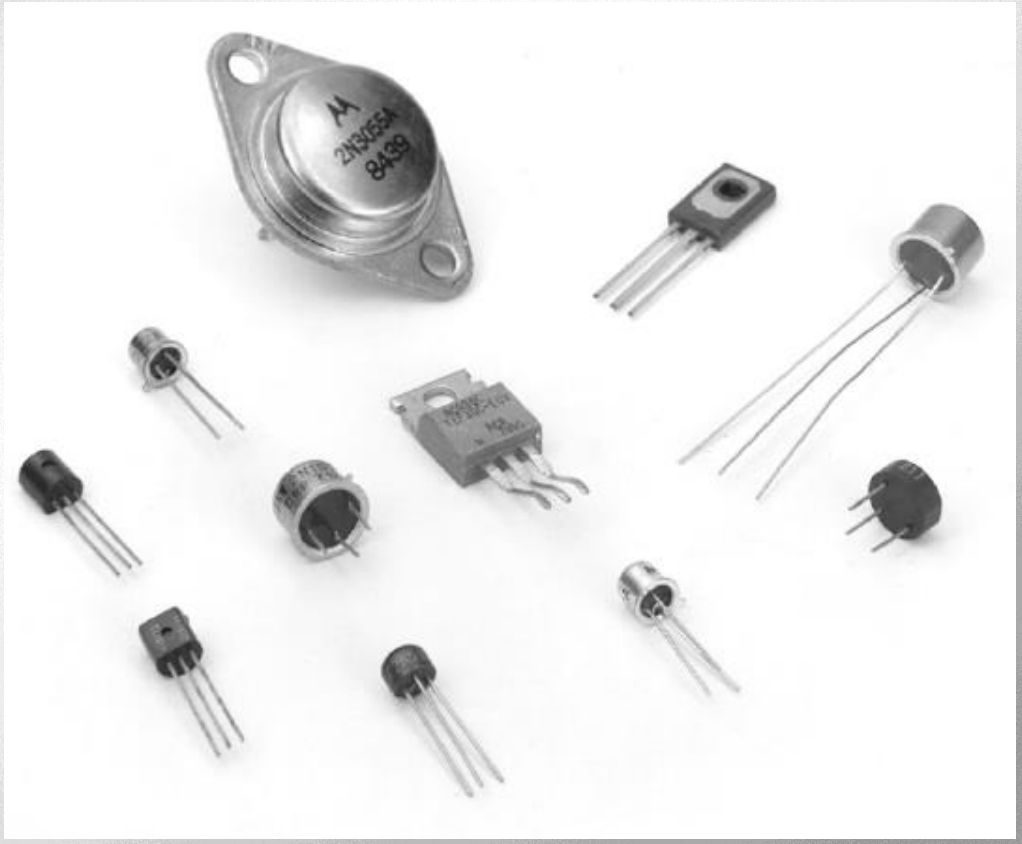
Bipolar Transistors

- Very little base-emitter current is required for emitter-collector current to flow
- Control of the above larger current by a smaller current is *current gain* or *beta* (β)



Bipolar Transistors

- Transistors can be used as as *switches* for voltage and current
- *Saturation* – when further increases in input result in no output change (logic HI or 1)
- *Cutoff* – when the input signal reduces output current to zero (logic LO or Ø)
- Saturation & cutoff regions can represent *digital ON/OFF or 1/Ø values* - Stable Operating Points for logic circuit use

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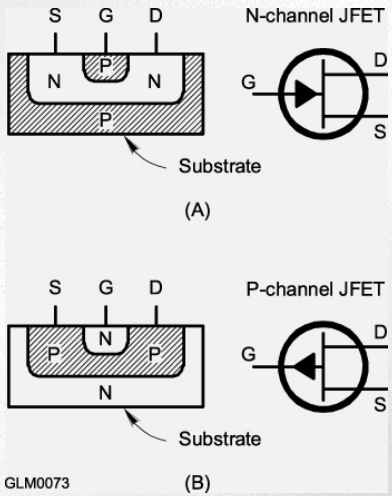
Field Effect Transistor (FET)

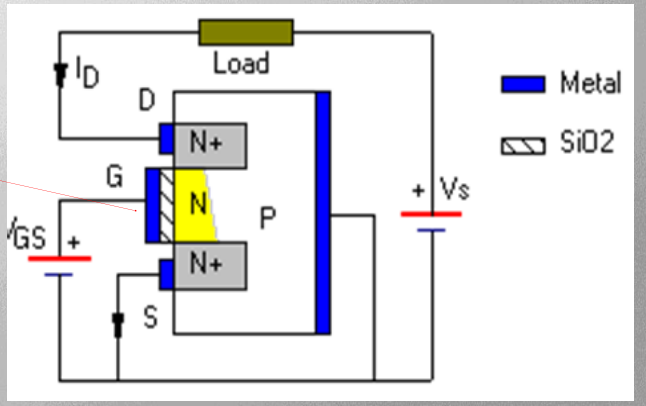
The FET has 3 electrodes; Drain (D), Source (S) and Gate (G)

Current flow is controlled by the *voltage* between gate and source.



Junction FET or JFET

Metal-Oxide-Semiconductor FETs (MOSFETs) insulate the gate from the channel with a thin layer of oxide



(Static Sensitive!)

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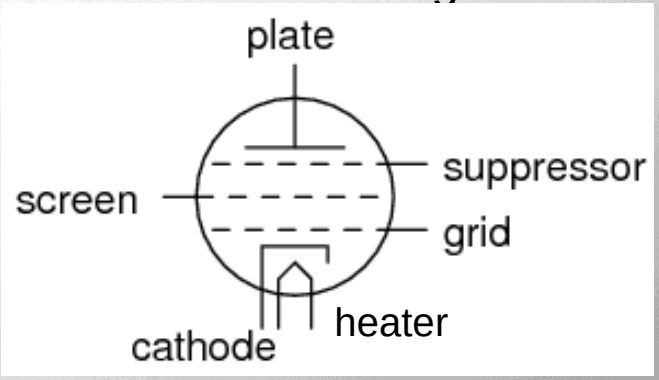
Vacuum Tubes

- Tube terminology:
  - *Filament or heater* – heats the cathode to allow it emit electrons
  - *Cathode* – source of electrons (negative bias)
  - *Control grid* – regulates electron travel between the cathode and plate
  - *Screen grid* – reduces grid-to-plate capacitance
  - *Suppressor grid* – prevents electrons from traveling between the plate and control/screen grids
  - *Plate* – collects electrons



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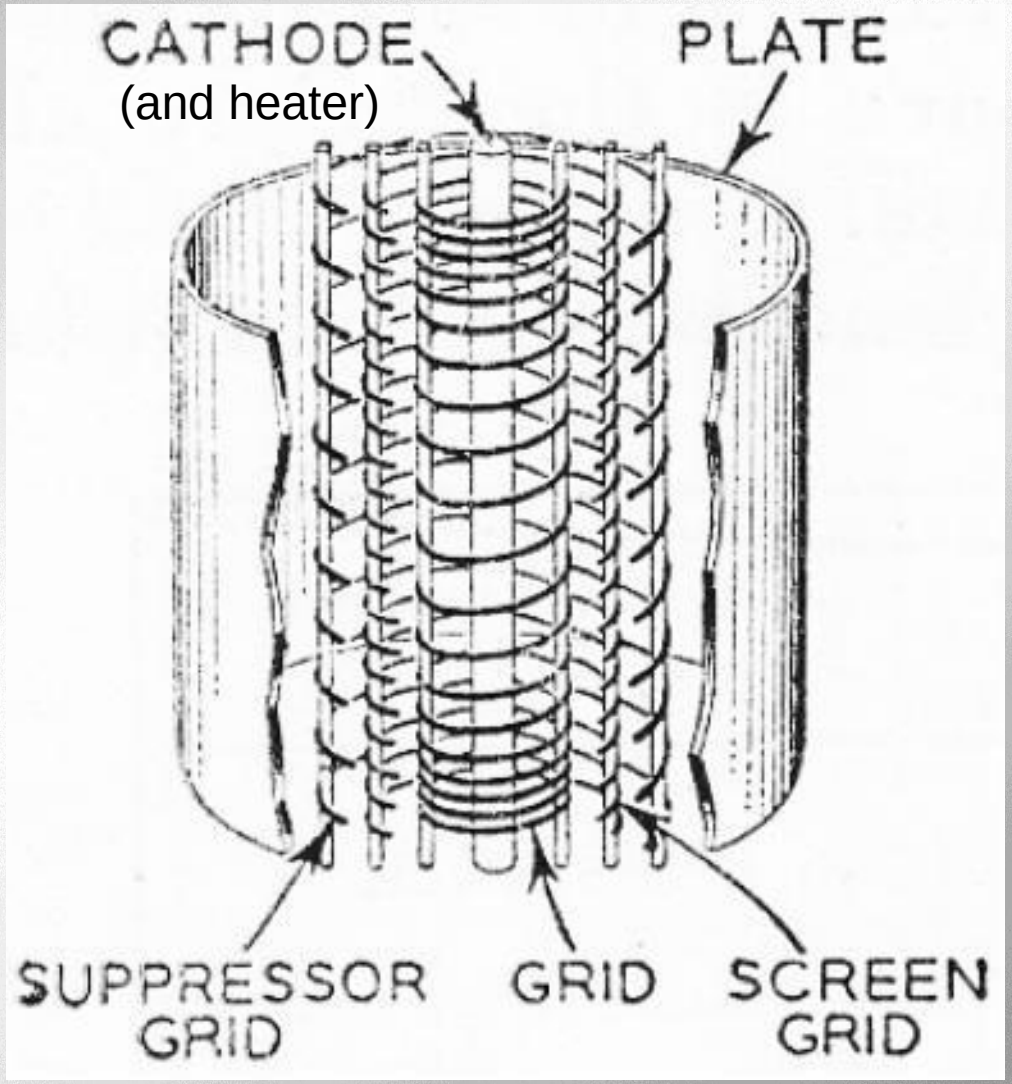
Pentode Cross-Section



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Vacuum Tubes

- All *amplifying* tubes have at least 3 electrodes
- Compared to transistors, the tube is most like the field effect transistor (FET)
- Vacuum tubes sometimes operate at *hazardous voltages* as high as
2000 to 3000 volts
(use **CAUTION!**)

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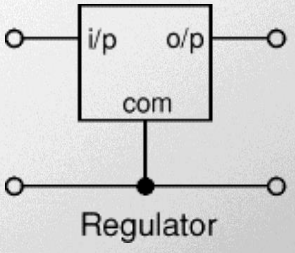
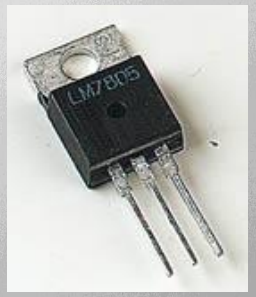
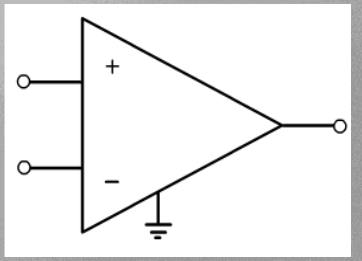
Analog Integrated Circuits (ICs)

- ***Analog*** ICs or “chips”:
- Can have an output value anywhere between zero volts and the supply voltage
- Used for amplification, filtering, measurement, and power control
- A linear voltage regulator is used to maintain a power supply output at a constant voltage over a wide range of currents *(Analog)*
- Operational amplifiers (op amps) are used for dc and audio circuits *(Analog)*







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Digital Integrated Circuits (ICs)

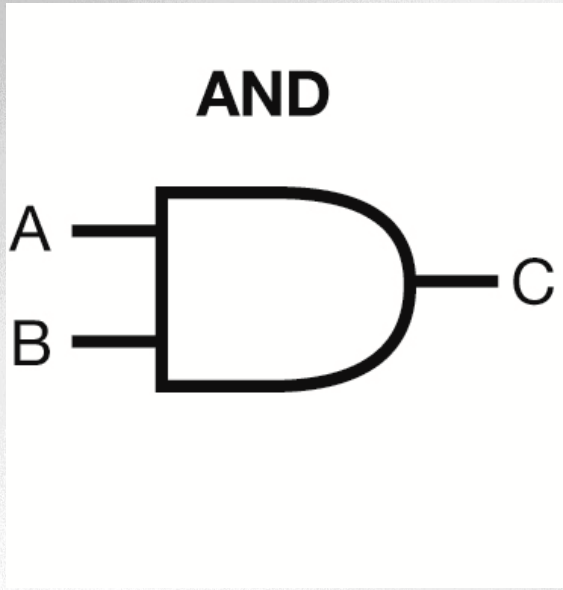
- Digital ICs operate with discrete values of voltage and current which can easily represent the binary numbers system (logic) values 0 and 1 (lo, hi)
- Digital electronic circuits operate with only two stable states of operation, ON or OFF (see above)
- Digital circuits can perform computations or control functions
- CMOS (complementary-symmetry metal-oxide semiconductor) technology is popular because of its high speed and low power consumption (vs. TTL) - *often Static Sensitive!*

Digital Logic Basics

- The basic building blocks of digital circuits are called *gates*
  - *Inversion* (changing a 1 to a 0 and vice versa)
  - OR and AND functions
  - Inverted versions are NOR and NAND
  - Truth tables explain the functions implemented by the gates

Digital Logic Basics

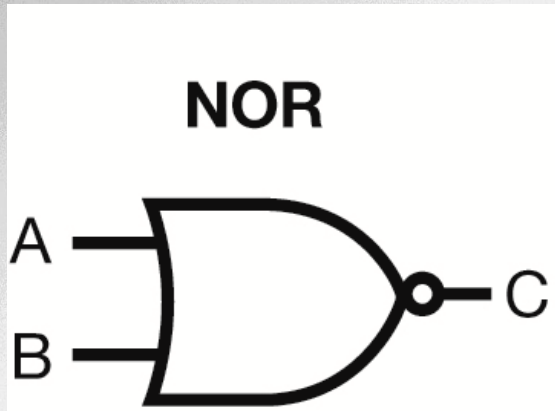
For a two input AND gate, the output is high only when both inputs are high



A	B	C
0	0	0
0	1	0
1	0	0
1	1	1

Digital Logic Basics

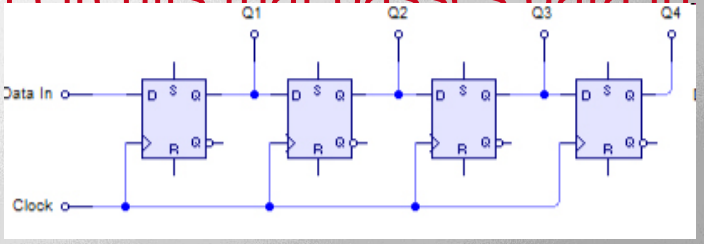
For a two input NOR gate, the output is low when either or both inputs are high.



A	B	C
0	0	1
0	1	0
1	0	0
1	1	0

Digital Logic Basics

- Flip-flop – has 2 stable output states (Hi, Lo) - when pulsed by the clock output O changes to whatever logic level is present at input D
- Sequential logic – built on flip-flops feeding other flip-flo`ps (used in counters)
- Examples : A 3-bit counter (one with 3 flip-flops) can count $2^3 = 8$ different states - a 4-bit counter (one with 4 flip-flops, shown below) can count $2^4 = 16$ different states
- Shift register – a clocked array of circuits that passes data in steps along the array



2^3 2^2 2^1 2^0

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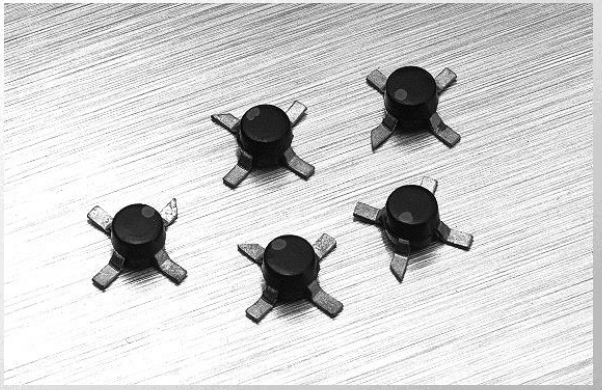
RF Integrated Circuits

- RF ICs are designed for functions commonly used for *radio frequencies*
- Low-level high-gain amplifiers
- Mixers
- Modulators and demodulators
- Filters



- MMIC (monolithic microwave integrated circuit) - designed to work through microwave frequencies

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Microprocessors & Components

- A microprocessor (AKA microcontroller) is a computer on a single Integrated Circuit
- Capable of performing billions of instructions per second using combinations of digital logic gates
- Has parallel and serial input-output ports, counters and timers
- Most are built from CMOS logic components
- A microprocessor can replace complex digital circuitry

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Microprocessor Components

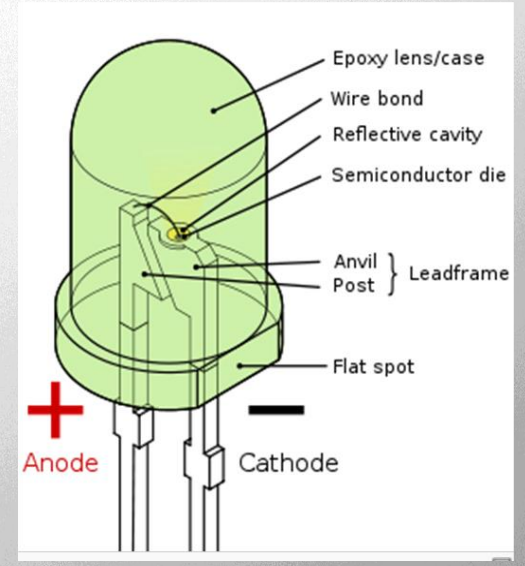
- Memory:
- Volatile memory loses the data stored when power is removed
- Nonvolatile memory retains data permanently even when power is off
- Random-access memory (RAM) can be read or written to in any order
- Read-only memory (ROM) stores data permanently and can’t be changed

Microprocessor Components

- Interfaces:
- Serial interface transfers one bit of data in each operation
- Parallel interface transfers multiple bits of data in each operation
- RS-232 serial interface has been replaced by USB (universal serial bus) serial interface
- Modern computers don’t have RS-232 ports; you may need to use a USB to RS-232 converter to interface with your transceiver

Microprocessor Components

- Visual Interfaces:
- *Indicator* – device that presents ON/OFF information (LED)
- *Display* – device capable of presenting text or graphics in visual form
- An LED is a special diode that produces light when it is forward biased
- LEDs are available in several different colors, including white
- LEDs are replacing *incandescent* light bulbs because they last longer, react faster, and consume less power.



Microprocessor Components

- *Liquid crystal display* (LCD) – created by sandwiching liquid crystal material between transparent glass panels
  - When voltage is applied to the electrodes on the front panel, the liquid crystals twist and turn the segment from light to dark-colored
  - LCDs require ambient or back lighting since the liquid crystal layer does not generate light. They offer high contrast in situations with high ambient lighting

Take Quiz 1

G6A03 - What is the approximate forward threshold voltage of a germanium diode?

A. 0.1 volt

B. 0.3 volts

C. 0.7 volts

D. 1.0 volts

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G6A05 - What is the approximate forward threshold voltage of a silicon junction diode?

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G6A07 - What are the operating points for a bipolar transistor used as a switch?

A. Saturation and cutoff

B. The active region (between cutoff and saturation)

C. Peak and valley current points

D. Enhancement and depletion modes

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G6A09 - Which of the following describes MOSFET construction?

A. The gate is formed by a back-biased junction

B. The gate is separated from the channel by a thin insulating layer

C. The source is separated from the drain by a thin insulating layer

D. The source is formed by depositing metal on silicon

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G6A10 - Which element of a vacuum tube regulates the flow of electrons between cathode and plate?

A. Control grid

B. Suppressor grid

C. Screen grid

D. Trigger electrode

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G6A12 - What is the primary purpose of a screen grid in a vacuum tube?

A. To reduce grid-to-plate capacitance

B. To increase efficiency

C. To increase the control grid resistance

D. To decrease plate resistance

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G6B02 - What is meant by the term MMIC?

A. Multi-Mode Integrated Circuit

B. Monolithic Microwave Integrated Circuit

C. Metal Monolayer Integrated Circuit

D. Mode Modulated Integrated Circuit

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G6B03 - Which of the following is an advantage of CMOS integrated circuits compared to TTL integrated circuits?

A. Low power consumption

B. High power handling capability

C. Better suited for RF amplification

D. Better suited for power supply regulation

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G6B06 - What kind of device is an integrated circuit operational amplifier?

A. Digital

B. MMIC

C. Programmable Logic

D. Analog

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B. MMIC

C. Programmable Logic

D. Analog

G7B03 - Which of the following describes the function of a two-input AND gate?

A. Output is high when either or both inputs are low

B. Output is high only when both inputs are high

C. Output is low when either or both inputs are high

D. Output is low only when both inputs are high

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G7B05 - How many states does a 3-bit binary counter have?

A. 3

B. 6

C. 8

D. 16

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G7B06 - What is a shift register?

A. A clocked array of circuits that passes data in steps along the array

B. An array of operational amplifiers used for tri-state arithmetic operations

C. A digital mixer

D. An analog mixer

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G6B08 - How is an LED biased when emitting light?

A. In the tunnel-effect region

B. At the Zener voltage

C. Reverse biased

D. Forward biased

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G6B09 (A)
How does a liquid crystal display compare to an LED display?

A. Higher contrast in high ambient lighting

B. Wider dynamic range

C. Higher Power consumption

D. Shorter lifetime

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How does a liquid crystal display compare to an LED display?

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B. Wider dynamic range

C. Higher Power consumption

D. Shorter lifetime

General License Course
Chapter 4.6

Practical Circuits

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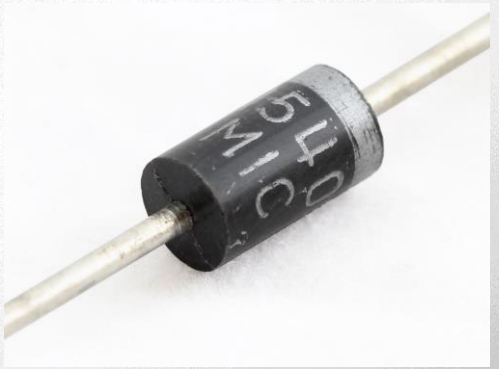
Rectifiers

- A rectifier diode is an electronic device that converts alternating current (AC, which periodically reverses direction) to direct current (DC, which flows in only one direction). The process is known as rectification.



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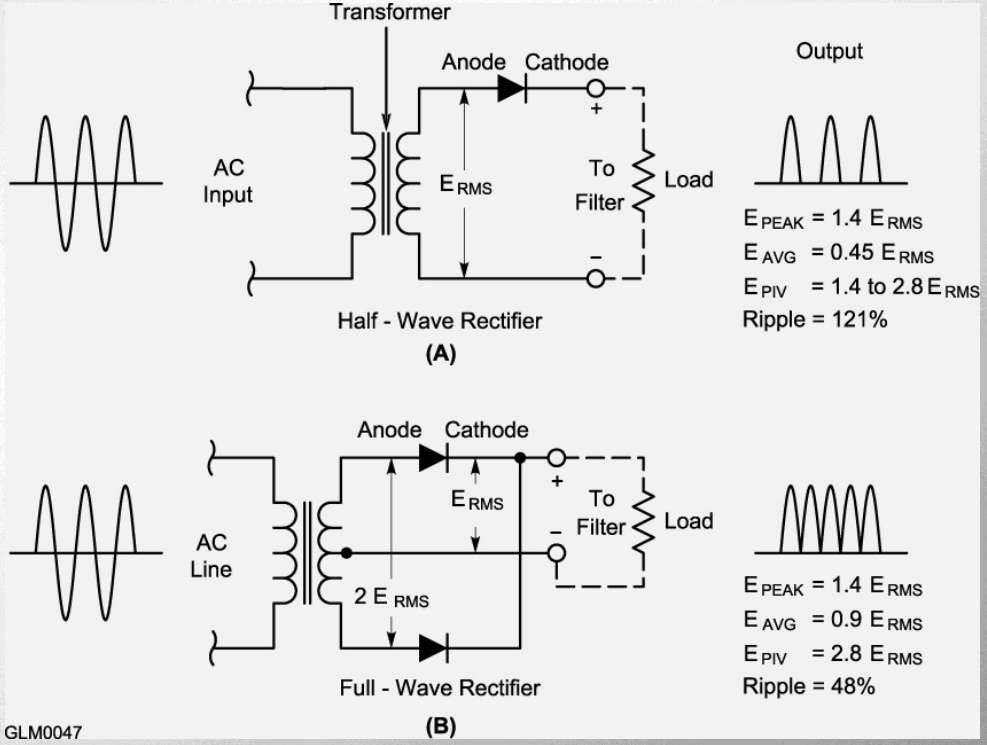
Rectifiers

- Half-wave rectifier - allows current to flow in one-half of the input ac waveform (180˚) from the transformer, as shown in “A” Advantage: only one diode is required
- Full-wave center-trapped rectifier - two half-wave rectifiers operating on alternating half cycles, as shown in “B”, using the transformer center tap for the current’s return path



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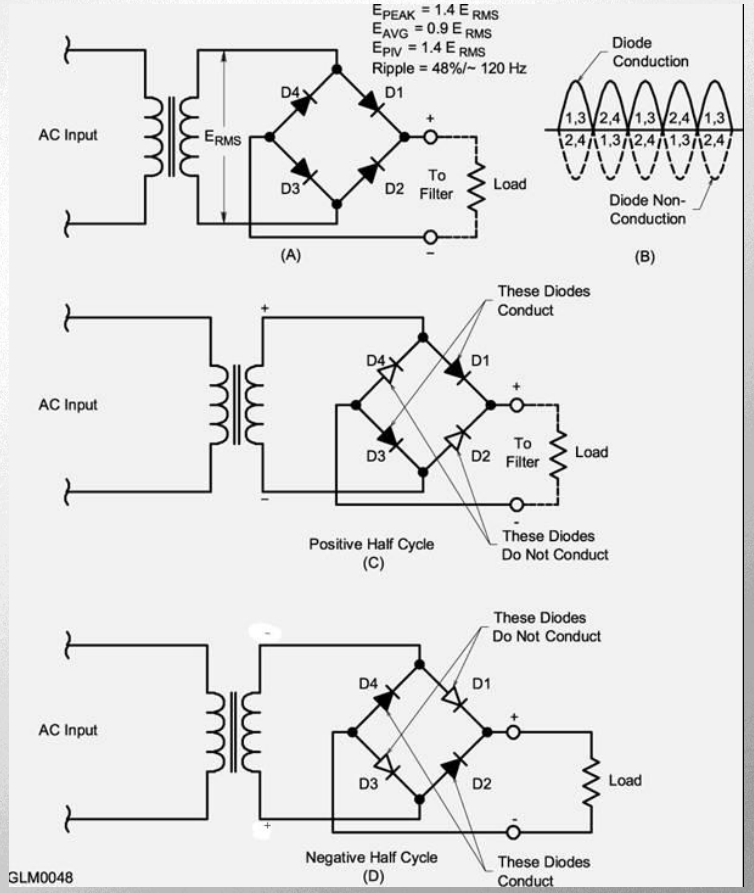
Rectifiers

- Full Wave Rectifier Circuits
- Advantage – output is produced during entire 360˚ of the ac cycle
- Output is a series of pulses at twice the frequency of the input voltage
- Full-wave bridge rectifier – uses a pair of diodes on alternating ac cycle halves



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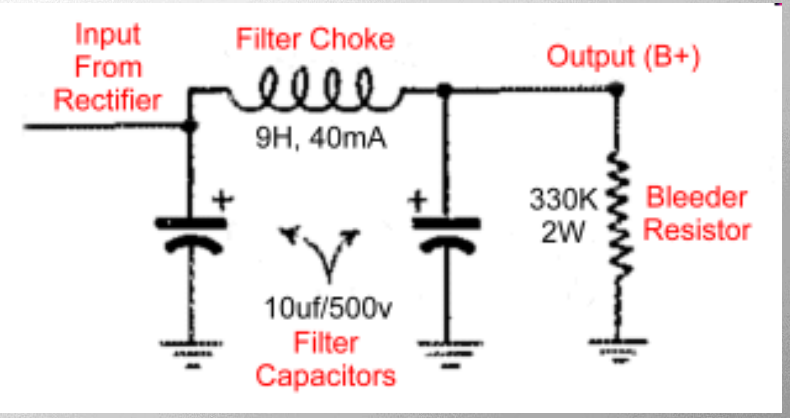
Filter Circuits

- A Rectifier's *pulsed output* is often unusable as DC
- *Filter networks* – made up of capacitors and inductors
- an inductor to filter (resist) current variations
- a capacitor to filter (resist) voltage variations



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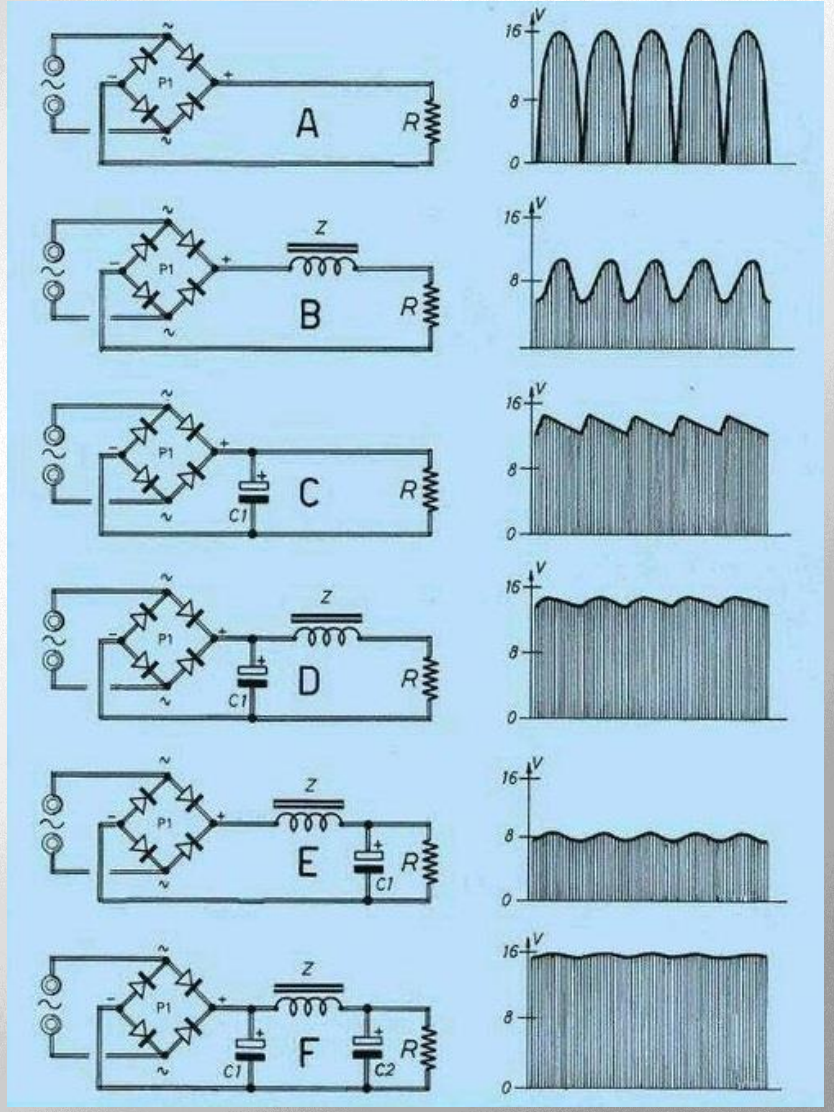
Power Supply Filtering



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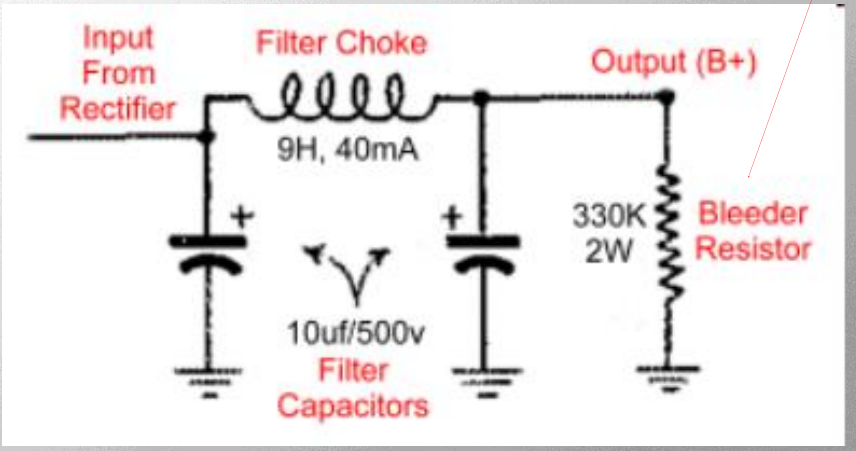
Power Supplies

- Power supply safety:
- Fuses (transformer primary side) are used to protect against short circuits or excessive current
- *Bleeder resistors* discharge energy stored in the PS filter capacitors when the supply is turned off

Working on power supplies – wait for the bleeder resistor to discharge energy, even if the PS is unplugged



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Power Supplies

- **Switching** or Switchmode supplies:
- Transistors switch current pulses at a high frequency (20 kHz or more*) through a transformer then capacitors and inductors filter the voltage
- High frequency operation allows small, lightweight components (transformers, capacitors, inductors) to be used
- **Linear** supplies are very heavy due to their large, iron-core power transformer and large filter inductors/capacitors

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**RFI supression must be included in the design.*

Batteries

- Large marine or RV storage batteries are often used as emergency backup power supplies
- Liquid-electrolyte or gel-electrolyte batteries are rated at 12 V but should be maintained at 13.8 V
- Lead-acid batteries are useful until their output drops to 10.5 V
- Discharging batteries past their minimum voltage will reduce the life of the battery

Batteries

- ***Never*** attempt to recharge a carbon-zinc, alkaline, or silver-nickel type battery (the chemical reaction cannot be reversed)
- Battery self-discharge gradually reduces stored energy over time
- Slow this discharge by storing in a cool, dry place
- Freezing will damage batteries with liquid or gel electrolytes

Rechargeable Batteries

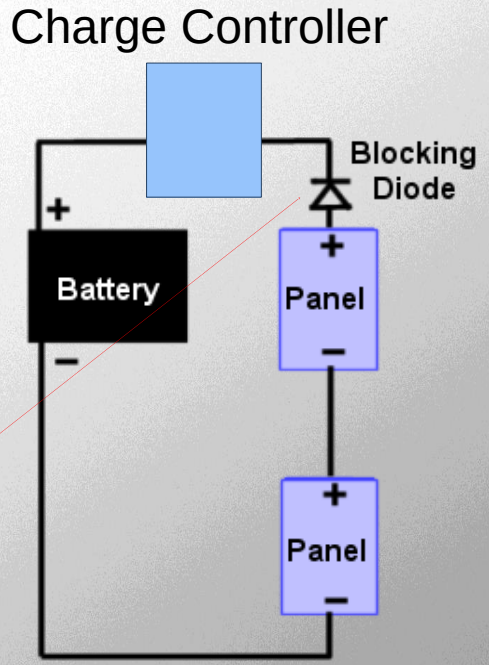
- Different types of rechargable batteries require different charging methods
- NiCad, NMH, Li-Ion
- Use the *proper type of charger* to maximize the life and usefulness of the battery
- NiCds (or Nicads) – designed to have low internal resistance to supply high discharge current

Alternative Power

- *Solar Power – photovoltaic conversion* of sunlight directly to electricity
- Solar cells are a special type of diode
- The forward voltage created as the electrons cross the P-N junction is approximately 0.5 V dc (open circuit voltage) when fully illuminated
- Individual solar cells can be connected in series to create higher voltages (24 cells to create 12 V) AND in parallel to provide more current. *SERIES-PARALLEL*
- *Wind generators* use DC generators to charge batteries; an inverter is used to convert to AC, if needed

Energy Storage

- Disadvantage: Wind and solar power require a substantial energy storage system; No wind or sun means no power
- Excess power needs to be stored during peak periods of generation (batteries are the most common method) – a Charge Controller must be included to prevent damage to the batteries
- Diodes (in series) prevent the batteries from discharging back through the solar panels



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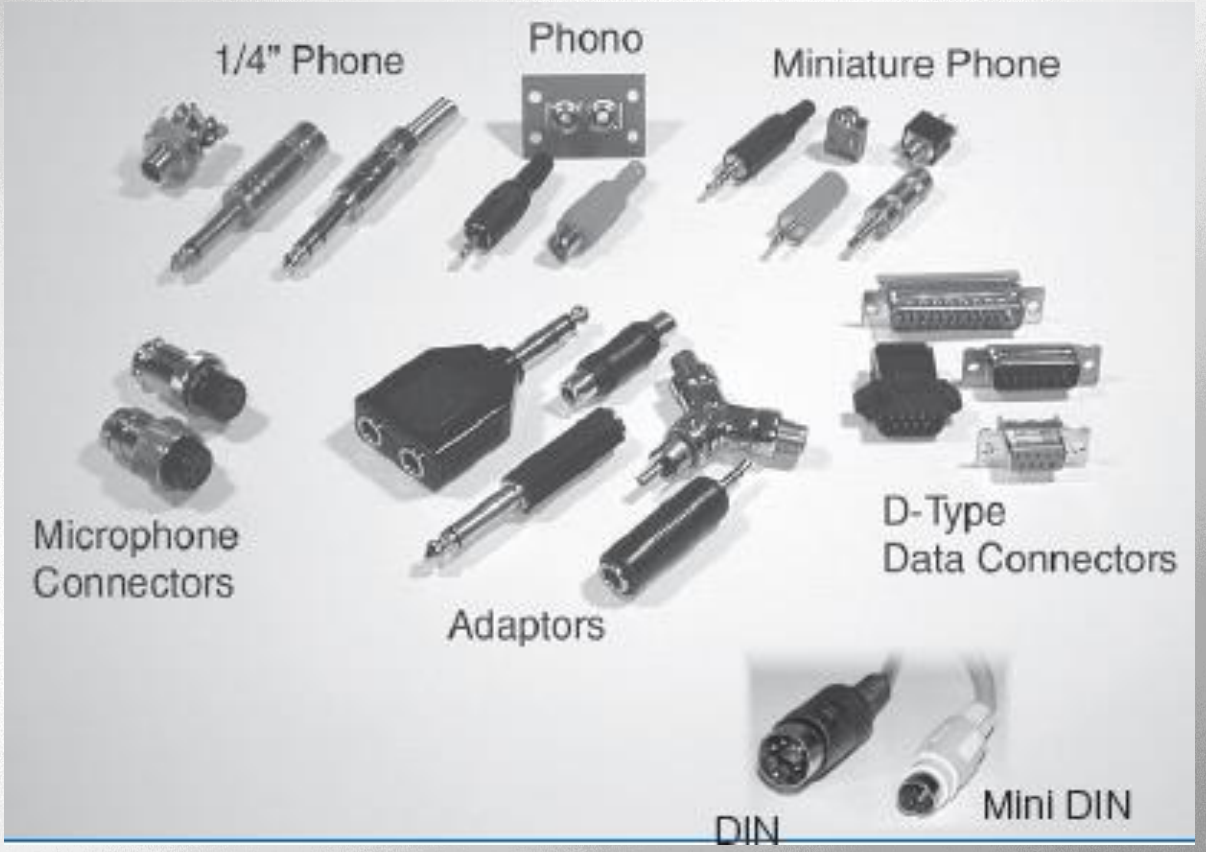
Audio Connectors

- Consumer electronics and Amateur Radio share many of the same connectors



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Audio Connectors

Phono plugs (also called RCA connectors) are commonly used for low frequency (audio) and DC signals

DIN or mini-DIN connectors are keyed and have up to 9 pins and are used for audio or control signals for radio equipment

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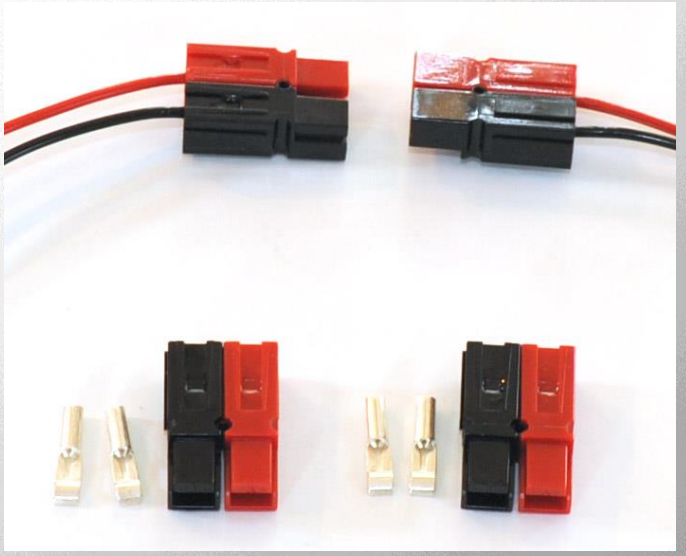
Power Connectors

Anderson Powerpole connectors have become the standard for connecting radios and associated devices to 12 vdc supplies



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RF Connectors

Special RF feed line connectors:

“PL-259” (aka UHF) connectors can be used up to 150 MHz

“BNC” connectors can be used up to 4 GHz

“N” connectors are moisture resistant and used up to 10 GHz

*“SMA”** connectors are small threaded connectors designed for miniature coaxial cable and are rated up to several GHz

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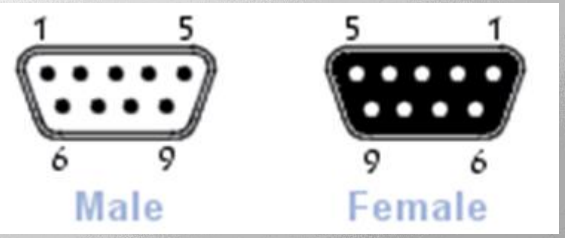
* You can’t spell SMALL without SMA!

Data Connectors

- Digital data is exchanged between the computers and radios:
  - *D-type* connectors are used for RS-232 (COM ports) and parallel ports
  - D-type 9-pin connector is referred to as DB-9 or ***DE-9*** (commonly used for serial ports)
- 25-pin D-type connector used for parallel ports
- *USB* ports are standard for modern computers



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Take Quiz 2

G7A01 - What is the function of a power supply bleeder resistor?

A. It acts as a fuse for excess voltage

B. It discharges the filter capacitors when power is removed

C. It removes shock hazards from the induction coils

D. It eliminates ground loop current

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G7A02 - Which of the following components are used in a power supply filter network?

A. Diodes

B. Transformers and transducers

C. Capacitors and inductors

D. All these choices are correct

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G7A03 - Which type of rectifier circuit uses two diodes and a center-tapped transformer?

A. Full-wave

B. Full-wave bridge

C. Half-wave

D. Synchronous

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G7A04 - What is characteristic of a half-wave rectifier in a power supply?

A. Only one diode is required

B. The ripple frequency is twice that of a full-wave rectifier

C. More current can be drawn from the half-wave rectifier

D. The output voltage is two times the peak input voltage

G7A04 - What is characteristic of a half-wave rectifier in a power supply?

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D. The output voltage is two times the peak input voltage

G7A05 - What portion of the AC cycle is converted to DC by a half-wave rectifier?

A. 90 degrees

B. 180 degrees

C. 270 degrees

D. 360 degrees

G7A05 - What portion of the AC cycle is converted to DC by a half-wave rectifier?

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G7A06 - What portion of the AC cycle is converted to DC by a full-wave rectifier?

A. 90 degrees

B. 180 degrees

C. 270 degrees

D. 360 degrees

G7A06 - What portion of the AC cycle is converted to DC by a full-wave rectifier?

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B. 180 degrees

C. 270 degrees

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G7A07 - What is the output waveform of an unfiltered full-wave rectifier connected to a resistive load?

A. A series of DC pulses at twice the frequency of the AC input

B. A series of DC pulses at the same frequency as the AC input

C. A sine wave at half the frequency of the AC input

D. A steady DC voltage

G7A07 - What is the output waveform of an unfiltered full-wave rectifier connected to a resistive load?

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G7A08 - Which of the following is characteristic of a switchmode power supply as compared to a linear power supply?

A. Faster switching time makes higher output voltage possible

B. Fewer circuit components are required

C. High-frequency operation allows the use of smaller components

D. Inherently more stable

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G4E08 - In what configuration are the individual cells in a solar panel connected together?

A. Series-parallel

B. Shunt

C. Bypass

D. Full-wave bridge

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G4E09 - What is the approximate open-circuit voltage from a fully illuminated silicon photovoltaic cell?

A. 0.02 VDC

B. 0.5 VDC

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G4E10 - Why should a series diode be connected between a solar panel and a storage battery that is being charged by the panel?

A. To prevent overload by regulating the charging voltage

B. To prevent discharge of the battery through the panel during times of low or no illumination

C. To limit the current flowing from the panel to a safe value

D. To prevent damage to the battery due to excessive voltage at high illumination levels

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G4E11 - What precaution should be taken when connecting a solar panel to a lithium iron phosphate battery?

A. Ground the solar panel outer metal framework

B. Ensure the battery is placed terminals-up

C. A series resistor must be in place

D. The solar panel must have a charge controller

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G6A01 - What is the minimum allowable discharge voltage for maximum life of a standard 12-volt lead-acid battery?

A. 6 volts

B. 8.5 volts

C. 10.5 volts

D. 12 volts

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G6A02 - What is an advantage of batteries with low internal resistance?

A. Long life

B. High discharge current

C. High voltage

D. Rapid recharge

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G6B04 - What is a typical upper frequency limit for low SWR operation of 50-ohm BNC connectors?

A. 50 MHz

B. 500 MHz

C. 4 GHz

D. 40 GHz

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G6B07 - Which of the following describes a type N connector?

A. A moisture-resistant RF connector useful to 10 GHz

B. A small bayonet connector used for data circuits

C. A low noise figure VHF connector

D. A nickel plated version of the PL-259

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G6B11 - What is an SMA connector?

A. A type-S to type-M adaptor

B. A small threaded connector suitable for signals up to several GHz

C. A connector designed for serial multiple access signals

D. A type of push-on connector intended for high-voltage applications

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G6B12 - Which of these connector types is commonly used for low frequency or dc signal connections to a transceiver?

A. PL-259

B. BNC

C. RCA Phono

D. Type N

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General License Course
Chapter 4.7

Basic Test Equipment

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Analog Meters

- A Volt-ohm meter (VOM) is the most basic piece of test equipment
- Measures – volts, current, resistance
- Tests – continuity, diodes, transistors
- Analog Meters
- Analog meters have a moving needle and calibrated scales on the meter face
- Analog meters are useful for finding a maximum or minimum reading, such as **when adjusting a tuned circuit**

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Digital Meters

- Digital meters (DMMs) offer significantly greater precision than analog meters
- Digital meters often have useful features:
- *auto-ranging* to automatically select the proper display range
- *peak hold* to capture maximum values
- When measuring voltage, the meter should have a high input impedance to place the minimum load on the circuit being measured

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Loading Effect of a Voltmeter

- High resistance circuits are susceptible to **Voltmeter loading.**

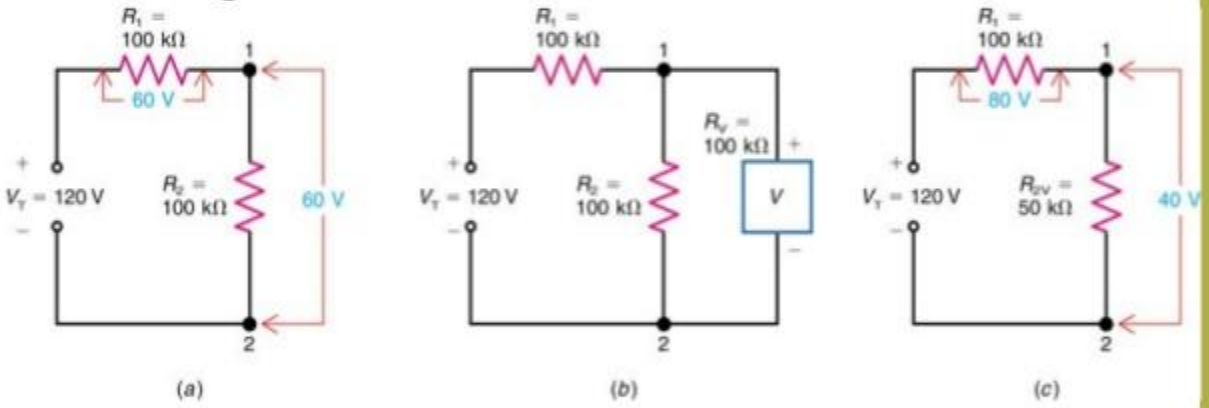


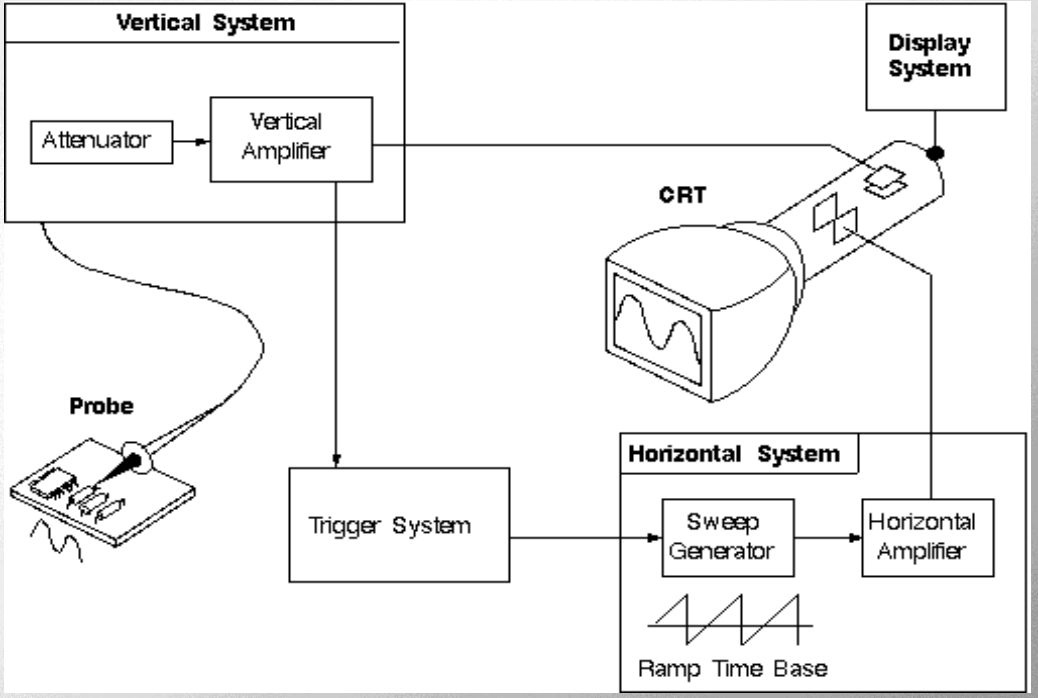
Fig. 8-8: How loading effect of the voltmeter can reduce the voltage reading. (*a*) High-resistance series circuit without voltmeter. (*b*) Connecting voltmeter across one of the series resistances. (*c*) Reduced *R* and *V* between points 1 and 2 caused by the voltmeter as a parallel branch across R_2. The R_{2V} is the equivalent of R_2 and R_V in parallel.

Oscilloscope

- The oscilloscope (O-scope) provides a visual display of voltage vs. time
- Updated rapidly enough to give a real-time picture of the signal
- Fast-changing complex waveforms can be measured
- External signals are connected to horizontal and vertical channel amplifier inputs to control the display
- Variable gain and update rates are available to display many types of signals.

Oscilloscope

An oscilloscope is an item of test equipment that contains horizontal and vertical channel amplifiers



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Oscilloscope

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Monitoring Oscilloscope

- The transmitter's attenuated RF output connects to the vertical channel of the oscilloscope to monitor the signal
- Monitoring helps adjust CW keying waveforms, mic gain, and speech processing
- The scope shows the effects of any adjustments that might cause distortion
- A "scope" provides information that numeric meters can't measure.

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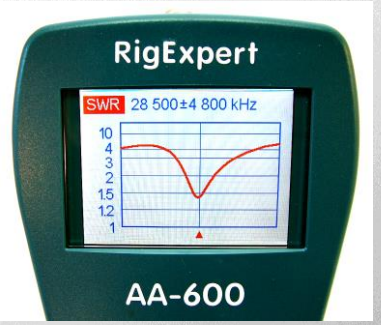
Impedance & Resonance Measurement

- *An antenna analyzer* contains a signal generator, frequency counter, SWR bridge, and impedance meter
- Connects to the antenna and feed line to measure **Standing Wave Ratio** (SWR) using very small signals for measurements
- Impedance measurements show resonance
- Measures feed line/coax velocity factor, electrical length, and characteristic impedance
- Can be negatively affected by strong nearby signals



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Field Strength & Power Meters

- Field strength meters measure the electrical field of transmitted signals
- Field strength meters can be used during antenna and transmitter adjustments
- Field strength meters can be used to measure antenna radiation patterns
- Standing Wave Ratio (SWR) can be determined from forward and reflected power measurements made with a *directional wattmeter*

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Field Strength Meter

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Take Quiz 3

G4B01 - What item of test equipment contains horizontal and vertical channel amplifiers?

A. An ohmmeter

B. A signal generator

C. An ammeter

D. An oscilloscope

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G4B02 - Which of the following is an advantage of an oscilloscope versus a digital voltmeter?

A. An oscilloscope uses less power

B. Complex impedances can be easily measured

C. Greater precision

D. Complex waveforms can be measured

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A. An oscilloscope

B. A field strength meter

C. A sidetone monitor

D. A wavemeter

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G4B04 - What signal source is connected to the vertical input of an oscilloscope when checking the RF envelope pattern of a transmitted signal?

A. The local oscillator of the transmitter

B. An external RF oscillator

C. The transmitter balanced mixer output

D. The attenuated RF output of the transmitter

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B. It allows for higher voltages to be safely measured

C. It improves the resolution of the readings

D. It decreases the loading on circuits being measured

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G4B06 - What is an advantage of a digital multimeter as compared to an analog multimeter?

A. Better for measuring computer circuits

B. Less prone to overload

C. Higher precision

D. Faster response

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G4B09 - When is an analog multimeter preferred to a digital multimeter?

A. When testing logic circuits

B. When high precision is desired

C. When measuring the frequency of an oscillator

D. When adjusting circuits for maximum or minimum values

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A. Standing wave ratio

B. Antenna front-to-back ratio

C. RF interference

D. Radio wave propagation

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G4B11 - Which of the following must be connected to an antenna analyzer when it is being used for SWR measurements?

A. Receiver

B. Transmitter

C. Antenna and feed line

D. All these choices are correct

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G4B12 - What effect can strong signals from nearby transmitters have on an antenna analyzer?

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B. Received power that interferes with SWR readings

C. Generation of harmonics which interfere with frequency readings

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G4B13 - Which of the following can be measured with an antenna analyzer?

A. Front-to-back ratio of an antenna

B. Power output from a transmitter

C. Impedance of coaxial cable

D. Gain of a directional antenna

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Next Week
Chapters 5.1 – 5.4

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