The ARRL General Class License Course

All You Need to Pass Your General Class Exam

LEVEL 2: General

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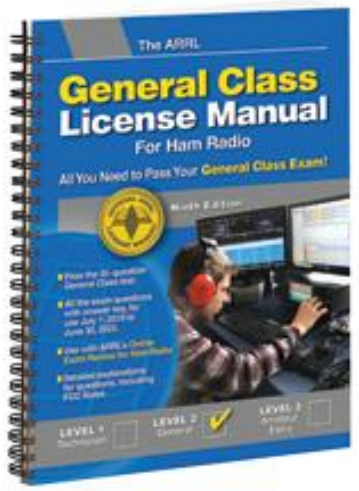

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Module 4b

ARRL General Class
Chapter 4 – Components and Circuits
(4.5, 4.6, 4.7)

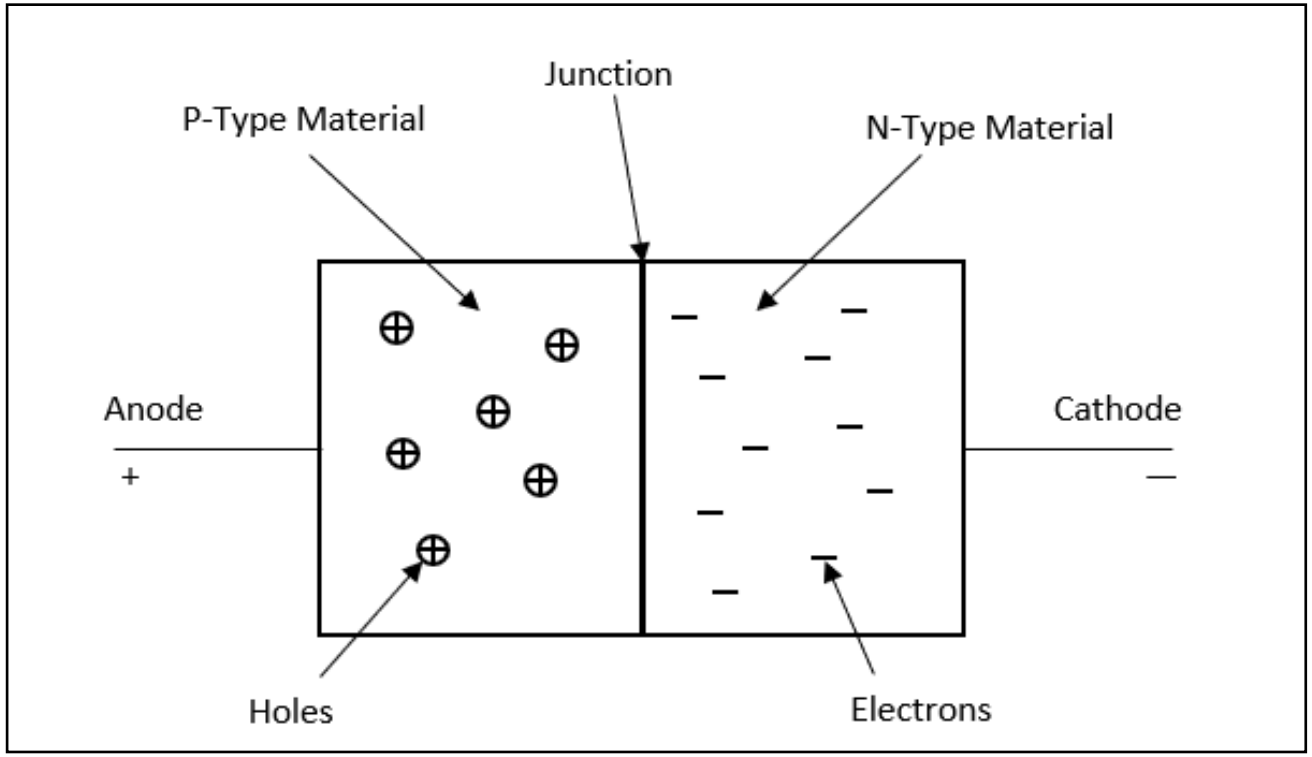
Active Components, Practical Circuits, Basic Test Equipment

Semiconductor Components

- The most common active components are made of semiconductors
- Most are made of silicon and germanium
- Electrical properties can be controlled by addition of small amounts of *dopants* (impurities) such as indium and phosphorus
- If the impurity creates an excess of electrons, the result is an *N-type* material. The opposite is *P-type*.
- Where N-type and P-type are in contact is a *PN junction*

Diodes & Rectifiers

- A semiconductor junction diode uses a PN junction to block current flow in one direction
- Wire leads are attached to each layer
- Current flows when positive voltage is applied from P-type to N-type material (*forward bias*)



Diodes & Rectifiers (cont.)

- Voltage applied in opposite direction is *reverse bias*
  - Pulls electrons away from junction so no current flows
- Voltage required to force electrons across junction is the *junction threshold voltage* (V_F)
  - For silicon diodes, $V_F \cong 0.7$ V
  - For germanium diodes, $V_F \cong 0.3$ V

Types of Diodes

- Light Emitting
- Laser
- Avalanche
- Zener
- Schottky
- Photodiode
- PN junction
- Transient Voltage Suppression
- Gold Doped
- Constant Current
- Peltier
- Silicon Controlled Rectifier
- PIN
- Varactor

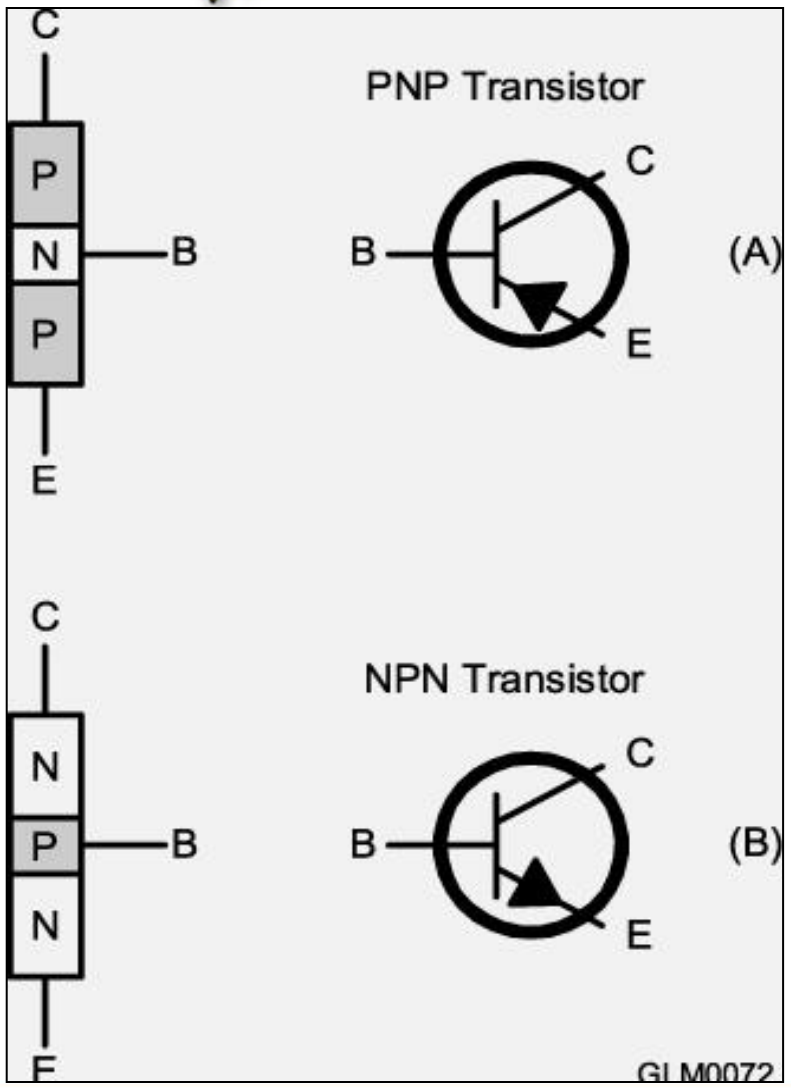
Diode Ratings

- Peak inverse voltage (PIV): Maximum reverse voltage before breakdown occurs (allowing current to flow in reverse direction)
- Average forward current (I_F): Exceeding diode's rating will destroy the diode's internal structure
- Junction capacitance (C_J): When reverse biased, layers of P- and N-type material act like capacitor plates. The larger the C_J the longer it takes to switch to conducting forward current.

Bipolar Transistors

- Adding a 3rd layer of semiconducting material creates a device that can amplify signals called the *transistor*
- Figure here is a *bipolar junction transistor* (BJT)
- Unlike the diode, it requires power to function
- It has 3 electrodes
  - Collector (C)
  - Base (B)
  - Emitter (E)

Controlled by current flow between base and emitter

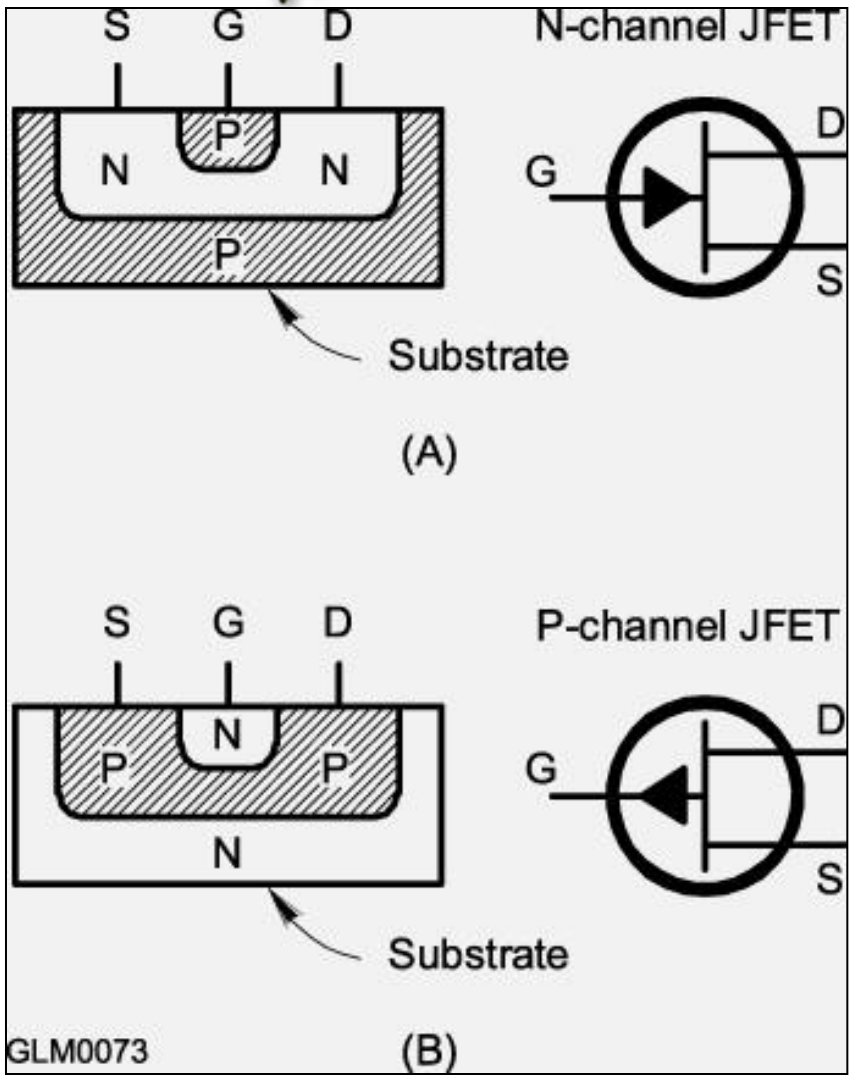


Bipolar Transistors (cont.)

- Very little base-emitter current is required for collector-emitter current to flow
- The control of a large current by a smaller current is *amplification*
- Ratio of collector-emitter current to base-emitter current is *current gain*
  - Current gain for dc signals is *ß*
  - Current gain for ac signals is h_{fe}

Field Effect Transistors (FET)

- 3 electrodes: Drain (D), Source (S), and Gate (G)
- Instead of controlling drain-source current with gate-source current, the voltage between gate and source is used
- Instead of current gain, FET has *transconductance* (g_m) which is the ratio of source-drain current to gate voltage
- MOSFETs (metal-oxide semiconductor FET) use oxide layer to insulate the gate



Additional Transistor Notes

- High amplification makes them ideal for use as switches (both voltage and current)
- With enough voltage, transistors can be driven into *saturation* where further increases in input result in NO change in output
- High enough input signals can reduce output current to zero called *cutoff*
- Saturation and cutoff conditions are excellent representation of digital ON/OFF signals in logic circuits

PRACTICE QUESTIONS

What is the approximate junction threshold voltage of a germanium diode?

A. 0.1 volt
B. 0.3 volts
C. 0.7 volts
D. 1.0 volts

What is the approximate junction threshold voltage of a conventional silicon diode?

A. 0.1 volt
B. 0.3 volts
C. 0.7 volts
D. 1.0 volts

What are the stable operating points for a bipolar transistor used as a switch in a logic circuit?

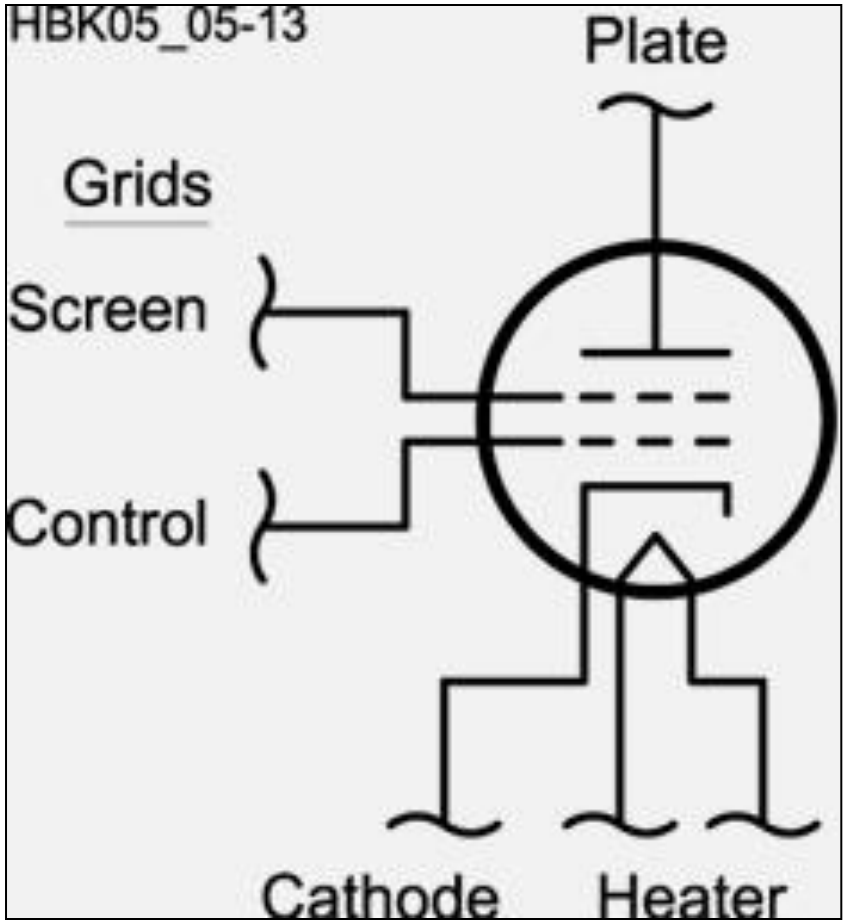
A. Its saturation and cutoff regions
B. Its active region (between the cutoff and saturation regions)
C. Its peak and valley current points
D. Its enhancement and depletion modes

Which of the following describes the construction of a MOSFET?

A. The gate is formed by a back-biased junction
B. The gate is separated from the channel with 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

Vacuum Tubes

- Have at least 3 electrodes called *elements*
- 3 basic parts:
  - A source of electrons
  - Electrode to collect electrons
  - Intervening electrodes that control electrons traveling from source to collector
- Compared to transistors, most like the FET
- Operate at high (hazardous) voltages (2000-3000 V). **Exercise caution!**



Tube Terminology

- Filament or heater – heats the cathode, causing it to emit electrons
- Cathode – source of electrons
- Control grid – grid closest to cathode, used to regulate electron travel between cathode and plate
- Screen grid – electrode that reduces grid-to-plate capacitance
- Suppressor grid – prevents electrons from traveling from plate to control or screen grid
- Plate – collects electrons which is called *plate current*

PRACTICE QUESTIONS

Which element of a triode vacuum tube is used to regulate the flow of electrons between cathode and plate?

A. Control grid
B. Heater
C. Screen grid
D. Trigger electrode

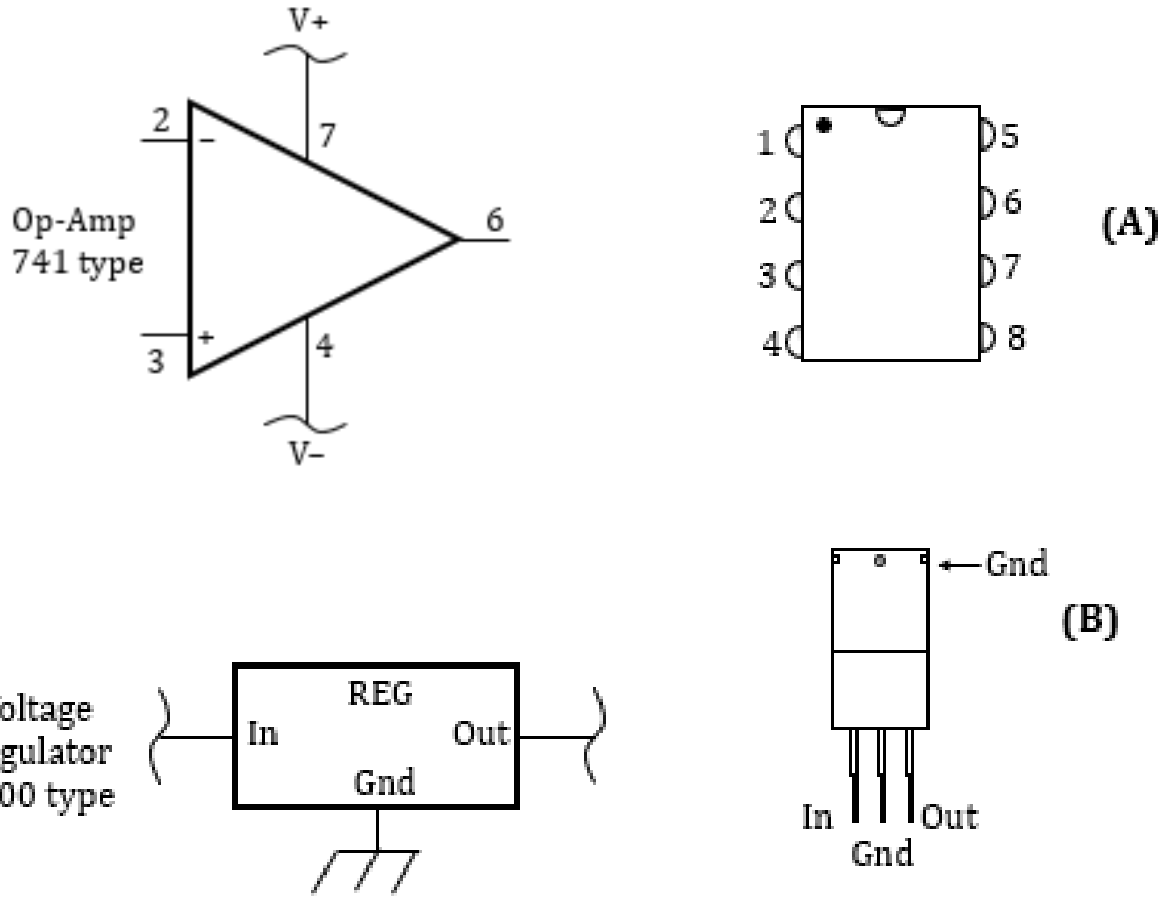
What is the primary purpose of a screen grid in a vacuum tube?

A. To reduce grid-to-plate capacitance
B. To increase efficiency
C. To increase the control grid resistance
D. To decrease plate resistance

Analog Integrated Circuits (IC's)

- Operate over a continuous range of voltages and currents
- Used for amplification, filtering, measurement, voltage regulation, and power control
- Most common analog IC's are the operational amplifier and linear voltage regulator
  - Op amps are used for dc and audio circuits … inexpensive source of gain
  - Linear voltage regulators maintain power supply output at constant voltage over a wide range of currents

Figure 4.22



The popular 741 op-amp symbol and dual in-line package (DIP) connections are shown at (A). A common 3-terminal voltage regulator, the 7800-series, is shown in the TO-220 package at (B).

Digital Integrated Circuits

- Digital IC's operate with discrete values of voltage and current representing the binary numbers system values 0 and 1 (representing OFF and ON)
- Used for performing computations or controlling functions
- The most popular logic family in use is *CMOS* (complementary metal-oxide semiconductors) technology (known for high speed and low power consumption)

Table 4.4: Logic Family Characteristics

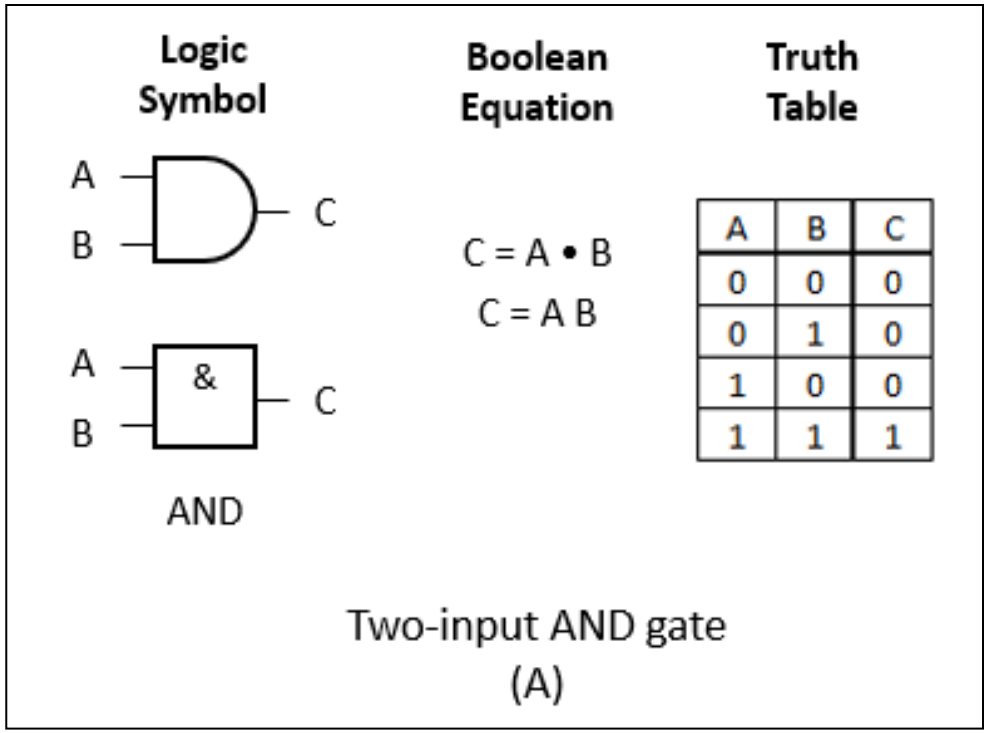
FAMILY NAME	MAX OPERATION FREQUENCY	POWER CONSUMPTION	POWER SUPPLY
TTL	100 MHz	High	5 V
CMOS	1 GHz	Low	3-5 V
CMOS (CD4000)	1 MHz	Very Low	3-15 V

Digital Logic Basics

- The basic building block of digital circuits are called *gates* that perform *inversion* (changing 1 to 0 and vice versa) and the OR and AND functions
- The most common gates in use are the inverter, NAND and NOR
- More complex functions (e.g., microprocessors, signal processors, etc.) are constructed from combinations of these functions
- Circuits that use gates to combine binary inputs to generate a binary output or combination of binary outputs are called *combinational logic*

See Figure 4.23 for details

Figure 4.23: Schematic symbols for the basic digital logic functions with the logic equations and truth tables that describe their operation.



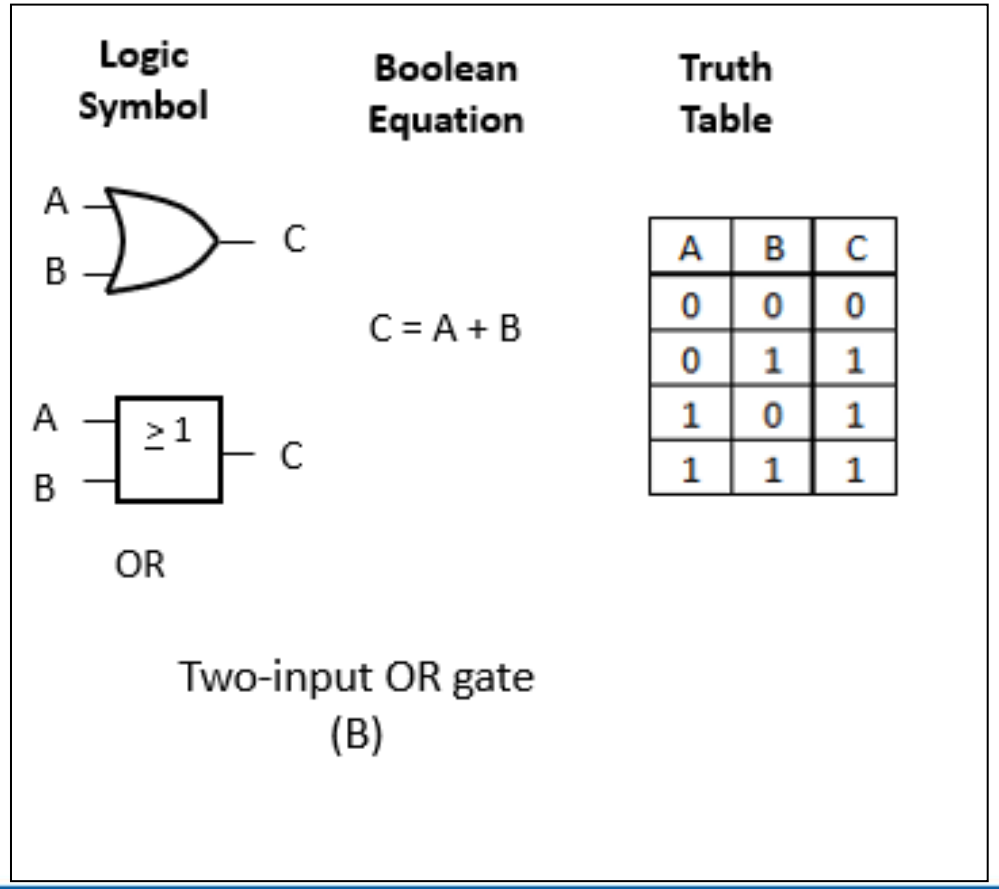
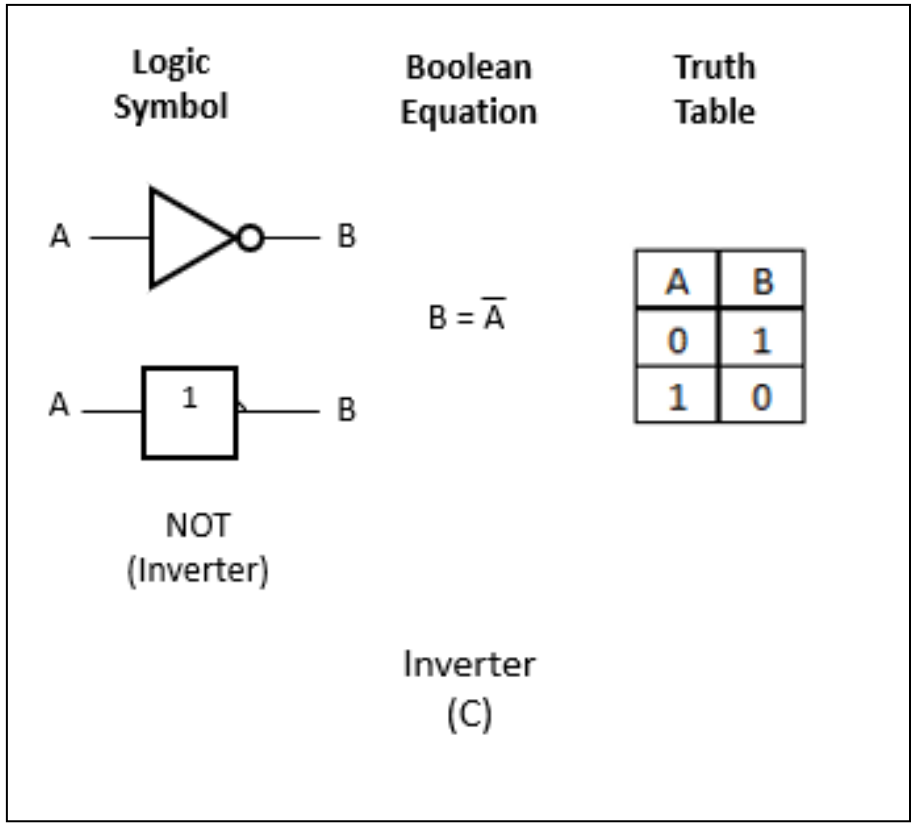


Figure 4.23: Schematic symbols for the basic digital logic functions with the logic equations and truth tables that describe their operation (cont.).



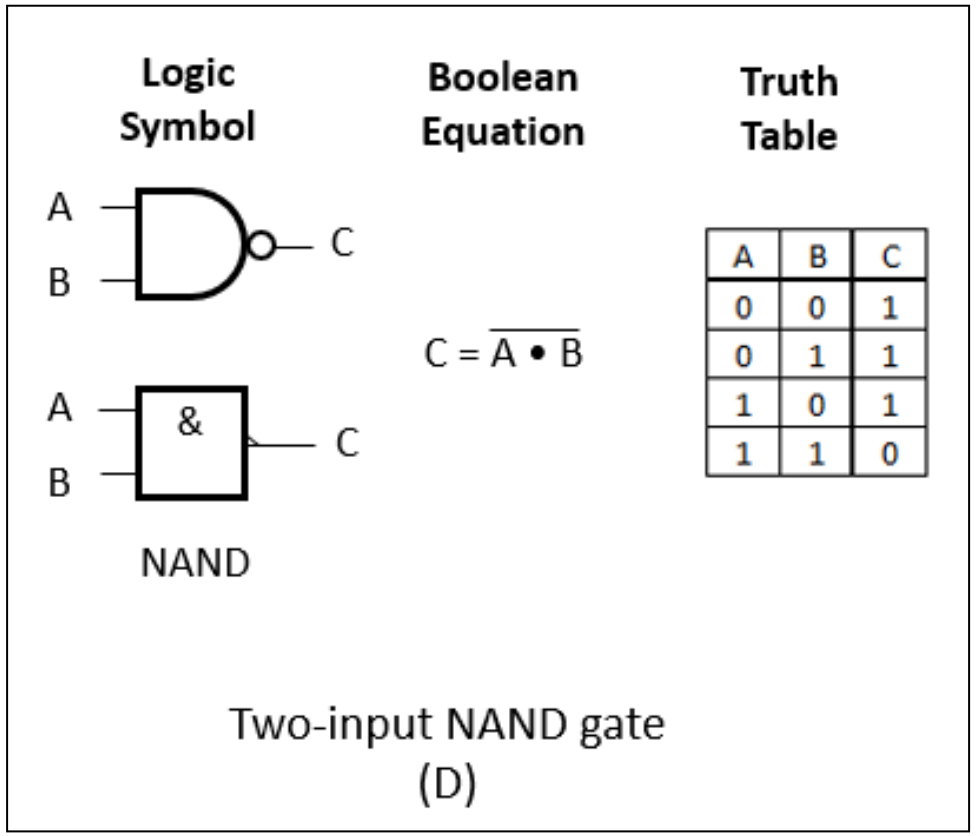
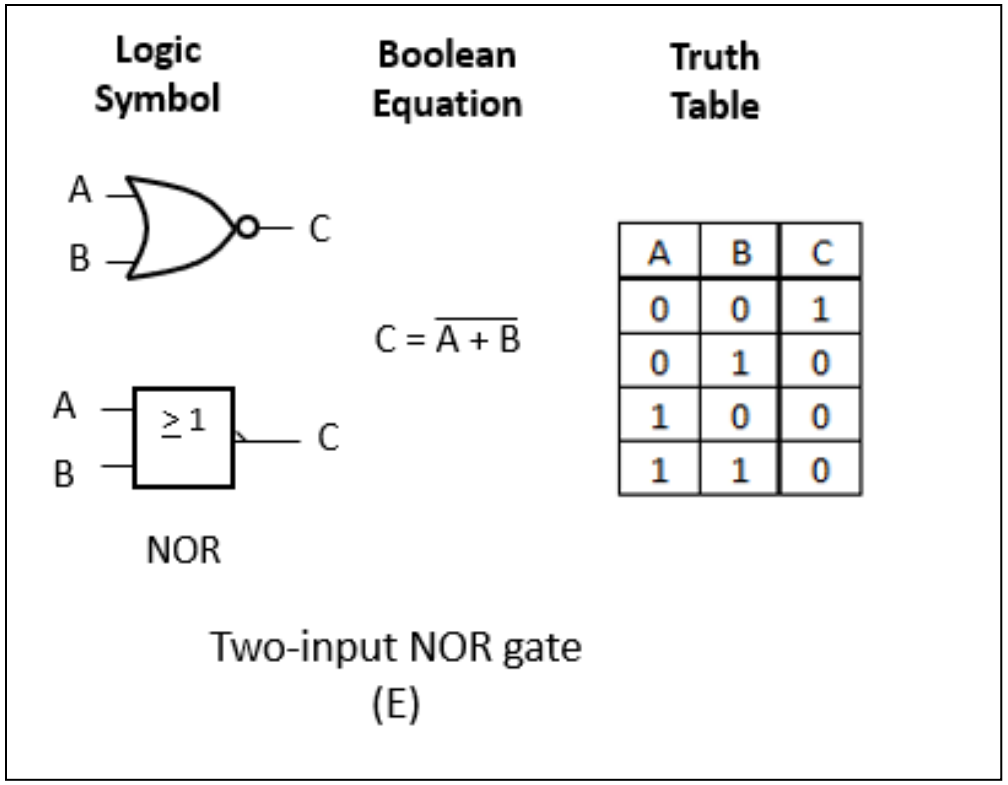
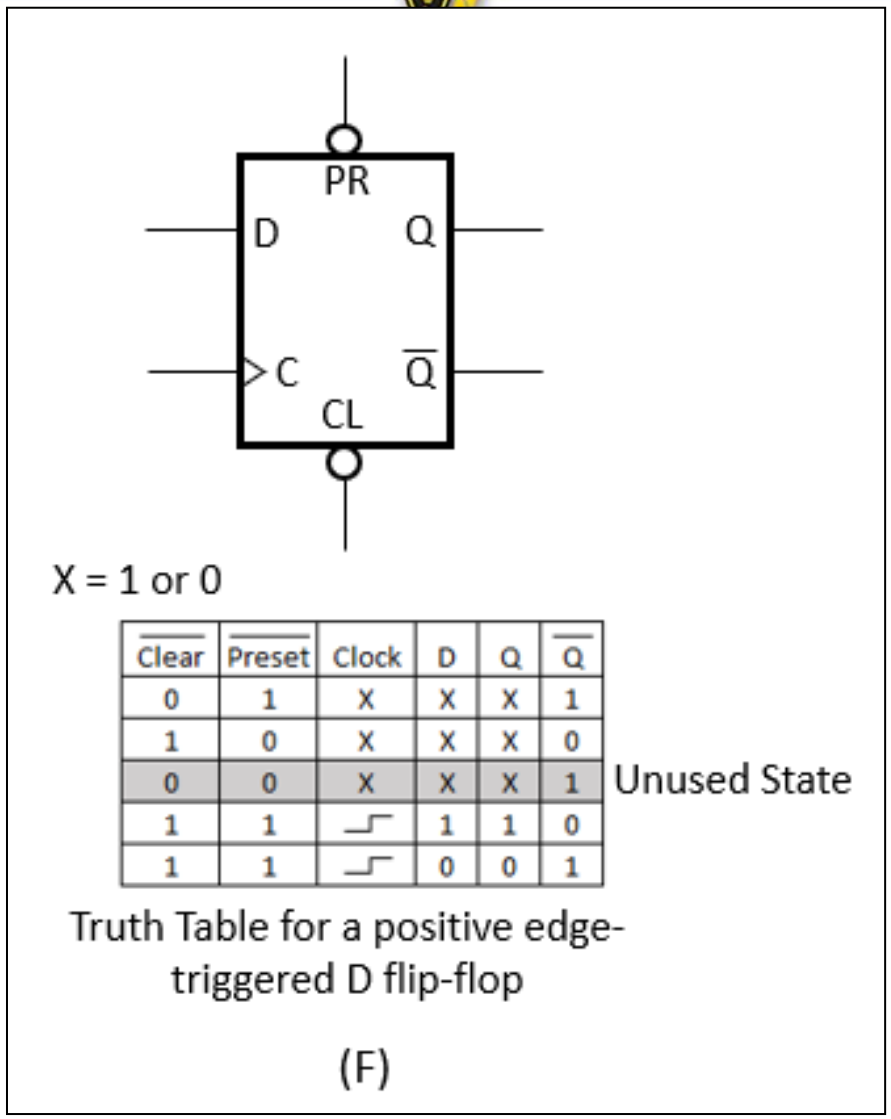


Figure 4.23: Schematic symbols for the basic digital logic functions with the logic equations and truth tables that describe their operation (cont.).



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

Two-input NOR gate
(E)



$\overline{Clear}$	$\overline{Preset}$	Clock	D	Q	$\overline{Q}$	
0	1	X	X	X	1	
1	0	X	X	X	0	
0	0	X	X	X	1	Unused State
1	1	⎍	1	1	0	
1	1	⎍	0	0	1	

Truth Table for a positive edge-triggered D flip-flop

(F)

Digital Logic Basics (cont.)

- *Sequential logic circuits* combine binary signals in a way that depends on time and on the sequence of inputs to the circuits
- Basic building block of sequential logic is the *flip-flop*
  - Responds to clock signal that causes it outputs to change based on input
  - The 2 outputs (Q and Q-bar) are always in opposite states
  - Connecting flip-flops together so that one flip-flop's output feeds the next one's input creates 2 important circuits; *counters* and *shift registers*

Counter Logic

- The outputs of the chain of flip-flops make up a binary number or state representing the number of clock signals that have occurred
- Each flip-flop stores one bit of the total count
- Highest number a counter can represent is 2^N (N = number of flip-flops that make up the counter)
- A 3-bit counter (3 flip-flops) can count 2^3 (= 8) states, 4-bit (2^4) can count 16 states, 5-bit (2^5) counts 32 states, etc.

Shift Registers

- Slightly different arrangement of the flip-flop array than in counters
- Stores a sequence of 1s and 0s from its input as the flip-flop outputs
- Each clock signal causes the value at the shift register's input to pass or shift to the next flip-flop in the string
- Some shift registers circuits can be configured to shift up and down (or forward/backward)
- A simple form of digital memory

RF Integrated Circuits

- Designed for functions such as …
  - Low-level high-gain amplifiers, mixers, modulators/demodulators, filters
- Greatly reduce number of discrete devices require to build radio circuits
- Monolithic microwave integrated circuits (MMIC) are special types of RF IC's that work through microwave frequencies
  - Perform several functions
  - Enables construction of low-cost cell phones, GPS receivers, etc.

PRACTICE QUESTIONS

What is meant by the term MMIC?

A. Multi-Megabyte Integrated Circuit
B. Monolithic Microwave Integrated Circuit
C. Military Manufactured Integrated Circuit
D. Mode Modulated Integrated Circuit

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

What kind of device is an integrated circuit operational amplifier?

A. Digital
B. MMIC
C. Programmable Logic
D. Analog

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

Which of the following describes the function of a two input NOR 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

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

A. 3
B. 6
C. 8
D. 16

What is a shift register?

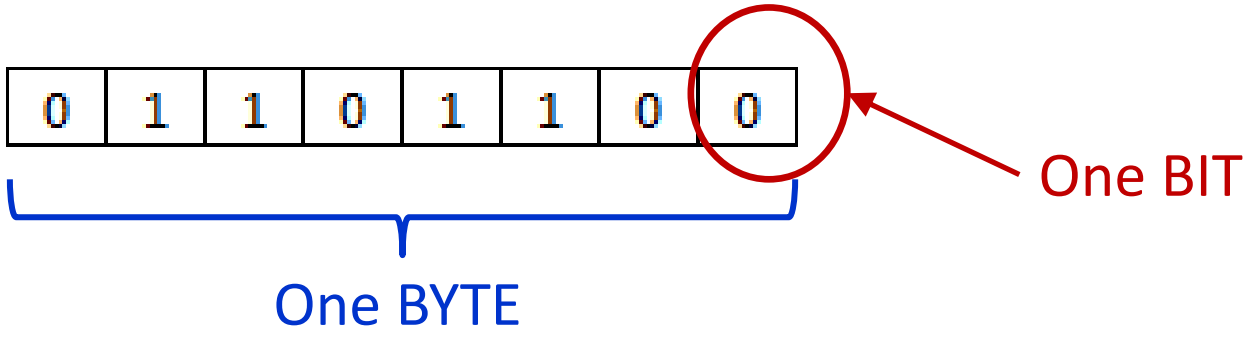
A. A clocked array of circuits that passes data in steps along the array
B. An array of operational amplifiers used for tri-state arithmetic operations
C. A digital mixer
D. An analog mixer

Microprocessors & Related Components: Memory

- Microprocessors are capable of performing millions of computing instructions per second
- Programs must be stored in *memory* devices so the microprocessor can read these instructions
  - *Volatile* memory loses data when power is removed
  - *Nonvolatile* memory stores data permanently, even without power
  - *Random-access memory* (RAM) can be read from or written to
  - *Read-only memory* (ROM) stores data permanently and cannot be changed

Data Interfaces

- Microprocessors communicate through data interfaces
  - Two types: Serial & Parallel
  - Serial transfers one *bit* of data in each transfer operation
  - Parallel transfers multiple bits in each operation



Visual Interfaces

- Amateur equipment uses two types of devices to present information visually
  - Indicators & displays
- Indicators: Presents ON/OFF information visually by the presence or absence of color or light
  - Common indicators: Incandescent light bulbs & light-emitting diodes (*LED*s)
- Displays: Presents text or graphics information in visual form

LEDs

- Have largely replaced incandescent light bulbs in amateur equipment
  - Last longer, can be turned on/off more quickly, use less power, generate less heat
- Available in many colors
- Made from special types of semiconductor material that emit light when the PN junction is *forward biased*

Liquid Crystal Displays (*LCD*)

- Most common type of display
- Created by sandwiching liquid crystal material between glass panels
- A pattern of electrodes is printed in a thin film on the front panel with a single electrode covering the rear panel
- Voltage applied to front panel causes the crystals to twist in a configuration that blocks light
- LCDs require ambient or back lighting (light source behind the crystal layer) since the crystal layer does not generate light on its own

PRACTICE QUESTIONS

What is meant by the term ROM?

A. Resistor Operated Memory
B. Read Only Memory
C. Random Operational Memory
D. Resistant to Overload Memory

What is meant when memory is characterized as non-volatile?

A. It is resistant to radiation damage
B. It is resistant to high temperatures
C. The stored information is maintained even if power is removed
D. The stored information cannot be changed once written

How is an LED biased when emitting light?

A. Beyond cutoff
B. At the Zener voltage
C. Reverse biased
D. Forward biased

Which of the following is a characteristic of a liquid crystal display?

A. It utilizes ambient or back lighting
B. It offers a wide dynamic range
C. It consumes relatively high power
D. It has relatively short lifetime

Practical Circuits: Rectifiers

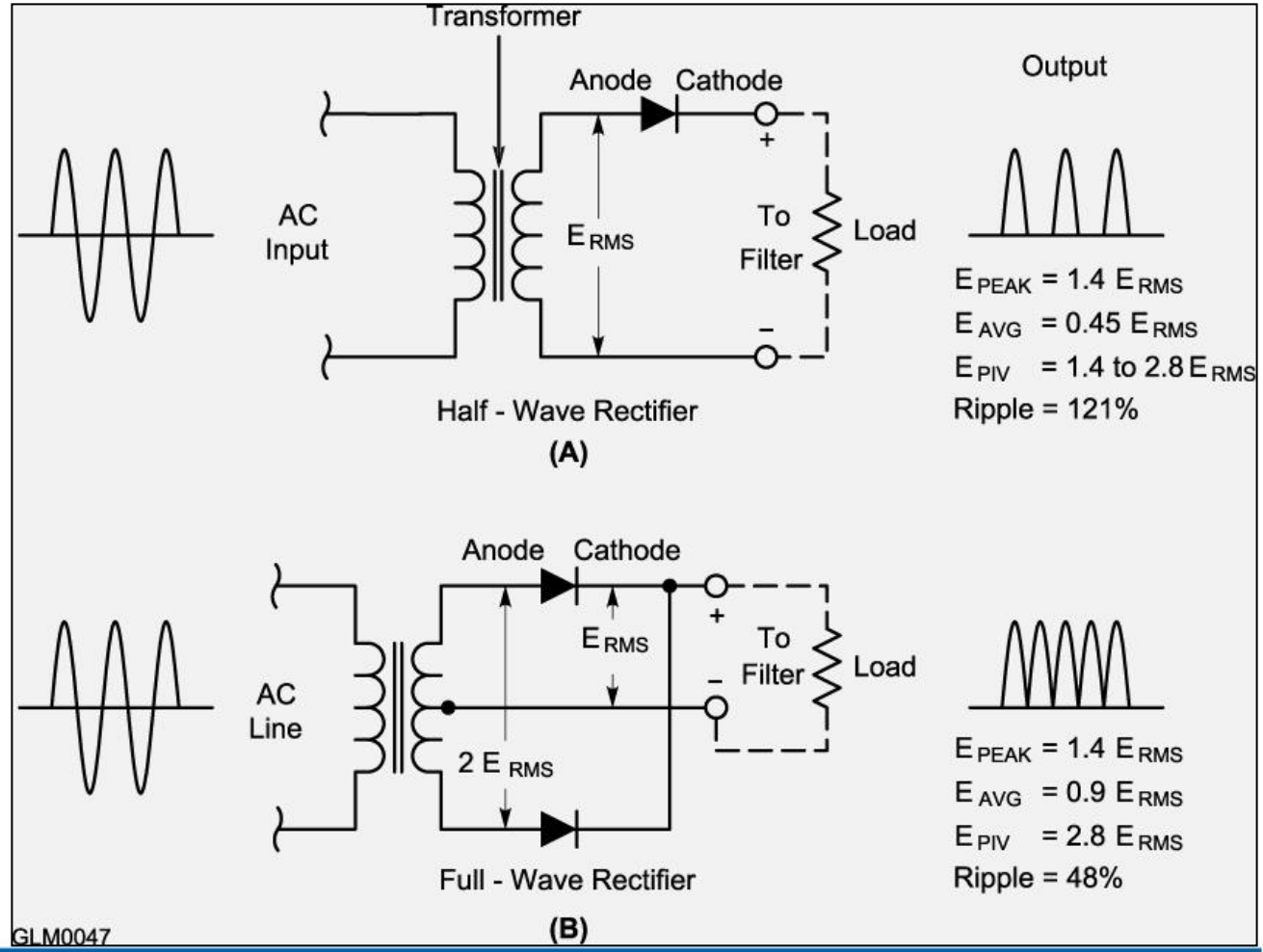
- Amateur radio electronic equipment requires dc power, so a *power supply* is required to run it from household ac power
  - Most amateur equipment uses dc power at 13.8 V (chosen to be compatible with vehicle power systems)
- Power supplies have 3 basic parts …
  - Input transformer, rectifier, and filter-regulator output circuit

Rectifier Circuits

(A)Half-Wave Rectifier. Converts only one-half of the input waveform (180°). This creates a series of pulses of current in the load at the same frequency as the input voltage.

(B)Full-Wave Rectifier. Converts entire input waveform (360°). This is really 2 half-wave rectifiers operating on alternate half cycles. Requires that the transformer be center-tapped to provide a return path for current flowing to the load.

Figure 4.24: Basic Rectifier Circuits (half-wave & full wave)

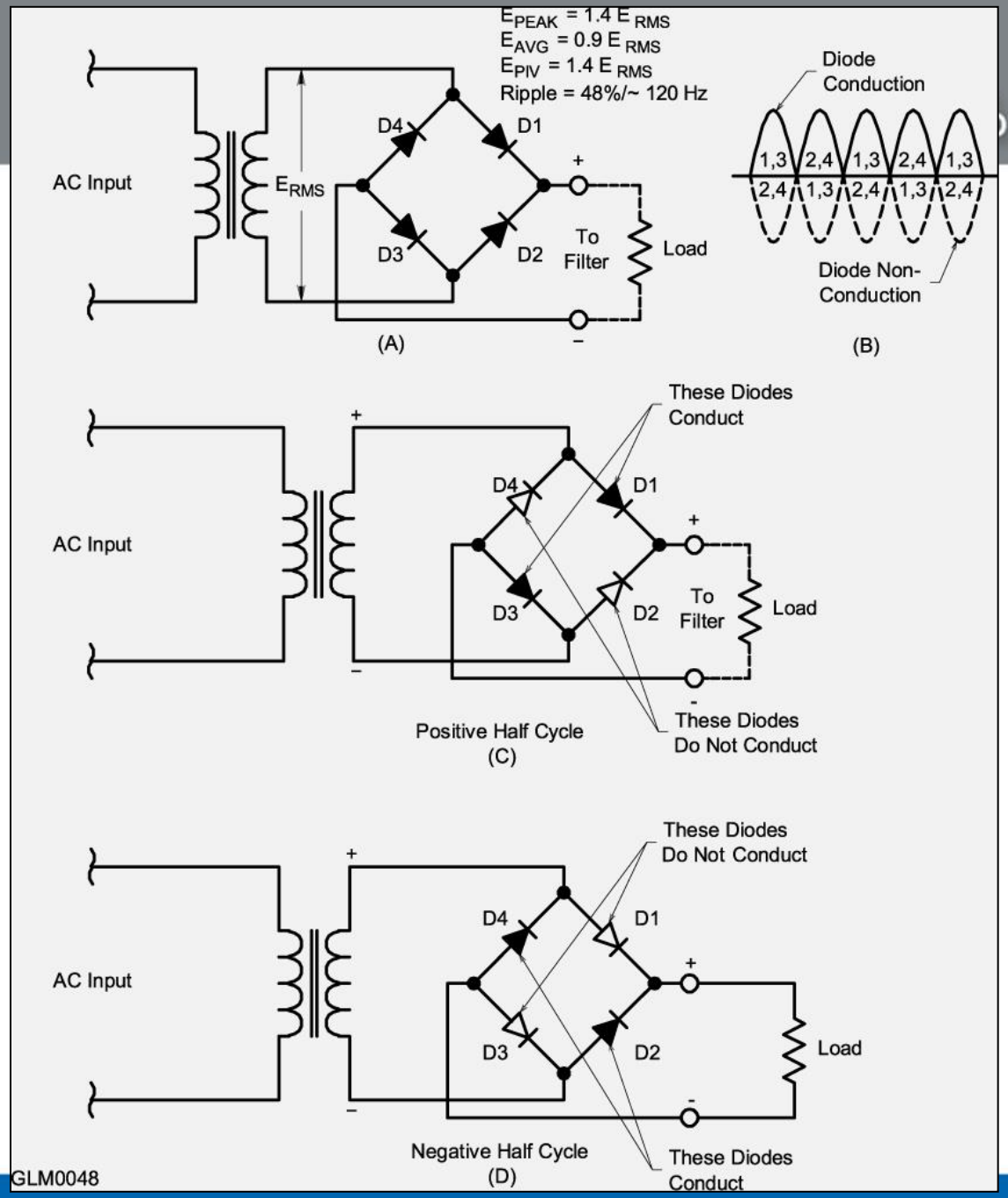


Rectifiers (cont.)

- The advantage of the full-wave rectifier is that output is produced during the entire 360° of the wave cycle (more efficient)
- The output from full-wave rectifiers is a series of pulses at TWICE the frequency of the input voltage

Full-Wave Bridge (Fig 4.25)

Another type of full-wave rectifier. This circuit adds 2 diodes (total of 4), but eliminates the need for a center-tapped winding.



Power Supply Filter Circuits

- Rectifiers output pulses of dc current don't provide a stable voltage for direct use by electronic circuits
- The variation in output voltage is called *ripple*
- Pulses must be smoothed out by a *filter network* … consists of capacitors or capacitors AND inductors
- Most common way to reduce ripple is a *filter capacitor* or *capacitor-input filter*
- Older high-voltage circuits may use *choke inductors*

Power Supply Safety

- *Fuses* in the primary are used to protect against short circuits or excessive current loads
- *Bleeder resistors* discharge stored energy when the supply is turned off
- Working on power supplies – wait for the bleeder resistor to discharge energy, even if it is unplugged

Switchmode or Switching Supplies

- Another type of power supply filter, called *linear filters*
- AC input is first rectified and filtered
- Transistor switch pulses at high-frequency (20 kHz or more) to transfer energy to a filter capacitor (smoothes out ripple)
- High frequency enables power supply to quickly change to current demands and means that small, lightweight inductors & capacitors can be used to filter the output

PRACTICE QUESTIONS

What useful feature does a power supply bleeder resistor provide?

A. It acts as a fuse for excess voltage
B. It ensures that the filter capacitors are discharged when power is removed
C. It removes shock hazards from the induction coils
D. It eliminates ground loop current

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

A. Diodes
B. Transformers and transducers
C. Quartz crystals
D. Capacitors and inductors

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

What is an advantage 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 output voltage of the transformer

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

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

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

Which of the following is an advantage 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. All these choices are correct

Batteries & Chargers

- Two battery types: *primary* and *secondary*
- Primary
  - Disposable, discarded after discharging
  - *Battery chemistry*: carbon-zinc, alkaline, silver-nickel
  - Preferable to secondary batteries for emergency operation because ac power may not be available for charging
- Secondary
  - Can be recharged/reused many times
  - Battery chemistry: nickel-cadmium (NiCd), nickel-metal hydride (NiMH), lithium-ion (Li-ion), lead-acid

Table 4.8: Battery Types & Characteristics

BATTERY STYLE	CHEMISTRY	TYPE	FULL-CHARGE (V)	ENERGY RATING (mAh)
AAA	Alkaline	Disposable	1.5	1100
AA	Alkaline	Disposable	1.5	2600-3200
AA	Carbon-Zinc	Disposable	1.5	600
AA	Nickel-Cadmium (NiCd)	Rechargeable	1.2	700
AA	Nickel-Metal Hydride (NiMH)	Rechargeable	1.2	1500-2200
AA	Lithium	Disposable	1.7	2100-2400
C	Alkaline	Disposable	1.5	7500
D	Alkaline	Disposable	1.5	14,000
9 V	Alkaline	Disposable	9	580
9 V	Nickel-Cadmium (NiCd)	Rechargeable	9	110
9 V	Nickel-Metal Hydride (NiMH)	Rechargeable	9	150
Coin Cells	Lithium	Disposable	3-3.3	25-1000

Storage Batteries (Larger Secondary Batteries)

- Used for emergency or portable power to replace power supplies operating from ac power
- Battery chemistry: lead-acid, liquid electrolyte, gel electrolyte (*gel-cells*)
- Rated as “12 V” batteries, but are actually 13.8 V
- Lead-acid batteries can produce useful power down to 10.5 V
- Discharging below minimum voltage will reduce battery life

Batteries (cont.)

- Limiting amount of current drawn keeps battery cool and extends life
- Some battery types (NiCds) are designed to have low internal resistance to supply high discharge currents
- Batteries slowly lose charge when not in use. This is called *self-discharge* (minimize by keeping battery cool & dry, but avoid freezing as the expanding water can crack the case or damage electrodes).

Alternative Power

- Solar Power: photovoltaic conversion of sunlight to electricity
  - Solar panels/cells are special type of diode … silicon PN-junctions
- In solar cells, photons are absorbed by electrons that then have enough energy to travel across the PN junction and create dc current flow
  - The forward voltage created (≈ 5V) is measured as the *open-circuit voltage*
- Wind/solar power systems require substantial energy storage
- In solar systems, battery connection is made through a series-connected diode to prevent battery from discharging back through the panel during periods of low illumination when voltage is reduced

PRACTICE QUESTIONS

What is the name of the process by which sunlight is changed directly into electricity?

A. Photovoltaic conversion
B. Photon emission
C. Photosynthesis
D. Photon decomposition

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

A. 0.02 VDC
B. 0.5 VDC
C. 0.2 VDC
D. 1.38 VDC

What is the reason that a series diode is connected between a solar panel and a storage battery that is being charged by the panel?

A. The diode serves to regulate the charging voltage to prevent overcharge
B. The diode prevents self-discharge of the battery through the panel during times of low or no illumination
C. The diode limits the current flowing from the panel to a safe value
D. The diode greatly increases the efficiency during times of high illumination

Which of the following is a disadvantage of using wind as the primary source of power for an emergency station?

A. The conversion efficiency from mechanical energy to electrical energy is less than 2 percent
B. The voltage and current ratings of such systems are not compatible with amateur equipment
C. A large energy storage system is needed to supply power when the wind is not blowing
D. All these choices are correct

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

What is an advantage of the low internal resistance of nickel-cadmium batteries?

A. Long life
B. High discharge current
C. High voltage
D. Rapid recharge

Connector Terminology

- Pins: contacts that extend out of the connector body (*male*)
- Sockets: hollow, recessed contacts (*female*)
- Keyed connectors: specially shaped (bodies or inserts) to prevent damage from connecting incorrectly
- Plugs: connectors installed on ends of cables
- Jacks/receptables: connectors installed on equipment
- Adapters: make connections between 2 different connector styles
- Splitters: divide signals between 2 connectors

Power Connectors

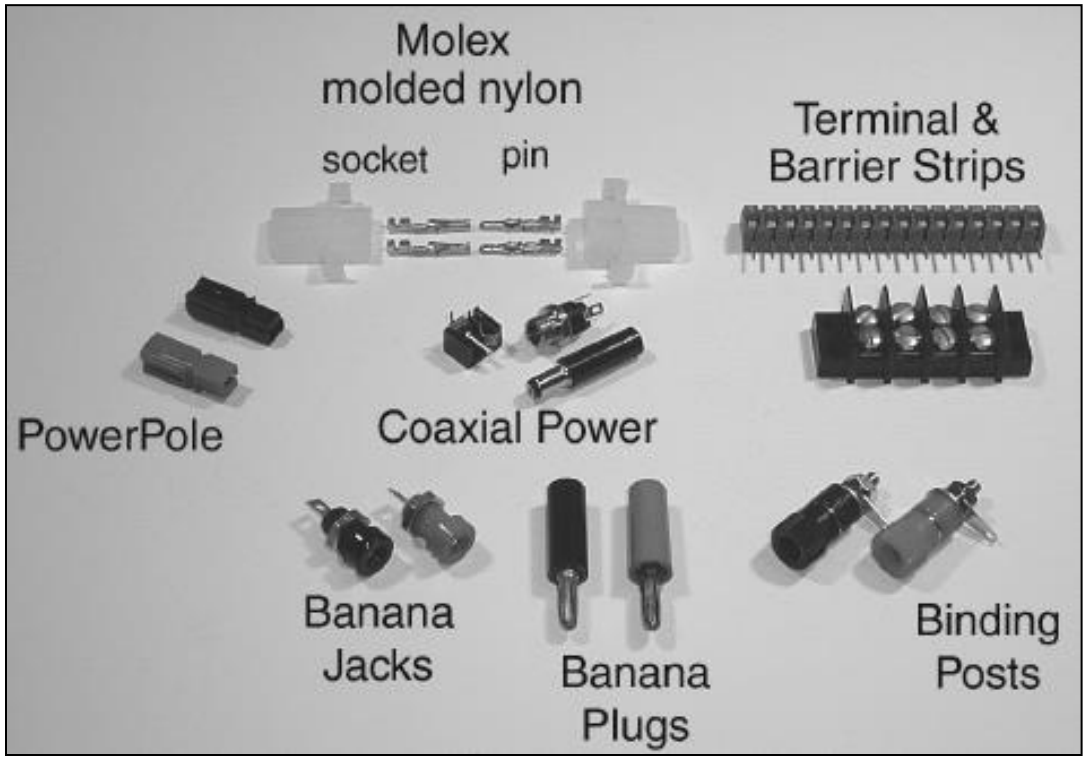


Fig 4.28: Connectors used on amateur equipment

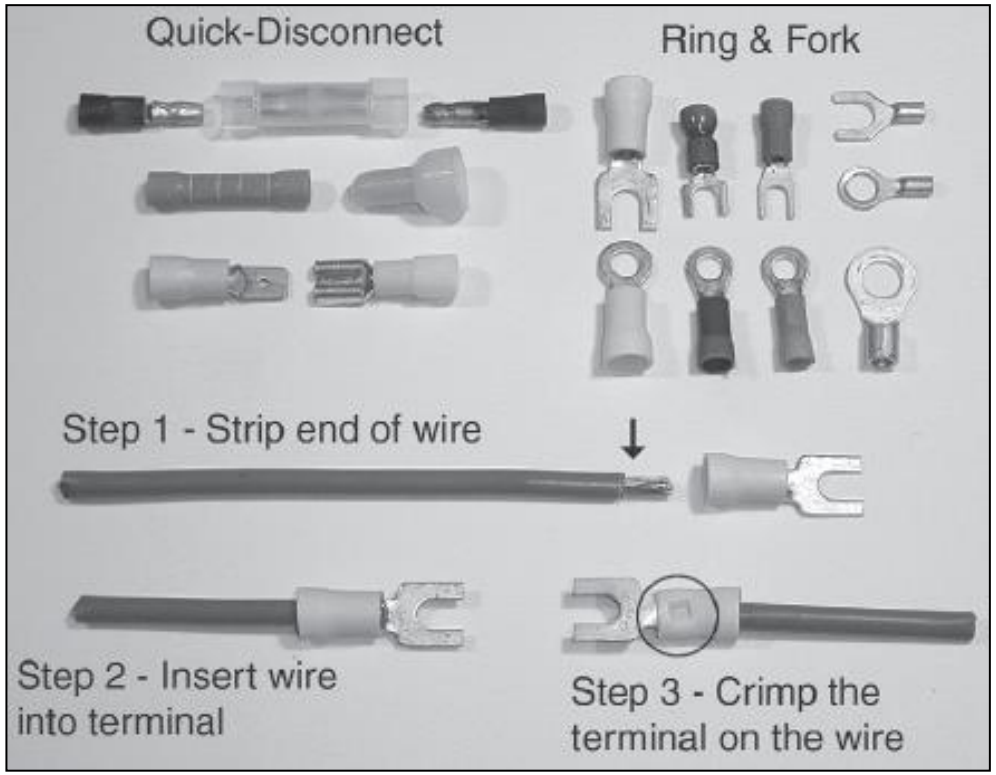


Fig 4.29: Terminals that are crimped to ends of wires.

Power Connectors (cont.)

- Anderson Powerpole connectors have become the standard used by ARES
  - Anderson connectors are “sexless” … by standardizing on a single style, equipment can be easily shared and replaced
- Note that these (see previous figure) are *crimp terminals* … special crimping tools are used for attaching the wire to the terminal (avoid using pliers or other tools for making these connections)

Audio Connectors

- Come in ¼-inch, ⅛-inch (miniature), and subminiature varieties
- Contact at end of plug is the *tip*
- Connector at base of plug is the *sleeve*
- 3rd contact (if applicable) between tip and sleeve is the *ring* (called TRS or tip-ring-sleeve)
- *Phono* plugs/jacks (also called *RCA* connectors) are used for audio, video and low-level RF signals

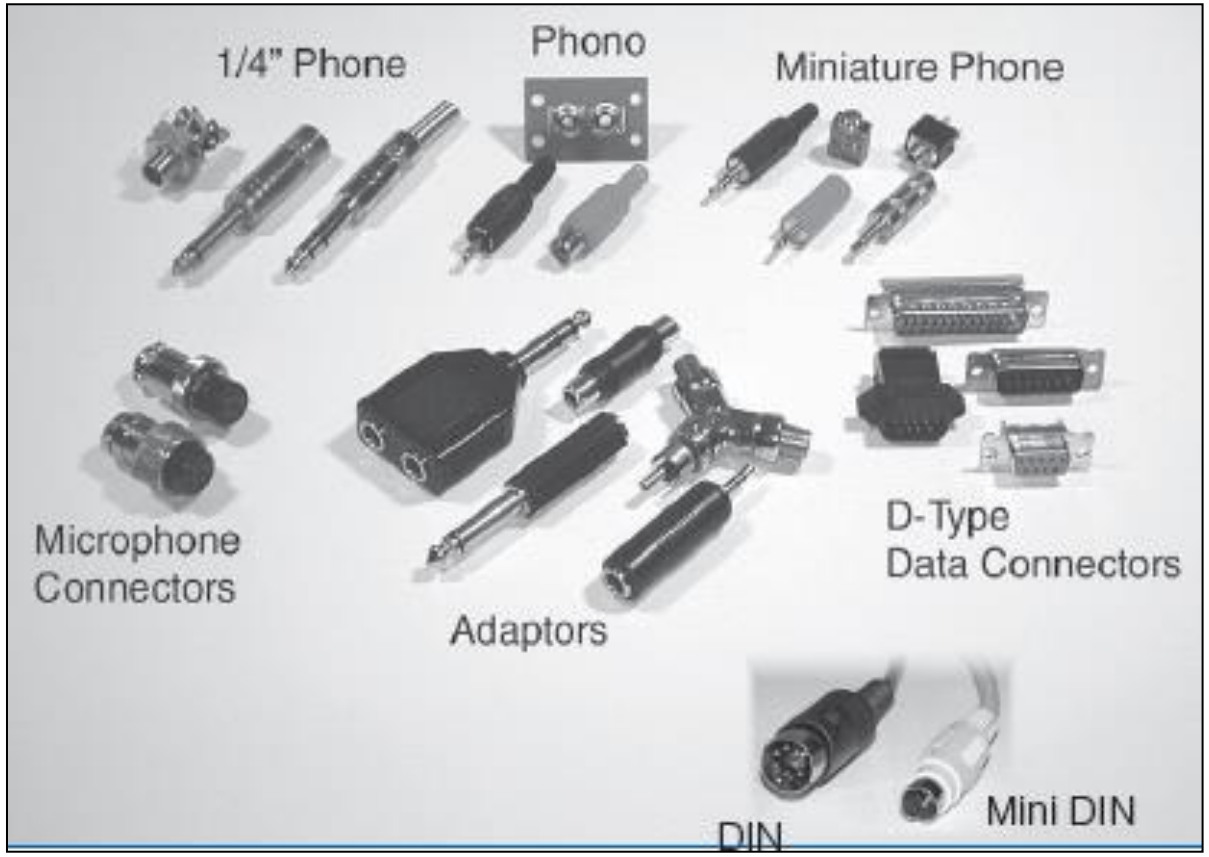
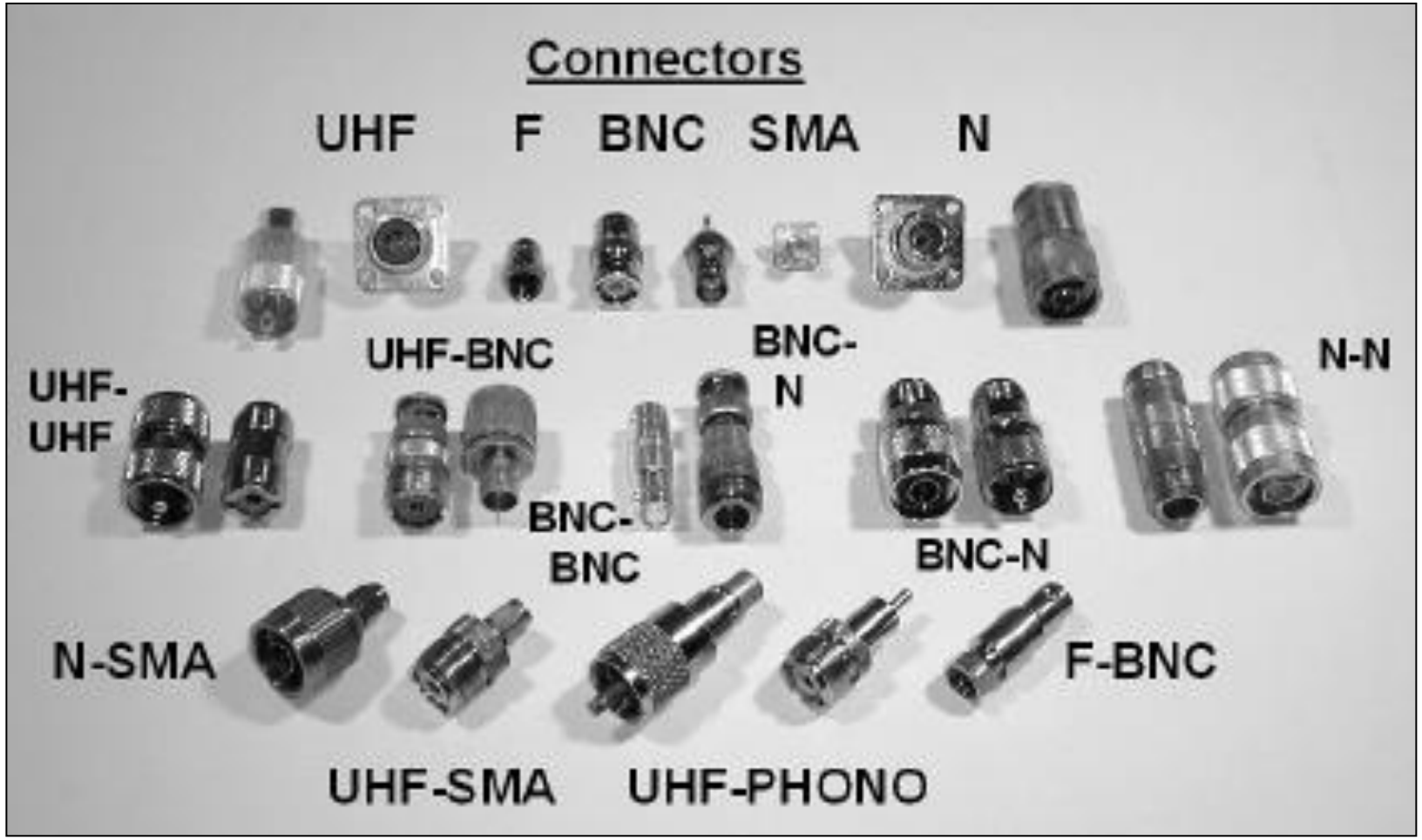


Fig. 30: Samples of audio connectors.

RF Connectors

Fig. 4.31: Each type of RF connector is specially made to carry RF signals and preserve the shielding of coaxial cable. Adapters are available to connect one style of connector to another.



RF Connectors (cont.)

- Radio signals require special connectors for use at RF frequencies
- Connectors must have about the same impedance as the feed line (or some of the signal will be reflected by the connector)
- Most common connector is the UHF family in Fig. 4.31 (UHF does not refer to frequency)
- UHF connectors are typically used up to 150 MHz and can handle legal-limit transmitter power at HF

RF Connectors (cont.)

- UHF connector drawbacks: lack of weather proofing, inconsistent performance above 150 MHz, limited power handling at higher frequencies
- Type N series connectors address these drawbacks
  - Can be used to 10 GHz
- SMA connectors are small threaded connectors designed for miniature coax and are rated to 18 GHz. Handheld transceivers often use SMA connectors to attach antennas.

Data Connectors

- Digital data is exchanged between computers and radio equipment more that ever before in amateur radio
- D-type connectors are used for RS-232 (COM port) interfaces
- The model *number* of a D-type connector specifies the number of circuits and a P or S depending upon whether the connector uses pins (male) or sockets (female). For example, D-type 9-pin connectors referred to as DB-9 or DE-9 are used for COM ports on PCs.
- The **D** refers to its shape …

PRACTICE QUESTIONS

Which of the following connectors would be a good choice for a serial data port?

A. PL-259
B. Type N
C. Type SMA
D. DE-9

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 threaded connector used for hydraulic systems
D. An audio connector used in surround-sound installations

What is a type SMA connector?

A. A large bayonet connector usable at power levels more than 1 KW
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

Which of these connector types is commonly used for audio signals in Amateur Radio stations?

A. PL-259
B. BNC
C. RCA Phono
D. Type N

Which of these connector types is commonly used for RF connections at frequencies up to 150 MHz?

A. Octal
B. RJ-11
C. PL-259
D. DB-25

Basic Test Equipment: Analog & Digital Meters

- A *volt-ohm-meter* (a.k.a. *VOM* or *multimeter*) is the simplest and very versatile piece of test equipment. There are two types: analog and digital.
- Functions: measures voltage, measures current, measures resistance, checks continuity, tests diodes, tests transistors, frequency counter, measures capacitance, measures inductance, and interfaces to PCs to record readings

Analog & Digital Meters (cont.)

- Digital multimeters (DDM) offer greater precision than analog meters
- For finding a peak or minimum reading (for example, when adjusting or tuning a circuit). Experienced hams often prefer analog meters since it's easier to just watch the analog meter needle move than the display on a digital meter.
- Meters should affect the circuit being measured to the smallest degree possible. When measuring voltage, meters should have a high input impedance so that it places the minimum load on the circuit.

Oscilloscope (or Scope)

- Provides a visual display of voltage against time
- Display is updated thousands or millions of times per second to give a real-time view of the signal's characteristics (allows for measurement of fast-changing waveforms that can't be measured by other meters).
- Signals are connected to the scope through horizontal and vertical *channel amplifiers*. Amplifier gain is variable to adjust vertical sensitivity of the scope's display.

Monitoring Oscilloscope

- Used for monitoring transmitted signals by connecting the attenuated RF output of the transmitter to the vertical channel of the scope
  - This assists in adjusting keying waveforms, microphone gain, and speech processing
  - When adjusting keying waveforms, the operator can clearly see the effects of any adjustments or conditions that might cause distortion or key clicks on the transmitted signal

Impedance & Resonance Measurements

- An *antenna analyzer* contains a CW signal generator, frequency counter, SWR bridge, and impedance meter
  - Connects to the antenna feed line to measure SWR without having to transmit a signal at high power
  - Measures feed line velocity factor, electrical length, and characteristic impedance, and other parameters
  - Because they use small signals, accuracy can be affected by strong signals from nearby transmitters

Field Strength & RF Power Meters

- Other useful tests include antenna efficiency and radiation pattern which is measured with a field strength meter
- Field strength meters are often used for comparing relative levels of RF output during antenna and transmitter adjustments
- Radiation pattern is measured by placing field strength meter in one location and rotating the antenna. Or, the meter can be carried to different locations to determine radiation pattern of a fixed antenna.

Field Strength & RF Power Meters (cont.)

- Directional wattmeters measure both *forward* and *reflected power* (P_F and P_R) in the line
- Standing wave ratio (*SWR*) can be calculated from forward and reflected power measurements:

$$SWR = \frac{1 + \sqrt{P_R / P_F}}{1 - \sqrt{P_R / P_F}}$$

PRACTICE QUESTIONS

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

A. An ohmmeter
B. A signal generator
C. An ammeter
D. An oscilloscope

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. Input impedance is much lower
D. Complex waveforms can be measured

Which of the following is the best instrument to use when checking the keying waveform of a CW transmitter?

A. An oscilloscope
B. A field strength meter
C. A sidetone monitor
D. A wavemeter

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

Why is high input impedance desirable for a voltmeter?

A. It improves the frequency response
B. It decreases battery consumption in the meter
C. It improves the resolution of the readings
D. It decreases the loading on circuits being measured

What is an advantage of a digital voltmeter as compared to an analog voltmeter?

A. Better for measuring computer circuits
B. Better for RF measurements
C. Better precision for most uses
D. Faster response

Which of the following instruments may be used to monitor relative RF output when making antenna and transmitter adjustments?

A. A field strength meter
B. An antenna noise bridge
C. A multimeter
D. A Q meter

Which of the following can be determined with a field strength meter?

A. The radiation resistance of an antenna
B. The radiation pattern of an antenna
C. The presence and amount of phase distortion of a transmitter
D. The presence and amount of amplitude distortion of a transmitter

Which of the following can be determined with a directional wattmeter?

A. Standing wave ratio
B. Antenna front-to-back ratio
C. RF interference
D. Radio wave propagation

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

What problem can occur when making measurements on an antenna system with an antenna analyzer?

A. Permanent damage to the analyzer may occur if it is operated into a high SWR
B. Strong signals from nearby transmitters can affect the accuracy of measurements
C. The analyzer can be damaged if measurements outside the ham bands are attempted
D. Connecting the analyzer to an antenna can cause it to absorb harmonics

What is a use for an antenna analyzer other than measuring the SWR of an antenna system?

A. Measuring the front-to-back ratio of an antenna
B. Measuring the turns ratio of a power transformer
C. Determining the impedance of coaxial cable
D. Determining the gain of a directional antenna

What is an instance in which the use of an instrument with analog readout may be preferred over an instrument with digital readout?

A. When testing logic circuits
B. When high precision is desired
C. When measuring the frequency of an oscillator
D. When adjusting tuned circuits

END OF MODULE 4b

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Feel free to contact me if you find errors or have suggestions for improvement.