THE ARRL

TENTH EDITION

GENERAL

LICENSE COURSE

FOR HAM RADIO

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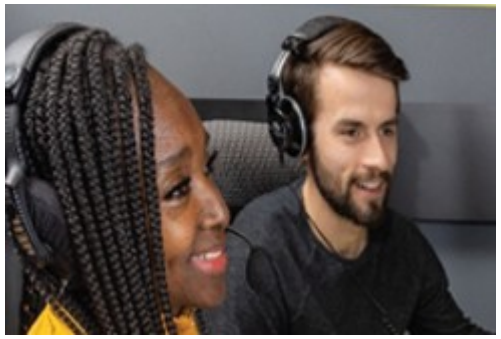

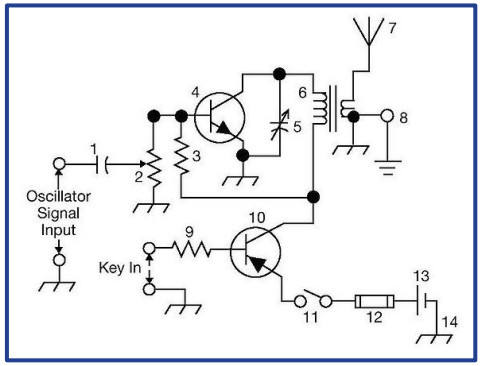

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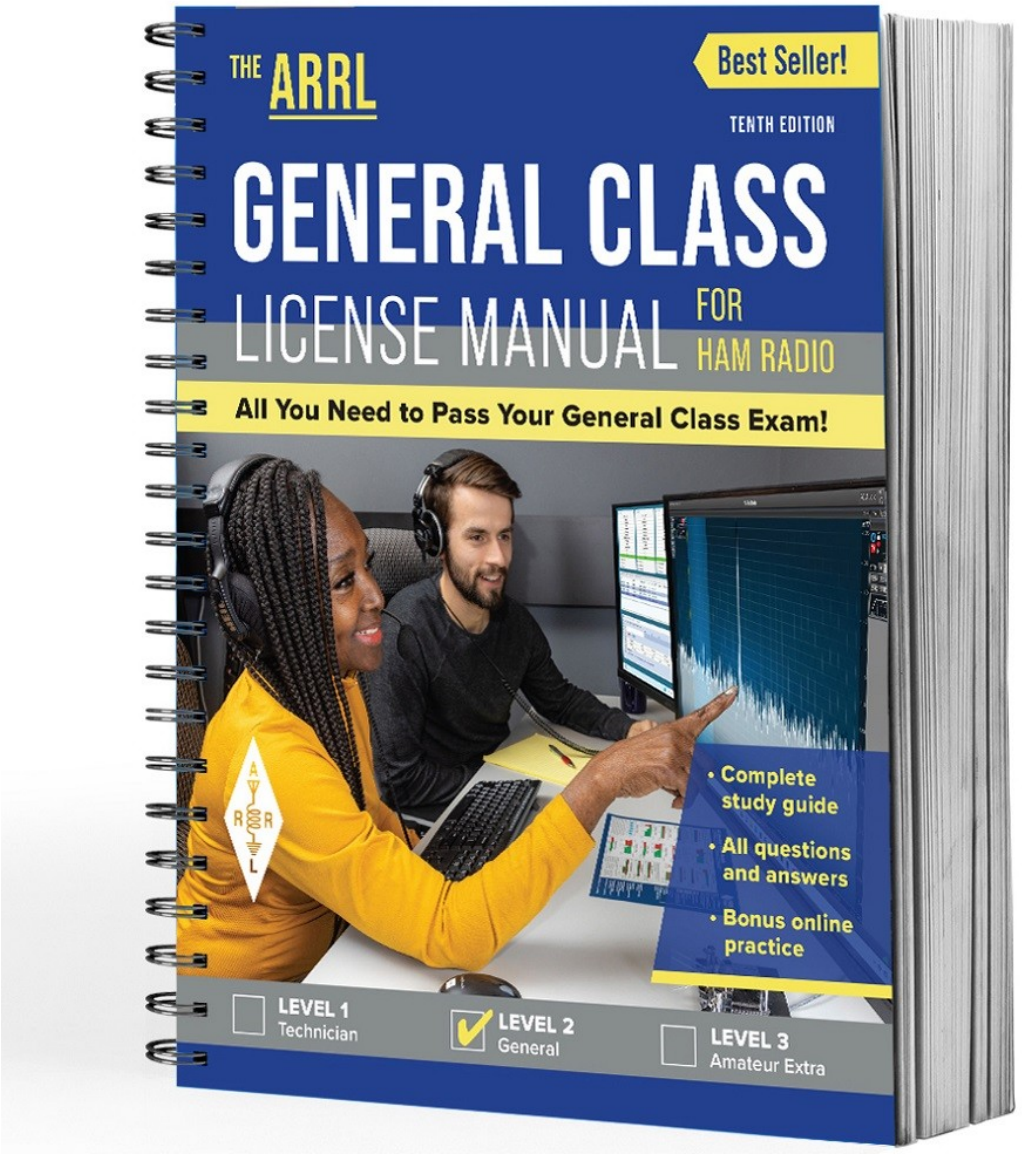


Chapter 4 Part 3 of 3

ARRL General Class
Components and Circuits
Sections 4.6, 4.7

Practical Circuits, Basic Test Equipment

Section 4.6

Practical Circuits: Rectifiers

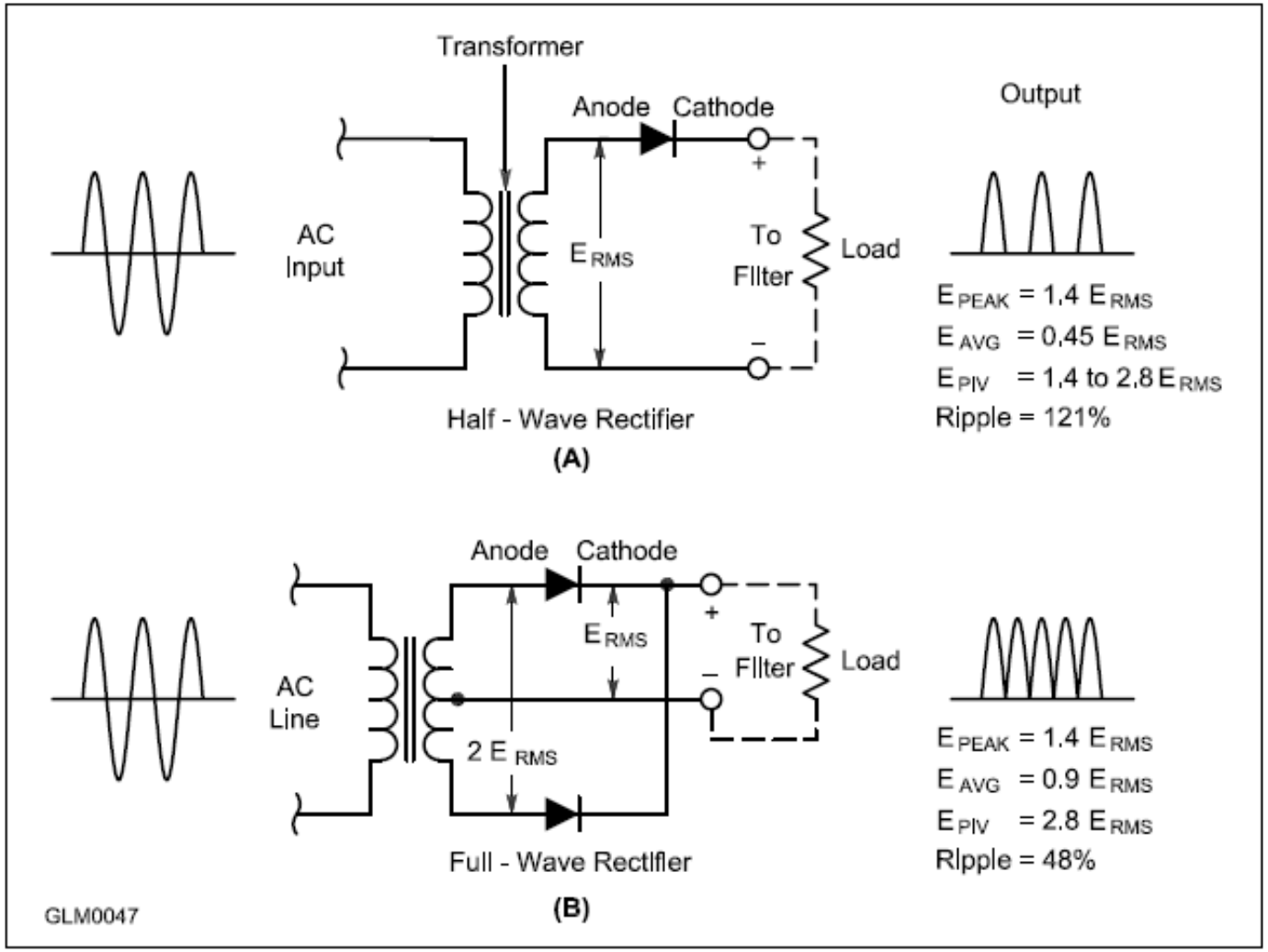
- Amateur radio electronic equipment requires dc power, so a *power supply* is required to run it from household ac power
  - Most amateur equipment uses dc power at 13.8 V (chosen to be compatible with vehicle power systems)
- Power supplies have 3 basic parts …
  - Input transformer, rectifier, and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

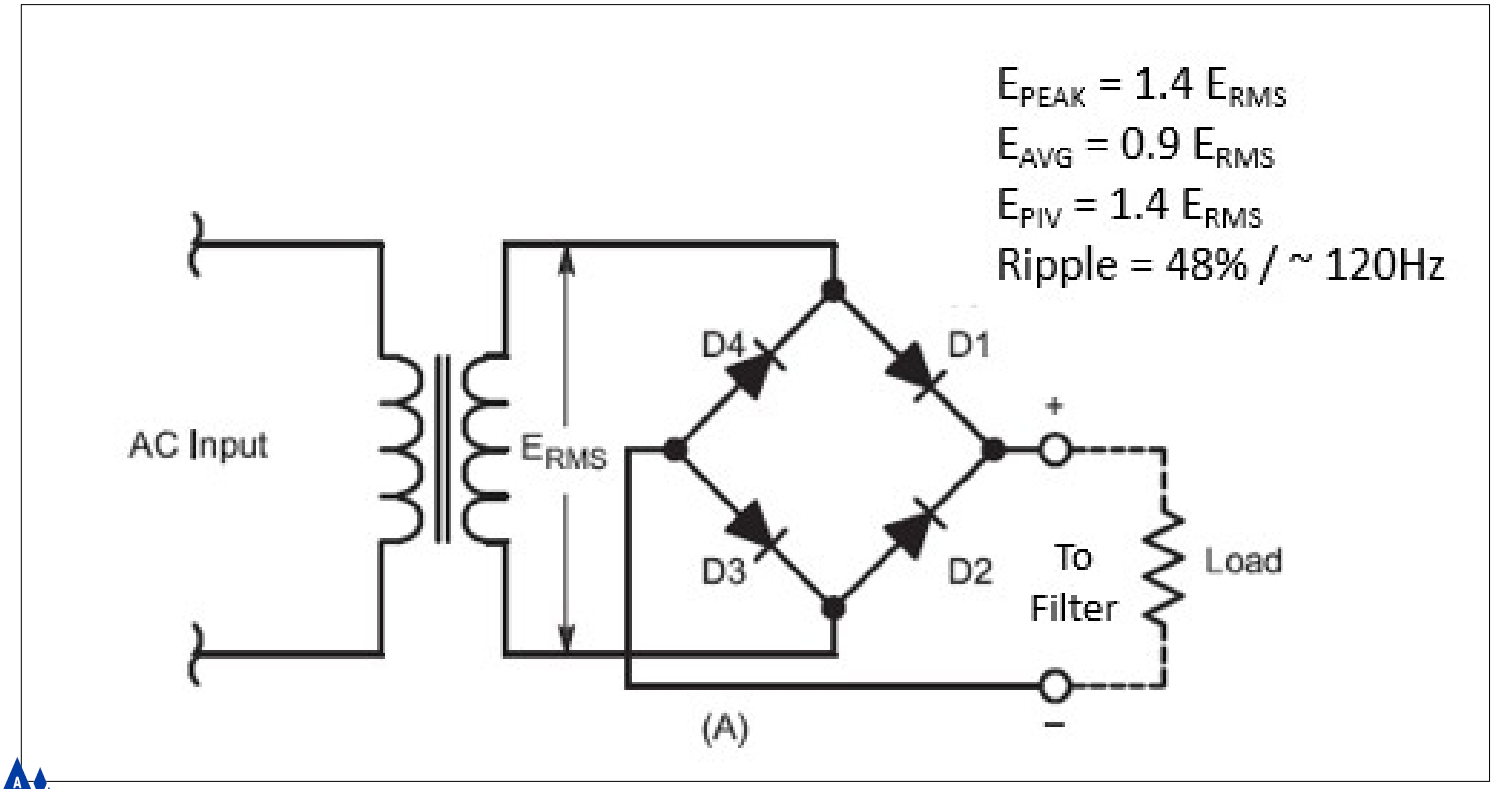


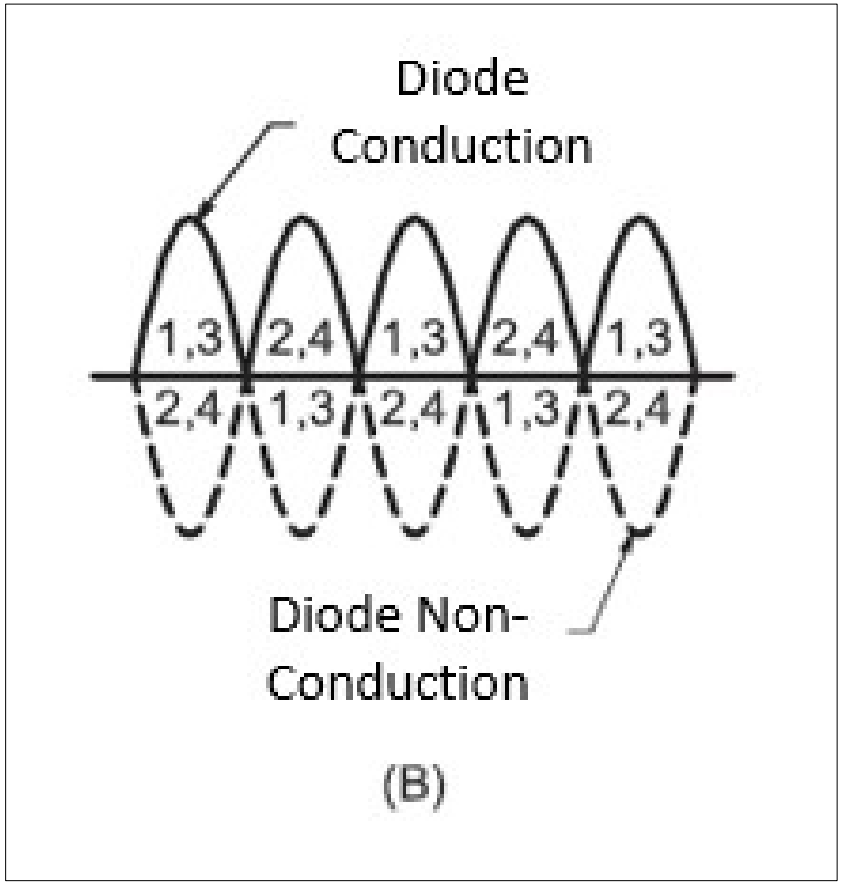
Rectifiers (cont.)

- 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)

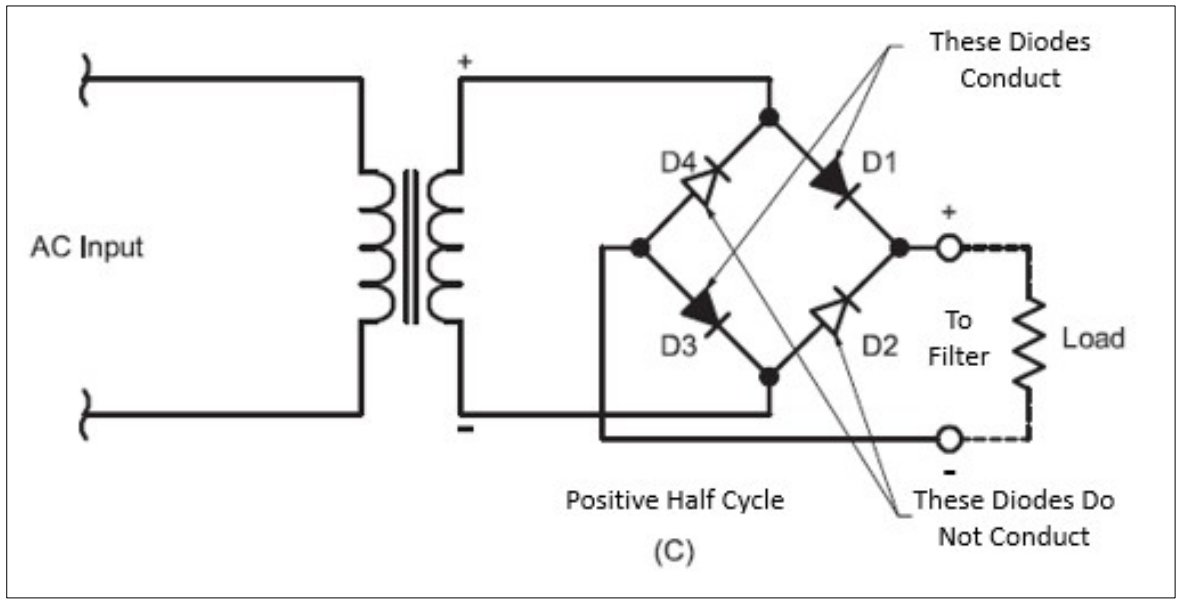
Another type of full-wave rectifier. This circuit adds 2 diodes (total of 4), but eliminates the need for a center-tapped winding.

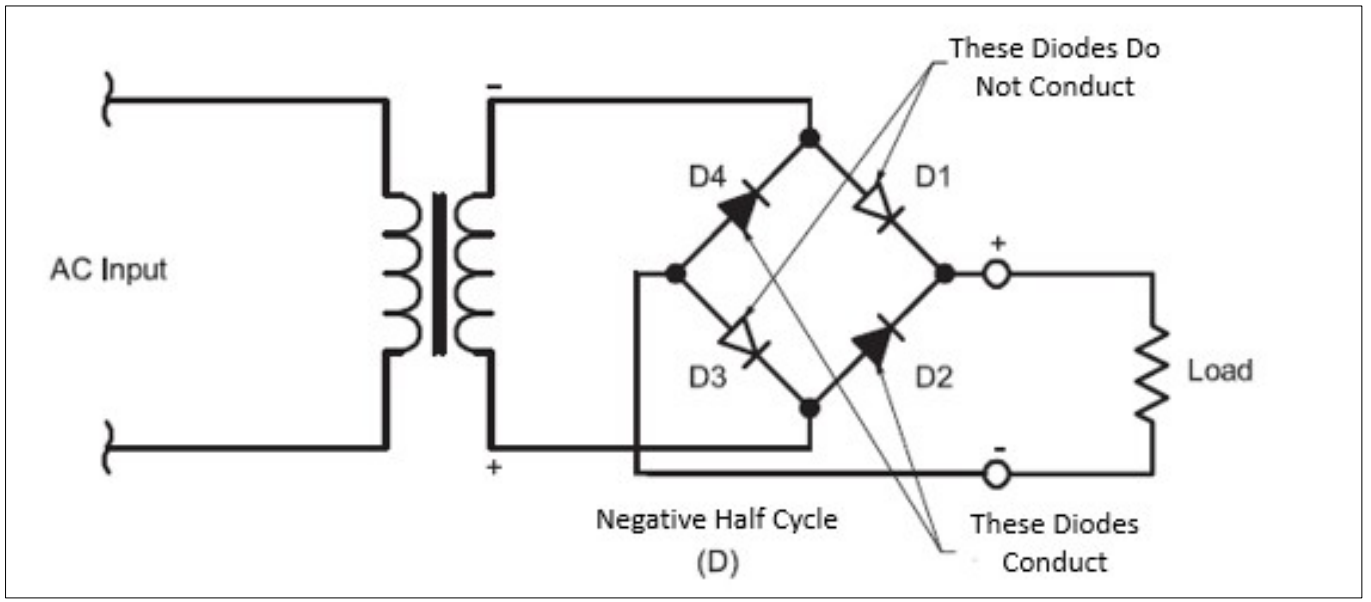




Full-Wave Bridge, cont. (Fig 4.25)

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

- Rectifier's 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 (see Fig 4.27)

- 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

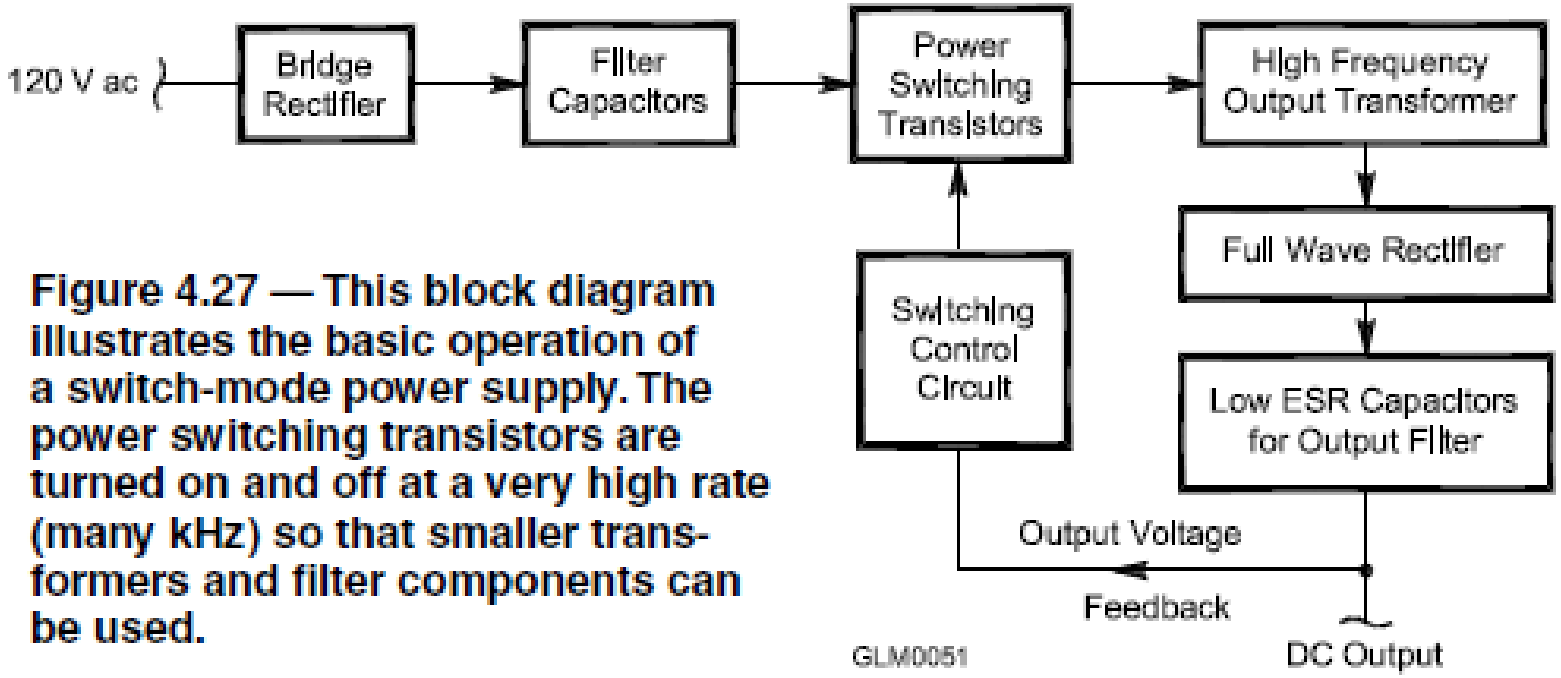


Figure 4.27 — This block diagram illustrates the basic operation of a switch-mode power supply. The power switching transistors are turned on and off at a very high rate (many kHz) so that smaller transformers and filter components can be used.

Switchmode or Switching Supplies (cont.)

AC input is first rectified and filtered. Transistor switch then supplies current pulses to a small inductor or transformer, which transfers the energy into another filter capacitor that smoothes the pulses for a steady output voltage. The high frequency of the pulses means that the supply can react quickly to changing current demands. The high frequency also means that small, lightweight inductors and capacitors can be used to smooth the pulses and filter the output.

PRACTICE QUESTIONS

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

G7A01 (B) Page 4-36

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

G7A02 (C) Page 4-35

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

G7A03 (A) Page 4-35

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

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 (B) Page 4-35

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 (D) Page 4-35

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 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

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 ... called *self-discharge* (minimize by keeping battery cool & dry, but avoid freezing … 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 giving them enough energy to travel across the PN junction and create dc current flow … the forward voltage created (≈0.5V) is called the *open-circuit voltage*
- Wind/solar power systems require substantial energy storage
- When connecting a solar panel to a lithium iron phosphate battery, use a charge controller to avoid overcharging the battery
- Solar connections are made through a series-connected diode to prevent battery from discharging back through the panel during periods of low illumination / reduced voltage
- Solar panels and solar cells are made of silicon PN-junctions that are exposed to sunlight and arranged in a series-parallel configuration

PRACTICE QUESTIONS

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

A. Series-parallel
B. Shunt
C. Bypass
D. Full-wave bridge

G4E08 (A) Page 4-39

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

G4E09 (B) Page 4-39

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

G4E10 (B) Page 4-39

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

G4E11 (D) Page 4-39

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

G6A01 (C) Page 4-39

What is an advantage of batteries with low internal resistance?

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

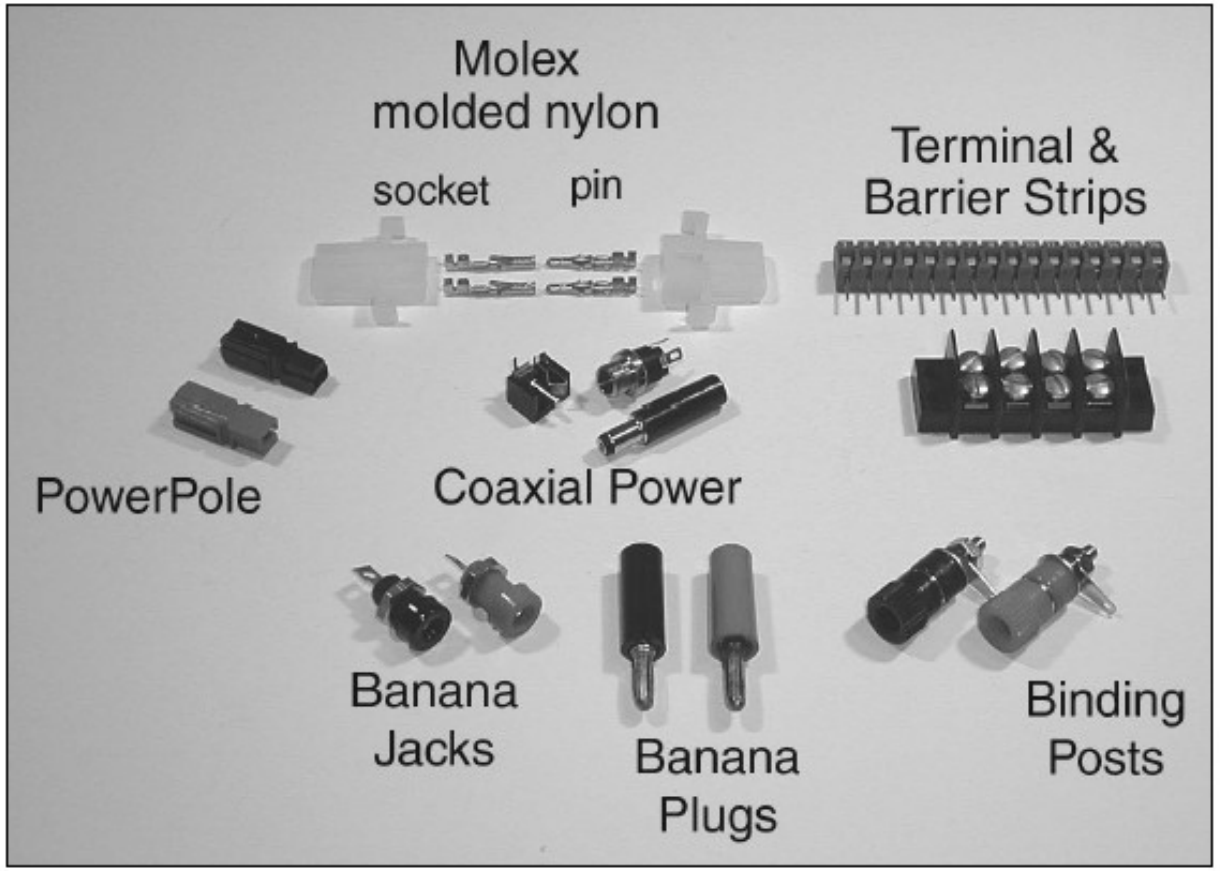


Fig 4.28: Connectors used on amateur equipment

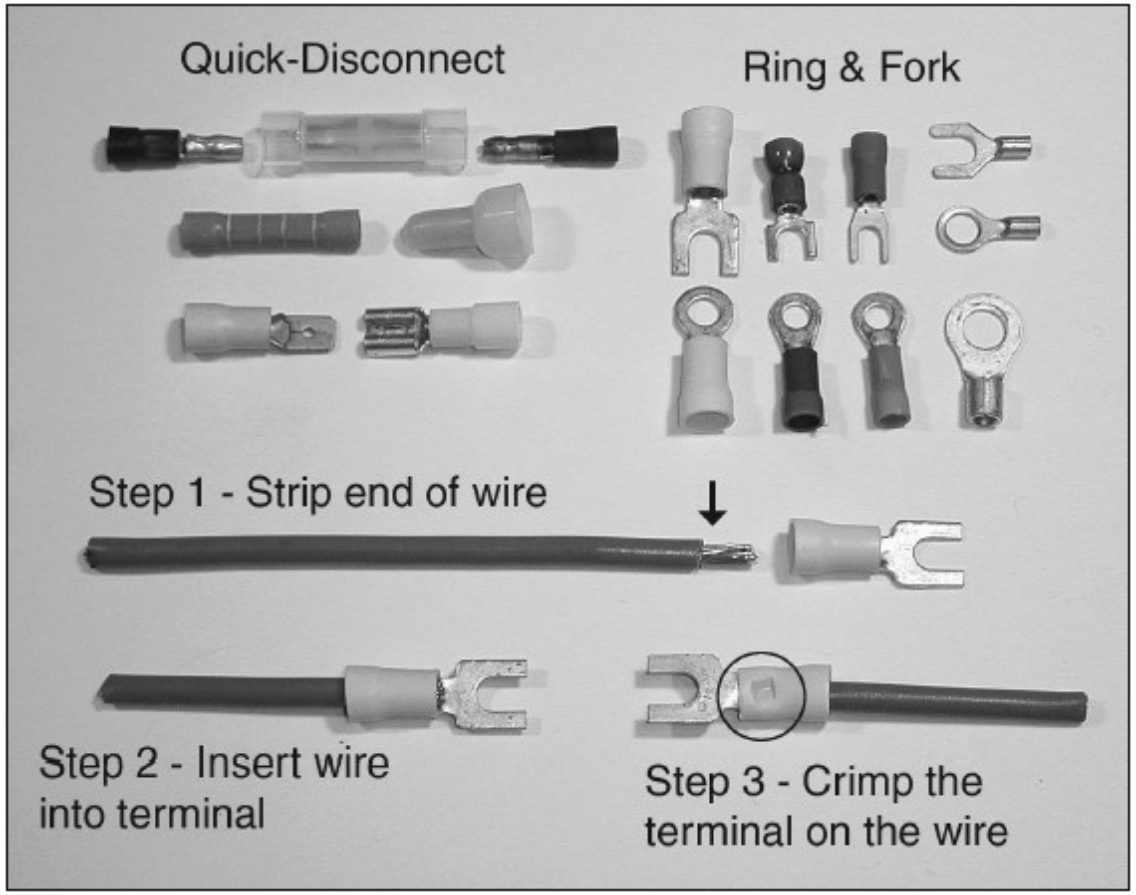


Fig 4.29: Terminals that are crimped to ends of wires

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* (also called *TRS* or tip-ring-sleeve)
- *Phono* plugs/jacks (also called *RCA* connectors) are used for audio, video and low-level RF signals & control signals

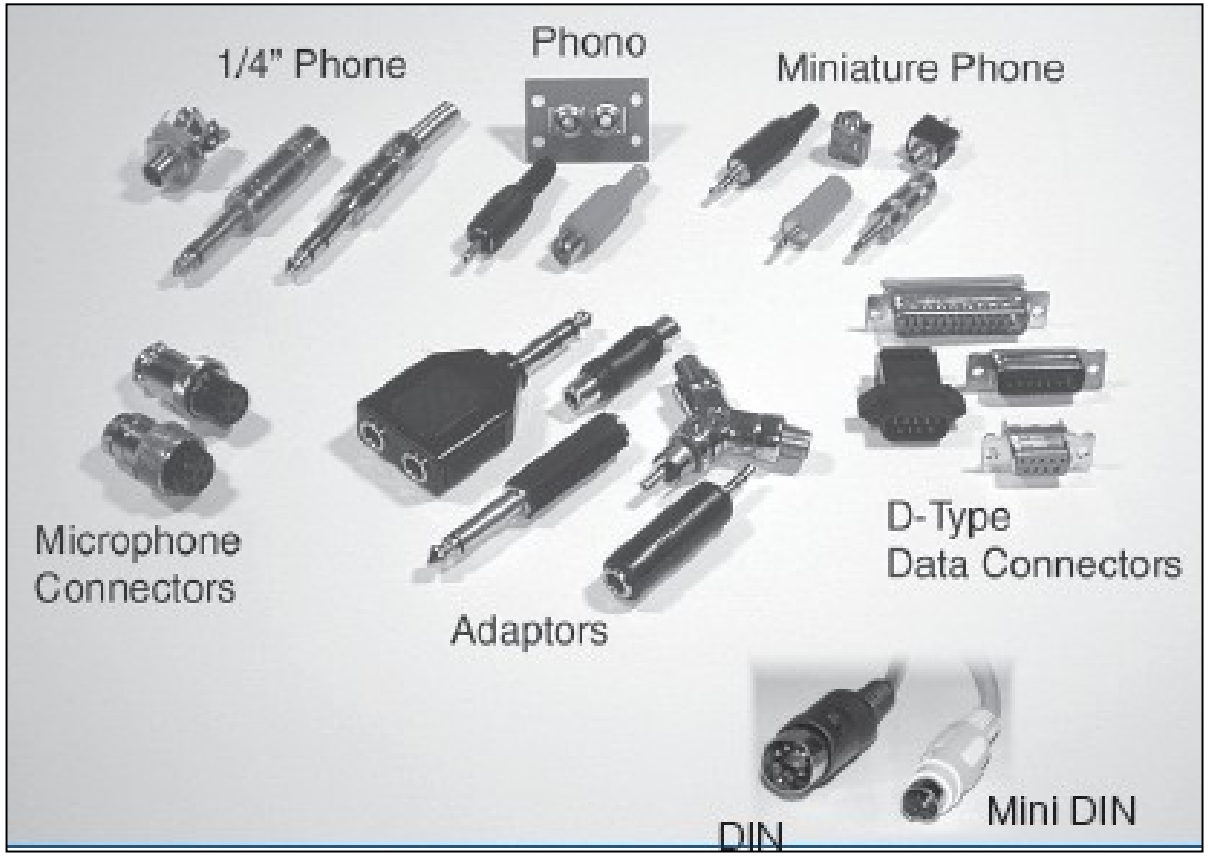
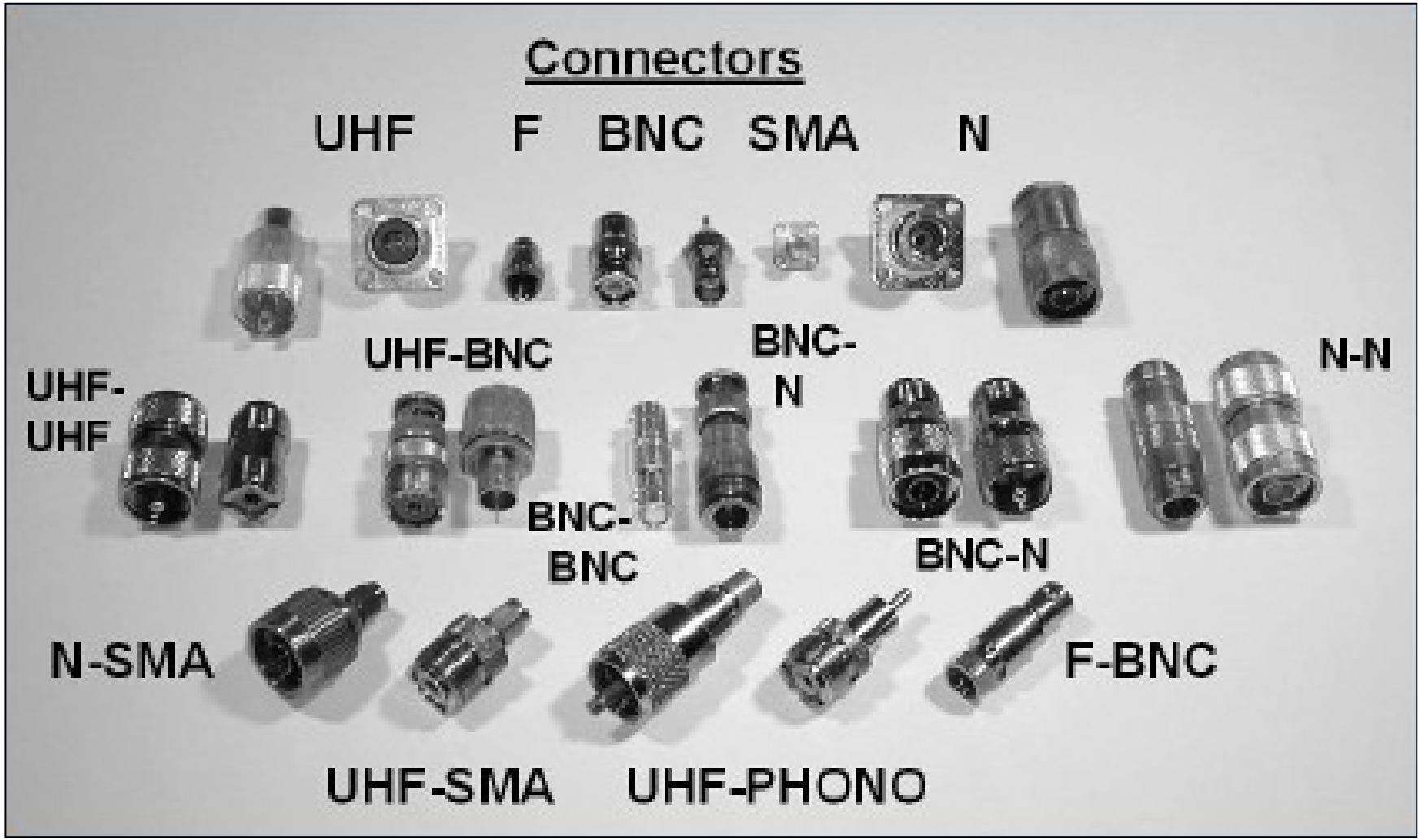


Fig. 4.30: Samples of audio connectors

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 *ultra high frequency**)
- UHF connectors are typically used up to 150 MHz and can handle legal-limit transmitter power at HF

** UHF connector design was named during an era when "UHF" meant frequencies over 30 MHz. Today, Ultra High Frequency refers to frequencies between 300 MHz and 3 GHz.*

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
- BNC connectors are used for low power (common in handhelds for antennas) … upper limit for low SWR operation is 4 GHz
- SMA connectors are small threaded connectors designed for miniature coax, rated to 18 GHz ... also used for handheld 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

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

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

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

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

G6B12 (C) Page 4-41

Section 4.7

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 … 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 (DMM) 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 (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 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 (CW transmitter), operator can see (on scope's display) 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; 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

G4B01 (D) Page 4-44

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

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

G4B03 (A) Page 4-45

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 do voltmeters have high input impedance?

A. It improves the frequency response
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

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

A. Better for measuring computer circuits
B. Less prone to overload
C. Higher precision
D. Faster response

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

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

G4B11 (C) Page 4-45

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

A. Desensitization which can cause intermodulation products which interfere with impedance readings

B. Received power that interferes with SWR readings

C. Generation of harmonics which interfere with frequency readings

D. All these choices are correct

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

G4B13 (C) Page 4-45

END OF CHAPTER 4 PART 3 OF 3

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