Chapter 4.4 ~ 4.7

Components and Circuits (continued)

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Reactance, Impedance and Resonance

* Chapter 4.4

Chapter 4 Components and Circuits

4.4 Reactance, Impedance and Resonance
4.5 Active Components
4.6 Practical Circuits
4.7 Basic Test Equipment

4.4 Reactance, Impedance and Resonance

(Page 4-20)

Reactance

G5A02 – What is reactance?
Opposition to the flow of alternating current caused by capacitance or inductance.
G5A03 – Which of the following causes opposition to alternating current in an inductor?
Reactance.
G5A04 – Which of the following causes opposition to alternating current in a capacitor?
Reactance.

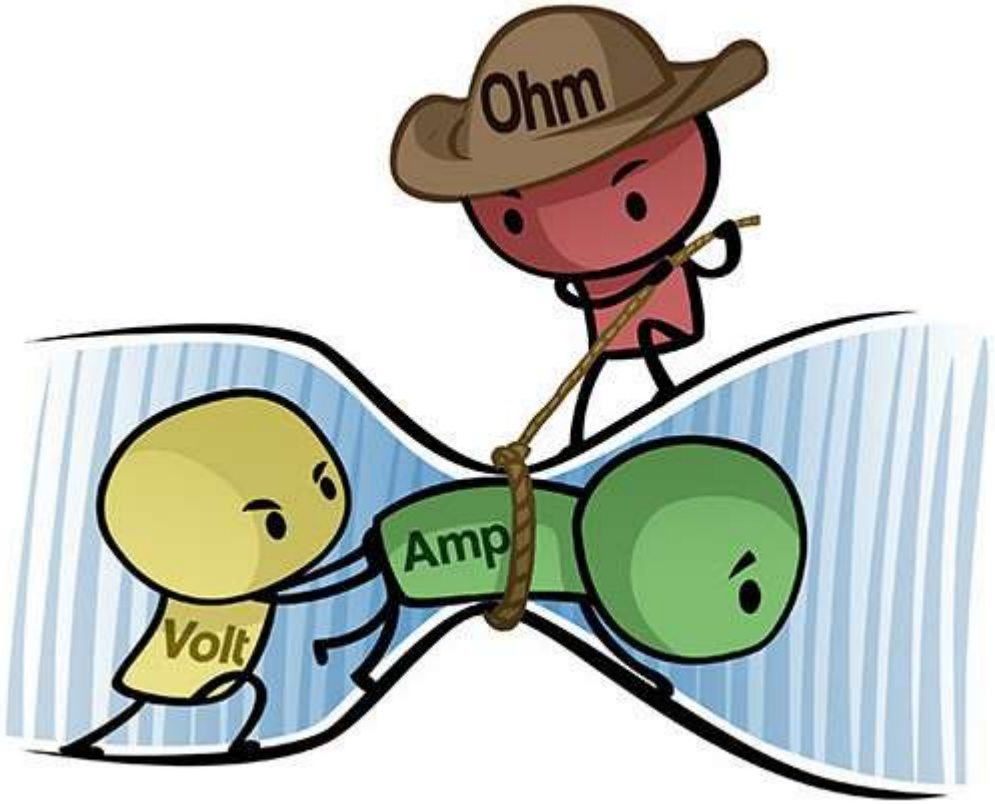
4.4 Reactance, Impedance and Resonance

(Page 4-20)

Reactance

G5A05 – How does an inductor react to AC?
As frequency of the applied AC increases, the reactance increases.
G5A06 – How does a capacitor react to AC?
As frequency of the applied AC increases, the reactance decreases.
G5A09 – What unit is used to measure reactance?
Ohm.
G6A06 – Why should wire-wound resistors not be used in an RF circuit?
The resistor's inductance could make the circuit performance unpredictable.

4.4 Reactance, Impedance and Resonance



4.4 Reactance, Impedance and Resonance

(Page 4-19)

Reactance

Capacitors and Inductors resistance to the flow of ac current is called reactance (X) measured in ohms (Ω) [G5A02, G5A03, G5A04, G5A09].

Capacitors and Inductors store and release energy in the circuit.

Capacitors store energy in an electric field.

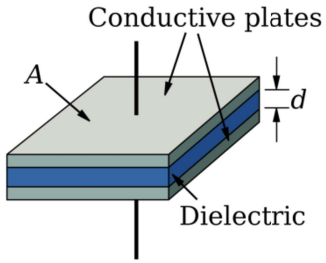
Inductors store energy in a magnetic field.

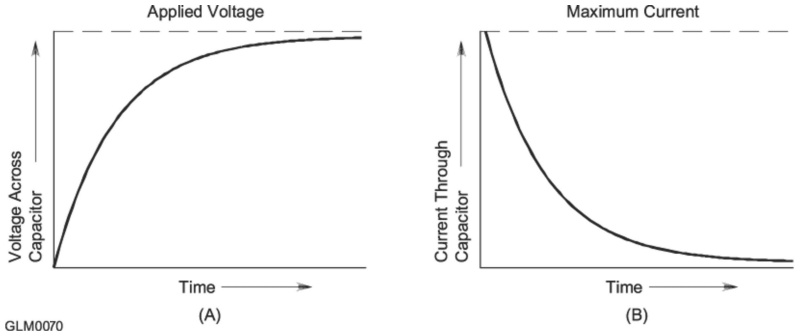
4.4 Capacitive Reactance

(Page 4-20)

Capacitor

Capacitor behavior as an initial dc voltage is applied





A capacitor blocks dc current, resists low frequency ac current and passes high frequency ac current.

The opposition to ac current flow from the stored energy in a capacitor is called capacitive reactance denoted as X_C.

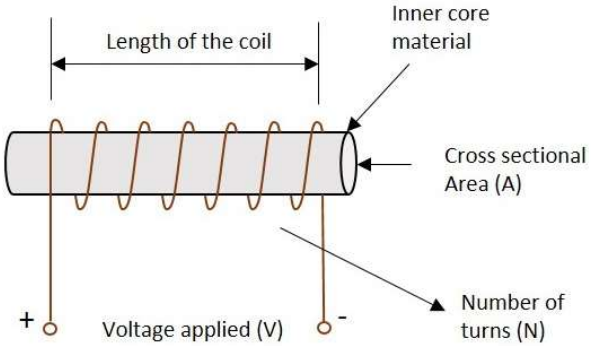
$$Xc = \left(\frac{1}{2\pi fC}\right)$$ Where f = frequency in Hz and C = capacitance in farads

As the frequency of a signal increases capacitive reactance decreases and vice–versa [G5A06].

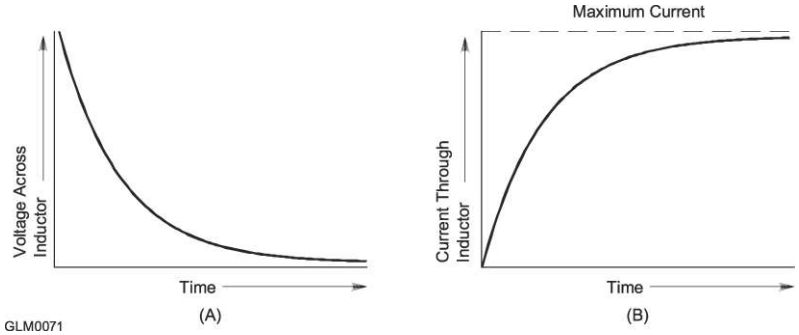
4.4 Inductive Reactance

(Page 4-21)

Inductor



Inductor behavior as an initial dc voltage is applied



An inductor blocks high-frequency and passes low-frequency ac currents.

The opposition to ac current flow from the stored energy in an inductor is called inductive reactance denoted by X_L.

$X_L = 2\pi fL$ Where f = frequency in Hz and L = inductance in henrys

As the frequency of a signal increases inductive reactance increases and vice–versa [G5A05].

4.4 Parasitic Inductance and Capacitance

(Page 4-22)

Parasitic means an unwanted characteristic resulting from components physical construction.

The wire leads on components can add some inductance to the part. The spacing between wires on a circuit board can add capacitance. The gap between the wires in a coil have capacitance. In an RF circuit (or high-speed computers) these characteristics can alter the operation of the circuit.

All inductors and capacitors have some amount of resistance with their reactance. Components placed close together on a circuit board will interact with each other.

Good designs will consider this effect and take steps to make sure that the interaction will not alter the operation of the circuit at the intended operational frequencies. Spacing sensitive components farther away from noisy areas is one way. Metal shielding can reduce noise coupling between parts. Placing ground planes or traces between PCB traces is another possible solution.

4.4 Impedance and Resonance

(Page 4-23)

Impedance and Resonance

G5A01 – What happens when inductive and capacitive reactance are equal in a series LC circuit?
Resonance causes impedance to be very low.
G5A07 – What is the term for the inverse of impedance?
Admittance.
G5A08 – What is impedance?
The ratio of voltage to current.
G5A10 – Which of the following devices can be used for impedance matching at radio frequencies?
All these choices are correct.
G5A11 – What letter is used to represent reactance?
X.
G5A12 – What occurs in an LC circuit at resonance?
Inductive reactance and capacitive reactance cancel.

4.4 Impedance and Resonance

(Page 4-23)

Impedance and Resonance

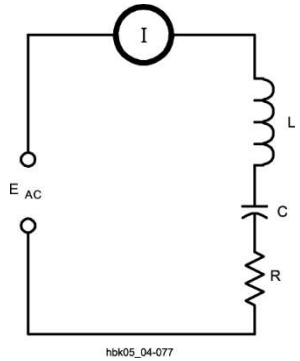
G5C07 – What transformer turns ratio matches an antenna's 600-ohm feed point impedance to a 50-ohm coaxial cable?
3.5 to 1.
G6A11 – What happens when an inductor is operated above its self-resonant frequency?
It becomes capacitive.
G7C03 – What is one reason to use an impedance matching transformer at a transmitter output?
To present the desired impedance to the transmitter and feed line.

4.4 Impedance and Resonance

(Page 4-23)

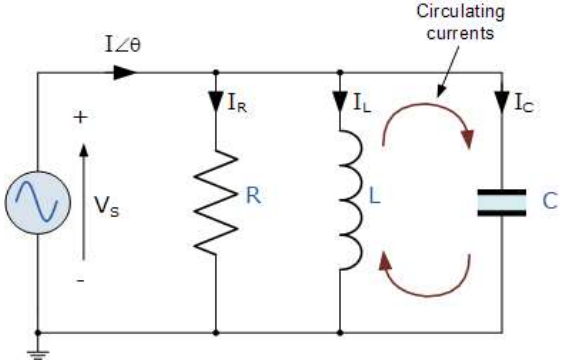
Resonance in a circuit or antenna is the condition in which the XC and XL are equal and cancel each other out.

Series Resonance



Circuit resistance is at a minimum

Parallel Resonance



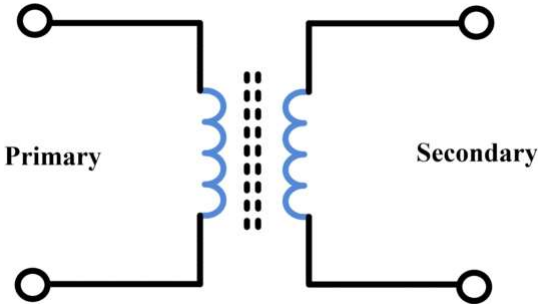
Circuit resistance is at a maximum

Resonance is useful in filters and tuning circuits to select or reject specific frequencies.

4.4 Impedance Transformation

(Page 4-24)

Transformers are used to change the ratio of voltage and current while transferring energy. This change causes the impedance between the primary and secondary of the transformer to be changed or "transformed".



$\sqrt{(Z_p/Z_s)} = N_p/N_s$ [G5C07]

Np/Ns is defined as the turns ratio of the transformer and is always expressed as the larger vs the smaller number, i.e. 5:1.

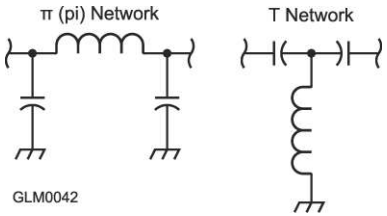
Remember – the secondary can have more turns than the primary, but the ratio will be "larger:smaller". When the secondary has more turns, we are trying to go from lower to higher Z.

4.4 Impedance Matching

(Page 4-24 to 4-25)

Maximum Power Transfer Theorem states that maximum power is transferred when the source and load impedances are equal and purely resistance.

Transmitter and Antenna impedances typical are 50Ω but antenna impedance usually varies as the operating frequency changes.



An impedance-matching network (pi or T Network, adjustable or fixed component) can be used to maintain the desired impedance match.

- Specialized RF impedance transformers may also be used.
- Special lengths and connections of transmission line can also perform impedance matching.

What is reactance?

[G5A02]

A. Opposition to the flow of direct current caused by resistance
B. **Opposition to the flow of alternating current caused by capacitance or inductance**
C. A property of ideal resistors in AC circuits
D. A large spark produced at switch contacts when an inductor is de-energized.

Resistors, Capacitors and Inductors all oppose current flow but do it in different ways. Impedance is Z = R ± j.
Resistors oppose current with resistance "R" only, whether AC or DC.
Capacitors and Inductors oppose current flow by their reactive component of impedance. "± j"
Capacitors want to control/stabilize the voltage.
Inductors want to control/stabilize the current.

Which of the following devices can be used for impedance matching at radio frequencies?

[G5A10]

A. A transformer
B. A Pi-network
C. A length of transmission line
D. **All these answers are correct**

This question is easy to get wrong because any of the three suggested devices will do impedance matching. It depends on the situation as to which one is the best choice. The RF transformer can work over a range frequencies and is used for antenna to coax matching in many installations. The Pi-network is good inside a radio or tuner but is frequency limited if discrete components are used. A length of transmission line can work best outdoors and is easier to protect from weather but is frequency limited by design of the fixed length.

Which of the following describes one method of impedance matching between two AC circuits?

[G5A11]

A. **Insert an LC network between the two circuits**
B. Reduce the power output of the first circuit
C. Increase the power output of the first circuit
D. Insert a circulator between the two circuits

This is a standard way to match RF circuits and radios to an antenna. Many antenna tuners use LC network (Pi or T) to interface the antenna to the radio.

What happens when an inductor is operated above its self-resonant frequency?

[G6A11]

A. Its reactance increases
B. Harmonics are generated
C. **It becomes capacitive**
D. Catastrophic failure is likely

This is not an easy question. Self-resonance is when the component's expected reactance is equal to the parasitic reactance. The component will look like an open or short circuit at the self-resonant frequency. But above this frequency, the parasitic reactance will switch from inductive or capacitive to the opposite type. Meaning that an inductor will look like a capacitor above its self-resonant frequency. A capacitor will look like an inductor above its self-resonant frequency. This can cause significant problems with a RF circuit and should be avoided.

Chapter 4 Active Components

4.4 Reactance, Impedance and Resonance
4.5 Active Components
4.6 Practical Circuits
4.7 Basic Test Equipment

4.5 Active Components

(Page 4-23)

Semiconductor Components

G6A03 – What is the approximate junction threshold voltage of a germanium diode? 0.3 Volts.
G6A05 – What is the approximate junction threshold voltage of a silicon diode? 0.7 Volts.
G6A07 – What are the operating points for a bipolar transistor used as a switch in a logic circuit? Saturation and Cutoff.
G6A09 – Which of the following describes the construction of a MOSFET? The gate is separated from the channel by a thin insulating layer.

Component Schematic Symbols

(Page 4-9)

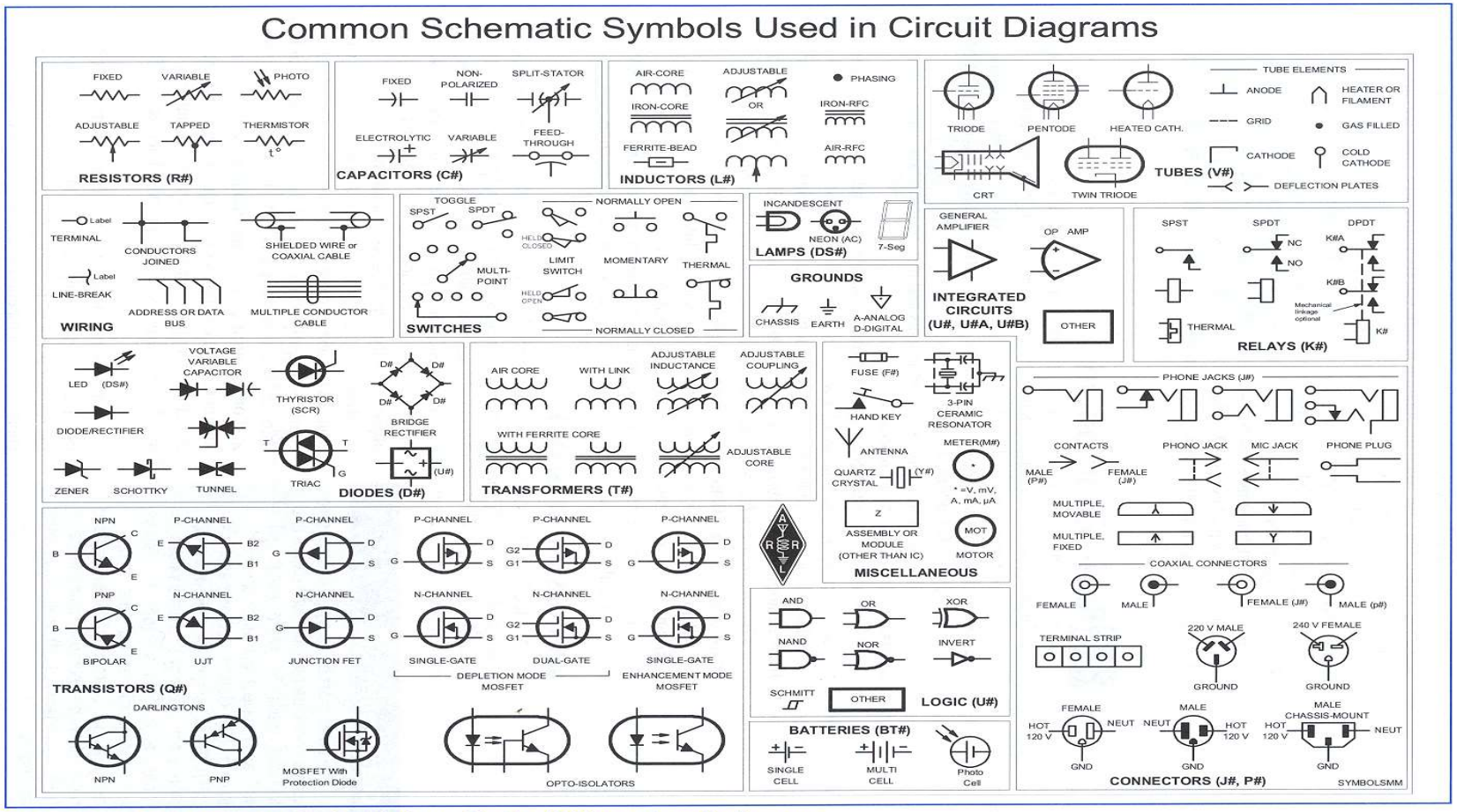


Figure 4-4 — These are the standard symbols used by the ARRL on schematic diagrams.

Semiconductor Components

(Page 4-25)

Active components are used to amplify, switch, shape or otherwise process a signal. They usually require power and may have passive components inside them.

Materials that conduct electricity better than an insulator but not as good as metal like Silicon (Si) and germanium (Ge) devices are examples of semiconductors.

The electrical properties of semiconductors can be controlled by the addition of small amounts of indium (In) and phosphorus (P). The addition of these dopant impurities is called doping.

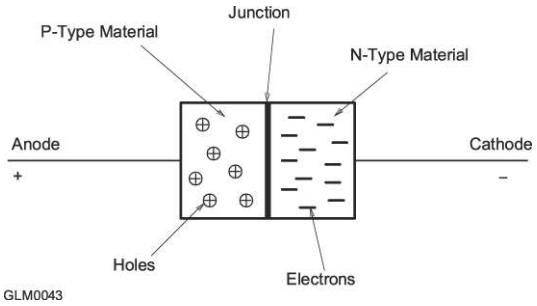
Material high in electrons results in a N-type material, otherwise the impurity creates a P-type material which has holes that will easily accept electrons.

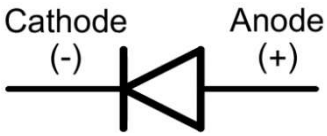
Semiconductors are created from the combination of N-type and P-type material. Where they are in contact a PN junction is formed.

Diodes and Rectifiers 1 of 2

(Page 4-26)

A semiconductor **junction diode** uses a PN junction to **block** current flow in one direction and **allow** current flow in the opposite direction.





** Symbol is reversed from drawing above

- Current flows when a positive voltage is applied from the P-type to the N-type material and is called **forward bias.**
- Voltage applied in the reverse direction is called **reverse bias.**
- The diodes forward bias must exceed the **junction threshold voltage (V_f)** to conduct.
- (V_f) is 0.7 V for silicon and 0.3 V for germanium [G6A03, G6A05]

Diodes and Rectifiers 2 of 2

(Page 4-26)

Diode Ratings and Parameters

- Peak inverse (or reverse) voltage (PIV) – The maximum reverse voltage that may be applied before reverse breakdown occurs.
- Average forward current (I_F) – Limit for the power dissipation, I_F x V_F, of the diode.
- Junction capacitance (C_J) – Affects the operation of the diode at high frequencies and it's switching speed.

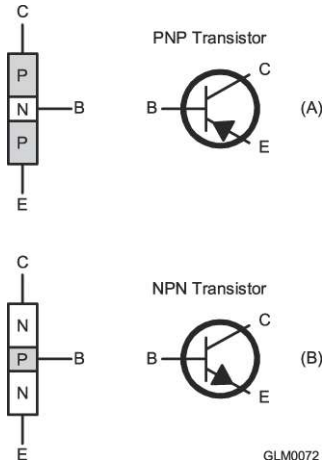
Types of Diodes

- *PIN diode* – conducts ac signals with a low forward voltage drop, used for RF switching and control.
- *Schottky diode* – low junction capacitance allows operation at high frequencies
- *Varactor diode* – the reverse-biased junction acts as a capacitor and is used as a variable capacitor by changing the reverse voltage.
- *Zener diode* –used as a voltage regulator while in reverse breakdown.
- *Rectifiers* – high-power (current, voltage and power dissipation) devices.

Bipolar Transistors

(Page 4-27)

Bipolar transistors are made from P- and N-type material and use current to control their operation. Bipolar transistors have three electrodes – Base, Collector and Emitter.



- The base-emitter current (a low value) controls the amount of current flowing between collector and emitter.
- The control of a large current by a smaller current is called amplification.
- The ratio of collector-emitter current to base-emitter current is called current gain.
- Current gain for DC signals is represented by the symbol β (Beta).
- Current gain for AC signals is represented by the symbol h_{FE}.

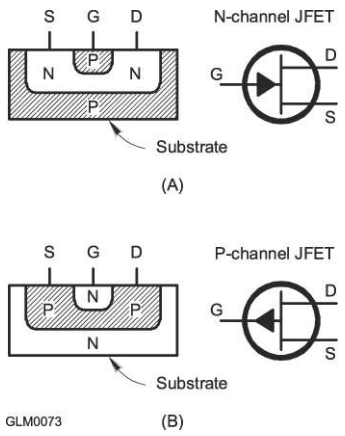
Switching

A transistor amplifier may be used as a switch by biasing it between two states; saturation (on) and cutoff (off) [G6A07]

Field-Effect Transistors (FET)

(Page 4-27)

FET transistors are made from P- and N-type material and use voltage to control their operation. FET transistors have three electrodes – Gate, Drain and Source.



- The gate-source voltage controls the amount of current flowing between source and drain.
- Instead of current gain, the FET has transconductance (gM) – the ratio of source-drain current to gate-source voltage.
- Junction FET (JFET) – constructed with the gate material in direct contact with the material that connects the source and drain electrodes.
- Metal-oxide-semiconductor FET (MOSFET) or the insulated-gate FET (IGFET) - have an insulated layer of oxide between the gate and the rest of the transistor [G6A09].
- JFET's and MOSFET's are highly sensitive.

Active Components

* Chapter 4.5

4.5 Active Components

(Page 4-25)

Vacuum Tubes

G6A10 – Which element of a triode vacuum tube is used to regulate the flow of electrons between the cathode and plate?

Control grid.

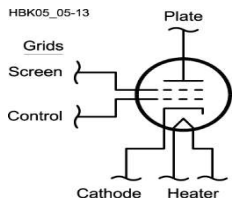
G6A12 – What is the primary purpose of a screen grid in a vacuum tube?

To reduce grid-to-plate capacitance.

Vacuum Tubes

(Page 4-27 to 4-28)

The vacuum tube is the oldest device capable of amplification and is still used in high-power audio and RF amplifiers. Tubes are similar in operation to FET transistors because both devices are controlled by **voltage** [G6A12].



A vacuum tube has 3 basic elements:

- A source of electrons
- An electrode to collect electrons
- Intervening electrodes that control the electrons traveling from the source to the collector
- Tube types are; diode – two elements, triode – three elements, and tetrode – four elements, and so forth.

Vacuum Tubes

(Page 4-28)

- **Filament or Heater** – heats the cathode causing it to emit electrons.
- **Cathode** – (-V)source of electrons.
- **Control grid** – is the grid closest to the cathode and is used to regulate electron travel between the cathode and plate. [G6A10] Also the input for the tube.
- **Screen grid** – is the electrode that reduces the control grid-to-plate capacitance and that diminishes the tube's ability to amplify at high frequencies. [G6A12].
- **Suppressor grid** – an electrode that prevents electrons from traveling from the plate to the control/screen grid.
- **Plate** – the electrode that collects electrons, called plate current (+V). Also is the output of the tube.

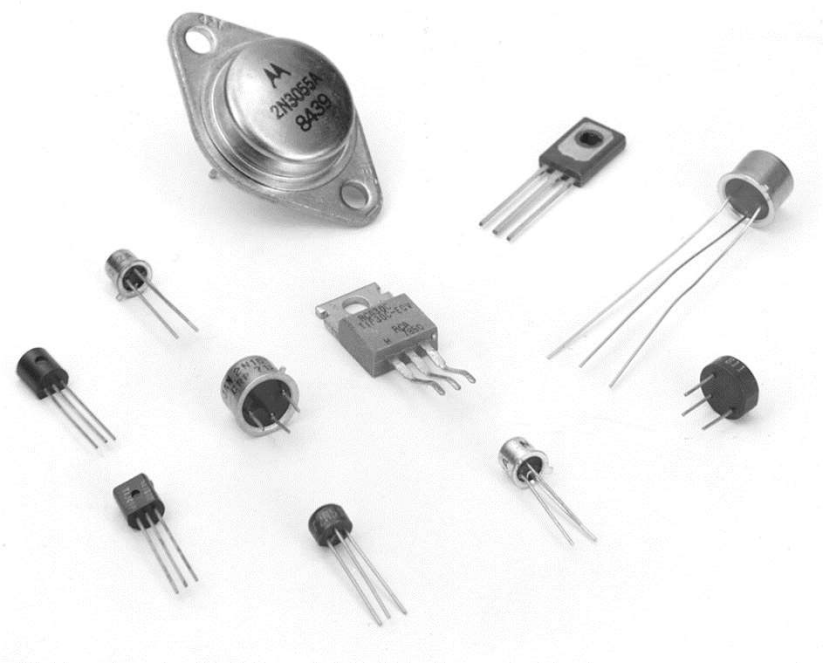
Vacuum Tube Amplifiers

Tubes are commonly used devices in RF power amplifiers and high-power audio amps.

The high voltages in vacuum tube amplifiers require special safety precautions to prevent electrical shock.

Transistor Package Types

(Page 4-29)



- Identified with a package numbers beginning with “TO” (for Transistor Outline).
- Typical package types are TO-3, TO-92 and TO-220.
- Low power devices have insulated plastic packages.
- Power transistors that have metal cases which are direct connected to collector or source. The case may need to be insulated from the heat sink they are mounted on.

Analog and Digital Circuits

(Page 4-29)

Semiconductor Components

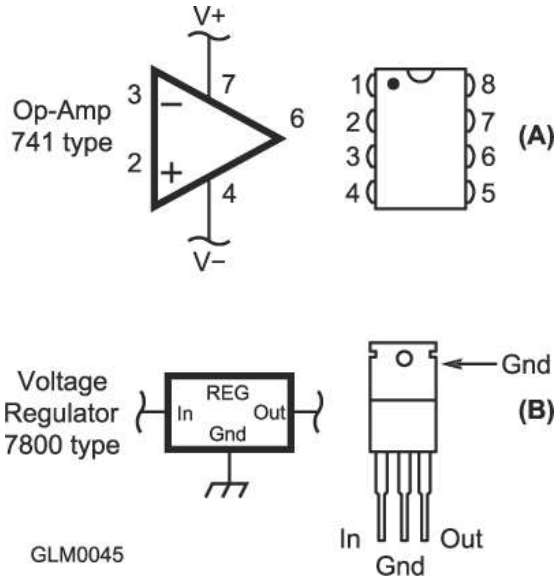
G6B02 – **What is meant by the term MMIC?**
Monolithic Microwave Integrated Circuit.
G6B03 – **Which of the following is an advantage of CMOS integrated circuits compared to TTL integrated circuits?**
Low power consumption. (TTL is old technology today, CMOS is current.)
G6B06 – **What kind of device is an integrated circuit operational amplifier?**
Analog.
G7B03 – **Which of the following describes the function of a two-input AND gate?**
Output is high only when both inputs are high.
G7B05 – **How many states does a 3-bit binary counter have?** 8
G7B06 – **What is a shift register?**
A clock array of circuits that passes data in steps along the array.

Analog and Digital Integrated Circuits

(Page 4-29 to 4-30)

Integrated circuits (IC) have many transistors, diodes, resistors, capacitors and other devices on a silicon chip.

Two common types of IC are; analog (or linear) and digital (or logic)



- Analog circuits are used for signal processing that includes; amplification, filtering, measurement and power control.
- We might know the analog IC more by the common name of "op amp" or operational amplifier. [G6B06]
- Linear voltage regulators maintain power supply voltage for a range of output currents.

Analog and Digital Integrated Circuits

(Page 4-30 to 4-31)

- Digital IC perform logic using two states. (1/0, H/L, True/False - these are called binary logic states)
- Digital IC exist in logic families sharing common operation aspects; TTL and CMOS are the most common like AND, OR and NOT.
- The Complimentary metal-oxide semiconductor (CMOS) digital IC is the most popular because of its low power consumption. [G6B03]

Digital Logic Basics

(Page 4-30 to 4-31)

The basic logic building blocks for digital logic gates are AND, OR and NOT.

There are several combinations of the basic functions that we use in computer chips.

Flip-flop circuits combine binary signals in a way that depends on a clock signal and sequence of the inputs creating what is called sequential logic.

Counters and shift registers are created by connecting one flip-flops output to the next one's input.

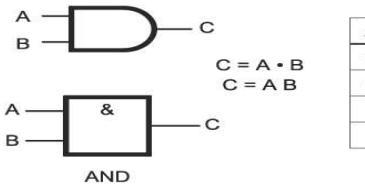
The highest number that a counter can represent is 2N where N is the number of flip-flops in the counter. [G7B05]

Shift registers pass or shift their input value to the next flip-flop triggered by the clock signal. [G7B06]

Digital Logic Basics

(Page 4-30 to 4-31)

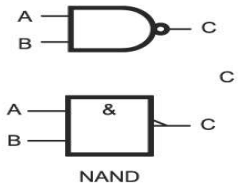
Logic Symbol | **Boolean Equation** | **Truth Table**



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

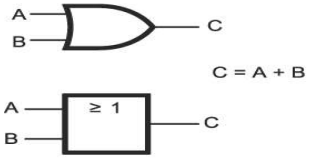
Two-input AND gate
(A)

Logic Symbol | **Boolean Equation** | **Truth Table**



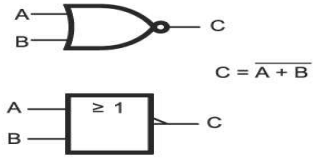
A	B	C
0	0	1
0	1	1
1	0	1
1	1	0

Two-input NAND gate
(D)



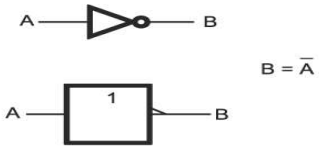
A	B	C
0	0	0
0	1	1
1	0	1
1	1	1

Two-input OR gate
(B)



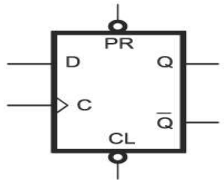
A	B	C
0	0	1
0	1	0
1	0	0
1	1	0

Two-input NOR gate
(E)



A	B
0	1
1	0

Inverter
(C)



X=1 or 0

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

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

(F)

GLM0046

RF Integrated Circuits

(Page 4-32)

RF integrated circuits (IC) are designed to perform functions at RF frequencies such as:

- Low level high gain amps
- Mixers
- Modulators
- Demodulators
- Filters

RF ICs greatly reduce the number of discrete components and board level connections reducing cost and improving reliability

Monolithic Microwave Integrated Circuits (MMIC) modules are used at microwave frequencies [G6B02]

Devices like cell phones, GPS receivers and wireless products use MMIC modules.

Microprocessors and Related Components

(Page 4-32)

Microcontrollers (MCU) are a special type of microprocessor with flash program memory, RAM memory, digital and analog circuits (timers, PWM circuits, DAC, ADC) serial communications and I/O ports (Arduino UNO)

- More widely known microprocessors (MPU) would be the CPU in your computer or laptop from Intel, AMD and other MPU makers (Raspberry Pi)
- MPU and MCUs can execute millions of instructions per second from Flash or RAM memory and store the intermediate data in RAM memory.

Microprocessors require memory to store the programs for execution.

- Volatile memory loses data it stores when power is removed
- Non-volatile memory stores data permanently even if power is removed.
- Random-access memory (RAM) can be read from or written to in any order
- Read-only memory (ROM) stores data permanently and cannot be changed.
- Flash and SRAM memory is the industry standard today for most MCUs.

Data Interfaces (1 of 2)

(Page 4-32)

Microprocessors and computers use two type of interfaces for communicating with the outside world, serial and parallel

Interface	Typical Speed
RS-232	115 Kbit/sec
USB 1.1	1.5 Mbits/sec
USB 2.0	480 Mbits/sec
USB 3.0	5 Gbits/sec
Firewire	800 Mbits/sec

Serial interfaces (COM Ports) transfer one bit of information in each transfer operation

- USB ports are now replacing COM ports on computers
- Serial to USB converters are required for many applications
- USB-C is the physical connector and USB 3 is the electrical signal. This is the latest technology and it can move large amounts of data quickly.

Data Interfaces (2 of 2)

(Page 4-32)

USB and serial interfaces are used to connect computers to transceivers and TNC's as well as accessories such as antenna switches and rotors.

Parallel interfaces used to connect memory to the MPU/MCU, or the CPU to hard drives and video cards. High speed serial interfaces are replacing the parallel interfaces today.

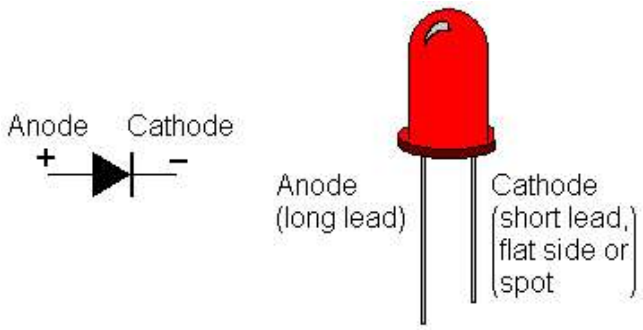
Network connections are serial interfaces:

- Ethernet, IEEE 802.3, 10/10/1000 Mb/s, wired
- WiFi, IEEE 802.11, wireless
- Bluetooth – for short distances (headsets, etc.)

Visual Interfaces (LEDs)

(Page 4-33)

Amateur radio equipment uses two types of devices to present information visually; indicator and display.



- An indicator is a device that presents ON/OFF information visually by presence/absence/color of light.
- Common indicators are incandescent lights or LEDs.
- An LED is a diode made from special types of material that emit light when the PN junction is forward biased [G6B08].
- LED's last longer than light bulbs, can be turned on/off quicker, use less power and generate less heat.

Visual Interfaces (LEDs)

(Page 4-33)

The liquid crystal display (LCD) is created by sandwiching the liquid crystal fluid between transparent glass panels that have transparent circuits put on the glass to make the LCD operate.

LCD panels need ambient light or a back light since the LCD does not generate any light on its own.

A low power LCD will use reflected light (ambient light) to show the digits and icons on the display.

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

G6A12

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

This is a technical question about how a tube with 4 or more electrodes works. Remember these tubes will have Cathode, Control Grid, Screen Grid(s) and Plate. The screen grid helps the tube limit its ability to amplify high frequency signals. In other words, it provides more control over the tubes operation to keep it from becoming an oscillator, which would likely destroy the tube.

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

G6A07

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

In a switch, you are trying to have the transistor fully turned on or fully turned off. This dissipates the least amount of heat when ON and has the least amount of leakage when OFF.

Which of the following describes the construction of a MOSFET?

G6A09

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

Remember the picture of a MOSFET, like a long john doughnut. It is built in a planar fashion with the Gate sitting on the top of the Source to Drain channel. Most MOSFET parts are built as Enhancement Mode (need Gate voltage to turn ON) but there are Depletion Mode devices (need Gate voltage to turn OFF).

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

G6B03

A. **Low power consumption**
B. High power handling capability
C. Better suited for RF amplification
D. Better suited for power supply regulation

CMOS technology is used for most of the electronic parts built today and some of the other answers can be confusing. It helps if you understand that the question is dealing with only IC parts like logic gates.

Remember that CMOS circuits and either fully ON or fully OFF with voltage (but use very little current) so the power consumption answer is the correct one. CMOS circuits mainly draw power when they are in the process of switching states.

What kind of device is an integrated circuit operational amplifier?

G6B06

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

Key word in the question is amplifier so Analog is the right choice. Operational amplifiers are commonly used in microphones and sensors – voltage, current, capacitance, inductance, resistance, light, temperature, pressure, and pH.

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

G6B05

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

ROM and Flash memories are examples of non-volatile memory. Power can be removed and the information is still stored in the memory device. This is done by an electron charge in the storage cell. For One Time Programmable devices this link is a fuse.

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

G6B09

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

This is a question that forces you to read all the answers. There are three answers that are characteristics pertaining to an LCD display.

4.6 Practical Circuits

(Page 4-33)

Rectifiers and Power Supplies

G7A01 – What is the function of the power supply bleeder resistor?
It discharges the filter capacitors when the power is removed.
G7A02 – Which of the following components are used in a power supply filter network?
Capacitors and Inductors.
G7A03 – Which type of the rectifier circuit uses two diodes and a center-tapped transformer?
Full-wave rectifier.
G7A04 –What is characteristic of a half-wave rectifier in a power supply?
Only one diode is required.

4.6 Practical Circuits

(Page 4-33)

Rectifiers and Power Supplies

G7A05 - **What portion of the AC cycle is converted to DC by the half-wave rectifier?**
180 degrees.
G7A06 - **What portion of the AC cycle is converted to DC by the full-wave rectifier?**
360 degrees.
G7A07 – **What is the output waveform of an unfiltered full-wave rectifier connected to a resistive load?**
A series of DC pulses (camel humps) at twice the frequency of the AC input.
G7A08 – **Which of the following is an characteristic of a switch-mode power supply as compared to a linear power supply?**
High frequency operation allows the use of smaller components.

Rectifiers and Power Supplies

(Page 4-34)

All equipment requires power from some sort of power source; battery, solar panel, AC line.

Handheld and mobile radios typically are powered by batteries.

Most ham equipment uses 13.8V DC power to operate. A power supply is needed to run off the household ac line.

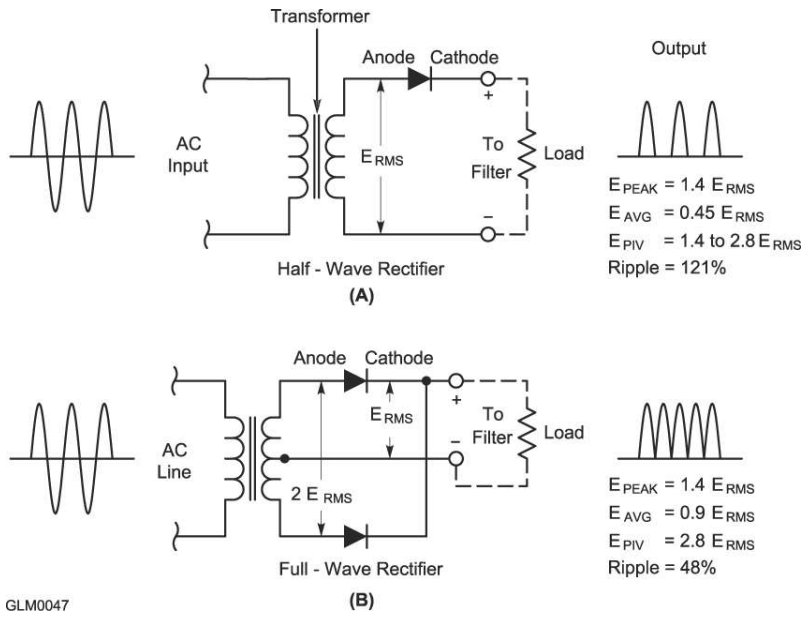
A basic power supply has three basic parts; an input transformer, a rectifier and a filter-regulator output circuit.

Power supplies that use a transformer, capacitor or inductor filters and linear voltage regulators to provide filtering and regulation are called linear mode power supplies.

Rectifier Circuits
Half-Wave and Full-Wave

(Page 4-34)

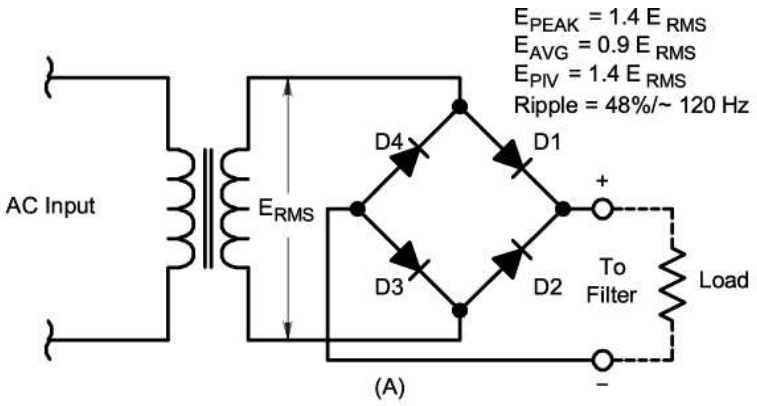
After the AC transformer, there will be a rectifier circuit that converts bipolar AC waveform into DC pulses.

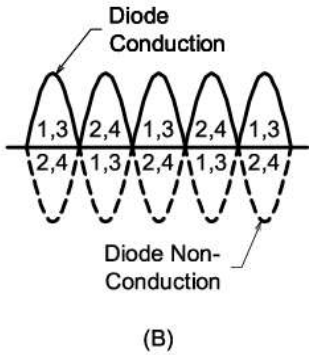


- Half-wave circuit transfers power only ½ of the time (180°) [G7A05]
- Only one diode is required in a half-wave rectifier [G7A04]
- The full wave rectifier advantage is that it produces output during the entire 360° of the AC cycle [G7A06]
- The output of the full wave rectifier is a series of pulses at twice the frequency of the input voltage [G7A07]
- A Full-wave center-tapped rectifier requires a transformer that has a center tap connection
- Full wave rectifier circuit uses two diodes and a center-tapped transformer [G7A03]
- A full-wave center-tapped circuit requires a transformer secondary voltage twice that of the half-wave circuit

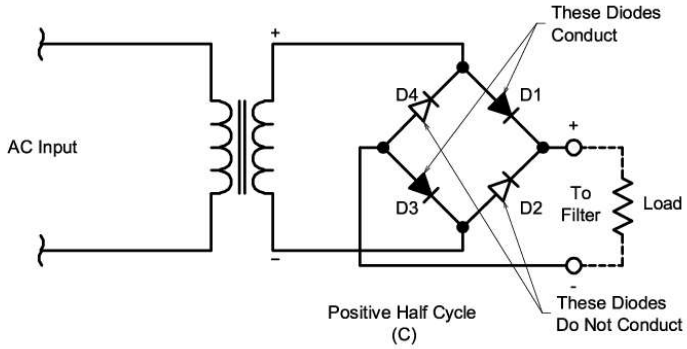
Rectifier Circuits
Full-Wave Bridge

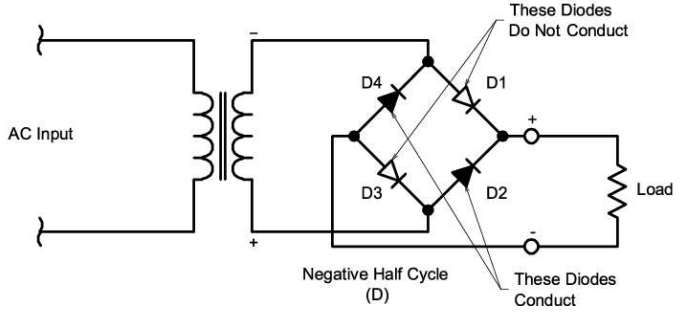
(Page 4-34)





- Bridge rectifiers do not need a center-tapped transformer
- Rectifier diode pairs supply half the load current as compared to the half-wave rectifier which has all the load.



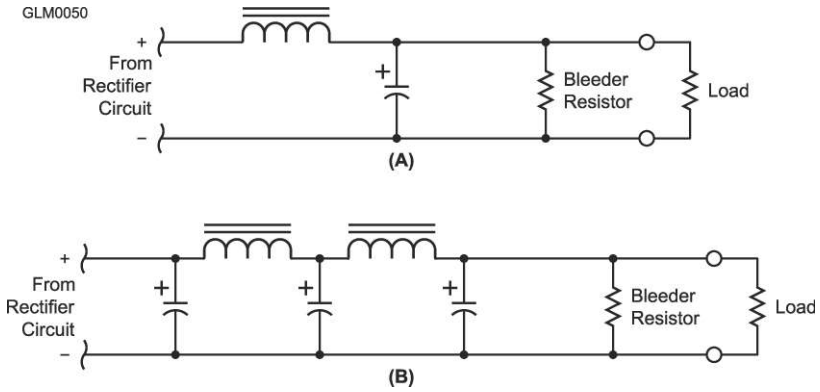


Power Supply Filter Circuits

(Page 4-35)

A rectifier's output pulses of DC current must be smoothed out by a filter network consisting of capacitors or capacitors and inductor for most electronics to work correctly. [G7A02]

The variation in output voltage caused by the current pulses is called ripple measured as the percentage of peak-to-peak variation as compared to the average output voltage.



- The most common way of reducing ripple is a large filter capacitor.
- Older high voltage supplies might use an inductor in the filter circuit along with 2 sets of filter capacitors.
- This is typically called a PI filter. π

The percentage variation in the output voltage between full-load and no-load is called the power supply's voltage regulation.

Power Supply Safety

(Page 4-33)

Safety is important in power supply design because of the connection to the AC line and because of the amount of energy involved.

Fuses are used in the AC line and the DC output circuits to protect against current overloads.

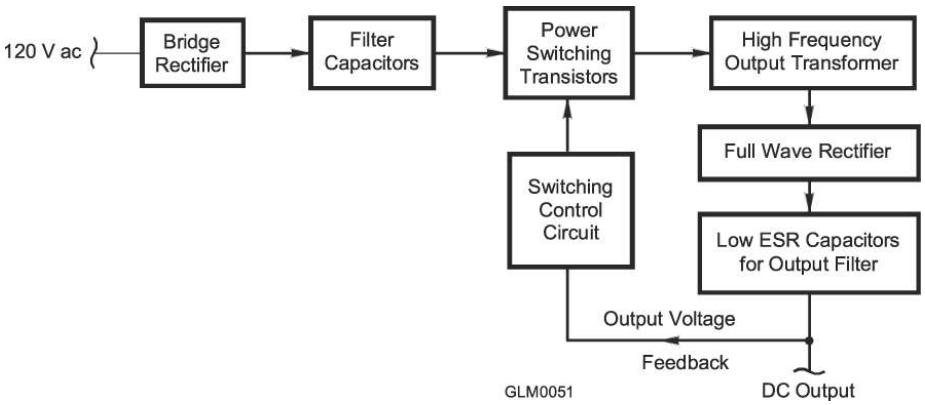
Bleeder resistors are used to discharge the stored energy in capacitors when AC power is removed. These resistors should not affect the operation of the power supply and will take some time to discharge the power supply.

Using a "cheater stick" is recommended when working on high voltage power supplies. This stick is a power resistor with clip leads and used to check that the that filter caps are discharged before working on a piece of equipment. Tube based radios and RF amplifiers use very high voltage supplies.

Switch-mode or Switching Supplies

(Page 4-36)

Switching regulator power supplies use high-frequency pulses of current to control the output voltage



- Uses a transistor switch to create a pulse frequency in the range of 20 kHz (can be higher frequency) from the 120 V ac line.
- Power supply reacts quickly to load demands.
- The high frequency means the smaller, light weight inductors and capacitors can be used to smooth the pulses and filter the output [G7A08]

Practical Circuits

* Chapter 4.6

4.6 Practical Circuits

(Page 4-37)

Batteries and Chargers

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

G4E09 – What is the approximate open-circuit voltage from a fully illuminated silicon photovoltaic cell? 0.5 VDC

G4E10 – What is the reason that a series diode is connected between a solar panel and a storage battery that is being charged by the solar panel?

To prevent discharge of the battery through the panel during times of low or no illumination (sunlight).

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

The solar panel must have a charge controller.

G6A01 – What is the minimum allowed discharge voltage for maximum life of a standard 12-volt lead-acid battery? 10.5V

G6A02 – What is an advantage of the low internal resistance of nickel-cadmium batteries? High discharge current.

Batteries and Chargers

(Page 4-37 to 4-39)

There are two basic types of batteries; primary (discard) and secondary (re-chargeable).

Larger secondary batteries (storage batteries) such as deep-cycle lead-acid marine or RV batteries can produce useful power down to about 10.5V.

Storage battery float voltage is 13.8 V.

NiCad (NiCd) batteries are designed to have a low internal resistance to supply high discharge currents. [G6A02]

Batteries are used in many ham radio products like 2M (144 MHz) and 70cm (440 MHz) radios. The battery packs are rechargeable and will operate the radio for many hours.

Alternative Power

(Page 4-39)

Alternative power sources:

- Generator (most often used)
- Solar
- Wind

Solar power is most often referring to photovoltaic conversion of sunlight to electricity. [G4E08]

Solar panels use many silicon PN junction cells to build the system.

Typically, the open-circuit cell voltage is about 0.5V for each cell. [G6E08]

A solar panel with a 12V output would be made up of at least 24 cells connected in series. Solar Cells in the panel are connected in parallel to generate higher power.

4.6 Practical Circuits

(Page 4-37)

Connectors

G2B04 – **What is the typical upper frequency limit for a low SWR operation of 50-ohm BNC connectors?** 4 GHz

G6B07 – **Which of the following describes a type N connector?**

A moisture-resistant RF connector useful to 10 GHz.

G6B11 – **What is an SMA connector?**

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

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

RCA Phono.

Connectors

(Page 4-37)

Connectors are a convenient way to make electrical connection by using mating electrical contacts.

Keyed connectors ensure that connectors can only go together one way, ensuring the correct connection.

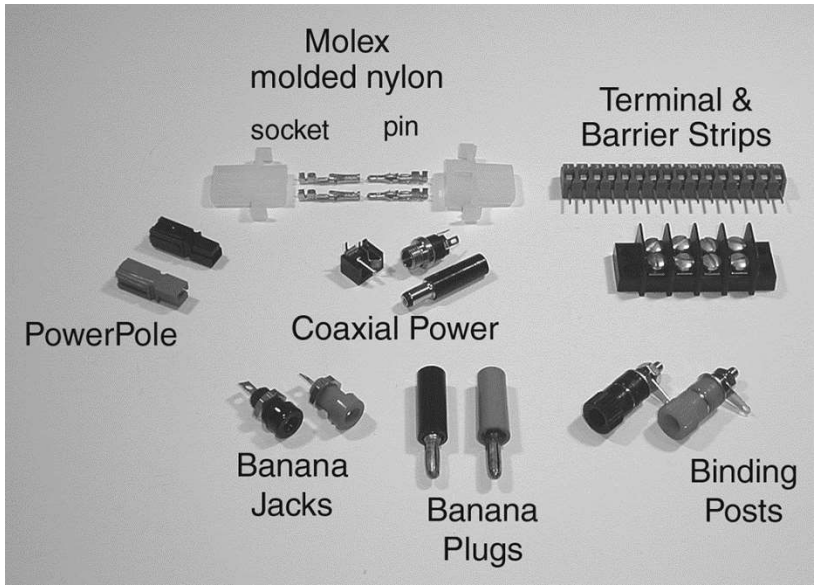
There are many examples of connectors on pages 4-40 and 4-41.

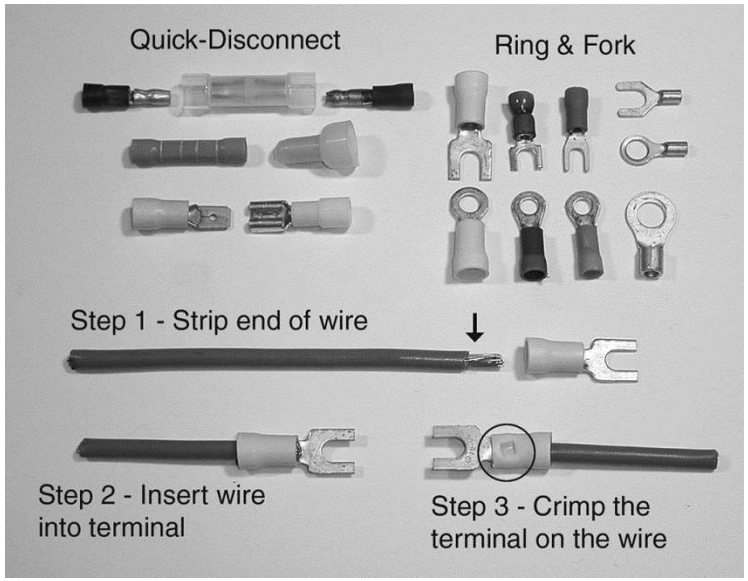
Power Connectors

(Page 4-40)

There are a large number of power connectors but Anderson PowerPole connectors for 12V units are the ARES and EMCOM preferred power connection because they are keyed and used widely.

Wall warts use a variety of barrel type connectors for lower power units.



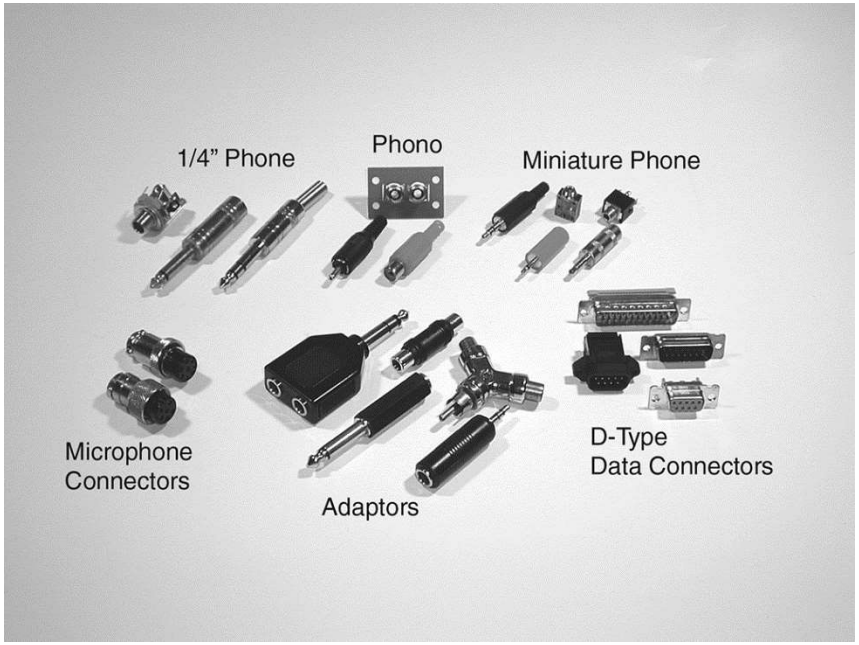


Audio and Control Connectors

(Page 4-41)

Phone plugs and jacks can be used for audio connections and come in sizes of ¼” and 1/8” typically. They consist of a tip, ring and sleeve.

Phono plugs and jacks (RCA connectors) are used for audio, video, low level RF and control signals. [G6B14]

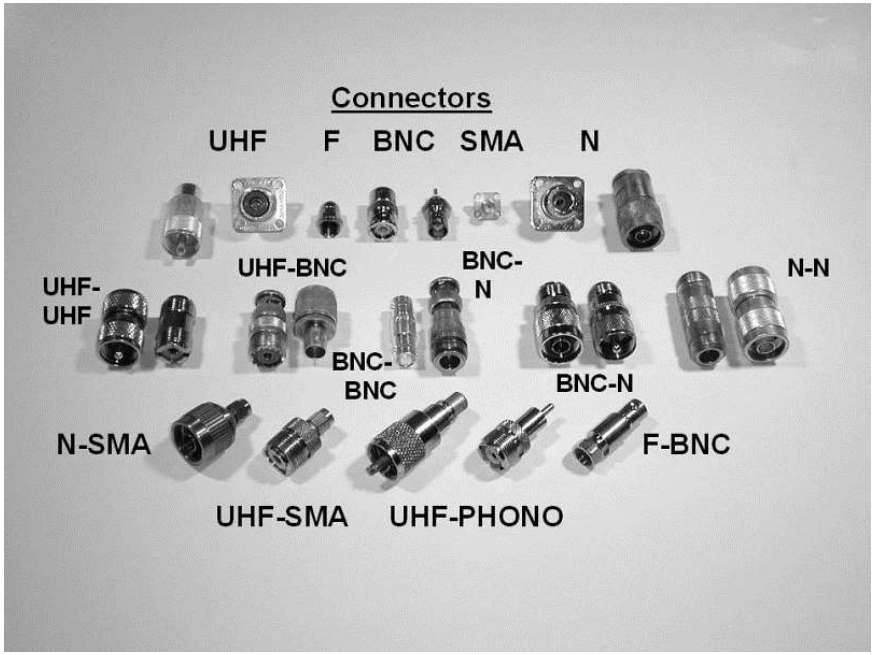


- DIN connectors are used for ham radios for digital mode, computer control of the radio and linear command/control interfaces and have up to 8 pins.
- Microphone connections can be 4 or 8 pin round connectors or eight pin RJ-45 on newer rigs.

RF Connectors

(Page 4-41 to 4-42)

The most common RF connector is the UHF family of PL-259/SO-239 style parts and can handle up to legal limit power on HF. [G6B13]



- UHF connectors are used up to 150 MHz but many radios use it for 70 cm operation also.
- N-type connectors are used for VHF and UHF applications because of better RF capability and lower return loss and can be used up to 10GHz. [G6B07]
- BNC connectors are used on oscilloscopes, test equipment and low power RF (handhelds).
- Handheld radios use the SMA connectors (up to 18GHz) for antenna connections. [G6B11]

Data Connectors

(Page 4-42)

D-type connectors were used for RS-232 (COM port) interfaces.

DB-9 and DB-25 (modem) connectors were common computer serial port connector, but DB-9 (serial port) and DB-15 (VGA display) are the only ones used much today.

USB connectors are more popular today but there are a number of styles of connectors that will not interchange with each other:

- USB Mini
- USB Micro
- Apple Lightning
- USB 3 Type C

Since serial com ports are not found on most new computers, USB to RS-232 to adapter cables are available.

Basic Test Equipment

* Chapter 4.7

4.7 Basic Test Equipment

(Page 4-42 to 4-43)

Basic Test Equipment (1 of 2)

G4B01 – **What item of test equipment contains horizontal and vertical channel amplifiers?** An oscilloscope.
G4B02 – **Which of the following is an advantage of an oscilloscope vs digital voltmeter?** Complex waveforms can be measured. (viewed)
G4B03 – **Which of the following is the best instrument when checking the keying waveform of a CW transmitter?** An oscilloscope.
G4B04 – **What signal source is connected to the vertical input of an oscilloscope when checking the RF envelop pattern of a transmitted signal?** The attenuated RF output of the transmitter.
G4B05 – **Why is a high impedance desirable for a voltmeter?** It decreases the loading on the circuit being measured.
G4B06 - **What is an advantage of a digital voltmeter as compared to an analog voltmeter?** Higher precision.

4.7 Basic Test Equipment

(Page 4-42 to 4-43)

Basic Test Equipment (2 of 2)

G4B09 – **When is an analog multimeter preferred to a digital multimeter?** When adjusting circuits for maximum or minimum values.
G4B10 – **Which of the following can be determined with a directional watt-meter?** Standing wave ratio (SWR)
G4B11 – **Which of the following must be connected to an antenna analyzer when it is being used for SWR measurements?** Antenna and feed line.
G4B12 – **What effect can strong signals from nearby transmitters have on an antenna analyzer?** Received power that interferes with SWR readings.
G4B13 – **Which of the following can be measured with an antenna analyzer?** Impedance of the coaxial cable.

Basic Test Equipment

(Page 4-43)

As you gain experience with radios, accessories and antennas, you'll find yourself needing to make simple checks and tests.

Volt-Ohm-Meter (VOM) is a great first piece of test equipment.

A SWR meter is a piece of equipment that you can use all the time in your operating station.

An Antenna Analyzer can used very useful if you are working on antennas or setting up an antenna.

Analog and Digital Meters

(Page 4-44)

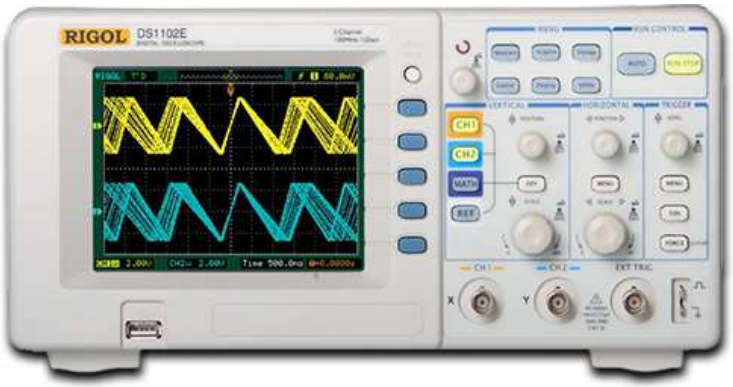
A VOM (volt-ohm-meter) is probably the first piece of test equipment most amateur's use.

- Analog and digital versions
- Digital multi-meter (DMM) can provide greater precision than analog meters. [G4B06]
- Analog meters are easier to read when adjusting a circuit. [G4B14]
- When measuring voltage, the meter should have a high input impedance (1M ohm or more) to minimize load on the circuit under test. [G4B05]

Oscilloscope Basics

(Page 4-41 to 4-42)

The oscilloscope is one of the most versatile pieces of test equipment available able to observe complex and fast changing waveforms that are beyond the ability of meters to measure. [G4B02]

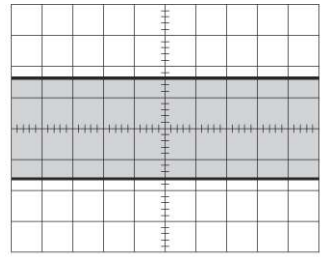


- External signals are connected to the horizontal and vertical amplifiers.
- An internal time base usually sweeps the electron beam along the horizontal axis (trace) at a highly stable calibrated rate so the scope can make accurate measurements of time and frequency.

Oscilloscope Waveform Monitoring

(Page 4 – 44)

A monitoring oscilloscope attached to the attenuated output of the transmitter is useful in seeing the quality of your signal and checking for modulation percentage, distortion and key clicks. [G4B04, G4B03]



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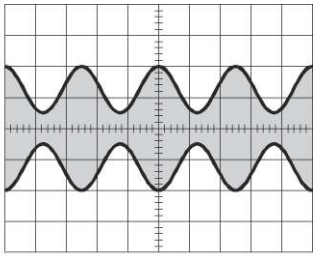
(A)



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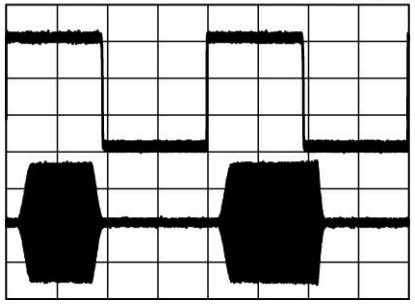

Impedance and Resonance Measurements

(Page 4-45)

An antenna analyzer is very useful when building or testing an antenna.

The analyzer can check for resonant frequency of the antenna without transmitting. [G4B11] (Some RF power is produced by the analyzer)

Other measurements capabilities are [G4B13]:

- Impedance (R +/-j)
- Standing Wave Ratio (SWR)
- Coax velocity factor
- Electrical length of a cable
- Resonant Frequency

Antenna analyzers use **small signals** to make measurements so they can be affected by strong RF signals. [G4B12]

Field Strength and RF Power Meters

(Page 4-45)

A field strength meter can be used for antenna efficiency and radiation pattern testing. [G4B09] The field strength meter can be affected by other RF signals.

A field strength meter can be used for comparative measurements during antenna and transmitter adjustments. [G4B08]

Directional wattmeter (SWR meter) is placed in the transmission line and measures the forward and reflected power. [G4B10]

SWR (standing wave ratio) can be calculated from forward and reflected power measurements using the following formula:

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

Thanks to:

* Information from:
  - The ARRL Library
  - ARRL General Class License Manual
  - Gordon West General Class License Class
  - Various websites