Amateur Radio Service General Class

Exam Preparation Class
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Session 3
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These slides are uploaded to my website

https://k7ojl.com/class-course-materials/general-class-course-materials/

just before class each week.

Depending on how the class goes, they may get updated after the class.

Questions from Last Week?

Any Issues with hamstudy.org?

Class Overview

- Computer Stuff
- Electrical Principles
- Circuits & Components
- Safety

Computer Stuff

Factoids

- Most modern transceivers have one or more **microprocessors** onboard
- The radio's basic setup is stored in **ROM** (read only memory)
- Computers operate in binary: 0's and 1's (on or off). All operations in a computer are performed using binary arithmetic
- A **Shift Register** in a computer is an array or circuits that passes data in steps along the array
- Most modern computers are **CMOS** based (complementary metal–oxide–semiconductor) rather than **TTL** (transistor-transitor logic) as CMOS uses significantly less power

"We can't replace your old computer. That would be age discrimination."

Computers have both "**volatile**" memory which erases when power is removed and "**non-volatile**" memory which persists

The microprocessors or micro controllers in the transceiver serve to replace complex circuitry for functions that can better be handled digitally

G7B06

Binary Truth Table

AND	OR	NAND	NOR	XOR
0 and 0 = 0	0 or 0 = 0	0 nand 0 = 1	0 nor 0 = 1	0 xor 0 = 0
0 and 1 = 0	0 or 1 = 1	0 nand 1 = 1	0 nor 1 = 0	0 xor 1 = 1
1 and 0 = 0	1 or 0 = 1	1 nand 0 = 1	1 nor 0 = 0	1 xor 0 = 1
1 and 1 = 1	1 or 1 = 1	1 nand 1 = 0	1 nor 1 = 0	1 xor 1 = 0

Binary 0's and 1's are represented in a computer by voltages. A '0' is represented by a voltage below a specific threshold and a '1' is represented by a voltage above a specific threshold.

The Truth Table indicates what the result is when combining two inputs through a type of a gate.

Five gate types are common: AND, OR, Negative AND, Negative OR, and Exclusive Or.

The test has two possible questions about the Binary Truth Table.

In the case of an AND gate, the output will be high (1) only when both inputs are high (1's)
In the case of a NOR gate, the output will be low (0) when either or both of the inputs are high (1's)

G7B03, G7B04

Bits, Bytes, and Words

Binary data is stored in the computer in "words". Depending on the computer and the type of processing, a word may be 3-8 bits in length (or longer).

|		
3 bits	0-7	8 States
4 bits	0-15	16 States
5 bits	0-31	32 States
6 bits	0-63	64 States
7 bits	0-127	128 States
8 bits	0-255	256 States

G7B05

Electrical Principles

Ohms Law

- All the equations in the diagram to the right are derived from the two Ohms Law equations:

$E = I * R$

$P = E * I$

- Most of the test questions will be about power (watts)
  - You may need a calculator capable of taking a square root of a number
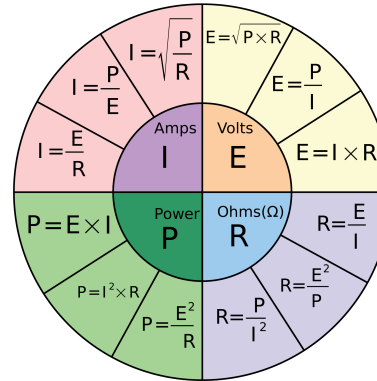

Be careful of questions in metric measurements (kilohms and milliwatts for instance). Convert to base units and then do the math, e.g., 1.25 kilohms = 1250 ohms or 7 milliamperes = .007 amperes

A Reminder

The RMS value of an AC signal produces the same power dissipation in a resistor as the DC voltage of the same value.

Multiply the peak voltage by 0.707 to obtain the RMS voltage.

A peak voltage of 80 volts AC would be the equivalent of 56.56 volts DC into a resistor.
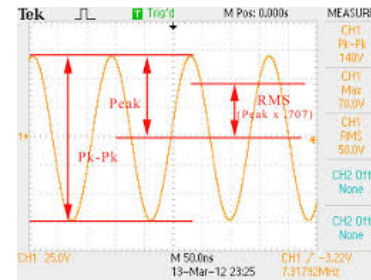
Peak to Peak voltage is twice the peak voltage. So, a sine wave with an RMS voltage of 120.0 volts would have 339.4 voltes peak to peak voltage.

PtP = 120.0/.707*2

G5B07, GB08, G5B09, G5B11,

What is the RMS voltage across a 50 ohm dummy load dissipating 1200 watts?

Known values:
Resistance of 50 ohms,
Power of 1200 watts

Unknown value: RMS voltage

G5B03, G5B04, G5B05, G5B06, G5B12. G5B13, G5B14

What is the RMS voltage across a 50 ohm dummy load dissipating 1200 watts?

Known values:
Resistance of 50 ohms,
Power of 1200 watts

Unknown value: RMS voltage

Formula:

E = Square Root (Power * Resistance)

$= \sqrt{(50 * 1200)}$

$= \sqrt{(60,000)}$

$= 244.948$

G5B12: E=I*R so E=I*50 In the formula P=I*E substitute E=I*50 so 1200=I^2*50 so I^2 = 1200*50 so I=$\sqrt{1200*50}$ = 244.948

G5B03, G5B04, G5B05, G5B06, G5B12. G5B13, G5B14

Peak Envelope Power

- The maximum power that an amateur radio station may emit is stated as PEP: Peak Envelope Power
- PEP is a calculated based on Ohms Law on power

Power = voltage squared divided by resistance

- In the case of alternating current (RF is alternating current at a very high frequency), the voltage is the Root Mean Square (RMS) of the peak power
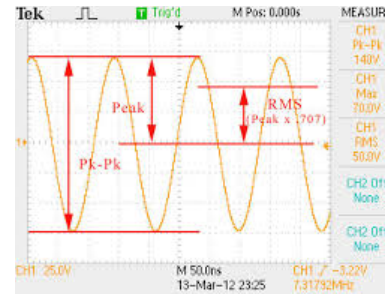
E = I * R   or I = E / R

P = I * E   or P = E / R * E or P = E^2 / R

What Is an Oscilloscope?

- An oscilloscope is a type of electronic test instrument that allows observation of varying signal voltages, usually as a two-dimensional plot of voltage over time
- Scopes usually have a horizontal and a vertical channel amplifier
- Used to visualize AM, CW, FM, SSB, and digital signals. Very complex wave forms can be displayed

To display a signal on a scope, connect the vertical channel to the attenuated output of the transmitter

An oscilloscope is the best instrument to use when checking the waveform of a CW signal

G4B01, G4B02, G4B03, G4B04

Voltage Calculations with an Oscilloscope

- The scope will measure peak-to-peak voltage
- Half of the peak-to-peak voltage is the peak voltage
- Peak Envelope Power can then be calculated as the Root Mean Square of the Peak Voltage divided by the Resistance
- RMS of alternating current is .707 * peak voltage squared
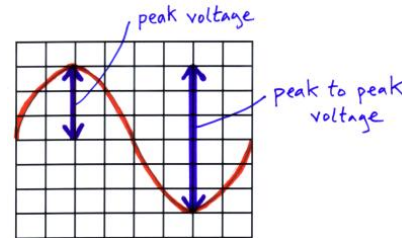
Ohms Law:
Power = Voltage^2 ÷ Resistance

G5B06: What is the PEP output from a transmitter that has 200 volts peak-to-peak across a 50 ohm dummy load?

Peak Voltage: 200 volts peak-to-peak divided by 2 = 100 volts

RMS Voltage: .707 * 100 volts = 70.7 volts

Power = 70.7 volts squared divided 50 ohms = 70.7 * 70.7 ÷ 50 = 99.96 rounded up to 100 watts PEP

Note: The ratio of peak envelope power (PEP) to average power for an unmodulated carrier is 0.707
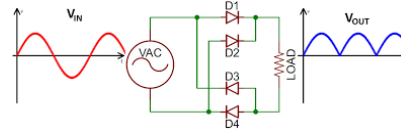
Rectifiers

- A **rectifier** converts alternating current to (pulsed) direct current
- Two major classes: **half-wave** & **full-wav**e
- A half-wave rectifier outputs half of the AC cycle where a full-wave rectifier outputs the full 360 degrees of the AC cycle
- The output of an unfiltered rectifier will be a series of DC pulses
  - From a half-wave: the input frequency
  - From a full-wave: twice the input frequency

G7A05, G7A06, G7A07

Half-wave
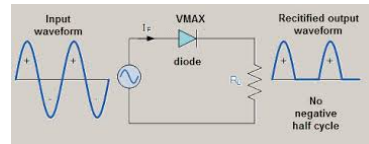
Full-wave

Peak Inverse Voltage refers to the maximum voltage a diode or other device can withstand in the reverse-biased direction before breakdown.

In a full-wave rectifier the PIV is equal to the normal peak output of the power supply.

In a half-wave rectifier the PIV is twice the peak output of the power supply

The advantage of a half-wave rectifier in a power supply is that only one diode is required

G7A04

Linear vs Switched Power Supplies

- In a l**inear power supply**, a large (heavy) transformer is used to isolate the rectifier from the input supply (and possibly to step up or step down the voltage going to the rectifier)

- In a **switched power supply** fast-switching transistor(s) (usually operating in the HF frequency range) replaces the transformer with a much lighter-duty transformer as well as replaces the diode(s).

- The advantage of switched mode power supplies is that they have **fewer and smaller components**. The disadvantage is that RF energy is also being generated. Switched mode power supplies are usually less expensive.

All "wall wart" power supplies are switched-mode power supplies and many imported wall warts have inadequate or non-existent RF filtering and consequently can be very noisy.

G7A08

A Full-Wave Rectifier

Unregulated Power Supply - Block Diagram

www.CircuitsToday.com
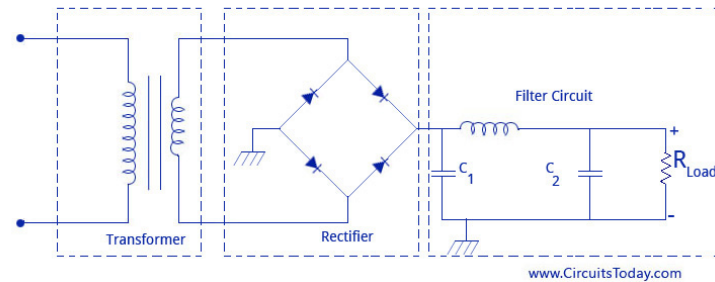
Capacitors C1 and C2 are part of the smoothing circuit and generally can give quite a shock after power is removed from the circuit. **Bleeder resisters** are put in the circuit to slowly discharge the capacitors when power is removed.

The filtering circuit on the right is made up of capacitors and inductors. Their purpose is to smooth out the pulsing DC coming from the rectifier circuit. The inductor initially opposes the incoming pulse forcing the capacitor C1 to charge. When the inductor reaches saturation, current passes. As the pulse decreases, the inductor opposition decreases and the C1 starts releasing its charge. C2 also charges and discharges as the output from the inductor still has some pulsing. The result is a fairly smooth DC current to the load.

C1 and C2 are "electrolytic capacitors" meaning they have a positive lead and a negative lead and may not be put backwards into the circuit as they will immediately short-circuit. The reverse voltage will destroy the dielectric layer and the capacitor will likely overheat and possibly explode. They are used because they have a much higher capacitance for a given volume (and consequently carry a pretty good voltage even after power is removed)

There is also a full-wave rectifier made up of two diodes and a center-tapped transformer

G7A01, G7A02, G7A03

Digital vs Analog VOM

Sometimes being able to see the needle swing on an analog meter helps to "feel" the way a part of a circuit is behaving. This is very useful for adjusting tuned circuits.

Digital meters generally offer better precision.

One important specification of a voltmeter (digital or analog) is the input impedance. High impedance means lower "loading" on the circuit being measured. That is, the meter has little or no effect on the circuit. The same is true for oscilloscopes.

G4B05, G4B06, G4B14

Batteries

- There are several different battery chemistries. Each has important differing characteristics
- **Lead acid batteries** are less expensive, less efficient, and are easily damaged if discharged too far. Minimum charge: 10.5 volts on a 12v battery
- Because **nickel-cadmium batteries** have low internal resistance, they have a high discharge current (don't short them!!), useful on transmit. They will self-discharge over time
- **Carbon-zinc** are the most common primary cell batteries. They may NOT be recharged … ever.

Lithium-iron-phosphate batteries (LiFePO 4) are the newest chemistry in general availability. They are quite light-weight and carry a very large charge for the size of the battery. They can be almost completely discharged without damaging the battery and provide a fairly constant voltage until the discharge point is reached. Improperly handled they will catch fire.

G6A01, G6A02

Solar Panels

- Solar cells convert sunlight to electrical energy through "**photovoltaic conversion**"
- A single solar cell will output about 0.5 VDC. A panel is made up a number of cells wired in parallel to increase the current and in series to increase the voltage
- A **diode** is connected between the solar panel(s) and the batteries to prevent the panels from discharging the batteries during darkness

G4E08, G4E09, G4E10

Wind Power, Anyone?

The biggest disadvantage is a larger energy storage system is required for periods when the wind isn't blowing.

G4E11

Mobile Power

- In a mobile transceiver installation, wire the power directly to the battery block

- Use 10 gauge wire

- Fuse both the positive and negative leads

- Do not try to power anything more than a 5-watt transceiver from the vehicle's auxiliary power socket (cigarette lighter) as that is not wired for the amperage the radio will draw

- Use keyed connectors in the power wiring in the car to prevent the chance for improper mating (which will definitely let the "magic smoke" out of the radio)

G4E03, G4E04

Circuits and Components

This circuit (a Hartley oscillator) will be in the test (without the red dots). You will be asked to identify one or more of the components on the diagram.
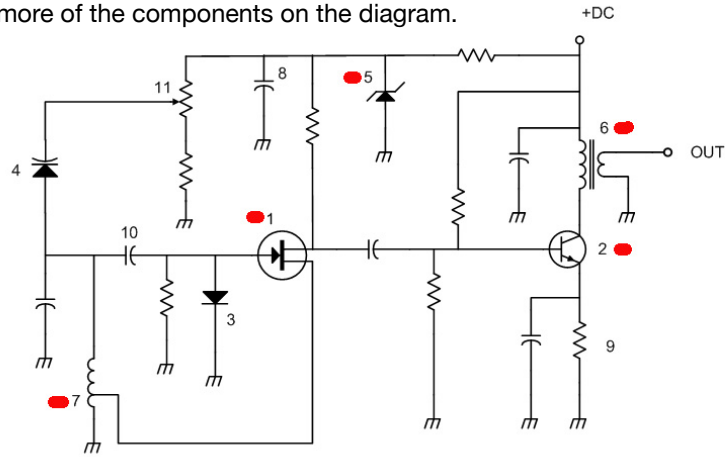
Figure G7-1

1: Field Effect Transistor

2: NPN Junction Transistor

3: Diode

4: Varactor   or Varicap

5: Zenier diode

6: Multiple-winding transformer

7: Tapped inductor

8: Capacitor

9: Resistor

10: Capacitor

11: Variable resister or potentiometer

G7A09, G7A10, G7A11, G7A12, G7A13

Resistors

- **Kirchoff's Current Law**: The total current is the sum of all currents in each branch; the total current entering and leaving the circuit must be the same
- Resistors in series add
- Resistors in parallel add as reciprocals
- Resistors may change value with temperature change. Check the "temperature coefficient rating"
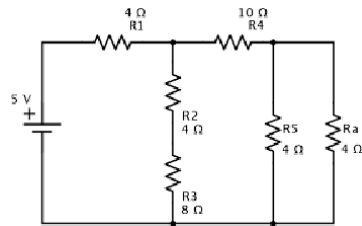
Resistances

$$R_{series} = R_1 + R_2 + \ldots R_n$$

$$R_{parallel} = \cfrac{1}{\cfrac{1}{R_1} + \cfrac{1}{R_2} + \cdots \cfrac{1}{R_n}}$$

$$R_{tot} = \frac{R_1 \cdot R_2}{R_1 + R_2}$$

Resistors can be formed from a variety of materials. The material used in a resistor may have an effect on the circuit. For instance, wire wound resistors should not be used in radio frequency circuits because the wire is shaped like an inductor and adds not only resistance to the circuit but also adds reactive resistance to the circuit.

G5B02, G5C03, G5C04, G5C05, G5C15, G6A06

How Much Current?

4 Ω
R1

10 Ω
R4

5 V

R2
4 Ω

R5
4 Ω

Ra
4 Ω

R3
8 Ω

Solve in steps from right to left.

Simplify the circuit for each step.

Finally apply Ohms Law as the voltage and resistance are now known.

Capacitors

- The formulas are the opposite of resistors
- **Electrolytic capacitors** are capable of handling large voltages and currents. They have a + and - lead and must be installed correctly or the capacitor will fail. They have the advantage of high capacitance for a given volume
- An advantage of **ceramic capacitors** is their small size and inexpensive cost
- Capacitors also have **reactance**, which is the opposition to the flow of AC

Series Capacitances

$$C_{total} = \cfrac{1}{\dfrac{1}{C_1} + \dfrac{1}{C_2} + \ldots \dfrac{1}{C_n}}$$

$$C_{Tot} = \frac{C_1 C_2}{C_1 + C_2}$$

Capacitors in Parallel

$$C_{Total} = C_1 + C_2 + C_3$$

Beware of questions that mix units of measure (picofarads and nanofarads). Get everything into base measurements

As the frequency of the applied AC increases, the reactance in a capacitor decreases (opposite of an inductor)

G5A04, G5A06, G5C08, G5C09, G5C12, G5C13, G5C17, G5C18, G6A04, G6A13, G6A14

Inductors

- **Inductance** is the opposition to the flow of alternating current measured in **Henries**
  - Inductance is a subclass of **reactance**
- As the frequency of the applied AC increases, the reactance increases
- Treat inductors like resistors when solving for inductance in a circuit
- If an inductor is operated above its self-resonant frequency it becomes capacitive
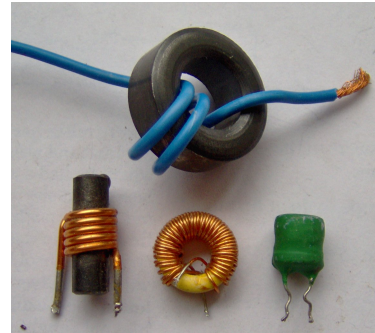
- The performance of a **ferrite core** at different frequencies is determined by the composition, or "mix" of materials used

G5A05, G5C10, G5C11, G5C14, G6A11, G6B01

Types of Inductors

- **Inductors** can be "air" wound, wound around a ceramic core, or wound around a **ferrite** (iron) core. Each has advantages and disadvantages
  - Inductors that need to be close to each other are placed at right angles so they don't influence each other
- Ferrite core inductors are often used because
  - Large inductance values can be achieved
  - The magnetic properties of the core can be optimized for specific frequency ranges
  - The magnetic field is primarily contained in the core thus reducing inductive influence on neighboring components

G6A08

Reactance

- **Reactance** is the general term for the opposition to the flow of alternating current caused by capacitance or inductance
- Reactance in capacitors and inductors varies with frequency
  - As the frequency increases, capacitive reactance decreases
  - As the frequency increases, inductive reactance increases
- Reactance is measured in **ohms** but denoted by the letter 'X'

The reactance of an inductor or a capacitor is a function of the frequency and the value of the inductor (in Henries) or the capacitor (in Farads).
For instance, to calculate the reactance of an inductor, the formula is:
reactance = 2 * pi * frequency * inductance
where the frequency is measured in Herz and the inductance is measured in Henries

The formula for the reactance of a capacitor is:
reactance = 1 / (2 * pi * frequency * capacitance)
where the frequency is measured in Hertz and capacitance is measured in Farads

G5A02, G5A03, G5A09

Filters

- **Filters** are used to attenuate unwanted signals and are made up of inductors (usually wound around a ferrite core) and capacitors
- Filter types include
  - **Bandpass**: Allows only a specific frequency range through, attenuates everything above and below half-power
  - **Low Pass**: Allows only signals below the **cutoff frequency** through, attenuates everything above
  - **High Pass**: Allows only signals above a frequency through, attenuates everything else
  - **Notch Filters**: Reduces interference from carriers in the receiver passband
- There is always some **attenuation** of signals within the pass band. This is called "Insertion Loss"
- A filter's maximum ability to reject signals outside its passband is called "**Ultimate Rejection**"

The impedance of a filter as compared to the impedance of the transmission line into which it is inserted should be about the same.

G4A01, G7C06, G7C14, G7C15, G7C12

Impedance

- Yet another measure of the opposition to the flow of alternating current and is measured in Ohms, but denoted by the letter 'Z'
- Impedance is calculated on the sum or difference of the resistance and reactance of either an inductor or a capacitor
- Impedance is usually measured at a circuit level to determine how to match one circuit to another
  - e.g., matching the transmitter's 50 ohms impedance to the antenna's impedance

The formula for calculating impedance is a complex number (part real, part imaginary):

$Z=R+jX$ (for primarily inductive circuits) or $Z=R-jX$ (for primarily capacitive circuits)

G5A01

Impedance Matching

- Matching is done to maximize the transfer of power from one circuit to another
- Matching can be accomplished by:
  - Place an inductor/capacitor (LC) circuit between the two networks (sometimes called a "**pi network**")
  - Attaching a length of transmission line (called a "**stub**")
  - Placing a transformer between the two networks
- Generally, an **antenna coupler** or **antenna tuner** is used to match the antenna system to the transmitter
- If the mismatch becomes large enough, RF energy may flow back to the radio on the outside of the coax. Putting an impedance in the current's path, such as a common mode choke, an "ugly balun", or ferrite beads at the point where the feed line joins the antenna will reduce or eliminate the RF energy flow

G4A06, G5A07, G5A08, G5A10, G5A11, G6B10

Transformers

- **Transformers** are two inductors parallel to each other such that mutual inductance transfers energy from one side to the other
- The **ratio of the number of turns** on the two sides determines whether the transformer steps "up", "down" or not at all
  - Reversing a step-up transformer makes it a step-down transformer
- In a step-up transformer the primary wire is a larger gauge because it is handling more current
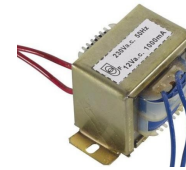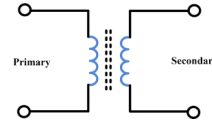
G5C01, G5C02, G5C16

Turns Ratio

$$\frac{Es}{Ep} = \frac{Ns}{Np}$$

The voltage ratio between the primary and secondary equals the ratio of turns between the primary and secondary

$$\frac{Np}{Ns} = \sqrt{\frac{Zp}{Zs}}$$

To Match Impedance

The square root of the primary impedance divided by the secondary impedance is equal to the ratio of the number of primary turns to the secondary turns

Solve:

What is the RMS voltage across a 500-turn secondary winding in a transformer if the 2250-turn primary is connected to 120 VAC?

What is the turns ratio of a transformer used to match and audio amplifier having 600 ohm output impedance to a speaker having 4 ohms impedance?

G5C06, G5C07

SAFETY!!

Antenna / Tower Safety

- Disconnect all power and feed lines before working on an antenna
- Protect against unauthorized access, particularly for ground-mounted antennas
- Bond all lightning grounds together
- Don't use solder to bond grounds, it'll melt from the heat

- ALWAYS us a harness, hardhat, and safety glasses when working on a tower
  - Harness appropriate for weight of the climber and within useful life
- Use a ground spotter when climbing a tower

G0A06, G0B07, G0B08, G0B11, G0B14

RF Exposure

- The **Maximum Permissible Exposure** (MPE) depends on length of exposure and frequency
- RF energy affects tissue by **heating** it
- MPE must be calculated if more than 50 watts PEP to the antenna
  - Any change to equipment or antenna requires a re-calculation

- MPE calculated by
  - FCC Bulletin 65 and/or
  - Computer model and/or
  - Measurements with a calibrated field strength meter and calibrated antenna
- The **duty cycle** affects RF exposure. The shorter the duration of the exposure, the higher permissible exposure levels

What to do if the calculation shows excessive exposure for a neighbor? Prevent pointing the antenna system at the neighbor.

Feeding directly (without doing any matching) a random-wire HF antenna will likely put high levels of RF on the metal objects in the station and you may experience painful RF burns.

Time Averaging is the total RF exposure averaged over a certain time.

If your station evaluation shows RF energy radiating from you station exceeds permissible limits you must take action to prevent human exposure to the excessive RF fields.

G8B08, G9B01, G0A01, G0A02, G0A03, G0A04, G0A05, G0A07, G0A08, G0A10, G0A11

Electrical Safety in the Shack

- Governed by the **National Electrical Code**
- Ground all chassis together (no daisy-chaining!) to keep RF off the equipment and avoid **ground loops** (which will cause hum on the output signal)
- Use appropriately sized fuses or circuit breakers on all voltage-carrying wires
- Minimum wire gauges
  - 15 amp: 14 gauge
  - 20 amp: 12 gauge
- Employ and do not disable electrical interlocks

- **Ground Fault Circuit Interruptors** (GFCI) are used to disconnect the circuit if current flows from one or more voltage-carrying lines to ground

Grounding all the chassis together will also help to eliminate RF "hot spots".

In a 240v circuit, fuse both the wires carrying voltage.

A resonant ground connection will cause high RF voltages on the enclosures of station equipment. This is mitigated by grounding all chassis together.

In addition a ground wire that has high impedance on the transmitting frequency may cause RF on the chassis which might give an RF burn.

G4C05, G4C06, G4C09, G4C10, G4C11, G4C13, G0B01, G0B02, G0B03, G0B05, G0B06, G0B12

Generators

- The gasoline/diesel motor on the generator will also generate carbon monoxide. Do not use inside the home
- When using a generator, be sure to disconnect those circuits from the utility power feed
- Install the generator in a well ventilated space

Final Safety Note:

Lead-tin solder can contaminate food if hands are not washed carefully after handling the solder

G0B04, G0B09, G0B10, G0B13

Questions? Comments?