Amateur Radio Service Technician Class

Exam Preparation Class

September — October 2018

Session 3

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These slides will be uploaded to my website

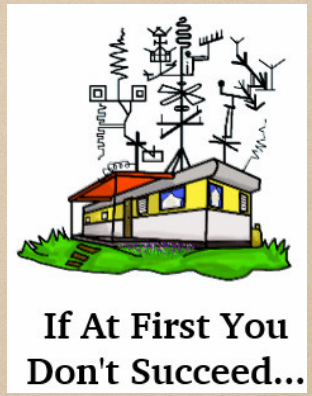
https://k7ojl.com/technician-class-materials/

just before class each week.

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

Class Overview

- Questions?
- Antenna Gain
- Modes
- Interference
- Volts, Ohms, Amperes, and Farads



Questions from Session 1 or 2?
Questions about Amateur Radio?

A Satellite Contact Video

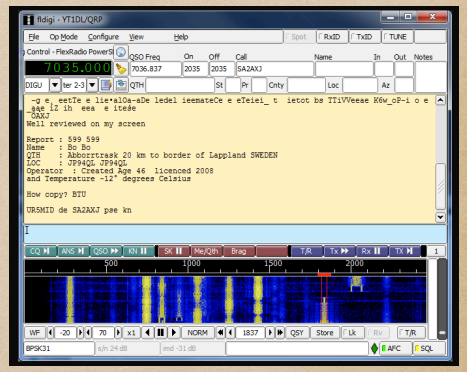
- https://www.youtube.com/watch?v=pj0VqsYzGVA&t=393s

SO-50

Digital Communications

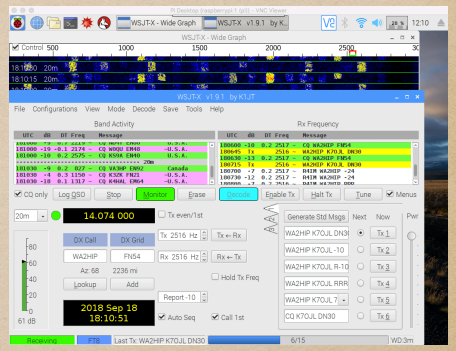
Digital Communications

- The original digital mode is CW (international morse code)
  - CW frequencies are from 50.0-40.1 MHz (10 meter band) and 144.0-144.1 MHz (2 meter band)
  - Many hams us an electronic keyer when sending CW
- A computer is used to generate and decode many other digital modes
  - The computer's sound card is used to send audio to the radio's microphone input, generate the PTT signal, and converts audio from the radio's speaker output into digital form
  - The physical connection from the radio is to the computer's microphone or line input



New Digital Modes

- Digital modes include Packet Radio, IEEE 802.11, JT65, FT8, PSK (phase shift keying), and may more
- FT8 (pictured to the right) is one of the newest enabling communications in very low signal-to-noise conditions transmitting and receiving in 15-second windows
- Joe Taylor K1JT has developed a suit of low SNR applications used for moon bounce (EME), weak-signal propagation, meteor scatter, and others
- Some modes include check sums for error detection, automatic repeat requests in case of error, header records containing metadata about the transmission
- Multipath signals will seriously degrade reception and increase error rates



Automatic Packet Reporting System

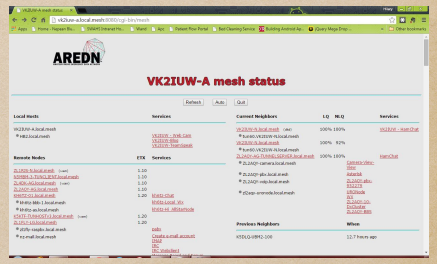
- APRS is an application capable of providing real-time tactical digital communications together with a map showing the location of stations
  - Requires a GPS receiver to provide position information to the transmitting application
- Popular mobile text messaging application
- Many amateur weather stations use APRS to send their weather information to various weather data systems
- https://aprs.fi/#!addr=salt%20lake%20city%2C%20ut

Other RF Digital Modes

- Digital Mobile Radio (DMR)
  - Two "time multiplexed" conversations on a 12.5 kHz channel
  - Users connect to "talkgroups" which are conference rooms for like interests
  - Inexpensive cost to play
- D-Star
  - Developed in Japan, supported by ICOM, Kenwood, and Elecraft
  - Has very fast data transfer capability
- System Fusion
  - Developed by Yaesu and proprietary to Yaesu
  - Growing in popularity
- DMR, D-Star, and System Fusion are all incompatible with each other

Mesh Networking

- Commercial WIFI gear (part 90 equipment) repurposed to work on amateur frequencies (part 97)
  - Several WIFI channels are within amateur radio bands
- Makes a self-healing, multi-path routing, high-speed data network
- Amateur Radio Emergency Data Network (AREDN) is where the firmware and additional information is available



Some Other Digital Mode Information

- PSK (phase shift keying) is a very popular keyboard to keyboard protocol as well as the ability to transfer files
- IRLP (internet radio linking project) is a technique to connect amateur radio systems, such as repeaters, using Voice Over Internet Protocol (VOIP). A popular IRLP repeater in our area is on 449.425(-) connected to the Western Reflector
  - DTMF (dual-tone multi-frequency tones, similar to the touch tones on a phone) tones are used to connect and disconnect reflectors
- Echolink is another VOIP system. There are Echolink applications that can run on your laptop or smart phone. Registration is required before using Echolink (to prove you are a licensed amateur).
- There are online services, printed directories, and subscription services to find repeaters and VOIP services

And Finally, Amateur TV

- Slow scan tv as well as fast scan systems are available
  - Analog only at the moment. Hams are working on a non-patented digital codec
- NTSC is the standard for fast scan color analog signals
- Typically used on the 70cm band and higher frequencies.
- Fast scan tv has a bandwidth of about 6 MHz (that's why they're on the higher frequencies!)
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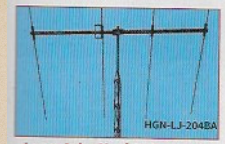
Antenna Gain

Reprise

Antenna Gain and Front to Back Ratio



Long John Yagi Antennas

Perfect for the DXer or contester, these HF beam antennas from Hy-Gain are factory-tuned to offer no-compromise performance on a specific band. These antennas also work quite well in a stacked configuration. Designed to fit a 2" OD mast, they easily handle 1,500 watts and feature full-size elements. The antennas' aluminum tubing and stainless steel hardware contributes to excellent all-weather durability. For optimal performance, DX Engineering recommends a 50 Ω balun be installed at the feedpoint.

Part Number	Band(s)	Gain	Boom Length	Max. F/B	Number of Elements	Price
HGN-LJ-103BA	10M	7.5 dBi	8'	24 dB	3	**$179.95**
HGN-LJ-105CA	10M	10.7 dBi	24'	36 dB	5	**$289.95**
HGN-LJ-153BA	15M	7.9 dBi	12'	25 dB	3	**$229.95**
HGN-LJ-155CA	15M/12M	9.7 dBi	26'	25 dB	5	**$429.95**
HGN-LJ-203BA	20M	7.3 dBi	17'	23 dB	3	**$329.95**
HGN-LJ-204BA	20M/17M	8.2 dBi	26'	28 dB	4	**$539.95**
HGN-LJ-205CA	20M/17M	8.7 dBi	34'	30 dB	5	**$769.95**

dBi, dBm, dB

All are decibel measurements, a relative measurement of two different power levels

dBi always refers to antenna gain vs a theoretical isotropic reference antenna

dBm always refers to milliwatts, a relative measurement of amplification

dB is any relative measurement of two power levels and the reference point must be specified

Antenna Gain vs Number of Elements

hy-gain

Tri-Band HF Beam Antennas

If you want to get active on the 20, 15 and 10 meter bands, Hy-Gain's TH series antennas are an excellent choice. These durable antennas offer excellent gain in an efficient package. You can select the right-sized antenna for your specific installation, whether it's on a rooftop or a tower. These lightweight, multi-element Yagis also feature aluminum tubing for reduced stress on your rotator. Visit DXEngineering.com for the complete specs.

HGN-TH-3JRS	Tri-Band Yagi, 3-Element, 600 W, 8 dBi Gain	**$379.95**
HGN-TH-3MK4	Tri-Band Yagi, 3-Element, 1,500 W, 8 dBi Gain	**$499.95**
HGN-TH-5MK2	Tri-Band Yagi, 5-Element, 1,500 W, 9 dBi Gain	**$789.95**
HGN-TH-7DX	Tri-Band Yagi, 7-Element, 1,500 W, 9.6 dBi Gain	**$899.95**

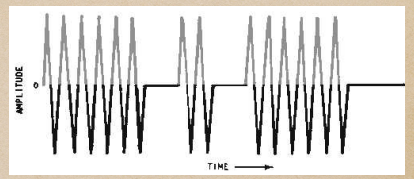
Modes

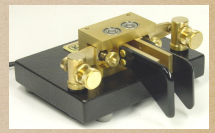
Common Transmission Modes

- Continuous Wave (CW)
  - Mode to carry morse code and several digital capabilities
- Amplitude Modulation (AM)
  - Radio stations on the AM band, for example
- Frequency Modulation (FM)
  - Radio stations on the FM band, for example
- Single Side Band
  - Either upper or lower sideband

Continuous Wave

- An oscillator generates the signal
- Transmitter is either on or off … no modulation of the carrier
- Some digital modes, such as RTTY, alternate between higher amplitudes and lower amplitudes
- Very narrow bandwidth
  - CW Morse code is 150 Hz (use a 500 Hz filter)
  - Other CW modes are only slightly wider

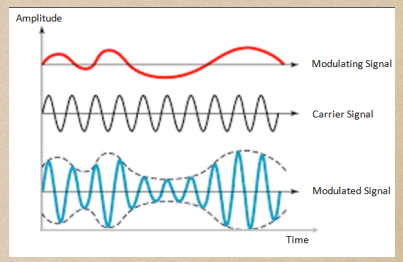


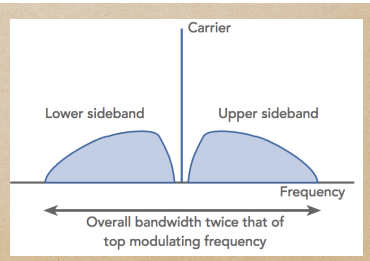


Signal to Noise Ratio: One way to improve the SNR is to narrow the bandwidth of the received signal. A CW signal carrying morse code is about 150 Hz wide. If the receiver is receiving a bandwidth of 6 kHz (the width of an AM broadcast signal), there is a lot of unwanted noise surrounding the CW signal. Most modern transceivers have a set of filters of various widths that can be switched in to narrow the received bandwidth thus making the desired signal more prominent.

Amplitude Modulation

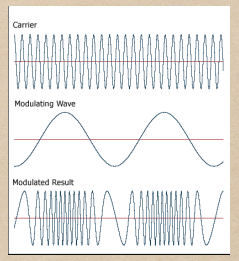
- A microphone or similar generates a modulating signal
- An Oscillator generates a carrier signal
- A mixer combines the modulating signal and the carrier
- The amplitude of the resulting wave form varies in time with the modulating signal
- AM signals are about 6 kHz wide and have a center carrier with an upper and a lower sideband

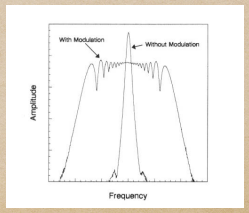




Frequency Modulation

- An oscillator generates a carrier
- A microphone or similar creates a modulating wave
- A modulator varies the carrier frequency over time with the modulating wave
- FM voice signals have a bandwidth up to 25 kHz
- When using a repeater, the strongest FM signal wins





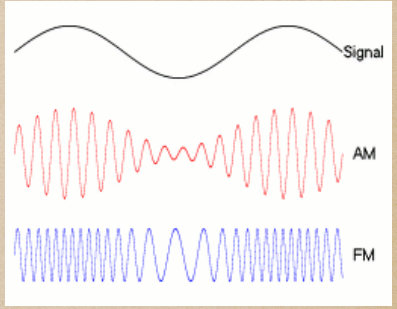
Frequency deviation is used in FM radio to describe the maximum difference between an FM modulated frequency and the nominal carrier frequency. The width of an FM signal varies as the carrier is modulated. The amount of variation in the width is call “deviation”. If the fully modulated signal “deviates” more that 25 kHz, it is over deviating. Usually that is caused by talking too loudly into the microphone or holding the microphone too close to the mouth.

If someone receiving your HT signal says you are “over deviating”, move the microphone away from your mouth.

Some multi-function transceivers have a microphone gain setting. If you are over-deviating, also check the mike gain setting.

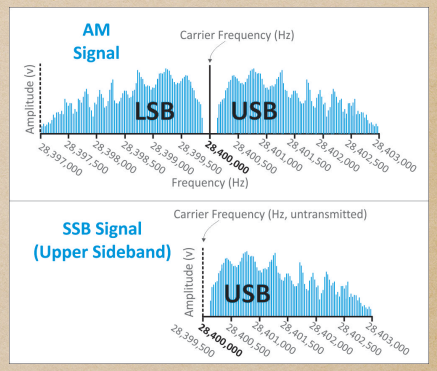
AM vs FM

- In AM modulation, the amplitude of the signal varies. Low signal means lower amplitude
- In FM modulation, the frequency of the signal expands or contracts based on the modulating signal



Single Side Band

- A form of amplitude modulation
- An oscillator generates a carrier
- A microphone or similar creates the modulating wave
- A mixer combines the carrier and the modulating signal
- A filter strips the center carrier and unwanted sideband
- SSB signals have about a 3 kHz bandwidth (use a 2.4 kHz filter)
- Convention for SSB voice is to use lower sideband on 40 meters and below and to use upper sideband on 60 meters and above
- Digital modes using single sideband as the carrier are always upper sideband regardless of the frequency



When SSB was beginning to be implemented, the circuitry to filter out the unwanted sideband made it fairly easy to generate a lower sideband signal for transmitted signals below 50 meters and to easily generate an upper sideband signal for transmitted signals above 50 meters. In today's solid-state transmitters, that's no longer the case, but the convention remained.

Note that digital communications are always upper sideband, regardless of the frequency band.

Multi-mode Transceiver

- A transmitter and receiver in the same box with a method to switch the receiver out of the circuit when the transmitter is operating
  - Multiple bands and modes
  - Switching modes switches in the proper filter
- Most include a Receiver Incremental Tuning (RIT) control to manage the pitch of a SSB signal
- Usually have multiple bandwidth choices to reduce noise or interference
- The ability of the receiver to pull out weak signals is the receiver's sensitivity
- The selectivity of the receiver is its ability to discriminate between multiple signals

Some Important Definitions

- Oscillator: a circuit that generates a signal at a specific frequency
- Mixer: a non-linear device that takes two radio signals and creates the sum and difference frequencies of the two input frequencies
- Automatic Gain Control (AGC): Used to (somewhat) level out the huge variations in signal strength making the audio relatively constant. The AGC speed can often be set
- Transverter: A device that converts the RF input and output of a transceiver to another band. Often used for microwave and very low frequency systems
- RF Preamplifier: If needed (and rarely is needed) is placed between the antenna and the receiver to boost weak signals
- Modulation: the process of combining speech with an RF carrier

Transverter is a combination of the words “transmitter” and “converter”. Since there is no commercial equipment available to amateurs in the gigahertz frequencies, enterprising hams build home-brew transverters to take emissions in the 2 meter band and “up” them to the desired gigahertz frequency and conversely receive on the desired gigahertz frequency and “down” the signal to a frequency in the 2 meter band.

Interference

The FCC Rules

The FCC regulates any device that emits radio frequency emissions. Commercial radio equipment is regulated under Part 90 and amateur radio equipment under Part 97. Everything else is regulated under Part 15.

Part 15 devices are either “unintentional emitters” such as computers or TV receivers (they may generate RF signals as part of their operation but they aren’t intended to transmit them) or “low power intentional emitters” such as garage door openers, cordless phones, wireless microphones, etc. which must transmit / receive RF signals to function.

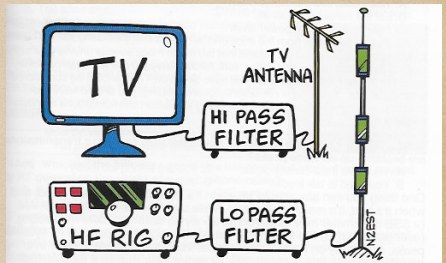
Part 15 devices must not interfere with Part 90 and Part 97 devices and must accept normal emissions from those devices.

If your neighbor feels his TV is being interfered with by your transmissions from a certified Part 97 device, the FCC says it’s your neighbor’s TV that’s the problem….

The FCC relies on the manufacturer of Part 15 devices to do the required testing and submit the results as part of the application for Part 15 certification. Some foreign manufactories are less than comprehensive with their testing and compliance. Particular offenders for amateur radio are grow lights, LED lights, and wall-wart power supplies. Cheap TVs from Asia are emitter offenders and often don’t include the filtering needed to accept normal interference from Part 90 / 97 devices.

Interference Mitigation

- First, carefully check your station equipment that all connections are tight and are made of quality materials
  - Does your TV see the interference?
- While you may employ a low-pass filter on your antenna feed line, never install a filter on your neighbor's equipment. That must be done by their service provider
- Snap-on ferrite chokes are helpful to prevent RF on microphone cables and phone lines



High-pass filter: allows high frequencies to pass, attenuates frequencies below the cut-off frequency.

Low-pass filter: allows low frequencies to pass, attenuates frequencies above the cut-off frequency

There are also "bandpass filters" (attenuates frequencies above and below a specific bandwidth) and "band-reject filters" (attenuates frequencies in a specific bandwidth, such as the FM band)

I'm Being Interfered With!

- Check for local noise sources such as wall-warts, LED lights, USB chargers, etc.
- If it's coming from a neighbor?
  - Work with the neighbor to identify the source
  - Inform the neighbor of the relevant FCC regulations (you're licensed, their device is not)
  - Make sure your station is meets good practice standards
- Use shielded ethernet cables to reduce propensity to couple
- Ferrite cores on cables where applicable

How About Mobile Interference?

- Connect power directly to battery and battery ground. Fuse both leads close to the battery
  - The cigarette lighter is a poor power source
- Alternator whine? Turn on the mobile radio's noise blanker. Employ DC / AC filters on the positive lead
- Poor audio reports?
  - Right frequency?
  - Sufficient voltage?
  - Bad location?

Volts, Ohms, Amperes,
Henries, and Farads? Oh My!

Electromotive Force

- The force behind electron flow
- Symbol is 'E'
- Measured in Volts, 'v'
- Measured by a voltmeter
- Measurement is made in parallel with the circuit
- May also be called "electric potential'

Current … The Flow of Electrons

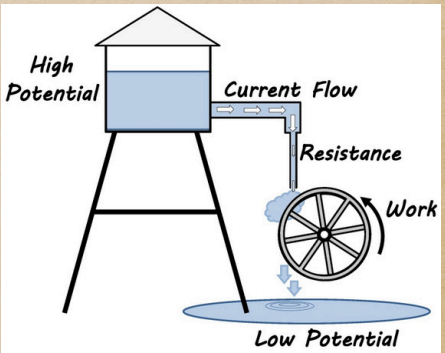
- The symbol for current is 'I'
- The amount of current flowing is measured in 'Amperes', denoted by an 'A'
- Current is measured by an 'ammeter'
- Measurement is made in series with the circuit
- Current flowing in one direction is called "direct current"
- Current flowing in one direction and then the other is called "alternating current"

Resistors Oppose the Flow

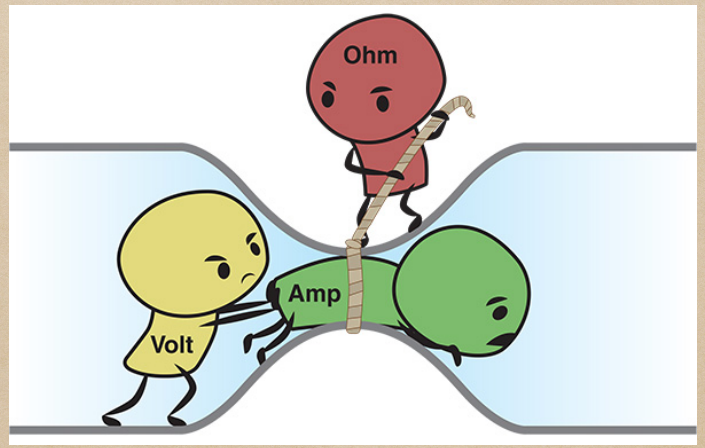
- Resistance is measured in 'ohms'
- The symbol for ohms is the Greek letter 'Ω'
- Resistance is measured by an 'ohmmeter'
- The resistance in a circuit usually cannot be directly measured, but can be calculated
- The current that doesn't pass is dissipated as heat

The Water Analogy

- Electromotive Force = water pressure
- Current = the water flow
- Resistance = the constraints in the plumbing

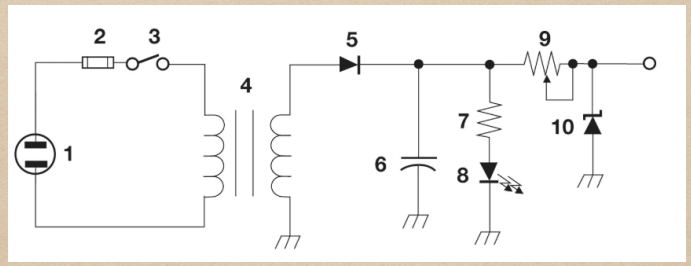


Volts, Amps, Ohms



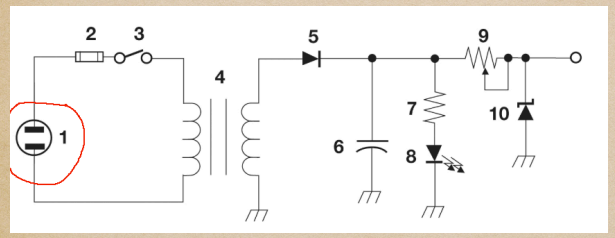
Other Electrical Components

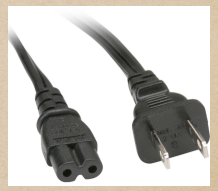
Schematic Diagrams



This is one of three possible schematic diagrams that may be on the test. The various components are numbered and the test question(s) will ask you to identify the component.

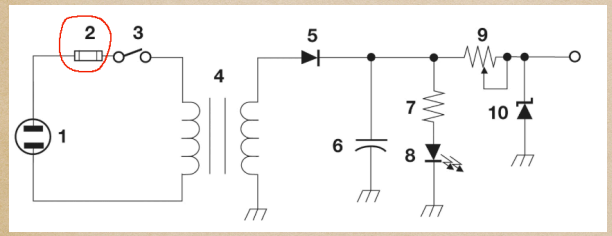
Power Source





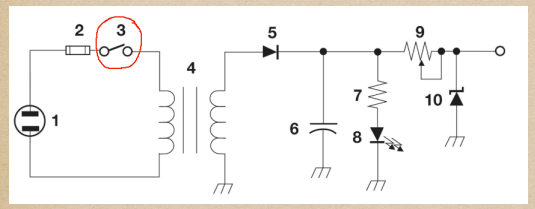
Either Alternating Current or Direct Current is used to provide voltage and current to an electronic device. In this particular diagram, the input is alternating current because it is feeding a transformer.

Fuse



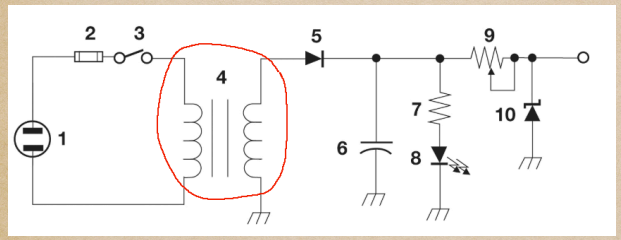
A fuse is used to protect a circuit from drawing too much current. Fuses are rated by how many amperes of current can pass before the fuse opens the circuit. Fuses are made of a resistive material that gets hot and melts when the rated current draw is exceeded.

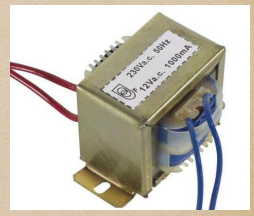
Switch



Switches come in a variety of configurations. The switch in this diagram is a “single pole, single throw” switch. It can be used to either complete or interrupt a single circuit.
Other configurations of this switch type include “single pole, double throw”,“double pole, single throw”, “double pole, double throw” and more.
There are also rotary switches, momentary switches, and gang switches.

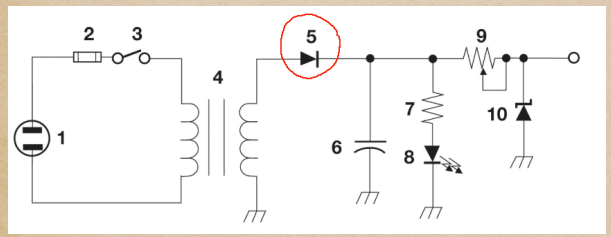
Transformer

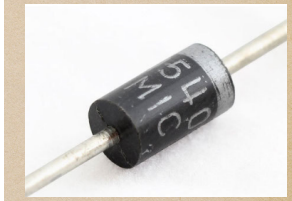




A transformer is a static electrical device that transfers electrical energy between two or more circuits through electromagnetic induction.
They are used to isolate one circuit from another and/or to increase or decrease the voltage from one side to the other.
The amount of increase (or decrease) depends on the ratio of the number of turns in the coil on each side of the transformer.
The transformer in this circuit has a iron core, signified by the two parallel lines in the middle of the transformer.

Diode





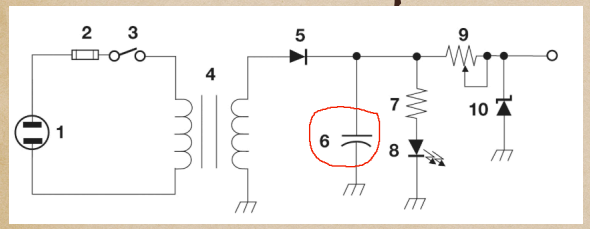
A diode is a two-terminal electronic component that conducts current primarily in one direction; it has low (ideally zero) resistance in one direction, and high (ideally infinite) resistance in the other.

The two electrodes are the anode and cathode. The cathode side is marked with a stripe.

Current flows from the anode to the cathode. Diodes have a threshold voltage value and current will flow when the threshold is exceeded.

While they will normally only allow current to flow in one direction, a very high voltage applied to the cathode can cause the diode to break down and allow current to flow in the reverse direction.

Capacitor



A capacitor consists of two or more conductive surfaces separated by an insulator. The insulator can be air, a vacuum, or other solid material such as plastic or paper.

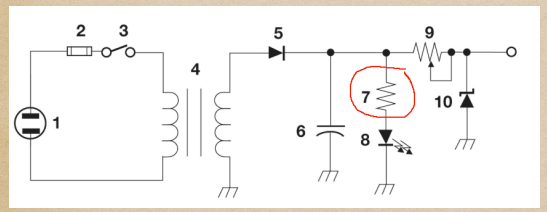
Applying voltage higher than the rated value can cause the capacitor to short circuit.

Capacitance is measured in Farads

One farad is a rather large amount of power stored in a capacitor. Capacitors capable of being charged to one or more farads are massive and found in places like the large Hadron collider in Cern, Switzerland.

The capacitors used in most electrical circuits have fractions of a farad capacity, usually measured in microfarads (1/1,000 of a farad), nanofarad (1/1,000,000 of a farad), and picofarads (1/1,000,000,000 of a farad).

Resistor

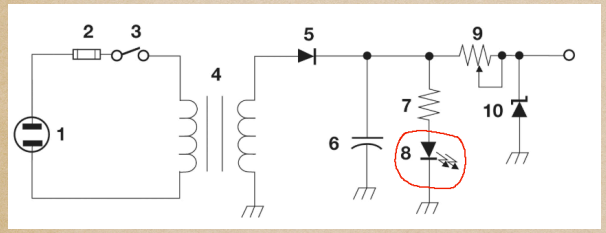


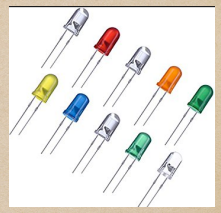
A resistor restricts, but doesn't inhibit, current flow in a circuit. Some of the current is converted into heat, the rest flows through the resistor.

Resistors come in various compositions and power ratings (the amount of current and voltage the resistor can accomodate).

Resistance is measured in Ohms (Ω)

Light-Emitting Diode



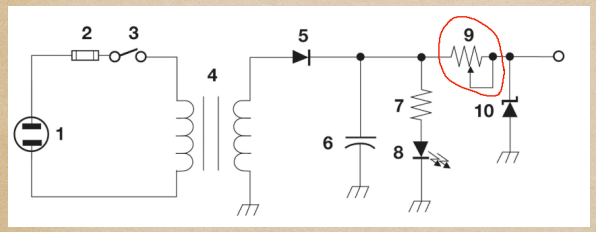


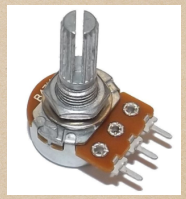
LED's are a special type of diode. They allow current to flow in one direction, but convert some of the energy into light.

The positive (anode) lead will be the longer lead and have a flat edge on the outer casing

Diodes have very low resistance and will short a circuit if not coupled with a resistor to limit the current flow through the LED.

Variable Resistor





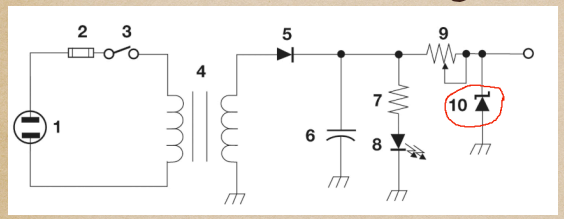
A variable resistor, aka potentiometer, is often used as a voltage divider (when all three pins are used) or as a variable resistor when two pins are used (as in this example).

A common use of a potentiometer is as a volume control in a radio.

The outer two pins have a fixed amount of resistance between them.

When a potentiometer is turned all the way to the left, the center conductor (also called the “wiper”) has zero resistance. Turned all the way to the right, the center conductor has the full resistance.

Schottky Diode



A schottky diode was the first semiconductor invented. It is a very fast diode compared to a “normal” diode. The amount of voltage needed to cause current to flow is very low, meaning the diode can switch on or off quickly.

The Schottky Diode is distinguished from “normal” diodes by the “curly” cathode indicator. Note that in a Schottky Diode, the current flows from the cathode to the anode whereas in normal
diodes, current flows from the anode to the cathode (compare #5 to #10)

Schematic 2

1. A Resistor
2. A Transistor
3. A lamp
4. A battery
5. Common or Ground

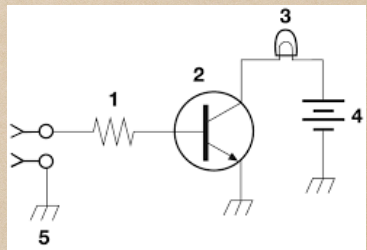


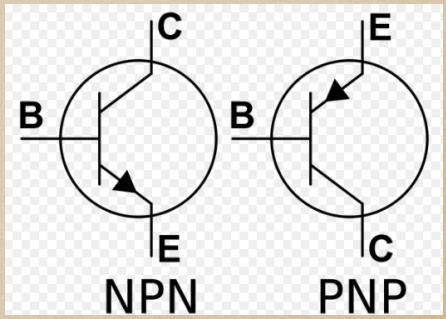
Figure T-1

Common or ground is the return path for the current flowing in the circuit

The only thing this circuit does is turn on a lamp if some other part of the circuit (which isn't shown) draws current.

Transistors

- B: Base, C: Collector, E: Emitter
- Two flavors, distinguished by the emitter arrow
- Transistors are excellent amplifiers
  - A small modulated signal on one pair of pins will modulate a larger carrier on the other pair
- They are also excellent switches
  - Current won't flow on one pair if a signal is present on the other pair



A Field Effect Transistor (FET) is a transistor that amplifies or switches voltage (instead of current)

When input voltage applied to Base/Emitter, it changes the resistance between the Collector and Emitter. That then affects how much current can flow between the Collector and Emitter

Amplification is called "gain" and is measured in "dBm"

The 3rd Schematic

1. A connector to/from some other part of the schematic
2. A variable capacitor
3. A variable inductor
4. An antenna

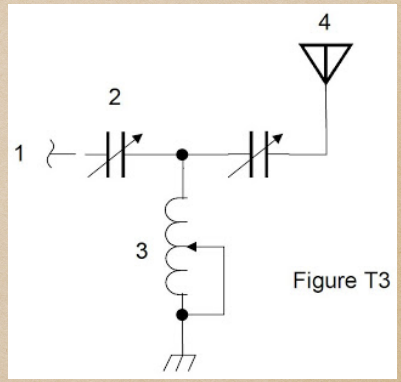
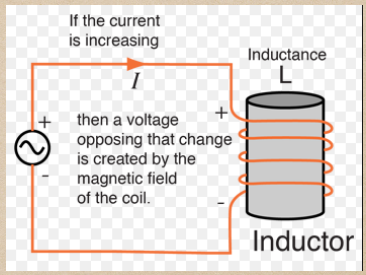


Figure T3

This circuit actually works, whereas the other two circuits are pretty much nonsense. This circuit is a trans match to make the transmitter think it's seeing a 50 ohm impedance.

Inductance

- An inductor is a coil of wire and may have an air core or some type of a metal core
- Inductors store electrical energy in a magnetic field
- Inductors oppose rising current until the magnetic field is full and then passes the current.
- As the incoming current falls, the inductor releases the magnetic field



Inductance is measured in "henries"

One henry is a very large amount of power. Most of the inductors in today's electrical circuits are measured in milli henries and micro henries.

Inductance vs Capacitance

Inductors

- Stores energy in the form of a magnetic field
- A current can pass through an inductor but will create a magnetic field as it does so
- As a property of the magnetic field, when the current suddenly increases or decreases, the current within the magnetic field will change in the opposite direction. This resists, or impedes, the change in current across the circuit. The inductor inhibits the current from changing instantly.

Capacitors

- Stores energy in the form of an electrical field
- As a current is applied to the circuit, charges accumulate on the plates of the capacitor. Therefore, voltage cannot change instantly across a capacitor
- When the current decreases the capacitor will release the charge

A Rectifier

A Practical Example

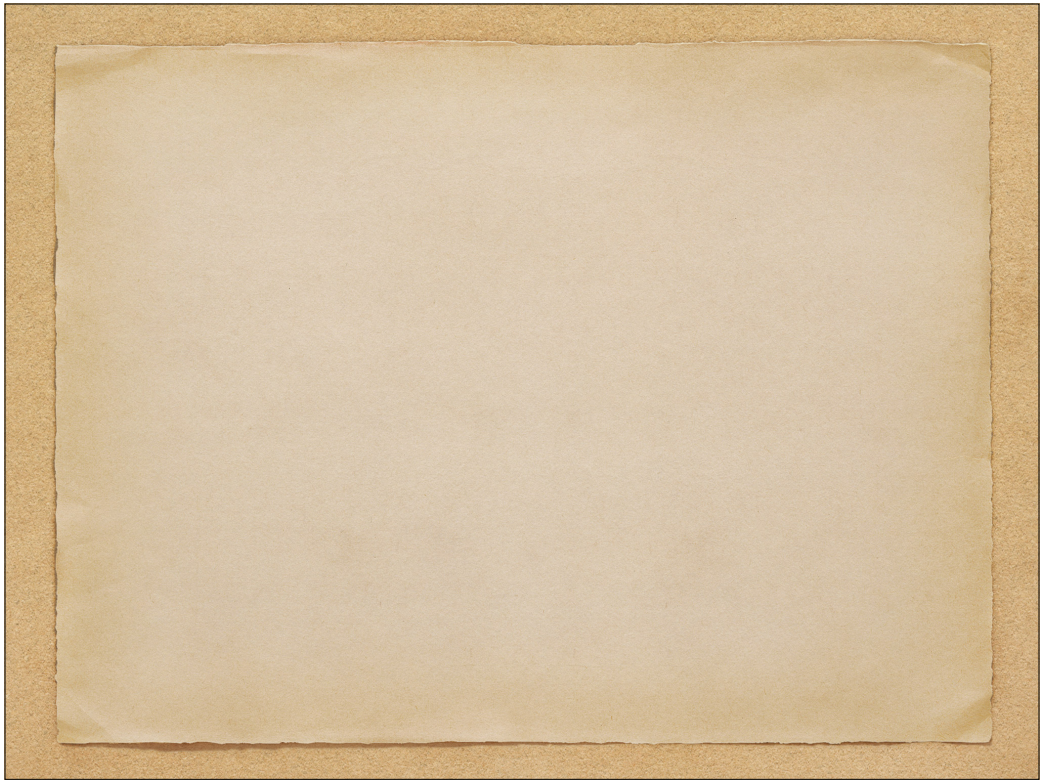
Good Things to Know

- Some battery types are rechargeable. Carbon-zinc batteries are not
- Copper, gold, aluminum are a good conductors of electricity. Wood, glass, and rubber are good insulators.
- Copper wire has some resistance, meaning that the voltage will drop as the length of the wire increases. Heavier wire has less resistance. Shorter lengths have less loss.
- Opposition to the flow of AC current is called impedance and is also measured in ohms

If a battery is rechargeable, it will say so

Most power supplies (as well as the automotive charging system) deliver 13.7 volts which will draw down to 12.5 volts when transmitting

How Much Power Does a Transceiver Need?

- Modern transceivers require at least 12 volts of power
  - Most power supplies, as well as the automotive charging system, deliver 13.7 volts which will drop to about 12.5 volts when transmitting
- The amount of current needed is determined by:
  - The efficiency of the transmitter at full power
  - The receiver and control circuit requirements
  - The efficiency (regulation) of the power supply
  - The amount of heat dissipation
- A 100 watt transmitter will required about 20-25 watts on transmit and 1-5 watts on receive

That's All for Today!