FCC License Guide: How to obtain your FCC Ham License: A guide to obtaining your ham license, but not a buyer's guide or a Consumer's Report service

I am happy to help you obtain your amateur radio license. I have been a licensed ham since 1957 and hold an extra class license. I am also an ARRL Certified License Instructor. I can work with you in person, on the internet (Messenger or Zoom), via Email, SMS, or by telephone. My callsign is NI6A, located in El Cerrito, CA See: https://www.qrz.com/db/NI6A Email ni6a@arrl.net

Please tell me a little about your technical background, if any, and your motivating reason to become a ham radio operator.

Beginning FCC Licensing Information

Entry grade is the technician class. It provides full privileges on Ham VHF bands and above, and limited privileges on HF bands.
See:
https://www.arrl.org/files/file/Regulatory/Band%20Chart/Band%20Chart%20-%2011X17%20Color.pdf

Or download the Amateur Radio Frequency band plan pdf here:
https://www.hero.radio/_files/ugd/ceee03_700dfd99d69e4ceb8023ddca1dc24516.pdf

1. Visit the American Radio Relay League's Ham License start page:
http://arrl.org/getting-licensed
All the questions and answers are published and available on-line. No other questions will be allowed. See the Question pool page: http://www.arrl.org/question-pools
At this writing (June 10, 2023) it seems that some of these links to the FCC Question pools are broken. However, https://www.hero.radio/amateur-radio-exam-pool-questions this link, by the Hawaii Emergency Radio Operators is fully functioning for download.

2. Out of the question pool, only 35 questions will be asked on the Technician class. You are allowed 7 incorrect answers. Obtain the Technician class license first. Then at the same session or a later session, take the General license test.
http://arrl.org/getting-your-technician-license

3. The General Class license also only asks 35 questions. You can take that test after you pass the Technician class license. Again 7 incorrect answers are permitted.
http://arrl.org/upgrading-to-a-general-license

4. I am available to go over the questions and answers to provide context and understanding, so that you know how to utilize the information. You will have to know some basic knowledge, such as, what frequencies you can and cannot operate, power limits, basic operating skills, electronic know how, etc. This is what I can happily offer. As you might know, Amateur Radio is not as simple as operating a cell phone, nor is simply buying a radio any guarantee that you will be able to use it effectively.

My primary goal is to help get you your ham license first, and then help you get on the air in that order, so that you gain experience and eventually expertise. I am willing to help, but in another sense, please know that you do not need me, nor need to read any books, or take any classes, other than simply study the published question pool and answers (freely available here).

There are approximately 450 questions and answers in the Question and Answer Pool for the Technician and General Tests. The test only asks 35 questions of which you will need to answer correctly 28 or more.

The Extra Class license test has approximately 600 plus possible questions, while only 50 questions will be asked on the actual test.

Technician Class Question and Answer Pool 2022-2026
http://www.ncvec.org/page.php?id=373
If this link is broken, try: https://www.hero.radio/2022-2026-technician-question-pool

Or try https://hamexam.org/view_pool/18-Technician

There are 426 Questions in the Technician class pool and you will need 28 correct answers to pass. There are 3 graphics in the Technician pool.

General Class Question and Answer Pool
https://www.w5yi.org/page.php?id=369

The **current** Question Pool starting on July 1, 2023 is (current):
https://hamexam.org/view_pool/19-General%20(NEW)

The current general class Pool and syllabus Word Docx:
http://ncvec.org/downloads/General%20Class%20Pool%20and%20Syllabus%202023-2027%20Public%20Release%20with%202nd%20Errata%20April%2015%202023.docx

The current general class Pool PDF
http://ncvec.org/downloads/General%20Class%20Pool%20and%20Syllabus%202023-2027%20Public%20Release%20with%202nd%20Errata%20April%2015%202023.pdf

There are 454 questions in the current General class Question Pool

Extra Class Question and Answer Pool https://www.w5yi.org/page.php?id=356
If this link is broken try: https://www.hero.radio/extra
Or https://hamexam.org/view_pool/17-Extra

For the EXTRA class license there are 622 possible questions contained in the question pool, 50 of these questions will appear on your exam. To pass the Amateur Extra Class amateur radio operators license examination you must answer a minimum of 37 of the 50 questions correctly.

Focusing on the Technician Test, there are 10 broad categories which in turn are broken up into subcategories:
T0 Safety
T1 - Commission's Rules
T2 - Operating Procedures
T3 - Radio Wave Propagation
T4 - Amateur Radio Practices
T5 - Electrical Principles
T6 - Electronic And Electrical Components
T7 - Practical Circuits
T8 - Signals And Emissions
T9 - Antennas And Feed Lines
There are 3 Graphics that are asked in sections T6C and T6:

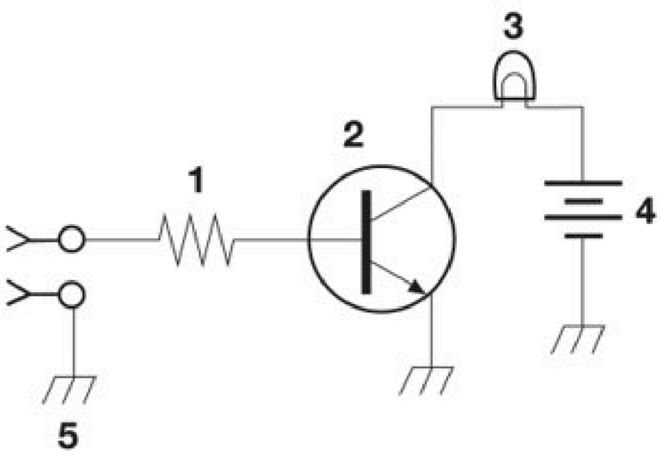


Figure T-1

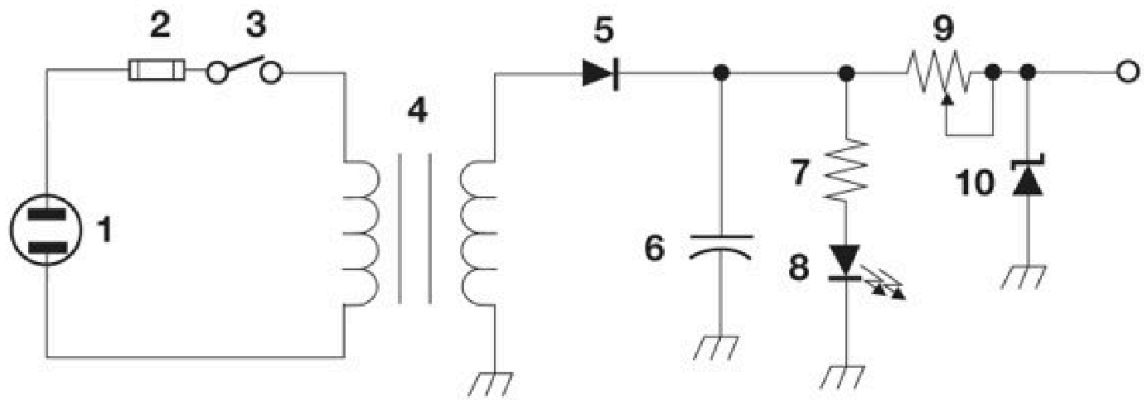


Figure T-2

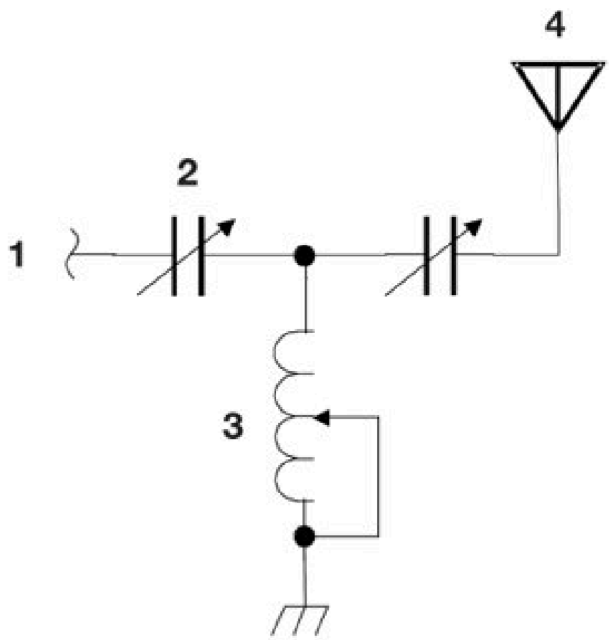


Figure T-3

In short, there is no need to hesitate, as you can start studying now on the internet; but again, if you want me to help guide you, I am happy to do so, but I want everyone to know that all you need to know to pass the test is available on-line.

You and I together can go through all the questions sequentially one by one, and you can ask questions, or I can pontificate on a few that may call for extra explanations, context, and/or explanation of the general concepts. That may take 2 or 3 hours. Then you take the test at locations of your choice or on-line.

See this helpful page: http://www.arrl.org/getting-your-technician-license
and this http://www.arrl.org/ham-radio-license-manual

As an ARRL registered License Instructor, I can get the ARRL **technician license study book** for $11.20
https://home.arrl.org/action/Store/Product-Details/productId/2003373076
Or for $25 their spiral bound edition.
https://home.arrl.org/action/Store/Product-Details/productId/2003373064

Let me know if you want me to order either book for you.

This book by Gordon West is perhaps the most accessible, but again, I question if you need a book at all. If you think that you do, then you can find it on amazon https://www.amazon.com/2022-2026-Technician-Class-WB6NOA-Gordon/dp/0945053010/ref=sr_1_1 Gordon is a genius instructor, using mnemonics, humor, and simplicity to make the learning experience fun and useful. It is the best available.

There are also many sample tests online. One can be found here.
http://www.arrl.org/exam-practice

https://www.qrz.com/hamtest

This is one quick search for the technician sample tests
https://www.google.com/search?client=firefox-b-1-d&q=sample+technician+ham+test

For example, https://hamradioprep.com/free-ham-radio-practice-tests/

YouTube has many as well:
https://www.youtube.com/results?search_query=sample+technician+ham+test

Ham Radio Exam offers a free license study app for both I phone and I pad here
https://apps.apple.com/us/app/ham-radio-exam-tech/id601991935

Their nifty ap is also available for android
https://play.google.com/store/apps/details?id=com.delasystems.hamradioexamtech&hl=en_US&gl=US

No data shared with third parties and no data is collected, but it does include ads.

This is a **very** helpful website https://hamexam.org/ replete with the full question/answer pool, sample exams, flash cards, and more.

Here is an open book sample exam from the Hawaii Emergency Radio Operators website https://www.hero.radio/ve-examination

Take their on-line exam See: https://www.hero.radio/remote-exam-sessions

Also, the Benicia Amateur Radio Club offers one day ham crams. In the AM session, you are given the questions and answers to study. After lunch, you take the test. They have a 90% + pass success rate. See: https://beniciaarc.com/hamclass/

See https://www.karoecho.net/events for more classes and exams.

Basic concepts and terms:

You do not need to be an electronics' expert or very technical to pass the test, but the following will sketch the basic science, rules, and concepts concisely explained. Just as one needs to know what the definition of cosine means in order to study trigonometry; one needs to know basic radio terms as a practical operating skill. Further, some terms are specific to ham radio exclusively, albeit they may have origins in historical developments of telegraphy and radio experimentation. Those terms may be used as jargon to proudly proclaim one's superior knowledge or status. We will attempt to discourage such boasting, by differentiating essential terminology from useless jargon. Don't be put off, you can simply memorize the FCC Question and Answer Pool in a few hours with zero technical knowledge or understanding. But in case you want more, see the following clarifications.

Context

Frequency and Bandwidth:

As the radio frequency measured in Hertz (Hz) increases the wavelength gets shorter in relation to time. More waves are compressed without increasing the time domain. Hertz (Hz) is used where we once used kc (kilocycles per second) or cycles per second (CPS) to honor Heinrich Rudolf Hertz, an experimental physicist, who proved in 1886 that radio waves can be transmitted and received through space. Shortly afterward, Marconi completed the first transatlantic radio transmission in 1901.

1 Hz equals 1 cycle per second
One Kilo-Hertz (1 kHz) equals one thousand cycles per second (1 kc)
1 Mega-hertz (MHz) signifies for a million Hertz,
1 Giga-Hertz (GHz) signifies one billion Hertz

Alternating Current (AC) in the US vibrates at 60 Hz and operates at 115 VAC and 230 VAC for normal household applications.
Audible sound for humans, in comparison, ranges from 20 Hz to 20,000 Hz (20 KHz)
Sub-audible tones in the rage of 67 Hz to 257 Hz are very commonly used to control repeater systems.

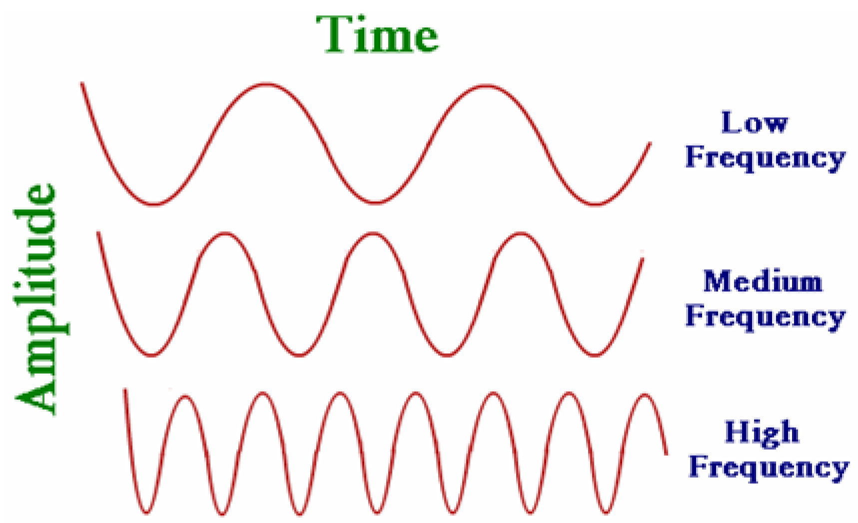
CW (Continuous Wave) Is an unmodulated carrier that is broken up in short and long signals (dots and dashes) thus facilitating Morse Code. The signal can be filtered to 100 Hz or less, thus requiring reduced spectrum space. It has many advantages over voice and other digital modes.
AM (Amplitude Modulation) is best considered to be double Sideband with a modulated carrier (using amplitude modulation). It generally is 6 kHz wide.
DC Direct Current. Most ham radios use 12 Volts DC (VDC) to power their radios. A 12 VDC power supply converst 115 VAC (wall current) to 12 VDC. One can alkso use an auto battery or preferred the newere 13.6 VDC LiFePo4 (Lithium Iron Phosphate) batteries.
LSB: Lower Sideband
USB: Upper Sideband
SSB (Single Side Band) requires half the spectrum, space of AM (3 kHz) with a nulled carrier except when speaking (modulated), It is best described as ½ double sideband without carrier. It's duty cycle is much improved over DSB.
FM (frequency modulation): Ham radio utilizes both NBFM (Narrow Band FM at 12.5 kHz width, and the more common WBFM (Wideband FM) utilizing 15 kHz bandwidth and frequency modulation techniques. This is the most popular mode in VHF and higher.
Digital Data: There are too many digital modes to describe here. RTTY (Radio Teletype) utilizes frequency shift keying (FSK). RTTY is limited to 300 BAUD signal rate below 28 MHz RTTY was the first digital mode widely used in amateur radio. Alsowidely used are Packet Radio (AX.25), APRS, MT 2000, PSK 31, VARA, Winlink, etc.
Digital Voice: Voice modes are commonly transmitted via FM, AM, or SSB, but more recently, voice can be transmitted in a digitized form. Popular are Fusion, DMR, and D-STAR. Each system offers unique advantages. For example, . D-STAR stands for Digital Smart Technologies for Amateur Radio. It is an open standard digital communication protocol established by JARL(Japan Amateur Radio League)..
TV over amateur radio requires more bandwidth.of the Radio Spectrum because it encodes more data. Thus its use is restricted to specific bands and frequencies to reduce interference.
Long Wave (LW) is below the AM Broadcast band of 520 kHz low frequency is also known as **LF**, 30–500 kHz and very low frequency (**VLF,** 3–30 kHz) bands.
Medium Wave (MW) 525 KHz 1800 AM Broadcast Band and the 160 meter band (1.8 MHz or 2. MHz). 3.5 MHz to 55 MHz is the **HF (High Frequency)** shortwave bands (HF – high frequency)
VHF: Above 55 MHz is (Very High Frequency) **VHF** which covers FM Broadcast band around 100 MHz), the 2 meter ham band and the 1.25 meter ham band (220 MHz).
Ultra High Frequency UHF) is above 300 MHz and covers the ham 70 cm UHF Band (440 MHz) and the GMRS UHF Band 460 MHz)
The **microwave band** starts at 1 GHz (1000 MHz)
Each band demonstrates unique properties and applications
For VHF and above frequencies communications are restricted to line-of-sight, albeit some degree of bending and bounce/reflection does extend the distances.
If there are no obstructions, such as hills, mountains or tall buildings in the way, the coverage can be 50 miles or more given good antennas and normal power. In flat

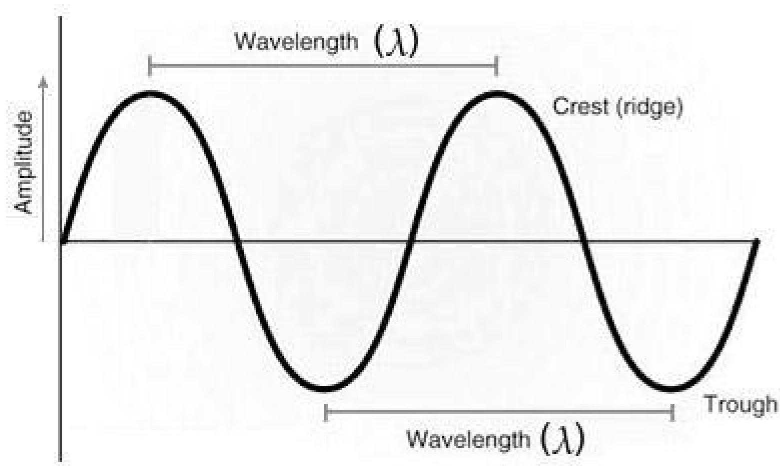
terrain with buildings or hills in the way coverage may be less than 2 miles, unless very good antennas are used.
LUF (Lowest Usable Frequency) indicates the lowest usable frequency for communications between two specific points
MUF (Maximum Usable Frequency) indicates that any frequency higher will not produce ionospheric skip.
Shortwave 1.8 MHz – 55 MHz frequencies can bounce off the ionosphere (20,000 feet above the earth and refract down providing worldwide coverage depending on ionospheric conditions. The ionospheric conditions (called propagation characteristics, changes all the time, Propagation is dependent upon the sunspot cycle, time of year, and time of day. We call that skip or bounce and can provide worldwide communications dependent upon conditions and antennas used.

The sunspot cycle cycles every 11 years going from a very reflective high-density ionosphere at the peak of a cycle, to a rarefied ebb or trough at the bottom of the cycle. The study of shortwave wave propagation is a fascinating adventure, but beyond the scope of this license preparation manual. Ask your Elmer for more.

Hertz = Frequency in cycles per second. Named after Hertz
LF (Low Frequency) below the AM broadcast band of 520 KHz
MW (Medium Wave) the AM Broadcast Band 520 KHz -1700 KHz)
HF (High Frequency) above the AM Broadcast band to 54 MHz)
VHF – very high frequency
Frequency Hz, KHz, MHz, GHz (see above)
Wavelength: basic formula
$\lambda = C/f$ where,
λ (Lambda) = Wavelength in meters
c = Speed of Light (299,792,458 m/s)
f = Frequency
For convenience sake we use 300 as the constant instead of 299, and we use the frequency in MHz.
An example: The wavelength (λ) of a signal on 150 MHz equals 300/150 or 2 meters. Hence, we call hams operating on 147 Mhz to be on the 2 meter ham band (approximately).
Example: A 30 Mhz signal would have a wavelength 10 meters long.

The frequency of a waveform is the number of times a complete waveform is repeated in a fixed time period. The length is measured from peak to peak or trough to trough. The unit of frequency is Hz which corresponds to the number of waveforms that repeat in 1 second. So, if a wave repeats 5 times in one second its frequency would be 5 Hz.

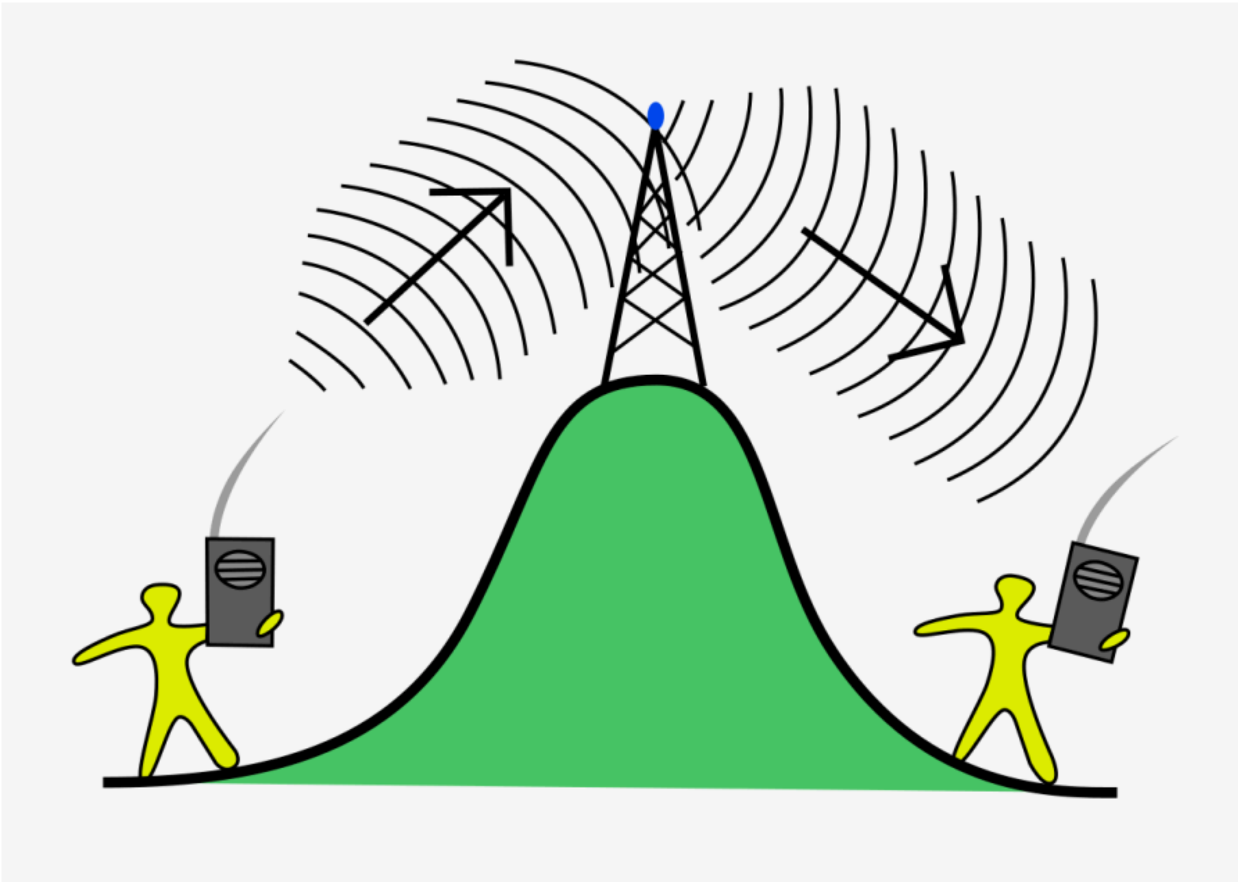




Thanks to https://www.everythingrf.com/rf-calculators/frequency-to-wavelength for these graphics

Annotated Glossary
Duplex and Simplex operation
Simplex communication is accomplished when two stations are operating in the same frequency (receive and transmit are the same).
Duplex operation occurs when the transmit frequency is different from the receiver frequency. It can also be called split operation.
Repeater Operation
Repeater systems utilize duplex operations. The signal comes into the repeater on one frequency (input frequency) and is instantaneously retransmitted out on an output frequency. The repeater is located usually at a high spot or otherwise in a favorable location that allows low power stations or otherwise poorly located stations to talk to

each other through the repeater who would not otherwise be able to talk direct (on simplex).



Repeater locations can be linked via RF links, telephone, cell phone, and/or internet therefore increasing their coverage. Extensive linked systems such as Echolink, C4FM (Fusion), DMR, etc., are becoming increasingly common.

Radio utilizes three general components: Inductance (L), Capacitance (C), and Resistance (R).

Inductance: An inductor is an electronic component consisting of a coil of wire with an electric current running through it, creating a magnetic field. The unit for inductance is the henry (H), named after Joseph Henry, an American physicist who discovered inductance independently at about the same time as English physicist Michael Faraday. One henry is the amount of inductance that is required to induce 1 volt of electromotive force (the electrical pressure from an energy source) when the current is changing at 1 ampere per second.

Capacitance: Capacitance is the capacity to store energy in a capacitor, is measured in farads (F) or more commonly, microfarads (μF) $C = Q / V$ or $Q = CV$. Q is the charge in Coulombs and V is the voltage.

1 farad= 1Coulomb/1volt

Capacitors in Parallel

Capacitors can be connected in series or parallel. If there are n capacitors connected in parallel then the equivalent capacitance is additive:

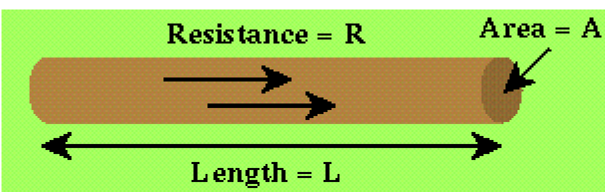
$Cp = C1 + C2 + C3 + \ldots\ldots\ldots + Cn$

If capacitors are connected one after the other forming a chain, then it is connected in series. **In series,** increasing capacitors produce decreased capacitance. For capacitors in series, the total capacitance can be found by adding the reciprocals of the individual capacitances and taking the reciprocal of the sum. Therefore, the total capacitance will be lower than the capacitance of any single capacitor in the circuit. $V = V_1 + V_2 + \ldots \rightarrow Q / C = Q / C_1 + Q / C_2 + \ldots.$

We can divide each side by Q, and then we get the final form of the capacitance formula (or its inverse, precisely speaking):

$1 / C = 1 / C_1 + 1 / C_2 + \ldots.$

In other words, the inverse of total capacity is the sum of the inverses of every single capacitance.
Resistance: Resistance is a value that measures how much the component "resist" the passage of electrical current, the value is measured in ohms (Ω). One way to calculate resistance:



R=ρAL,m where ρ is the resistivity, a material's property in Ohms.
Another form to calculate the resistance is applying Ohm's law (see below)
Resistance in series is directly additive.

Impedance: Impedance is a measure of the opposition that a circuit presents to the flow of alternating current (AC). It is measured in ohms (Ω) and is calculated using the following formula: $Z = \sqrt{(R^2 + X^2)}$ where Z is the impedance in ohms, R is the resistance in ohms, and X is the reactance in ohms.

Reactance is a measure of the opposition that a circuit presents to the flow of AC due to capacitance or inductance, and is calculated using the following formulas:
For capacitive reactance: $Xc = 1/(2\pi fC)$ where Xc is the **capacitive reactance** in ohms, f is the frequency in hertz (Hz), and C is the capacitance in farads (F).

For **inductive reactance**: $Xl = 2\pi fL$ where Xl is the inductive reactance in ohms, f is the frequency in hertz (Hz), and L is the inductance in henries (H).

Once you have calculated the values of R and X, you can substitute them into the formula for impedance to calculate Z. $Z = \sqrt{(R^2 + X^2)}$
Impedance is represented with the symbol Z and measured in Ohms (Ω). You can measure the impedance of any electrical circuit or component. The result will tell you how much the circuit resists the flow of electrons (the current). There are two different effects that slow the current, both of which contribute to the impedance:

- Resistance (R) is the slowing of current due to effects of the material and shape of the component. This effect is largest in *resistors*, but all components have at least a little resistance.
- Reactance (X) is the slowing of current due to electric and magnetic fields opposing changes in the current or voltage. This is most significant for *capacitors* and *inductors*.

Total impedance is simple if the circuit has several resistors, but no inductors or capacitors. First, measure the resistance across each resistor (or any component with resistance), or refer to the circuit diagram for the labeled resistance in ohms (Ω). Combine these according to how the components are connected:[9]
Resistors in series (connected end to end along one wire) can be added together. The total resistance R = R1 + R2 + R3...
Resistors in parallel (each on a different wire that connects to the same circuit) are added as their reciprocals. To find the total resistance R, solve the equation 1/R = 1 / R1 + 1 / R2 + 1 / R3 ...
If there are only inductors in the circuit, or only capacitors, the total impedance is the same as the total reactance. Calculate it as follows:[10]
Inductors in series: Xtotal = XL1 + XL2 + ...
Capacitors in series: Ctotal = XC1 + XC2 + ...
Inductors in parallel: Xtotal = 1 / (1/XL1 + 1/XL2 ...)
Capacitors in parallel: Ctotal = 1 / (1/XC1 + 1/XC2 ...)
Inductive reactance increases with the rate of change in the current direction, or the frequency of the circuit. This frequency is represented by the symbol f, and is measured in Hertz (Hz). The full formula for calculating inductive reactance is $X_L = 2\pi f L$, where L is the inductance measured in Henries (H).
Capacitive reactance: This formula is similar to the formula for inductive reactance, except capacitive reactance is **inversely** proportional to the frequency. Capacitive reactance $X_C = 1 / 2\pi f C$.. C is the capacitance of the capacitor, measured in Farads (F). You can measure capacitance using a multimeter and some basic calculations.
As explained above, this can be written as $1 / \omega C$.
Subtract inductive and capacitive reactance to get total reactance. Because one of these effects increases as the other decreases, these tend to cancel each other out. To find the total effect, subtract the smaller one from the larger.
You will get the same result from the formula X total = |XC - XL|
To calculate impedance from resistance and reactance in series you can't just add the two together, because the two values are "out of phase." This means that both values change over time as part of the AC cycle, but reach their peaks at different times.[12] Fortunately, if all of the components are in series (i.e. there is only one wire), we can use the simple formula Z = √(R2 + X2).

The mathematics behind this formula involves "phasors," but it might seem familiar from geometry as well. It turns out we can represent the two components R and X as the legs of a right triangle, with the impedance Z as the hypotenuse.

Calculate impedance from resistance and reactance in parallel. This is actually a general way to express impedance, but it requires an understanding of complex numbers. This is the only way to calculate the total impedance of a circuit in parallel that includes both resistance and reactance.
Z = R + jX, where j is the imaginary component: √(-1). Use j instead of i to avoid confusion with I for current.
You cannot combine the two numbers. For example, an impedance might be expressed as 60Ω + j120Ω.

If you have two circuits like this one in series, you can add the real and imaginary components together separately. For example, if Z1 = 60Ω + j120Ω and is in series with a resistor with Z2 = 20Ω, then Z total = 80Ω + j120Ω.

See Appendix A below for the application of LC and RLC Circuits, which comprise the backbone of radio communications.

Signal to Noise Ratio (SNR): The two important characteristics of a radio receiver is sensitivity and selectivity. A weak radio signal may be considered to be buried in the noise (inaudible) because the ambient noise floor is greater than the signal strength. A good receiver has an excellent signal to noise ratio (SNR) which amplifies the signal (sensitivity) and filters out the noise (selectivity)..

Receive Gain (Receiver sensitivity): The ability of a receiver to hear weak signals includes a sensitive detector stage and an efficient balanced amplifier stage. There are many schemes to increase the receiver's sensitivity, including adding a preamplifier stage. The main limiting factor in any radio receiver is the internal noise that is generated. For many radio communications applications either the signal to noise ratio or the noise figure is used.

Receiver selectivity: In general, the characteristic of separating adjacent channel interfering signals, ambient noise, front end overload, IMD (Intermod products), harmonics, parasitic radiation, internal circuit and component noise, atmospheric static, or solar or interstellar noise, etc.

Dynamic Range, in general, can be said to be the ratio of being very sensitive while not jeopardizing selectivity. Dynamic range characteristics are a bit more technically to design than simple SNR characteristics, because it factors in the intelligibility of any given weak signal in the presence of strong signals, accommodating both weak and strong signals at the same time. Intermodulation Distortion (IMD) or third order products and front-end over loading (desensing) are factored along with the basic SNR, thus eliciting the dynamic range factor. The RF circuit design of the radio will determine the factors that govern the dynamic range, so it is important to consider dynamic range of your receiver beforehand. It is an important measure of a good receiver. Dynamic Range is the ratio of the largest measurable signal to the smallest measurable signal. For dynamic range specifications a figure called the minimum discernible signal (MDS) is often used. This is normally taken as a signal equal in strength to the noise level. The smallest measurable signal is typically defined as that equal to the noise level, or alternatively the “Noise Equivalent Exposure” or that point where the Signal-to-noise ratio (SNR) is 1. Technically, it can be described as the range of signal amplitudes over which an electronic communications channel can operate within acceptable limits of distortion. The range is determined by system noise at the lower end and by the onset of overload at the upper end. While sensitivity is required for many applications, this is of little use if strong nearby transmissions both in frequency and amplitude mean that the sensitivity cannot be maximized.

There are three common ways to quantify and express Dynamic Range:

as a simple numeric ratio, in decibels (dB), or as a binary value; the application will determine which is used. In the real world of sensors or wireless signals, the front-end analog circuitry must handle signals which can span a wide dynamic range of 100 dB or more.

Noise: The ability to filter out noise (static) and interference caused by natural atmospherics, ambient manmade products, or internal circuits inherent in the radio is a major feature of a good radio. There are many kinds of circuit designs, noise blankers, DSP (Digital Signal Processing), DNR (Digital Noise Reduction), Roofing, IF filtering, AF filtering, and many other filtering methods, and noise attenuation methods. The ambient noise floor is what limits our ability to receive weak signals, second only to poor antennas.

Decibels: A decibel is a logarithmic unit of signal strength. Doubling the signals intensity/amplitude is measured as 3 dB gain. When transmitting, doubling your output power is equivalent to 3 dB gain. For example, a 100 watt signal in a 3 dB gain antenna (assuming no transmission line loss) would be equivalent to a 200 watt radio. Transmitting into a 6 dB gain system would be equivalent to 400 watts, and transmitting into a 9 db gain system would be the equivalent of 800 watts ERP over a unitary gain antenna all else being the same.

On receive it is similar. The stronger the signal into the receiver, the better. By convention, hams use **S units** to measure signal strength. This is the equivalent of 5 µV signal at the receiver’s 50 ohm antenna input. One S-unit corresponds to a difference of 6 dB, equivalent to a voltage ratio of two. Therefore, the difference between a S3 and an S4 received signal is 6db.

We can also measure the presence of RF (radio frquency0 signals with a field strength meter using dBm (a logarithmic unit of power level), expressed in decibel (dB) and referenced to a power level of one milliwatt (mW). Calculations are beyond the scope of this license instruction guide, but such may be used for calculating the RF density at any location.

Antennas – rubber ducks and gain antennas. The short rubberlike antennas that attach to most handheld radios are nicknamed rubberducks. They provide a resonant impedance match but have negative gain. The longer rubberized rubberducks are called extended rubberducks to differentiate them from “whip” antennas. They have less loss than the shorter varieties. “Whip” antenna is a hold over from the old days when mobile

HF automobiles were equipped with long antennas that whipped around in the wind or when in motion. Today, one can still obtain mobile antennas that are classified as "whips". Any shortened antenna sacrifices performance for length due to inductor and/or capacitor losses.

A halfwave dipole is equivalent to 2.1 db gain, using "i" to stand for an isotropic antenna. When comparing antennas, be careful to not conflate dBi with dBd, the latter is gain over a ½ wave dipole a half wave above perfect ground. The general rule is that the higher the gain, the better the antenna, however, gain antennas are directional, i.e., what is gained in one direction is lost in another.

Antennas are a huge subject in radio due to their critical importance. Ask your Elmer for more information, obtain the ARRL Amateur Radio Handbook or ARRL Antenna Handbook, use a search engine, or YouTube for more. Antennas can be a lifetime research project to ham radio enthusiasts.

Transmission lines: Most often used are **coaxial cable and open-wire lin**e, which has various nuanced configurations such as ladder line and window line. Transmission loss can degrade both your transmit and receive capabilities. Choosing the correct transmission line type can be critical especially with long lengths and at VHF and above.

PL and CTSS Tones: These are mostly sub-audible tones In the range of 67 Hz to 255 Hz (the lower the frequency, the less audible). The PL tone or Digital code accompanies the RF signal in transmit mode. It is used to selectively key one or more function on the receiving station's radio. Subaudible Tones are most frequently used to activate repeaters or receiver squelch systems. The most common names are **CTCSS** (Continuous Tone Coded Squelch System) and also called, **PL** (Private Line). Similarly digital codes (**DCS**) may also be used for the same purposes.

PTT: Push To Talk button or switch on a radio that activates your transmission. Also called keying your radio or transmit switch. Always release the switch/button to be able to receive.

KEY: Keying the transmitter or keying down is the same as using the PTT to transmit. "Key" is a holdover from Morse code days when the telegraph key was used to transmit Morse code signals. Morse code, and hence keys are still in use, but are dying out. There are different kinds of keys, such as straight keys.(straight up and down); sideswipers or semi-automatic keys nicknamed bugs; and "paddles", which activate automatic keyers. Morse code can also be generated by keyboards and computer programs to key transmitters.

Doubling: The term used when two stations transmit at once on the same frequency interfering with each other.

Squelch: a receiver setting to squelch out ambient noise floor (static) but not a received signal. Set your squelch at the lowest level that prevents static.

Scan: Radios can be set to scan specific frequencies or entire bands. It is a personal option.

Memory channels (code Plugs): These are frequencies and characteristics that are programmed into the radio's memory fr quick access. Every radio has a different procedure.

VFO mode/Frequency Modes: In VFO or frequency mode the operator can move to any specifically frequency of choice within the range of the radio versus memory/channel mode where you can only select frequencies and characteristics that are programmed in the radio's memory.
MESH: A mesh network is a highspeed network in which devices -- or nodes -- are linked together, branching off other devices or nodes. These microwave networks, such as WiFi routers, are set up to efficiently route data between devices and clients. They help organizations provide a consistent connection throughout a physical space.
AREDEN: An Amateur Radio Emergency Data Network (AREDN™) is a highspeed data network built with Amateur Radio Operators and Emergency Communications Infrastructure in mind. AREDN™ is self-configuring and self-healing. Where possible, AREDN™ will establish connections with as many other AREDN™ compatible devices (nodes) as possible and form a redundant mesh like network.
https://www.arednmesh.org/content/what-aredn-network
PACKET: Packet radio represents an amateur radio digital communications protocol (AX.25) which is based on the commercial X.25 network link protocol. It is an error free digital communications system widely used in amateur radio. APRS is a subset of Packet and is also widely in use.
VARA: A highspeed digital modem protocol.
Winlink: A digital platform enabling packet, VARA, and other modem schemes to interoperate while providing gateways services between bands.
FUSION: A digital voice networking system using C4FM encoding supported by Yaesu.(See above under Digital Voice)
Elmer: Ham jargon for a ham radio elder/instructor
Band Plan: The allocation of ham bands for various modes, frequency privileges, and power limitations. See:
https://www.hero.radio/_files/ugd/ceee03_700dfd99d69e4ceb8023ddca1dc24516.pdf
The FCC in collaboration with the International Amateur Radio Union (IARU), the International Telecommunication Union (ITU) establishes bandplan allocations in regard to frequencies, modes, power, and other standards. The ARRL in turn, establishes a suggested efficient "use" bandplan. Lastly, local repeater coordinating bodies consisting of local hams establish bandplans based on minimizing interference. In Northern California that is the Northern Amateur Relay Council of Northern California
http://narcc.org/

73: Best wishes. Jargon held over from the telegraph days. It is used in closing instead of goodbye, best regards, etc. Note, that 73's would be redundant as the "s" is assumed.

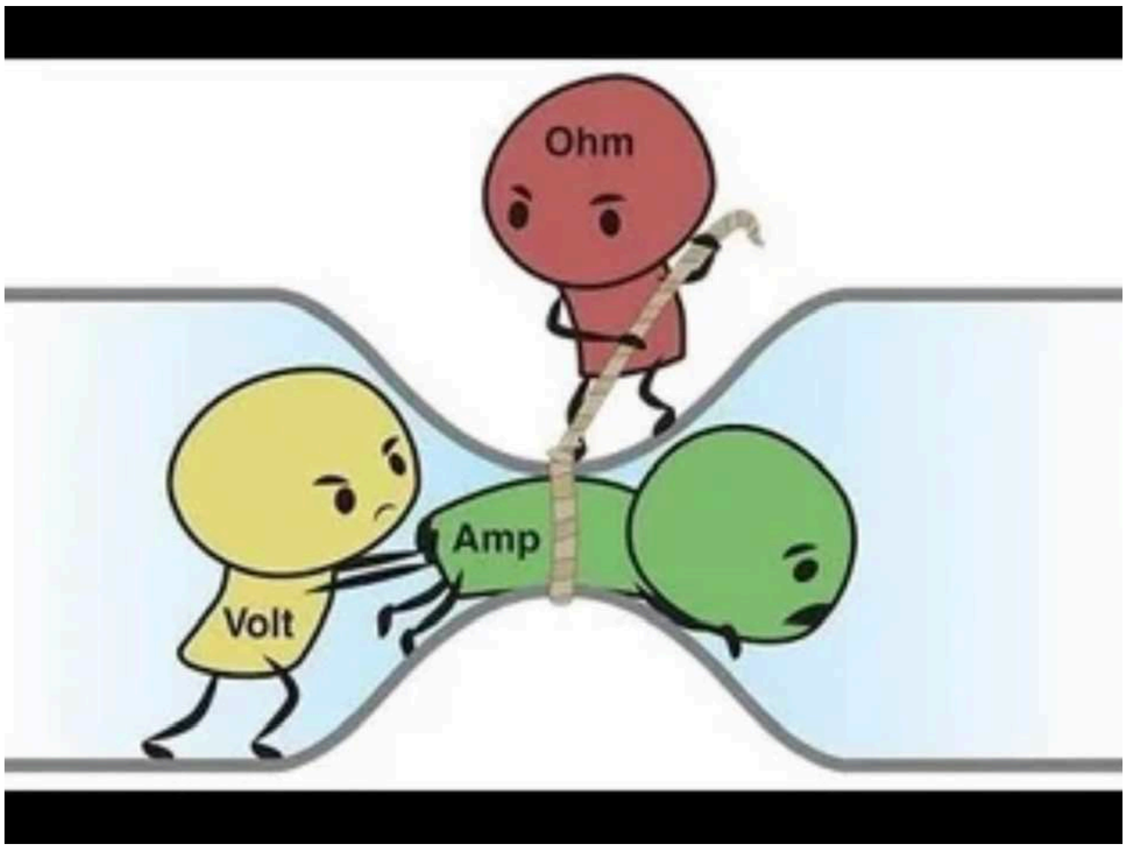
ARES (Amateur Radio Emergency Service).
RACES (Radio Amateur Civil Emergency Services)
MARS (Military Amateur Radio System)

Power
Power Input is usually twice that of the output power due to heat losses. Thus a 100 watt radio utilizes 200 watts of power when keyed in transmit mode.

That is called transmit output power. The FCC limits the amount of output power for hams at 1.5 KW maximum, but there are more limitations according to specific restricted frequency bands and operator class privileges.

ERP (Effective Radiated Power) and Antenna Gain: Your effective radiated power can be estimated after adding antenna gain and subtracting feedline loss from the output power at the radio.

Power: Ohms Law



Current measured in amperes depends upon voltage (EMF force) and is resisted by Ohms. The quantity of amperes times the voltage, along with the minimum amount of resistance (every circuit has resistance (except a short circuit) determines the quantity of power (measured in watts).

Watts: The measure of power (P) measured in Watts, and defined in Ohms law as P (Watts) = Volts (E) times Amps (I) transposed or P = IE Ohms. “Amps” is short for Amperes. “Volts” is short for voltage.
Example: A 200 Watt light bulb in the average US household that uses a steady 120 volt voltage system (E), draws 1.666 Amps (I). The same amount of brightness (200 Watts) at 12 Volts draws 16.66 amps (I) because the voltage is 1/10th the electromotive force.

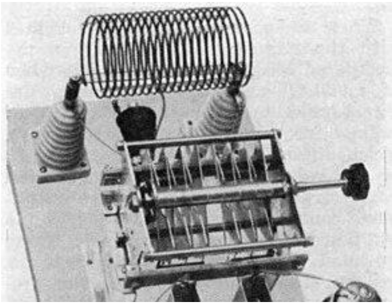
Similarly, a ham radio that uses 100 Watts output, utilizes about 200 watts of input power because of inefficiency in the internal radio's circuitry. That radio will need a power supply that supplies at least 16.66 amps; i.e., a 20 amp 12 volt DC power supply that is capable of continuous duty at least 16.66 amperes.

To reiterate the constituents of Ohms law from these 4 Quantities
E represents electromotive force, EMF and is measured in voltage or volts or V.
I represents the intensity of electrical current and is measured in amperage or amps or A.
R represents resistance and is measured in ohms or the omega symbol; Ω
P represents power or electrical energy and is measured in wattage or watts or W.
Ohms Law is very versatile. We can derive the following quantities. We also know that I, current in amps, is directly proportional to voltage, but inversely proportional to R (resistance measured in Ohms). Therefor:
I = E / R: Amps is equal to volts divided by resistance.
Also using Algebra:
E = I x R Volts (represented by the letter E) is equal to amps (I) times resistance (R).
E = P / I = *√ (PxR)*
E = P / I Volts is equal to watts (P) divided by amps.
E = √ (PxR) Volts is equal to the square root of the answer to watts times resistance.
I = E / R = P / E = √ (PxR)
I = P / E Amps is equal to watts divided by volts.
I = √ (PxR) Amps is equal to the square root of the answer to; watts divided by resistance.
P = I x E = $E^2 / R = I^2 \times R$
P = I x E Watts is equal to amps times volts.
$P = E^2 / R$ Watts is equal to volts squared divided by resistance.
$P = I^2 \times R$ Watts is equal to amps squared times resistance.
$R = E / I = P / I^2 = E^2 / P$
R = E / I Resistance is equal to volts divided by amps.
$R = P / I^2$ Resistance is equal to watts divided by the answer to; amps squared.
$R = E^2 / P$ Resistance is equal to volts squared divided by watts.

If you know the value of any 2 entities, you can find the third by using one of these formulas.

Appendix A: LC and RLC Circuits, which comprises the backbone of radio communications. **

After we know capacitance, inductance, resistance, impedance, reactance, voltage, and current, we are ready to make up radio circuits. The basic resonant circuit is the LC circuit. The following circuitry descriptions may seem heavily technical, but are critical to understanding how radio works. However, as has been indicated, you can still pass the test through memorization of the Question/Answer pool without complete technical understanding, which can come later.

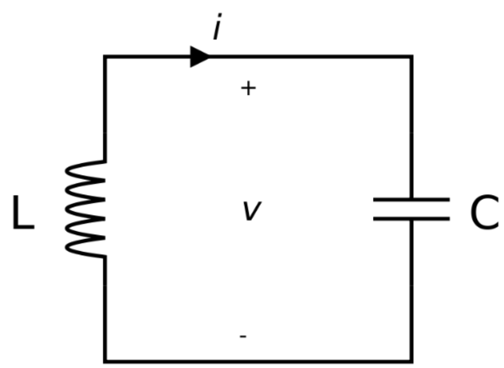


Output tuned circuit of shortwave radio transmitter

An LC circuit, also called a resonant circuit, tank circuit, or tuned circuit, is an electric circuit consisting of an inductor, represented by the letter L, and a capacitor, represented by the letter C, connected together. The circuit can act as an electrical resonator, an electrical analogue of a tuning fork, storing energy oscillating at the circuit's resonant frequency.

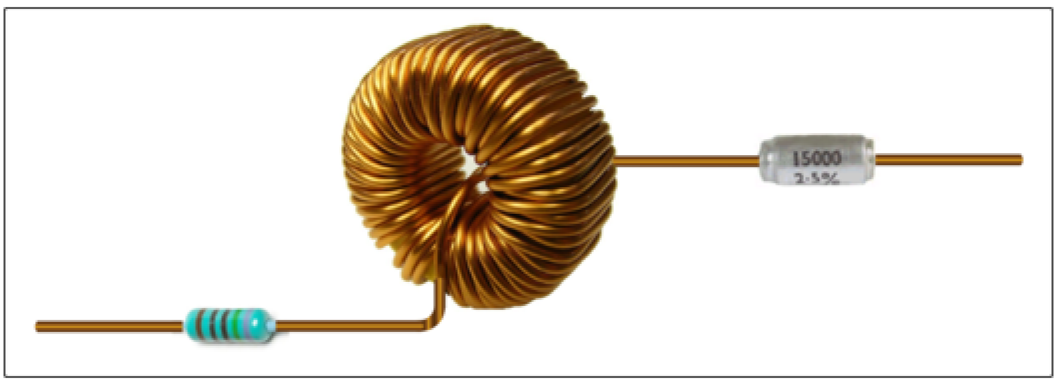
LC circuits are used either for generating signals at a particular frequency, or picking out a signal at a particular frequency from a more complex signal; this function is called a bandpass filter. They are key components in many electronic devices, particularly radio equipment, used in circuits such as oscillators, filters, tuners and frequency mixers.

An LC circuit is an idealized model since it assumes there is no dissipation of energy due to resistance. Any practical implementation of an LC circuit will always include loss resulting from small but non-zero resistance within the components and connecting wires. The purpose of an LC circuit is usually to oscillate with minimal damping, so the resistance is made as low as possible. While no practical circuit is without losses, it is nonetheless instructive to study this ideal form of the circuit to gain understanding and physical intuition. For a circuit model incorporating resistance, see RLC circuit.



The diagram above is a simple LC Circuit

The diagram below is a RLC circuit containing a resistor, a coil (inductor), and capacitor.



RLC Circuit: An RLC circuit is an electrical circuit consisting of a resistor (R), an inductor (L), and a capacitor (C), connected in series or in parallel. The name of the circuit is derived from the letters that are used to denote the constituent components of this circuit, where the sequence of the components may vary from RLC.

The circuit forms a harmonic oscillator for current, and resonates in a manner similar to an LC circuit. Introducing the resistor increases the decay of these oscillations, which is also known as damping. The resistor also reduces the peak resonant frequency. Some resistance is unavoidable even if a resistor is not specifically included as a component. RLC circuits have many applications as oscillator circuits. Radio receivers and television sets use them for tuning to select a narrow frequency range from ambient radio waves. In this role, the circuit is often referred to as a tuned circuit. An RLC circuit can be used as a band-pass filter, band-stop filter, low-pass filter or high-pass filter. The tuning application, for instance, is an example of band-pass filtering. The RLC filter is described as a *second-order* circuit, meaning that any voltage or current in the circuit can be described by a second-order differential equation in circuit analysis.
The three circuit elements, R, L and C, can be combined in a number of different topologies. All three elements in series or all three elements in parallel are the simplest in concept and the most straightforward to analyze. There are, however, other

arrangements, some with practical importance in real circuits. One issue often encountered is the need to take into account inductor resistance. Inductors are typically constructed from coils of wire, the resistance of which is not usually desirable, but it often has a significant effect on the circuit.

Basic concepts

Resonance

An important property of this circuit is its ability to resonate at a specific frequency, the resonance frequency, f_0. Frequencies are measured in units of Hertz. In this article, angular frequency, ω_0, is used because it is more mathematically convenient. This is measured in radians per second. They are related to each other by a simple proportion,

$$\omega_0 = 2\pi f_0 \, .$$

Resonance occurs because energy for this situation is stored in two different ways: in an electric field as the capacitor is charged and in a magnetic field as current flows through the inductor. Energy can be transferred from one to the other within the circuit and this can be oscillatory. A mechanical analogy is a weight suspended on a spring which will oscillate up and down when released. This is no passing metaphor; a weight on a spring is described by exactly the same second order differential equation as an RLC circuit and for all the properties of the one system there will be found an analogous property of the other. The mechanical property answering to the resistor in the circuit is friction in the spring–weight system. Friction will slowly bring any oscillation to a halt if there is no external force driving it. Likewise, the resistance in an RLC circuit will "damp" the oscillation, diminishing it with time if there is no driving AC power source in the circuit.

The resonant frequency is defined as the frequency at which the impedance of the circuit is at a minimum. Equivalently, it can be defined as the frequency at which the impedance is purely real (that is, purely resistive). This occurs because the impedances of the inductor and capacitor at resonant are equal but of opposite sign and cancel out. Circuits where L and C are in parallel rather than series actually have a maximum impedance rather than a minimum impedance. For this reason they are often described as antiresonators; it is still usual, however, to name the frequency at which this occurs as the resonant frequency.

Natural frequency

The resonance frequency is defined in terms of the impedance presented to a driving source. It is still possible for the circuit to carry on oscillating (for a time) after the driving source has been removed or it is subjected to a step in voltage (including a step down to zero). This is similar to the way that a tuning fork will carry on ringing after it has been struck, and the effect is often called ringing. This effect is the peak natural resonance frequency of the circuit and in general is not exactly the same as the driven resonance frequency, although the two will usually be quite close to each other. Various terms are used by different authors to distinguish the two, but resonance frequency unqualified usually means the driven resonance frequency. The driven frequency may be called the undamped resonance frequency or undamped natural frequency and the peak frequency may be called the damped resonance frequency or the damped natural frequency. The reason for this terminology is that the driven resonance frequency in a series or parallel resonant circuit has the value.

$$\omega_0 = \frac{1}{\sqrt{LC}} \ .$$

This is exactly the same as the resonance frequency of a lossless LC circuit – that is, one with no resistor present. The resonant frequency for a *driven* RLC circuit is the same as a circuit in which there is no damping, hence undamped resonant frequency. The resonant frequency peak amplitude, on the other hand, does depend on the value of the resistor and is described as the damped resonant frequency. A *highly damped* circuit will fail to resonate at all, when not driven. A circuit with a value of resistor that causes it to be just on the edge of ringing is called critically damped. Either side of critically damped are described as underdamped (ringing happens) and overdamped (ringing is suppressed).
Circuits with topologies more complex than straightforward series or parallel (some examples described later in the article) have a driven resonance frequency that deviates from the undamped resonance frequency, damped resonance frequency and driven resonance frequency can all be different.

Damping

Damping is caused by the resistance in the circuit. It determines whether or not the circuit will resonate naturally (that is, without a driving source). Circuits that will resonate in this way are described as underdamped and those that will not are overdamped. Damping attenuation (symbol α) is measured in nepers per second. However, the unitless damping factor (symbol ζ, zeta) is often a more useful measure.

$$\zeta = \frac{\alpha}{\omega_0} \ .$$

The special case of $\zeta = 1$ is called *critical damping* and represents the case of a circuit that is just on the border of oscillation. It is the minimum damping that can be applied without causing oscillation.

Bandwidth

The resonance effect can be used for filtering, the rapid change in impedance near resonance can be used to pass or block signals close to the resonance frequency. Both band-pass and band-stop filters can be constructed and some filter circuits are shown later in the article. A key parameter in filter design is bandwidth. The bandwidth is measured between the cutoff frequencies, most frequently defined as the frequencies at which the power passed through the circuit has fallen to half the value passed at resonance. There are two of these half-power frequencies, one above, and one below the resonance frequency where $\Delta\omega$ is the bandwidth, ω_1 is the lower half-power frequency and ω_2 is the upper half-power frequency. The bandwidth is related to attenuation by where the units are radians per second and nepers per second respectively.[citation needed] Other units may require a conversion factor. A more general measure of bandwidth is the fractional bandwidth, which expresses the bandwidth as a fraction of the resonance frequency and is given by

The fractional bandwidth is also often stated as a percentage. The damping of filter circuits is adjusted to result in the required bandwidth. A narrow band filter, such as a notch filter, requires low damping. A wide band filter requires high damping.

Q factor

The Q factor is a widespread measure used to characterize resonators. It is defined as the peak energy stored in the circuit divided by the average energy dissipated in it per radian at resonance. Low-*Q* circuits are therefore damped and lossy and high-*Q* circuits are underdamped and prone to amplitude extremes if driven at the resonant frequency.[a] *Q* is related to bandwidth; low-*Q* circuits are wide-band and high-*Q* circuits are narrow-band. In fact, it happens that *Q* is the inverse of fractional bandwidth *Q* factor is directly proportional to selectivity, as the *Q* factor depends inversely on bandwidth. For a series resonant circuit (as shown below), the Q factor can be calculated as follows:[

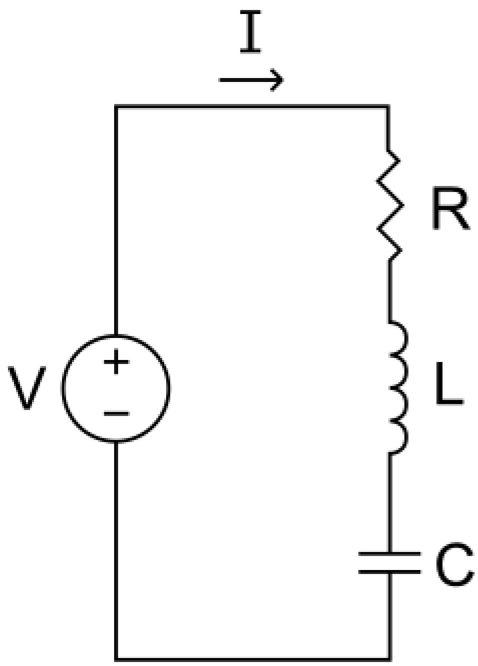
$$Q = \frac{X}{R} = \frac{1}{\omega_o RC} = \frac{\omega_o L}{R} = \frac{1}{R}\sqrt{\frac{L}{C}} = \frac{Z_o}{R}\ ,$$

Scaled parameters

The parameters ζ, B_f, and Q are all scaled to ω_0. This means that circuits which have similar parameters share similar characteristics regardless of whether or not they are operating in the same frequency band.

The article next gives the analysis for the series RLC circuit in detail. Other configurations are not described in such detail, but the key differences from the series case are given. The general form of the differential equations given in the series circuit section are applicable to all second order circuits and can be used to describe the voltage or current in any element of each circuit.

RLC Series circuit



RLC series circuit

- *V*, the voltage source powering the circuit
- *I*, the current admitted through the circuit
- *R*, the effective resistance of the combined load, source, and components
- *L*, the inductance of the inductor component
- *C*, the capacitance of the capacitor component

In this circuit, the three components are all in series with the voltage source. The governing differential equation can be found by substituting into **Kirchhoff's voltage law (KVL)** the constitutive equation for each of the three elements.

The properties of the parallel RLC circuit can be obtained from the duality relationship of electrical circuits and considering that the parallel RLC is the dual impedance of a series RLC. Considering this, it becomes clear that the differential equations describing this circuit are identical to the general form of those describing a series RLC.
For the parallel circuit, the attenuation *α* is given by

$$\alpha = \frac{1}{2RC}$$

and the damping factor is consequently

$$\zeta = \frac{1}{2R}\sqrt{\frac{L}{C}}\ .$$

** Wikipedia https://en.wikipedia.org/wiki/RLC_circuit

Appendix B: The FCC Registration Number (FRN)

All FCC licensees will need to register for a free FRN account before the FCC will issue any licenses. You can obtain it before you take the License test or after you pass the test, but before your callsign is issued.

So, first get the number and make a note of it, your username, and your password etc. The FRN is essential. There is no fee for the FRN #.
https://www.fcc.gov/wireless/support/knowledge-base/universal-licensing-system-uls-resources/getting-fcc-registration.

Although the FCC license costs $35, you do not have to pay until you take the test.

"When the FCC receives the examination information from the VEC, it will email a link with payment instructions to each qualifying candidate. The candidate will have **10 calendar days,** from the date of the application file number being issued, to pay. After the fee is paid, and the FCC has processed an application, examinees will receive a second email from the FCC with a link to their official license or, in very rare instances, an explanation for why the application was dismissed or denied. The link will be valid for 30 days.

** Applicants do not have to wait for the FCC email to pay the fee. They can look up their application in the FCC application search system using their FRN: https://wireless2.fcc.gov/UlsApp/ApplicationSearch/searchAppl.jsp
If the applicant has a pending application in the system, that means the VEC has submitted the application to the FCC, and the fee can be paid by logging into the CORES system. **

If an applicant fails to pay within the 10-day window, the application will be dismissed by the FCC. The application will have to be refiled to the FCC which will restart the 10-day window.
Exam candidates do not have to retest if the 10-day payment window is missed. An application can be refiled to the FCC, by the coordinating VEC, at any time before the CSCE expires. Contact the VEC listed on your CSCE to have the application refiled to the FCC.

Per usual procedures, examinees that pass multiple exams at one session, will have one application transmitted to the FCC reflecting the highest level license class earned. Again, our VEC procedures have not changed. The new license candidates have an extra step before the license is issued. VE teams can point candidates to our FCC Application Fee webpage. Our new ARRL VEC CSCEs also include information about the application fee and points candidates to the webpage. The FCC rule pertaining to CSCEs will not change. CSCE credit will continue to be valid for 365 days, starting from the date of issuance."
https://www.arrl.org/fcc-application-fee

Just in case, the above information becomes outdated, try this from https://beniciaarc.com/frn-info/ Thanks to the Benicia Amateur Radio Club

Applying for an FRN Number

"The Federal Communications Commission (FCC) now requires all applicants to establish an online account in the Commission Registration System (CORES) and a FCC Registration Number (FRN) in order to issue a Radio License. These instructions will show you how to obtain an FRN prior to test day.

Part 1: Establish FCC Username account

1. Go to https://apps.fcc.gov/cores and click on **REGISTER** in the *Need a Username?* box.
2. Fill in the requested information:
   - Username (your email address)
   - Password (12-15 characters)
   - Name
   - Secondary email address (optional)
   - Phone number
   - Security question and answer
3. Click on **Create Account**. Watch your email for a message with the subject *FCC Account Request Verification* and click on the link in the message to validate your new account.
4.

Part 2: Register for new FRN

1. Go to https://apps.fcc.gov/cores and fill in your username and password in the *Username Login* box and click **LOG IN.**
2. Click on **Register new FRN.**
   - Check boxes to indicate an individual with a contact address in the US, then click **CONTINUE**.
   - Check box to proceed with a CORES FRN Registration and click **CONTINUE**.
   - Fill in the requested information (including SSN) and click **SUBMIT.**
3. If successful, you will get this message: "Thank you for registering with the FCC. As of today, Feb XX 2019 XX:XXPM, you have been assigned the following FCC Registration Number (FRN): 0XXXXXXXXX. **Please print this page for your records.** "

If you have an FRN but don't remember it:

Go to https://apps.fcc.gov/cores and click on **SEARCH**. Then in the FRN dropdown menu select *Last Name* and enter your Last Name and click **SEARCH**. Use *Advanced Search* if you have a common name.

Updated May 2023"

~ Benicia Amateur Radio Club (BARC)

Link to this Guide

https://docs.google.com/document/d/1fxqUTX32vFsj1qhkEO8xocSVptRRZtVK/edit?usp=drive_link&ouid=104819173365313078565&rtpof=true&sd=true

Link to the cloud subdirectories and files for quick license reference
https://drive.google.com/drive/folders/1L371PoJ-NGReDZ6wahf23p-x8HImYRkJ?usp=sharing

Ham Radio License Classes and Tests in the Bay Area
https://www.karoecho.net/events#h.etipyct5ww0v

ni6a rev6 -- 08/09/2023