HAMATEUR CHATTER

The Milwaukee Radio Amateurs Club

October 2012, Volume 20, Issue 10

One of the World's Oldest Continuously Active Radio Amateur Clubs—since 1917

Presidents' Letter

Over the last few weeks Erv N9YNU has been holding an on air General class. He has been holding this every Tuesday night on the MRAC repeater and Thursday nights on the MAARS repeater. The idea behind this class was to ask the questions and see who has the correct answer. Erv is using the Gordon West book to teach from. We are also coming up with some material that will be put on the website regarding this effort. I think this idea has some room for growth and future expansion. If you have any suggestions please let Erv know. As a continuing effort on education, we are exploring more educational type programs for our club meetings. If there are topics that you would like to see at our meetings let us know.

At this months meeting, we are going to have a program about the club repeater. There will be a brief history of the repeater along with pictures of the repeater site. This is a community site, shared with other local organizations. The history of this site and how it all came about is interesting.

Starting with the October meeting I plan on providing time for people to ask questions or even to brag about operating. We will also use this time to ask for ideas for future club activities. I think a little club interaction is a good thing. Who knows it might even keep people awake.

Novembers 3rd is the MRC 91 swapfest at the Elk's lodge across from AES. We will have a club table at the swapfest. We are looking for people to help staff the table. The more people we have the less anyone has to stay at the table.

Look forward to seeing you at the meeting.

Dave KA9WXN

Directors' Meeting Minutes

Board of directors meeting called to order at 7:06 pm by Dave Shank, KA9WXN, club president.

Director's present: Mark, AB9CD, Michael KC9CMT, Dave KA9WXN, Hal, KA9OZN, Joe, N9UX, Al, KC9IJJ
Absent: Dan, N9ASA

Preliminary discussions:

The meeting minutes from the June meeting were accepted as published in the September HamChatter by a unanimous voice vote 6-0. The club Treasury holds a significant amount for this time of year, $18,000+/- in the club accounts. Two people renewed in the month of September, their names will be added to the club roster by the club secretary. The drive for renewals for the 2013 year will be addressed during the club meeting on this Thursday.

Swapfest fliers were finalized and printed by Dan, N9ASA at Kinkos'. Loren now has the 500 fliers that he requested. Fliers will be available for distribution starting this month. A total of 1000 fliers were printed out during the first run. There has been some discussions regarding using Joe, N9UX's PayPal account to accept reservation funds for the swapfest.

Swapfest: The tables will be numbered this year. The club secretary will be keeping the swapfest reservation records again this year. Al, KC9IJJ has volunteered to print the tickets again this year.

MRAC Officers:

Terms Expiring in 2014

- President – Dave, KA9WXN
- V-President– Dan, N9ASA
- Secretary – Mike, KC9CMT
- Treasurer – Joe, N9UX
- Director – Mark, AB9CD

Terms Expiring in 2013

- Director – Al, KC9IJJ
- Director – Hal , KB9OZN

The Club Phone Number is: (414) 332-MRAC or

(414) 332- 6 7 2 2

Visit our website at:

www.w9rh.org

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Board of Directors' Meeting Minutes

Complimentary tickets will be sent out to various clubs in December. The club secretary will take care of this mailing.

Meetings: September, West Mountain Radio. October, November, Open. Future Ideas, oscilloscope & how it works and Arduino, HT's & QRP radios. Also some technical repeater issues can be discussed. IRLP & VOIP. Linux as a OS to rival Windows. Presentation on Ham Radio Deluxe.

Old Business:

Pioneer Village: The situation at Pioneer Village is in transition. Our club wants to retain our storage area in their basement and use their facility for special events.

The idea of donating $300 to the ARRL spectrum defense fund was brought forward by Michael, KC9CMT. This will be discussed when new business is discussed.

Phone Bill: The club will be looking into changing our phone vendor, to get a cost advantage. A change in phone service would require a new gateway at the repeater site. This may cost $100 extra. Using AT&T has not been an advantage to the club.

Committee Reports: History is being worked on by Dave DeFebo, WB9BWP. He will have new DVD's to distribute to the Board members at the membership meeting this Thursday. Club secretary will be being in material from storage to be scanned by Mark, AB9CD.

Public Relations: Education in Ham radio is being given in classes this fall by one of the other repeater groups in the area. Ham University is something that has been discussed. A solid schedule of classes pertaining to various subjects should be made up. Joe, N9UX will work on this topic. A motion was made to send the spectrum defense fund at ARRL $200 this year by Michael, KC9CMT, seconded by AL, KC9IJJ. Motion passed by a voice vote of 6-0. The Membership will be informed of the board's decision to send funds to ARRL. We will consider funding the ARRL Spectrum Defense Fund yearly. This motion was brought by Mark, AB9CD, seconded by Hal, KA9OZN. Motion passed by a voice vote of 6-0.

A motion was made to adjourn the meeting at 8:48 pm by Hal, KA9OZN, seconded by Michael KC9CMT. Meeting adjourned at 8:55 pm.

Membership Meeting Minutes

The MRAC membership meeting was called to order at 7:06 pm by Dave, WB9BWP, club and board president. The Mic was passed around for introductions. A sign-in sheet was circulated for the recording of membership attendance.

Preliminary discussions:

The membership meeting minutes were accepted as published in the September HamChatter by a motion initiated by Dave, KA9WXN and seconded by Joe, N9UX, accepted by the membership by a unanimous voice vote.

Tonight's meeting presentation will be on DC Power Solutions by Darren Rook, KC9SSL or West Mountain Radio based here in Wisconsin. Darren is an engineer with West Mountain. The presentation stated with a overview of Anderson Powerpoles. All of West Mountains power products use these connections. West Mountain is located in Waukesha, just off Sunset Drive.

Tonight's Presentation:

DC power solutions; Anderson Powerpoles are a genderless, but keyed type connector. It is a reliable connection, with standard color codes; 15, 30 & 45A contacts use the same connector. Each connector has a locking clip incorporated into the design. DC distribution; the RIGrunner, Cleans up your wires and no longer requires the daisy chaining of cables. These devices handle up to 40A. If a fuse trips, there is a led indicator and a buzzer. They can be configured in a number of ways. Their newest model, the RIGrunner 4005i,gives the user individual control over each powerpole. Software logging and control. Can be access via the internet. Will send the user an E-mail if a fuse is blown. Incorporates a LCD panel to control and view power uses.

DC battery backup:

West Mountain Radio PWRgate; uninterruptable DC power, 4-stage charger keeps battery maintained. Uses a lead acid sealed battery by design. When main power is lost battery kicks in immediately. Darren gave a PWRgate demo using a emergency light.

PWRgaurd: Protects your gear from over or under voltage. An external signal can control the disconnect. Device will disconnect battery at 10.5 volts.

DC measurement:

PWRcheck: Measures voltage and current at the same time. Bi-directional power/current detection. Logging to internal device memory. PWRcheck to keep track of your solar arrays, batteries, and more.

Battery/Supply Testing: CBA4 from West Mountain Radio. Electronic load, constant current, constant power, constant resistance, power profile, and other tests. Measures capacity of a battery, determines power profile of a power supply or solar cell.

Q&A to West Mountain Radio: A question was brought up about a vintage piece of equipment, no longer offered by anyone. West Mountain also sells a DC go box. There are some plans in the works for a DC booster, but do not any in the works at this time. There is a demonstration of products on the front table for all to examine.

Dave, KA9WXN called the club business meeting to order at, 8:05 pm. Joe, N9UX gave the treasurers report for the summer when we were not in session as a group. The auction was a big success this year. August was the picnic, with costs not as of yet being paid out. The P.O. Box key has been transferred from Mark, AB9CD to Joe, N9UX. Standard phone expenses were incurred during the off-season. Virtual accounts are the General, and Repeater accounts.

Membership Meeting Minutes

Motion made by AL, KC9IJJ to accept the treasurers report as read, Seconded by Hal, KA9OZN. Approved by a voice vote of the membership.

Topics of Discussion:

1000 swapfest fliers were printed up with 500 being turned over to Loren for distribution. Field day was reported to be a success. Next year's FD will be at the same place, Konkel Park in Greenfield. The storage situation at Pioneer Village is being worked on by Mark, AB9CD. There has been discussion about setting up a special event station at PV the weekend prior to FD. Christmas party for club? The club may stay with the same format as last year, a party during the meeting after the swapfest. Swapfest income will pay for the meeting costs of food etc... The Board of Director's would like to donate $200 to the ARRL spectrum defense fund. This was discussed with the membership without any dissenting comments.

The club is still considering giving classes, radio classification, electronic technologies etc... The MRC91 is giving radio classes this fall at AES. Tech, General and then Extra in that order. Information about classes in general subjects can be submitted to the Editor of the Newsletter for publication. The deadline is the 15th of each month for the submission of articles.

Question: Does the club have a repeater maintenance schedule and are any new part being ordered. The repeater is in very good shape. No parts are now on order. Maintenance is handled by Dave, KA9WXN with an assist by Dan, N9ASA. The building that houses our repeater also houses a number of other groups repeater and associated equipment. Perhaps the club should do another program during a membership meeting about the repeater and facility. Our repeater is on the channel 10/36 broadcast tower. MATC owns the facility that houses our repeater.

Everett, K9PSK announced that October 3rd is the SMARC auction and October 14th is the SEWFARs swapfest.

Special event stations:

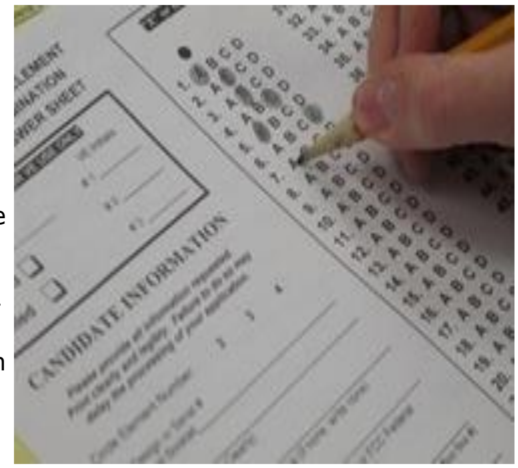
Some contacts were made during the picnic using a dipole tree mounted. 100+ contacts were made by the club station at the AES SuperFest. QSL cards are still being received by the club. Certificates and/or QSL cards will be sent out by the club to all contacts. The AES station was used during this event, they have two TS-2000 radios for HF work. AES allowed us to use a FT-9100 for our FD event. Future events suggested, wounded warriors, light house events. Naval historical events.

There will be a food gathering with Pancho after the club meeting.

Dave accepted motions to adjourn the meeting at 8:14 pm. Motion made by Jim, KB9MMA, seconded by Pancho, N9OFA. Meeting adjourned at 8:16 pm. Room policed of trash and returned to an acceptable condition as found before the meeting commenced. A parts raffle will commence after a short break.

ARRL Newsline

FCC News: FCC Seeks to Change Amateur Radio Licensing Rules



The FCC has issued a *Notice of Proposed Rulemaking* that seeks to change the way it licenses Amateur Radio operators.

On October 2, the FCC released a *Notice of Proposed Rulemaking* in WT Docket No. 12-121 that seeks to change the Amateur Radio licensing rules, especially as they concern former licensees. Acting upon an April 2011 *Petition for Rulemaking* filed by the Anchorage VEC to give permanent credit to radio amateurs for examination elements they have successfully passed, the FCC proposes to revise Section 97.505 to require that Volunteer Examiners (VEs) give examination credit to an applicant who can demonstrate that he or she formerly held a particular class of license. In addition, the Commission seeks to shorten the grace period during which an expired amateur license may be renewed and to reduce the number of VEs needed to administer an amateur license examination.

Postage Rates to Increase in January

The US Postal Service has announced that as of January 27, 2013, the cost to mail First Class letters, postcards and packages within the US will go up. The cost to mail a first class letter will be 46 cents, while the cost to mail a postcard will be 33 cents, an increase of 1 cent for each. This is the third increase for postcard postage in less than two years; in April 2011, the USPS boosted the postcard stamp price from 28 cents to 29 cents, and from 29 cents to 32 cents in January 2012. The USPS will also introduce a First Class Mail Global Forever Stamp in January. This new stamp will allow customers to mail 1-ounce letters anywhere in the world for one set price of $1.10. The cost to mail flat-rate Priority Mail packages and letters will also increase.

Severe Weather Preparedness

Cold Weather Advisory

Frostbite Overview

Frostbite occurs when tissues freeze. This condition happens when you are exposed to temperatures below the freezing point of skin. Hypothermia is the condition of developing an abnormally low body temperature. Frostbite and hypothermia are both cold-related emergencies.

The condition has long been recognized. A 5000-year-old pre-Columbian mummy discovered in the Chilean mountains offers the earliest documented evidence of frostbite. More recently, Napoleon's surgeon general, Baron Dominique Larrey, provided the first description of the mechanisms of frostbite in 1812, during his army's retreat from Moscow. He also noted the harmful effects of the freeze-thaw-freeze cycle endured by soldiers who would warm their frozen hands and feet over the campfire at night only to refreeze those same parts by the next morning.

Although frostbite used to be a military problem, it is now a civilian one as well. The nose, cheeks, ears, fingers, and toes (your extremities) are most commonly affected. Everyone is susceptible, even people who have been living in cold climates for most of their lives. Some groups of people at greatest risk for frostbite and hypothermia include people:

- who spend a great deal of time outdoors, such as the homeless, hikers, hunters, etc.;
- under the influence of alcohol;
- who are elderly without adequate heating, food, and shelter;
- who are exhausted or excessively dehydrated; who are mentally ill.

Frostbite Causes

Your body works to stay alive first, and to stay functioning second.

- In conditions of prolonged cold exposure, your body sends signals to the blood vessels in your arms and legs telling them to constrict (narrow). By slowing blood flow to the skin, your body is able to send more blood to the vital organs, supplying them with critical nutrients, while also preventing a further decrease in internal body temperature by exposing less blood to the outside cold.

As this process continues and your extremities (the parts farthest from your heart) become colder and colder, a condition called the hunter's response is initiated. Your blood vessels are dilated (widened) for a period of time and then constricted again. Periods of dilatation are cycled with times of constriction in order to preserve as much function in your extremities as possible. However, when your brain senses that you are in danger of hypothermia (when your body temperature drops significantly below 98.6 F), it permanently constricts these blood vessels in order to prevent them from returning cold blood to the internal organs. When this happens, frostbite has begun.

- Frostbite is caused by two different means: cell death at the time of exposure and further cell deterioration and death because of a lack of oxygen.

  - In the first, ice crystals form in the space outside of the cells. Water is lost from the cell's interior, and dehydration promotes the destruction of the cell.

  - In the second, the damaged lining of the blood vessels is the main culprit. As blood flow returns to the extremities upon rewarming, it finds that the blood vessels themselves are injured, also by the cold. Holes appear in vessel walls and blood leaks out into the tissues. Flow is impeded and turbulent and small clots form in the smallest vessels of the extremities. Because of these blood flow problems, complicated interactions occur, and inflammation causes further tissue damage. This injury is the primary determinant of the amount of tissue damage that occurs in the end.

It is rare for the inside of the cells themselves to be frozen. This phenomenon is only seen in very rapid freezing injuries, such as those produced by frozen metals.

Frostbite Symptoms

A variety of frostbite classification systems have been proposed. The easiest to understand, and perhaps the one that gives the best clues to outcome, divides frostbite into two main divisions: superficial and deep.

In superficial frostbite, you may experience burning, numbness, tingling, itching, or cold sensations in the affected areas. The regions appear white and frozen, but if you press on them, they retain some resistance.

- In deep frostbite, there is an initial decrease in sensation that is eventually completely lost. Swelling and blood-filled blisters are noted over white or yellowish skin that looks waxy and turns a purplish blue as it rewarms. The area is hard, has no resistance when pressed on, and may even appear blackened and dead.

- The affected person will experience significant pain as the areas are rewarmed and blood flow reestablished. A dull continuous ache transforms into a throbbing sensation in 2 to 3 days. This may last weeks to months until final tissue separation is complete.

At first the areas may appear deceptively healthy. Most people do not arrive at the doctor with frozen, dead tissue. Only time can reveal the final amount of tissue damage.

There are milder conditions related to frostbite, including frostnip, chilblains, and trench foot.

- Frostnip refers to the development of paresthesias (tingling sensations) that occur due to cold exposure. They disappear upon rewarming without any tissue damage.

- Chilblain (or pernio) refers to a localized are of tissue inflammation that appears as swollen and reddish or purple. These develop in response to repeated exposure to damp, cold conditions above the freezing point. Chilblains may itch or be painful.

Severe Weather Preparedness

Trench foot was described in World War I as a result of repeated exposure to dampness and cold and exacerbated by tight boots. The affected feet are reddened, swollen, painful or numb, and may be covered with bleeding blisters. This condition is still observed in some homeless persons today.

What is hypothermia?

The body maintains a relatively stable temperature whereby heat production is balanced by heat loss. Normally, the core body temperature (when measured rectally) is 98.6 degrees F or 37 degrees C. When the outside environment gets too cold or the body's heat production decreases, hypothermia occurs (hypo=less + thermia=temperature). **Hypothermia is defined as having a core body temperature less than 95 degrees F or 35 degrees C.**

Body temperature is controlled in the part of the brain called the hypothalamus, which is responsible for recognizing alterations in the body temperature and responding appropriately. The body produces heat through the metabolic processes in cells that support vital body functions. Most heat is lost at the skin surface by convection, conduction, radiation, and evaporation. If the environment gets colder, the body may need to generate more heat by shivering (increasing muscle activity that promotes heat formation). But if heat loss is greater than the body's ability to make more, then the body's core temperature will fall.

As the temperature falls, the body shunts blood away from the skin and exposure to the elements. Blood flow is increased to the vital organs of the body including the heart, lungs, kidney, and brain. The heart and brain are most sensitive to cold, and the electrical activity in these organs slows in response to cold. If the body temperature continues to decrease, organs begin to fail, and eventually death will occur.

What are the signs and symptoms of hypothermia?

The body starts to slow as the temperature drops. Aside from the cold that is felt and the shivering that may occur, mental function is most affected initially. A particular danger of hypothermia is that it develops gradually, and since it affects thinking and reasoning, it may go unnoticed.

Initial hunger and nausea will give way to apathy as the core body temperature drops.
This is followed by confusion, lethargy, slurred speech, loss of consciousness, and coma.

- Often the affected person will lie down, fall asleep, and die. In some cases, the patient will paradoxically remove their clothes just before this occurs.

The decrease in brain function occurs in direct relationship to the decrease in body temperature (the colder the body, the less the brain function). Brain function stops at a core temperature of 68 F (20 C).

The heart is subject to abnormal electrical rhythms as hypothermia progresses. Ventricular fibrillation, a disorganized rhythm in which the heart is unable to pump, may occur at core temperatures below 82.4 F (28 C). This is one type of cardiac arrest.

Hypothermia Symptoms by Body Temperature			
Celsius	**Fahrenhe**	**Description**	**Symptoms**
37	98.6	No hypothermia	No hypothermia
Below	95	Definition of hypothermia	N/A
32 to 35	89.6 to 95	Mild hypothermia	Shivering Lethargy, apathy, confusion Rapid heart rate
28 to 32	82.4 to 89.6	Moderate hypothermia	Shivering stops Increased confusion or delirium Slowing heart rate; may be come irregular
Below 28	Below 82.4	Severe hypothermia	Coma Ventricular fibrillation May appear deceased
20	68		Brain activity stops

Introduction to Capacitors—Part I

Just like the *Resistor*, the **Capacitor**, sometimes referred to as a **Condenser**, is a simple passive device, and one which stores its energy in the form of an electrostatic charge producing a potential difference (*Static Voltage*) across its plates. In its basic form, a capacitor consists of two or more parallel conductive (metal) plates which are not connected or touch each other, but are electrically separated either by air or by some form of insulating material such as paper, mica, ceramic or plastic and which is called the capacitors **Dielectric**.

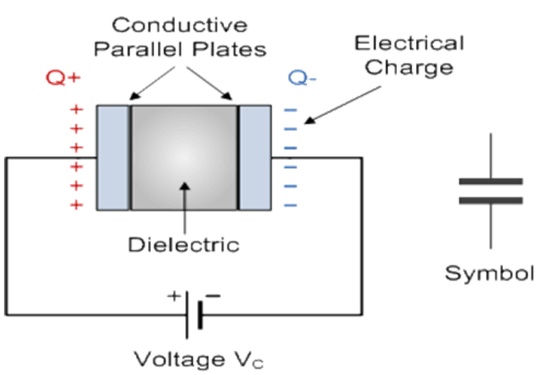
A Typical Capacitor

The conductive metal plates of a capacitor can be either square, circular or rectangular, or they can be of a cylindrical or spherical shape with the general shape, size and construction of a parallel plate capacitor depending on its application and voltage rating.

When used in a direct current or DC circuit, a capacitor charges up to its supply voltage but blocks the flow of current through it because the dielectric of a capacitor is non-conductive and basically an insulator. However, when a capacitor is connected to an alternating current or AC circuit, the flow of the current appears to pass straight through the capacitor with little or no resistance.
If a DC voltage is applied to the capacitors conductive plates, a current is unable to flow through the capacitor itself due to the dielectric insulation and an electrical charge builds up on the capacitors plates with electrons producing a positive charge on one and an equal and opposite negative charge on the other plate.

This flow of electrons to the plates is known as the capacitors **Charging Current** which continues to flow until the voltage across both plates (and hence the capacitor) is equal to the applied voltage Vc. At this point the capacitor is said to be "fully charged" with electrons. The strength or rate of this charging current is at its maximum value when the plates are fully discharged (initial condition) and slowly reduces in value to zero as the plates charge up to a potential difference across the capacitors plates equal to the applied supply voltage and this is illustrated below.

Capacitor Construction



The parallel plate capacitor is the simplest form of capacitor. It can be constructed using two metal or metallized foil plates at a distance parallel to each other, with its capacitance value in Farads, being fixed by the surface area of the conductive plates and the distance of separation between them. Altering any two of these values alters the value of its capacitance and this forms the basis of operation of the variable capacitors.

Also, because capacitors store the energy of the electrons in the form of an electrical charge on the plates the larger the plates and/or smaller their separation the greater will be the charge that the capacitor holds for any given voltage across its plates. In other words, larger plates, smaller distance, more capacitance.

By applying a voltage to a capacitor and measuring the charge on the plates, the ratio of the charge Q to the voltage V will give the capacitance value of the capacitor and is therefore given as: $C = Q/V$ this equation can also be re-arranged to give the more familiar formula for the quantity of charge on the plates as: $Q = C \times V$

Although we have said that the charge is stored on the plates of a capacitor, it is more correct to say that the energy within the charge is stored in an "electrostatic field" between the two plates. When an electric current flows into the capacitor, charging it up, the electrostatic field becomes more stronger as it stores more energy. Likewise, as the current flows out of the capacitor, discharging it, the potential difference between the two plates decreases and the electrostatic field decreases as the energy moves out of the plates.

The property of a capacitor to store charge on its plates in the form of an electrostatic field is called the **Capacitance** of the capacitor. Not only that, but capacitance is also the property of a capacitor which resists the change of voltage across it.

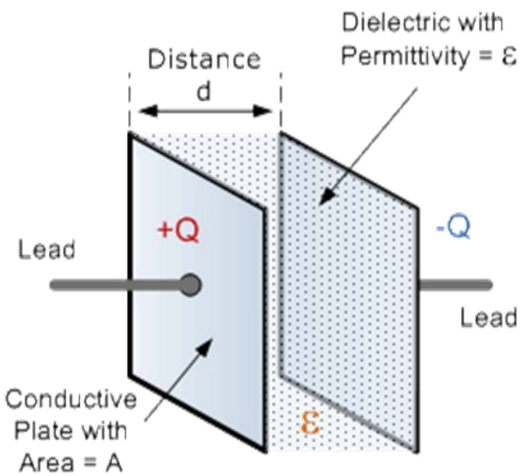
The Capacitance of a Capacitor

The unit of capacitance is the **Farad** (abbreviated to F) named after the British physicist Michael Faraday and is defined as a capacitor has the capacitance of **One Farad** when a charge of **One Coulomb** is stored on the plates by a voltage of **One volt**. Capacitance, C is always positive and has no negative units. However, the Farad is a very large unit of measurement to use on its own so sub-multiples of the Farad are generally used such as micro-farads, nano-farads and pico-farads, for example.

Units of Capacitance

- Microfarad (μF) 1μF = 1/1,000,000 = 0.000001 = 10^{-6} F
- Nanofarad (nF) 1nF = 1/1,000,000,000 = 0.000000001 = 10^{-9} F
- Picofarad (pF) 1pF = 1/1,000,000,000,000 = 0.000000000001 = 10^{-12} F

The capacitance of a parallel plate capacitor is proportional to the area, A of the plates and inversely proportional to their distance or separation, d (i.e. the dielectric thickness) giving us a value for capacitance of C = k(A/d) where in a vacuum the value of the constant k is 8.84×10^{-12} F/m or 1/4.п.9 x 10^{9}, which is the permittivity of free space. Generally, the conductive plates of a capacitor are separated by air or some kind of insulating material or gel rather than the vacuum of free space.



The Dielectric of a Capacitor

As well as the overall size of the conductive plates and their distance or spacing apart from each other, another factor which affects the overall capacitance of the device is the type of dielectric material being used. In other words the "Permittivity" (ε) of the dielectric. The conductive plates are generally made of a metal foil or a metal film but the dielectric material is an insulator.

The various insulating materials used as the dielectric in a capacitor differ in their ability to block or pass an electrical charge. This dielectric material can be made from a number of insulating materials or combinations of these materials with the most common types used being: air, paper, polyester, polypropylene, Mylar, ceramic, glass, oil, or a variety of other materials.

The factor by which the dielectric material, or insulator, increases the capacitance of the capacitor compared to air is known as the **Dielectric Constant**, **k** and a dielectric material with a high dielectric constant is a better insulator than a dielectric material with a lower dielectric constant. Dielectric constant is a dimensionless quantity since it is relative to free space. The actual permittivity or "complex permittivity" of the dielectric material between the plates is then the product of the permittivity of free space (ε_o) and the relative permittivity (ε_r) of the material being used as the dielectric and is given as:

Complex Permittivity

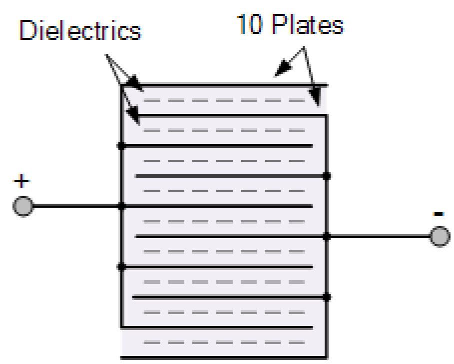
$$\varepsilon = \varepsilon_0 \times \varepsilon_r$$

As the permittivity of free space, ε_o is equal to one, the value of the complex permittivity will always be equal to the relative permittivity. Typical units of dielectric permittivity, ε or dielectric constant for common materials are: Pure Vacuum = 1.0000, Air = 1.0005, Paper = 2.5 to 3.5, Glass = 3 to 10, Mica = 5 to 7, Wood = 3 to 8 and Metal Oxide Powders = 6 to 20 etc.

This then gives us a final equation for the capacitance of a capacitor as:

$$\text{Capacitance, } C = \frac{\varepsilon_0\, \varepsilon_r\, A}{d} \text{ Farads}$$

One method used to increase the overall capacitance of a capacitor is to "interleave" more plates together within a single capacitor body. Instead of just one set of parallel plates, a capacitor can have many individual plates connected together thereby increasing the area, A of the plate. For example, a capacitor with 10 interleaved plates would produce 9 (10 - 1) mini capacitors with an overall capacitance nine times that of a single parallel plate.



9 mini capacitors in one

Modern capacitors can be classified according to the characteristics and properties of their insulating dielectric:

- Low Loss, High Stability such as Mica, Low-K Ceramic, Polystyrene.
-
- Medium Loss, Medium Stability such as Paper, Plastic Film, High-K Ceramic.
- Polarized Capacitors such as Electrolytics, Tantalum's.

Voltage Rating of a Capacitor

All capacitors have a maximum voltage rating and when selecting a capacitor consideration must be given to the amount of voltage to be applied across the capacitor. The maximum amount of voltage that can be applied to the capacitor without damage to its dielectric material is generally given in the data sheets as: WV, (working voltage) or as WV DC, (DC working voltage). If the voltage applied across the capacitor becomes too great, the dielectric will break down (known as electrical breakdown) and arcing will occur between the capacitor plates resulting in a short-circuit. The working voltage of the capacitor depends on the type of dielectric material being used and its thickness.

The Experimenters Bench

The DC working voltage of a capacitor is just that, the maximum DC voltage and NOT the maximum AC voltage as a capacitor with a DC voltage rating of 100 volts DC cannot be safely subjected to an alternating voltage of 100 volts. Since an alternating voltage has an r.m.s. value of 100 volts but a peak value of over 141 volts!. Then a capacitor which is required to operate at 100 volts AC should have a working voltage of at least 200 volts. In practice, a capacitor should be selected so that its working voltage either DC or AC should be at least 50 percent greater than the highest effective voltage to be applied to it.

Another factor which affects the operation of a capacitor is **Dielectric Leakage**. Dielectric leakage occurs in a capacitor as the result of an unwanted leakage current which flows through the dielectric material. Generally, it is assumed that the resistance of the dielectric is extremely high and a good insulator blocking the flow of DC current through the capacitor (as in a perfect capacitor) from one plate to the other. However, if the dielectric material becomes damaged due excessive voltage or over temperature, the leakage current through the dielectric will become extremely high resulting in a rapid loss of charge on the plates and an overheating of the capacitor eventually resulting in premature failure of the capacitor. Then never use a capacitor in a circuit with higher voltages than the capacitor is rated for otherwise it may become hot and explode.

Introduction to Capacitors Summary

The job of a capacitor is to store charge onto its plates. The amount of electrical charge that a capacitor can store on its plates is known as its **Capacitance** value and depends upon three main factors.

- The surface area, A of the two conductive plates which make up the capacitor, the larger the area the greater the capacitance.
- The distance, d between the two plates, the smaller the distance the greater the capacitance.
- The type of material which separates the two plates called the "dielectric", the higher the permittivity of the dielectric the greater the capacitance.

The dielectric of a capacitor is a non-conducting insulating material, such as waxed paper, glass, mica different plastics etc, and provides the following advantages.

- The dielectric constant is the property of the dielectric material and varies from one material to another increasing the capacitance by a factor of k.
- The dielectric provides mechanical support between the two plates allowing the plates to be closer together without touching.
- Permittivity of the dielectric increases the capacitance.
- The dielectric increases the maximum operating voltage compared to air.

All capacitors have a maximum working voltage rating, its WV DC so select a capacitor with a rating at least 50% more than the supply voltage.

There are a large variety of capacitor styles and types, each one having its own particular advantage, disadvantage and characteristics. To include all types would make this tutorial section very large so in the next tutorial about The Introduction to Capacitors I shall limit them to the most commonly used types.

Types of Capacitor

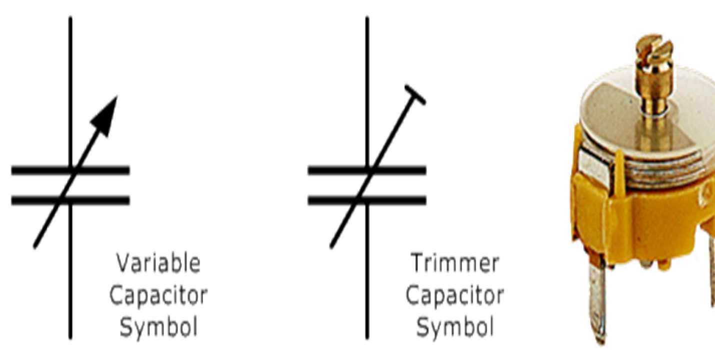
There are a very, very large variety of different **types of capacitor** available in the market place and each one has its own set of characteristics and applications, from very small delicate trimming capacitors up to large power metal-can type capacitors used in high voltage power correction and smoothing circuits. The comparisons between the the different *types of capacitor* is generally made with regards to the dielectric used between the plates. Like resistors, there are also variable types of capacitors which allow us to vary their capacitance value for use in radio or "frequency tuning" type circuits.

Commercial types of capacitor are made from metallic foil interlaced with thin sheets of either paraffin-impregnated paper or Mylar as the dielectric material. Some capacitors look like tubes, this is because the metal foil plates are rolled up into a cylinder to form a small package with the insulating dielectric material sandwiched in between them. Small capacitors are often constructed from ceramic materials and then dipped into an epoxy resin to seal them. Either way, capacitors play an important part in electronic circuits so here are a few of the more "common" types of capacitor available.

Dielectric Capacitor

Dielectric Capacitors are usually of the variable type were a continuous variation of capacitance is required for tuning transmitters, receivers and transistor radios. Variable dielectric capacitors are multi-plate air-spaced types that have a set of fixed plates (the stator vanes) and a set of movable plates (the rotor vanes) which move in between the fixed plates. The position of the moving plates with respect to the fixed plates determines the overall capacitance value. The capacitance is generally at maximum when the two sets of plates are fully meshed together. High voltage type tuning capacitors have relatively large spacing or air-gaps between the plates with breakdown voltages reaching many thousands of volts.

Variable Capacitor Symbols



The Experimenters Bench

As well as the continuously variable types, preset type variable capacitors are also available called **Trimmers**. These are generally small devices that can be adjusted or "pre-set" to a particular capacitance value with the aid of a small screwdriver and are available in very small capacitances of 500pF or less and are non-polarized.

Film Capacitor

Film Capacitors are the most commonly available of all types of capacitors, consisting of a relatively large family of capacitors with the difference being in their dielectric properties. These include polyester (Mylar), polystyrene, polypropylene, polycarbonate, metallized paper, Teflon etc. Film type capacitors are available in capacitance ranges from as small as 5pF to as large as 100uF depending upon the actual type of capacitor and its voltage rating. Film capacitors also come in an assortment of shapes and case styles which include:

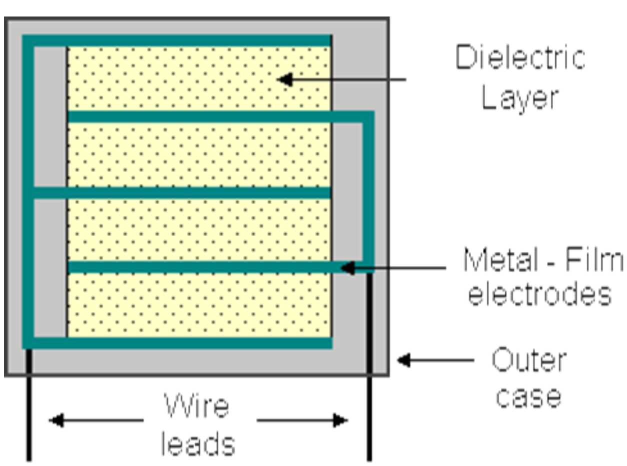
- Wrap & Fill (Oval & Round) - where the capacitor is wrapped in a tight plastic tape and have the ends filled with epoxy to seal them.
-
- Epoxy Case (Rectangular & Round) - where the capacitor is encased in a molded plastic shell which is then filled with epoxy.
-

Metal Hermetically Sealed (Rectangular & Round) - where the capacitor is encased in a metal tube or can and again sealed with epoxy.

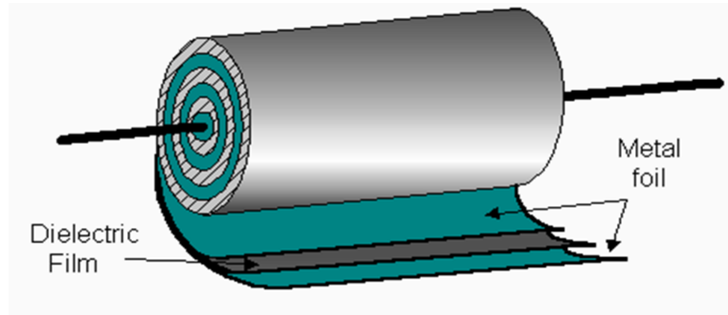
with all the above case styles available in both Axial and Radial Leads.

Film Capacitors which use polystyrene, polycarbonate or Teflon as their dielectrics are sometimes called "Plastic capacitors". The construction of plastic film capacitors is similar to that for paper film capacitors but use a plastic film instead of paper. The main advantage of plastic film capacitors compared to impregnated-paper types is that they operate well under conditions of high temperature, have smaller tolerances, a very long service life and high reliability. Examples of film capacitors are the rectangular metallised film and cylindrical film & foil types as shown below.

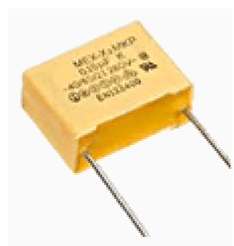
Radial Lead Type



Axial Lead Type



The film and foil types of capacitors are made from long thin strips of thin metal foil with the dielectric material sandwiched together which are wound into a tight roll and then sealed in paper or metal tubes.



Film Capacitor

These film types require a much thicker dielectric film to reduce the risk of tears or punctures in the film, and is therefore more suited to lower capacitance values and larger case sizes.

Metallized foil capacitors have the conductive film metallized sprayed directly onto each side of the dielectric which gives the capacitor self-healing properties and can therefore use much thinner dielectric films. This allows for higher capacitance values and smaller case sizes for a given capacitance. Film and foil capacitors are generally used for higher power and more precise applications.

Ceramic Capacitors

Ceramic Capacitors or **Disc Capacitors** as they are generally called, are made by coating two sides of a small porcelain or ceramic disc with silver and are then stacked together to make a capacitor. For very low capacitance values a single ceramic disc of about 3-6mm is used. Ceramic capacitors have a high dielectric constant (High-K) and are available so that relatively high capacitances can be obtained in a small physical size.

The Experimenters Bench

Ceramic Capacitor

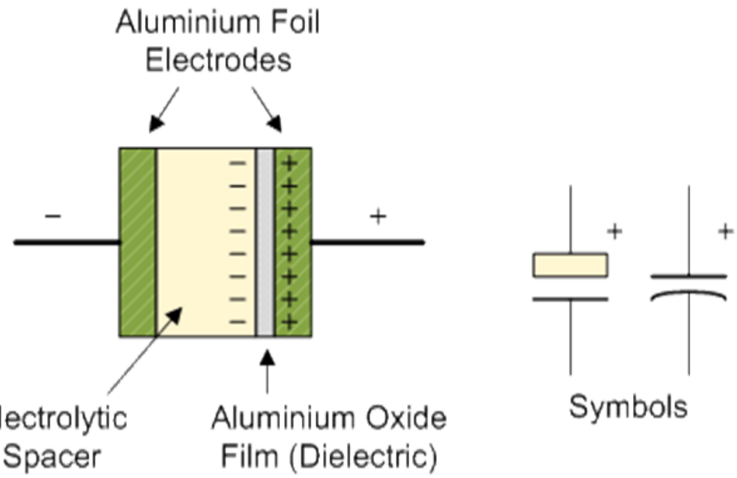
They exhibit large non-linear changes in capacitance against temperature and as a result are used as de-coupling or by-pass capacitors as they are also non-polarized devices. Ceramic capacitors have values ranging from a few picofarads to one or two microfarads but their voltage ratings are generally quite low.
Ceramic types of capacitors generally have a 3-digit code printed onto their body to identify their capacitance value in pico-farads. Generally the first two digits indicate the capacitors value and the third digit indicates the number of zero's to be added. For example, a ceramic disc capacitor with the markings 103 would indicate 10 and 3 zero's in pico-farads which is equivalent to 10,000 pF or 10nF.
Likewise, the digits 104 would indicate 10 and 4 zero's in pico-farads which is equivalent to 100,000 pF or 100nF and so on. Then on the image of a ceramic capacitor above the numbers 154 indicate 15 and 4 zero's in pico-farads which is equivalent to 150,000 pF or 150nF. Letter codes are sometimes used to indicate their tolerance value such as: J = 5%, K = 10% or M = 20% etc.

Electrolytic Capacitors
Electrolytic Capacitors are generally used when very large capacitance values are required. Here instead of using a very thin metallic film layer for one of the electrodes, a semi-liquid electrolyte solution in the form of a jelly or paste is used which serves as the second electrode (usually the cathode). The dielectric is a very thin layer of oxide which is grown electro-chemically in production with the thickness of the film being less than ten microns. This insulating layer is so thin that it is possible to make capacitors with a large value of capacitance for a small physical size as the distance between the plates, d is very small.

Electrolytic Capacitor

The majority of electrolytic types of capacitors are **Polarized**, that is the DC voltage applied to the capacitor terminals must be of the correct polarity, i.e. positive to the positive terminal and negative to the negative terminal as an incorrect polarization will break down the insulating oxide layer and permanent damage may result. All polarized electrolytic capacitors have their polarity clearly marked with a negative sign to indicate the negative terminal and this polarity must be followed.
Electrolytic Capacitors are generally used in DC power supply circuits due to their large capacitances and small size to help reduce the ripple voltage or for coupling and decoupling applications. One main disadvantage of electrolytic capacitors is their relatively low voltage rating and due to the polarization of electrolytic capacitors, it follows then that they must not be used on AC supplies. Electrolytics generally come in two basic forms; **Aluminum Electrolytic Capacitors** and **Tantalum Electrolytic Capacitors**.

Electrolytic Capacitor



1. Aluminum Electrolytic Capacitors

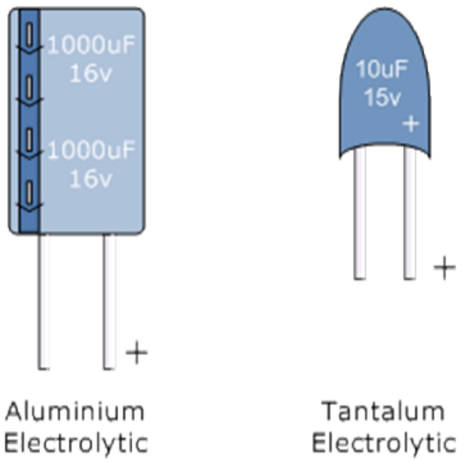
There are basically two types of **Aluminium Electrolytic Capacitor**, the plain foil type and the etched foil type. The thickness of the aluminum oxide film and high breakdown voltage give these capacitors very high capacitance values for their size. The foil plates of the capacitor are anodized with a DC current. This anodizing process sets up the polarity of the plate material and determines which side of the plate is positive and which side is negative.

The etched foil type differs from the plain foil type in that the aluminium oxide on the anode and cathode foils has been chemically etched to increase its surface area and permittivity. This gives a smaller sized capacitor than a plain foil type of equivalent value but has the disadvantage of not being able to withstand high DC currents compared to the plain type. Also their tolerance range is quite large at up to 20%. Typical values of capacitance for an aluminium electrolytic capacitor range from 1uF up to 47,000uF.

Etched foil electrolytic's are best used in coupling, DC blocking and by-pass circuits while plain foil types are better suited as smoothing capacitors in power supplies. But aluminium electrolytic's are "polarized" devices so reversing the applied voltage on the leads will cause the insulating layer within the capacitor to become destroyed along with the capacitor. However, the electrolyte used within the capacitor helps heal a damaged plate if the damage is small.

Since the electrolyte has the properties to self-heal a damaged plate, it also has the ability to re-anodize the foil plate. As the anodizing process can be reversed, the electrolyte has the ability to remove the oxide coating from the foil as would happen if the capacitor was connected with a reverse polarity. Since the electrolyte has the ability to conduct electricity, if the aluminum oxide layer was removed or destroyed, the capacitor would allow current to pass from one plate to the other destroying the capacitor, "so be aware".

Aluminium & Tantalum Electrolytic Capacitor



Electrolytic's are widely used capacitors due to their low cost and small size but there are three easy ways to destroy an electrolytic capacitor:

Over-voltage - excessive voltage will cause current to leak through the dielectric resulting in a short circuit condition.

Reversed Polarity - reverse voltage will cause self-destruction of the oxide layer and failure.

Over Temperature - excessive heat dries out the electrolytic and shortens the life of an electrolytic capacitor.

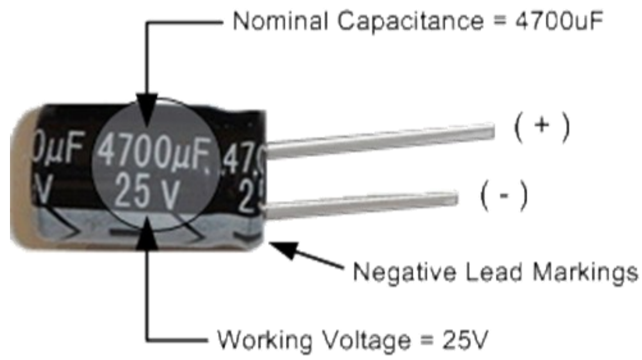
In the next tutorial about Capacitors, we will look at some of the main characteristics to show that there is more to the **Capacitor** than just voltage and capacitance.

Capacitor Characteristics

There are a bewildering array of capacitor characteristics and specifications associated with the humble capacitor and reading the information printed onto the body of a capacitor can sometimes be difficult especially when colors or numeric codes are used. Each family or type of capacitor uses its own unique identification system with some systems being easy to understand, and others that use misleading letters, colors or symbols. The best way to figure out what a capacitor label means is to first figure out what type of family the capacitor belongs to whether it is ceramic, film, plastic or electrolytic.

Even though two capacitors may have exactly the same capacitance value, they may have different voltage ratings. If a smaller rated voltage capacitor is substituted in place of a higher rated voltage capacitor, the increased voltage may damage the smaller capacitor. Also we remember from the last tutorial that with a polarized electrolytic capacitor, the positive lead must go to the positive connection and the negative lead to the negative connection otherwise it may again become damaged. So it is always better to substitute an old or damaged capacitor with the same type as the specified one. An example of capacitor markings is given below.

Capacitor Characteristics



The capacitor, as with any other electronic component, comes defined by a series of characteristics. These **Capacitor Characteristics** can always be found in the datasheets that the capacitor manufacturer provides to us so here are just a few of the more important ones.

1. Nominal Capacitance, (C)

The nominal value of the **Capacitance**, C of a capacitor is measured in pico-Farads (pF), nano-Farads (nF) or micro-Farads (μF) and is marked onto the body of the capacitor as numbers, letters or colored bands. The capacitance of a capacitor can change value with the circuit frequency (Hz) y with the ambient temperature. Smaller ceramic capacitors can have a nominal value as low as one pico-Farad, (1pF) while larger electrolytic's can have a nominal capacitance value of up to one Farad, (1F). All capacitors have a tolerance rating that can range from -20% to as high as +80% for aluminium electrolytic's affecting its actual or real value. The choice of capacitance is determined by the circuit configuration but the value read on the side of a capacitor may not necessarily be its actual value.

2. Working Voltage, (WV)

The **Working Voltage** is the maximum continuous voltage either DC or AC that can be applied to the capacitor without failure during its working life. Generally, the working voltage printed onto the side of a capacitors body refers to its DC working voltage, (WV-DC). DC and AC voltage values are usually not the same for a capacitor as the AC voltage value refers to the r.m.s. value and NOT the maximum or peak value which is 1.414 times greater. Also, the specified DC working voltage is valid within a certain temperature range, normally - 30°C to + 70°C.

Any DC voltage in excess of its working voltage or an excessive AC ripple current may cause failure. It follows therefore, that a capacitor will have a longer working life if operated in a cool environment and within its rated voltage. Common working DC voltages are 10V, 16V, 25V, 35V, 50V, 63V, 100V, 160V, 250V, 400V and 1000V and are printed onto the body of the capacitor.

3. Tolerance, (±%)

As with resistors, capacitors also have a **Tolerance** rating expressed as a plus-or-minus value either in picofarads (±pF) for low value capacitors generally less than 100pF or as a percentage (±%) for higher value capacitors generally higher than 100pF.

The tolerance value is the extent to which the actual capacitance is allowed to vary from its nominal value and can range anywhere from -20% to +80%. Thus a 100μF capacitor with a ±20% tolerance could legitimately vary from 80μF to 120μF and still remain within tolerance.

Capacitors are rated according to how near to their actual values they are compared to the rated nominal capacitance with colored bands or letters used to indicated their actual tolerance. The most common tolerance variation for capacitors is 5% or 10% but some plastic capacitors are rated as low as ±1%.

4. Leakage Current

The dielectric used inside the capacitor to separate the conductive plates is not a perfect insulator resulting in a very small current flowing or "leaking" through the dielectric due to the influence of the powerful electric fields built up by the charge on the plates when applied to a constant supply voltage. This small DC current flow in the region of nano-amps (nA) is called the capacitors **Leakage Current**. Leakage current is a result of electrons physically making their way through the dielectric medium, around its edges or across its leads and which will over time fully discharging the capacitor if the supply voltage is removed.

When the leakage is very low such as in film or foil type capacitors it is generally referred to as "insulation resistance" (R_p) and can be expressed as a high value resistance in parallel with the capacitor as shown. When the leakage current is high as in electrolytic's it is referred to as a "leakage current" as electrons flow directly through the electrolyte.

Capacitor leakage current is an important parameter in amplifier coupling circuits or in power supply circuits, with the best choices for coupling and/or storage applications being Teflon and the other plastic capacitor types (polypropylene, polystyrene, etc.) because the lower the dielectric constant, the higher the insulation resistance.

Electrolytic-type capacitors (tantalum and aluminum) on the other hand may have very high capacitances, but they also have very high leakage currents (typically of the order of about 5-20 μA per μF) due to their poor isolation resistance, and are therefore not suited for storage or coupling applications. Also, the flow of leakage current for aluminium electrolytic's increases with temperature.

5. Working Temperature, (T)

Changes in temperature around the capacitor affect the value of the capacitance because of changes in the dielectric properties. If the air or surrounding temperature becomes to hot or to cold the capacitance value of the capacitor may change so much as to affect the correct operation of the circuit. The normal working range for most capacitors is -30°C to +125°C with nominal voltage ratings given for a **Working Temperature** of no more than +70°C especially for the plastic capacitor types.

Generally for electrolytic capacitors and especially aluminium electrolytic capacitor, at high temperatures (over +85°C the liquids within the electrolyte can be lost to evaporation, and the body of the capacitor (especially the small sizes) may become deformed due to the internal pressure and leak outright. Also, electrolytic capacitors can not be used at low temperatures, below about -10°C, as the electrolyte jelly freezes.

6. Temperature Coefficient, (TC)

The **Temperature Coefficient** of a capacitor is the maximum change in its capacitance over a specified temperature range. The temperature coefficient of a capacitor is generally expressed linearly as parts per million per degree centigrade (PPM/°C), or as a percent change over a particular range of temperatures. Some capacitors are non linear (Class 2 capacitors) and increase their value as the temperature rises giving them a temperature coefficient that is expressed as a positive "P". Some capacitors decrease their value as the temperature rises giving them a temperature coefficient that is expressed as a negative "N". For example "P100" is +100 ppm/°C or "N200", which is -200 ppm/°C etc. However, some capacitors do not change their value and remain constant over a certain temperature range, such capacitors have a zero temperature coefficient or "NPO". These types of capacitors such as Mica or Polyester are generally referred to as Class 1 capacitors. Most capacitors, especially electrolytic's lose their capacitance when they get hot but temperature compensating capacitors are available in the range of at least P1000 through to N5000 (+1000 ppm/C through to -5000 ppm/C). It is also possible to connect a capacitor with a positive temperature coefficient in series or parallel with a capacitor having a negative temperature coefficient the net result being that the two opposite effects will cancel each other out over a certain range of temperatures. Another useful application of temperature coefficient capacitors is to use them to cancel out the effect of temperature on other components within a circuit, such as inductors or resistors etc.

7. Polarization

Capacitor **Polarization** generally refers to the electrolytic type capacitors but mainly the Aluminium Electrolytic's, with regards to their electrical connection. The majority of electrolytic capacitors are polarized types, that is the voltage connected to the capacitor terminals must have the correct polarity, i.e. positive to positive and negative to negative. Incorrect polarization can cause the oxide layer inside the capacitor to break down resulting in very large currents flowing through the device resulting in destruction as we have mentioned earlier.

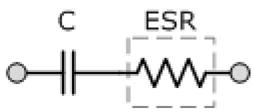
The majority of electrolytic capacitors have their negative, -ve terminal clearly marked with either a black stripe, band, arrows or chevrons down one side of their body as shown, to prevent any incorrect connection to the DC supply.

Some larger electrolytic's have their metal can or body connected to the negative terminal but high voltage types have their metal can insulated with the electrodes being brought out to separate spade or screw terminals for safety.

Also, when using aluminium electrolytic's in power supply smoothing circuits care should be taken to prevent the sum of the peak DC voltage and AC ripple voltage from becoming a "reverse voltage".

8. Equivalent Series Resistance, (ESR)

The **Equivalent Series Resistance** or **ESR**, of a capacitor is the AC impedance of the capacitor when used at high frequencies and includes the resistance of the dielectric material, the DC resistance of the terminal leads, the DC resistance of the connections to the dielectric and the capacitor plate resistance all measured at a particular frequency and temperature.



ESR Model

In some ways, ESR is the opposite of the insulation resistance which is presented as a pure resistance (no capacitive or inductive reactance) in parallel with the capacitor. An ideal capacitor would have only capacitance but ESR is presented as a pure resistance (less than 0.1Ω) in series with the capacitor (hence the name Equivalent Series Resistance), and which is frequency dependant making it a "DYNAMIC" quantity.
As ESR defines the energy losses of the "equivalent" series resistance of a capacitor it must therefore determine the capacitor's overall I^2R heating losses especially when used in power and switching circuits. Capacitors with a relatively high ESR have less ability to pass current to and from its plates to the external circuit because of their longer charging and discharging RC time constant. The ESR of electrolytic capacitors increases over time as their electrolyte dries out. Capacitors with very low ESR ratings are available and are best suited when using the capacitor as a filter.

As a final note, capacitors with small capacitances (less than 0.01 uF) generally do not pose much danger to humans. However, when their capacitances start to exceed 0.1 uF, touching the capacitor leads can be a shocking experience. Capacitors have the ability to store an electrical charge in the form of a voltage across themselves even when there is no circuit current flowing, giving them a sort of memory with large electrolytic type reservoir capacitors found in television sets, photo flashes and capacitor banks potentially storing a lethal charge.
As a general rule of thumb, never touch the leads of large value capacitors once the power supply is removed. If you are unsure about their condition or the safe handling of these large capacitors, seek help or expert advice before handling them.
The next tutorial in our section about Capacitors, we look at how they store electrical charge on their plates and use it to calculate the capacitance value.

Capacitance and Charge

We saw in the previous tutorials that a **Capacitor** consists of two parallel conductive plates (usually a metal) which are prevented from touching each other (separated) by an insulating material called the "dielectric". We also saw that when a voltage is applied to these plates an electrical current flows charging up one plate with a positive charge with respect to the supply voltage and the other plate with an equal and opposite negative charge.

Then, a capacitor has the ability of being able to store an electrical charge Q (units in **Coulombs**) of electrons.

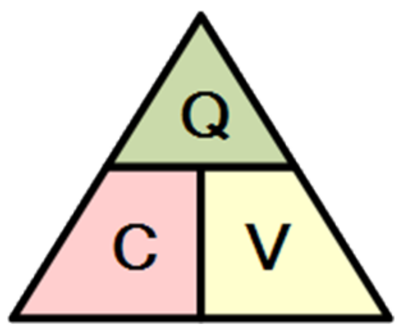
When a capacitor is fully charged there is a potential difference, p.d. between its plates, and the larger the area of the plates and/or the smaller the distance between them (known as separation) the greater will be the charge that the capacitor can hold and the greater will be its **Capacitance**.
The Capacitors ability to store this electrical charge (Q) between its plates is proportional to the applied voltage, V for a capacitor of known capacitance in Farads. Capacitance C is always positive and never negative. The greater the applied voltage the greater will be the charge stored on the plates of the capacitor. Likewise, the smaller the applied voltage the smaller the charge. Therefore, the actual charge Q on the plates of the capacitor and can be calculated as:

Charge on a Capacitor

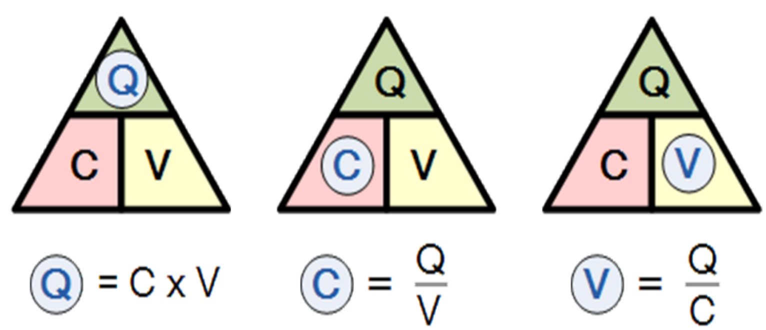
$$Q = C \times V$$

Where: Q (Charge, in Coulombs) = C (Capacitance, in Farads) x V (Voltage, in Volts)

It is sometimes easier to remember this relationship by using pictures. Here the three quantities of Q, C and V have been superimposed into a triangle giving charge at the top with capacitance and voltage at the bottom. This arrangement represents the actual position of each quantity in the *Capacitor Charge* formulas.



and transposing the above equation gives us the following combinations of the same equation:



Units of: Q measured in Coulombs, V in volts and C in Farads.
Then from above we can define the unit of **Capacitance** as being a constant of proportionality being equal to the coulomb/volt which is also called a **Farad**, unit F.

The Experimenters Bench

As capacitance represents the capacitors ability (capacity) to store an electrical charge on its plates we can define one Farad as the "*capacitance of a capacitor which requires a charge of one coulomb to establish a potential difference of one volt between its plates*" as firstly described by Michael Faraday.

So the larger the capacitance, the higher is the amount of charge stored on a capacitor for the same amount of voltage. The ability of a capacitor to store a charge on its conductive plates gives it its **Capacitance** value. Capacitance can also be determined from the dimensions or area, A of the plates and the properties of the dielectric material between the plates. A measure of the dielectric material is given by the permittivity, (ε), or the dielectric constant. So another way of expressing the capacitance of a capacitor is;

with Air as its dielectric

$$C = \frac{Q}{V} = \varepsilon \frac{A}{d}$$

with a Solid as its dielectric

$$C = \frac{Q}{V} = \varepsilon_0 \varepsilon_r \frac{A}{d}$$

where A is the area of the plates in square meters, m^2 with the larger the area, the more charge the capacitor can store. d is the distance or separation between the two plates. The smaller is this distance, the higher is the ability of the plates to store charge, since the -ve charge on the -Q charged plate has a greater effect on the +Q charged plate, resulting in more electrons being repelled off of the +Q charged plate, and thus increasing the overall charge. ε_0 (epsilon) is the value of the permittivity for air which is 8.84×10^{-12} F/m, and ε_r is the permittivity of the dielectric medium used between the two plates.

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Early Radio: Military Communications

"Home Is Where You Dig It"1
(Observations on Life at the Khe Sanh Combat Base)
©1992 Peter Brush

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Men who received orders to Vietnam had certain expectations of the place, based on their general life experiences and their training. We expected to work hard, to be bored, to experience excitement and danger. It was reasonable to anticipate the tropical climate, periods of thirst and dreary food, being dirty and tired, and other aspects of a year-long camping trip. Everyone who participated in the siege of Khe Sanh likely had these expectations. I don't think these Marines expected that their problems would include dealing with rats, yet virtually everyone who wrote about Khe Sanh included descriptions of them.

In 1962, the Special Forces were the first at Khe Sanh, arriving by truck. Weapons specialist Frank Fowler made an observation about the place that would be repeated many times when he mentioned the rats. Noting the numbers present, he said,
One time we went into the village and bought some metal rat traps because it was so bad. We were using mosquito nets on our bunks to keep the rats off. I remember one night there was a big metal rat trap with teeth on it. And I remember the first rat we got. When [the trap] snapped it woke me up. And then the rat started dragging the thing off!
Fowler was not to be envied his task of separating his live rat from the trap. A cornered rat will fight like a "cornered rat," and will attack its attacker.

The Marines joined up with the Special Forces and their rats in 1966. Colonel Tom Horne presided over the transformation of the Army position into the Marine Corps Khe Sanh Combat Base. He recalled, "My memory of that place is waking up with fifteen or twenty rats on the bed with me!" In 1967, when the buildup of forces on both sides began in earnest, the Roman Catholic chaplain of 3/26 ran into the furry Khe Sanh Welcome Wagon on his first night when a rat lost its footing on the dirt ledge of his bunker, fell on his chest, and bounced to the floor with a squeal.

Initially the U.S. strategy for winning the war in Vietnam was merely one of attrition. In 1967, critics pointed out that attrition was an indication that the U.S. was losing the initiative in Vietnam, and not a strategy in itself. Consequently, when the NVA began moving large numbers of troops into I Corps in the summer of 1967, General Westmoreland made plans to engage them in large numbers, to apply massive firepower in a decisive engagement, to allow the U.S. to finally bask in the warm light at the end of the tunnel.

Khe Sanh seemed like the place. Between twenty and forty thousand NVA surrounded five thousand Marines. Khe Sanh was in the mountainous area where North Vietnam, South Vietnam, and Laos came together. It was far from the heavily populated coastal plain, and the South Vietnamese government was not particularly active. This would minimize coordination problems with the ARVN and allow the application of air and artillery assets with the least possible number of civilian casualties. Most important of all was the fact that the NVA seemed willing to fight at Khe Sanh.

In a sense both sides besieged each other. The Marines could only be supplied by air and could not have evacuated the base without sustaining unacceptable casualties. The NVA were trapped by their military and political goals (whatever they might have been) and by the greatest application of air power in history.

Even as late as December, 1967, Khe Sanh was considered relatively good duty, as those things went in Vietnam. I requested transfer there from a nearby fire base because Khe Sanh had a reputation for great physical beauty, few rocket and mortar attacks, and relatively comfortable living conditions.

Early Radio: Military Communications

Aesthetically, Khe Sanh had it all - mountains, valleys, streams, triple canopy jungle in several shades of green, elephants and tigers. The local population were mostly tribal Bru Montagnards rather than ethnic Vietnamese.

This good duty was more apparent than real, and at about 5:00 a.m. on the morning of 21 January, 1968, a reconnaissance team radioed that a flight of rockets had been launched from a nearby hill and would land on the combat base. This initial attack was small by later standards, consisting of about one hundred 82 mm mortar shells and sixty 122 mm rockets. But fifteen minutes after the attack began, one rocket landed in the midst of the main ammunition storage area, with devastating results.

This dump contained eleven thousand units of ordnance that immediately began burning. Red-hot artillery and recoilless rifle rounds were hurled into nearby trenches. CS tear gas was ignited and filled the entire area with gas as thick as fog. About 10:00 a.m. the fire set off a large quantity of C-4 plastic explosive and other explosives. At the airstrip all the navigational aids were destroyed, several helicopters were damaged or destroyed, living quarters for the Marine air group were destroyed, the control tower was rendered inoperative, and the runway was cratered. All this on the first day of incoming rocket, artillery, and mortar attacks that would continue for the next 76 days.

The mess halls were immediately secured. In the atmosphere of flying metal it would not do for two hundred Marines to congregate in one place. C-rations were issued and the men took their meals in their bunkers. The rat population began to take off, and Khe Sanh took on the look of "a shanty slum on the outskirts of Manila." Continuous aerial bombardment, shelling and digging and bulldozing of positions filled the air with red dust. Smoke filled the air, smoke from incoming, from diesel generators, from burning latrines, from burning ordnance, from trash fires. Water was restricted, and few were able to bath regularly. The monsoon rain served to drive the rats inside the bunkers, where they "ran across the dirt floors, gnawing at shelves and boots and fingers, chittering in fear when the big guns fired, and sometimes scratching faces as they raced across sleeping Marines in the dark bunkers." Time magazine reported that the: rats became frantic under fire. When incoming starts, the rats race for the bunkers and wildly run up to the ceilings made of runway matting and logs. One sergeant killed thirty-four rats, establishing a base record.

Ernest Spencer described the rats at Khe Sanh in Welcome to Vietnam, Macho Man:
There were always rats at Khe Sanh. Not your stereotypical Asian variety of chopstick-using rat. Khe Sanh rats are snarling suckers with big heads. Having evolved in a jungle environment, those rats are capable of fighting anything.
The rats began exerting themselves several breeding cycles into the siege. A rat jumps on my chest one night. On my back on my cot, I slap at him with my left hand while I try to shield my face with my right. He is grinning at me, I swear.
Rats love the sandbag walls. Since the walls are several layers thick, the rats have a lot of room for their quarters. You can hear them in there screaming, eating, fucking, and kicking each others' asses. Rats are nasty - they are always fighting.
Rats behave more logically during the siege than we do. They let their feelings out. You can hear them squeaking and going berserk during a barrage. Us macho men just sit there quietly and take it.
The floors of our bunkers were constructed of wooden pallets over dirt, and invariably food fell between the pallet slats, providing feed for the rats. Trash cans were emptied into drums placed in each unit area, to be collected and hauled to the base dump. As the supply of food at the dump increased, so, too, did the rat population, which then moved back into the base area.
Initially there were only mouse traps at Khe Sanh, but they served more to irritate than kill the rats. Rat traps were requisitioned from supply and given a priority after ammunition, C-rations, mail, and personnel.
As the incoming continued, the men were restricted to their underground quarters unless they had reason to be above ground. At night the rats would climb into trash cans to eat scraps from the C-rations. With smooth metal sides, these containers served as rat traps of sorts and in the morning the Marines would bludgeon them to death with tent poles, then throw them back in the trash.

Ray Stubbe notes in *Valley of Decision*:
Officially, base policy was to drown rats after killing them to kill the fleas which were infected with plague virus. The animals couldn't be poisoned; local Bru children who helped fill sandbags and cleaned out the garbage dumps collected the rats, broke their legs, and put them in their pockets to take home. Later they would be eaten.

Eventually rat traps became available and were issued to each unit. My battery was allocated seven traps, which were baited with C-ration cheese or peanut butter. Morning after morning each trap yielded its victim, always seven full traps. After a few weeks we quit bothering with their traps, feeling that no progress was being made.
The NVA constructed trenches ever closer to the perimeter of Khe Sanh, eventually putting them in a position to snipe at the garbage detail carrying trash to the dump. This resulted in cessation of the garbage detail. Trash began to pile up throughout the base, spreading food for the rats everywhere. The rat problem in the bunkers got worse. At first the rats seemed content to remain beneath the pallets. With time they became bolder and ventured around the bunker whenever the lights were put out. Finally we were forced to leave the lights on continually in an attempt to keep the rats off our cots and stretchers.

Life at Khe Sanh settled into a routine. One night in March my roommate and I were lying in their small bunker, reading by candlelight. About 10:00 p.m. Corporal Hawker put the candle out and settled into a casualty bag on top of his cot. Immediately he heard noises in front of him at ground level. Slowly, stealthily, Hawker grabbed a flashlight in one hand and an assault knife in the other. While he was getting into position to attack, the rat had silently climbed onto the cot, inches from Hawker's face. When the light snapped on, Hawker slashed empty air; and the startled rat ran across his face. Terrified, Hawker zipped the casualty bag up completely, then began thrashing to get back out, afraid he had trapped the rat inside the bag. The rat escaped, and I chuckled myself to sleep.

As the NVA battered the base, supply problems became evident. Three C-ration meals per day were reduced to two. With only twelve different meals to chose from, meal time turned from a pleasant break in the daily routine into just another ordeal. Many of us quit bothering to heat our rations, concluding that the grease from roast beef and potatoes didn't taste worse than the gravy it would become if heated, only different. As stomachs shrunk with the reduced rations, it took more will power than many could muster to consume even two meals per day. Uneaten rations went into the trash, further increasing the rat population.

NVA incoming was not steady at Khe Sanh; some days saw less than two hundred rounds fired at the base while the daily record was 1,307. The humid environment was corrosive to ammunition; and regularly, directives were received to turn in old small-arms ammo for replacement with fresh stock. As the old bullets would be dumped at sea, some Marines loaded their M-16 magazines exclusively with tracers, venturing down to the trash dump to shoot rats. In the gloom of the monsoon, it looked like laser beams emitting from the rifle barrels as the Marines honed their marksmanship skills on the rats.

One Recon Marine, David Doehrman, liberated several steaks from a locked freezer in the mess hall. He and his friends cooked them on camp stoves, gorging themselves, then settled down to sleep in their bunks. Doehrman's hand "dangled over the metal tray containing the remaining steaks, and he was bitten by a rat during the night." This incident caused Doehrman to be placed on medical hold to receive a series of rabies shots.

Doehrman's incident perhaps explains the origin of a story that circulated at Khe Sanh, which claimed that some Marines were putting peanut butter on their toes and sticking their feet between the pallets, hoping to get bit. The rationale being a rat bite would cause one to be evacuated from the base to receive shots for rabies.

Knives, traps, and tent poles weren't the only weapons the Marines used against rats. Stubbe relates an incident when one gunnery sergeant became so incensed at a rat that kept paying him a visit that "one night he pulled out his .45-caliber pistol and shot the thing as it scurried above a poncho the gunny had hung across the ceiling. He killed the rat, but the hole in the poncho became a drain for rainwater . . ."
One night, just as I was about to put out my lantern, I noticed a cat-sized rat nonchalantly wandering into my bunker, sniffing the ground. Amazed at the boldness of this rodent, I grabbed the only weapon I could find close by. Cocking my arm, I launched a jungle boot at the rat, hoping to knock him out of the bunker. Instead, the panicked rat ran right toward me, only turning when he realized that safety lay in exactly the opposite direction.

Always the rats were big. Gustav Hasford describes them in *The Phantom Blooper*:

Every twenty meters, I stoop down and tug at the barbed wire with det cord crimps to see if the wire has been cut. The tugging scares up bunker rats big enough to stand flat-footed and b**t-f**k a six-by.

If true, Hasford would be describing a serious rat problem. But rats cannot take on a two-and-one-half ton truck, are not as large as cats, and do not have large heads. The average cat weighs eleven pounds, while even a large Norway rat weighs less than two pounds.

How many rats were there at Khe Sanh? Even though the Marines never attempted a census, estimates using certain assumptions can be made. The lesser bandicoot (*Bandicota bengalensis*) is one species of rat common to southern Asia. Each female can produce a litter per month, with seven pups per litter, for a daily rate of increase of over eleven percent. The rats at Khe Sanh may or may not have been reproducing at their biological maximum (i.e., rats were being killed by Marines, but it is also likely they were being driven into the base from without by aerial bombardment). There are approximately as many rats in the world as people, unevenly distributed. If the rat population equaled the human population at Khe Sanh, and assuming the above optimum rate of increase, theoretically there could have been one hundred thousand rats by day 27 of the siege, one-half million rats on day 43, and over one million by day 50. Whatever their number, the rats at Khe Sanh were like the rain and the shrapnel - always irritating, always present, always threatening.
But Westmoreland's plan for a Dien Bien Phu in reverse never happened. Various NVA regimental-sized attempts to mass for an attack on the base were broken up by artillery and aerial bombardment. Battalion and company-sized probes against the Marines' perimeter were beaten off. By March 9, Saigon reported that NVA strength around Khe Sanh had been reduced to 6,000 to 8,000 men. On April 9, for the first time in weeks, not one enemy shell crashed into the combat base.

The NVA departed from Khe Sanh; by April 15 the U.S. Command announced that the operation for the relief of the base had been concluded and all objectives had been secured. The siege was over.

Westmoreland claimed the NVA lost between 10,000 and 15,000 men and hailed the confrontation as a great U.S. victory.

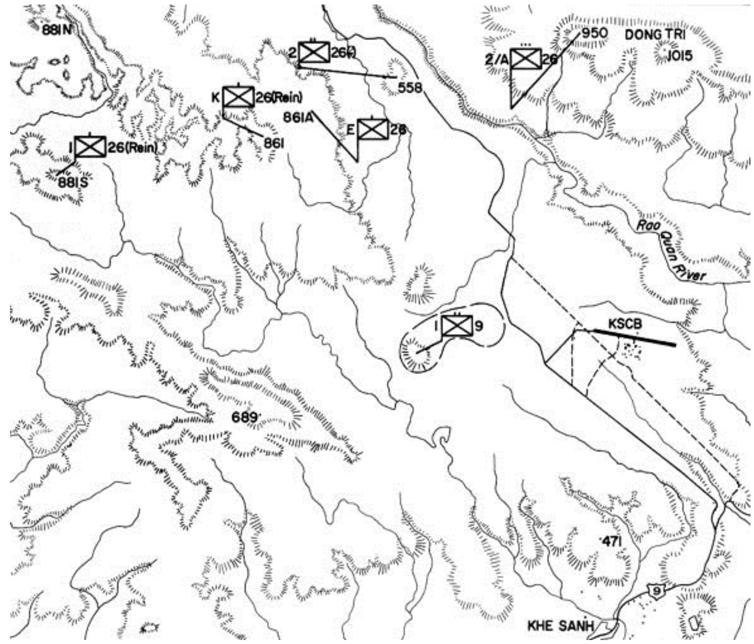
Army units entered the base, the first to arrive by land in months. They stared at us in disbelief; some of the Marines wore beards, all needed haircuts, all were exhausted. Our clothes were filthy, and we were unwashed. The 1st Cavalry had this attitude that they had "relieved" us, that they had "broken" the NVA siege. We largely ignored them.
The largest convoy I have ever seen in Vietnam formed up; and we drove to Camp Carroll, the nearby fire base from where I had been sent to Khe Sanh five months previously. Khe Sanh was no longer a Garden of Eden. The aerial bombardment had turned the countryside into moonscape; everything had been destroyed. Not a tree was left standing. There were no shades of green.

NVA General Vo Nguyen Giap claimed that Khe Sanh was never very important to the NVA, only serving as a feint to draw U.S. forces away from the populated areas during Tet. Giap considered Khe Sanh an NVA victory.

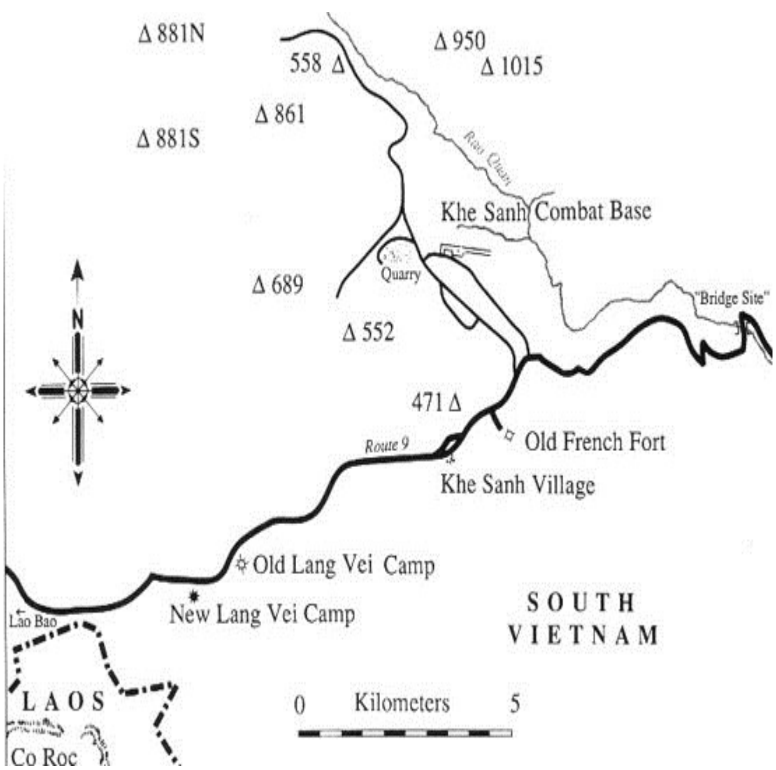
Early Radio: Military Communications

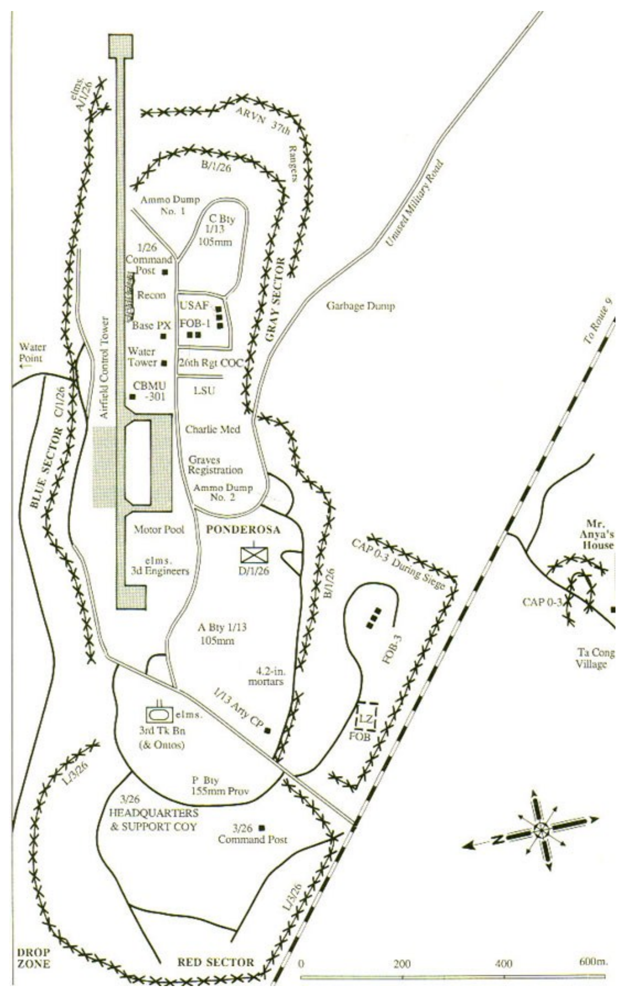
In June, 1968, it was announced that Khe Sanh was being abandoned. The Marines proceeded to dismantle the base, slashing sandbags, blowing up their fortified positions, filling in trench lines with bulldozers, hauling away everything of possible use to the enemy. The last Marines left on July 6. In their leaving, both sides turned the base over to the rats, whose population likely expanded still further now that the monsoon had ended, air and artillery strikes had ceased, and there was no human population to harass them. The rats were free to police the remaining ration scraps within the base and the huge quantity of body parts that must have lay without. And when this food supply was consumed, they, too, would depart Khe Sanh.

The COMM-Tech bunker in 1/13 area after a direct 122mm rocket hit.



Unit Locations on surrounding Hills.





Map showing main unit locations, perimeter and airstrip.

Early Radio: Military Communications

The preceding story is dedicated to all who served and died at Khe Sanh 1962 - 1972

Wisconsin Traffic Nets

Name of Net, Frequency, Local Time	Net Manager
Badger Weather Net (BWN)	W9IXG
Badger Emergency Net (BEN)	NX9K
Wisconsin Side Band Net (WSBN)	KB9KEG
Wisconsin Novice Net (WNN)	KB9ROB
Wisconsin Slow Speed Net (WSSN)	NIKSN
Wisconsin Intrastate Net - Early (WIN-E)	WB9ICH
Wisconsin Intrastate Net - Late (WIN-L)	W9RTP
ARES/RACES Net 3967.0 kHz, 0800 Sunday	WB9WKO

* Net Control Operator needed. Contact Net Manager for infor-

Next Regular Meeting

The next meeting will be on Thursday, October 25th at 7:00PM. We meet in the Fellowship Hall of Redemption Lutheran Church, 4057 N Mayfair Road. Use the south entrance. Access the MRAC Yahoo group for important details about the February Meeting.

Meeting Schedule:

October 25nd, 2012

November 29th, 2012

January 31st, 2013

February 28th, 2013

SwapFest: February 16th, 2013

Please do not call the church for information!

Club Nets

Please check in to our nets on Friday evenings.

Our ten meter SSB net is at **8:00 p.m.** at **28.490 MHz USB** Our two meter FM net follows at **9:00 p.m**. on our repeater at **145.390 MHz** with a minus offset and a **PL of 127.3 Hz.**

Visit our website at: **www.w9rh.org**

Or phone (414) 332-MRAC or 332 - 6722

Chatter Deadline

The **DEADLINE** for items to be published in the **Chatter** is the 15th of each month. If you have anything (announcements, stories, articles, photos, projects) for the 'Chatter, please get it to me before then.

You may contact me or Submit articles and materials by e-mail at: **Kc9cmt@earthlink.net**

or by Post to:

Michael B. Harris

807 Nicholson RD

South Milwaukee, WI 53172-1447

VE Testing:

October 27th, 2012—AES 9:30 am to 11:30 am.

November 24th, 2012—AES 9:30 am to 11:30 am.

ALL testing takes place at: Amateur Electronic Supply 5720 W. Good Hope Rd. Milwaukee, WI 53223

Area Swapfests

November 3rd, 2012

Milwaukee Repeater Club Hamfest

Location: Milwaukee, WI
Type: ARRL Hamfest
Sponsor: Milwaukee Repeater Club
Website: http://www.mrc91.org

MRAC Working Committees

95th Anniversary:

- Dave—KA9WXN

Net Committee:

- Open

Field Day

Dave—KA9WXN, Al—KC9IJJ

FM Simplex Contest

- Joe – N9UX
- Jeff – K9VS

Ticket drum and drawing

- Tom – N9UFJ
- Jackie – No Call

Newsletter Editor

- Michael-KC9CMT

Webmaster

- Mark Tellier—AB9CD

Refreshments

- Hal—KB9OZN

Membership Information

The Hamateur Chatter is the newsletter of MRAC (Milwaukee Radio Amateurs' Club), a not for profit organization for the advancement of amateur radio and the maintenance of fraternalism and a high standard of conduct. MRAC Membership dues are $17.00 per year and run on a calendar year starting January 1st. MRAC general membership meetings are normally held at 7:00PM the last Thursday of the month except for November when Thanksgiving falls on the last Thursday when the meeting moves forward 1 week to the 3rd Thursday and December, when the Christmas dinner takes the place of a regular meeting. Club Contact Information

Our website address **http://www.w9rh.org**

Telephone **(414) 332-MRAC (6722)**

Address correspondence to:

MRAC, Box 240545, Milwaukee, WI 53223

Email may be sent to: **w9rh@arrl.net .** Our YAHOO newsgroup:

http://groups.yahoo.com/group/MRAC-W9RH/

CLUB NETS:

• The Six Meter SSB net is Thursday at 8:00PM on 50.160 MHz USB

• Our Ten Meter SSB net is Friday at 8:00PM on 28.490 MHz ± 5 KHz USB.

• Our Two Meter FM net follows the Ten meter net at 9:00PM on our repeater at 145.390MHz - offset (PL 127.3)

The HamChatter is a monthly publication of the Milwaukee Radio Amateurs' Club.
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MRAC Website: http://www.W9RH.org
Editor: Michael B. Harris, Kc9cmt, kc9cmt@Earthlink.net

Milwaukee Area Nets

Mon.8:00 PM 3.994 Tech Net

Mon.8:00 PM 146.865- ARES Walworth ARRL News Line

Mon.8:00 PM 146.445 Emergency Net

Mon.8:00 PM 146.865- ARES Net Walworth

Mon.8:45 PM 147.165- ARRL Audio News

Mon. 9:15 PM 444.125+ Waukesha ARES Net

Mon.9:00 PM 147.165- Milwaukee County ARES Net

Tue.9:00 AM 50.160 6 . Mtr 2nd Shifter's Net

Tue. 7:00 PM 145.130 MAARS Trivia Net

Tue. 8:00 PM 7.035 A.F.A.R. (CW)

Wed. 8:00 PM 145.130 MAARS Amateur Radio Newsline

Wed. 9:00 PM 145.130 MAARS IRLP SwapNet d FM-38 Repeaters (IRLP 9624)

Thur. 8:00 PM 50.160, 6 Mtr SSB Net

Thur. 9:00 PM 146.910 Computer Net

Fri. 8:00 PM 28.490 MRAC W9RH 10 Mtr Net SSB

Fri. 9:00 PM 145.390 W9RH 2 Mtr. FM Net

Sat. 9:00 PM 146.910 Saturday Night Fun Net

Sun 8:30 AM 3.985 QCWA (Chapter. 55) SSB Net

Sun 9:00 AM 145.565 X-Country Simplex Group

Sun 8:00 PM 146.91 Information Net

Sun 8:00 PM 28.365 10/10 International Net (SSB)

Sun 9:00 PM 146.91 Swap Net