Bob's TechTalk #26
by Bob Eckweiler, AF6C

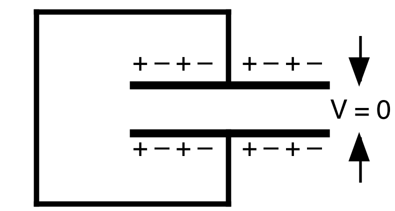
Capacitors - Part I of IV

An Introduction:

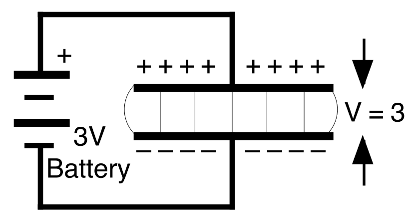
Last month on the ten-meter net the discussion turned to capacitors, and some of the participants thought it would make a good topic for ***TechTalk***. After all, capacitors are found in virtually every electronic component; they play an important part in antennas, power supplies, and tuned circuits, without which radios wouldn't work.

So what is a capacitor, and what does it do? *Capacitance* is one of three basic building blocks of electronic circuits. The others being *resistance* and *inductance*. We've discussed resistance, and ohms law, in prior ***TechTalk*** articles. Perhaps we'll get to inductance in a future series. We know resistance dissipates electrical energy; briefly, inductance stores electrical energy in a magnetic field and capacitance stores electrical energy in an electric field.

The basic capacitor is made up of two parallel conductive plates separated by a dielectric such as air. Many other dielectric materials can be used and we'll discuss them later. Initially, the two plates have an equal number of free electrons on them (because they are conductive), and there is no electric field between the plates; the capacitor is said to be discharged. When a battery is placed across a capacitor (see Figure 1) a current flows in the circuit as electrons flow into the negative plate and electrons leave the positive plate. This current is limited only by any resistance in the wires and battery. As the electrons flow in the capacitor, the difference in electrons between the negative and positive plates creates an electric field between the plates. When the magnitude of this electric field is equal to the battery voltage, no more current flows and the capacitor is said to be charged. If you were to measure this electric field between the plates by inserting a probe, you would find that the field varies linearly as you move from one plate to the other. In other words when half way between the plates the field would measure half of the full field, referenced to one of the plates.



Discharged capacitor. Plates have equal positive and negative charges.



Charged capacitor. One plate is positively charged the other is negatively charged. An electric field (thin lines) exists between the plates.

Figure 1 - The Capacitor

The number of electrons that a capacitor can hold is determined by the size of the plates, the dielectric material between the plates and the distance between between the plates (the closer the plates the more electrons that the plates can hold.)

Here's some interesting facts: A French scientist named Charles-Augustin Coulomb (1736 – 1806) coined the term Coulomb, which is a measurement of electrical charge (or in other words: a known quantity of electrons!) One Coulomb is the amount of electrons that pass a given point when one ampere is flowing. If you're curious, that equals 6.24 million trillion electrons – a very large number to all but a few politicians! A capacitor that will hold one Coulomb of charge when one volt is placed across it has a capacitance of one *farad,* named for British scientist Michael Faraday (1791 – 1867). One farad is a heck of a lot of capacitance (see sidebar) so capacitors in normal use are marked as microfarads, µf (one-millionth of a farad) or picofarads, pf (one-millionth of a microfarad).

Back in the earlier days of electronics, when *Hertz* were known as *megacycles-per-second* (mcs), or just megacycles for short, capacitors were known as *condensers,* and picofarads were called *micromicrofarads* (µµf). These terms have all but disappeared, but you may hear old-timers refer to them or see them used in older books. A heated discussion about using "condenser" happened in the late fifties. Many complained that it was an air-conditioning component and not an electrical component!

The capacitance of a capacitor can be calculated from its physical properties. The equation for a two plate capacitor is straightforward:

$$C = \frac{0.225KA}{d}$$

where:

C = capacitance in picofarads
K = dielectric constant
A = the area of one plate
d = distance between plates

The dielectric constant depends upon the material in between the plates. Vacuum has a dielectric constant of one by definition. Air's dielectric constant is also around one (1.0006). Paper used to be a very common dielectric, but has been replaced with polyester film or similar materials. Other materials provide K in the range of 1 to 7,500 as shown in Table 1. The dielectric also acts as an insulator. Some materials resist voltage breakdown better than others, also as shown in Table one. A third consideration for a dielectric is how it varies with external parameters such as temperature, frequency, etc. While stability might not be critical in a power supply, it is in a frequency determining circuit such as an oscillator, a filter or even an IF amplifier. Sometimes, however, a capacitor utilizing a dielectric that changes with temperature can be used to compensate for other components that drift with temperature in a frequency determining circuit. Some ceramic capacitors are made with known temperature coefficients for just this purpose.

Material	K	V/mil*
Free Space	1.0000	75
Air	1.0006	75
Paper	2.5	500
Polyester Film	3.0	1,000
Transformer Oil	4.0	400
Mica	5.0	5,000
Glass	6.0	3.000
Ceramic (BST)	7,500.0	75

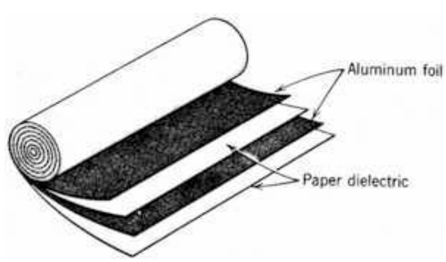
*1 mil = 0.001 inch

Table 1 – Dielectric Properties

Capacitor construction varies; often there are multiple alternating plates. This allows for higher capacitance since both sides of the plates are active areas. Capacitors may also be made of two long strips of foil alternating with two strips of dielectric material and then rolled into a cylinder (See Figure 2). Numerous other types of construction exist, each with its own benefits and drawbacks.

One type of capacitor that is very common is the electrolytic capacitor. It has very high capacitance for its size, and is normally a polarized device. The circuit it is used in must be designed so that the capacitor terminal marked positive is always more positive than the negative terminal.

The electrolytic capacitor is made up of two aluminum plates with an absorbent material between them. The material is saturated with a conductive liquid or gel called an electrolyte. The capacitor is then *formed* during manufacturing by applying a current limited voltage across the two plates. The current that initially flows creates a very thin layer of aluminum oxide at the positive aluminum plate. Aluminum oxide is a very good insulator. The aluminum plates are usually rolled and placed in an aluminum can that also houses the electrolyte. Electrolytic capacitors may also be made using tantalum instead of aluminum. Tantalum provides an even higher capacitance per unit volume, but is more restricted in its voltage range. One of the major uses of electrolytic capacitors is as filters in power supplies and power leads. They are also useful as coupling capacitors at lower frequencies.



Paper Capacitor Construction
Figure 2

Electrolytic capacitors can be easily damaged by applying excessive voltage or voltage of the wrong polarity. Reverse polarity will go unnoticed at first, with some reduction in capacitance until the oxide plating is used up. The electrolyte will then heat and give off gas possibly causing the capacitor to explode. Most electrolytic capacitors have a vent system to let the gas escape, but the vent is initially sealed and when it opens it is often accompanied by a bang that would make many firecrackers proud! The electrolytic material is corrosive and should be cleaned up quickly if it leaks to prevent further damage. We'll discuss electrolytic capacitors further in an upcoming *TechTalk*. Next month we'll continue our discussion of capacitors.

Farad Capacitors!!!

Capacitors in the Farad range are now available! These low voltage capacitors are used primarily for memory backup. The Panasonic "Gold Series" are sold by **Digi-Key**.

73, from AF6C

This article is based on the TechTalk article that originally appeared in the February 2004 issue of RF, the newsletter of the Orange County Amateur Radio Club - W6ZE.

