TECHNICAL BULLETIN NO. 01

CAPACITORS...WHAT ARE THEY?

"What is a capacitor?" Webster's Collegiate Dictionary says:

> "Capacitor: A device giving capacitance usually consisting of conducting plates or foils separated by thin layers of dielectric with the plates on opposite sides of the dielectric layers oppositely charged by a source of voltage and the electrical energy of the charged system stored in the polarized dielectric."

Now that the capacitor has been "defined," let's correlate this definition to a schematic drawing of the capacitor and the associated circuitry necessary for the capacitor to perform fully to its definition.

Figure 1 illustrates all of the elements necessary to the definition. The "two metallic conductors" and the "dielectric material" are obvious. The addition of the plate connections, Switch S_1, and the energy source, allows the capacitor to fulfill its function of "storing electrical energy." The plate connections, Switch S_2, and the load, control the energy release factors to a "predetermined rate" and "predetermined time".
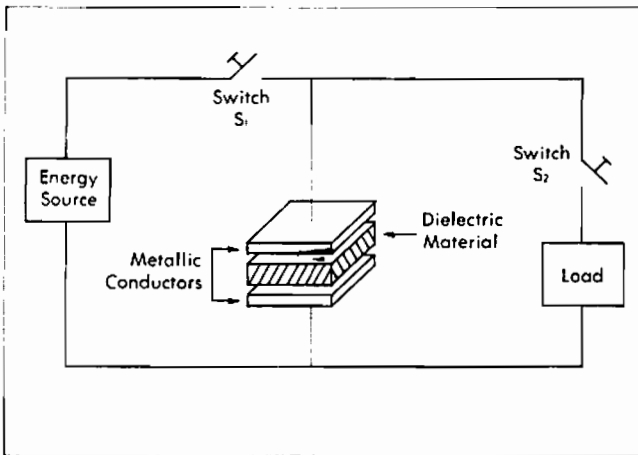

Figure 1

Now that we know what a capacitor is and basically how it works, we must have some means of measuring or rating it. Since its function is to store energy, we measure or rate it by its ability to store this energy. The term used to describe this ability is "capacitance."

"Capacitance" then is a measure of the quantity of electrical charge that can be held per unit of voltage differential between the metallic conductors (electrodes). The basic unit of capacitance is the "farad" but, since the farad is a very large number, "microfarad" (one millionth of a farad) and "picofarad" (one millonth of a microfarad) are in most common usage.

The mathematics associated with the conversion from the primary definition of capacitance equals quantity of electrical change per unit voltage differential to the basic geometrical formula for capacitance is shown in Figure 2. With this geometrical formula, a capacitor engineer can design units to known values.

Q=Charge in statcoulombs
V=Potential in statvolts
K=Effective dielectric constant of materials between plates
A=Area in square centimeters
f=Force between plates in dynes
d=Distance between plates in centimeters

$$C = \frac{Q}{V} = \frac{\sqrt{\frac{KAf}{2\pi}}}{d\sqrt{\frac{8\pi f}{KA}}} = \frac{1}{d}\sqrt{\frac{K^2 A^2}{16\pi^2}} = \frac{KA}{4\pi d} \text{ Statfarads}$$

Converting to farads and inches:

1 farad $= 9 \times 10^{11}$ statfarads
1 inch $= 2.54$ centimeters

$$C = \frac{KA(2.54)}{4\pi d(9\times10^{11})} = \frac{.224 KA(10^{-12})}{d} \text{ farads}$$

$$= \frac{.224 KA}{d} \text{ picofarads}$$

Figure 2

To fully understand just how the capacitance (C) measures the ability of a capacitor to store energy, Figure 3 illustrates the derivation of the formula concerned and shows the direct relationship between energy and capacitance.

The increment of work (dW) done in bringing up an increment of charge (dQ) against a potential (V) is by definition:

$$dW = VdQ$$

and since each succeeding increment of work becomes greater to add each succeeding increment of charge against an increasing voltage potential, the total work (energy) required to charge a capacitor is a summation for all values of charges (dQ) between O and Q. This we do by integration.

$$W \text{ (Energy)} = \int_0^Q VdQ = \int_0^Q \frac{(Q)}{C} dQ = \frac{1}{2}\frac{Q^2}{C} = \frac{CV^2}{2}$$

$$\text{where: } V = \frac{Q}{C}$$

Figure 3

From the basic formula we note that C varies directly with the dielectric constant (K) and area (A); and inversely with the distance between the plates (d). Both (A) and (d) are geometrically controlled figures, but what is this dielectric constant (K) and how is it determined?

The dielectric constant (K) of a material is a direct measure of its ability to store electrons when compared to air.

If we make a capacitor with given "A" and "d" dimensions, and use just clean dry air as our dielectric, it will measure a certain value of capacitance. Now, if we substitute some other dielectric for the air and remeasure the capacitance, we will find that our capactance value has increased. If the capacitance figure doubled, for instance, this would mean that the second dielectric had a dielectric constant of 2 (twice that of air).

Figure 4 is a chart of various common dielectric materials and their approximate dielectric constants.

DIELECTRIC CONSTANTS AT 25°C	
Dielectric Material	K(Dielectric Constant)
Vacuum	1.0 (exact)
Air	1.0001
Teflon	2.0
Polystyrene	2.5
Polypropylene	2.5
Polycarbonate	2.7
Polysulfone	2.7
Mylar	3.0
Kapton	3.2
Polyethylene	3.3
Kraft Paper (impregnated)	2.0 to 6.0
Mica	6.8
Aluminum Oxide	7.0
Tantalum Oxide	11.0
Ceramics	35.0 to 6000+

Figure 4

And that's what a capacitor is!

What is a capacitor? Why it's "something that an electronic circuit won't work without!"

TECHNICAL BULLETIN NO. 02

CAPACITORS...VERSATILE JOB PERFORMERS

Whenever a capacitor is designed into an electronic circuit, it has been selected to do a specific job - and certain capacitors will perform certain jobs better than some others.

Let us examine these jobs that must be performed by the capacitors and analyze the important factors leading to the proper selection.

BLOCKING

Whenever direct current (DC) is applied to a capacitor, the capacitor effectively "blocks" this current and will not allow it to pass through. Utilizing this property of the capacitor, a design engineer can isolate a circuit element from the DC supply. For this job, he has a choice to make among many dielectrics, each of which will allow a different amount of tiny "leakage current" to pass through itself. This "leakage current" is a normal result of the random passage of electrons through or around the dielectric (usually in the microampere range), and should not be confused with the normal DC current supply. Thus, the design engineer can match the dielectric with the critical value of "leakage current" that his curcuit can tolerate without malfunction.

COUPLING (DE-COUPLING)

Just as the capacitor will block out direct current, it will appear to pass alternating current (AC). The capacitor is really charging and discharging in opposite directions each half-cycle as the impressed AC voltage alternates in polarity. To the rest of the circuit this has the same effect as though the capacitor were allowing the passage of the AC signal. By using this ability of the capacitors, the design engineer can "couple" one portion of a circuit to another portion of a circuit or even to a different circuit. Here, the inherent dissipation factor of the capacitor style can be critical if the heating effect of the AC voltage is appreciable.

BY-PASSING

This job is a good example of the combination of blocking and coupling functions. In this case, the capacitor is used to separate the DC and AC portions of a mixed signal current. Here, the capacitor is placed in parallel with a circuit element. The purpose here is to insure that the DC portion does appear on the circuit element —but not the AC portion! By properly choosing the capacitor rating, the AC signal sees an apparently low impedance path "through" the capacitor compared to the circuit element and consequently "by-passes" the circuit element. The DC signal sees a low impedance path through the circuit element and travels that way. Obviously, both the leakage current and dissipation factor parameters are to be considered in any application where these factors are critical.