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Electric Guitar & Bass Tone Capacitors

By Tom Colella, Engineering Manager

As a rock/blues guitarist in the Sixties, and still an active artist, as well as an electronic engineer with a long-standing tenure of certain distinction for the past 40+ years, I have had the opportunity to keenly study and appreciate various capacitor types and their relationship to tones generated in guitars and amplifiers.

Capacitor Basics

A capacitor is a passive electrical component that consists of two metal electrodes (plates) separated by a dielectric insulator. The electronic symbol for capacitance is C and the unit of measurement is Farad. A capacitor that has a capacity of 1 Farad is an extremely large device in physical size. The most common unit of measurement is microfarad (µf) [10^{-6} Farads].

The emphasis of this discussion is centered on film capacitors since this type gives the best music reproduction. Yet, there are two styles of film capacitors, film and foil, as well as metallized designs.

Film, Foil and Metallized

In the film and foil construction, the electrodes are separate sheets of metal foil wound with sheets of dielectric material. These electrode sheets (foils) extend alternately out of each end of the capacitor roll beyond the dielectric, which provide a large mass of metal material to which the leads attach (see **Figure 1: Capacitor Construction** and **Figure 2: Film and Foil**).

The metallized capacitor type of construction greatly reduces the physical size of the capacitor. The discrete foil sheets are replaced with a thin layer of 99% pure aluminum, which is vapor deposited directly upon the dielectric material. Since the dielectric material is present at each end of the capacitor along with the metal electrode material, direct attachment of the leads is not possible (see **Figure 1: Capacitor Construction** and **Figure 3: Metallized**).

The end-terminations of the metallized unit are accomplished by the application of a fine, molten-metal spray. The spray makes contact with the layer of 99% pure aluminum electrode that results with plate contact. As the metal spray particles stack up against the aluminum electrodes, there is a compression bond that results in a resistance value higher than that of discrete metal foils. The leads are attached to this metal spray, which adds additional resistance.

So what does this mean? There is a complex filter robbing the true, clear sound reproduction. For this and a number of reasons – including the fact that such capacitors are susceptible to increased series resistance – I do not recommend metallized capacitors for guitar tone controls.

A capacitor manufacturer can utilize various combinations of dielectrics and impregnation oils in the construction of each type of capacitor. That's why it's necessary to carefully select the combinations of these materials to achieve certain tonal quality.

What the vintage experts used

In the late 1940s and early 1950s, most of the capacitor designs were limited to film and foil construction, basically Kraft paper and foil, oil impregnated. This style of capacitor was used on the first models of electric guitars made by Les Paul and Leo Fender.

Capacitors and Tone Control

The tone capacitor is connected to the *tone-control* potentiometer (pot) and the *ground* (shield) wire. The capacitor and resistance of the pot work together to form a filter network, which either passes the high frequencies to ground giving the *dark tones*, or passes low frequencies to ground giving the *bright tones* in music reproduction (see **Figure 4: Two Pickup Guitar Illustration**). The guitar player must consider that the larger the capacitance, the *darker* the tone – the smaller the capacitance, the *brighter* the tone.

Electrically, the voltage of the capacitor does not really matter since the voltage on the tone capacitor is minimal – only *signal* voltage. From my years of experience, I have proven that in order to achieve the best sound, using the largest capacitor that will physically fit in the guitar is the optimum selection. The larger diameter capacitor gives more surface area for the internal lead connection, thus making for a lower series resistance and a better frequency response. Personally, I prefer either a 400V or 600V type.

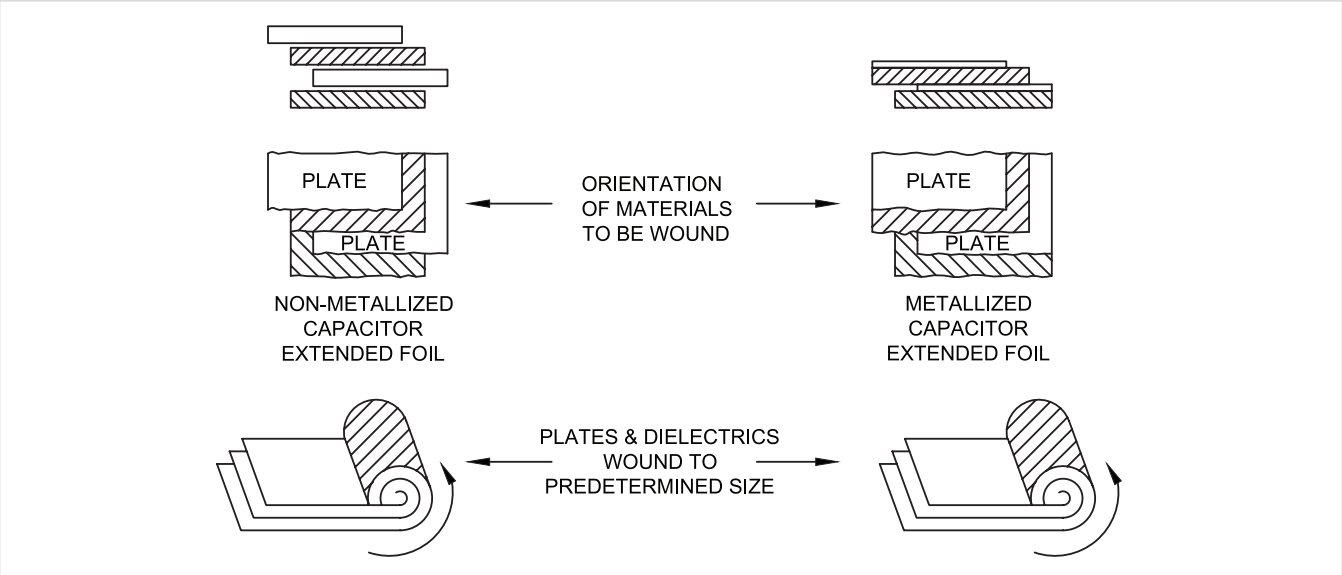


Figure 1: Capacitor Construction

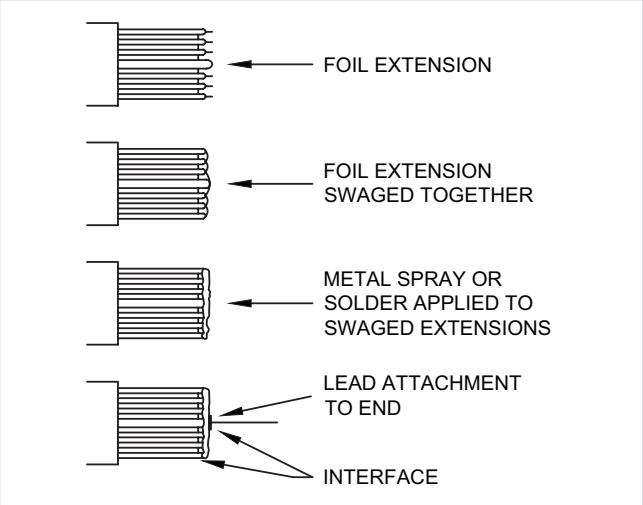


Figure 2: Film and Foil

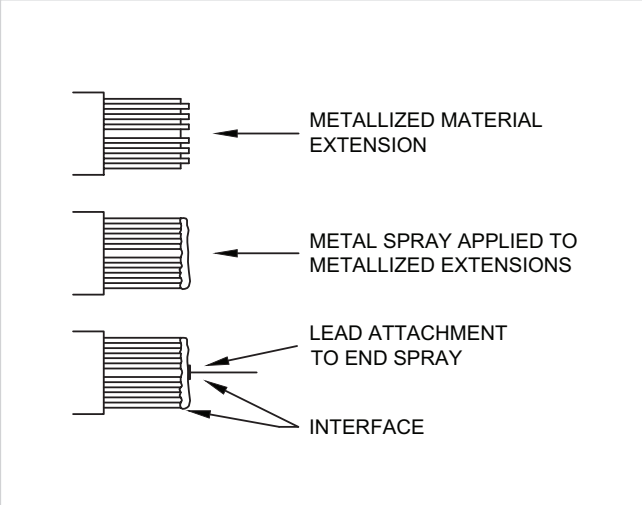


Figure 3: Metallized

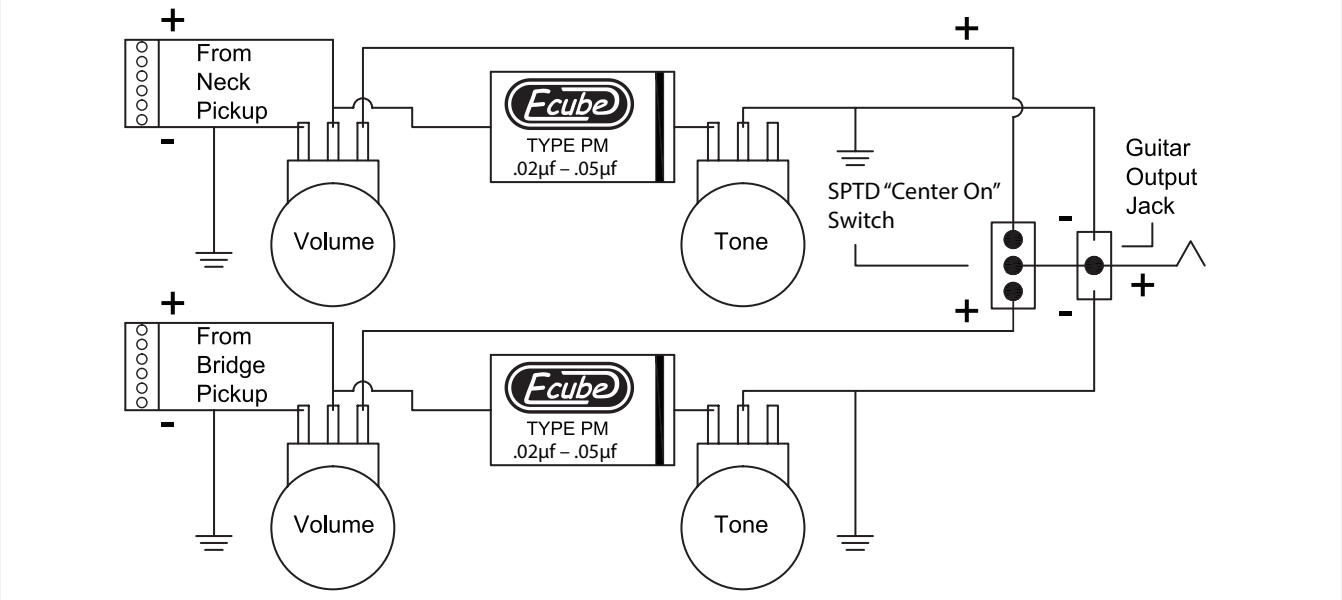


Figure 4: Two Pickup Guitar Illustration

Fender and Gibson

Generally, the vintage Fender guitars used a .047µf to a .1µf film/foil capacitor. The older style Gibson guitars used a .022µf film/foil capacitor. To achieve the *darker, warmer* sound, I recommend a .1µf capacitor. Many of my Jazz musician friends install the .047µf value capacitor in their guitars, which has that *darker, warmer* sound, but with a little more clarity and brightness. For playing rock and blues, I use the .022µf capacitor, which allows for a wide variety of tones and tonal combinations, combining *dark, warm* and *bright* tones (see **Figure 5: Tom Colella's Set-up in the Gibson Les Paul Using Electrocube Type PM Retro Capacitors)**.

Figure 5: Tom Colella's Set-up in the Gibson Les Paul Using Electrocube Type PM Retro Capacitors

Of course, all of this depends upon the values of the tone-control potentiometer as well as the type and style of the pickups. If the guitar is played with the pot wide open, then the capacitor is bypassed in the circuit; thus, the selection of the capacitor does not matter – it isn't used!

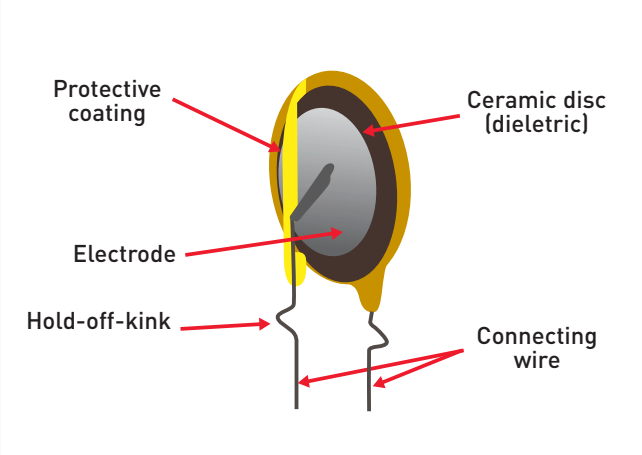


Figure 6: Basic Ceramic Capacitor Construction

Capacitor recommendations

I suggest purchasing a variety of capacitor values, and performing the set-up in various combinations per the musician's personal taste, using the Electrocube AM or PM Series Retro Capacitors. Then, leisurely, through trial and error by the musician, the most advantageous set-up is achieved. Experimentation will lead to a realistic evaluation of the sound generated.

Ceramic Capacitors

Most of the later model guitars use ceramic capacitors in the tone control network. The basic reason is the manufacturers' bottom line: Ceramic capacitors are cheap! I do not recommend the use of ceramic disc capacitors in tone controls. The construction of a typical ceramic capacitor is shown (see **Figure 6: Basic Ceramic Capacitor Construction)**. The dielectric of this capacitor is a ceramic material and the electrodes are silver alloy. The capacitor is stacked alternating ceramic with silver electrodes in a number of layers until the nominal capacitance is achieved (see **Figure 7: Internal Ceramic Capacitor Construction)**.

There are two major drawbacks in using ceramic capacitors. First, they pick up mechanical vibrations such as with a microphone, turning them into unwanted electrical signals. These vibrations cause a squeezing or oscillation of the ceramic dielectric that produces a small voltage in the capacitor. This small voltage (in microvolts) can cause audio distortion and poor tone control – this distortion is called *microphonics*.

The second problem with ceramic capacitors is the poor audio frequency response. The tone control is a band-pass type of filter allowing certain audio

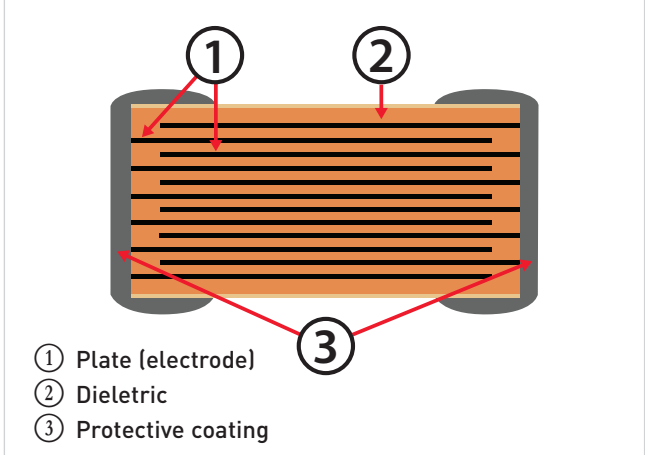
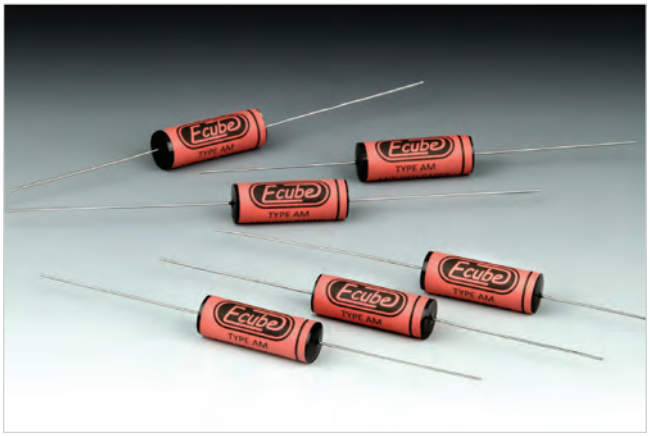
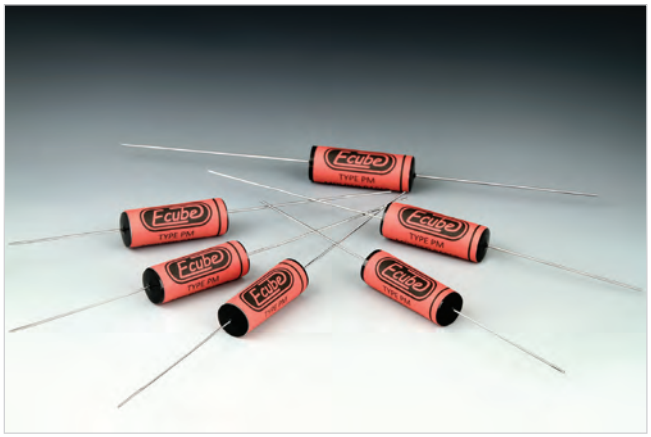


Figure 7: Internal Ceramic Capacitor Construction



Electrocube Type AM Capacitors



Electrocube Type PM Capacitors

frequencies and shunting to ground undesired audio frequencies. Ceramic capacitors have a poor series resistance (ESR) and a low insulation resistance (IR), which adds additional resistance to the tuned circuit – thus, poor audio response.

Summary

Electrocube has taken the 1940s capacitor designs and audio-enhanced them, using current technology and manufacturing techniques, to achieve a truly superior *retro-style* audio capacitor. I recommend Type AM Retro Capacitors (Paper/Foil) or Type PM Retro Capacitors (Polyester/Foil) for tone controls for guitar and bass applications. Ultimately, all musician's choices are based upon user preference, quality of tone and size constraints.

For questions and/or a quote, contact Sales at 909-595-4037 or info@electrocube.com.

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