By Theo Hartman - GJD Contributor

One of the questions we often get at the shop is why older Germanium transistors sound different than their modern-day counterparts, even when the specimens compared are nominally the same gain, part-number and specification.

If you are satisfied with Mojo as an answer or that intervening years have magically aged the parts into sounding the way they do, I would encourage you to stop reading here. If, however, your curiosity gets the better of you, read on.

Different species of transistor have been designed over the years to function well in specific applications: radio, audio, power. But there can be sonic differences between 2 transistors that spec out the same on paper (and even on some bench tests).

Why should this be so? It turns out the fuzz face is an excellent tool for understanding what's going on. It gives us a glimpse of two underlying phenomenon that can influence the musicality of a transistor. One of these factors is inherent in the circuit itself. The second requires a look at the inside of the transistors being used. These two phenomena interact. In my opinion, the fuzz face shines as a musical circuit precisely because of its ability to compound this interaction; but is also means that transistor selection is even more critical to the end result.

For a primitive circuit with fewer than a dozen parts, a fuzz face has a lot going on. A transistor pair provides sufficient gain to clip the incoming audio signal, and there is a tunable positive feedback path, the "Fuzz" control. From an electrical standpoint it's not the most robust design in the world because it depends so heavily on the right gains in the transistors to function well. For a good analysis of the circuit, I recommend R.G. Keen's "The Technology of the Fuzz Face."

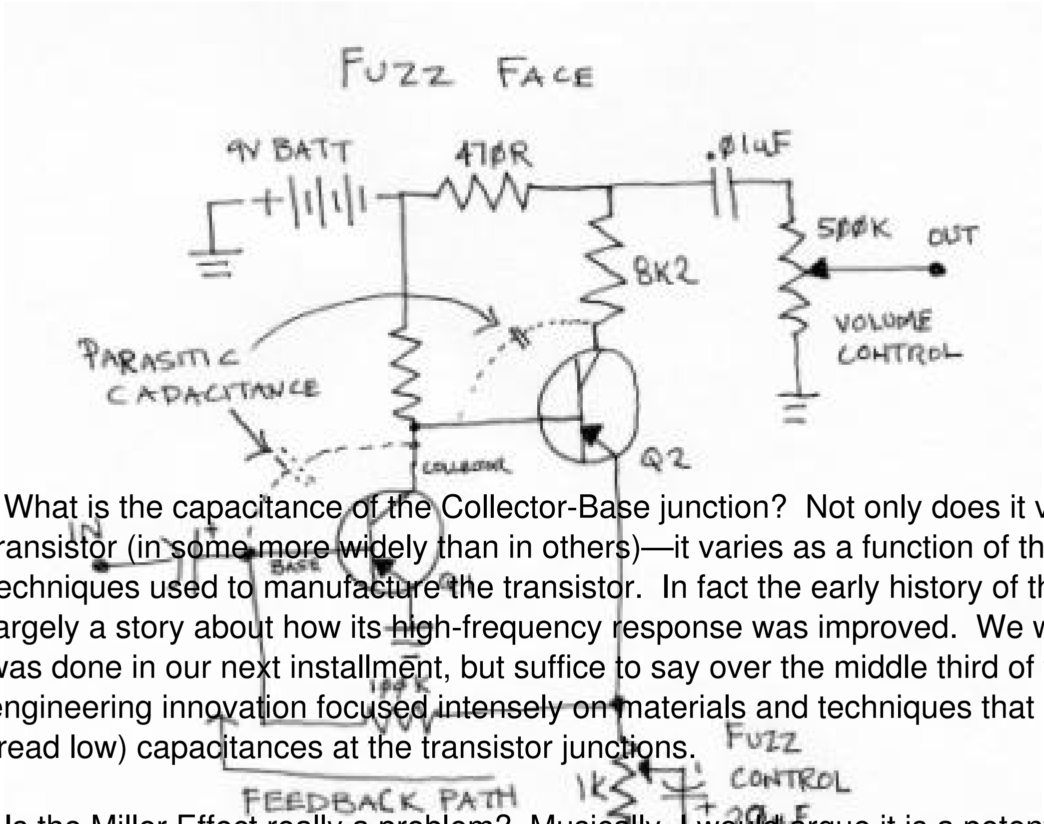
In its simplicity however, the fuzz face excels at exaggerating the certain differences among the transistors selected. It does this by means of a peculiar side-effect of amplification called the Miller Effect.

Almost as soon as engineers achieved amplification, they began to observe the Miller Effect. Simply stated, the Miller Effect says that any capacitance between the input and output of an amplifier gets multiplied by the amplification factor of the circuit.

What does this mean? If you are familiar with the tone control of your electric guitar or bass, you know that the value of the attached capacitor, the "Tone Cap", determines how much high frequency (treble) gets bled to ground—and therefore removed from the signal—when you roll back on your tone control.

The Miller Effect is similar. It equates to a loss in high frequency. In the fuzz face example, the capacitance between the Base and Collector electrodes of the each transistor gets multiplied by the effective gain of that transistor, and a corresponding portion of the treble is lost. The transistor not only amplifies, it behaves as a low-pass filter.

One way to visualize what is happening is to imagine what would happen if you placed an external capacitor across the Collector-Base junction. Your audio (input) signal shows up on one side of the capacitor. The 180-degree out-of-phase amplified audio from the Collector of the transistor shows up on the other. When the two audio signals 180-degrees out of phase encounter each other, some cancellation takes place.



What is the capacitance of the Collector-Base junction? Not only does it vary from transistor to transistor (in some more widely than in others)—it varies as a function of the materials and techniques used to manufacture the transistor. In fact the early history of the transistor is largely a story about how its high-frequency response was improved. We will examine how this was done in our next installment, but suffice to say over the middle third of the 20th century engineering innovation focused intensely on materials and techniques that yielded controllable (read low) capacitances at the transistor junctions.

Is the Miller Effect really a problem? Musically, I would argue it is a potential asset. Analog designers certainly learned to accommodate the Miller Effect in their creations. In fact many good tube amp builders exploit the Miller Effect (which occurs in tubes as well) in their designs to achieve their desired frequency response.

However, the transistor foundries of the 1950's and 1960's didn't design product for fuzz pedals. They were headed, technologically speaking, more or less in the opposite direction. By the end of the 60's, frequency response and junction geometry had advanced sufficiently to give birth to the integrate circuit, the "chip".

Density and frequency response have only increased since then, but gone is that narrow window of time and practice where the junction capacitances were high enough to compound with the Miller Effect to create the weird musical contours we know and love (or hate) in the fuzz face.

In the next installment we'll talk a little bit about how alloy-junction transistors were made and how they contributed to the musicality of the fuzz face.

[Hartman Electronics](#)