Potato Experiments

Mike Rivers, August 2017

In some recent interviews and short videos, Sylvia Massy described a trick for getting a unique sound by connecting a potato in series with the amplifier's speaker leads – actually two potatoes, one in series with each lead. She first showed this as a way to process a vocal track, and recently used it on a guitar track. That got me curious. A couple of weeks ago, my local supermarket had 5-pound bags of Russets on sale for 99 cents. Since it's been too hot or too rainy to work outside and no projects to do inside, I picked up some experimental material and went off to see just what I could do with potatoes, amplifiers, and guitars.

First thing I did, after making up a couple of test leads terminated with nails to stick into the potatoes, was hooked it all up, plugged in a guitar, and, honestly, I wasn't excited with the results. The guitar still sounded like it did without the potatoes but a whole lot quieter, requiring driving the input well into distortion in order to get to a barely playable level.

So I dreamed up some hypotheses and took my bag of potatoes to the workshop, intent on studying their electrical characteristics and trying to get a clue as to what sound characteristics Sylvia found interesting other than just plain overdriven distortion.

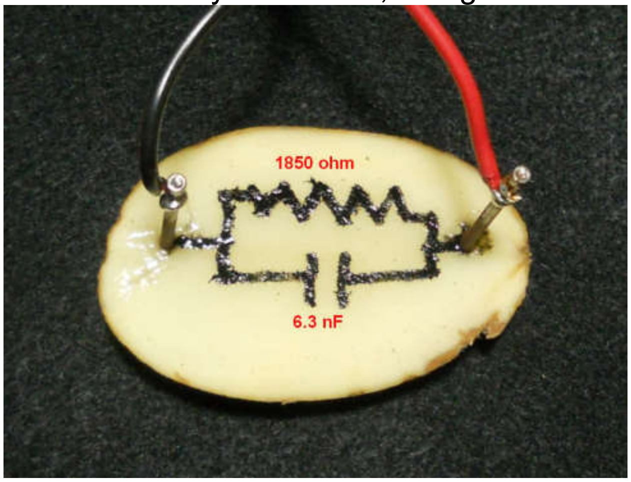
Biasing The Speaker?

My first thought was that the potato was acting like a battery, biasing the speaker's voice coil off its resting position and into a region of non-linear travel. That might work with a potato the size of The Great Pumpkin and corresponding large electrodes, but not with a Russet and a couple of 10d nails. Open circuit voltage is about 0.13 V with short circuit current being only about 72 μA - not enough to electrocute a fly, much less move a speaker cone.

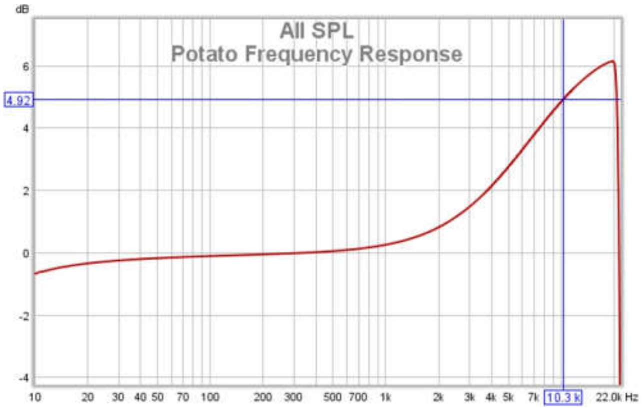
The terminal voltage of a battery is a function only of the chemistry, but you can make it deliver more current by making it bigger. Also, to make a good battery, you need dissimilar materials for the electrodes (an anode and a cathode), and I suspect that the nails, which corroded fairly quickly after being inserted in the potato, behaved differently enough to produce a DC voltage. In the interest of pure science and to try to make a better battery, I replaced the two plain steel nails with a 12 gauge copper wire and a galvanized nail (the classic science project "potato battery"). This rig measured a terminal voltage of 0.95 volts, and a short circuit current of 180 μA – a more serious battery for sure than with two ordinary nails, but still not giving even a faint click when connected to a speaker. So I discarded the voice coil bias hypothesis.

Electrical Characteristics

Next, I measured the potato's internal resistance. Actually, first I calculated it from the DC open circuit voltage and short circuit current – right around 1800 Ω. Under AC conditions, my batch of potatoes was fairly consistent, though the resistance varies with frequency, ranging from about 1900 Ω at 100 Hz to about 1100 Ω at 20 kHz. This suggests that it behaves like a resistor shunted by a capacitor. Lacking a working capacitance meter, I pulled some small chokes out of the junk box and found one that resonated with the potato in the audio band. From this, I calculated the capacitance at around 6.3 nanofarads (0.0063 μF), which is consistent with the rising frequency response.



My test setup for electrical measurements was a signal generator driving a 60 watt solid state power amplifier. To save my ears, I used an 8 ohm resistor as a dummy load rather a loudspeaker. Stay tuned for loudspeaker measurements.



Here's a plot of the frequency response of a representative potato. It's quite flat up to 1 kHz, where it begins rising to about +5 dB at 20 kHz. Since there isn't much above about 5 kHz coming out of a guitar amplifier, the high frequency rise is probably negligible. Sylvia also mentioned a rising high frequency response, so it's good to know that at least someone else observed what I measured what and found similar results.

For what it's worth, AC measurements when using the copper and galvanized nail test leads were almost identical to those with the plain nails.

Next came gain, or rather loss, measurements. With the dummy load connected directly to the amplifier, I established a baseline by setting the amplifier's gain and generator output level to deliver 30 watts (15.5 volts) into the load with nothing clipping. When connecting the potato between the amplifier output and the dummy load, the amplifier is still delivering 15.5 volts at its output terminals, but it's now driving about 1800 Ω (at 1 kHz) rather than 8 Ω. The amplifier is delivering only about 130 mW of power to the load rather than 30 W, with most of the voltage being dropped across the potato. This is all in agreement with Ohm's Law – no surprises here. With the amplifier loafing at less than 1/8 of a watt, the power loss is nearly 25 dB. No wonder, when replacing the dummy load with a speaker, it wasn't very loud.

"Turn it up!" you say? Well, you can't, at least not with this amplifier, nor any practical instrument amplifier that I know of. Mr. Ohm tells us that in order to drive 30 watts into 1800 Ω, we'd need 230 volts, and the amplifier's power supply won't deliver it. And even if it could, the speaker would only be seeing a fraction (8/1808) of that voltage. But you can make it bleed while trying, and this may be part of the trick.

As an aside, Sylvia cautions not to use a tube amplifier with a potato, because they (the amplifier, not the potato) tend to blow up. This isn't surprising since with the potato in series with the speaker, the amplifier is running essentially with no load. Transients can cause large voltage spikes in the primary of the amplifier's output transformer, which, at high levels, can cause the transformer windings to arc over. The warning to never run a tube amplifier unloaded has been around since the early audiophile days. Solid state amplifiers have no output transformer and voltage and current are limited by the power supply, so they're more tolerant of no-load operation.

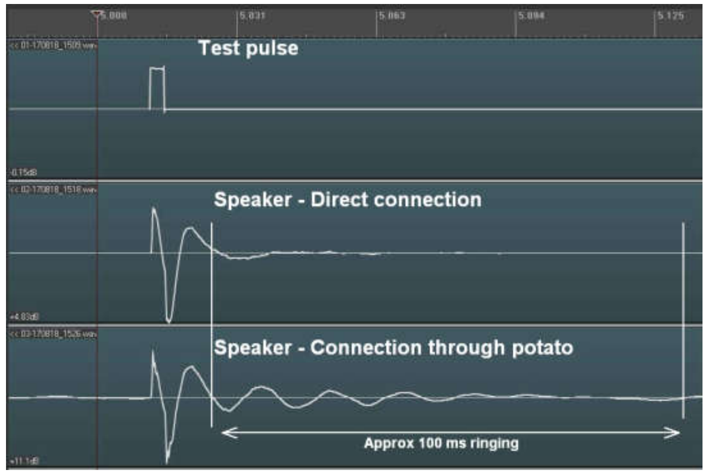
Compression, Limiting, or Worse

Thinking about other possibilities for more dynamic characteristics, I considered that the potato might be non-linear with voltage or current, causing it to behave like a compressor or limiter. Sadly, there's nothing interesting to write about here. The potato's series resistance at a given frequency remained the same at any voltage between 1 and 15 volts.

Speaker Damping

The high resistance between the amplifier and speaker suggests that the speaker would be underdamped. Perhaps what Sylvia hears from the potato-fied guitar is a result of the speaker ringing. To check this out, I replaced the dummy load with a guitar amplifier speaker, aimed a measurement mic at the cone, and recorded the speaker's response to a pulse. To establish a reference, I first measured the speaker when connected directly to the amplifier and therefore properly damped. Next, I inserted a potato in a speaker lead, adjusted the amplifier's gain to produce the same peak acoustic output as without the potato, and again recorded the speaker's response to the pulse. This, while predictable, proved to be interesting. We may be getting somewhere here.

The properly damped speaker settled down after about 14 milliseconds. With the potato in the circuit, there was a bit of overshoot at both the leading and trailing edges of the pulse, and ringing continued out to about 100 milliseconds. I can't really guess what this might do to the sound of a guitar other than perhaps muddy up the high frequencies, but at least it's a measurable and explainable effect of adding the potato in the circuit.



When playing around a bit with a guitar, a potato, and the speaker – with the understanding that I'm neither a rock guitarist nor a rock recording engineer – I found the effect of the potato to be indistinguishable from that of an 1800 Ω fixed resistor, aided, perhaps, by a touch treble boost. However, given the sad state of studio maintenance shops these days, in the heat of a session, when seeking some inspiration for the guitarist, it's probably easier to find a potato and a couple of nails than a resistor.

One Potato, Two Potato . . .

Sylvia used two potatoes in her video clip, one connected in series with each speaker lead. I tried this as part of my initial experimentation, and the only difference it made was an additional loss of volume due to increased series resistance. This might also increase the ringing, but that wasn't something that I could hear. In the video, she has one potato labeled "+" and the other labeled "-." While there's some value in maintaining the amplifier's original acoustic polarity when fooling with the speaker wiring, this is AC, and there's no plus and minus. But it's cute.

Another two-potato hypothesis was that, given that they're organic objects, any time delay through a potato is bound to be different for any two samples, even both halves of the same potato. When summed (differenced, actually) at the speaker voice coil, cancel certain frequencies could be out of phase and therefore be cancelled or attenuated. There is a small phase shift associated with the rising high frequency response through a potato, about 20° at 20 kHz, however the actual time delay through any potato was too small to measure. Splitting a signal and recording it as two channels, each through its own potato, when summed, showed no comb filtering anywhere within the audio range. It seems that two potatoes just adds more resistance, and more power loss to the speaker.

Fuzzy Conclusions

Setting aside the possibility that, since she lives closer to Idaho than I do, her potatoes just work better than mine, I’m coming to the conclusion that this is a Sylvi (like Jedi) Mind Trick. Throw the guitarist an amplifier that looks familiar but with a huge reduction in power and quite a different gain structure and his first inclination is likely to start cranking the input gain up in order to get sufficient playing volume, thus driving the preamp stage into clipping. If he backs that off, then turns the master gain up, he’ll get a different sort of distortion as the output stage runs out of voltage and turns the guitar signal into square waves.

Regardless of how the gains are adjusted adjusted, in order to get a useful volume, it’s necessary to push the amplifier to near hemorrhaging, which, understandably, will create large amounts of distortion. It may be possible to finagle some previously unattainable flavor of distortion by finding a balance between a hard-driven but not clipping input stage and an output stage that’s not capable of delivering sufficient voltage to follow the input signal accurately. If this idea is indeed worth a hoot, it might be better applied to a direct track through a re-amp setup. That gives you a better shot at playing with the gain settings while not boring the guitar player during a tracking session who can barely hear his crazily tricked-out amp.

The Mind Trick part is that the guitarist is bound to think it’s such a wacky idea that he’s going to try his best to get a sound with the setup that works better than what he had been using. Or maybe he’ll just end up playing the part better. Sylvia is known for doing things in session that set the players off balance in order to get them out of a rut (read her book Recording Unhinged), and that, folks, is why people hire her to produce and engineer their recordings.

Afterwards

Sylvia got a kick out of this writeup and suggested that I try a light bulb. Now this has some real possibilities. Although the cold resistance of a light bulb is still several times the voice coil impedance so there’s a lot of power loss at the speaker, the bulb’s resistance increases as the filament heats up, causing it to act as a compressor as you play louder. In fact some of our favorite compressors use exactly this principle. Unlike with the potato, this is an effect that’s both measurable and, ummm, interesting when playing a guitar. Keep in mind that these days it’s mighty hard to find a light bulb with a real filament. She also said that a fluorescent bulb was amazing, but I’ll leave that to another rainy day.