The Tone Stack Explained in English for Humans

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The guitar amp. Why does one control seem to alter what another one does? Why does the mids knob affect volume? And why is the treble pot more like a blend control? Because they're connected in ways we could not intuit.

After searching repeatedly for a layperson's explanation of the tone stack – the EQ section found in guitar amps – I realized one would not be forthcoming. There seemed to be two camps: guitarists, who, despite an adorable belief that the three knobs do what the labels suggest, have no understanding of it; and amp builders, who understand it too well and talk to each other in Martian.

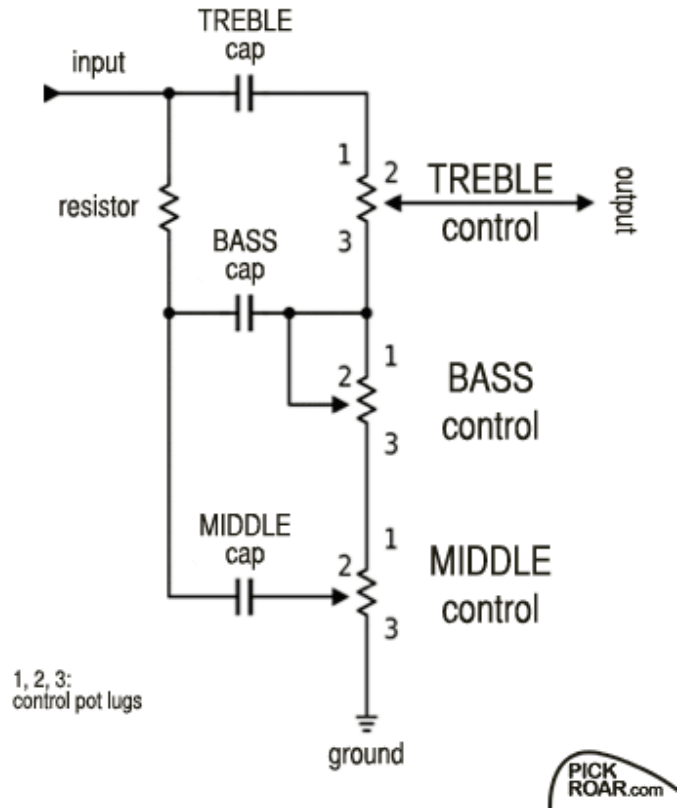
As I forced myself to learn it anyway, I took notes using the ordinary language that my brain prefers. Those notes became this article. An understandable description for players who want to better grasp how to get the tones they seek.

I will sometimes have to use words like capacitor and resistor, but only to identify where we are. You don't have to know how they work. It is however handy to know that:

A **high-pass** filter lets sounds above a set frequency through, and is formed by a **capacitor** followed by a **resistor**.

A **low-pass** filter lets sounds below a set frequency through, and is formed by a **resistor** followed by a **capacitor**.

I recommend opening the little circuit diagram in a new window to keep your bearings while reading. Unnervingly, if you see it enough it even begins to make sense. The diagram and the article describe the so-called FMV tone stack; the design used by Fender, Marshall, and Vox, and the hundreds who followed in their footsteps. Here's how it looks:



I've dispensed with off-putting things like component values that, as players rather than builders, we don't need to worry about, but the layout is complete, the real deal. It is called a stack because in an electrical diagram the sections sit on top of each other like this, incoming signal at the top, ground at the bottom.

TREBLE

The treble circuit is first in the tone stack. The signal comes in, hits the treble capacitor, then, in place of a single resistor to complete a high-pass filter, like a neat little component on a circuit board, it instead sees the combined resistance of all three pots – the Treble, Bass, and Middle pots – which lie in a row between the treble cap and ground. "The resistances of these three add up and can be thought of as a single resistor."*

A pot, the knob you turn on the front of the amp, is a variable resistor.

So, being at the top of the stack, the treble circuit has the longest journey in terms of resistance, which is resistance against losing stuff to ground. It sees resistance from the Treble pot, then the Bass pot, then the Mids pot, with ground at the end. So, quite aside from the effects these later pots, Bass and Mid, have on their own bits of the sound, their setting already affects the high-pass filter at the beginning, moving its cutoff point, that is, the point at which sounds are deemed high-frequency enough to be let through to the treble control; basically determining the range of what falls under 'treble.'

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Turning the treble control clockwise imposes the least attenuation of this high-end sound isolated by the high-pass filter made by the treble capacitor and the three pots. (It seems we can never *add* or *boost* in the tone stack. It's all about *resisting loss* to ground, like trying to keep water in a hole-ridden bucket. Carrying the bucket down the hill, you can't add more water, just try to stop too much getting out. So we resist loss as much as possible when a control is on *10*, and allow it as much as possible – "oh to hell with it, let it leak out!" – on *0*, turned fully counter-clockwise.)

Signals above the cutoff frequency pass "right through the [treble] capacitor to the top terminal"* of the treble pot. Turning it up, you're favoring the signal, the product of our high-pass filter, that's making it to that terminal. BUT. Turning it down doesn't simply drain more top end to ground, because off the bottom terminal of the treble pot the next controls are waiting: bass and mid. Over here, as the dial twists counter-clockwise, you're not just attenuating treble but choosing to listen more to bass and middle, shifting the amp's focus. Think of a flashlight beam; turning this control down is like sweeping the flashlight from right to left across a dark room. You thought the bright and pretty soprano on the right was the only one there – she was all you could see. Now as you pan left you find a baritone and a tenor standing in the corner. And they're singing.

So the treble control is not a simple more/less top-end knob, it's a balance control between the product of a high-pass filter (on the right of its dial) and the filter created downstream (left of the dial) by the next two controls in the stack: bass and mid. When the *Introduction to Tube Amplifier Theory* says in its short summary, my notes in brackets,

"[the treble] potentiometer acts as a balance between the output of a high-pass filter formed by C8 [the treble capacitor] and the three potentiometers [treble, bass, mid], and the output of the complex filter created by R11 [resistor behind bass and mid pots], C9 [bass pot cap], C10 [mid pot cap] and VR3 [bass knob] and VR4 [mid knob],"

that is what they're talking about. I had to read it about 25 times.

BASS

The bass control is the only one that acts mostly like it should, in a sensible, predictable way, at least when considered on its own, so let's be grateful to it. For the treble control, we made a high-pass filter in order to play with stuff up there in the zingy, sparkly ceiling of sound. For the bass we want the opposite, a low-pass filter, so we can play with stuff down in the low end. To make one of these you just put the components of a high-pass filter the other way around: resistor *then* capacitor. Presto. A low-pass filter.

This arrangement, resistor then cap, says "everything below this frequency point gets through." So, all available low end gets through. That's not controllable though, it's *everything*, no lower limit, and would sound like a boomy mess. Luckily, the arrangement that comes next, of that same cap *then* the bass knob – a variable resistor – makes a *high-pass* filter right afterwards.

Cap then resistor, high-pass; resistor then cap, low-pass, remember?

So you have a low-pass filter ("all bass this way, please") running into a high-pass filter ("okay, okay, not ALL bass, jeez.") Where the cutoff frequency steps in between the two, to sort the welcome from the unwelcome, varies with the setting of the bass knob. If the audible bass were a hump on a graph, turning the control up would move the left wall of the hump further left as the cutoff frequency descended, deeper toward the very boot soles of sound, letting increasingly low frequencies through. Turning it down would shift the left wall of the hump to the *right*, narrowing the hump, the range of bass that gets through.

Sadly, the bass control isn't *completely* normal, even though it's the most normal of the three. Treble has the longest journey in terms of resistance adding up to affect its filter, like we talked about, because it's first in the stack. Bass has the next longest; the resistance of both the bass pot *and* the mid pot, which is last in the stack, add together to be the 'resistor' in this high-pass filter (bass cap + bass, mid pots = filter.)

So again the setting of the mid pot, separately from the effect it will have directly on the mid range, teams up with the bass pot to determine how much resistance the high-pass filter in the bass circuit encounters, resistance against losing bass to ground.

You start to see how interactive this shit is.

Resistance Recap

- The resistance of the treble pot only affects the 'treble filter'.
- The resistance of the bass pot affects the 'bass filter' and the 'treble filter'.
- The resistance of the mid pot, last in the chain, affects all three.

MIDDLE

Here we are at the last control. Yes, on the front of the amp the middle control is in between the other two, but that's some well-meaning deception by the amp designers; electrically it's last, which becomes significant.

The mid circuit largely copies that of the bass: coming off the same resistor, in fact, it places its own capacitor to form another low-pass filter; then that capacitor and the mid pot, the 'variable resistor' here, form a high-pass filter. It's the same setup, except the high-pass filter starts way higher up in frequency, because mids are higher than bass, silly.

It'd be nice to think that, being last in the tone stack, the mid control made fabulous logical sense, what with there being no other pots after it to vary the resistance to ground like treble and bass have to put up with. But where would the fun be in that?

The output from the mid circuit's low- and high-pass filters is delivered to the wiper terminal, the central lug, of its control, the mids knob. You can see from the diagram that despite similarities this doesn't look identical to the bass portion of the circuit. The effect of this is that the mids knob does not raise and lower the cutoff frequencies of its high-pass filter as the bass control does, enlarging or shrinking its range. It acts instead on their amplitude, their 'volume'. This seems to make sense: if you don't like the mid voicing of an amp, at least one with this standard kind of tone stack, you can't alter it, only raise or lower how loud that predetermined mid voicing is. The mids are where they are. Okay. Understandable. People with a working concept of the tone stack sometimes talk about the mid control as a way to fill in the big valley missing from midrange frequency response created by the way the two other tone controls work. Patching an imperfect design.

The mid knob, in addition to its other duties, controls how loudly the entire signal leaves the tone stack.

Being last in the stack means this knob affects other things at the same time. The stack can be thought of as Treble, Bass, Middle, Ground. Middle is the last one before ground; its bottom lug is *connected* to ground. Turning it down, that is, turning its wiper towards ground, doesn't just send more and more mid range frequencies to their doom like a regular control, it shorts to ground the mid cap in its little high-pass filter, the cap feeding the pot at the wiper. Things start to collapse backwards from there. The mid cap was the one also creating a *low*-pass filter in partnership with an earlier resistor, which is now also being grounded out via their connection. And, oh dear, that resistor was shared, serving as the resistor in the *bass* circuit's low-pass filter too, so the bass is disappearing into ground as well. Treble is next, via it's inextricable relationship with these two… Soon few frequencies are left standing but scattered stragglers. The amp is noticeably quieter because almost every range of sound it makes is being diverted to ground, where signals are sent to die.

I like to think of this as scientific proof that if you aggressively scoop your mids you are confused by tone and trying to avoid as much of it as possible, a grounded mid pot not just reducing mids but eliminating much of the rest of the amp's sound.

But more importantly this explains why the mid control not only attenuates the mid frequencies, “it also attenuates the overall level of the output signal.”*

So: the mid knob, in addition to its other duties, controls how loudly the entire signal leaves the tone stack, before continuing its journey. This level holds sway of course over what happens next inside an amp, and so on and so on until you go mad or join the Metro forum. But the tone stack, isolated such as we have traveled it here, has at least begun to make sense. I hope.

THE CAVEAT AND THE ASTERISK

The reason I looked for a layman’s explanation of the tone stack is because I am a layman. With good reason you may now be pondering the apparent paradox in a man hoping to bring clarity to a subject he *doesn’t understand* by writing about it.

It’s true: I don’t understand physics or electrical circuits especially well. In the absence of a satisfying explanation of the subject I simply forced myself to look at the dryer literature until it made sense. Hours and hours with articles and diagrams. The wife was quite worried. However I have no training in these fields and extensive training in humility; if something’s not right here, I believe you. Just tell me what it is.

I’m just a picky musician who fiddles with tone a lot. The more I tweaked the controls, the more curious I became about their relationships, about what was going on back there. It certainly wasn’t as simple as each control independently adding or removing whatever the label said underneath. It appears as a strange knowledge gap when only amp-building electrical geniuses know this stuff, while we legions of guitar tone obsessives spend hours coaxing our results from controls we greatly misunderstand.

** Quotes from ‘Introduction to Tube Amplifier Theory’ by David Sorlien and Stephen Keller, a gem which, as the most-digestible of the not-very-digestible available literature on amplifier design, I learned much from, and encourage you to read should you seek a more technical understanding of the tone stack.*

Introduction to Tube Amplifier Theory, PDF.