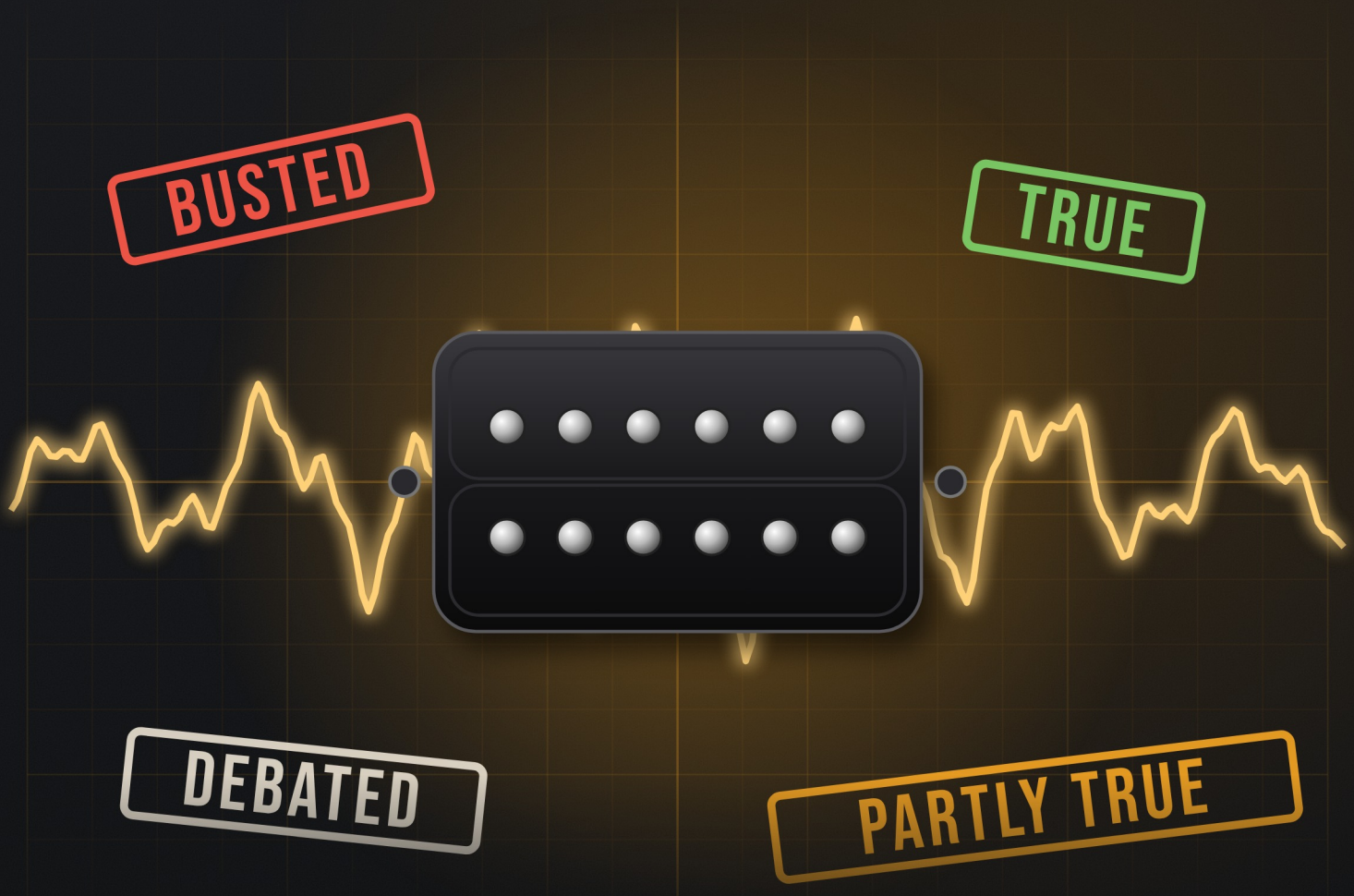
SECOND EDITION - ILLUSTRATED

TONE MYTHS VS. REAL EVIDENCE

CHASING TONE

GUITAR MYTHS PUT TO THE TEST

What the Science Really Says About Wood, Pickups, Strings, Amps, and Your Hands



WOOD | PICKUPS | STRINGS | AMPS | PEDALS | YOUR EARS

ANDREW DOMINGUEZ

FROM THE BENCH AT TRINFINITY GUITARS

TRINFINITY Enterprises

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Second Edition, Illustrated

Andrew Dominguez

Chasing Tone: Guitar Myths Put to the Test

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Introduction: Why Tone Myths Stick

I build and repair guitars, and my shop is Trinfinity Guitars. Spend any time behind a repair bench and you'll hear tone claims nonstop. Nitro lets a guitar breathe. Old wood sings. Higher resistance means a hotter pickup. A better cable opens up your amp. Swap the nut and the whole guitar wakes up.

I have worked on guitars for more than 20 years, and for about the last 4 I have built under the Trinfinity Guitars name. Over those years, players have brought guitars to my bench wanting parts swapped to fix a sound that really came from the setup or the amp. I wrote this book to save players money and frustration by separating real physics from marketing hype. Good tone starts with knowing what actually shapes the signal.

Some of those claims are right. Some are half right. A lot of them fall apart the moment you hide the gear and match the volume. This book is my attempt to sort them out with the best evidence I could find. For a handful of claims, that means a blind listening test on real guitars. Controlled listening tests on guitars are rare, though, so for most claims it means careful measurements and the physics of how a guitar works. Where that's all we have, I'll say so, and where a verdict rests on the physics and my own reading of it, I'll tell you that too. Either way, it's the evidence talking, not the loudest guy on the forum.

Before we get into wood, pickups, strings and amps, I want to show you how I'm going to judge each claim, and why so many shaky ones have survived for decades.

Why I wrote this book

I get asked about tone all the time at the bench. "Will this pickup fix my muddy neck position?" "Is a bone nut worth it?" "Should I hunt down an older guitar?" Players want straight answers, and they deserve them, because every one of those questions comes with a price tag attached.

That puts me in the middle. When a part swap will make a real difference, I want to tell you so. When it won't, I'd rather you keep your money for strings, a good setup, or a lesson. I can't do that if I just repeat what I've heard. So I went looking for what's actually been tested.

I build guitars, so I have a stake in this too. Builders like stories about magic wood and secret methods, because those stories sell guitars. I've tried to let the evidence lead even where it cuts against what my own trade likes to say.

Why tone myths spread

If so many tone claims are shaky, why does everybody believe them? It's not because guitar players are gullible. It's because the human ear is wired into a human brain, and the brain doesn't just record sound. It mixes what reaches your ears with what you expect to hear.

Your brain hears what it expects

The clearest proof I know of comes from the speaker world, not the guitar world. In 1994, Toole and Olive at Harman ran listening tests comparing what people heard with the speakers in plain view against what they

heard with the speakers hidden. According to Olive's own blog write-up of that work, 40 Harman employees rated four speakers of very different size and price, both sighted and blind [1]. When they could see the speakers, the company's own big, expensive models got a clear ratings boost. (Those two were built the same apart from their crossovers.) The small, inexpensive Harman speaker went the other way. With the speakers in view, it was rated below a large, expensive competitor's speaker. Blind, it was slightly preferred over that same speaker [1]. And real differences, like where the speaker sat in the room, showed up plainly in the blind test but almost disappeared when people could see what they were listening to [1].

Read that last part again. Seeing the gear didn't just add a fake difference. It also hid a real one. Expectation works in both directions.

Violins tell the same story. In a double-blind study published in 2012, 21 experienced violinists played three new violins against three famous old Italian ones, including two by Stradivari [2]. Only 8 of the 21 picked an old violin as the one they'd most like to take home, and the violin rejected most often was a Stradivari [2]. Take away the label and the legend, and the "old is better" edge went away. I'll come back to these studies in Chapter 13, and to old guitars in Chapter 5.

Sighted, unmatched comparisons fool everybody

Think about how most of us compare gear. We plug in pedal A, play a bit, plug in pedal B, play a bit more. We know which one is which. We play a little differently on each. And one of them is almost always a little louder than the other.

That last point matters more than most players realize. A slightly louder sound tends to seem fuller and clearer, and a small level difference is easy to miss as a level difference. So the louder option often wins, and the player walks away sure he heard a tone difference. Chapter 13 explains why your ears work that way and how to take loudness out of the contest.

Marketing loves a good story

Gear makers have every reason to tell you their product sounds better, and a good story sells better than a frequency chart. Words like "vintage-correct," "airy," "sweet" and "woody" point at a feeling, not a measurement. Price itself becomes part of the story. If a part costs a lot more, it must sound better, right?

Sometimes even the makers say so. Seymour Duncan, a pickup company, published an article on pickup resistance in which its vice president of engineering says the common belief (higher resistance means a louder, hotter pickup) isn't totally accurate, and that misinformation on the subject is rampant [3]. When a company that sells pickups tells you a pickup myth is wrong, it's worth paying attention.

Some tone claims are true

This is the part that makes myths so sticky. Plenty of tone claims are correct, and the true ones lend their credibility to the false ones sitting next to them.

Take guitar cables. A cable has *capacitance*, which is the ability to store a little electric charge, like a tiny reservoir. Manfred Zollner, who wrote a large book on the physics of the electric guitar, puts typical cable capacitance at about 100 pF per meter (pF, or picofarads, is a very small unit of capacitance) [4]. With a passive pickup (the ordinary kind, with no battery), that capacitance works together with the pickup's coil to set its *resonance*, a frequency where the circuit naturally rings and gives a small boost. More cable means

more capacitance, and that pulls the resonance lower and takes some sparkle off the top [4]. So "a long cable can dull your tone" is a real, measurable effect. You'll see it in Chapter 7.

Now a player who has heard that true claim about cables also hears that gold-plated, oxygen-free cables sound sweeter. Both claims are about cables. Both come from people who sound like they know their stuff. Why would one be true and the other not? That's exactly the kind of question this book is built to answer.

The kinds of evidence, strongest to weakest

Not all evidence is equal. When I weigh a tone claim, I sort what I've found into four rough tiers.

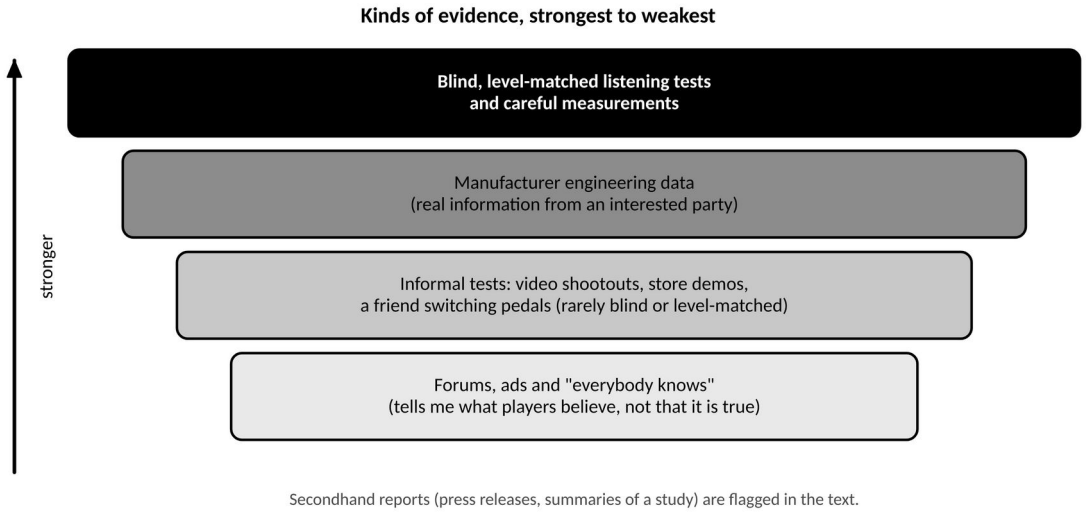


Figure I.1: The four tiers of evidence used in this book, strongest at the top.

Blind controlled tests and careful measurements

At the top are controlled listening tests where the listeners don't know what they're hearing and the volume is matched, plus careful lab measurements. A blind test answers the question players actually care about: can people hear it? A measurement answers a different question: is there a physical difference, and how big is it?

Measurements can cut through a lot of noise. Remember the resistance myth? Zollner compared a pickup reading 9.1 kOhm (thousands of ohms; ohms measure electrical resistance) with one reading 17.8 kOhm, and for the same string vibration the 9.1 kOhm pickup put out more voltage [5]. The number on the box said one thing; the measurement said another.

Both kinds of evidence have limits, and I'll point them out as we go. A measurement can show a difference that's far too small to hear. And a blind test that finds nothing only means those listeners didn't hear a difference under those conditions. It doesn't prove no difference exists. Controlled listening tests on guitars are also rare. Only a handful of the claims in this book have one behind them, so many of my verdicts rest on measurements and physics instead. A lot of the best listening research was done on violins, acoustic guitars and hi-fi speakers, not electric guitars. When I lean on research from a nearby field, I'll say so. One source comes up again and again: Manfred Zollner's book on the physics of the electric guitar. It's a large, careful body of measurements, but it's one person's work, so where a verdict leans only on him, keep that in mind.

Manufacturer engineering data

Next come the measurements and technical articles that gear companies publish. Much of it is honest, useful engineering. The Seymour Duncan article I just mentioned is a good example [3]. But a company that sells a product has a reason to frame its data in a friendly light, and it rarely publishes blind listening tests. I treat it as real information from an interested party.

Informal tests

Below that are informal tests: video shootouts, store demos, a buddy switching between two pedals while you listen. These can be fun and sometimes point at something real. But they're almost never blind, almost never level-matched, and the same person usually knows which option is which. That's the exact setup that let expectation fool those Harman listeners.

Forums, ads and "everybody knows"

At the bottom are forum threads, ad copy, and the stuff "everybody knows." These tell me what players believe, which is useful, because I need to know what claim I'm testing. They are not evidence that the claim is true. A thousand people repeating something doesn't make it more likely to be right. It just makes it louder.

A note on secondhand reports

Sometimes the best I could find was a press release, a blog post or a magazine summary of a study, rather than the study itself. When that's the case, I'll tell you in the text or in the source line. A press release written by a university to describe its own research is usually close to the mark, but it's still a summary, and summaries leave things out.

The verdict labels

Every myth in this book gets one of six verdicts, and only one. Sometimes I add a plain word after the label about what it means for you, but the label is the verdict.

- Busted: the claim has been tested and failed, or basic, well-measured physics rules it out.
- Mostly busted: the core of the claim is wrong, though a small real effect exists. I also use this label when the effect is real but the stated cause is wrong. If a magnet swap changes your sound because it changes the output level, not because of the magnet's "voice," the claim is Mostly busted. Right effect, wrong cause is always Mostly busted.
- Partly true: there's a real, measured effect, but it's smaller, narrower, or more conditional than the claim says.
- True: the claim is well supported. A large, well-measured electrical or physical effect can be True even without a listening test, and when a verdict rests on measurement like that, I'll say so in the text.
- Debated: real evidence points both ways, or the effect is measured and real but whether it's "better" is a matter of taste.
- No good evidence either way: nobody has tested it in a controlled way, and neither the measurements nor the physics settle it. When no test exists and the physics can't call it either, this is the label you'll see.

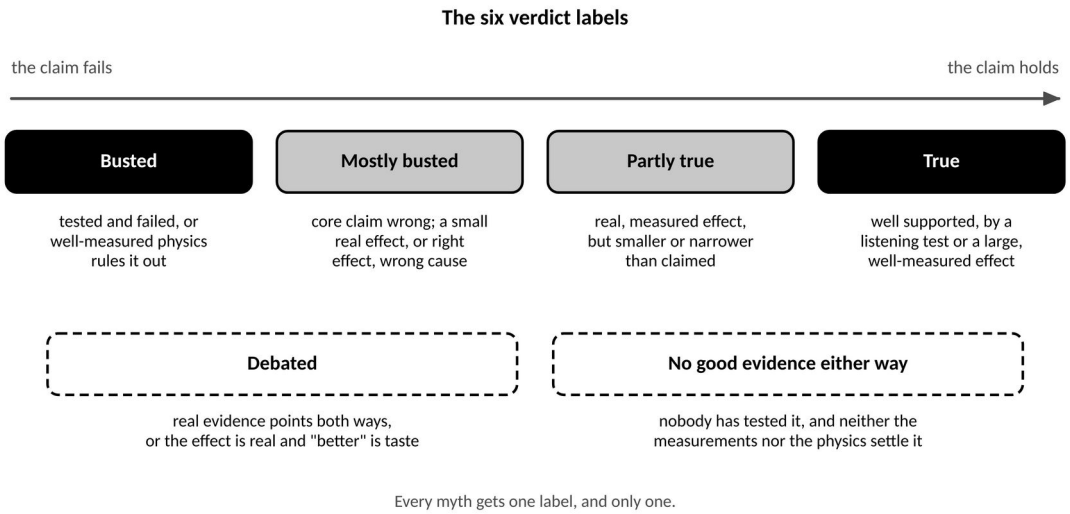


Figure I.2: The six verdict labels. Debated and No good evidence either way sit off the line because they say the evidence is split or missing.

A missing listening test doesn't automatically earn that label. Controlled listening tests on guitars are rare, so many verdicts rest on measurements and physics instead. If a measured change is far smaller than differences people are known to miss, or the physics shows the stated cause can't be doing the work, a claim can still be Busted or Mostly busted. If it's a big, well-measured shift in the sound, it can be True. Either way, the verdict and the evidence above it tell you what it rests on: a listening test, measurements, or the physics.

"No good evidence either way" comes up more than you might expect. It's not a cop-out. It's an honest answer. When nobody has run the test, the right response isn't "it must be true" or "it must be false." It's "we don't know yet."

You might ask, "So if a myth is busted, does that mean the gear is worthless?" Not at all. A part can look great, feel great in your hands, last longer, or make you want to play more. Those are real reasons to buy something. They just aren't the same as changing the sound coming out of your amp.

How each chapter works

Each chapter starts with a few paragraphs that set up the topic and explain any physics you need in plain words. I'll define hard terms when they come up, the Glossary at the back has short versions of the common ones, and there's no math beyond simple numbers.

Then, from Chapter 2 on, come the myths, one at a time, and each one follows the same layout.

- The claim: what players say, in a sentence or two.
- The evidence: what the research and measurements show, and what the physics says, with numbered citations.
- The verdict: one of the six labels above, with a short explanation of why.
- Try it yourself: where it makes sense, a simple way to test the claim at home.

If you want to run one of those home tests properly, read Chapter 13 first. It walks you through a fair blind test step by step: how to match volume, how to hide which option is which, how many tries you need, and how to tell whether your score beats lucky guessing.

Near the end of each chapter you'll find a short section called "What this means for your money." That's where I boil the verdicts down to plain advice on what's worth spending on and what isn't. Chapter 14 pulls all of those together into one priority list.

Every chapter ends with a numbered list of sources. (Chapter 14, which only draws the others together, is the exception.) The small bracketed numbers in the text point to that list, so you can check my work. I'd encourage you to. I've worked hard to stay inside what the research actually says, and where the evidence is thin or mixed, I'll tell you plainly instead of rounding up to a confident answer.

One more thing. This book is about tone, not upkeep. Cleaning, string changes, fret care and setup checks are covered in my book *Guitar Care and Maintenance*, so I won't repeat those steps here. And if you want the specs and numbers behind each part of an electric guitar, from frets to pickups to pots, my book *Inside the Electric Guitar* goes part by part.

That's the plan. One claim at a time, I'll show you what was tested, what wasn't, and what I'd do with my own money.

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Chapter 1: What Tone Really Is

Every tone argument I've ever heard at the bench comes back to one thing: a steel string moving back and forth. Wood, pickups, magnets, caps, cables, tubes and speakers all matter only because of what they do to that moving string, or to the signal that comes off it. If you understand the string, you can sort most tone claims into "makes sense" and "doesn't add up" before you ever spend a dime.

So before we put any myths to the test, I want to walk you through what happens in the second or two after you pick a note. I'll keep it plain. No equations, just simple numbers and a few new words, and I'll define each one as we go.

The short version goes like this. Your hand puts energy into the string. The string vibrates in many ways at once. Part of that energy leaks into the guitar, part turns into sound or signal, and the rest dies away as heat. Where you pluck, where the pickup sits and where the energy leaks out decide most of what you hear. The rest of the book is about the parts that come after.

More than 20 years of bench work has shown me how often a guitar sounds dull or harsh only because the setup is off. Once the neck relief, action and pickup height are set right, a player can feel like he is hearing a different guitar. Before chasing new gear, make sure the instrument you already own is set up right.

One string, many pitches at once

Pick your open low E and you hear one note. But the string isn't doing one thing. It's doing a whole stack of things at the same time.

The lowest and usually loudest of these is the *fundamental*. That's the whole string swinging back and forth in one big arc, and it's the pitch you'd name if someone asked what note you played. On top of that, the string also vibrates in two halves, in three thirds, in four quarters and so on. Each of those smaller vibrations makes its own higher pitch. These are called *harmonics* or *partials*. (Strictly, a harmonic is a partial that sits at an exact whole-number multiple of the fundamental. On a guitar the two words get used for the same thing, and I'll use both.)

The mix of partials, how loud each one is and how fast each one fades, is what we mean by *timbre*. Timbre is the reason a guitar and a piano playing the same note don't sound alike. When players say "tone," they mostly mean timbre.

Each of those vibration patterns has spots along the string that stay still. Those still spots are called *nodes*. The fundamental has nodes only at the two ends. The second partial, vibrating in halves, also has a node right in the middle at the 12th fret. The third partial has nodes at one third and two thirds of the string, and so on. Joe Wolfe's music acoustics pages at the University of New South Wales (UNSW) show the idea neatly: touch a string lightly at a point that splits it into equal parts and you mainly leave the vibrations that have a node there [1]. That's how you play a natural harmonic at the 12th fret.

Hold on to the idea of nodes. It explains a lot of what comes next.

Why a note changes as it rings

You might ask, "Why does a note sound bright right after I pick it and then go soft and round?" The high partials die first.

When you pluck, you pull the string into a sharp bend, a kink, and let go. Wolfe explains that those sharp kinks carry the high-frequency parts of the sound, and that those parts fade quickly. So a second or more after the pluck, the string has settled toward its lower vibrations and the note sounds mellower [1].

That fading is called *decay*. Every partial has its own decay rate. The bright attack, the body of the note and the mellow tail you hear as it rings out are really the partials dropping out one after another. Anything that changes how fast certain partials die (old strings, fret buzz, a neck that soaks up energy at one frequency) changes your tone. You'll see that idea in almost every chapter.

Inharmonicity, in one minute

I said the partials sit at whole-number multiples of the fundamental. That's the ideal string. A real string is a little stiff, and stiffness changes things.

Wolfe points out that a real string resists bending, and that this stiffness affects the higher partials more than the lower ones. The result is that the higher partials come out progressively sharp of where they "should" be. The effect is biggest on thick strings, especially thick plain ones, and on a plucked string nothing pulls the partials back into step (a violin bow does) [2]. That's called *inharmonicity*: the partials are not quite in perfect step with each other.

Manfred Zollner, whose book on the physics of the electric guitar I mentioned in the Introduction, gives an example. On a wound low E string, the 20th partial sits about 2.5% sharp [3]. That sounds like a lot, but his listening work found that a synthesized string with typical guitar inharmonicity was barely distinguishable from the real one, even on headphones [4]. He also notes that distortion can make even weak inharmonicity easier to hear, because the out-of-step partials mix and create new tones [4].

For most of us, inharmonicity is a small part of the story. It comes back in Chapter 8, where it matters for the scale length debate.

Where you pluck is a tone control

Now let's put nodes to work. A pluck can't start a vibration that needs to stand still at the exact spot you plucked. If you pluck right at the middle of the string, you can't excite the second partial, because the middle is that partial's node. You also knock out the fourth, the sixth and every other even one.

Traube and Smith describe this in a 2001 paper: in the ideal case, the sound lacks every harmonic that has a node at the pluck point [5]. Pluck at one fifth of the length and you lose every fifth partial. Engineers call this pattern a *comb filter*. Picture a hair comb laid over the list of partials: the teeth cut out evenly spaced ones and leave the rest.

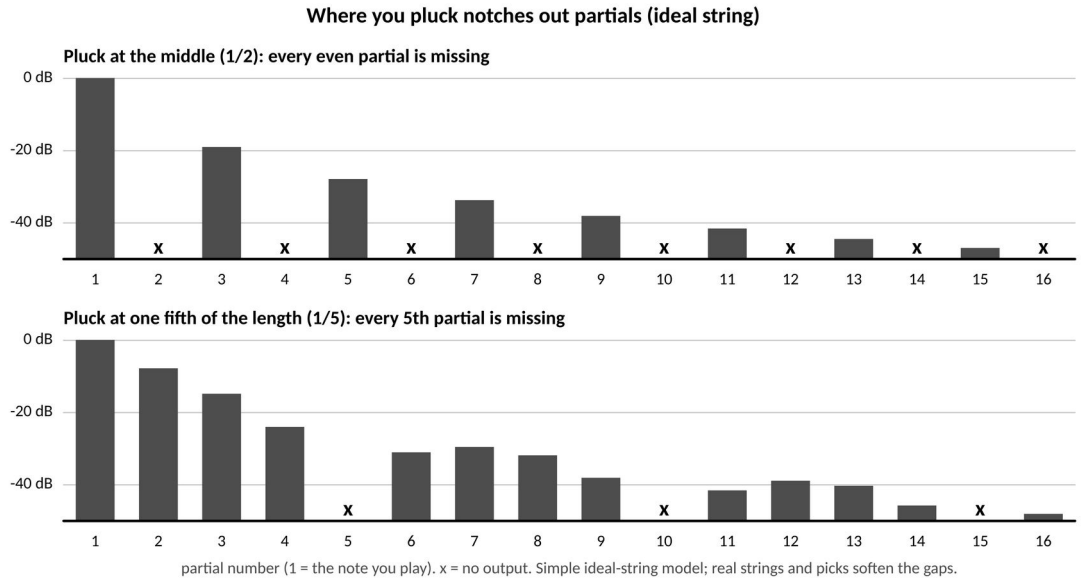


Figure 1.1: An ideal plucked string, figured from the simple textbook model. Plucking at 1/n of the length removes every nth partial. Real strings and picks soften the gaps, but the pattern is what Traube and Smith measured.

This is no small effect. Traube and Smith built a method that could find where a string had been plucked just from a recording. On the open A and D strings of a classical guitar, they located the pluck point within 1 cm across 18 plucks [5]. If you can find the pick position from the sound alone, the pick position is clearly stamped on the sound.

They also note that plucking close to the bridge gives a tone that is quieter, brighter and sharper [5]. That description comes from their experience, not from a listening test in that paper, but every guitarist knows it. Pick near the bridge and it snaps. Pick over the end of the neck and it goes round and sweet.

How far from the bridge do we normally pluck? Zollner gives typical pluck points of about 6-10 cm from the bridge [6]. Traube's later thesis on the classical guitar found that plucking position is the main gesture a player uses to change timbre, with a normal range of about 3-20 cm from the bridge [7]. Moving your hand a few centimeters changes which partials get notched out. That's a tone control you carry with you, and it costs nothing. Chapter 9 digs into what else your hands do.

Try it yourself: Play the same open string three times: once right next to the bridge, once halfway to the neck, and once over the last fret. Keep the same pick and the same force. You'll hear three different guitars.

The pickup listens from one spot

The pickup works on the same rule from the other end. A magnetic pickup hears the string at one place along its length. If a partial has a node right under the pickup, that spot isn't moving for that partial, so the pickup can't hear it.

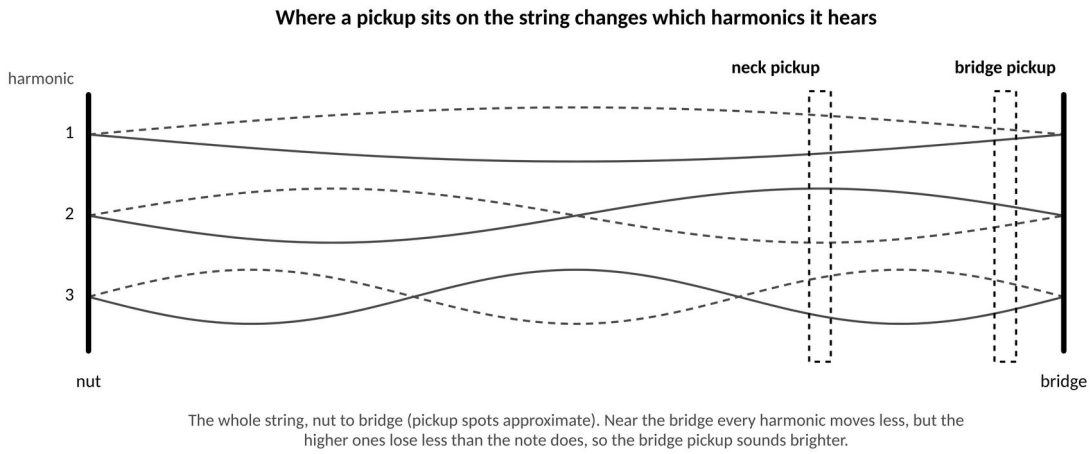


Figure 1.2: The first three harmonics on an open string, with the usual neck and bridge pickup spots. Each pickup hears a different mix of the same string.

Mohamad, Dixon and Harte described this in a 2017 conference paper. The pluck point is one comb filter on the string's partials, and the pickup position is a second comb filter stacked on top of it [8]. The effect is strong and predictable. Their method could work out where the pickup sat from the audio alone, with errors averaging about 3.28 mm for the pickup and about 7.05 mm for the pluck point across a range of amp effects, though the errors grew with heavy distortion [8].

So why is your neck pickup warm and your bridge pickup bright? Mostly because they're listening to the string at different spots. Near the bridge, the string's motion is small, but it is rich in the quick, short wiggles of the high partials. Out toward the neck, the big swings of the low partials dominate. Each pickup sees a different mix, and each position notches out a different set of partials. That's a large, measured cause of the neck and bridge pickup difference, and it has nothing to do with the wood under them.

I have a soft spot for this one, because it ends so many arguments. Two pickups of the exact same model, one at the neck and one at the bridge, sound very different. Same magnet, same wire, same guitar. The only thing that changed is where they listen.

What a magnetic pickup actually senses

Let's get specific about the pickup itself, because it doesn't work the way a microphone does.

A magnetic pickup is a permanent magnet with a coil of very fine wire wrapped around it, several thousand turns. The steel string sits in the magnet's field. When the string moves, it changes how much magnetic field passes through the coil, and that change makes a small voltage in the wire. Horton and Moore modeled this in a 2009 paper and found their model matched their measurements well, except very close to the magnet [9].

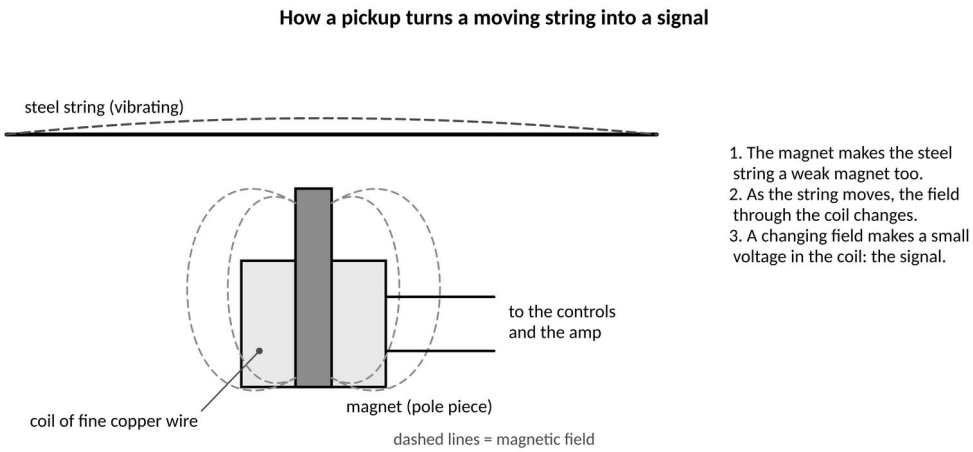


Figure 1.3: A magnetic pickup senses steel moving in its magnetic field. It does not hear the air or the wood.

Three things about that matter for tone.

First, the pickup cares mostly about up-and-down motion, meaning motion toward and away from the pole pieces. Horton and Moore found side-to-side motion makes a much smaller signal [9]. Paté, Le Carrou and Fabre found the same thing: the pickup signal followed the string's motion toward the pickup much more closely than its motion parallel to the top, and on their guitar the parallel motion was almost not picked up at all [10]. The direction you push the string when you pick changes how much of its motion the pickup ever hears.

Second, the pickup isn't a perfectly clean window. Horton and Moore found the output is not a pure copy of the string's motion, so the pickup itself adds some harmonics [9]. And the pickup doesn't hear a single point. Zollner describes a sensing "window" about 1 cm wide for a single coil, set by the magnet pole rather than the coil. A humbucker hears the string at two spots, about 18-19 mm apart on Gibson-style pickups, and that adds its own comb filtering, strongest on the low strings [11]. He also notes that output falls about 3 to 4 dB per millimeter as the string gets farther from the pickup [11]. (A *decibel*, or dB, is the usual unit for comparing loudness. The bigger the dB number, the bigger the difference.)

Third, the pickup doesn't steal energy from the string in any way Paté and his colleagues could measure. Their pickup added no measurable damping [10]. *Damping* means anything that soaks up vibration energy and makes a note die faster. (Very strong magnets set too close can pull on the string. That's a pickup height issue, and Chapter 6 covers it.)

One more big point. A magnetic pickup senses steel moving in a magnetic field. It does not sense the air, and it does not sense the wood. Whatever the body is doing, the pickup only hears it if it changes how the string moves.

The pickup is also a filter

There's one more stage before the signal even leaves your guitar. The pickup's coil is an electrical part with its own behavior. It has *inductance*, a coil's natural resistance to quick changes in current. Together with the small *capacitance* (the ability to store a little electric charge) of the coil and, much more, of your guitar cable, it forms a *resonance*: a frequency where the circuit rings and gives a boost.

Helmuth Lemme, in his long web article on pickups, puts that resonant peak at about 2,000-5,000 Hz for most pickups with a normal cable plugged in. (Hz, or hertz, means vibrations per second.) Above the peak, treble falls off. A lower peak sounds warmer and a higher one sounds brighter [12]. Zollner reports the same range, and notes that a Stratocaster pickup with nothing plugged into it resonates at about 9 kHz (kilohertz, or thousands of hertz) before the cable pulls it down [13].

So the pickup is really two filters in one. Its position on the string decides which partials it can hear. Its electrical resonance, set together with the cable and the controls, decides how much treble survives. Chapter 6 covers pickups and Chapter 7 covers the pots, caps and cable that shape that peak.

Where the string's energy goes

Now for the question behind half the myths in this book. When you pluck, the string holds a fixed amount of energy. Where does it go?

A string sits between two ends. On a fretted note, those ends are the fret and the saddle. If those ends were perfectly solid, the string would only lose energy to the air and to its own internal friction. But no support is perfectly solid. Each end moves a tiny bit, and every bit of motion lets energy leak out of the string and into the guitar.

Engineers measure how easily a support takes energy from the string. Paté's team called it *conductance*. A high number means the support moves easily and drains energy fast. A low number means the support stays put. On their test guitar, a solid-body built as a replica of a Les Paul Junior, the highest conductance they measured on the neck was roughly 60 times the highest at the bridge. Those are one guitar's peak values, not a rule for every guitar, but the bridge moved so little that they treated it as a rigid end [10]. Fleischer, working at the Bundeswehr University Munich, found the same pattern on a budget Strat-style guitar. Most readings at the bridge were tiny, and the few bridge peaks he did see came from the vibrato hardware rather than the wood. At the neck, the readings were much higher [14]. In an earlier study of six solid-body guitars, he found the neck moves much more than the bridge, and he treated the body as mostly a drain on the string's energy rather than a source of sound [15].

So on a solid-body electric, the neck is the soft end. Of the energy the string loses to the guitar, most goes out through the neck. That's not the same as saying the guitar is the main drain. Paté's team found that a string's own losses (air drag and friction inside the string itself) set how long most notes ring. The guitar takes a big bite mainly at notes that line up with a neck resonance [10].

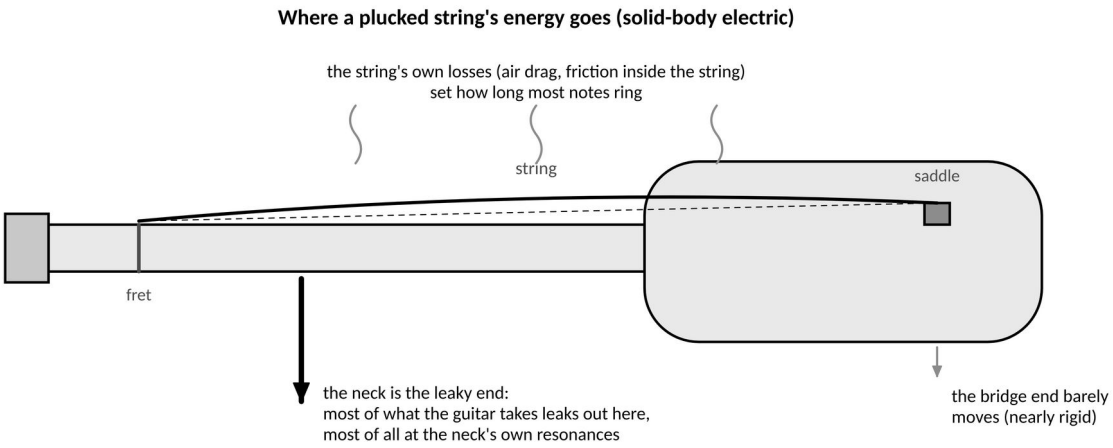


Figure 1.4: On a solid-body, the string's own losses set how long most notes ring. Of the energy the guitar takes, most leaks out through the neck (Paté and others; Fleischer).

This is also where *dead spots* come from. A *resonance* in this sense is a frequency where something naturally wants to vibrate, like a swing that goes highest when you push it at just the right rhythm. The neck is a long beam, and it has its own resonances. When a note you fret lines up with one of them, the neck starts swinging along and drains that note fast. Fleischer argued that dead spots come from resonances of the instrument (his example was a body resonance at 430 Hz), and made the point that the bridge of a solid-body is much less mobile than the neck [16]. Paté's team found a 12th-fret dead spot on their carefully made guitar where the note died more than 2 seconds faster than its neighbors [10]. Even on a different kind of guitar, the neck isn't a side issue. Rau and colleagues, in a 2017 conference paper, measured a hollow-body electric with a floating bridge and found that losses at the neck were comparable to those at the bridge at some frequencies [17].

Your body is part of this too. Le Carrou, Paté and Chomette found that the player's hands and body damp the guitar's vibrations and shift some of its resonant frequencies by less than 5% [18]. Your guitar on a stand and your guitar in your hands are not quite the same instrument.

We'll go deep on necks, joints and sustain in Chapter 3.

Acoustic versus solid-body: two different machines

If wood matters so much on an acoustic, why wouldn't it matter on an electric? It's a fair question, and the answer is that the two guitars are built to do opposite jobs.

An acoustic guitar is a machine for giving away the string's energy. Wolfe points out that the strings themselves radiate almost no sound, because they have too little area to push much air. The bridge carries the string's vibration into the top, which is light and springy (spruce about 2.5 mm thick). The top moves, and the top moving the air is the sound you hear. The back matters much less for most frequencies, and the sides barely flex at all [19]. The air inside the body has its own resonance too, and it couples with the top to strengthen the low end [19]. On an acoustic, the string has to hand energy to the top, or there's no sound. The top is the speaker. That's why top wood and bracing matter so much, and Chapter 4 covers acoustics in depth.

A solid-body is close to the opposite. The bridge sits on a heavy, stiff slab that barely moves at string frequencies [10, 14]. The body isn't supposed to radiate much at all. What you hear through the amp comes from the string's motion over the pickup. The body and neck can only change that sound indirectly, by

draining energy from the string at the frequencies where they do move, and on a solid-body that happens mostly at the neck [10, 15].

That doesn't mean the body does nothing. It means the body works through a much narrower door. Whether that door is wide enough to hear is the subject of Chapter 2.

Tracing the signal chain

Let's zoom out. Every note you play passes through a chain of links, and each one can change the sound. Here's the whole trip, from your brain to your brain, and where each link lives in this book.

- Your hands. Where you pluck, how hard, at what angle and with what (flesh, nail or pick) set the starting mix of partials. Chapter 9.
- The string. Gauge, material, age and scale length decide how the string stores and loses energy, and what the pickup can sense. Chapter 8.
- The guitar. Body wood, neck, joint, nut, hardware and finish decide where energy leaks out of the string. Chapters 2, 3 and 5 cover electrics; Chapter 4 covers acoustics, where the wood is the speaker.
- The pickup. Its position, height, magnet and coil decide what it hears and how it colors it. Chapter 6.
- The circuit and cable. Volume and tone pots, tone caps and the capacitance of your cable shape the pickup's resonant peak. Lemme puts typical cable capacitance at about 300-1,000 pF for a whole cable (at roughly 100 pF per meter, that's a 3-10 m cable), which is a lot next to the pickup's own winding [12]. Chapter 7.
- Pedals. Buffers, true bypass, and the boxes that change the sound on purpose. Chapter 12.
- The amp. Tubes, transistors and modelers, and how hard the guitar drives them. Chapter 10.
- The speaker and cabinet. The speaker has its own frequency range and its own character, and it shapes everything before it. Chapter 11.
- The room. Walls, floors and where you stand shape what reaches you. Also Chapter 11.
- Your ears and brain. Loudness, expectation and what you just paid for all shape what you think you hear. Chapter 13.

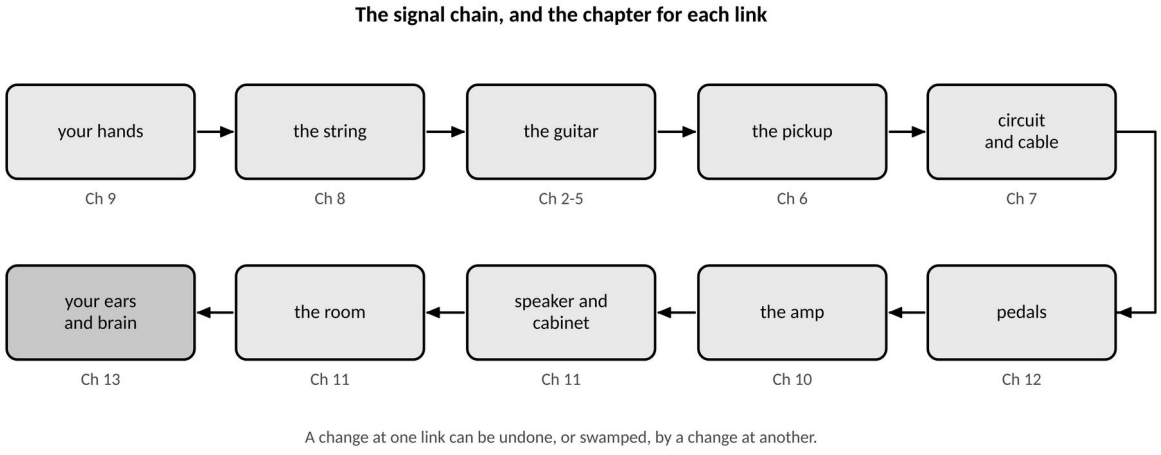


Figure 1.5: Every link in the chain can change the sound. The chapter that covers each link is shown under it.

Chapter 14 pulls it all together into a list of where your tone money does the most good.

Notice something about that list. A change at one link can be undone, or swamped, by a change at another. A darker pickup can be offset by a brighter speaker. A small difference in output can be matched with the volume knob. When someone says a part "transformed" their tone, the first question I ask is what else changed at the same time.

Why this matters before the myths

Most tone myths fail in one of two ways. Some put the cause in the wrong link of the chain, like crediting the body wood for a difference that really comes from pickup position. Others are true in principle but too small to hear next to the big movers, like the stiffness of a string bending its upper partials a little sharp.

Keep the big movers in mind as you read. Pick position and pickup position are strong, measured comb filters [5, 8]. The pickup's resonance, set with the cable and controls, decides how much treble survives [12, 13]. And on a solid-body, the string's own losses set how long most notes ring, while the neck, not the bridge, is where it loses most of the energy that goes into the guitar [10, 14]. When a claim lines up with those, it has a real shot. When it doesn't, it needs better evidence than a product page.

What this means for your money

The cheapest tone controls you own are free. Moving your picking hand toward the bridge or toward the neck changes which partials you hear more than many upgrades will. Switching pickups changes which spot on the string you're listening to, which is a big part of why positions sound so different.

On an electric, the parts that touch the signal directly (strings, pickups, the circuit, the amp and the speaker) have a direct path to your ears. The wood has only an indirect one. On an acoustic, it's the other way around: the top is the sound. Keep that difference in mind before you pay extra for a wood upgrade on a solid-body.

Before you buy anything, figure out which link of the chain you're unhappy with. A dull guitar might need fresh strings or a shorter cable more than new pickups. A harsh one might need a different speaker more than a new guitar. The chapters ahead will help you tell the difference.

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Chapter 2: The Wood Under the Pickups

Walk into any guitar store and you will hear it before long. Alder is warm, ash is snappy and bright, mahogany is warm in the mids, maple is punchy and bright. This isn't only forum talk. Fender's own support page describes its body woods in just those terms [1]. In 2025, PRS started a video series on Paul Reed Smith's "Rules of Tone," and the first episode was about wood [2]. When the biggest makers in the business say wood shapes your sound, it's no surprise that players believe it.

I build guitars, and I love wood. I love how a good piece of maple looks under a clear coat, and I love a light body that doesn't wreck my shoulder by the end of the night. So I'm not here to tell you wood is boring. I'm here to answer a narrower question: how much does the wood under the pickups change the sound that comes out of your amp?

The short answer comes first. On a solid-body electric, the pickup hears the string, not the body. Wood can only change the sound by changing how the string vibrates, and on a solid-body that path is small. The research on this is real but thin. The best lab studies used somewhere between one and six guitars, and a couple of the tests people quote online weren't real guitars at all. I'll show you what was measured and where it runs out.

Why a solid-body is not an acoustic guitar

In Chapter 1 we saw that a plucked string vibrates at its main note and a whole stack of higher notes, called *harmonics*, all at the same time. We also saw that where you pick and where the pickup sits each cut certain harmonics out in a predictable pattern, an effect called *comb filtering*. Researchers can measure that pattern so clearly that they can work out the pickup's position from a recording alone [3]. That is a big part of why a neck pickup sounds round and a bridge pickup sounds bright. Keep it in mind, because it has nothing to do with wood.

Now think about how an acoustic guitar works. Its bridge and top are built to move. The top is the speaker. The string has to hand its energy over to the top, or you'd hear almost nothing. That's why wood matters so much on an acoustic, and we'll get to that in Chapter 4.

A solid-body works the other way around. The bridge sits on a heavy, stiff slab that barely moves at the frequencies a string plays. The magnetic pickup reads the motion of the steel string directly. Whatever the body is doing, that motion is not what goes down the cable to your amp.

So how could the body wood matter at all? Only one way. Wherever the parts holding the string's ends move, they soak up a little of the string's energy. Scientists call that soaking up *damping*. If a support drains energy from one harmonic, that harmonic dies away sooner, and the tone changes a little over the life of the note. That's the only door the wood has into your sound. The real question is how wide that door is.

To measure it, researchers use something called *driving-point conductance*. Hard name, simple idea: shake a spot on the guitar at a certain frequency and see how easily it moves. A spot that moves easily takes energy from the string. A spot that barely moves hands almost all of it back.

Paté, Le Carrou and Fabre, a research team in Paris, measured this on a solid-body test guitar [4]. The highest readings at the neck were far higher than the highest at the bridge (Chapter 1 gives the numbers). In plain words, the neck end of the string is the leaky end, and the bridge end barely gives.

Fleischer, at the Bundeswehr University Munich, found the same pattern on a budget Squier Bullet Strat-style guitar with a bolt-on neck [5]. Most of his readings at the bridge were tiny, below 0.002 s/kg (the unit doesn't matter here, only the comparison). A few larger readings, up to about 0.01 s/kg around 568-650 Hz (*hertz*, or vibrations per second), came from the vibrato bridge hardware, not the wood. The body itself showed only a weak bump around 900 Hz. Over at the nut end of the neck, readings reached 0.026 s/kg near 170 and 210 Hz. His report makes the point directly: on an acoustic the bridge is the end that gives, but on a solid-body it's usually the neck.

Years earlier, Fleischer measured six solid-body guitars held in playing position, using laser vibrometry, a way of measuring tiny vibrations with a laser beam so nothing touches the guitar [6]. The neck moved much more than the bridge. He treated the body as mostly parasitic. Its motion doesn't add anything to the sound; it only drains energy from the string.

You might ask, "So why does my Les Paul sound so different from my Strat?" Because almost everything else is different too. Different pickups, sitting at different spots under the string, at different heights. Those act on the signal far more strongly than the wood does. We'll spend all of Chapter 6 on pickups.

Myth: Alder is warm, ash is bright, mahogany is warm in the mids

> **The claim:** *The body wood sets a solid-body's basic voice. Alder is full and warm, ash is snappy and bright, mahogany is warm in the mids, and maple is bright [1].*

Let's start with what's true. Different woods really are different materials. Zorič, Kaljun, Zveplan and Straže tested walnut and ash body blanks, which are just slabs of wood with no guitar built from them [7]. The ash was heavier, at 807 kg per cubic meter against 623 for the walnut. It was also stiffer. Its first bending mode, the lowest frequency at which the blank naturally flexes like a diving board, sat at 923 Hz against 748 Hz for walnut. Its internal damping was a little lower too (0.008 against 0.011 on their damping scale). Ash came out ahead only in that lowest mode. Walnut was lighter, more even in structure and less damped at higher modes, and the authors actually judged walnut the better choice for a solid body [7].

So ash and walnut aren't the same stuff. No argument there. But notice what this study didn't do. It built no guitars, recorded no notes and plugged nothing into an amp. It tells you about wood blanks.

The same group took the next step a couple of years later. Ray, Kaljun and Straže built two guitars that matched in every way except the body: one ash, one walnut, with the same bolt-on neck (a commercial composite neck with a maple fingerboard) and the same electronics [8]. The bodies were cut to a basic shape from same-size blanks, not full production bodies. They set each guitar on elastic supports, had an experienced guitarist pluck every open string six times by hand with a pick, and measured how quickly each note died away.

How long the main note of each string lasted did not differ in any significant way between the two bodies. Some higher harmonics on the two lowest strings did last longer on the ash guitar: on the low E from the 2nd harmonic up, and on the A from the 3rd harmonic up. On the G, B and high E strings the differences were minor. The ash body had lower damping than the walnut (0.093 against 0.121). The authors concluded that, under their test conditions, the stiffer ash came out ahead.

So the ash guitar did measure differently. Now look at how much is riding on it. It's two guitars, one body of each wood, so we can't tell whether it's about ash versus walnut or about this piece of ash versus that piece of walnut. Nobody listened to the recordings to see if a person could hear the difference. And the effect showed up as some upper harmonics on the low strings hanging on a bit longer, not as an overall bright or warm voice. If anything, that leans the same way as the "ash is brighter" story, but it's one body of each wood, on elastic supports rather than in someone's hands, and nobody listened.

Compare that with the things we know move your tone a lot. Pick near the bridge, then near the neck, and whole groups of harmonics come and go [3]. Raise or lower a pickup, or swap one, and the change is easy to hear. Next to those, a small shift in how long some harmonics last on two strings is a whisper.

What would settle the question? Several bodies of each wood, built into real guitars that are otherwise identical, played through an amp, with listeners who can't see which guitar is which. In the research I've seen, nobody has done that test on body wood. The physics says the effect should be small, and the one measurement on matched real guitars agrees.

Verdict: Mostly busted. Wood species really are different materials, and on matched guitars that showed up as small changes in how long some harmonics last on the low strings. No controlled test on real, matched guitars has shown you can hear a species signature like "alder warm, ash bright."

Try it yourself: Play one open chord picking right next to the bridge, then over the end of the neck. That change comes from pick position alone, and it is far bigger than anything a wood swap has been shown to do.

Myth: Blind listening tests prove you can hear the wood

> **The claim:** *There's a study where listeners picked out tonewood differences 91.7% of the time, so the case is closed.*

This one comes up a lot, so let's look at what that study actually did. Jasinski, Oleś, Tokarczyk and Pluta wanted to know if tonewood is audible on an electric guitar [9]. They didn't use guitars. They used rectangular planks of four materials: sapele, pine, plywood and rosewood. Each plank got the same hardtail bridge, the same kind of nut, a single tuner, a humbucker and a single-coil pickup. There was no separate neck and no neck joint. Fresh strings went on for each test, and a machine did the plucking, 10 plucks per string so every pluck was the same.

The planks did sound different on paper. Harmonic levels varied by up to about 5 dB between materials. Then they ran a listening test where people heard a reference sound and had to pick which of the next sounds matched it. The authors themselves describe this test as informal. It ran remotely, with 67 listeners using their own headphones at home. On average, listeners got 91.7% right. Even the hardest pair, plywood against rosewood, came in at 76.3%. The authors concluded that the wood used in an electric guitar can affect its sound. One thing the paper doesn't say is whether the clips were matched in loudness, and the woods changed the overall output level a lot. Some listeners may have been picking out a level difference rather than a tone difference.

So that sounds like case closed, right? Not quite. Remember what we just covered. On a real solid-body, the neck is the leaky end of the string, and the bridge end barely moves. On a plank with no neck, the string's other end sits right on the wood itself. That puts the wood in a much bigger role than it has on a real guitar. Also, there was one plank per material. Nobody tested two pieces of pine against each other, so we can't tell if listeners were hearing "pine versus rosewood" or just "this plank versus that plank."

What the study does show is worth something. When the wood is the main thing holding the string, people can hear the difference. That's a fair result. It just doesn't tell you what happens in a Strat or a Les Paul, where the bridge sits on a stiff body and a neck is doing most of the moving.

The one listening study that did use real, matched guitars looked at fretboards, not bodies. We'll get to it at the end of this chapter, and its results were mixed.

Verdict: Mostly busted. Listeners clearly heard differences between planks of different woods, so something real was there. But neckless planks are not guitars, the test was informal by the authors' own description, the clips may not have been level-matched, and one plank per material can't separate the species from the single piece of wood. It doesn't close the case for real guitars.

Myth: Wood makes no difference you'd notice

> **The claim:** *Somebody stripped a guitar all the way down to a string stretched over a pickup, and it sounded the same as the real guitar. So on an electric, the wood makes no difference you'd notice.*

You've probably seen this one if you spend any time on guitar YouTube. In early 2022, Jim Lill posted a video comparing a series of builds against his Tom Anderson T-style guitar [10]. He started with a cheap partscaster and tried swapping parts like pickups, neck joints and saddles. Then he built a 2×4 "guitar," and finally strung six strings between a bench and a shelf, keeping the same pickup, pickup height and angle as the real guitar. According to Guitar World's write-up, the real guitar and the bare-string rig sounded almost the same [10].

I like that video. It makes people stop and think, and that's always good. But it's an informal test. Nothing in the coverage points to a blind test, there was no listening panel, and there were no statistics. One person, one pickup, one set of recordings. It's a strong demonstration of how much of the sound comes from the string and the pickup. It's not a measurement of how much is left over.

On the other side, we have the Ray study from the last section. It found real, measurable differences in how long some harmonics lasted on two otherwise matched guitars with different bodies [8]. That's not zero. Wood changes stiffness, weight and internal damping, and those are real material differences [7]. The physics says those differences can reach the string, just not by much.

There are also places nobody has tested. A very light, thin or chambered body might move more than a solid slab. A loud, high-gain amp can make the guitar body and strings feed back with the speaker, and the body's *resonances* (the frequencies where it naturally likes to vibrate) might play a bigger role there. I didn't find any study on either one. So I can't tell you they matter, and I can't tell you they don't.

Verdict: Partly true. In practice the body's share of the amplified sound is small, and the most famous demo of that is informal but makes the point well. But "no difference you'd notice" goes past the evidence as a rule: small differences have been measured, and some situations have never been tested.

Myth: Rosewood boards are warm, maple boards are bright

> **The claim:** *A maple fretboard gives you a bright, snappy tone, and rosewood gives you a warm one.*

This idea shows up in store guides and in just about every forum thread where somebody asks which board to get. Here we're in luck. Of the electric-guitar wood questions, this is the one where a research team ran a formal listening test on matched, real guitars.

Paté, Le Carrou, Navarret, Dubois and Fabre had six guitars built to match, apart from the fretboard: three with ebony boards and three with rosewood [11]. No maple boards were in the study. They ran two tests. In the first, guitarists listened to recordings and sorted them into groups that sounded alike. The guitarists did hear differences between individual guitars. But when the researchers looked at the groups, they did not split into ebony and rosewood. Whatever the listeners were hearing, it wasn't the board wood.

In the second test, guitarists played the guitars and talked about them freely. This time their descriptions did separate the two woods. The main difference was in what players called precision, meaning how clear and separate the notes sound. Attack and balance played smaller roles. The ebony boards came out ahead on precision, and the rosewood guitars were linked to a warmer sound where the notes blend together more [11]. This second test was run in dim light so the players couldn't see which board was which, and none of them noticed the color difference. But they could still feel the boards under their fingers, so touch was part of the picture. Only four of the six guitars were used in it, because two had necks shaped too differently.

So what could a fretboard actually do? The board is glued to the neck. That means it changes the neck's stiffness and weight. As we saw earlier, the neck is the main route by which a solid-body drains energy from the string [4]. A neck has its own resonances, frequencies where it naturally likes to flex. Change its stiffness and weight, and those frequencies move. When a note lines up with a neck resonance, that note dies faster. We call that a dead spot, and we'll dig into it in Chapter 3.

Put that together and the picture changes. Swapping a board could change *which notes* die early. That's a real thing. What it doesn't give you is a general bright or warm filter over everything you play. Nobody has directly measured a board swap moving a dead spot. That's the mechanism the physics points to, not a tested result.

There's another catch with casual comparisons. A Fender-style maple board often comes as a one-piece maple neck with finish on the playing surface. A rosewood board is a separate piece glued on top. Those necks are built differently, so when someone compares a maple-board Strat to a rosewood-board Strat, they're comparing more than the fretboard wood. They also feel different under your hand, which may explain some of what players report.

This study is one research team, six guitars (four in the playing test), ten professional players and no maple at all. It's the best test anyone has run on fretboard wood, and its blind listening part didn't back up a warm-or-bright story, but it can't speak to maple directly.

Verdict: No good evidence either way. The one controlled study compared ebony and rosewood, not maple. In blind listening, people heard differences between guitars but couldn't group them by board wood. When players played the guitars with the boards hidden from sight but not from touch, they did describe rosewood as warmer. Nobody has tested maple against rosewood on matched guitars, and the physics only says a board may shift which notes decay faster.

Try it yourself: Record the same short part on two of your guitars with different boards, have a friend rename the files, and see if you can sort them. Remember the guitars differ in more than the board, so even a correct guess doesn't prove it was the wood.

Where wood might still matter

I don't want you leaving this chapter thinking a guitar is just strings and a pickup on a stick. Wood matters to how a guitar feels in your hands and how it looks. Those are real reasons to choose one wood over another.

For sound, the evidence points to the neck more than the body. Of the energy a string loses to a solid-body guitar, most goes out through the neck [4, 5]. So neck wood, the neck's build and the joint likely matter more than the body. That's what Chapter 3 is about.

And some questions are still open. Nobody has tested several bodies of each species to separate the wood type from the single piece. Nobody has run a blind test of body wood with real, matched solid-body guitars through an amp. Light, thin and chambered bodies, and loud high-gain rigs, haven't been studied for this. If someone runs those tests, I'll happily update this chapter.

What this means for your money

Don't pay extra for a body wood because of how it's supposed to sound. Pay for it because you like the weight or the look. Those are good reasons, and they're real.

If you want to change your tone, start with the things that clearly move it. Your pick position. Your pickups and how high they sit. Those make changes you can hear from across the room, and Chapter 6 covers the pickup side in detail.

When you try a guitar in a store, play every note up the neck on each string and listen for notes that die early. That tells you more about the guitar than the wood on the spec sheet.

Same goes for fretboards. Pick the one you like to look at and like the feel of under your fingers. That's a perfectly good reason, and it's the one the evidence actually supports.

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Chapter 3: Necks, Joints, Nuts, and Hardware

Sustain is one of those words every guitar player uses and almost nobody defines. We all know what we mean, though. You hit a note, and you want it to hang there and sing instead of dying out like a wet firecracker. Sellers know we want that, so sustain gets pinned on all kinds of parts: neck-through construction, a heavy brass block, a bone nut, a big chunky bridge.

In Chapter 2 we found that the body of a solid-body electric is a pretty minor player in the sound. This chapter is about where the rest of the action is. For most notes, the string's own losses (air drag and friction inside the string itself) decide how long the note lasts. Where the guitar does take a big share, it's at the neck, and mostly at notes that line up with a neck resonance. Once you see that, a lot of sustain claims start to look different.

I'll take the usual suspects one at a time. Same warning as last chapter: the best lab work here studied a small number of guitars, sometimes just one. That's enough to show how things work. It's not enough to settle every argument, and I'll tell you where the gaps are.

The neck is where the guitar's share leaks out

Here's a quick refresher. In Chapter 1 we saw that a string vibrates at its main note and a stack of higher notes, called *harmonics*, all at once. In Chapters 1 and 2 we saw that a string only loses energy in a few ways: through its own losses, and through whatever holds its two ends. On the solid-body the Paris team studied, the string's own losses set how long most notes rang [1]. If a support moves, it soaks up some of the string's energy. That soaking up is called *damping*, and *sustain* is just how long a note lasts before it fades out.

Researchers measure how much a support moves with a number called *driving-point conductance*. Shake a spot at a certain frequency and see how easily it moves. A high number means that spot drains energy from the string. A low number means it hands the energy back.

Paté, Le Carrou and Fabre measured this on a solid-body guitar in Paris. The highest readings at the neck were far above the highest at the bridge, and the bridge moved so little that they treated it as a rigid end [1]. That guitar was measured resting on straps, not in someone's hands. Fleischer measured six solid-body guitars with a laser vibrometer (Chapter 2). The neck moved much more than the bridge [2]. On a Squier Bullet Strat-style guitar, most of his bridge readings were more than ten times smaller than his highest readings at the nut end of the neck [3]. Chapter 2 has his numbers.

Why does the neck move so much? Think of it as a long, thin beam held at one end by the body and loaded at the other end with a headstock full of tuners. Like any beam, it has *resonances*, which are frequencies where it naturally likes to swing back and forth. When a note, or one of its strong low harmonics, matches one of those frequencies, the neck starts swinging along with the string. That pulls energy out of the string fast, and the note dies early.

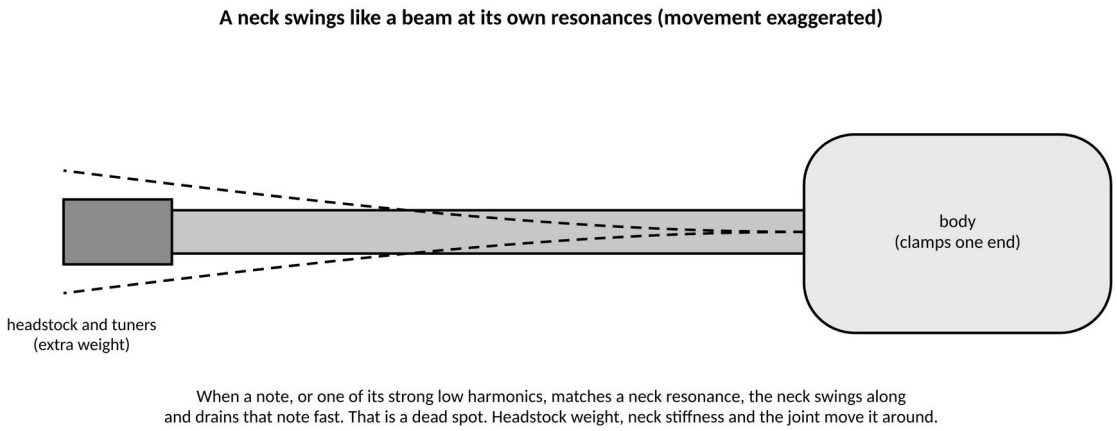


Figure 3.1: The neck acts like a beam clamped at the body with a weight on the far end. Its resonances are where dead spots come from.

There's one more piece that surprises people. You are part of the guitar. Le Carrou, Paté and Chomette studied what happens to an electric guitar when a player holds it [4]. The player's hands and body added damping to the guitar's own vibrations and shifted the frequencies of the lowest neck and body motions slightly, by less than 5% for the first two. How much depended on where the fretting hand sat relative to the way the neck was flexing. So the same guitar can behave a little differently depending on how you hold it. Oddly, the same team's model predicted that notes would ring a bit longer with a player holding the guitar than with it hanging free [4].

Keep this picture in mind for the rest of the chapter. The string's own losses set the pace for most notes. Of the energy the guitar does take, the bridge end is close to a brick wall and the neck end is the leaky end, leaking most at its own resonances.

Myth: Neck-through and set necks sustain longer than bolt-ons

> **The claim:** *Neck-through guitars sustain best, glued-in set necks come next, and bolt-on necks sustain the least because the joint is a weak link.*

This is close to gospel in guitar circles. R.M. Mottola, who writes on lutherie, describes it as conventional wisdom on his page about the subject, and he notes he couldn't find any formal research on it before his own [5]. So he ran a test, and it's a clever one [6].

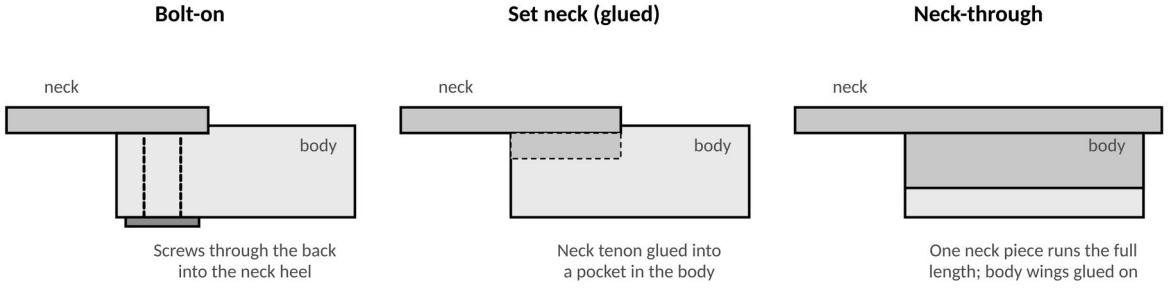


Figure 3.2: The three common ways a neck joins the body, seen from the side.

He built one purpose-made test instrument, a two-string solid-body "guitar analog" with a single pickup, as a neck-through. He tested it. Then he sawed the neck off and bolted it back on, and tested it again, both with and without a spacer in the joint. Finally he glued the neck in, like a set neck, and tested it once more. Same instrument throughout. Only the joint changed.

To make every pluck the same, he used a breaking-wire method: a thin wire pulls the string sideways until the wire snaps, so the string gets released the same way each time. Each pluck was made at 18.5 inches from the nut, with 15 recordings per string for each version of the guitar. He defined sustain as the time it took the note to drop by 21 dB.

Here are his average results, in seconds, for the high E and then the low E string:

- Neck-through: 2.82 and 12.13
- Bolt-on, no spacer: 3.35 and 15.80
- Bolt-on, with spacer: 3.58 and 17.08
- Glued in: 3.42 and 14.01

Look at that order. The neck-through came in last on both strings. The bolt-on, the supposed weak link, sustained longest. That is the exact opposite of the myth.

Then he played the recordings for five listeners. They could not reliably tell which version sustained longer. They could pick out the bolt-on as the loudest, but sustain differences didn't come through.

Now the limits. This is one simple two-string test rig, not a production guitar, and the versions were made in order, neck-through first. That means some of the change could come from the order itself rather than the joint. He didn't report statistical tests, so we can't say how solid the differences are. American Lutherie is a builders' journal, not an academic one, and five listeners is a small panel. Mottola himself calls the study limited in scope. He says he repeated the experiment on three instruments, but those results aren't shown.

Does any other research help? Fleischer suggested that a bolted joint probably adds more damping than a glued one [2]. But that's his hypothesis, not a sustain measurement. Meanwhile his dead-spot work on electric basses found high neck conductance on bolted and glued necks alike [7]. Neither joint type got a free pass.

From the physics, I'd put it this way. The joint changes the neck's stiffness and its resonances a bit. That moves *where* the energy leaks happen more than it changes how much sustain the guitar has overall. A tight, well-fitted bolt-on joint is not a leak in itself. A loose or sloppy joint of any type could plausibly add damping, but nobody I found has tested that.

Verdict: Mostly busted. The only controlled test, on a purpose-built two-string test instrument, found the opposite of the claim: the bolt-on sustained longest, and listeners couldn't hear a sustain difference. One simple rig can't settle it for every real guitar, but nothing supports the claimed ranking, and the physics says a well-fitted joint mostly moves the neck's resonances rather than adding a leak. In the end, set neck, neck-through or bolt-on comes down to player preference.

Myth: More mass means more sustain

> **The claim:** *A heavier bridge, a brass sustain block or a heavy body will make notes ring longer.*

Every Strat owner has seen the ads for brass blocks. The idea makes sense on its face. Heavy things are harder to shake, so a heavy bridge should hold the string's end still and keep the energy in the string.

And that part of the physics is right. A string loses energy wherever its supports move. Add mass at the bridge, and the bridge moves less. Less movement means less energy lost on that side.

But remember the start of this chapter. For most notes, the string's own losses set how long it rings. Of the energy the guitar takes, the bridge side is already the quiet end: the Paris team found their bridge so stiff they treated it as rigid [1], and Fleischer's bridge readings were tiny next to his neck readings [3]. So adding mass at the bridge lowers a loss that was already small next to the others. And it does nothing at all for a note that dies early because the neck is swinging along with it.

One detail is worth a look. On Fleischer's Strat-style guitar, the only noticeable bridge-side energy paths showed up around 568-650 Hz (*hertz*, vibrations per second). Those came from the vibrato bridge assembly, not the wood [3]. That's the one place where bridge hardware itself showed up as a way for energy to leave. It suggests that how stiff and well-fitted a vibrato unit is can matter at certain frequencies, more than how much it weighs. A heavier block could also move the vibrato's own resonances around, which could change particular notes for better or worse.

What about the body's weight? A group of students at the University of Leicester built a simple math model of a chambered guitar for a student physics journal [8]. In their model, high E sustain dropped from 0.64 to 0.54 seconds when the body was chambered, and they put that mostly down to the lighter body. That's an example of how the mass idea works on paper. But it's a model, not a measurement, and it's a student exercise. I wouldn't hang any money on it.

For a belief this common, the testing is thin. I couldn't find a controlled comparison of a brass block against a zinc or steel one in an otherwise identical Strat, or of heavy and light bridges on matched guitars.

Verdict: Mostly busted. Mass at the bridge does cut bridge-side losses, so there's a small real effect. But on a solid-body most of the loss is in the string itself, the guitar's share goes mostly through the neck, and no controlled test has shown that a heavier bridge or block gives sustain you can hear.

Myth: A bone, brass or TUSQ nut transforms an electric's tone

> **The claim:** *Swap your plastic nut for bone, brass or TUSQ and you'll get more sustain and stronger harmonics on every note.*

Graph Tech's page for TUSQ, its synthetic nut and saddle material, says it produces stronger mid and high-range harmonics and better sustain [9]. The page gives no measurements, no test method and no listening test to back that up.

The problem with the nut is a simple one. The *nut* is the slotted piece at the top of the neck that the strings rest on before the headstock. It's one end of the vibrating string, but only when you play an open string. The moment you press down at any fret, the fret becomes the end of the string. The nut is now outside the part that's vibrating. It's just sitting there.

On open strings, though, the nut is the end of the string, and that's a lot of notes if you play open chords. There it sits on top of the neck. As we covered, what really decides energy loss at the neck end is how much the neck itself moves [1, 7]. A harder, better-fitted nut might lose a hair less energy than a soft or badly cut one. But the neck under it is doing most of the work.

I looked for a published, controlled test of nut materials on an electric. I didn't find one. What turned up were forum posts and sales pages. So we have a clear physical limit (open strings only) and no direct measurements.

What does matter about a nut? How well it's cut. Slots at the right height, no binding, no buzz. A string that sticks in a slot will go out of tune when you bend or use the vibrato, and a slot that's too low will buzz. Those are real problems, and fixing them can make a guitar feel and play far better. That's a setup issue, not a material one. My book *Guitar Care and Maintenance* shows how to check nut height and when to hand the filing to a tech.

Verdict: Mostly busted. The nut is only the end of the vibrating string on open notes, so it has very little to work with on anything you fret. No controlled test of nut materials was found. A well-cut slot matters far more than what the nut is made of.

Try it yourself: Play the open A string, then the same note fretted on the low E string. If the nut were shaping your tone, only the open one would have it. Keep in mind the two notes are also on different strings, so not every difference you hear belongs to the nut.

Myth: Dead spots are a defect of cheap guitars

> **The claim:** *If your guitar has a dead spot, it's a cheap, badly made guitar. Good guitars don't have them.*

A *dead spot* is a note on the neck that dies much faster than the notes around it. You play up the D string and everything rings, then one note goes thud. Lots of players think that's a sign of poor quality. The research says it's something else.

Fleischer studied this in a series of reports. In one he found a dead spot at the 4th fret of the D string on a Strat-style guitar, with a short decay, and a "live spot" at the 11th fret that rang on [10]. His view is that the instrument's own resonances cause dead spots. When a note lines up with one, the neck swings and steals the energy.

He went further with five electric basses [11]. The bodies moved much less than the necks. The neck conductance showed sharp peaks, while the bridge conductance stayed small and flat. The first bending mode of the neck, its lowest natural swing, sat at about 40-49 Hz on regular basses and 67 Hz on a carbon-fiber bass. In a second report he showed that at a dead spot, the note's decay time is roughly half, or even a third, of a live spot [7]. He called neck conductance a strong indicator of dead spots.

Price didn't buy anybody out of it. The basses in that study included a Music Man StingRay 5, which he described as higher priced, and a Carvin LB 76, which he described as high in reputation and price [7]. They showed the same kind of neck-conductance peaks, the marker he ties to dead spots, as the cheaper basses did. Those peaks turned up on screwed-on and glued-in necks alike.

On guitars, his budget Squier Bullet had dead spots where the neck conductance was high for the first one or two harmonics [3]. He also found that a Les Paul-type guitar with a symmetric headstock showed smaller differences between the bass and treble sides than the Strat-style guitar with its one-sided headstock. So headstock shape plays a part.

Then there's the Paris team. Their test guitar was a carefully handmade Les Paul Junior replica, hardly a cheap guitar. It had a dead spot at the 12th fret of the G string, where *T30* (the time a note takes to drop by 30 dB) was more than 2 seconds shorter than the frets around it [1]. They also found a dead spot at the 9th fret, but

only for string motion side to side. The pickup barely hears side-to-side motion; the authors found that direction was almost not picked up at all. So that second dead spot was far harder to hear through the amp [1].

Guitar makers take this seriously, too. A joint project between Yamaha and McGill University, which ran from 2023 to 2025, lists dead spots among the issues it set out to understand [12]. Its project page doesn't give any results.

Put it together and here's the picture. Every neck is a beam with resonances, so every guitar has notes where the neck steals more energy and notes where it steals less. Whether you notice depends on how close a resonance lands to a note, how strong it is, and how you hold the guitar [4]. Headstock weight and shape, neck stiffness and the joint can move those resonances around. That's why tricks like a heavier headstock or a clamp on the headstock can shift a dead spot. They can move it. They can't remove the neck's resonances.

Build choices can make dead spots worse or milder. That's different from saying only cheap guitars have them. Most of the data is on basses and a handful of guitars, and nobody has surveyed how bad dead spots get at different prices.

Verdict: Busted. A carefully handmade guitar had a measured dead spot, and high-priced basses showed the same neck resonance peaks that cause them. Dead spots come from ordinary neck resonance, so even good instruments have them. Whether cheap guitars have worse ones hasn't been tested.

Try it yourself: Play every note up to the 12th fret on each string and let each ring. Mark any note that dies early, then try holding the guitar differently, or clip a small clamp to the headstock with a soft cloth under the jaws (and don't leave it on), and see if it moves.

What about the finish?

You may be wondering where nitro and poly finishes fit into all this. The finish question deserves its own space, and I give it that in Chapter 5, alongside aging and the idea of a guitar "opening up."

What this means for your money

Don't pay for a neck-through or set neck because you've been told it sustains more. Buy one if you like the feel or the look. A well-fitted bolt-on is not a sustain problem, and the only real test found it held its own just fine.

Before you spend on a brass block, a heavier bridge or a fancy nut, play the guitar up the neck and listen. If a few notes die early, that's the neck, and a heavier bridge won't fix it.

Spend your nut money on a good cut, not an exotic material. Proper slot height and slots that don't bind will help your tuning and playability. Those are problems you can feel every time you play.

When you shop for a guitar, test for dead spots by ear. Every guitar has some notes that ring a little less. What you want to know is whether any of them bother you, on the strings and frets where you actually play.

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Chapter 4: Acoustic Guitars, Where Wood Really Matters

In Chapter 2 I spent a lot of time telling you that the wood under your pickups matters a lot less than the internet says. If you play acoustic, you may have been waiting for me to say the same thing here. I won't. On an acoustic guitar, wood is not a side issue. The wood is the speaker.

That doesn't mean every claim about acoustic tonewood holds up. Some of the most expensive beliefs in the guitar world (rare back woods, for one) took a real beating when researchers finally tested them blind. Other beliefs are closer to the truth than the skeptics give them credit for. The trick is knowing which part of the guitar is doing the work.

So we'll start with how an acoustic guitar makes sound in the first place. Once you see that, most of the myths in this chapter sort themselves out.

How an acoustic guitar makes sound

A string by itself makes almost no sound. It's too thin to push much air. Pluck a string stretched between two posts and you'll barely hear it. On a guitar, the string's vibration travels through the saddle and bridge into the top, and the top has enough surface area to move the air in front of it [1].

That top is usually spruce or another light, springy wood, and it's thin, about 2.5 mm according to Joe Wolfe at the University of New South Wales [1]. Think of it as the cone of a speaker made out of wood. The braces glued under it have two jobs. They keep the top from bulging and twisting under the pull of the strings on the bridge, and they shape how the top bends and moves when it vibrates [1].

What about the back? Wolfe describes it as much less important to the sound than the top at most frequencies, partly because your body is pressed against it and soaks up its motion. The sides barely move in and out at all [1].

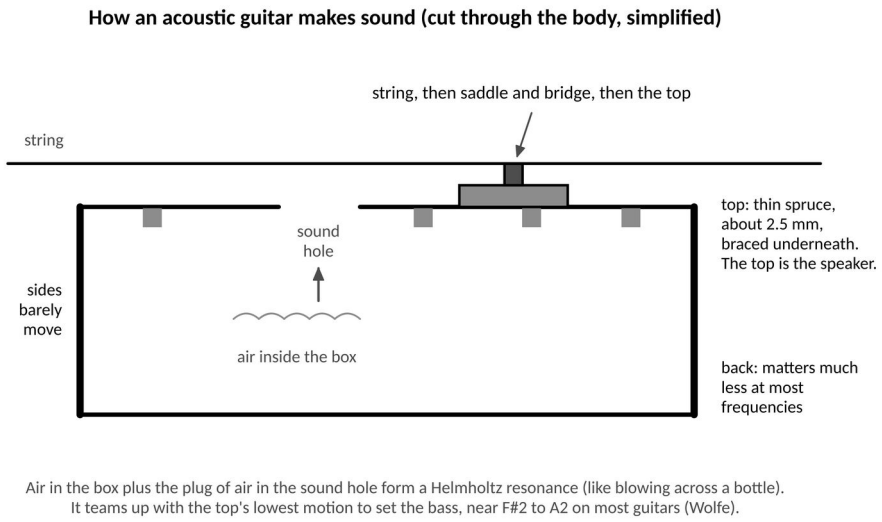


Figure 4.1: On an acoustic, the string drives the top through the bridge, and the top moves the air. The air in the box sets the bass.

Then there's the air inside the box. The body and its sound hole form what's called a *Helmholtz resonator*. That's the same thing that happens when you blow across the top of a bottle and get a note. The air in the body acts like a spring, and the plug of air in the sound hole acts like a weight bouncing on that spring. A *resonance* is a frequency where something naturally wants to vibrate and gives a boost. For this air resonance, a bigger opening pushes the note up and a bigger box pulls it down [2]. Because a guitar's walls flex, the real resonance sits a bit lower than the simple bottle math would predict, often near or a little under the pitch of the A string [2]. Wolfe puts the air resonance somewhere between about the F# on the 2nd fret of your low E string and the open A string (F#2 to A2), depending on the guitar [1].

The air resonance doesn't act alone. It teams up with the top's lowest way of moving, where the whole top pumps in and out like a drum skin. Each of these patterns of motion is called a *mode*. When the air and the top are tied together, they push each other apart into two strong low peaks instead of one [1]. B.E. Richardson and his team at Cardiff University compared this to a bass-reflex loudspeaker. On one experimental guitar they measured, the air and top coupled to give strong peaks near 100 Hz and 230 Hz (hertz, or vibrations per second) [3]. When they measured 10 real guitars, the lowest of these coupled modes ran from 88 to 109 Hz, and the main top mode from 172 to 248 Hz [3].

Above roughly 400 Hz in their example, the top dominates the radiation [3]. Richardson's group also made the point that the height of those peaks matters more than their exact pitch, and that the top's properties are what shape the overall playing qualities of the guitar [3]. An older paper led by Richardson, on building synthetic guitar tones, reported that thinning the top from about 3.0 mm to 2.2 mm made audible changes, though it doesn't describe a formal listening test [4]. They also suggested that small shifts in where the top stays still near the bridge (its *nodal lines*) could change the sound a lot, maybe more than shifts in pitch of the modes [4].

If I had to rank the parts of an acoustic, the top and its bracing come first by a long way. The air in the box sets the bass. The back and sides trail well behind. Most of this chapter's myths sort themselves out from that order.

Myth: Back and side wood defines the tone

> **The claim:** *Brazilian rosewood is rich and complex, mahogany is warm and woody, maple is bright. Pick your back wood and you've picked your sound.*

This is one of the most repeated ideas in the acoustic world, and a lot of money rides on it.

It's also one of the few acoustic myths that has been put to a proper blind test. In 2018, Carcagno, Plack and colleagues at Lancaster University, working with luthier Roger Bucknall and acoustics researchers J. Woodhouse and C. Fritz, published a study in the Journal of the Acoustical Society of America [5]. The details here come from the paper's published abstract and the university's summary of it [5, 6]. Bucknall built six steel-string guitars that were the same in every way except the back and side wood: Brazilian rosewood, Indian rosewood, mahogany, maple, sapele and walnut. Then 52 guitarists played them while wearing welder's goggles in a dim room, so they couldn't see which was which. They rated all six about the same for overall sound. In a separate blind test, 31 of those same guitarists had a hard time telling the guitars apart at all by sound or feel. Vibration measurements on the guitars found only small differences, and Plack summed it up by saying the acoustic differences between the guitars were minimal [5, 6].

A later paper by Merchel and colleagues, which I'll come back to below, summed up this work as showing either a marginal effect of back wood on overall sound ratings or none [7].

That fits the physics. The back is a second, smaller radiator, mostly active in those low pumping modes, and the player's body damps it [1, 3]. *Damping* is anything that soaks up vibration and makes it die away faster. Changing the back's species changes its stiffness and weight a little, which nudges the low modes a little. A good builder can also make up for that by adjusting thickness or bracing.

Now the limits. This was one study of one guitar design, and the guitars were new. It can't rule out small differences that a few expert players care about, or bigger effects in other body shapes or bracing styles. In the real world there's another problem. When you compare a rosewood guitar to a mahogany one in a store, they usually differ in more than back wood. Different top, different bracing, different finish, sometimes a different factory. You can't pin the difference on the back.

Verdict: Mostly busted. In the best blind test we have, players rated six back woods, from Brazilian rosewood to sapele, about the same and could barely tell them apart. The physics puts the back well behind the top.

Try it yourself: If you shop with a friend, have them hand you two guitars of the same model and top wood with different backs while your eyes are closed. See if you can still pick the one you thought you'd love.

Myth: Solid wood beats laminate every time

> **The claim:** *Solid wood vibrates more freely and has richer overtones. Laminate sounds choked and boxy, and it never opens up.*

You'll find this claim on plenty of retailer blogs. One from early 2026 says solid wood moves more freely, that laminates sound compressed, and that solid wood guitars open up as they age [8].

First, what is laminate? It's several thin layers of wood glued together with the grain of the middle layer running crosswise, like plywood. That makes it much stiffer across the grain. It usually adds some glue weight and may add damping. It also resists cracking when humidity swings, which is a real plus.

As far as I could find, nobody has published a blind listening test that compares solid and laminate guitars built to the same design. So we have to reason from the physics and from bits of other work.

Start with what we know. The top does most of the radiating [1, 3]. So a laminated top is the case that could really matter. A laminated top changes the balance of stiffness and weight that builders tune, and cheap laminate tops are often made thick to survive abuse. Measurements by D.P. Hess, plus a model he fitted to them, show that changing a top's mass and stiffness moves the guitar's low resonances and its output [9]. Which way the sound moves depends on how the top is built, not on the word "laminate."

Back and sides are a different story. The back wood study above showed that changing the back's species barely registered with players [6]. That study didn't test laminates, so I'm making an inference here, but it suggests that laminated back and sides are mostly a structural and cost choice.

There's one more piece. Luthier R.M. Mottola wrote a trade-journal article (practical shop testing, not a peer-reviewed study) where simple bending tests showed spruce plywood was about as stiff along the grain as solid spruce and stiffer across it [10]. He also mentions that one of the best-sounding steel-strings he'd heard had laminated back and sides. That's one person's ear, so take it as a story, not proof [10].

The claim that solid wood "opens up" and laminate doesn't belongs in Chapter 5, and I'll warn you now: the evidence there doesn't support either kind of wood transforming with playing.

Verdict: No good evidence either way. Nobody has run a controlled blind test of solid against laminate guitars of the same design. The physics points to a solid top as the change most likely to matter, because the top is the speaker, and laminated back and sides probably matter little. But that hasn't been tested, so "every time" goes past the evidence.

Try it yourself: Have a friend hand you a laminate-top and a solid-top guitar of similar size and price while your eyes are closed, with fresh strings of the same brand on both, and say which you prefer, several times. Then try two guitars with solid tops where one has laminate back and sides.

Myth: Top species (Adirondack vs Sitka, cedar vs spruce) makes a huge difference

> **The claim:** *Adirondack spruce is loud and punchy, Sitka is clear, and cedar is warm and dark. The top species is the biggest choice you make.*

Classical guitar writer B. Werner describes spruce as clearer and more articulate and cedar as warmer and more responsive, though he also cautions that design and bracing matter as much as the wood [11]. That's a fair-minded version of what most players believe.

The best study on top wood is the same Merchel paper I mentioned above, and it didn't compare species at all. It compared boards of one species. Merchel, Altinsoy and Olson worked with Taylor, which measured a large batch of Sitka spruce (density 352 to 540 kg/m^3) and picked low, median and high billets to build nine 814ce guitars that differed only in the density and stiffness of their tops, their braces, or both [7]. Then 23 listeners (13 professional or student guitarists and 10 amateurs) compared recordings of the guitars in blind pairs.

They heard real differences. The listeners were reliable at spotting a hidden repeated pair, and they preferred tops that were low in both stiffness and density; stiffness on its own gave only a weak tendency [7]. All of that was within Sitka spruce. The authors note the results apply to the one guitar model they tested.

So top wood properties matter. That matches the physics and Richardson's work on top thickness [3, 4]. But notice what that study tells us about species. If one species can vary that much from board to board, then

labels like Sitka, Adirondack and cedar describe averages that overlap. A builder who thins and braces each top to a target stiffness also cancels out a good part of the difference between species.

I could not find a controlled study that compares Adirondack to Sitka, or cedar to spruce, on guitars built the same way. So when someone says the species makes a "huge" difference, part of what they hear may be the particular board, the particular builder, or the expectation that comes with the name.

Verdict: No good evidence either way. A top's stiffness and density make audible differences even within one species. But no blind test has compared species at matched build, and the physics can't say whether species matters more than the board-to-board spread, so "huge" is not supported.

Myth: Scalloped or forward-shifted bracing gives more bass and volume

> **The claim:** *Shave the braces down between the ends (scalloping) or move the X-brace closer to the sound hole, and you get a bigger, boomier, louder guitar.*

This one is all over guitar forums. One forum thread on Martin bracing connects forward-shifted and scalloped bracing with more bass and volume, and one poster said he thinks of scalloping as widening the guitar's bass range [12]. Makers push bracing too. Taylor says its V-Class bracing makes a guitar louder, gives more sustain and puts the top more in tune with the strings, but the page shows no measurements [13].

The physics behind the claim makes sense. Braces set how stiff the top is and where it bends. Scalloping takes wood off the brace between its ends and the bridge area, so the top gets lighter and more flexible in some spots while staying stiff where it needs to be. Moving the X forward leaves more free top near the bridge. Either change can lower the main top resonance and let the top move more at low frequencies, which players hear as bass. The trade-off is strength: the same changes make the top weaker against string pull.

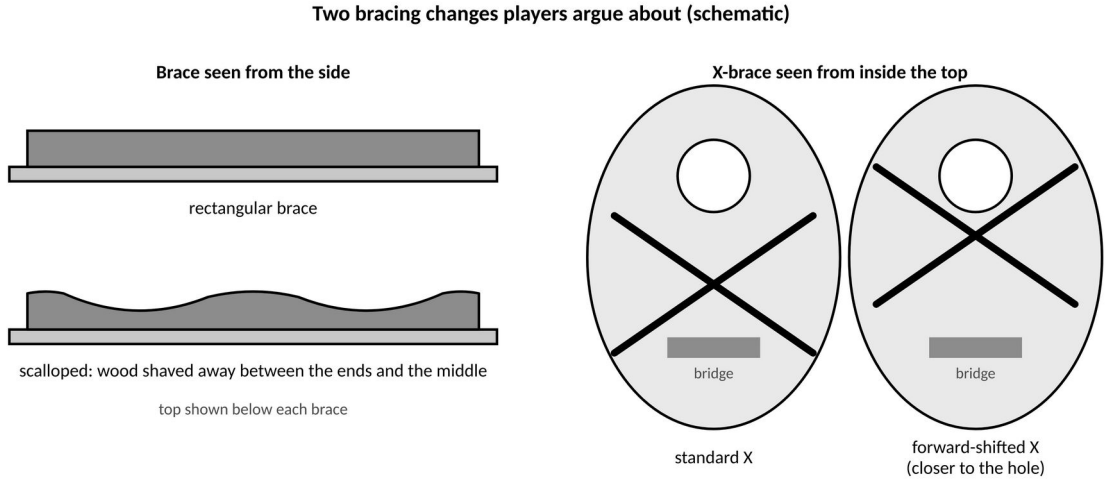


Figure 4.2: Scalloping shaves wood off a brace; a forward-shifted X sits closer to the sound hole. No matched blind test of either has been published.

What do the studies say? Not as much as you'd like. P. Dumond and N. Baddour modeled a single brace on a spruce plate. In one paper, a scalloped brace with the same center and end height as a rectangular one raised four of the five modes they looked at by about 4.5 to 5.6%, and lowered one by 0.9% [14]. Their point was that a shaped brace lets a maker move several modes at once in ways a plain rectangular brace can't. In another paper, they showed a scalloped brace strongly changed a mode whose peak sat under the scallop and left

others mostly alone [15]. Notice the direction: in their model, scalloping didn't simply drop everything lower. It reshaped the top. Their plate's modes were all above about 600 Hz, too, so this doesn't speak to bass directly.

Hess fitted a simple model to his measurements on a real guitar and used it to predict what changing top mass and stiffness would do. Cutting plate mass by 20% was predicted to raise the sound level above the second resonance. Halving both mass and stiffness (with a 28% smaller plate area) was predicted to give an even gain of about 3.2 dB [9]. Those are model predictions, not measurements, but they support the idea that a lighter, more flexible top can be louder. Richardson's older work also suggested that moving the still lines near the bridge, which bracing controls, can change the sound a lot [4].

But nobody has built otherwise identical steel-strings with scalloped versus straight bracing, or forward versus standard X, and run a blind listening test. The modeling uses simple plates, not full guitars. And the famous pre-war forward-shifted sound is tangled up with old wood and with the fact that only the good ones tend to survive.

Verdict: No good evidence either way. Bracing clearly changes how the top moves. But nobody has tested scalloped or forward-shifted bracing against standard bracing on matched guitars, and the plate models don't settle whether these changes add bass and volume.

Myth: Bridge pins and saddle material change acoustic tone a lot

> **The claim:** *Swap plastic pins for bone, ebony or brass, or put in a bone saddle, and your guitar wakes up.*

This is the cheapest upgrade in the acoustic world, so it's no surprise people love it. Writing in Acoustic Guitar magazine, M. Keith ties pins to bridge mass: lighter pins for a livelier sound, heavier ones for more sustain and less dynamic range. He also says the difference is minor on most factory guitars and that a big jump, like plastic to brass, will probably be the most audible [16]. That's an expert's opinion, not a test, but it's a pretty level-headed one.

The best measurement I found is from Hess, who tested changes on a solid-spruce-top Loar LH-200 using an impact hammer, a sensor on the top and microphones [9]. Adding 22.5 g to the bridge, which worked out to a 34% increase in the top's effective mass in his model, lowered the sound level and the top's motion and pulled the second resonance down. Swapping plastic pins for brass ones adds about 22.4 g, nearly the same weight, so Hess expected comparable results, though he didn't report measuring the pins themselves [9]. So heavy brass pins can plausibly change the sound, and the reason is weight at the bridge. Hess only measured from 70 to 270 Hz, so this tells us about the low end, not the sparkle.

For saddles, I found only a manufacturer demo, and it was informal listening with no measurements. Yamaha swapped a bone saddle and nut for wood and described the sound as slightly muffled and warmer. Layered paper was more muffled still, with the strings sinking into it, and rubber couldn't even hold the guitar in tune [17]. That makes sense: a soft material soaks up string energy right where it should pass into the bridge.

Between two hard materials (bone, hard plastic, or a synthetic like TUSQ) the physics points to very small changes. The saddle and pins are tiny and stiff compared with the top. Fit and contact matter more than the material. A saddle that sits flat and tight in its slot passes energy well. One that rocks or has a gap under it doesn't, whatever it's made of. No controlled blind study of bone versus synthetic saddles exists that I could find.

One note: if your guitar has an undersaddle pickup (a piezo pickup, a thin strip under the saddle that senses pressure rather than string motion), saddle fit and flatness directly affect the plugged-in sound. That's a separate story.

Verdict: Partly true. Adding about the weight of a set of brass pins to the bridge measurably changed the low end in Hess's tests, and soft or badly fitted saddles dull the sound. Swapping one hard saddle material for another has never been shown to matter much.

Try it yourself: Before you buy a new saddle, check the fit of the one you have. If it doesn't sit flat on the bottom of the slot, fixing that is the upgrade.

Myth: Bigger body means more bass

> **The claim:** *A dreadnought or jumbo has more bass than an OM, and an OM has more than a parlor.*

From smallest to largest, the common sizes run roughly parlor, then L-00 and OM, then dreadnought and jumbo. This one mostly holds up, and the reason goes back to the air spring. Remember that a bigger box pulls the air resonance down [2]. A guitar can't put out low notes efficiently below its lowest air and top resonance. So a lower resonance means the guitar supports deeper notes better. A bigger top also has more area to push air [1].

Luthier B. Galloup, writing in Premier Guitar, gave rough air resonance figures from his experience: about 95 Hz for a Martin dreadnought, below 90 Hz for a Gibson jumbo, 100 to 115 Hz for OM and L-00 sizes, and 110 to 125 Hz for a parlor [18]. Treat those as a builder's estimates, not a measured survey. His point was that small guitars aren't quieter in their range; they just can't pump the bottom end. Your low E string's fundamental is at 82 Hz, so you can see why that matters.

A 2023 master's thesis at Purdue by A.C. Fernandez used an adjustable test body to check this. I could only see the abstract, so take the details lightly. It reports that more body depth lowered the Helmholtz and first resonances, and a bigger sound hole raised them. It also notes that luthiers usually aim for resonances of around 95 to 105 Hz [19]. Hess showed the same thing another way: adding a 5 cm tube to the sound hole lowered the first resonance from 116 to 98 Hz and the Helmholtz from 130 to 110 Hz [9]. And Richardson's measured guitars had their lowest coupled mode between 88 and 109 Hz [3].

Body volume isn't the only knob, though. Sound-hole size, top stiffness and weight, and bracing all move these resonances. A well-designed small guitar can be tuned fairly low, and a stiff, heavy big guitar can sound tight. Small guitars also often sound more even and focused, which some players hear as less bass even when the balance is just different. Nobody seems to have run a blind listening study comparing body sizes at matched construction.

Verdict: True. Bigger air volume and a bigger top lower the bass resonances and move more air. This rests on well-settled physics and measurements, not a listening test. It's a strong tendency, not a law, because sound-hole size, top and bracing can shift the bass a lot at any size.

Try it yourself: Hum or sing a low note into the sound hole of different guitars and listen for where the body suddenly rings loudest. Bigger bodies usually ring lower.

What this means for your money

If you're buying an acoustic, spend your money on the top and the builder, not the back. If you're paying for one upgrade, make it a solid top: it hasn't been tested blind, but the top is the speaker. A well-made guitar from a builder who works each top to how it actually flexes will do more for your sound than a rare back wood ever will.

- Don't pay a big premium for Brazilian rosewood back and sides because of tone. Buy it because you love how it looks, if you can afford it.
- Choosing laminate back and sides on a solid-top guitar is a sensible way to save money and get a guitar that handles humidity changes better.
- Body size is a real tone choice. Pick it by the bass and balance you want, then play several of the same model, since tops vary.
- Before you buy fancy pins or a new saddle, make sure the saddle fits well. If you want to try heavy pins, know that they change the bridge weight, and that can cut low-end output.

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Chapter 5: Finishes, Aging, and Opening Up

Walk into any vintage guitar shop and you'll hear a certain kind of talk. The old nitro finish lets it breathe. The wood has dried out and gotten more resonant over the decades. This one has been played hard, so it's opened up. And if you can't afford the real thing, there's a new guitar with roasted wood and a finish that's been beaten up to look decades old.

These ideas all share something: they're about time. Time in the finish, time in the wood, time under a player's hands. And they all ask you to pay for that time, sometimes a lot.

I get asked about this stuff at the bench all the time. Some of it has real science behind it. Some of it falls apart the moment you hide the guitar from the listener. In this chapter we'll look at finishes first, then the idea that guitars open up with playing, then roasted wood, and finally the big one: whether old guitars really sound better.

A quick reminder from Chapter 4: on an acoustic, the thin top is the speaker, so anything that changes the top can change the sound. On a solid-body electric, the pickup reads the string, and the body barely moves. That difference will come up again and again.

Finishes

Myth: A thin nitro finish sounds better than poly on an acoustic

> **The claim:** *Nitrocellulose lacquer is thin and lets the top vibrate. Polyurethane is thick and plastic and chokes the guitar.*

You'll see this everywhere. A 2024 gear article sums up the belief that thicker poly finishes damp the wood's natural vibration, while admitting that studies are limited [1].

First, a couple of terms. *Damping* is anything that soaks up vibration so it dies away faster. Engineers often describe it with a number called *Q*: a high Q means something rings a long time, a low Q means it dies out quickly.

Any finish adds a little weight and a thin skin that soaks up some vibration. On a top that's only about 2.5 to 3 mm thick, that can show up in measurements. The question is whether it's the chemistry (nitro or poly) or just how much finish you pile on.

The most direct test I found came out in 2025. A. Straže and colleagues sprayed three coats of either nitrocellulose or two-part polyurethane on strips of Norway spruce and followed them for 300 days [2]. Both finishes raised damping compared with bare wood. Fresh nitro actually damped more than poly in two of the three vibration patterns they measured (in one, noticeably more) and a bit less in the third. But the nitro film was also heavier, so this test can't separate chemistry from the amount of finish. They also measured how well the wood turns vibration into sound. Two weeks after finishing, bare wood scored 1,026 on their scale, nitro 472 and poly 515 [2]. So in the two main bending modes, both finishes cut it roughly in half. The films were

thick, though, about 0.2 mm. Over time, as the finishes cured and hardened, damping went down and that score went up for both, though neither got back to bare wood [2].

H.P. Stephens tested 3 mm Sitka spruce bars with a shellac-based sealer and then four different top coats, including shellac types and a guitar lacquer, totaling about 83 to 84 micrometers of finish (a micrometer is a thousandth of a millimeter) [3]. The sealer did most of the work. It cut Q along the grain from about 149 to 114, and across the grain from about 47 to 9 [3]. After seven weeks, all four top coats had statistically the same effect. In other words, once the sealer was on, the kind of top coat didn't matter much.

A 2001 study by E. Obataya and colleagues on urushi, a traditional Asian lacquer (I only saw the abstract), found that coating changed damping more than anything else, especially across the grain, and that urushi behaved much like polyurethane [4].

None of this is a listening test on a finished guitar. These are strips and bars in a lab. And in the real world, a factory poly finish is often thicker than a boutique nitro one. So when players compare guitars, thickness and chemistry are mixed together.

Verdict: Mostly busted. Every finish adds damping to a thin top, and more finish means more damping, so a heavy finish can matter. But that's thickness, not chemistry. There's no good evidence that nitro beats poly at the same thickness, and in the one direct lab comparison fresh nitro damped more than poly in two of three vibration patterns, with a heavier film.

Myth: Nitro lets an electric breathe, poly chokes it

> **The claim:** *On a Strat or Les Paul, a thin nitro finish lets the body resonate, and poly smothers the tone.*

This is the same myth moved onto a solid-body, and it has a much harder time there.

In Chapter 2 we saw how little a solid-body moves. A. Paté and colleagues measured how readily the bridge and neck take energy from the string. The neck took it far more readily than the bridge on their test guitar, and the bridge barely moved [5]. H. Fleischer found the same pattern: on a Strat-style guitar, the bridge barely gave way, and the neck was usually the softer end of the string [6]. Across six solid-bodies he measured, the neck moved much more than the bridge, and he described body motion as rather parasitic, something that can drain energy from the string [7].

Now think about that. The finish sits on a slab that barely moves, and the pickup is reading the string, not the body. A thin film on that slab has almost nothing to act on. The finish studies above were done on thin acoustic spruce, where finishes matter most, and even there the different top coats ended up statistically the same once cured [3].

No one has run a controlled measurement or blind test of nitro versus poly on solid-body electrics that I could find. A very thick finish on a neck could, in theory, change the neck's stiffness and damping a little, but that hasn't been tested either. So this verdict rests on the physics, and on the lack of any test showing a difference.

Nitro does age, crack and feel different under your hand. That's a real reason to like it. It's just not a tone reason.

Verdict: Mostly busted. No study shows a plugged-in tone difference between nitro and poly on electrics, and the physics leaves a body finish very little to work on.

Opening up

Myth: Guitars open up with age and playing, and vibration devices speed it up

> **The claim:** *The more a guitar gets played, the more the wood loosens up and the better it sounds. Strap a vibration device on it and you can get there faster.*

Retailers say solid wood guitars open up as they age [8]. A 2013 Guitar World review of the ToneRite, a device that vibrates the guitar, says it speeds up the breaking-in process. The maker suggests 72 to 144 hours of use, and the reviewer thought a Gibson J-200 sounded louder after a week [9]. That was one person, listening without any blind setup.

B.M. Clemens and colleagues tested this properly in 2014 [10]. They took three pairs of new guitars, each pair the same model: Taylor 110, Martin D-1 and Collings OM2H. One guitar from each pair got a commercial vibration device for 348 hours, almost five times the maker's minimum. The other sat as a control. They measured the guitars before and after by tapping them with a small hammer and recording the response. The treated and untreated guitars changed by the same small amount. Then nine experienced guitarists rated them double-blind. The treatment made no significant difference, and the players couldn't pick out the treated guitar: five of nine guessed wrong for each pair [10]. The authors also worked out the stress on the wood. The device put about 4 kPa (kilopascals, a unit of pressure) on it, compared with about 400 kPa from a gentle strum [10]. Your strumming puts a hundred times more stress on the top than the gadget does.

Violin researchers have tested the same idea. In a study published in 2026, H. Pauget Ballesteros and colleagues had a soloist play a modern violin, one that had rarely been played before, every day for about six months, until the player said it had opened up. Two other violins sat in storage as controls. Measurements found no change in the played violin beyond the normal drift the stored ones showed too [11]. A. Piacsek and S. Lowery vibrated two violins for more than 1,600 hours and found no change in frequency response tied to the amount of vibration. That was a conference summary, not a peer-reviewed paper [12]. And a 2005 study by R. Inta, J. Smith and J. Wolfe compared a violin played regularly for three years with its twin kept in museum conditions. Listening panels found no more significant differences across 48 comparisons than chance alone would produce [13]. A review by Obataya also reports that listening tests found playing had no significant effect on the tone of guitars or violins [14].

So why do so many players swear their guitar changed? Some of it is real, just not what they think. Finishes keep curing for months, and in the Straže study damping dropped as the finish aged [2]. Humidity changes and fresh strings shift the sound too. And players adapt to an instrument. In the Inta study, the owner could pick out his own violin in 20 of 24 blind trials just by playing it, even though the listening panels heard no significant difference [13].

Verdict: Mostly busted. Players may well notice a change, but the stated cause is wrong. Controlled tests on guitars and violins found no physical or audible change from playing or vibration devices beyond what untouched controls did on their own. A finish curing over months, humidity, fresh strings and the player getting used to the instrument are more likely causes.

Try it yourself: Record your new guitar today with the same mic spot and strings you'll use later. Six months from now, record it again with fresh strings of the same kind and have a friend play the two clips back to you without telling you which is which.

Roasted wood

Myth: Torrefied tops sound like old wood

> **The claim:** *Roasting the top in an oven gives a brand-new guitar the sound of a vintage one.*

Torrefaction means heating wood in a low-oxygen setting. It breaks down part of the wood called *hemicellulose*, the part of the cell wall that soaks up the most moisture. Makers are confident about it. Taylor says its torrefied spruce tops tend to sound warmer and sweeter [15]. Yamaha says its own process gives new wood the structure of wood that's been played for years, with more extended lows and faster-fading highs, but the page gives no numbers or test data [16].

What does the lab work say? Obataya's 2016 review found that heat treatment can copy some of what centuries of aging do: higher stiffness for the weight, lower damping, less moisture uptake and a darker color [14]. But it depends a lot on the recipe. At 120 °C with moderate humidity, stiffness went up and damping went down, yet getting the wood wet again undid both. At very high humidity, damping went up steeply instead [14]. Chemical scans of wood heated at 160 °C or above didn't match naturally aged wood [14]. T. Noguchi, Obataya and K. Ando also described a real difference between naturally aged and heat-treated wood, based on damping [17].

Two more studies paint the same mixed picture. P. Zatloukal and colleagues heat-treated spruce for piano soundboards. Treatment at 180 °C cut moisture uptake by 36% and at 200 °C by 42%. Sound speed along the grain dropped 1.6% at 180 °C and rose 2.1% at 200 °C [18]. R. Krüger and colleagues treated other European woods at 160 °C for 8 hours as possible back and side woods for classical guitars, and found damping went up slightly for cherry and pear (I only saw the abstract) [19]. So roasting doesn't always lower damping.

There's also a short PDF on building guitars with torrefied spruce. The author and where it was published are unknown, so treat it as a weak source. It reports spruce samples treated at about 160 °C coming out about 3% lighter, about 5% stiffer and with about 20% less damping. No guitars were built, and the document itself says torrefaction shouldn't be seen as a shortcut to aged wood [20].

Nobody has published a blind listening test of torrefied tops against untreated ones on otherwise identical guitars that I could find, and nothing compares a torrefied guitar with a truly old one. Keep in mind too that a real guitar has finish, glue and braces adding their own damping, which may hide changes in the wood.

Verdict: Debated. The lab evidence points both ways. Roasting moves several wood properties the same way long aging does, and it clearly cuts moisture uptake. But it isn't chemically the same as old wood, and the results depend on the recipe. Whether a torrefied guitar sounds like a vintage one hasn't been tested blind.

Vintage

Myth: Old wood sounds better

> **The claim:** *Wood keeps drying and settling for decades. The older the guitar, the better it sounds.*

A post on a 2006 Seymour Duncan forum thread says it plainly: the more a guitar ages and settles, the better it will sound [21]. A lot of players and builders believe it.

There's real science on wood aging, and it's more interesting than the forum version. Noguchi, Obataya and Ando compared Japanese red pine aged about 121 to 296 years with 8-year-old wood. The old wood carried

sound faster and had lower damping [17]. Obataya's later review covers examples up to about 1,000 years old and finds the same direction [14]. In principle that could mean a slightly livelier, longer-ringing top.

But look at the details. Part of the effect goes away when old wood gets damp. Soaking it at very high humidity lowered stiffness and raised damping again, so old instruments kept in humid places may lose some of the aging effect [14]. Obataya also reported that the cause of the faster sound speed is still unexplained. Japanese cypress older than 800 years absorbed only a bit less moisture than new wood (about 7.7 to 8.6% against 9.2%), and 290 years didn't change it at all in red pine [22]. Another team studying old Hinoki wood from historic Japanese buildings found it looked stiffer at first, but after correcting for density and moisture there was no significant difference [23].

Now notice the timescales: 100 to 1,000 years, mostly in Japanese softwoods. A guitar from the 1950s isn't in that range, and nobody has measured 70-year-old mahogany or maple in guitars.

And when you go to the listening tests, the advantage disappears. The best evidence is from violins, where C. Fritz and colleagues ran three double-blind studies, which Chapter 13 covers in detail. In 2012, 21 experienced violinists preferred a new violin most often and rejected a Stradivari most often [24]. In 2014, well-known soloists guessed old or new about as well as a coin flip, according to a National Geographic report on the study [25]. In 2017, 137 listeners in Paris and New York on average preferred the new violins and thought they projected better [26]. If 300 years and the most famous names in the business don't survive a blindfold, I wouldn't bet on a few decades. Those tests bust the claim that old violins sound better (Chapter 13). What they can't tell us is whether old wood itself makes a difference, which is why the verdict here is more cautious.

Verdict: No good evidence either way. Very old wood does measure differently, carrying sound faster with less damping. But nobody has measured guitar-age wood in guitars or run a blind test of old against new guitars, so whether you'd hear it is unknown.

Myth: A '59 Les Paul sounds better because of old-growth wood and vintage parts

> **The claim:** *Fifties guitars were made from tight-grained old-growth wood, with Brazilian rosewood boards and pickups that will never be made the same way again. That's why they sound the way they do.*

The same 2006 forum thread lists the usual reasons: old dry wood, thin nitro, Brazilian rosewood fingerboards, and aged pickups with weakened magnets [21].

I could not find a single controlled blind study comparing 1950s Les Pauls, or any vintage electric, with modern copies. The claim has never been tested in published work. The idea that old-growth wood is denser and tighter and therefore sounds better has no guitar study behind it either. Until someone tests it, it stays a story.

Here's what we can say. A 1959 guitar is not quite 70 years old, well short of the centuries in the wood aging studies, and some of that aging effect washes out with humidity [14]. On acoustics, where wood matters most, swapping the back wood (including prized Brazilian rosewood) made little difference to players in the Lancaster blind tests, according to the university's summary of the study [27, 28]. And on an electric, the wood matters even less. A Premier Guitar column summarizes Zollner's view that the wooden structure has close to zero influence on the plugged-in tone [29]. That's a magazine summary of his position, so treat it as a pointer, not proof.

What about the pickups? Here there may be something real, but it cuts the other way. According to Wikipedia (a weak source on this point, with no direct citations), original PAF ("Patent Applied For") humbuckers, the

late-1950s Gibson pickups, varied a lot. Some of the winding machines had no automatic stop, so the number of turns varied from bobbin to bobbin, and the magnets were different grades of Alnico (the classic pickup magnet alloy), often not fully charged [30]. If that's right, there isn't one "'59 sound." There are particular guitars, often heard through particular amps on famous records. Chapter 6 covers pickups in detail.

Add in the price tag and the legend, and you've got about the strongest setup for expectation bias you could design. Chapter 13 covers that.

Verdict: No good evidence either way. No blind test of vintage against modern electrics exists. The physics gives wood only a small part in an electric's voice, and the old-violin tests are a reason for doubt, but none of that is a test of '59 Les Pauls.

Myth: Relic finishes and worn, played-in guitars sound better

> **The claim:** *A guitar that's been aged, or worn through with decades of playing, sounds looser and more open than a shiny new one.*

Gibson's Tom Murphy, in an interview reported secondhand by a gear website, said lacquer can have a damping effect. He left the sound question to players. Gibson itself doesn't officially claim specific sonic benefits for aged finishes on solid-bodies [31].

Murphy is right that a finish adds damping. The studies earlier in this chapter showed that on thin acoustic spruce [2, 3, 4]. But a relic job takes off or cracks some finish on a solid-body, where we've already seen the body is not what the pickup hears [5, 7]. Removing a bit of a film that had almost nothing to act on should change almost nothing. I found no study of relic versus non-relic electric guitars.

The "worn in by playing" half of the claim has been tested, just on violins. Two violins vibrated for more than 1,600 hours showed no change tied to the vibration [12]. A violin played for three years sounded no different to listening panels than its twin kept in a museum [13]. And Obataya's review reports that listening tests found playing had no significant effect on guitars or violins [14].

So what does a relic finish change? How the guitar looks and feels in your hands. That's real. A neck that feels broken in can make you play differently, and that can change your sound. But looks also bias our ears, and a guitar that looks old and loved will probably sound old and loved to most of us, until the lights go out.

Verdict: Mostly busted. No study shows a relic finish sounds better on an electric, the physics leaves little room for it, and controlled tests of playing-in found no change. The feel can be real, and it can change how you play.

What this means for your money

If you love the look and feel of nitro, buy nitro. Just know you're paying for how it ages and feels, not for a tone upgrade. On an acoustic, what matters more is how much finish there is. A thin, well-applied finish of either type is a better bet than a thick one.

- Don't buy a vibration device to open up a guitar. The best test we have showed no effect, even after far more hours than the maker suggests.
- Torrefied tops are a reasonable choice if you want wood that handles humidity better. Don't pay extra expecting a vintage sound.

- Vintage guitars can be great instruments and good investments, but there's no published evidence that the age of the wood makes them sound better.
- A relic finish is a style choice. Pay for it if you love it.

And if a new guitar seems to change over its first months, that may be real. The finish is still curing, and you and the guitar are still getting to know each other.

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Chapter 6: Pickups Without the Hype

Pickup swaps come up at my bench all the time. You can change one in an afternoon with a soldering iron, so it's the first place most players go when they don't like their sound. The catalogs know it. Product pages are full of words like "hot," "airy," "vintage-correct" and "sweet." Some of those words point at something you can measure. A lot of them don't.

There's plenty of good measurement work on pickups and almost no blind listening tests, so most of this chapter is measurement and circuit physics. Before we get to magnets and wire, let's look at what a pickup actually is.

Players bring guitars to my bench asking for higher-output pickups because they assume a bigger number on the box means better tone. Often, adjusting pickup height and pole pieces gives them the clarity they were after without spending a dime. A properly set up guitar will give a player tones he never guessed it had. Specs on a box never tell the whole story.

What a pickup really does

A magnetic pickup is a permanent magnet with a coil of very fine copper wire wrapped around it, several thousand turns of it. Your steel string sits in the magnet's field. When the string moves, it changes the amount of magnetic field passing through the coil, and that change makes a small voltage in the wire. Horton and Moore described this as a straightforward application of a basic law of electricity, and their model of the pickup's field matched their measurements well, except very close to the magnet (within about 5 mm) [1].

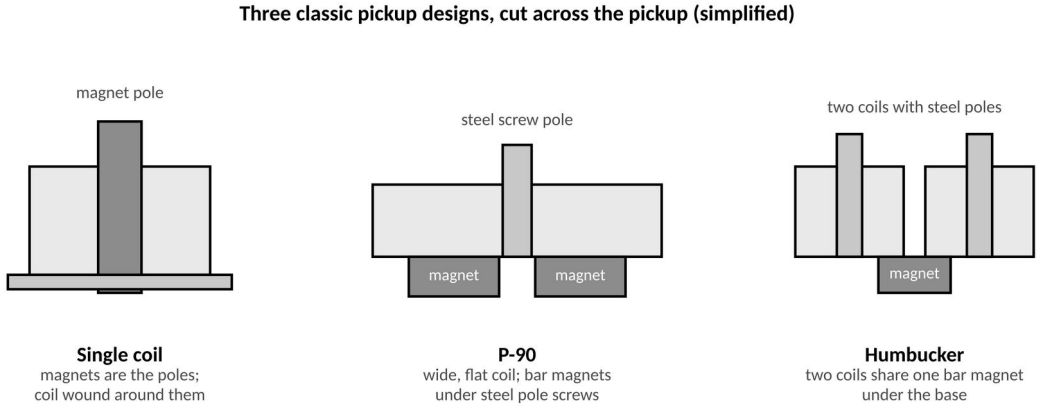


Figure 6.1: The three classic passive pickup designs, cut across the pickup (simplified).

Their work turned up a few things worth knowing. String motion toward and away from the pickup makes a much bigger signal than side-to-side motion. Side-to-side motion makes the signal go up and down twice per swing. And in both cases the output is not a clean copy of the string's motion. The pickup itself adds harmonics, which are the higher tones stacked above the note you play [1]. Another research team built their own single coils with controlled parts and found that frequency, string material, string thickness and the way the string moves all change the voltage you get [2].

Now for the part that matters most for tone. The coil is an inductor. *Inductance* is a coil's tendency to resist quick changes in the current flowing through it, and it's measured in henries (H). Helmuth Lemme puts typical pickup inductance at 1 to 10 H and calls it by far the most important number a pickup has [3].

The coil also has a little *capacitance*, which is the ability to store electric charge, like a tiny reservoir. The windings themselves have about 80-200 pF (picofarads, a very small unit of capacitance). Your guitar cable adds a lot more, about 300-1,000 pF [3]. Put an inductor and a capacitor together and you get *resonance*: a frequency where the circuit naturally rings and gives a boost. With a normal cable plugged in, most pickups resonate somewhere between 2,000 and 5,000 Hz (hertz, or vibrations per second) [3].

Zollner explains it the same way. Below the resonance the response is fairly flat. Near it there is a peak. Above it, treble falls off fast. A Stratocaster pickup with nothing plugged into it resonates at about 9 kHz, but a pickup's inductance working with a few hundred picofarads of cable typically lands in that 2-5 kHz range [4]. He says the height of the peak (engineers call it *Q*) is the second most important thing about a pickup after the resonant frequency itself. With the volume and tone pots and the amp connected, Q is typically about 3 [4]. What sets that height? The pots and amp input pulling on the signal, plus *eddy currents*, which are little swirls of current induced in metal parts like covers and magnets that soak up energy and flatten the peak [3, 4].

Lemme sums up the sound simply: a lower resonance sounds warmer, a higher one sounds brighter, and the height of the peak changes how pronounced that character is [3].

Two more pieces finish the picture. A pickup doesn't sense the string at a single point. It "sees" a short stretch of string, about 1 cm wide for a single coil, and that window is set by the magnet pole, not the coil [5]. A humbucker sees the string at two spots, about 18-19 mm apart on Gibson-style pickups. Sensing at two spots cancels certain frequencies, an effect called *comb filtering*, and the treble loss is especially strong on the low strings [5]. Lemme reports notches near 3,000 Hz for the low E and 4,000 Hz for the A on standard humbuckers [3].

That two-spot sensing is part of why humbuckers sound darker than single coils. Only part, though. Lemme says the difference between one coil and two is often overstated, because most of it comes from the shift in resonance [3]. Zollner says the common view (single coils bright and soft, humbuckers loud and dark) is not suitable as dogma, because pickups differ in inductance, resonance and damping, not only in how many coils they have [6]. *Damping* here just means anything that soaks up energy and lowers that resonant peak.

Almost every myth in this chapter boils down to that peak: where it sits and how tall it is. Pots, tone caps and cables also shape that peak, and they get their own treatment in Chapter 7.

Myth: Higher DC resistance means a hotter pickup

> **The claim:** *Look at the number on the box. The higher the resistance in thousands of ohms (kOhm), the louder and better the pickup.*

DC (direct current) resistance, or DCR, is the resistance of the copper wire in the coil, measured with an ordinary meter. Zollner quotes a magazine test that pointed to 12 kOhm against 8 kOhm as proof that one pickup had far more punch, and he asks whether that makes it "50% louder" [7]. Even Seymour Duncan, a pickup maker, says the idea that higher DCR means louder isn't totally accurate, and its engineering chief says misinformation on DCR is rampant [8].

Zollner offers the simplest test of all. If you pull the magnet out of a pickup, the DCR doesn't change one bit, but the output drops to almost nothing [9]. Resistance can't be the thing making the sound loud.

His measurements back that up. A pickup reading 9.1 kOhm put out more voltage than a vintage Strat pickup at 5.8 kOhm, which you'd expect. But a 17.8 kOhm humbucker put out less voltage than that same 9.1 kOhm pickup for the same string vibration [7]. Two pickups with the same DCR can differ by a factor of 4 in how much voltage they put out for the same string motion below the resonance. Magazine tests he cites even found two samples of the same model differing in DCR by 9.6% [7]. The reading also drifts with temperature, rising about 0.39% for every degree Celsius [9].

Why doesn't resistance track output? DCR only tells you about the wire: how long it is and how thin it is. Seymour Duncan points out that going from 43- to 44-gauge wire (thinner) on otherwise identical pickups raises DCR and changes the tone, but not necessarily the output [8]. Magnets matter too. At the same DCR, Seymour Duncan ranks Alnico II below Alnico V below ceramic for output. A stacked humbucker can read about 20 kOhm and still have near-vintage output, because one coil partly cancels the other [8].

So what does winding more wire actually do? In a Strat example, Zollner added 10% more turns. DCR went up about 10-11%, and output rose only 0.9 dB, a change you'd only just notice side by side. The bigger effect was that the resonance dropped about 10%, so the pickup lost brilliance [7]. More turns means more inductance, which pulls the resonant peak lower, and the pickup gets darker. That darker, thicker sound is a lot of what players mean by "hot."

A 2024 study by Batchelor and colleagues wound 15 pickups for each wire gauge, from 5,000 to 12,000 turns. As the turn count went up, the resonant frequency dropped steadily. At equal turns, the thicker 42-gauge wire gave a higher resonance than 44-gauge [10]. That paper is a preprint, meaning it has not yet been peer reviewed, and it measured pickups with nothing plugged in.

Lemme is blunt about it. He calls resistance the least interesting number of all and says measuring only resistance is a fundamental error [3]. Inductance is what you want, and most makers don't publish it.

Verdict: Mostly busted. Within one maker's line using the same wire and magnet, higher DCR does track more turns and somewhat more output. Across different designs it falls apart, and "hotter" pickups mostly get darker, not dramatically louder.

Try it yourself: Next time you shop, ignore the DCR and look for the inductance in henries and the magnet type. If a maker lists them, compare those instead.

Myth: Alnico is warm, ceramic is harsh

> **The claim:** *Alnico magnets give a warm, sweet tone. Ceramic magnets sound harsh and cheap.*

Alnico is a family of metal magnet alloys. Ceramic magnets are made from hard ferrites, a non-metal magnet material. You'll see the warm-versus-harsh line in catalogs and forums everywhere.

What does the physics say a magnet changes? Three things you can measure. First is field strength at the string, which sets output level and how hard the magnet pulls on the string. Second is whether the magnet conducts electricity. Third is how much it adds to the coil's inductance.

Zollner points out that ceramic magnets are electrical insulators, so they can't produce eddy currents [11]. That means less damping of the resonant peak than a conductive Alnico magnet sitting in the coil. Ceramic also adds very little inductance. Because of their shape, ceramic magnets are usually used as a bar under the coil, not as pole pieces. And when iron poles carry a ceramic magnet's field up through the coil, the eddy current losses can end up higher than in an Alnico single coil [11]. Nowhere in his section on ceramic does he

call it harsh. In his broader section on pickup magnets he notes that makers learned long ago that stronger magnets change the sound as well as the volume, but he doesn't use warm or harsh language either [12].

Seymour Duncan notes that makers sometimes use finer wire to mellow out ceramic pickups [8]. Lemme says eddy currents in the magnets themselves are fairly weak (soft iron parts and metal covers carry stronger ones), and he calls claims that one Alnico grade sounds one way and another grade another way completely misleading [3].

So where does the reputation come from? A ceramic pickup tends to be louder and tends to keep a sharper resonant peak. A louder signal pushes your amp into more distortion. Put those together and some players hear "aggressive." But that comes from output level, peak height and the rest of the design, not from some harsh quality baked into the magnet. Ceramic pickups are also often wound hotter or built with steel poles, which muddies any comparison.

Nobody has published a controlled blind test that swaps only the magnet in an otherwise identical pickup. The tendency is real in commercial pickups, but it's a pattern in how they're designed, not proof about the magnet.

Verdict: Mostly busted. Ceramic designs are often louder with a sharper peak, but design choices can move that either way. There is no evidence of a built-in warm or harsh magnet sound.

Myth: Alnico II versus V transforms the tone, and old magnets sound sweeter

> **The claim:** *Swapping an Alnico V magnet for an Alnico II changes everything. And vintage pickups sound sweeter because their magnets have weakened over the decades.*

Zollner measured both magnets: about 35 mT for Alnico II and about 60 mT for Alnico V, measured 2 mm away (mT, or millitesla, is a unit of magnetic field strength) [13]. Then he swapped them in the same coil. The frequency response changed by about 0.8 dB, which he judged inaudible. Across seven different humbucker bar magnets, the differences stayed under 0.4 dB [13]. In his book he adds that, very roughly, Alnico V gives about twice the field of Alnico II at the center of a single-coil magnet (at the string, the figures above show less than double), and that in most cases the stronger magnet gives a small gain in brilliance [14].

What does change? Output level, by up to about 6 dB [13]. That's a real difference. A pickup that's a few dB louder drives your amp harder, and an overdriven amp sounds different when it's pushed harder. So if nobody matches the volume, "the magnet changed my tone" isn't wrong. It just isn't the magnet's frequency response doing it.

Now aging. Zollner says good Alnico magnets lose about 0.1-1% of their strength after 10 years, and Alnico V is cited as losing under 5% in 100 years [15]. Normal temperature swings cause changes of about 0.5% either way that come right back. Meanwhile, the spread between brand-new magnets from production is around 10% either way, which is bigger than anything aging does [15]. He calls the claim that pickups lose noticeable power within two or three years physically unjustified, and he pokes fun at the idea that they reach an ideal tone after about 30 years [15].

Seymour Duncan agrees magnets lose strength slowly over many years, faster with heat, shock, strong outside fields and AC (alternating current). It says rubbing two pickups together to weaken them gives haphazard results, and it built a calibrator to set Alnico magnets to a target strength on purpose [16].

Zollner deliberately weakened magnets and measured what happened. Coil inductance dropped by about 7% in an Alnico II pickup, which raised the resonance about 3.5%, a shift he calls measurable but too small to

hear. In a Stratocaster pickup with Alnico V magnets, the magnetized coil had about 13% more inductance than the demagnetized one, which by my arithmetic is a resonance shift of about 6%. That was a different pickup from the Alnico II test, so it doesn't isolate the magnet grade, and he doesn't say whether that one is audible [13]. His overall view is that a magnet at full strength versus 80% makes a measurable difference but not an audible one, and that demagnetizing pickups in hopes of better treble doesn't really work. Mishandling, on the other hand, is a big deal: magnets stuck together side by side lost about a third of their strength, and repeated contact took up to about half [13].

So why do some old pickups seem sweeter? A weaker magnet means a slightly quieter pickup and less pull on the string. That can make a pickup set close to the strings behave better, and a quieter pickup pushes the amp less hard. Those side effects are the likely story, not sweeter treble. Keep in mind that Zollner's magnet article is a knowledge-base piece, not a peer-reviewed paper, and nobody has published a level-matched blind test of Alnico II versus V.

Verdict: Mostly busted. Alnico II versus V mainly changes output level and string pull, not the frequency response. Natural aging over decades is too small to hear, though magnets damaged by rough handling can lose a lot.

Try it yourself: If you're swapping a magnet anyway, record the same riff before and after, match the two files in level, and have a friend play them back in random order. No swap planned? Turn your amp up 2 or 3 dB and notice how much "better" the same pickup sounds. That's the size of change a magnet swap mostly makes.

Myth: Scatter winding and vintage wire insulation are magic

> **The claim:** *Hand-guided "scatter" winding and old-style plain enamel or Formvar wire give a pickup air, clarity and true vintage tone.*

Scatter winding means the wire is laid on the bobbin in a looser, less orderly pattern than a machine's neat layers. Plain enamel and Formvar are types of insulating coating on the wire.

Winding pattern and insulation thickness change how tightly the turns pack. That changes the coil's own capacitance, and if the bobbin is full, it changes how many turns fit, which changes inductance. Both move the resonant peak.

So how big is it? Zollner did the math. Doubling the coil's capacitance from 50 pF to 100 pF, with a 450 pF cable attached, shifts the resonance about 5%. That's the same shift you'd get by making your cable longer, going from 3.75 m to 4.15 m [17]. He says a difference that small can't be ruled out in a careful side-by-side test, but it's small.

Insulation thickness can matter more indirectly. Thicker double-coat wire takes about 20% more space, so on a full bobbin you'd fit about 17% fewer turns, which lowers inductance and output [17]. At the same number of turns, DCR only rises about 2% [17]. The varnishes themselves are non-magnetic and their electrical losses are negligible. He calls bobbin material effects highly secondary, and says it seems excessive to give the type of varnish much significance [17].

The Batchelor preprint I mentioned earlier found that wire gauge at equal turns does shift the resonance, and the authors suspect capacitance is part of the reason, though they didn't measure it directly [10].

Nobody seems to have published a measurement of a machine-layered coil against a scatter-wound coil with the same turns and wire, let alone a listening test.

Verdict: Mostly busted. The effect is real and measurable, but its size is about the same as using a slightly longer cable. Nothing about scatter winding or enamel type is special beyond that.

Myth: Wax potting kills tone

> **The claim:** *Potting a pickup in wax chokes it. Unpotted pickups sound more open and airy.*

Potting means soaking the pickup in hot wax so it fills the gaps in the coil and between the cover and the bobbin. Some vintage-style makers sell unpotted or lightly potted pickups as the more "open" option.

Why pot at all? A pickup can act like a microphone. If the windings or the cover can vibrate, they turn that vibration into signal, and at high gain that becomes squeal. Seymour Duncan describes potting as a way to saturate the coil with wax so nothing can wiggle, eliminating that microphonic feedback. Its article doesn't claim any tone loss [18].

Zollner measured how microphonic pickups are. At a very loud 114 dB of sound, a pickup picked up about 10 mV from the air, against a string signal of up to about 2 V [19]. That's tiny. The bigger issue is a part that rings: one Seymour Duncan pickup he tested, with its wax removed, showed a spike at 2.5 kHz in its response to sound in the air, which can color the sound at high gain. That's the kind of resonance wax between the bobbin and the cover is there to damp, and the least sensitive pickup he measured was one potted in a hard material [19]. With a well-damped housing, there is little effect on clean or stage-volume sound.

What about the electrical side? Wax does add a little coil capacitance, but Zollner calls that change marginal next to cable capacitance [17].

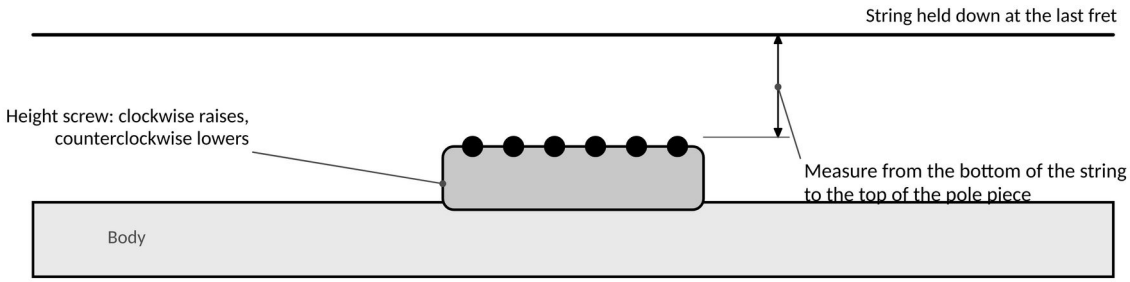
So an unpotted pickup can add some ringing from its own cover or coil, and some players might like a bit of that at clean volumes. That's taste, and it's fine. But it isn't tone from the strings, and nobody has blind-tested potted against unpotted versions of the same pickup.

Verdict: Mostly busted. The electrical effect of wax is marginal. Its main effect is the one it's meant to have: stopping squeal at high gain.

Myth: Pickup height only changes volume

> **The claim:** *Pickup height is a volume knob. Raise it for more output, lower it for less, and that's all.*

Yes, height changes volume, and fast. Zollner measured output falling about 3-4 dB for every millimeter you move the pickup away [5]. But moving it away also widens the window the pickup "sees" on the string, and that costs treble [5]. So height changes brightness as well as level.



Check the bass side and the treble side of every pickup.

Figure 6.2: Pickup height is measured from the top of the pole piece to the bottom of the string, with the string held at the last fret.

Then there's the magnet pulling on the string. Zollner found the magnet acts like a reverse spring, lowering the string's pitch, and the fundamental (the main note) gets detuned the most, by several hertz in his measurements [20]. That goes against the common claim that only the upper harmonics go off. The magnet also splits the string's up-and-down and side-to-side vibrations into slightly different pitches, and those beat against each other as a slow warble [20]. The effect grows as the magnet gets closer, and with strong magnets it can be heard. Lemme calls this "Stratitis" and says lowering the pickup cures it [3].

Sustain takes a hit too. At 2.5 mm from the strings, the magnetic damping is minor, less than the effect of resting your hand on the neck. But at 1 mm and 0.8 mm, which he notes are unusually close, the first two partials (the fundamental and the first overtone) lose a lot of energy [21].

The heights makers publish run from about 1.2 to 3.2 mm (my book *Inside the Electric Guitar* collects them in Chapter 19), so a pickup set to spec sits between Zollner's minor case at 2.5 mm and his heavy losses at 1 mm and closer. It's the very close settings that cost real sustain. Warble depends a lot on magnet strength, and Alnico V single coils with magnetic pole pieces are the classic offenders.

Verdict: Busted. Height changes level, brightness, tuning, warble and sustain, and all of those have been measured.

Try it yourself: Fret a note high up the neck on the low E string and let it ring. If it warbles or sounds slightly out of tune, lower the neck pickup a little at a time and listen again.

Myth: Active pickups are sterile

> **The claim:** *Active pickups, like EMGs, sound sterile, compressed and lifeless next to passive pickups.*

An *active* pickup is a passive coil followed by a small battery-powered preamp (a little amplifier) inside the guitar.

ElectroSmash, an electronics site, took apart the circuit of the EMG 81. It uses low-turn coils, about 4.18 kOhm per coil (roughly 5,500-6,000 turns), with an onboard preamp gain of about 5.5 times (14.8 dB) [22]. The circuit also rolls off the low end below about 241 Hz, which removes hum and the deepest bass, and the two coils are deliberately unbalanced electronically, which ElectroSmash ties to the pickup's signature sound. Because the preamp's output impedance (about 10 kOhm) is far lower than a passive pickup's at its resonance, the sound is relatively unaffected by your cable, pedals and amp input [22]. Impedance is just resistance to an AC signal like your guitar's; a low output impedance means the pickup can push a signal through a long cable

without the cable dulling it. Lemme makes the same point: a buffer inside the guitar shields the pickup from cable loading and lets the designer set the resonance on purpose [3].

On a passive pickup, your cable, pots and amp all help shape the resonant peak. On an active pickup, they don't. The designer picks the voicing, and it stays the same whatever you plug it into. ElectroSmash doesn't describe the sound as sterile [22].

"Sterile" names a voicing, not something built into active electronics. A different active design could be voiced like a vintage passive pickup. And a hotter output drives your amp harder, which changes the distorted sound too.

There is one difference players do feel. Passive pickups interact with the volume and tone knobs and the cable, and many players use that on purpose. Active pickups mostly don't, so they can feel less interactive. That's a difference in behavior, not proof of a worse tone.

Verdict: Mostly busted. "Sterile" is a voicing choice in particular products, not a property of active electronics. Active pickups do respond less to your knobs and cable, but nobody has blind-tested whether players hear them as worse.

What this means for your money

- Stop shopping by DC resistance. It barely tells you anything across brands. Inductance and magnet type tell you more, if the maker will share them.
- Set your pickup height before you buy anything. It changes volume, brightness and sustain, and it costs nothing.
- If a pickup swap sounds better, check whether it's just louder. Level-match before you decide.
- Don't pay extra for aged magnets, scatter winding or special wire coating on the promise of magic. The measured effects are small, about the size of changing your cable.
- Choose potted pickups if you play at high gain. You give up very little.
- Pick active or passive based on how you play. If you ride your volume knob a lot, passive may suit you better. If you want the same sound with any cable, active has the edge.

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Chapter 7: Pots, Caps, and Cables

The pickup gets all the attention, but it isn't working alone. Between the pickup and your amp sit a few of the cheapest parts on the guitar: a couple of knobs, one small capacitor, an output jack, and a cable. Players argue about every one of them. Should you use 250k or 500k pots? Is a paper-in-oil tone cap worth many times the price of a plain film one? Will a pricey cable make your rig sound better than a basic one?

In Chapter 6 we saw that a passive pickup has a resonant peak, a small boost in the upper mids where the pickup naturally rings, with treble falling off above it. Almost every part in this chapter works on that peak. Some parts move it lower. Some make it shorter. Once you know which part does which, you can sort the real effects from the marketing pretty fast.

One warning before we start, and it's the same one from Chapter 6. The evidence here is measurement and circuit physics. I didn't find a single controlled blind listening test on pots, tone caps or cables. So I'll tell you what the measurements say, and I'll tell you where they stop.

A quick refresher on the peak

I won't repeat all of Chapter 6, but here's the short version. Your pickup's coil and the *capacitance* around it (capacitance is the ability to store a little electric charge, and every wire and cable has some) form a resonant circuit. The amount of capacitance helps decide *where* the peak sits. More capacitance pulls the peak lower, and a lower peak sounds darker [1].

The height of the peak is a separate thing. Engineers call it *Q*. Zollner notes that with the volume and tone pots and the amp input connected, Q is typically about 3. With nothing hanging on the pickup but about 600 pF (picofarads, a very small unit of capacitance), Q can reach about 9 on the Jazzmaster pickup in his example, and he says that sounds shrill [2]. What pulls the peak down from 9 to 3? Mostly the *load*, which just means anything connected across the pickup that soaks up a bit of its signal. Resistance is the main kind of load here. *Resistance* is how hard a part makes it for current to flow, measured in ohms.

How much does the height matter? Lemme says the peak on real pickups ranges from barely there to about four times the level around it, which is roughly 0 to 12 dB, and that it's set by the magnet material in the coil, the metal cover and the resistive load [1]. Only the last of those is something you can change with a screwdriver and a soldering iron in an afternoon, and that's the pots.

So you have two levers. Capacitance moves the peak lower. Resistive load makes the peak shorter. Cables mostly pull the first lever (they also make the peak a little taller, as we'll see). Pots mostly pull the second. The tone cap does a bit of each, depending on where your tone knob sits. Keep that picture in your head and the rest of this chapter falls into place.

The knobs

Myth: 250k versus 500k pots makes a real difference

> **The claim:** *Use 250k pots with single coils to tame their brightness and 500k pots with humbuckers to open them up. The value of the pot changes the sound.*

A *potentiometer*, or pot, is the variable resistor behind each knob. The "250k" or "500k" is its resistance in thousands of ohms (kOhm). Even when the knob is on 10, the pot is still sitting across the pickup, so it acts as a load all the time.

Zollner describes the pot as a resistive load in parallel with the pickup that sets how much the resonant peak gets damped [2, 3]. *Damping* here means soaking up energy so the peak gets flatter. Helmuth Lemme, whose pickup article I leaned on in Chapter 6, measured a 1972 Strat pickup with 470 pF of capacitance across it and tried loads from 10 kOhm up to 10 MOhm (million ohms). The lower the load resistance, the lower the peak, and at 47 kOhm or less the peak vanished completely [1].

So the lore has the direction right. A 500k pot loads the pickup less, the peak stays taller, and the guitar sounds brighter. A 250k pot damps the peak more and sounds a bit softer on top. The pot value doesn't move the peak's frequency much. It mostly changes how tall it is.

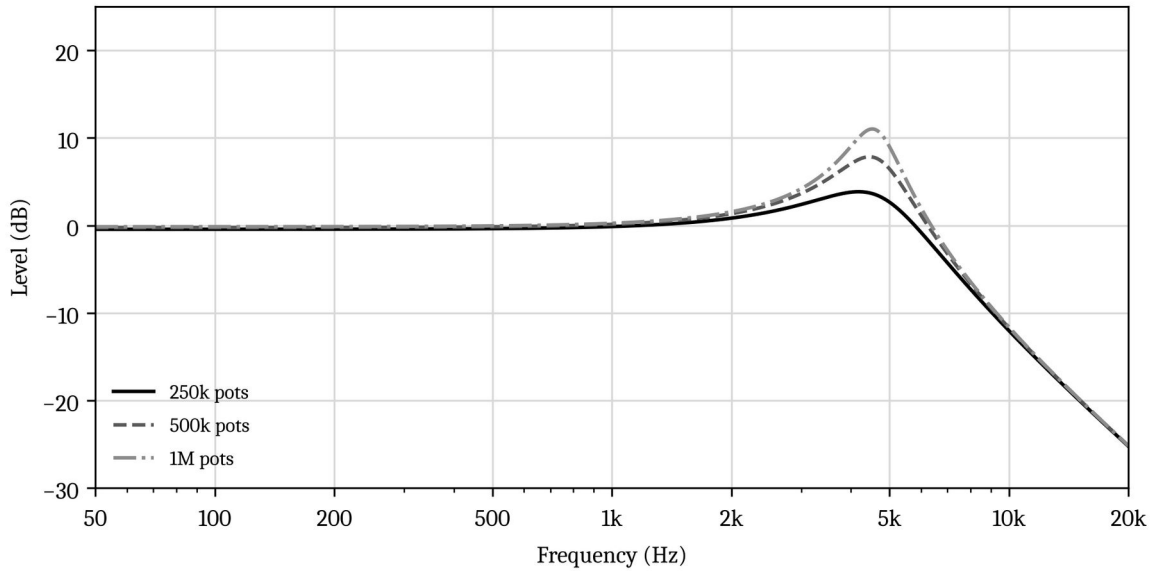


Figure 7.1: A simple circuit model of a Strat-type pickup (2.2 H, 5.8k) with 250k, 500k and 1M pots, volume and tone on full, 1 MOhm amp input and 450 pF of cable. Bigger pots mostly raise the height of the peak; its frequency moves only a little.

The number printed on a pot is only close. Zollner says today's pots are made to about plus or minus 20% [3], so a pot sold as 250k could measure anywhere from 200k to 300k, and he mentions outliers as far off as 350k, which would sound brighter, or 150k, which would sound duller, especially in older guitars [3]. Two pots with the same label can differ by a good part of the jump from one label to the next. If you've ever swapped a pot for "the same value" and heard a change, that could be why. Zollner suggests two simple fixes for a pot that reads too high: back the tone knob off a touch, or add a 0.9 MOhm resistor across it [3].

The volume pot has its own story. When you turn it down, you put resistance between the pickup and the cable's capacitance, and that damps the peak until it disappears. A high value makes this worse. Zollner says the 1M (one million ohm) volume pot on a Jazzmaster kills the treble hard when you turn it down even a little [3]. The usual cure is a *treble bleed*, a small capacitor across the volume pot that lets some highs slip past. Fender put a 1 nF (one nanofarad, or 1,000 pF) cap on the Telecaster's 1M volume pot starting in 1967 [3].

Two more limits. How much you hear depends on the pickup. A pickup that already loses a lot of energy to eddy currents in its metal parts (see Chapter 6) has less peak to protect, so the pot matters less. And on a guitar like a Les Paul, with two volume and two tone pots all hanging on the circuit, the total load is lower than any single pot's label suggests. I also couldn't find a published decibel number for a straight 250k versus 500k swap. Zollner's section shows curves rather than a single figure, but the direction and the mechanism are clear.

Verdict: True. Pot value changes the height of the pickup's peak. That rests on measurement rather than a listening test, and Zollner describes the result as a change in brightness. But the label is a rough guide, because a pot can be 20% off its printed value either way.

Try it yourself: Before you install new pots, check each one with a multimeter set to resistance (ohms), across the two outer lugs (the solder tabs on the outside). If you're chasing a particular sound, pick the ones that measure closest to what you want.

Myth: The type of tone capacitor changes your tone

> **The claim:** *Paper-in-oil, vintage-style bumblebee and Orange Drop tone caps each have their own sound, and the right type is worth paying for.*

A *capacitor* is a part that stores charge and lets high frequencies through more easily than low ones. In your tone control, the cap and the tone pot work together with the pickup to cut treble when you roll the knob down. Vintage parts makers sell replica "bumblebee" caps, and Zollner mentions the mojo claims around original ones [4].

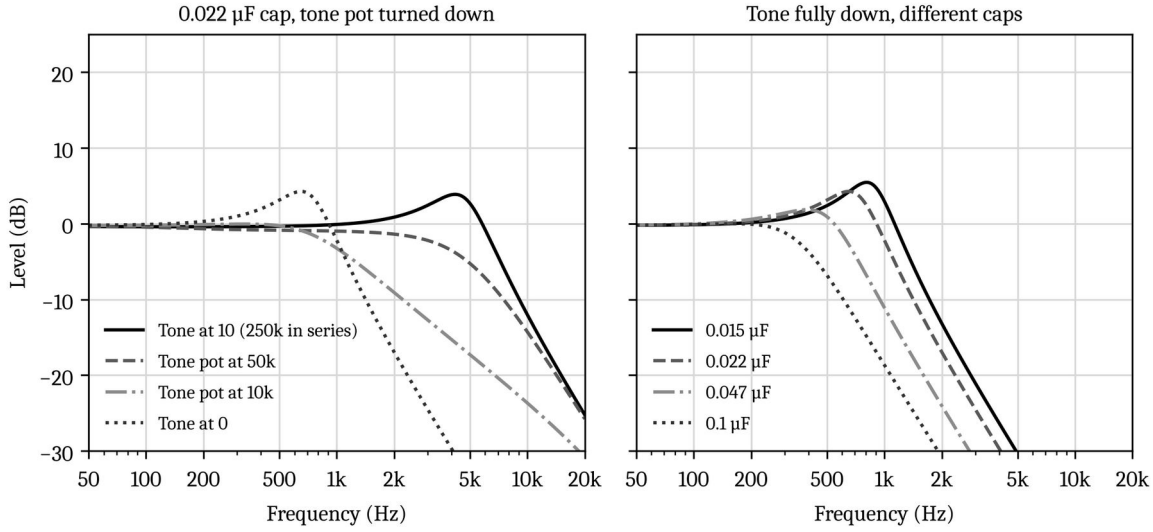


Figure 7.2: The same simple model with the tone control in play. Turning the tone down makes a new, lower peak, and the cap's value sets where it lands. The model uses only the cap's value, and Zollner's measurements found the cap's type made no audible difference.

He tested the question in two positions. First, tone knob all the way up. In that position the 250-500 kOhm pot is so much bigger than anything the cap does that the cap barely matters. Replacing the cap with a plain piece of wire changed the output by less than 0.01 dB [4]. (0.01 dB is a tiny sliver of a decibel.) If you play with your tone knob on 10, your tone cap is close to doing nothing at all.

Second, tone knob all the way down. On a Strat, that moves the resonant peak down to about 350 Hz [3]. Now the cap is working hard, and this is where cap types differ. Each type wastes a little energy as heat, a figure called the *dissipation factor*. Zollner lists typical values: polystyrene about 0.1%, polypropylene about 0.3%, polycarbonate about 1%, paper 4-8%, polyester 5-10%, and some ceramic types up to 30% [4]. That sounds like a big spread. But he rates paper and polyester caps as well suited and says they can be used without any audible loss. With the knob fully down, he puts the level effect of capacitor losses under 0.1 dB, and to show what heavy losses look like on his curves he had to model an artificial 60% capacitor, one he says nobody solders into a guitar [4]. He also checked distortion at a 2 V signal and found it under 0.01% for film caps and 0.1% for ceramic, which he ruled out as audible. His conclusion, in plain words: the losses of ordinary capacitors have no audible effect on the sound [4].

So what does matter? The *value*, measured in nanofarads (nF). A bigger cap gives a darker sound as you roll the knob down. A smaller one leaves the peak higher. Zollner points out that a 20% tolerance on a Strat tone cap, say 40 nF versus 60 nF, gives audible level differences [4]. Lemme goes further and suggests a switch with tone cap values from about 470 pF up to 10 nF, because the value is the thing that actually moves the sound [1].

That also explains a lot of vintage cap stories. Old caps can drift in value or leak. A drifted vintage cap is really just a different value, and that you can hear. Keep in mind Zollner's results come from measurement and modeling, not a blind listening test.

Verdict: Busted. Cap type makes no audible difference in a guitar tone circuit, by Zollner's measurements. The cap's value really does change the sound when the knob is turned down.

Try it yourself: If your tone knob feels too dark or too subtle, try a different value, not a different type. A cheap film cap in a new value will change more than an expensive cap in the same value.

The cable

Myth: Long cables dull your sound

> **The claim:** *A long guitar cable sucks the treble out of your tone.*

Every guitar cable is a capacitor. Two conductors (the center wire and the shield around it) run side by side for the whole length, and that stores charge. Zollner puts typical cable capacitance at about 100 pF per meter, give or take 30% [5]. A normal cable comes in around 300-600 pF, a very long run can reach about 1.5 nF, and special low-capacitance cables get down to about 70 pF per meter [5]. Lemme gives a range of about 300-1,000 pF and says that with a passive pickup, changing the cable changes the sound [1].

Why? Because that capacitance sits right across the pickup and helps set the resonant peak from Chapter 6. More capacitance pulls the peak lower, and in Zollner's description it also makes the peak more pronounced [5]. Above the peak, treble falls away fast. So a longer cable gives you a lower, darker peak and less sparkle on top.

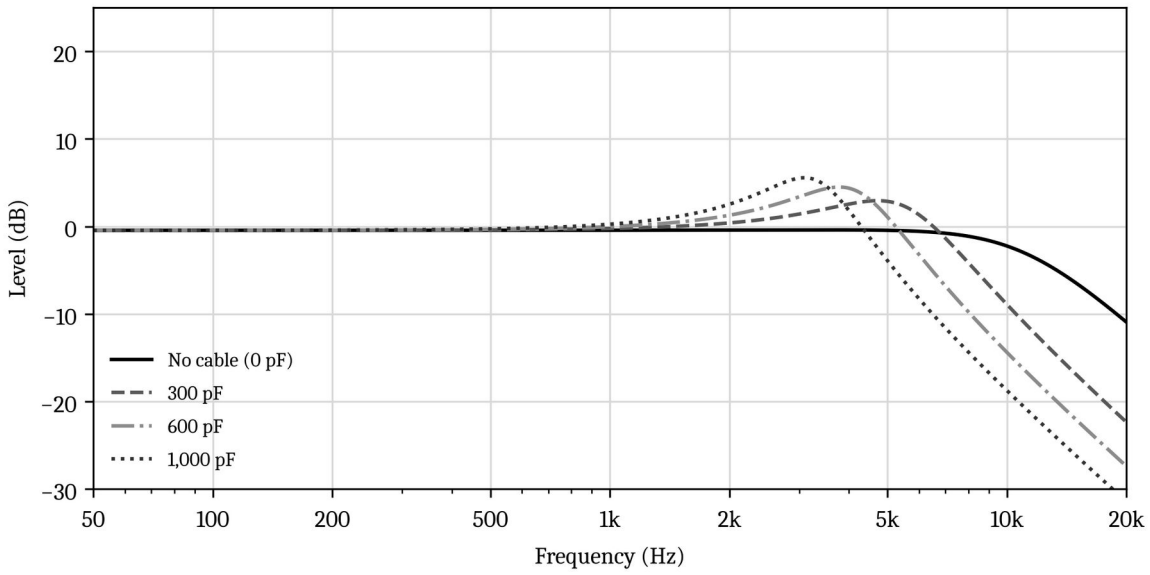


Figure 7.3: The same simple model with no cable and with 300, 600 and 1,000 pF of cable capacitance. More capacitance moves the peak lower and makes it taller.

How big is the effect? By my arithmetic, doubling the total capacitance lowers the peak by about 30%. Doubling the cable length does a little less, because the pickup's own capacitance doesn't change, but going from a 3 m (10 ft) cable to a 6 m (20 ft) one still drops the peak by roughly a quarter, and you lose more of the highs above it. Small changes are small, though. Zollner shows that stretching a cable from 3.75 m to 4.15 m, about 11% longer, shifts the resonance by about 5% [6]. A few feet makes little difference. Doubling the length makes a clearly noticeable one.

Players often add that a cheap cable is worse. Here the lore goes a bit sideways. Price isn't the problem. Capacitance per meter is, and it varies by roughly two to one between cable models. A cheap cable with low capacitance can sound brighter than a pricey one with high capacitance. The other things a cable has, like a few ohms of resistance and about 1 microhenry of inductance, are tiny next to a pickup's thousands of ohms [5]. Zollner also found that handling noise, the crackle some cables make when you step on them, isn't audible in good cables [5].

Verdict: True. Cable capacitance is part of your pickup's tone circuit, and more cable means a lower, darker peak. That rests on measurement and circuit physics. Price has nothing to do with it; the number that counts is capacitance per meter.

Try it yourself: Plug straight into your amp with your shortest cable, then your longest, with the same settings. Listen to the top end of a clean chord. That difference is your cable.

Myth: Expensive, gold-plated, oxygen-free cables sound better

> **The claim:** *Premium cables with oxygen-free copper, gold-plated plugs and fancy construction give you more clarity and detail.*

Let's go back to what a cable actually does in a passive guitar rig. Zollner says the resistance (a few ohms) and inductance (about 1 microhenry) of any normal cable are negligible, and that audible differences between

cables come from capacitance [5]. In his view, good cables with good plugs cost about 20 dollars all in, and sky-high prices can't be justified by physics [5].

His section doesn't talk about oxygen-free copper or gold by name, so here's the reasoning. Oxygen-free copper is purer copper with slightly lower resistance. But the cable's whole resistance is only a few ohms, and your pickup is thousands of ohms. Shaving a sliver off a few ohms does nothing you could hear. Gold plating on the plugs fights corrosion on the contacts. That's a reliability feature, not a tone feature.

So can two cables sound different? Yes, if their capacitance per meter differs. That's a number you can measure, and some makers publish it. If an expensive cable sounds brighter, look for a lower capacitance figure, not magic copper.

There are honest reasons to spend a bit more. Tough plugs that don't crackle, solid strain relief and good shielding against hum are worth paying for, because they keep your rig working. As far as I could find, nobody has published a credible blind test of premium against standard guitar cables.

Verdict: Busted. Conductor material, plating and price don't change the sound. Any real difference traces back to capacitance per meter, which you can check on a spec sheet.

Try it yourself: When you shop for a cable, look for the capacitance in pF per meter or per foot. If a maker won't tell you, that tells you something too.

The fix for long runs: buffers

So what do you do if your rig needs a lot of cable? Maybe you run a pedalboard, then a long cable to the amp across a big stage. That's where a *buffer* comes in.

A buffer is a small circuit, usually with no gain, that takes the pickup's signal and drives the next cable for it. To explain why that helps, remember *impedance* from Chapter 6: resistance to an alternating signal like your guitar's. A passive pickup is a high-impedance source, which means it's easily dragged down by what you hang on it. A buffer has a high input impedance, so it barely loads the pickup, and a low output impedance, so the cable after it can't load the pickup at all. Lemme makes this point too: a buffer isolates the pickup from cable loading [1]. The active pickups in Chapter 6 do the same thing inside the guitar.

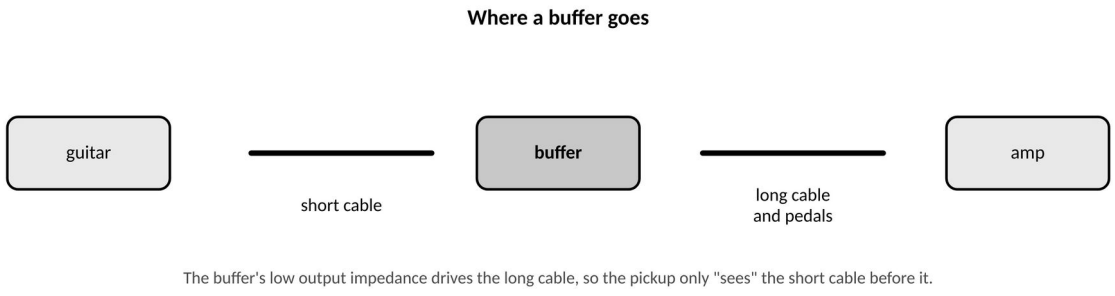


Figure 7.4: A buffer early in the chain drives the long cable, so the pickup only sees the short cable in front of it.

BOSS says treble loss from cable becomes noticeable around 18 feet, that real rigs can easily total 40 feet or more, and that a buffer can drive about 100 feet after it with little loss [7]. Keep in mind BOSS makes buffered pedals, so it has a stake. But the physics matches what Zollner and Lemme describe. Once a good buffer is in the chain, the length of cable after it stops mattering much.

Buffers come with their own debate, mostly about whether every pedal should be "true bypass" instead. That argument belongs to Chapter 12, along with where to put a buffer and which pedals don't like one.

Which change is biggest?

You might ask, "If I can only change one thing, which one will I hear most?" Nobody has run a listening test that ranks these against each other, so this is my own read of the numbers above.

For most players I'd put the cable first. Doubling the length of a passive rig's cable moves the peak down noticeably, and that's a change you can hear on any clean chord. The tone cap's value comes next, but only when the tone knob is down; with the knob on 10 it hardly counts. Pot value comes after that. It changes how tall the peak is, not where it sits, and the 20% tolerance means two pots with the same label can sound noticeably different. At the bottom of the list sit cap type and cable materials, where the measured differences are a small fraction of a decibel or nothing at all.

Notice something about that list. The parts that matter are the ones with a number you can measure: capacitance, resistance, length. The parts that don't matter are the ones sold with a story.

What this means for your money

- Pot values matter, but measure them. With a tolerance of about 20% either way, the printed label only gets you in the neighborhood.
- If your guitar goes dull when you roll the volume back, a treble bleed cap costs pocket change and usually fixes it.
- Don't pay extra for a tone cap's type. Spend your time picking the right value instead.
- Keep your cables as short as your stage allows, and look for a low capacitance number when you buy.
- Spend cable money on tough plugs and good shielding, not gold or special copper. About 20 dollars buys a good one, by Zollner's estimate.
- If you need a lot of cable, put a buffer early in the chain. Chapter 12 covers where.

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Chapter 8: Strings and Scale Length

Strings are the cheapest tone part on your guitar, and they're the one part every note has to pass through. You can argue about body wood all day, but the string is where the sound starts. On an electric, it's also the only thing the pickup can actually sense.

That makes strings a great place to test tone claims. Gauge, alloy, coating and age are easy to change, and a few researchers have measured them carefully. Zollner spent whole sections on strings, and most of this chapter leans on his measurements. The weak spot is the same one you'll see all through this book: lots of bench measurements, very few blind listening tests.

At the end of the chapter we'll look at scale length, the distance from nut to saddle, because it changes how the same set of strings behaves. I won't cover how to change or clean strings here. My book *Guitar Care and Maintenance* handles that.

A little string physics first

Two things about a string decide most of what follows: its tension and how much steel it puts over the pickup.

Tension is how hard the string is pulled tight. At a given pitch and scale length, a heavier string has to be pulled tighter to reach the same note. D'Addario's guide to string tension gives the formula and shows that, at the same pitch and scale, an 11-52 set carries more tension than a 9-42 set [1]. The article itself makes no claim about tone. It's just mechanics.

Here's what the formula means in plain numbers. For a plain steel string, the tension at a fixed pitch goes up with the square of the string's thickness. So moving from a .010 to a .011 high E raises the tension by about 21%. That's my own simple arithmetic from D'Addario's formula, not a measurement, but it shows how fast tension climbs with even a small gauge bump.

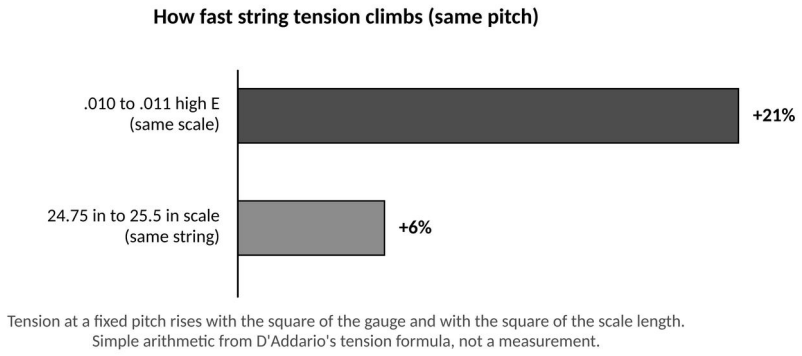


Figure 8.1: Small changes in gauge or scale move tension a lot.

The second thing is the pickup. A magnetic pickup senses steel moving in a magnetic field (Chapter 1 covers how). Zollner found that for plain strings, the pickup's output goes up with the string's cross-section, the area you'd see if you cut the string through. Double the diameter and, with everything else the same, the output

voltage goes up four times [2]. Wound strings are a different story. The winding raises the string's cross-section about seven times but the voltage only about twice, so wound strings are magnetically much less efficient [2].

Keep those two ideas in your pocket. Tension and steel explain most of what's true about strings, and the rest is about how the string hits the frets and how it loses energy.

Myth: Heavier strings give a bigger tone

> **The claim:** *Go up a gauge or two and you'll get a fatter, louder, punchier sound.*

This one has deep roots. Ernie Ball's buying guide says heavier gauges give hotter output and a punchier tone [3]. In a 2010 interview quoted by Guitar World, John Mayer allowed that bigger strings might give a better tone, but asked what good that is if you can't bend up to the note, and called the gauge argument about the silliest thing a guitarist can engage in [4]. Neither offers measurements, but plenty of players swear by it.

So what does the physics say? Quite a bit, and it mostly supports the claim, with some catches.

First, output. As we just saw, a thicker plain string puts more steel in the pickup's field, so it makes more signal [2]. That's real "hotter output," at least on the plain strings.

Second, energy. A heavier string at the same pitch sits at higher tension, so it's stiffer under the pick. Zollner points out that the force the string puts on the bridge doesn't depend on its diameter. But a heavier string can take a harder pluck for the same amount of movement, so it can sound louder if you dig in and use that [2].

Third, and this is the one I find most interesting, fret contact. Every time a vibrating string slaps the frets, it adds a burst of bright, buzzy treble. Zollner found that the threshold for that slap drops with lower action and lighter strings [5]. He also found that, at equal pluck force, heavier strings bounce less against the frets and sound fuller [2]. Another of his sections shows that fret contact adds treble, and that how hard the winding is changes how much [6]. So part of what players hear as "bigger" from heavy strings is really "less fret slap."

Now the catches. A lot of "bigger" is just "louder," and you can also get louder by turning up the amp or raising the pickups. Zollner ran a small listening test that shows how hard level differences are to hear: with Fender strings and equal pick force, a careful player could just barely pick out a difference of about 4 dB between the G and D strings, and in normal playing nobody noticed it [2]. That test was about string-to-string balance, not a gauge swap, but it's a reminder that small level changes are easy to miss.

There's also a big problem with how most of us test this. When you put on heavier strings, you almost always play them differently. You pick harder, you fight the bends, you change your touch. That alone changes the sound. I couldn't find any blind listening test that compared gauges at matched output.

On an acoustic, more tension and more pluck energy can drive the top harder. That follows from the same mechanics, but nobody seems to have measured it on acoustics specifically, so treat it as a sensible guess.

Verdict: Partly true. Heavier plain strings really do give more pickup output, store more energy and slap the frets less. But much of "bigger" is a level change the volume knob can also deliver, and no blind test of gauge alone has been done.

Try it yourself: Record the same riff on one guitar with a lighter set, then restring with a heavier set and record it again. Match the two files in level (Chapter 13) and have a friend play them back in random order. Expect your playing to change with the gauge; that's part of the result.

Myth: Nickel, pure nickel and stainless sound different on an electric

> **The claim:** *Pure nickel is warm and vintage, stainless is bright and edgy, and nickel-plated steel sits in the middle.*

Ernie Ball's guide says pure nickel gives vintage output with a warm tone and stainless gives a bright, crisp, edgy tone [3]. SIT Strings calls pure nickel warmer and stainless brighter than nickel-plated steel, without data [7]. These descriptions are everywhere.

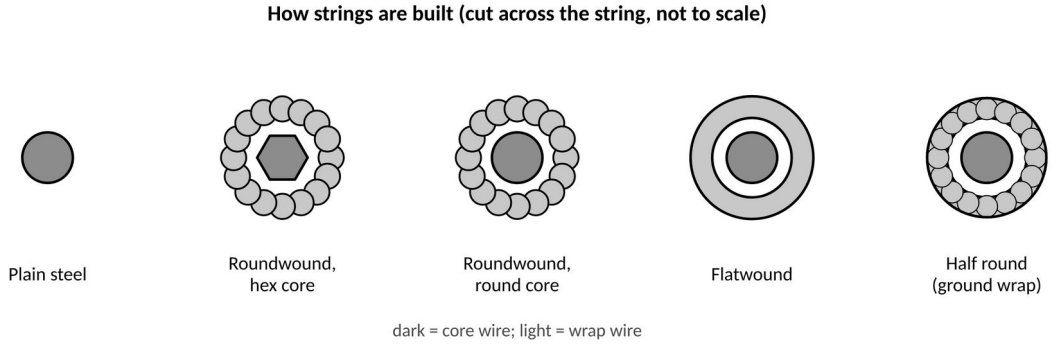


Figure 8.2: How strings are built, cut across the string (not to scale). The pickup senses the steel moving in its field.

Start with what the pickup can hear. A magnetic pickup only senses metal that a magnet can grab. Zollner looked at this closely. The nickel plating on a nickel-plated steel string is far too thin to matter magnetically, so the steel underneath does the work. Pure nickel is magnetic too, so it also works as a winding [6].

Then he measured. On a test bench that shook the strings the same way each time, a pure nickel wound string and a steel-wound string showed no difference in level. A nickel-coated steel-wound string read about 1 dB higher, and roughly half of that came from a slightly thicker core, leaving about 0.5 dB for the winding material itself [8]. That's a tiny difference. He also notes that the strings' mechanical vibration could still differ even when their magnetic behavior is about the same [8].

So where does the real difference come from? Fret contact, again. Zollner compared a nickel-plated steel set and a pure nickel set on the low E and heard a difference he described as just about noticeable. Then he raised the bridge so the strings stopped hitting the frets after the pluck, and the two sounded the same [6]. His explanation is that pure nickel is softer and soaks up more of the bright fret-contact treble. In a related section he notes that steel-wound strings sound more aggressive and treble-heavy than pure nickel when they bounce off the frets [5].

So the material difference is real, but it shows up mostly through the way the winding rings against the frets, not through the pickup.

What about stainless steel? Zollner's steel-wound test string was a Fender 350, a set Fender sells as stainless steel, and on his bench it showed no difference in level from the pure nickel Fender 150 [8]. So magnetically, stainless sits with the others. Its harder winding should add more fret-contact treble, as his bouncing-string note above suggests [5]. I found no blind listening test of stainless against nickel.

Verdict: Partly true. The magnetic output differences between nickel, nickel-plated and stainless windings are tiny, 0 to about 1 dB on Zollner's bench. The difference you can hear comes mostly from how hard the wrap is when it hits the frets, and in one test it disappeared when fret contact was removed.

Myth: Phosphor bronze and 80/20 sound different on an acoustic

> **The claim:** *80/20 bronze is bright and bell-like, and phosphor bronze is darker and warmer.*

This one is close to universal in shops and on string packs. Cream City Music's blog says 80/20 is brighter and phosphor bronze darker and warmer [9]. (Despite the name, the same blog describes 80/20 "bronze" as a mix of copper and zinc, the metals in brass, and gives phosphor bronze as roughly 92% copper and 8% tin, with a trace of phosphorus, about 0.2% [9].) D'Addario's own product page calls its 80/20 set its brightest acoustic string [10]. That's a maker's tone claim. The page lists tensions for the set, but it gives no measurement against phosphor bronze.

What does Zollner say? He reports that sources actually conflict on whether phosphor bronze is mellower or brighter than 80/20, and that manufacturers' claims about string materials are often vague or misleading [6]. He also points out that bronze is a very poor magnetic material, thousands of times weaker than steel or nickel [6]. That doesn't matter on a plain acoustic, since there's no magnetic pickup. It does explain why a bronze string can sound weak through a magnetic sound-hole pickup. In one of his tests, a string with half its winding in bronze was about 2 dB less sensitive than a steel-wound string with the same core [6].

On an acoustic, both alloys are non-magnetic, so any difference would have to come from the metal's density, hardness and how much energy it loses as it vibrates. Zollner notes that on piezo-equipped guitars, harder, low-loss winding materials sound more brilliant [6]. That's a general rule, though, not a phosphor bronze versus 80/20 test.

One side note on durability. The corrosion testing lab at the Silesian University of Technology published a bulletin article (not a peer-reviewed paper) on strings dipped in artificial sweat. The phosphor bronze acoustic string corroded much more readily than the others in their test, with a corrosion resistance measure about 50 times lower. The authors put that down to the bronze wrap and the steel core reacting with each other [11]. That's a lifespan question, not a "new string tone" question, but it might matter to you if your strings die fast.

Verdict: No good evidence either way. The brighter 80/20 claim is everywhere, but nobody has published a clean measurement or blind test comparing the two alloys, and the sources that exist contradict each other.

Try it yourself: Put a fresh set of each on the same guitar, a few days apart, and record the same strummed chord and single notes from the same mic spot. Have a friend rename the files A and B, then listen back later.

Myth: Coated strings sound dead

> **The claim:** *Coated strings last longer, but you pay for it with a dull, lifeless sound.*

MusicRadar noted that some players find coated sets have less top end than a fresh uncoated set [12]. Even GHS's own blog says coatings can subtly reduce brightness, while claiming its own coated set gives longer life without sacrificing tone [13]. On the other side, Elixir says its NANOWEB coating is so thin it sounds bright and close to uncoated, while its POLYWEB coating has a warmer, played-in tone. Elixir also says the coating keeps grime out of the gaps between the windings [14]. None of these give numbers.

The physics makes sense of both sides. A coating adds a thin layer of plastic with a bit of mass and some built-in *damping*, meaning it soaks up a little vibration energy. In principle that could soften the very top end of a brand-new string. But the coating also blocks the main thing that kills strings. As we'll see in the next myth,

Zollner found that gunk packed into the windings is the biggest source of string damping as strings age [15]. So a coated string might start a hair less bright and then stay bright longer.

Is there any measurement? The only one I found is a US patent filed by P. J. Everly. That's a patent, not a peer-reviewed study. It compared three strings coated with the inventor's own thin polymer film against uncoated ones, measuring how fast the sound level fell over the first 5 seconds. On two of the three, the coated string actually decayed more slowly. On the third, it decayed a bit faster [16]. The patent doesn't name the brand of the test strings, the inventor had a stake in the coating, and nobody has repeated the test independently. It's mixed, and if anything it leans slightly toward coated strings holding their sound.

There's one more problem with the claim. "Coated strings" isn't one thing. Some are wrapped in a polymer, some have only the winding coated, and some have a thin plated treatment. Lumping them together is too broad.

Verdict: No good evidence either way. Nobody has published a controlled measurement or blind test of new coated against new uncoated strings, and the only measurement found, from a patent, is mixed.

Myth: Old strings sound dull

> **The claim:** *Strings go dead with age, and fresh strings bring a guitar back to life.*

Every player believes this. So does Elixir, which blames dead strings on corrosion and residue from your fingers [14]. This time the measurements are strong.

Zollner compared an old and a new open low E string. The low partials barely changed. The second partial, at 164.8 Hz, died away at practically the same rate on both strings. (A *partial*, or harmonic, is one of the higher tones stacked above the note you play. Hz, or hertz, means vibrations per second.) But up at 2,391 Hz, the old string's ring time dropped to one seventh of the new string's [17]. That's the sparkle going away while the body of the note stays put. In his words, an old string sounds dull [17].

Why does it happen? Zollner names three causes: corrosion on the surface, changes in the string's cross-section (fret wear grinds grooves into it), and deposits of grease, skin and dust, mostly packed inside the windings. He found the deposits are the worst of the three. They soak up far more vibration energy than you'd expect [15]. On a partly used A string from a Les Paul Classic, he measured ring times 50-80% shorter than a fresh string, with the treble going fastest. He also found that measurable changes can show up after just a few minutes of playing [15].

A couple of his other findings explain what players notice. A plain high E that had been wiped clean showed no aging at all, but wiping wound strings only helped a little [17]. That fits the "gunk in the windings" story: a plain string has no gaps to fill. The fret-worn grooves also put little lumps and stiff spots along the string, and old strings make duller-sounding fret bounces too [17]. One more that surprises people: turning up the amp's treble can't fix it. A treble knob makes the treble louder, but it can't make the high partials ring as long as they did on a new string [17].

Corrosion plays a part as well. Zollner explains that when the nickel layer on a string gets damaged, sweat can set up a tiny battery effect between the steel and the nickel, and that eats away at the string. He gives no rule for when to change strings, only that they get duller over time [18].

Two corrosion studies point the same way. A 2024 paper in the journal Heliyon by Segura Alcaraz and colleagues corroded strings with artificial sweat and found the harmonic content got worse as corrosion

increased, and less so when the strings were protected by an experimental cathodic protection system, a small electric current that slows corrosion. The abstract gives no numbers [19]. The Silesian University bulletin I mentioned earlier (again, not peer reviewed) dipped D'Addario sets in artificial sweat for 30 minutes a day, five days a week, for three weeks, conditions the authors themselves call rather extreme. The corroded wound strings showed a clear drop in the strength of the fundamental, the main note, while plain strings were barely affected [11].

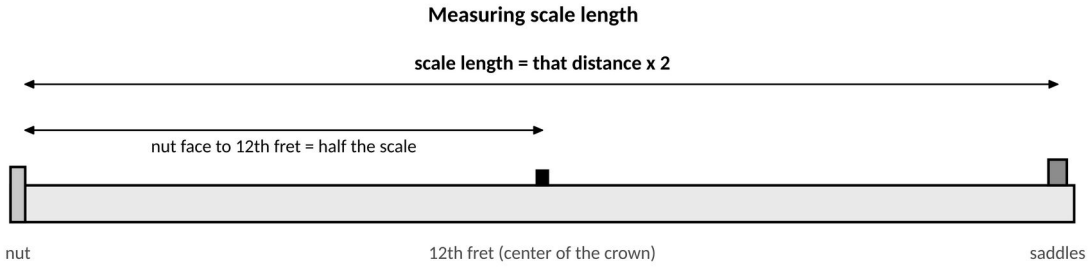
The limits are worth saying. Zollner's string samples had unknown histories and there weren't many of them. How fast your strings die depends a lot on your sweat and how often you play. But the direction is clear and the effect is big.

Verdict: True. Old wound strings lose their high partials much faster than new ones, with the low end barely touched. The main cause is grime packed into the windings, helped along by corrosion and fret wear.

Try it yourself: Before your next string change, record your open low E and let it ring out. Record it again once the new set has settled in, and compare how long the bright part of the note lasts.

Scale length

Scale length is the vibrating length of an open string, from the nut to the saddle. The two you'll hear about most are the 24.75-inch scale found on Les Paul-style guitars and the 25.5-inch scale on Strats and Teles.



The saddles sit a little behind the true scale point for intonation, so don't measure to them.

Figure 8.3: Scale length is twice the distance from the nut to the 12th fret.

Myth: Scale length changes the tone, and longer scales chime more

> **The claim:** *A longer scale spreads the harmonics out, which gives more chime and shimmer, while a shorter scale sounds warmer.*

Guitar Player ran a piece by Dave Hunter making this case. His argument is that harmonics sit farther apart on a longer string, and that this comes across as extra chime and shimmer [20]. It's a nice story. Let's see if it holds.

Start with tension. D'Addario's tension guide shows that the same set of strings at E standard carries more tension on a 25.5-inch Strat than on a 24.75-inch Les Paul [1]. Using their formula, the same string at the same pitch has about 6% more tension on the longer scale. That's my simple arithmetic, not a measurement. It's enough to change the feel, how hard bends are, and how easily the string hits the frets. If you've ever moved from a Les Paul to a Strat and felt the strings fight back a little, that's what you felt.

Now the "spread harmonics" part. Remember *inharmonicity* from Chapter 1: real strings are a little stiff, so their higher partials come out slightly sharp of where they'd be on a perfect string. Zollner gives an example. On a wound low E, the 20th partial sits about 2.5% sharp. Tune down a whole step and fret the 2nd fret to get back to E, and that grows to 3.9%. Fret the octave and it jumps to about 9.5% [21]. Measured at the same frequency, though, the octave note is no more out than the open string; it depends on the partial's frequency, not the fret. He also shows that lower tension means more inharmonicity, and that string length has a very strong effect on it [21].

At the same pitch, a perfect string's harmonics land at the same frequencies on any scale length. A longer string only spaces its still points (the nodes) farther apart along its length, and you can't hear that directly. The only spreading of the harmonics in frequency comes from stiffness, and working from Zollner's formula, the same string at the same pitch is slightly more inharmonic on the shorter scale, not the longer one. My rough arithmetic puts it at about 13% more on a 24.75-inch scale than on a 25.5-inch scale. So if anything, the shorter scale spreads its harmonics a little more. The popular explanation has it backwards.

Does that small difference matter? Probably not by itself. Zollner tested how well people can hear inharmonicity. A synthesized low E with a typical amount of it was barely distinguishable from the real string, even on headphones. He found inharmonicity is only clearly noticed when it's well above what guitar strings normally have [22]. That 13% bump on the shorter scale still leaves it below his rough audibility line. One exception: he notes that distortion can change the sound of even weakly inharmonic notes a lot, because the slightly off partials mix and create new tones [22]. So high-gain players might hear a bit more of it.

There's an even bigger problem with comparing scale lengths on real guitars. A 24.75-inch guitar and a 25.5-inch guitar almost never differ only in scale. They usually have different pickups, different construction, and their pickups sit at a different point along the string. Remember from Chapter 1 that pickup position works as a comb filter, notching out certain partials. If the scale changes and the pickup stays in the same spot, it's now sitting at a different fraction of the string. That alone would shift the tone. That's a reasoned guess, though. I found no study that measured it for these two scales, and no experiment that changed scale length while holding everything else the same.

So is scale length irrelevant? No. The tension difference is real, and tension changes how you play, how the strings feel and how much they slap the frets. All of that can change your sound. What doesn't hold up is the neat physics story about longer scales spreading harmonics for more chime.

Verdict: Mostly busted. The roughly 6% tension difference is real and changes feel and fret slap. But the "longer scale spreads the harmonics" explanation runs the wrong way, and no controlled test has isolated scale length's effect on tone.

What this means for your money

Strings are cheap, and fresh ones are the best-supported tone upgrade in this chapter. The evidence that old wound strings lose their treble is strong, and no amount of amp treble brings it back. If your guitar sounds dull, start there before you look at pickups or wiring.

Gauge is worth playing with, but judge it fairly. Heavier strings really do give more output and less fret slap. Lighter strings are easier to play. Pick the one that suits your hands and your style, then set the volume with the amp, not with your ego.

Don't pay extra for a string material because the pack calls it warm or bright. On electrics, the magnetic differences between nickel and stainless windings are tiny, and what you hear mostly comes from how the winding hits the frets. On acoustics, nobody has shown the alloy difference in a fair test.

Coated strings are a reasonable bet if your strings die fast. The worry about them sounding dead isn't backed by data either way, and they block the gunk that kills strings in the first place.

And when you shop for a guitar, choose scale length by feel. That 6% tension difference is something your fingers will notice every day. The chime story is something you can let go of.

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Chapter 9: Tone Is in the Fingers? Picks, Hands, and Setup

Hand two players the same guitar through the same amp, and they'll almost never sound alike. Every guitarist has seen it happen. Someone picks up your rig, plays one phrase, and it sounds like their record instead of yours. That's where the old saying comes from: tone is in the fingers.

I like that saying, and I also think it gets stretched too far. Some players use it to mean gear doesn't matter at all. Others use it as a polite way to end an argument. So in this chapter I want to look at what your hands actually do to a string, what the research says about picks, and whether the height of your strings off the frets (your *action*) changes your tone or your sustain.

One note before we start. I won't walk you through how to set up a guitar here. Truss rods, saddle heights and fret care belong in my book *Guitar Care and Maintenance*. This chapter is about what those settings do to the sound, not how to make the adjustments.

What the string knows about you

Here's a way to think about it that clears up a lot. The string has no idea who you are. It doesn't know your favorite players or how long you've practiced. The only thing it "knows" is what happened at the instant your finger or pick let go of it. Where along the string were you? How far did you push it, and in which direction? How fast did it leave? Was it flesh, a fingernail or the edge of a pick? Those few facts set the starting shape of the vibration, and the string takes it from there.

Every one of those things has been measured. Let's walk through them.

Where you pluck

Chapter 1 covered this, but it matters so much that it's worth a short recap. A pluck can't start any partial that needs to stand still at the spot you plucked. (A *partial*, or harmonic, is one of the higher tones stacked above the note you play.) Traube and Smith put it neatly in a 2001 paper: plucking at 1/n of the string length ideally removes every nth harmonic [1]. That pattern of evenly spaced gaps is called a *comb filter*. They add that the width of the finger or pick acts as a *low-pass filter*, meaning it trims some of the highest frequencies, because a wide contact can't make as sharp a kink in the string [1]. They also describe plucking close to the bridge as giving a quieter, brighter, sharper tone. That's a description from experience, not a listening test in their paper [1].

Traube's later thesis on the classical guitar found that plucking position is the main gesture a player uses to change timbre, with a normal range of about 3-20 cm from the bridge [2]. (*Timbre* is the color of a sound, the thing that makes two instruments playing the same note sound different.) Zollner gives typical pluck points of about 6-10 cm from the bridge [3].

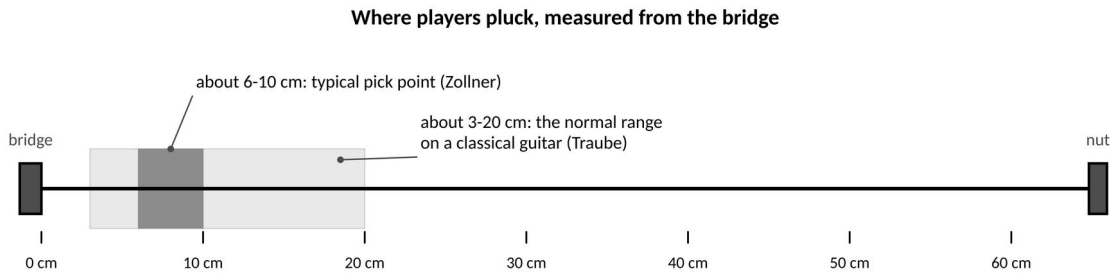


Figure 9.1: Pick position, to scale on a 25.5 in string. Moving your hand a few centimeters changes which partials get notched out.

How hard you pluck

You might think picking harder just makes a note louder. It doesn't. It changes the color too.

Zollner measured typical picking forces around 5 N, sometimes 10 N [3]. (A *newton*, N, is a unit of force. You don't need to picture it; just compare the numbers.) Then he measured what happens as you dig in. On the low E of a Stratocaster, going from a light pluck to a strong one raised the level at 4 kHz (4,000 vibrations per second, up in the bright part of the sound) by 39 dB. The fundamental, the main note, went up by only 7 dB [4]. (A 39 dB jump is enormous; a 7 dB jump is modest.) So picking hard didn't just turn the note up. It made it far brighter.

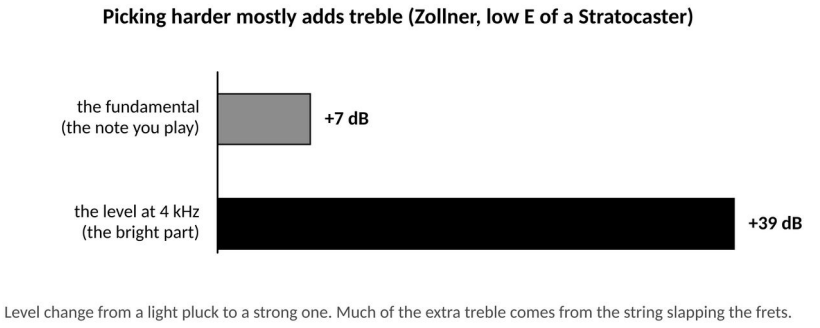


Figure 9.2: Digging in raised the bright part of the sound far more than the note itself.

Why? Mostly because the string starts slapping the frets. When a hard-picked string swings wide enough to hit the frets, every hit adds a burst of bright metal-on-metal noise. We'll come back to this when we get to action.

The angle and direction of your pick

Zollner also found that a steeper attack angle, where the pick strikes more sharply into the string, gives a more sudden, impulse-like start with less bass [3].

Direction matters even more on an electric, because of what the pickup listens to. A string doesn't just swing in one plane. It moves up and down (toward the pickup) and side to side (parallel to the top), and the two motions trade energy back and forth. Zollner notes that magnetic pickups and piezo pickups mainly sense

motion straight toward the guitar top [3]. Paté, Le Carrou and Fabre showed the same thing on a real solid-body: the pickup was much more sensitive to the up-and-down motion than to the side-to-side motion [5].

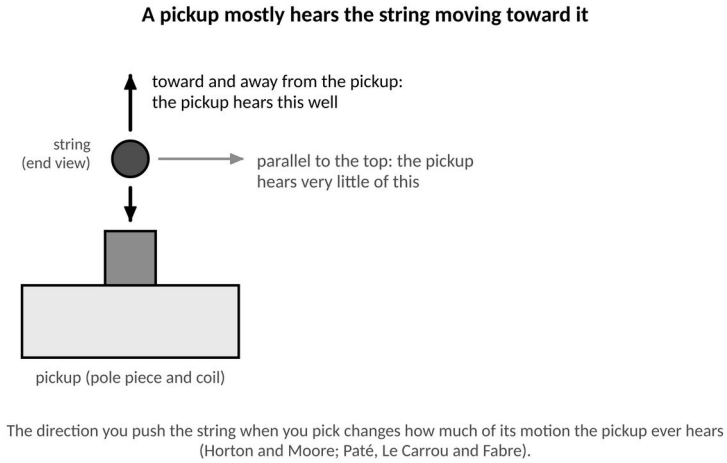


Figure 9.3: Pick toward the top and the pickup hears more of the motion. Pick parallel to the top and much of it goes unheard.

They found something else worth knowing. Dead spots, notes that die early because the neck soaks up their energy, can be different for the two directions. On their guitar, one dead spot (at the 9th fret) affected side-to-side motion and another (at the 12th fret) affected up-and-down motion. At a dead spot, the note died more than 2 seconds faster than at the frets next to it [5]. Put that together and it means the direction you push the string can change both what the pickup hears and how long the note lasts. That last part is my reading of their results, not something they tested with players.

Brauchler, Ziegler and Eberhard used a motor-driven pick 0.46 mm thick to study this in fine detail, with ten repeatable plucks. They found four stages to every pluck: the pick sticks to the string, it starts to slip and catch, it lets go, and the string swings free. They also found the two directions of motion differ in pitch by about 0.2 Hz, and that twisting of the string at the saddle couples them together [6]. The point for players is simple. A pluck isn't a single event. It's a little sequence, and your technique shapes every step.

How tiny the differences can be

One study shows just how sensitive this all is. Pluta and colleagues built a robot to pluck the low E string of a Martin D-X2e acoustic, 480 times in all, and changed how far the pick tip reached across the string in steps of 192 micrometers. (A micrometer is a thousandth of a millimeter.) They report that even that tiny change in plucking depth altered the sound's measured features significantly [7].

If a fraction of a millimeter changes the sound, no two human plucks are ever the same. That's a big part of why two players sound different.

Researchers are now working on capturing all of this. Perez-Carrillo used optical motion capture to track a player's fingers and pull out pluck position, timing, speed, direction and string displacement as the features that control the sound. The abstract, which is all I could read, gives no numbers on tone [8].

Nail, flesh and the classical player's two strokes

Traube's thesis looked at classical technique. A fingernail gave a thinner, brighter tone with more high-frequency content. The flesh of the finger gave a fuller, mellower tone [2]. Traube also compared the classical rest stroke (*apoyando*, where the finger comes to rest on the next string) with the free stroke (*tirando*). The rest stroke pushed the string more up and down, toward the top, and gave a louder, shorter note. The free stroke gave a softer, longer note [2]. Those descriptions partly come from how guitarists themselves describe the sounds, but they line up with the physics of direction we just covered.

Your body is part of the guitar

One more piece. Le Carrou, Paté and Chomette measured what happens when a player actually holds an electric guitar. The player's body and hands damp the guitar's vibrations (*damping* means soaking up energy so things die down faster), and they shift some of its resonant frequencies by less than 5% [9]. Their summary was that, as expected, the player damps the structure. You might ask, "So should I play standing up or sitting down?" In their work, sitting versus standing made very little difference to the predicted decay time [9]. Play however you're comfortable.

Myth: Tone is in the fingers

> **The claim:** *A great player sounds like themselves on any rig, so your hands matter more than your gear.*

Guitar World ran a story where Jared James Nichols described plugging into one of Eddie Van Halen's amps. It sounded incredible, he said, but he still sounded like himself [10]. That's the slogan in a nutshell. Stringjoy, a string company, pushed back in a blog post, arguing that tone comes from both the way you play and the gear you use [11].

So who's right? The research above makes one half of the case very well. Your hands control pluck position, which notches out partials. They control force, which in Zollner's measurement swung the treble by 39 dB while the fundamental moved by only 7 dB [4]. They control angle and direction, which decide how much of the motion the pickup even hears [3, 5]. And they control what touches the string, nail or flesh or pick [2]. Those are big, measured effects, often far bigger than the differences people argue about between pickups or caps. That's why two players sound different on the same rig.

Now the other half. Nothing in that research says gear doesn't matter. Your hands shape the string's starting vibration. After that, the pickup, the circuit, the amp and the speaker all take their own turns filtering and shaping it, as Chapters 6 and 7 showed and Chapters 10 and 11 will show. A player's touch can survive those changes, but those changes are real too.

What's missing is a blind listening test that compares "the same player on different rigs" with "different players on the same rig." Nobody has run it, and that's the experiment that would really settle this. Most of the measurements I've cited also used robots or a single player, which is good for control but tells us less about the range of real players.

Verdict: Partly true. Your hands shape timbre in large, measurable ways through pluck position, force, angle and what touches the string. But the slogan overreaches if it means gear doesn't matter, and nobody has tested whether a player's sound survives a change of rig.

Try it yourself: Play one phrase three ways on the same setting: soft near the neck, medium in your usual spot, and hard near the bridge. Record all three. You'll probably hear a bigger change than you expected.

Myth: Pick material and thickness change your tone

> **The claim:** *Metal picks are bright and harsh, celluloid is soft and mellow, and thicker picks sound fatter.*

Premier Guitar ran a long feature on picks that passed along Dunlop's descriptions of materials, with metal described as bright and harsh and celluloid as soft and mellow. It gave no measurements [12]. Ask most players and they'll tell you they can hear the difference.

Zollner measured pick forces on an Ovation with a piezo pickup. He found that a near-perfect, sudden release of the string was flat in its frequency content up to about 3 kHz, and only above that did the treble start to roll off, because the release isn't perfectly sharp [13]. Round, hard picks gave more and more treble loss. A high attack angle cut the bass. A sharp metal pick scraped along a wound string made extra little impulses, which you'd hear as added scratchiness [13]. He didn't compare thicknesses or give tables of numbers.

In a 2010 conference talk, written up in a lay-language summary, Sandra Carral compared a 0.46 mm pick with a 2 mm pick, using a plucking machine on an open E string. The thick pick made a louder sound. Its brightness started out higher, but after about 1 second the thin pick's sound was the brighter of the two [14]. (The study measured brightness with the *spectral centroid*, which is roughly the "center of gravity" of the sound's frequencies. A higher centroid means a brighter sound.) The summary gave no exact numbers and included no listening test.

The best robot study I found is the same Pluta team from earlier. They tested eight picks: nylon at 0.67, 0.80, 0.94 and 1.14 mm, polycarbonate at 1.30 mm, steel at 0.38 mm, rubber at 3.1 mm and felt at 3.2 mm. The material changed how sensitive the sound was to pluck depth. Steel and rubber reacted right away, while most of the nylon picks, the polycarbonate and the felt showed a flat stretch where small depth changes didn't matter much. Some measures of tone color varied strongly from one material to another [7]. The authors flagged a problem themselves. Just taking the same pick out of the robot and putting it back changed the loudness and brightness noticeably. They said plainly that their experiment couldn't be used to rank how different picks compare [7]. I respect that. It tells you how hard this is to test.

One more study, with a warning label. A 2019 paper by three authors in the International Scholastic Journal of Science, a student-level journal, tested five pick thicknesses on the open high E of an acoustic and found thicker picks gave stronger upper harmonics [15]. It looked at a single note, and the abstract (all I could read) gives no numbers. I mention it because it points the same way as Carral, but I wouldn't lean on it.

So what's going on? The pick's edge sets how sharp a kink it leaves in the string. A sharp edge gives a sudden release and more treble. A rounded or soft edge trims the top end, above roughly 3 kHz in Zollner's data [13]. Traube adds that a wider plectrum acts like a low-pass filter [2]. Thickness and stiffness decide how far the pick bends before it lets go. A stiff, thick pick drives the string farther and harder for the same hand motion, so the note is louder. A floppy pick lets go sooner with less energy. Material matters mostly through hardness, how slippery the surface is, and how the edge wears.

The trouble is that in real picks, material, thickness, bevel and wear all come bundled together. And just like with strings, you change your grip and attack when you change picks.

Verdict: Partly true. The pick's edge shape and stiffness measurably change loudness and treble. But clean comparisons of material alone are scarce, and the best robot study found the setup variation too large to rank picks.

Try it yourself: Grab a thin and a thick pick with similar edges. Play the same open string with each, at the same spot, and listen to the first second and the tail of the note separately.

Myth: Low action kills sustain, and high action gives a bigger tone

> **The claim:** *Low action chokes the strings and robs you of sustain, while high action lets the string swing freely for more volume and sustain.*

My New Microphone, a website on audio gear, makes the high action case directly: more height means more vibration, which means more volume and sustain [16]. Lots of players argue the flip side: that a slinky low action costs you tone.

Let's start with what the string actually does. Above a certain picking force, the string swings far enough to hit the frets near the end of the neck. Zollner measured that on an Ovation, where this limit was about 2 N. Picking forces often reach 5 N and occasionally 10 N, so this happens often in normal playing [4]. Fret contact works a bit like a *compressor* (an effect that squashes loud peaks): the first and second harmonics drop and the mids and highs rise. That's where the 39 dB treble jump on the Strat came from [4]. In his words, the lower the action and the lighter the strings, the lower the force needed for this to happen [4]. His examples had clearances of about 2.1-2.3 mm at the last fret [4].

Timing matters too. Zollner found that fret hits right after the pluck blend into the attack of the note. Hits later than about 50 milliseconds are heard as separate events, as buzz. In his example, extra hits came at about 200 and 350 milliseconds after the pluck [17]. He also notes that a little fret contact can be expressive, while strong, repeated hits make a clearly audible buzz [17].

The most direct evidence is the string material test from Chapter 8. Zollner heard a small difference between nickel-plated steel and pure nickel strings. When he raised the bridge so the strings stopped hitting the frets after the pluck, the difference went away [18]. Action changed what he heard, and it did it by changing fret contact.

So does low action kill sustain? Here the evidence runs thin. On a solid-body electric, the research puts most of a note's energy loss in the string itself, and of the energy the guitar does take, most goes out through the neck. Action height isn't part of that picture. Fleischer showed that the bridge of a solid-body is much less mobile than the neck, and he tied dead spots to resonances of the neck and body [19]. Paté's team could predict decay times on the G string to within 0.6 seconds from the string's own losses and the neck's behavior alone, without action in the picture at all [5]. On a hollow-body electric with a floating bridge, Rau and colleagues found that neck losses matched the bridge's at some frequencies [20]. Bilbao and Torin built a computer simulation of a string bouncing off frets and fretboard, which shows the mechanism, but they didn't vary the action [21]. None of these studies measured sustain against action height.

What about relief, the slight forward bow in the neck? Zollner gives typical action of about 1.5-2.5 mm at the last fret and lists makers' relief specs, but he says there's no single best relief. It's a matter of taste, and he makes no sustain claim [22]. He does point out that one fret sitting just 0.1 mm high is enough to spoil the note behind it [22]. That's a fret problem, not an action problem, and it's one more reason a guitar can sound choked.

Put it together. Action doesn't change how the string stores energy. It changes how easily the string slaps the frets. Low action plus hard picking means more fret contact, which adds a bright, buzzy, squashed attack and can choke the note if the contact keeps repeating. Higher action lets you dig in harder before that happens, so loud playing stays cleaner and the fundamental keeps more weight. That's the real kernel of truth in "high action, bigger tone." It's reasonable to think repeated fret hits pull some energy out of the string, but that's my inference from the mechanism, not a measurement. No source I found shows that a clean, buzz-free low action shortens sustain.

Verdict: Partly true. Low action changes your tone when it causes fret contact, adding treble and buzz and squashing the attack, and higher action lets you play harder without it. But no measurement shows that a buzz-free low action reduces sustain.

Try it yourself: Play one note softly, then dig in hard, and listen for the point where it turns bright and buzzy. That point tells you how much room your current action gives your picking hand.

What this means for your money

The most powerful tone controls in this chapter are free. Where you pick, how hard you pick and the angle of your pick change the sound by amounts bigger than many of the upgrades people argue about. Before you buy something to fix a tone you don't like, spend an evening moving your picking hand around.

Picks are cheap, so buy a handful and try them, but trust your hands over the label. Edge shape and stiffness matter more than what the pick is made of, and how you hold it may matter most of all.

Set your action for how you play. If you pick hard, a little more height keeps the string off the frets and keeps the note full. If you play lightly, low action is fine, and there's no good evidence it's costing you sustain. If a guitar sounds choked, look for fret contact or a high fret before you blame the wood. The adjustments themselves are covered in my book *Guitar Care and Maintenance*.

And when someone tells you tone is in the fingers, you can agree with them. Just don't let it talk you out of a better amp or speaker if that's what your ears are asking for.

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Chapter 10: Amplifiers: Tubes, Transistors, and Modelers

Ask a room full of guitar players whether tubes matter and you'd better pull up a chair. Few arguments in our world run longer or hotter. Some players won't touch anything without glass bottles glowing in the back. Others gig every week with a modeler in a backpack and never look back.

It makes sense that we care. The amp is where the small signal from your pickups becomes something loud enough to fill a room, and on most electric rigs it's also where your distortion comes from. But the stories told about amps run all the way from solid physics to hi-fi folklore that wandered into guitar shops.

The good news is that amps have been measured for decades, and modelers have now been put through real listening tests. The catch is that a lot of the measurements come from studio gear or hi-fi gear, not guitar amps, and a lot of the listening tests used recordings rather than a player standing in front of a cabinet. I'll flag that every time it comes up.

How an amp makes its sound

A guitar amp has two main jobs. The *preamp* takes the tiny signal from your pickups and makes it bigger. On most amps it's where the gain knob and tone controls live. The *power amp* takes that bigger signal and makes enough power to move a speaker. In a tube amp, both jobs are done by vacuum tubes (the British call them valves), glass bottles where a small voltage controls a stream of electrons. A solid-state amp does the same jobs with transistors, small parts made of semiconductor material. A modeler does the work in software and uses its electronics mainly to get the result back out.

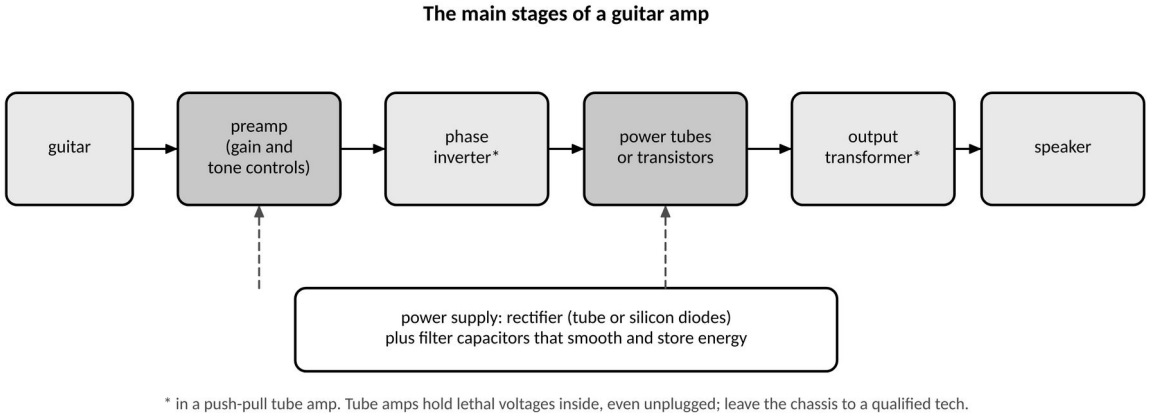


Figure 10.1: The main stages of a guitar amp. Tube and solid-state amps do the same jobs with different parts.

Push any amplifier past what it can cleanly deliver and it *clips*: the tops of the waveform get flattened. Clipping adds *harmonics*, which are extra tones at whole-number multiples of the note you play. The 2nd harmonic is twice the frequency of your note, an octave up. The 3rd is three times the frequency. You'll hear

players call these even-order and odd-order harmonics. Engineers roll all of them into one measurement called THD (total harmonic distortion), given as a percent of the signal.

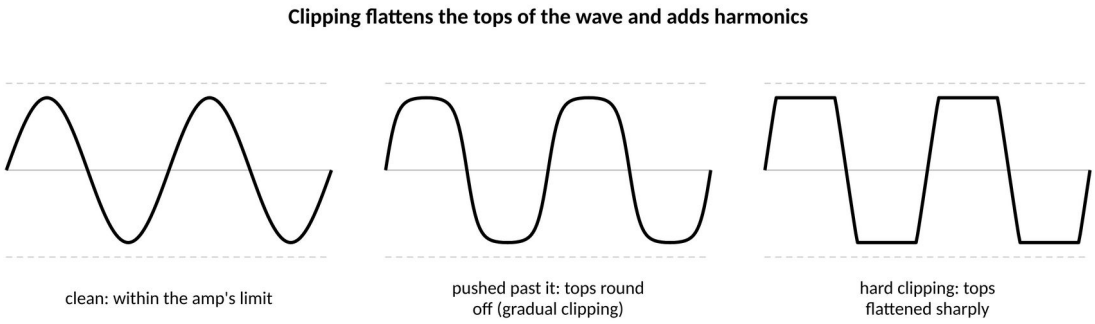


Figure 10.2: Clipping flattens the tops of the wave, and that adds harmonics. The shapes are drawn for illustration, not measured from an amp.

The power stage can be wired two ways. In a *single-ended* amp, one tube handles the whole wave. In a *push-pull* amp, tubes work in pairs, one pushing while the other pulls: one mainly handles the top half of the wave and the other the bottom half, and when played hard each may shut off for part of the wave (more on that under sag). A small stage called the *phase inverter* splits the signal so each side gets its half. Between the power tubes and the speaker sits the *output transformer*, which matches the power tubes to the speaker.

Last comes the power supply. Tubes run on high DC voltage (direct current, the steady kind), so the amp needs a *rectifier* to turn the AC (alternating current) from the wall into DC, plus big filter capacitors that smooth it out and store energy. Some amps use a tube rectifier. Most use silicon diodes, which are small solid-state parts.

One plain safety note before we go on: tube amps hold lethal voltage inside. Leave any work inside the chassis to a qualified tech.

Myth: Tubes sound warm because they make even harmonics

> **The claim:** *Tubes make even harmonics, which sound musical and warm. Transistors make odd harmonics, which sound harsh.*

This idea usually traces back to a paper by Russell Hamm, presented at the Audio Engineering Society (AES) convention in New York in September 1972 [1]. It's worth knowing what he tested. Hamm measured studio preamps and single amplifying stages, not guitar amps. He compared commercial preamps set for 40 dB of gain, and in his harmonic tests he drove each amplifier 12 dB into overload [1].

What he found is more interesting than the slogan. Triodes, the small tube type used in most guitar preamps, put out a strong 2nd harmonic with the 3rd close behind, and they clipped unevenly, flattening one side of the wave differently from the other. Pentodes, a different tube type, put out mostly the 3rd harmonic. Transistors also favored the 3rd and clipped both sides evenly, toward something like a square wave. Op-amps (amplifiers on a single chip) canceled the even harmonics entirely [1].

So Hamm's own conclusion was about the balance of harmonics as an amp overloads, not a simple rule that even is good and odd is bad. Notice too that his tube group included pentodes, which lean odd.

Hamm also took on the idea that tubes overload more gently, and his answer has two halves that are easy to mix up. Looked at one stage at a time, his distortion curves gave no sign that tubes break up more gently than

transistors, and he called that popular belief a myth. What differed was which harmonics grew as the stages were pushed. A transistor stage added mostly a strong 3rd harmonic and stayed usable for only about 10 dB of overload. A tube stage added a fuller spread (the 2nd, 3rd, 4th and 5th) and, in Hamm's judgment, stayed usable across 20 dB or more, beyond the 12 dB he drove on the bench. Over that range its electrical output rose only 2 to 4 dB, like a limiter, while the added edge kept it sounding loud [1]. So tubes don't break up more softly. They stay musical for longer once they do, with output barely rising, like a built-in compressor.

Why would uneven clipping go with even harmonics? Pakarinen and Yeh, in a review of methods for modeling tube guitar amps, explain it this way: clipping that treats both halves of the wave the same makes mainly odd harmonics, while clipping that treats them differently makes both even and odd [2]. That means the shape of the clipping is what counts, not whether it happens in glass or silicon. A solid-state circuit can be designed to clip unevenly too.

Power stages add their own wrinkle. The Valve Wizard, a well-known amp design site, explains that a perfectly balanced push-pull stage cancels all the even harmonics produced in the output stage, while the odd ones add together [3]. Real guitar amps are rarely perfectly balanced. The tubes are rarely an exact match, and the phase inverter goes out of balance when you overdrive it, so some even harmonics survive [3]. Barbour, writing in IEEE Spectrum in 1998, credited the soft, lush sound of single-ended amps like the Fender Champ to their large amount of 2nd-harmonic distortion. The Bassman and Twin he describes are push-pull designs, which (as above) cancel much of it. Barbour also writes that the output transformer plays a key role in an amp's sound, and designers he quotes go further, crediting it with much of what people call tube sound, especially when it saturates and compresses. In his own bench test, though, the transformer's distortion was far lower than that of any tube or transistor he measured, and what little there was leaned odd-order [4].

So the even-harmonic story fits small single-ended amps and preamp stages much better than it fits a big push-pull power section.

If it isn't only even harmonics, what makes a tube amp feel different? Barbour names designs with little or no *negative feedback* (feeding part of the output back to the input to keep the amp accurate), loose power-supply regulation and soft overload. He also gives credit to plain listener and cultural preference [4].

There's one more piece, and it involves your speaker. *Impedance* is resistance to an AC signal like your guitar's. *Damping factor* describes how firmly an amp holds the speaker under control. Don't mix it up with the damping in earlier chapters: a high damping factor means a tight grip on the speaker, not more of your tone soaked up. An amp with a high output impedance has a low damping factor. A Peavey patent explains that tube amps usually have a low damping factor because they use little negative feedback, while solid-state amps usually have a high one [5]. A speaker's impedance climbs near its own resonance (the frequency where it naturally vibrates most easily) and again in the treble, and with a low damping factor the amp's output rises right in those places [5]. The presence knob on many tube amps plays with this. It removes a variable amount of treble from the feedback signal, and the result is more treble at the output [6].

In other words, a tube amp and its speaker shape each other's sound. That's a big reason the speaker matters so much, and it's the subject of Chapter 11.

I didn't find a peer-reviewed study that ties listeners' "warmth" ratings of guitar amps to the balance of even and odd harmonics. Keep in mind too that Hamm's measurements came from studio preamps, not guitar amps.

Verdict: Partly true. Tube preamp stages do lean toward low harmonics, often the 2nd, and they stay usable further into overload. But push-pull power stages cancel much of their own even-order distortion, and a lot of "tube sound" comes from compression, sag (the supply voltage dipping when you play hard, covered below), the output transformer and how the amp works with the speaker.

Myth: A modeler can't match a real tube amp

> **The claim:** *Digital modelers and profilers are fine for practice, but they'll never sound like the real amp. Anyone can hear the difference.*

A modeler measures or learns how an amp turns its input into its output, then reproduces that behavior digitally. The question is simple: can listeners tell the copy from the original? Two published studies tried to find out.

The first, by Wright and colleagues at Aalto University, trained *neural networks* (computer models that learn a behavior from examples) to imitate two amps: a Mesa Boogie 5:50 Plus set for crunch and a Blackstar HT-5M set for high gain [7]. Listeners heard the clips on headphones in an acoustics lab. The test format is called MUSHRA: you rate several clips from 0 to 100 against a reference, and a hidden copy of the reference is slipped in among them as a check. Fourteen people took part, and five were dropped for rating the hidden real amp below 90 too often, leaving nine [7].

On the Mesa crunch sound, the models scored between 93 and 98, with the real amp as the hidden reference. The two larger models each got a perfect 100 in about 80% of trials, meaning listeners rated them as good as the real amp [7]. High gain was harder. The Blackstar models scored 75 to 93. The larger models landed in the top "Excellent" band, the smaller ones lower, and the authors note listeners could pick out the high-gain models from the reference [7]. The paper doesn't say how the amps were recorded.

The second study, by Düvel and colleagues, compared real amps against profiles made with a Kemper Profiling Amp. A computer analysis of the sounds found them highly similar. In a listening test with 177 people, listeners did only slightly better than chance at sorting the clips into real amp or profile, a difference the authors call rather small, and listeners' general musical sophistication made little difference [8]. I could only check the published summary of this one, so I can't tell you the details of the clips.

Pakarinen and Yeh make a fair point about all of this: measuring how "tube-like" a model sounds is very hard, so the best way to judge models is by listening [2]. That's what these two studies did.

Here's the limit, and it's a real one. Both tests used recordings played back to listeners. Nobody stood in a room playing through a speaker cabinet at stage volume, and "feel" wasn't tested at all. The Aalto panel was small and used headphones. And they tell us about one set of research models and one commercial profiler from around 2019-2020, not every modeler ever made.

Verdict: Mostly busted. On recordings, listeners in two controlled studies mostly could not tell good models or profiles from the real amp, especially at crunch settings. High-gain models were sometimes caught, and how a modeler feels to the player in a room hasn't been tested.

Try it yourself: Record a short dry guitar track, then play it back through your amp (with a mic) and through your modeler, matched in volume. Have a friend shuffle the clips and see if you can name which is which. Chapter 13 shows how to run a fair blind test.

Myth: A 100-watt tube amp is louder than a 100-watt solid-state amp

> **The claim:** *Tube watts are louder than transistor watts. A 100 W tube head will bury a 100 W solid-state amp.*

Start with how watts turn into volume. Doubling the power adds only about 3 dB, a step you'll notice but nowhere near twice as loud [9]. Your speaker's sensitivity can matter as much as the watts, and Chapter 11 works through those numbers.

Rated watts are measured at a stated amount of distortion. If two amps are rated at the same distortion figure, 100 W is 100 W, whatever is making it. So two ratings only compare fairly when the spec sheets name the same distortion level.

So where does the tube reputation come from? From what happens past the rating. When a solid-state amp hits its limit, it clips hard and sounds nasty, so players back off. A tube amp can be pushed well past its rated power into gradual clipping that still sounds usable and compressed, which raises the average level. That fits Hamm's results from earlier in this chapter: in his judgment, his tube stages stayed usable across 20 dB or more of overload, against about 10 dB for transistors, because of which harmonics grew, not because the overload itself was gentler [1]. Remember those were studio preamps, not guitar power amps.

The damping factor we just covered plays a part too. A tube amp's low damping factor lets its output rise near the speaker's resonance and in the treble [5]. That doesn't add watts, but it reshapes the response, lifting the speaker's resonance and treble region, so the same rated watts can sound bigger and more present.

I didn't find a controlled, published test comparing how loud equal-rated tube and solid-state guitar amps sound to listeners. The explanation above is solid physics, but nobody has put numbers on the real-world gap.

Verdict: Mostly busted. Rated at the same distortion, a watt is a watt. A tube amp can be pushed past its rating into usable clipping, which likely makes it seem louder, but nobody has measured that gap, and your speaker's sensitivity can matter as much as the watts. In the end, tube or solid-state comes down to player preference.

Myth: NOS tubes and tube rolling transform your tone

> **The claim:** *Old new-stock tubes from the golden era, or expensive premium tubes, will transform your amp. Rolling through brands is the way to find your tone.*

NOS stands for "new old stock": tubes made decades ago that were never used. *Tube rolling* means swapping tubes, usually preamp tubes like the 12AX7, to hear what changes. The 12AX7 is the most common preamp tube in guitar amps.

Do tubes actually differ? Yes, and the measurements show it. Tangible Technology, in a report last updated in 2004, measured 12AX7-type tubes from many makers, including new production and old reference tubes from GE, RCA, Mullard and Telefunken. In a low-gain test circuit, gain ran from 27.7 to 28.7 dB, a spread of about 1 dB. In a high-gain circuit it ran from 33.6 to 37.4 dB, a spread of about 4 dB [10]. Across all the tubes in the report, which also included close relatives such as the 12AY7, distortion at a high test level ranged from about 0.47% to 2.38%. All but one tube made mostly 2nd-harmonic distortion. One more finding: readings from a tube tester didn't track the gain they actually measured [10].

Kurt Prange, a sales engineer at Amplified Parts with an electrical engineering degree, compared current-production 12AX7s in 2013. He measured gain in a Fender blackface-style preamp at low, middle and high frequencies, and the brands differed. He also measured microphonic noise (the ringing a tube makes when

tapped) [11]. His listening comparisons, done in the first preamp socket of a Marshall JCM800, were not described as blind. He also warned that you shouldn't assume every tube from a given brand will land where his test samples did [11].

That warning matters. A few dB more gain in the first preamp tube changes how early an amp breaks up, and players hear that. It's a real effect. But it comes from the gain of the particular tube in the socket, not from NOS magic. Tubes of one type also vary from sample to sample, and the tests I found used too few tubes per brand to show that the brand matters more than that. And an old tube, even one sold as unused, is an aged part of unknown history.

I found no blind listening test of NOS against current-production tubes. Tangible Technology tested only a few samples of each type, and none of the sources I could check measured power tubes.

Verdict: Mostly busted. Tubes really do differ by a few dB of gain and a bit of distortion, enough to change when an amp breaks up. But the tests used only a few samples of each, so sample-to-sample spread can't be ruled out, and no blind test shows NOS or premium tubes are reliably preferred.

Try it yourself: With the amp off, unplugged and cooled down, swap your first preamp tube (usually marked V1, nearest the input jack; check your manual) for a spare of the same type. Match the volume before you judge, since a hotter tube will also be a louder one.

Myth: Tube rectifier sag is real, and you can feel it

> **The claim:** *An amp with a tube rectifier has "sag," a soft, spongy squeeze when you dig in. Skeptics say it's in your head.*

This is one I can back with a clear "yes." Aiken of Aiken Amplification defines *sag* as the power supply voltage drooping when a loud note suddenly asks for more current [12]. A tube rectifier has internal resistance, so the harder the amp pulls on it, the more voltage it drops. The power transformer's own wire adds more. His example: an extra 100 mA of current through a winding with 200 ohms of resistance costs about 20 V [12]. Small filter capacitors add dips of their own.

How big is the rectifier's share? Rob Robinette's amp guide gives typical drops of about 2 V for a silicon rectifier, about 15 V for a GZ34 tube rectifier, and up to 60 V for a 5Y3 [6].

To see where sag comes from, you need the amp's class. Designers sort power stages by how the tubes share the work. In a push-pull pair running in *Class A*, both tubes conduct through the whole wave, and the current the stage draws from the power supply stays constant. In *Class B*, each tube shuts off for half of the wave, so only one tube amplifies at a time. *Class AB* is a mix of the two: it runs in Class A at low levels and slides into Class B as you play harder and one tube of the pair starts shutting off for part of the wave [3]. Aiken explains that this is why sag shows up mainly in Class AB amps, where the power tubes draw much more current at full output than at idle. A true Class A amp draws about the same current either way, so it has little or no sag [12]. The Valve Wizard describes the same thing from the tube side: once one tube in a push-pull pair enters Class B, current demand rises, and with a tube rectifier the supply sags [3]. Pakarinen and Yeh note that bursts of playing can briefly pull the supply voltage down in Class AB amps, adding compression [2], and Barbour links tube rectifiers and loosely regulated supplies to a touch-sensitive kind of compression [4].

What does it do to your sound? Aiken lists compression, less headroom and more clipping. If the filtering isn't good enough, the 120 Hz ripple from the supply can even produce faint "ghost notes" [12]. He also notes that putting a resistor of about 100 ohms in series with silicon diodes can imitate a tube rectifier's sag [12].

How much you'll notice depends on the amp. Playing clean at low volume, there's little sag to hear. I found no blind listening test of a tube rectifier against a silicon one in the same guitar amp.

Verdict: True. Sag is a measurable, well-understood power supply effect, and it's bigger with tube rectifiers. It changes compression and headroom, most of all when a Class AB amp is played loud.

Try it yourself: If your amp has a tube rectifier, play the same hard chord at low volume and then with the amp turned up. Listen for the note to squash and bloom at the higher setting.

Myth: Audiophile power cords and fuses improve your amp's tone

> **The claim:** *A premium power cord or an audiophile fuse cleans up your amp's power and opens up the tone.*

This one comes straight from hi-fi forums. Let's look at where these parts sit. The fuse and power cord come before the power transformer, the rectifier and the big filter capacitors. Those parts are what actually regulate and store power for the amp.

Start with the fuse. Littelfuse's data sheet for a common slow-blow fuse lists a 1 A fuse at about 0.375 ohms and a 4 A fuse at about 0.0311 ohms [13]. Even with a full 1 A flowing through it, the 1 A fuse drops less than 0.4 V (current times resistance), about 0.3% of a 120 V wall supply. On the high-voltage side, a GZ34 tube rectifier drops about 15 V of a few hundred, and a 5Y3 up to 60 V [6]. The fuse is a rounding error.

What about the cord? Archimago, a measurement blogger who writes under a pen name, tested this in 2020 [14]. He used a hi-fi solid-state amp, not a guitar amp, and compared an "audiophile" power cord (thick 10-gauge wire) against a deliberately bad setup: a tarnished 50-foot garden extension cord plus a cheap generic lead. At 1 W there was no difference at all. At full power, 100 W, the garden cord gave about 0.1 dB less output and about 0.2 dB more distortion and noise. Hum didn't change [14]. Even a deliberately awful cord barely moved the needle.

There's no published blind test of audiophile fuses that I could find, and the cord test was done on hi-fi gear. But the physics is clear about the size of the effect.

One safety rule while we're here: never put in a fuse with a different rating from the one your amp calls for.

Verdict: Busted. The cord and fuse add resistance that's tiny next to the amp's own power supply. The one measurement found showed differences of 0.1-0.2 dB even with a deliberately poor cord.

What this means for your money

- Don't buy a tube amp only for "even harmonics." Buy the amp whose clipping, compression and feel you like, and know the speaker is part of that sound.
- Give modelers a fair hearing. On recordings, good ones have fooled most listeners. If you play at stage volume, test the feel in the room before you decide.
- If you want more volume, look at speaker sensitivity before you look at watts (Chapter 11). A few dB from a more sensitive speaker costs less than doubling your amp.
- Spare tubes are worth having, but they're a maintenance item, not magic. Judge a new tube by its gain and noise in your amp, at matched volume, not by its age or its label.
- If you love sag, look for an amp with a tube rectifier or one designed to imitate it. It's a real effect.
- Skip audiophile cords and fuses. Put that money toward a speaker, or a lesson.

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Chapter 11: Speakers and Cabinets: The Tone Filter You Can't Turn Off

Players will spend weeks choosing between two overdrive pedals that differ by a hair, then plug into whatever speaker came in the combo and never think about it again. I understand why. Speakers are heavy, they're hidden behind grille cloth, and swapping one means pulling the back off a cabinet. Nobody posts pictures of a speaker on their pedalboard.

But every note you play has to come out of that paper cone. Your pickups, cables, pedals and amp all feed it, and it gets the last word on what reaches the room. As we'll see, a guitar speaker is one of the most strongly colored parts of the whole chain. It's less a window than a filter.

In this chapter I'll cover what a speaker does to your sound, why speaker sensitivity is worth more than a lot of watts, whether new speakers really need breaking in, and why where you stand changes what you hear. Fair warning: the published data on guitar speakers is thinner than I'd like, and some of the best measurements come from hi-fi speakers. I'll point that out as we go.

What a guitar speaker does to your signal

A speaker is a motor pushing air. The amp's signal flows through a coil of wire, the *voice coil*, sitting in the field of a magnet. The coil moves back and forth and drives a paper cone. The cone is held in place by a flexible ring at its outer edge (the *surround*) and a springy corrugated disk near the center (the *spider*). Together those two make up the speaker's *suspension*. Like any spring-and-mass system, the speaker has a *resonance*, a frequency where it vibrates most easily. Speaker makers call it *fs*.

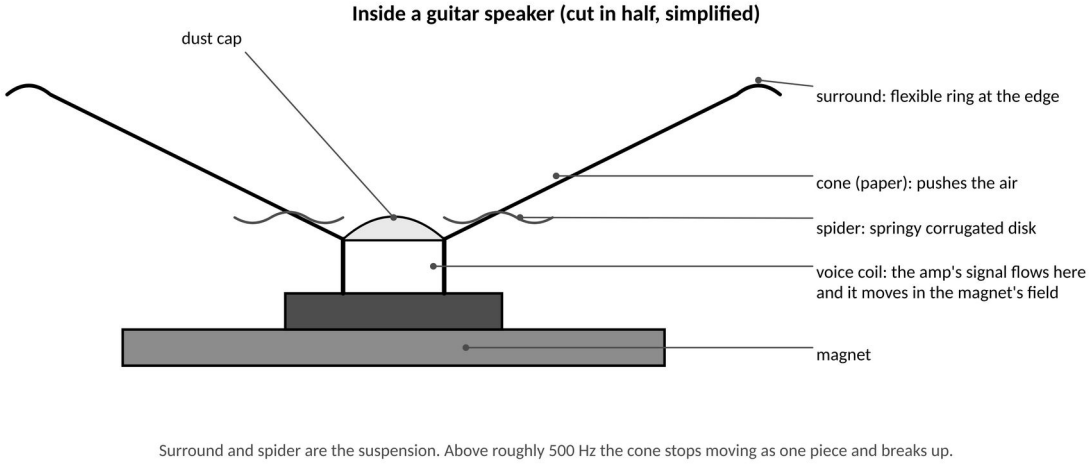


Figure 11.1: The parts of a guitar speaker (simplified).

First, a guitar speaker doesn't try to reproduce everything. Yeh, Bank and Karjalainen, who built computer models of a guitar speaker cabinet, describe guitar speakers as having a limited bandwidth, giving 100 to

6,000 Hz as an example (Hz, or hertz, means vibrations per second) [1]. Celestion engineer Ian White, quoted in Sound On Sound, gave a usable range of about 70 Hz to 6 kHz [2]. Celestion's own spec pages list the Vintage 30 at 70-5,000 Hz and the G12M Greenback at 75-5,000 Hz, with an fs of 75 Hz for both [3, 4].

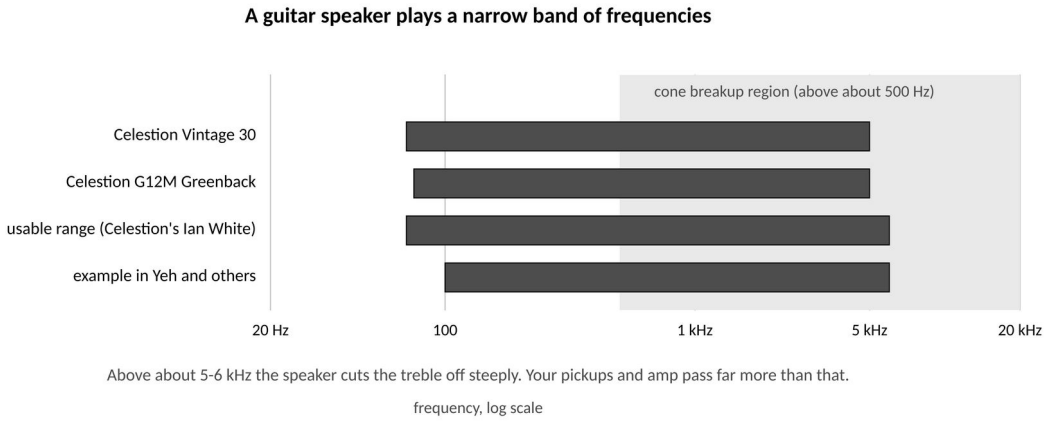


Figure 11.2: The frequency ranges quoted in this chapter, on one scale.

Your pickups and amp pass frequencies well above that range. So the speaker trims off the top end before any of it reaches your ears. It's a steep filter, and one you can't turn off.

Inside that range, the speaker isn't smooth either. Above roughly 500 Hz, most of the sound comes from *cone breakup*: instead of moving as one stiff piece, different parts of the cone flex and ripple in their own patterns [2]. Those patterns depend on how stiff the cone is, how heavy it is and how much it soaks up vibration (*damping*). They create peaks and dips all through the midrange and treble, which is where a guitar's character lives.

Yeh and his colleagues found that the biggest effect a guitar cabinet has on the sound is its frequency response, its pattern of boosts and cuts. The distortion the speaker itself adds is subtle by comparison [1]. That's useful to know. When we say a speaker has a "voice," we're mostly talking about that pattern of peaks and dips.

Reading a speaker spec sheet

Speaker spec sheets can look like alphabet soup, but three numbers carry most of the useful information, and we've already met them. The frequency range tells you roughly where the speaker starts and stops; for the two Celestions above, both top out around 5,000 Hz [3, 4]. The fs tells you where the low-end resonance sits. And the sensitivity tells you how loud the speaker plays from a given amount of power, which we'll get to in a moment.

What the spec sheet can't tell you is how the speaker sounds in between. Two speakers with nearly the same numbers can have very different breakup, and that's the part you hear most. Celestion does publish response curves, but as pictures, and the pages I checked don't say how they were measured. So use the numbers to narrow the field, and use your ears (at matched volume) to choose.

Myth: The speaker is one of the biggest tone controls in your rig

> **The claim:** *Change the speaker and you change the amp. After the guitar itself, it's one of the biggest tone decisions you'll make.*

This one is common advice, and the evidence backs it.

Start with the filtering we just covered. A speaker that stops near 5-6 kHz and has strong breakup peaks and dips through the mids is shaping your tone far more than a pot, a cable or most pedals. Sound On Sound's article on guitar speakers makes the point that speakers built with identical shapes and dimensions can still sound very different, because breakup depends on the cone's stiffness, mass and damping. It describes four 10-inch Celestions with similar specs that sounded audibly different from one another [2].

Then there's the electrical side. The speaker isn't only making sound; it's also the load the amp drives. Pakarinen and Yeh, in their review of tube amp modeling, list the speaker's acoustic and electrical effects as part of how a tube amp behaves [5]. As Chapter 10 explained, a Peavey patent lays out the mechanism: tube amps usually have a low *damping factor*, meaning they hold the speaker loosely, so the speaker's own resonance and its rising *impedance* (resistance to an AC signal) in the treble change what the amp puts out [6]. With a tube amp, swapping the speaker changes both the sound coming off the cone and the signal the amp sends it.

You might ask, "Then why does my speaker swap seem to matter less on my solid-state amp?" The same patent explains it: solid-state amps usually have a high damping factor [6]. They hold the speaker firmly, so the speaker's resonance and treble rise don't push the amp's output around as much. The speaker still filters the sound acoustically, but the electrical back-and-forth is smaller.

The cabinet adds its own effects. A box has its own resonance, and an open-back cabinet lets sound from the back of the cone wrap around and cancel some of the low end from the front. I wish I could give you numbers here, but I didn't find any published measurements comparing open-back and closed-back guitar cabinets.

If you record, there's one more filter on top: the microphone. Sound On Sound notes that moving a close mic across the speaker changes the sound significantly [2]. That follows from breakup. Different parts of the cone are doing different things, so a mic at the center hears a different speaker from a mic near the edge.

Verdict: True. Guitar speakers cover a narrow band, their breakup shapes the whole midrange and treble, and with a tube amp they also change what the amp delivers. Nobody has measured the speaker against every other link, so I won't call it the single biggest, but it's a strong filter you can't dial out.

Try it yourself: If you have two cabinets, or a friend's, run the same amp settings into each and play the same riff. Then, if you record, move your mic an inch toward the edge of the cone and listen again.

Myth: If you want more volume, get more watts

> **The claim:** *A louder rig means a bigger amp. Twice the watts, twice the volume.*

More watts do get you more volume, just less than most people think. Joe Wolfe of the University of New South Wales explains that doubling the power adds about 3 dB, and ten times the power adds 10 dB. A 10 dB increase sounds roughly twice as loud [7]. So going from 50 W to 100 W gets you 3 dB. That's a step up you'll notice, but nobody would call it twice as loud. To sound twice as loud from power alone, you'd need about ten times the watts.

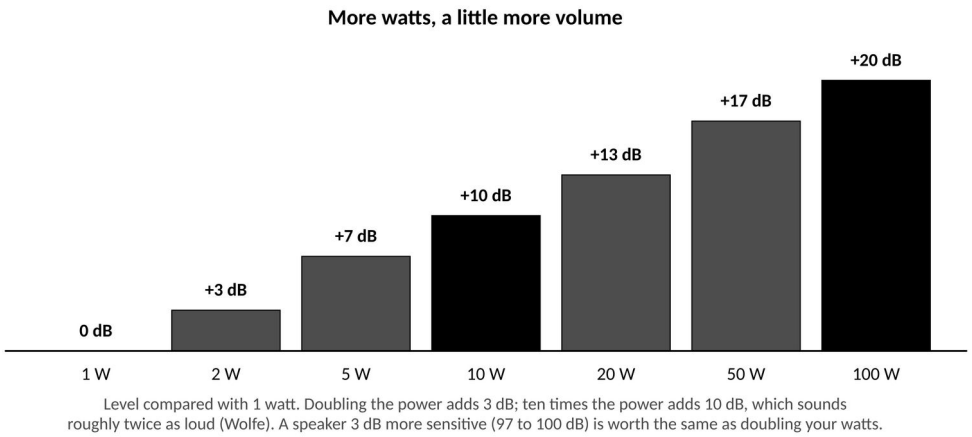


Figure 11.3: How watts turn into level. The step from 50 W to 100 W is only 3 dB.

Now look at the speaker side. *Sensitivity* tells you how loud a speaker plays from a fixed amount of power. Celestion lists the Vintage 30 at 100 dB and the G12M Greenback at 98 dB [3, 4]. Those 2 dB are worth about 1.6 times the amplifier power. Go from a 97 dB speaker to a 100 dB one and you gain 3 dB, the same as doubling your amp's wattage, without changing the amp.

A caution about reading spec sheets: Celestion's pages don't state the test conditions behind those sensitivity numbers. Comparing two speakers from the same maker is safer than comparing across brands, which may measure differently.

And remember that a more sensitive speaker isn't automatically a better-sounding one. The two Celestions above also have different breakup and different voices. Sensitivity is one more reason to choose your speaker carefully, not the only one.

Verdict: Partly true. More watts does mean more volume, but doubling the watts adds only 3 dB. A speaker a few dB more sensitive can give you the same gain, and a 10 dB jump (the one that sounds twice as loud) takes ten times the power.

Myth: New speakers need hundreds of hours to break in

> **The claim:** *A brand new speaker sounds stiff and harsh. Play it for a few hundred hours and it opens up.*

Speaker makers themselves say break-in is real. Celestion's blog says new speakers usually need a breaking-in period. It suggests a few minutes at low volume, then 10-15 minutes of clean, chunky playing with the power amp turned all the way up [8]. A. Lucas, known as "Big Tony," a senior lab technician at Eminence, wrote a break-in guide for Premier Guitar in 2009. He says break-in mainly loosens the suspension, the spider and the cone's edge, with the cone's stiffness playing a smaller role [9]. In his account the change is fastest in the first hours or days, and after about 50-100 hours of playing any change in tone is no longer noticeable. His own preferred method, a low-frequency test tone from a signal generator, does the job in 4-8 hours, though he calls it hard on the speaker and not practical for most players [9]. He didn't present any measurement data in that article.

It's worth noticing who is giving the advice. Both of these come from speaker makers, and both are sensible routines. Neither one comes with before-and-after measurements.

So what do the measurements say? Klippel, a company that makes speaker testing equipment, explains that running a suspension hard for a while causes a permanent rise in its *compliance*, which is how easily it gives. More compliance lowers the resonant frequency, fs [10]. Fs also drifts in the first hours after a speaker is built, as the glue cures.

Temperature matters at least as much. Over an extreme range, −40 °C to +40 °C, Klippel says compliance may rise by up to 200% and fs may fall by close to an octave [10]. Even a move from a warm, dry room (30 °C, 46% humidity) to a cooler, damper one (20 °C, 57% humidity) made repeated fs readings of the same speaker scatter by up to about 4% either way [10].

How big is break-in itself? Audioholics looked at this in 2005 for hi-fi speakers, not guitar speakers. They put a typical compliance increase at 5-10%. Then they modeled a 5% increase (modeled, not measured on a broken-in speaker) and found it would lower fs by about 2.4%, from 27.78 Hz to 27.11 Hz in their example, with differences in the main range of 0.02-0.09 dB [11]. The author also thought break-in takes only tens of seconds, not hours [11].

Put it together. Break-in is a real, permanent loosening of the suspension, and it lowers the speaker's resonance by a few percent. On a typical Celestion that resonance is down around 75 Hz [3, 4], so most of the change lands in the low end. Nobody has published a before-and-after measurement of a guitar speaker breaking in, so whether break-in changes the midrange and treble breakup that guitarists actually talk about is unknown. And the "hundreds of hours" idea has no measurement behind it at all.

So why do so many players swear their speaker opened up over months? Some of it may be the early loosening Lucas describes. Some of it may be the weather, given how much temperature moves fs. And some of it may be us. Over weeks of playing, we get used to a sound and learn how to work with it. I can't prove which of these is doing the work for any one speaker, but Chapter 13 shows how easily expectation changes what we hear.

Verdict: Partly true. The suspension does loosen permanently and the resonance drops a few percent, mostly affecting the low end. How much that changes a guitar speaker's voice hasn't been measured, and the hundreds-of-hours lore has no data behind it.

Try it yourself: If you want to break in a new speaker, follow the maker's own short routine and then just play. If it sounds different on a cold night than a warm one, temperature may be part of the reason.

Myth: The amp sounds the same wherever you stand

> **The claim:** *The tone I hear standing next to my amp is the tone the audience hears.*

Chapter 13 touches on the listening side of this. Here I want to look at it from the speaker's point of view, because this is where it starts.

The general physics rule is simple. Low notes spread out from a speaker in every direction. As notes get higher, the sound bunches into a beam that comes straight out in front of the cone. Step off to the side and the treble drops. Engineers call this *directivity*, or more casually, *beaming*.

Daniel Russell of Penn State's acoustics program shows how this works using the standard model of a speaker cone as a flat disk pushing air. When the sound's wavelength is long compared with the disk, the sound spreads about equally in all directions. As the pitch rises, the sound gets squeezed into a cone about 55 degrees out from the center line, and higher still, the main beam narrows to about 20 degrees each side [12]. He also

shows a measured 4-inch speaker in a box: at 250 Hz it sent sound out about equally all around, but at 10,000 Hz the level behind it was nearly 25 dB lower than in front [12].

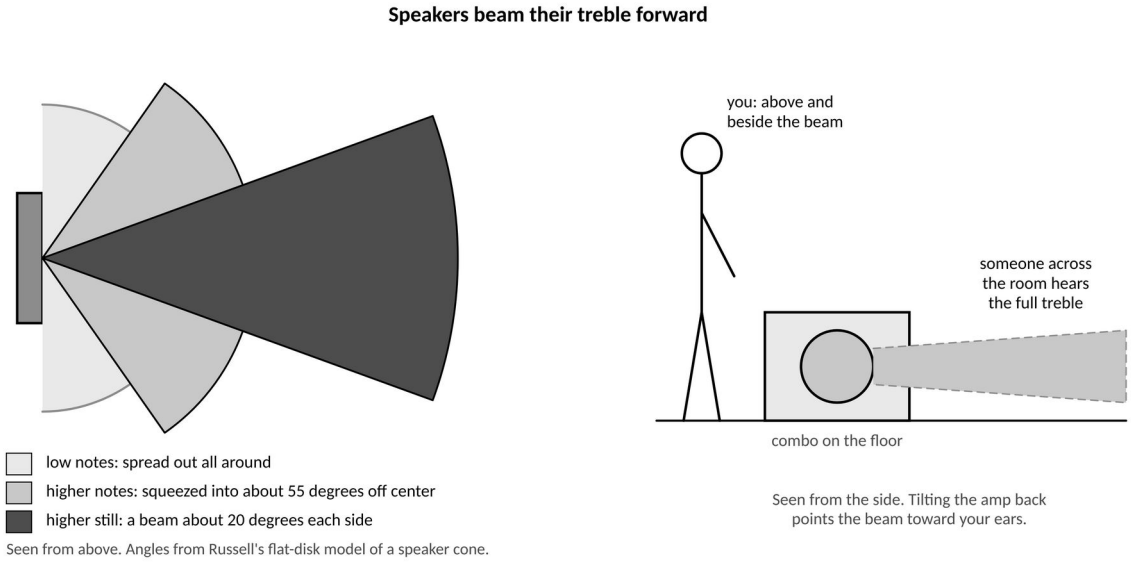


Figure 11.4: Low notes spread out; high notes beam forward. Standing beside or above a combo puts you off the beam.

A 12-inch guitar speaker is a big cone, so it beams more than a small one at the same pitch. Yeh and his colleagues describe guitar speakers as highly directional at high frequencies [1]. I couldn't find a published measurement of exactly how a specific guitar speaker spreads its sound, though. The speaker data sheets checked for this book show only the response straight in front, and the exact angle and pitch where beaming starts vary with the speaker and the cabinet.

Now picture a combo amp on the floor. You're standing above it or beside it, well off to the side of the beam. Someone across the room may be standing right in line with the cone. You hear less treble than they do. They get the fizz you never heard while dialing in. That's why so many players tilt their amps back.

Tilting points the beam up toward your ears instead of at your knees. Some players go the other way and put a diffuser in front of the speaker to spread the treble out. I haven't seen measurements showing how well those work, so I can't give you a verdict on them.

Then the room joins in. A 2025 TU Graz thesis on an ordinary hi-fi driver (not a guitar speaker, so take it as general background) used a standard weighting for what a listener hears in a typical room. It gives the sound straight from the speaker only about 12% of the weight; the rest goes to early reflections and the speaker's total output in all directions, which reaches you by way of the walls, floor and ceiling [13]. Walls and floors add or cancel some of the bass depending on where you stand, and so does the open back of a cabinet.

People really do hear these position effects. Sean Olive, a longtime acoustic researcher at Harman, described blind tests of hi-fi speakers in which moving a speaker to a different spot in the room clearly changed how listeners rated it. When listeners could see the speakers, that effect nearly disappeared [14]. Those were hi-fi speakers and listeners, but the physics of sound in a room doesn't care what's plugged into the speaker.

Verdict: Busted. Speakers beam their treble forward, and rooms add reflections that change with position. Where you stand changes what you hear, and in blind hi-fi tests even moving the speaker within the room changed listeners' ratings.

Try it yourself: Have a friend play the same chord over and over while you walk from beside the amp to straight in front of it, then across the room. Then tilt the amp back and do it again.

What this means for your money

- If you're happy with your amp but not your sound, try a different speaker before you buy a different amp. It's one of the strongest filters in the chain, and the one you can't turn off.
- When shopping speakers, compare sensitivity within one maker's line. A speaker 3 dB more sensitive gives you the same volume boost as doubling your watts.
- Don't stress about break-in. Follow the maker's short routine and play. Temperature can move a speaker's resonance about as much as break-in does, or more.
- Dial in your tone from where the audience will hear it, or at least check it there. Tilting a combo back so the speaker points at your ears costs nothing.
- If you record, spend time on mic placement before you spend money on gear. An inch on the cone can change the sound a lot.

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Chapter 12: Pedals: True Bypass, Magic Boxes, and Batteries

If pickups get players talking, pedals get them arguing. The pedal world runs on small makers, hand-built boxes and a lot of word of mouth, and that's a perfect home for myths. Some pedals sell used for prices that make people wince. Some players swear a dead battery is a tone secret. And a whole generation of pedals was sold on two words printed on the box: true bypass.

I like pedals. I also like knowing what's inside them. So in this chapter we'll open up five common claims and see what the circuit analyses and measurements say.

Nobody has run a proper blind listening test on any of the five pedal myths in this chapter. What we have is circuit analysis, one magazine shootout, two papers on delay chips, and advice from companies that sell pedals and batteries. I'll tell you who's selling what as we go.

A few pedal words

Before we start, some terms. *Bypass* is what a pedal does with your signal when it's switched off. A *true bypass* pedal uses its footswitch to connect the input jack straight to the output jack with plain wire when it's off, so the circuit is out of the path completely. A *buffered bypass* pedal sends your signal through a small circuit called a *buffer* even when the effect is off.

I introduced buffers in Chapter 7. A buffer takes your guitar's signal and drives the next cable for it, so that cable can't drag down your pickup. It does that because it has a high *input impedance* (it barely loads what comes before it) and a low *output impedance* (it can push a signal down a long cable without losing treble). *Impedance* is just resistance to an alternating signal like the one your guitar makes.

True bypass and buffers

Myth: True bypass is always better than buffered

> **The claim:** *A true bypass pedal leaves your tone untouched. Buffered pedals color your sound, so every pedal on your board should be true bypass.*

Where did this come from? It had a real starting point. A Fender article on the subject notes that many older pedals that weren't true bypass did cut the highs when switched off [1]. Players heard that, and true bypass became a selling point.

But true bypass has a cost that's easy to miss, and it goes back to Chapter 7. A guitar cable is a capacitor, about 100 pF per meter by Zollner's figures, with typical cables at 300-600 pF and very long runs reaching about 1.5 nF [2]. That capacitance sits across your passive pickup and pulls its resonant peak lower, so more cable means a darker sound. When every pedal on your board is true bypass and switched off, your pickup sees *all*

of the cable at once: the cable to the board, every little patch cable, and the long cable to the amp. Plain wire doesn't stop anything from adding up.

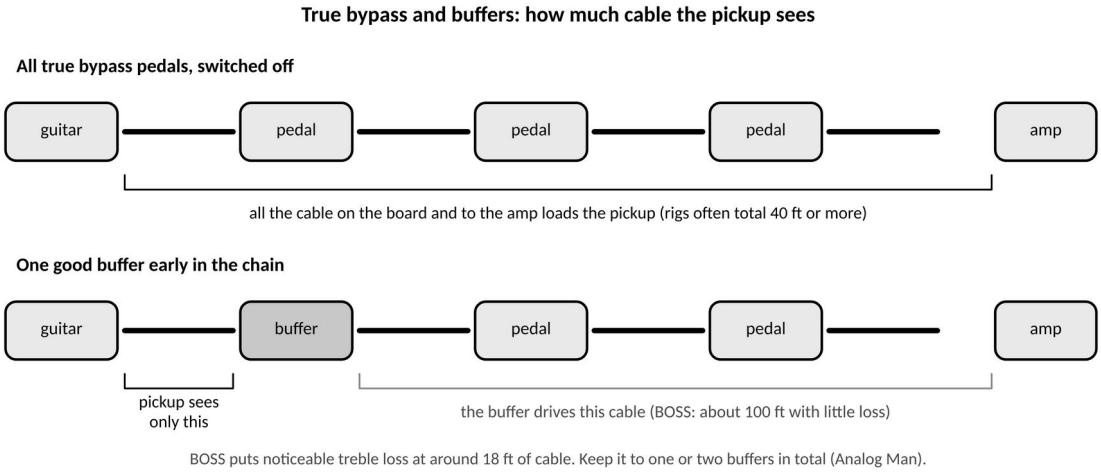


Figure 12.1: With every true bypass pedal off, the pickup sees all of the cable. One buffer early in the chain cuts that to the first short cable.

BOSS says the treble loss becomes noticeable at around 18 feet of cable, that real rigs often total 40 feet or more, and that a buffer can drive about 100 feet after it with little loss [3]. BOSS also says every one of its pedals includes a buffer [3], though a few larger models, such as the DD-500 delay, let you switch to true bypass instead [4]. Either way, BOSS has a stake in this answer.

Paul White, editor-in-chief of Sound On Sound, wrote on Roland's UK blog that true bypass has its own drawbacks [5]. The switching can make noise. The losses from cables and switch contacts add up across a board. And a true bypass delay cuts off its echoes the moment you step on it, instead of letting the tail fade out. His view is that a buffer early in the chain keeps the cable to the amp from dulling the highs, and that a well-designed buffer keeps both the quality and the level of the signal [5].

So buffers win? Not so fast. Buffers can cause trouble too. Analog Man, a pedal maker that builds and sells a buffer, advises on its buffer page keeping buffered pedals to one or two, because extra ones can dull the presence and feel [6]. An earlier Premier Guitar column by Tom Hughes, mostly passing along advice from Analog Man founder Mike Piera, says the same thing: keep the number of buffers in your path small [7]. A poorly designed buffer, or a stack of them, can color the sound. And as we'll see later in this chapter, some vintage fuzz pedals behave badly with a buffer in front of them [6, 8].

Notice who agrees here. BOSS, Roland (BOSS's parent company, which published White's piece) and Analog Man come at this from different angles, and they land in about the same place: one good buffer, in the right spot, is usually the best setup. Fender's article makes a similar point, suggesting one buffer at the start of a true bypass chain [1]. Several of these sources sell buffers, so weigh that. But the cable physics behind their advice is the same physics measured in Chapter 7.

Verdict: Busted. Neither is always better. True bypass avoids coloring a short, simple rig, but on a big board with long cables, one good buffer keeps your treble from draining away.

Try it yourself: Plug your guitar into the amp with one short cable and play a clean chord. Then run through your whole board with every pedal off and play it again. If the second one sounds duller, a single buffer near the start will likely bring it back.

Magic boxes

Myth: The Klon Centaur is magic, and the germanium diodes are the secret

> **The claim:** *The original Klon Centaur has a sound no other overdrive can match, thanks to its rare germanium diodes and secret circuit.*

The Klon Centaur is an overdrive pedal with a legend, and used ones sell for prices that ElectroSmash, an electronics site that analyzes pedal circuits, calls shocking. ElectroSmash openly asks whether the hype is justified [9].

Let's look at what's inside, based on their analysis [9]. The heart of the clipping is a pair of 1N34A germanium *diodes*. A diode is a part that lets current pass one way, but only once the voltage across it reaches a certain level, called its *forward voltage*. Two of them wired in opposite directions side by side act like a ceiling on the signal, and anything above that ceiling gets cut off. That's *clipping*, and it's what makes distortion. Germanium diodes have a forward voltage of about 0.35 V, versus about 0.7 V for silicon, so they start clipping at a lower level. ElectroSmash quotes the pedal's designer, Bill Finnegan, saying these diodes are the most important factor in how it sounds when it's distorting [9].

But the diodes are only part of the story. The circuit also has a stage that blends the clipped signal with clean signal that never touched the diodes. The gain knob has a second section that rebalances clean and dirty together as you turn it. A small chip called a charge pump turns the 9 V supply into +18 V and −9 V, which gives the later stages 27 V of *headroom*, meaning room for the signal to swing before it clips by accident. There's even an input buffer, built around a common chip with about 1 MOhm of input impedance. As for the famous black goo poured over the circuit board, its job was to keep people from copying the circuit.

ElectroSmash puts the sound down to good circuit design and says no exotic or expensive parts are needed [9]. The 1N34A diode is a cheap, widely made part. One fair caveat: real 1N34A diodes vary, so two units could differ a little.

Is there any listening evidence? In 2020, Premier Guitar ran a shootout by Joe Gore [10]. He recorded his playing once and *re-amped* it, which means playing the same recorded guitar signal back through each pedal so the performance is identical every time. He ran it through an original gold Klon and five cheaper clones. This was not a blind test. The clips were played in a fixed order, so listeners knew which was which. But he also compared the frequency curves, and the Klon and the Electro-Harmonix Soul Food came out nearly identical [10]. Gore still heard small differences, a bit more low end on the Klon and a bit more top on the Soul Food, but called them far from dramatic. That's informal evidence, not proof. Still, it lines up with the circuit analysis.

Verdict: Mostly busted. The Klon's sound comes from a clever, copyable circuit, not from rare parts, and a clone measured nearly the same. Nobody has run a controlled blind test of an original against its clones.

Echoes

Myth: Analog delay beats digital

> **The claim:** *Analog delays have warm, musical repeats. Digital delays sound cold and sterile.*

Most analog delay pedals use a chip called a *bucket-brigade device*, or BBD. Picture a line of people passing buckets of water down the line. The BBD does the same thing with tiny samples of your signal, passing them along a chain of capacitors, one step for each tick of a clock. The longer the chain or the slower the clock, the longer the delay.

An analog delay is actually a *sampled* system, just like a digital one. It takes snapshots of your signal at each clock tick, though it stores each one as an analog charge rather than a number. Raffel and Smith, in a 2010 paper on modeling these chips, point out that BBDs have built-in *aliasing* (false tones created when the sampling can't keep up with high frequencies), plus distortion and noise [11]. To hide those, practical pedals add *low-pass filters*, which cut the highs, and *companders*, which squeeze the signal before the chip and expand it after to bury the noise [11].

That's where the analog sound comes from. The repeats are filtered, a little distorted and a little squeezed. Each repeat goes through the chain again, so each one gets darker and dirtier than the last. Longer delay times mean a slower clock, which makes the repeats darker still. A clean digital delay, by contrast, gives back something much closer to what you played.

Which is better? That's the honest problem. Many players love the darker analog repeats because they sit behind the notes you're playing instead of fighting with them. That's a real musical reason, and it's a matter of taste.

Raffel and Smith also showed that each part of a BBD circuit can be modeled accurately from circuit analysis and measurement [11]. Holters and Parker, in 2018, presented a digital model that includes the BBD along with the filters around it [12]. So the analog character can now be built into a digital pedal on purpose.

Verdict: Debated. Analog and digital delays really do sound different, but "better" is taste, and the analog character can be modeled digitally.

Try it yourself: Set an analog delay to a long time with lots of repeats and listen to how each echo gets darker. If you like that, look for a digital delay with an analog mode before you decide you need the real chip.

Power and fuzz

Myth: Old carbon-zinc batteries make fuzz pedals sound better

> **The claim:** *Vintage fuzz pedals ran on carbon-zinc batteries, and an old carbon-zinc battery makes a fuzz sound warmer and better than a fresh alkaline.*

This one has a source on the claim side. ElectroSmash's germanium Fuzz Face build page says the original pedal ran on carbon-zinc batteries and claims they sound better than alkaline, but it doesn't give a test [13].

To sort this out, we need one term. *Internal resistance* is the resistance inside the battery itself. When a circuit draws current, some voltage gets lost across that resistance before it reaches the pedal.

Energizer's manual for carbon-zinc batteries says internal resistance is highest for standard carbon-zinc cells, lower for the "heavy duty" zinc chloride type, and lowest for alkaline [14]. It goes up as the battery gets colder. And it rises slowly as the battery is used, then shoots up near the end of its life [14]. Energizer's alkaline manual gives fresh cylindrical alkaline cells about 150-300 milliohms (thousandths of an ohm), though it doesn't cover 9 V batteries [15]. The datasheets for a 9 V carbon-zinc and a 9 V alkaline battery both list 9.0 V nominal, and neither lists internal resistance [16].

Now, how much current does a fuzz need? ElectroSmash's germanium Fuzz Face build draws about 2.5 mA (milliamps, thousandths of an amp) from 9 V, and that total includes its status LED [13]. That's tiny. A small current through a small resistance loses almost no voltage. So a fresh battery of either kind barely sags under a Fuzz Face.

That doesn't mean batteries never matter. ElectroSmash's analysis of the Fuzz Face says the tone does change with different batteries and as a battery drains. The battery's internal resistance adds to a 470-ohm resistor in the output transistor's collector circuit, which shifts the output level [8]. And as any battery wears out, its voltage drops and its internal resistance rises, so an old battery acts like a weaker, lower-voltage power supply.

Lower voltage changes a fuzz. It shifts the transistors' *bias*, which is their resting point when no note is playing, and it cuts headroom. The result is a gated, sputtery, more squeezed fuzz that some players love. But that's the falling voltage and rising internal resistance doing it, not anything magic in carbon-zinc chemistry. A worn-out alkaline would get there too, eventually, and a power supply you can turn down gets you most of the way.

Verdict: Mostly busted. A low or dying battery really does change how a fuzz sounds, but the cause is the dropping voltage and rising internal resistance, not carbon-zinc chemistry, and whether it sounds better is your call.

Try it yourself: If you have an adjustable pedal power supply, turn the voltage down a little at a time on your fuzz and listen. That gets you most of the "old battery" sound, on demand. If your fuzz is a positive-ground germanium design, check the maker's instructions first, and power it only from an isolated output or its battery, never from a daisy chain.

Myth: Germanium fuzz is better than silicon

> **The claim:** *Germanium transistors give a fuzz a warm, smooth, vintage sound. Silicon fuzz is harsh and second-rate.*

The original Fuzz Face used germanium *transistors*, the tiny parts that do the amplifying. Later versions moved to silicon. ElectroSmash itself describes germanium as warmer and creamier, but it also lays out the downsides plainly [8].

Here's what their analysis says [8]. Germanium parts are less consistent from one to the next, more sensitive to temperature, and have high *leakage*, which is a small current that flows through the transistor when it shouldn't. Their *gain* (how much they amplify) is uneven too. For the two transistors in a Fuzz Face, ElectroSmash gives an ideal gain of about 70-80 for the first and about 110-130 for the second. Silicon has more gain and a brighter, harsher top end. Makers moved to silicon because it's stable with temperature, cheap and consistent.

How uneven is germanium? The AC128, a classic germanium transistor, has a listed gain anywhere from 45 to 165 [13, 17]. Ian Poole of Electronics Notes says gain varies a lot even between transistors of the same type [17].

That's why ElectroSmash's build guide sets a target voltage of about −4.5 V on the second transistor and uses two adjustable trimmers to get there, since matched germanium parts are hard to find [13]. The same guide calls silicon transistors temperature independent and more stable [13]. They're not quite that, but they are far less sensitive to heat than germanium.

What does that mean on a gig? Leakage rises with heat, and that shifts the bias. So the same germanium fuzz can sound different on a hot stage than it did in a cold rehearsal room. When a germanium fuzz is biased well, many players hear it as smoother, and it cleans up nicely when you roll back the guitar's volume. A silicon fuzz has more gain and stays put, but it can sound brighter and harsher unless the circuit is adjusted for it.

So the difference is real and you can measure it. But "better" depends on what you want, and with germanium it also depends a lot on which transistors you got and how well someone biased them. A badly biased germanium fuzz can sound worse than a decent silicon one.

Verdict: Debated. Germanium and silicon fuzzes do differ in gain, leakage, temperature stability and bias. Which is better is taste, and a germanium fuzz is only as good as its parts and its setup.

Where things go on the board

Pedal order is a big topic, and most of it is taste. But there's one rule the sources back up, and it ties this whole chapter together.

A Fuzz Face has a very low input impedance, only about 5-8 kOhm, and it changes as you turn the Fuzz knob [8]. Compare that with the 250-500 kOhm pots in your guitar from Chapter 7. A Fuzz Face loads your pickups heavily, and that's part of why it reacts so well to your guitar's volume knob. It's talking straight to the pickup. Put a buffer in front of it and the fuzz no longer sees your pickup. It sees the buffer, and it responds differently [8]. Analog Man says vintage fuzzes like the Fuzz Face and Rangemaster can sound brittle after a buffer, and advises putting buffers and buffered pedals after them [6].

So here's a simple layout that follows the evidence:

- Vintage-style fuzz first, straight from the guitar.
- Then one good buffer, or one buffered pedal, early in the chain [1, 5].
- Keep it to one or two buffers in total [6, 7].
- Some pedals with a high output impedance, like the Phase 90, also benefit from a buffer after them, according to Analog Man [6].

After that, put things where they sound best to you.

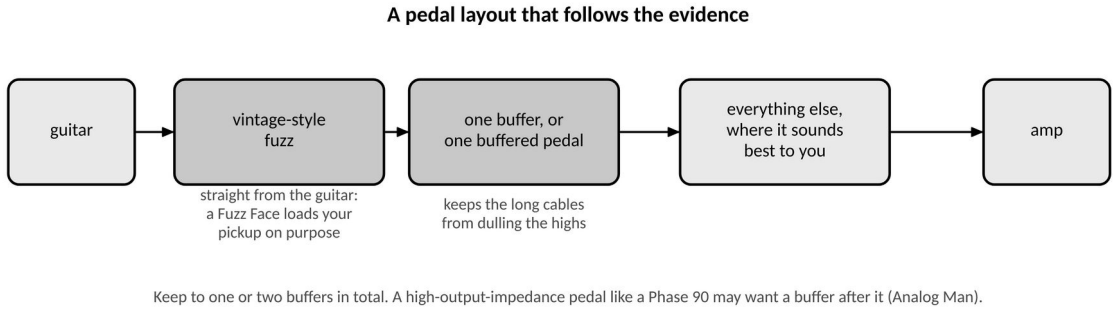


Figure 12.2: The one pedal-order rule the sources back up, plus the buffer advice from this chapter.

What this means for your money

- Don't pay extra just because a pedal says true bypass. On a big board, one good buffer often helps more than a board full of true bypass switches.
- Don't stack buffers. One or two is plenty.
- Put a vintage-style fuzz first, before any buffer.
- Before you pay collector prices for a famous overdrive, try a well-made clone of the circuit. The circuit is the thing.
- Choose analog or digital delay by ear. If you like dark repeats, an analog mode on a digital pedal may get you there.
- Skip the hunt for old carbon-zinc batteries. If you want a starved fuzz sound, an adjustable supply gets you most of the way, on demand.
- Buy germanium fuzz for the feel you like, from a maker who biases each one, and expect it to change a bit with temperature.

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Chapter 13: Your Ears Are Part of the Rig

We spend a lot of money on the gear between the strings and the speaker. Pickups, pots, pedals, amps, cabs. But there's one piece of the signal chain nobody sells you an upgrade for, and it's the one that makes the final call: you. Your ears pick up the sound, and your brain decides what it means.

That brain is smart, and it's also easy to fool. It blends what reaches your ears with what you expect, what you can see, how loud things are, and what you feel through your hands. Most of the time that's a good thing. It's why you can pick out your bandmate's voice across a noisy bar. But when you're trying to decide whether an expensive part sounds better than a cheap one, it can lead you right off a cliff.

This chapter is about that last link in the chain: what seeing the gear does to your hearing, why the louder option keeps winning, why the player and the audience can hear two different guitars, and why your amp changes as you walk around the room. I'll also show you how to run a fair blind test at home, so you can check any claim in this book yourself.

I do not play guitar myself, but I have spent more than 20 years listening closely to instruments on the bench and judging tone by ear. Ears tire. What sounds right after a long session may not sound right the next morning. Stepping away often fixes a tone problem faster than turning another knob.

The brain in the signal chain

First, a few terms. A *blind test* is one where the listener doesn't know which option is playing. A *double-blind test* goes one step further: the person running the test doesn't know either, so they can't give anything away by a look or a tone of voice. A *sighted test* is the normal way we compare gear, with everybody knowing what's what.

Myth: I can hear the difference, I don't need a blind test

> **The claim:** *An experienced ear is reliable. If I can hear a difference with my own ears in my own room, I don't need a blind test to prove it. Blind tests are flawed anyway.*

I understand this one. When you hear a difference, it feels completely real, and you really did experience it. The question is whether it came from the sound or from somewhere else.

The best-known test of this comes from the hi-fi world. In 1994, Toole and Olive presented a paper on blind versus sighted listening tests of loudspeakers, using a set of expensive high-end speakers plus a small, inexpensive speaker as a check on the sighted listeners [1]. The published abstract doesn't give the numbers, but Sean Olive, a longtime acoustic researcher at Harman, later described the experiment on his blog [2].

Here's what he reported. Forty Harman employees rated four loudspeakers of widely different size and price, on four pieces of music, once with the speakers in view and once with them hidden [2]. When listeners could see the speakers, ratings went up for the bigger, more expensive Harman models. Two of those speakers were built the same apart from their crossover (the circuit that splits the signal between the woofer and tweeter), yet seeing them still pushed their scores up [2]. When people could see them, a large, expensive competitor's

speaker was rated above a small, cheap Harman speaker. With the speakers hidden, the order flipped, and the small speaker was slightly preferred [2].

Where each speaker sat in the room made a clear difference in the blind ratings. When listeners could see the speakers, that real difference almost vanished [2]. So expectation didn't only add differences that weren't there. It also covered up differences that were. Olive's conclusion was that a listening test has to be done blind if you want the truth about how a product sounds [2].

A fair word of caution. These were speakers and hi-fi listeners, not guitars and guitar players. Nobody has measured the size of this effect for guitar gear the same way. And the full numbers from the 1994 paper sit behind a paywall; the figures above come from Olive's own summary. But I can't think of a reason guitar players would be immune. We see brand names, price tags, and the shape of the headstock just like anyone else.

Verdict: Busted. Controlled tests show that seeing the product shifts ratings toward expensive, familiar gear and can hide real differences. Sighted listening is not reliable on its own.

Try it yourself: Next time you're sure two pieces of gear sound different, have a friend switch between them while you look away. The blind test section later in this chapter shows you how to make that fair.

Myth: Old Italian violins sound better than any new instrument

> **The claim:** *A Stradivari or Guarneri violin has a sound no modern maker can match.*

This is a violin myth, but I'm including it because it's the best-tested version of the "old is better" belief in any instrument, and guitar players borrow it all the time.

In 2012, Fritz and colleagues published a double-blind study run at a violin competition in Indianapolis in 2010 [3]. Twenty-one experienced violinists, 19 of them professionals, played six violins in a hotel room: three new ones, two Stradivari and one Guarneri del Gesù [3]. In head-to-head pairs, the players chose an old violin on average in only about 3.7 of 9 pairings [3]. The violin preferred most often was a new one. The one rejected most often was a Stradivari. Only 8 of the 21 players chose an old violin as the one they'd most like to take home [3]. When 17 of them were asked to guess whether their favorite was old or new, 7 had no idea, 7 guessed wrong, and 3 guessed right [3].

That first test took place in a hotel room with fairly dry acoustics, not a concert hall, and the players weren't famous soloists. The next study changed both. In a study published in 2014, 10 well-known soloists tested 12 violins (6 old Italian, 5 of those by Stradivari, and 6 new) in a small rehearsal room and in a 300-seat hall in the Paris area [4]. I couldn't reach the journal page for this one, so these details come from a National Geographic report and the lab's own page. In their top-four picks, the new violins scored 35 points to the old ones' 4. The top two instruments were new, and when the soloists guessed old or new, they were right about half the time, which is what you'd get by flipping a coin [4].

Then the audience got its turn. A 2017 study, described in a press release from the French research organization CNRS, had 137 listeners in Paris and New York compare three Stradivari with three new violins, double-blind [5]. On average, listeners said the new violins projected better and preferred them. Neither players nor listeners could reliably tell old from new [5].

Does that mean every old violin is worse? No. These were small sets of instruments chosen by the researchers, and some critics argue players need more than a few hours to learn an instrument. What these three studies

found is that once you hide the label, the old instruments as a group weren't preferred and couldn't be picked out. And keep in mind these are violins. I found no comparable published double-blind study of vintage versus new guitars.

Verdict: Busted. As a blanket claim, it fails. Three double-blind studies with players and audiences found new violins were preferred on average, and nobody could reliably tell old from new. For vintage guitars no such test exists; see Chapter 5.

Myth: If it wins a quick A/B, it's the better gear

> **The claim:** *If one amp, pedal or setting sounds better in a quick A/B, it's the better one. A little extra volume doesn't sway the result.*

This is the most practical myth in the chapter, because it sneaks into almost every gear comparison you've made. The trouble is that the louder option often wins without anyone noticing it's louder.

Here's why. Your ear isn't equally sensitive at every pitch. It's most sensitive roughly between 1,000 and 5,000 Hz (hertz, or vibrations per second), and lows and very high tones need a lot more level to sound equally loud [6]. Researchers have mapped this with *equal-loudness contours*, curves showing how loud tones at different pitches have to be to seem equally loud. The original curves were published by Fletcher and Munson in 1933 [6]. The key point is that those curves change shape as the overall level changes. Turn something up, and the bass in particular seems to grow faster than the mids. Winer, an audio writer known for measurement-based advice, notes that louder playback makes the lows and highs seem more prominent [7]. Most of us hear that as "fuller" or "clearer."

So when a boost pedal or a hotter pickup comes in a little louder, it sounds richer, and your brain credits the gear, not the volume.

That's why the people who test audio for a living don't compare anything until the levels are matched. The international standard for detecting small audio differences, ITU-R BS.1116, requires the loudness of each sample to be adjusted before listening starts, uses double-blind testing with a hidden reference, and says about 20 listeners is often enough [8]. Winer, writing for a trade magazine, recommends matching levels within 0.1 dB [7].

Is louder always better, then? No. A study of concert listeners found people preferred classical, small jazz and big band music at roughly 73-85 dB, and liked it less when it got too loud as well as too soft [9]. I only had the abstract for that one, but the point is clear: louder wins only up to a point.

You may have heard a specific figure for how small a loudness bump can sway a listener. I couldn't find a solid published source for one, so I won't give you a number. Just match the levels as closely as you can, every time.

Verdict: Busted. Within comfortable levels, a louder option tends to sound fuller and clearer because of how hearing works, so a quick A/B is unfair until the levels are matched. That's why every fair test matches volume first.

Try it yourself: Play the same riff through your amp at two volume settings that are only a hair apart, and notice which one sounds "better." Then remember that feeling every time you compare two pieces of gear.

How to run a fair blind test at home

This isn't a myth. It's a method, and it's the tool you'll want for almost every "Try it" in this book. The idea is old. In 1982, Clark described a practical double-blind comparator in the Journal of the Audio Engineering Society, along with standards for matching and for checking the results with statistics [10]. The setup is called an *ABX test*: you hear A, you hear B, then you hear X, which is secretly one of the two, and you say which one it is. Here's how to run a home version for guitar gear.

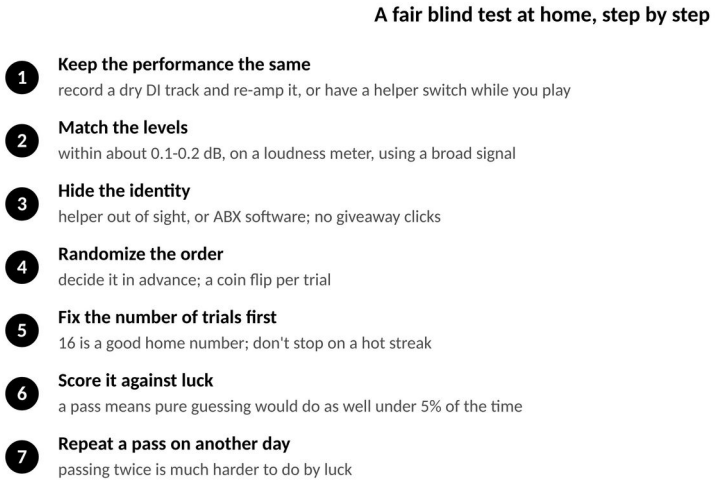


Figure 13.1: The home blind test, step by step.

Keep the performance the same

Your playing changes from take to take, and you'll play differently on gear you expect to like. The cleanest fix is to record a dry guitar track straight from the guitar (a DI, or direct, recording) and play it back through each option, which is called *re-amping*. Feeding a recording into a guitar amp needs a re-amp box (or an interface with a re-amp output) to bring it down to guitar level. If you're testing a guitar or something you have to play live, have a helper do the switching while you play the same short passage each time.

Match the levels

This is the step people skip, and it's the one that matters most. Use the loudness meter in your recording software and get the two options as close as you can, ideally within about 0.1-0.2 dB. A phone meter app is fine for a rough check in the room, but don't trust it to a tenth of a dB. Winer aims for 0.1 dB [7]. Keep test levels moderate and take breaks: long sessions at gig volume tire your ears, which spoils the test, and can damage your hearing. For electronics, Winer suggests a steady test tone and a voltmeter; for sound in the room, he suggests pink noise (a hiss with equal energy in each octave) [7].

One guitar-specific wrinkle: two pickups or two amps don't just differ in level, they differ in tone, so a single test tone can fool you. I'd match on a broad signal, like pink noise or a recorded riff measured with a loudness meter, rather than one pitch.

Hide the identity

You can't know which option is playing. A helper switches out of your sight, or ABX software does it for you. Make sure there are no giveaway clicks, pops or delays that tell you which is which.

Randomize the order

Don't let the helper pick the order on the fly, because people fall into patterns. Decide the order in advance, write it down, and have the helper follow the list [7]. A coin flip for each trial is an easy way to set it. Now and then the same option should come up twice in a row. That's fine; it's part of keeping you honest.

Decide the number of trials before you start

Pick your number up front and stick to it. Sixteen trials is a good number for a home test. Don't stop early just because you're on a hot streak. Stopping when you're ahead is how lucky guessers convince themselves they have golden ears. Winer suggests at least 5 or 6 trials, and notes that pure guessing gets 5 out of 5 about 3% of the time [7]. That's not rare enough to bet much on.

Keep score and check it against luck

Write down every answer, then compare your score to what a coin-flipper would get. Every trial is a 50-50 guess if you can't hear a difference, so here are the odds of doing at least this well by pure luck:

- 12 or more correct out of 16: about 3.8%. That's a pass.
- 11 or more out of 16: about 10.5%. Sounds good, but luck does that about one time in ten, so it's not a pass.
- 9 or more out of 10: about 1.1%. That's a pass.
- 15 or more out of 20: about 2.1%. That's a pass.

The usual line researchers use is 5%. If the odds of guessing your score are below that, your score would be unusual for a pure guesser, and you've likely heard something.

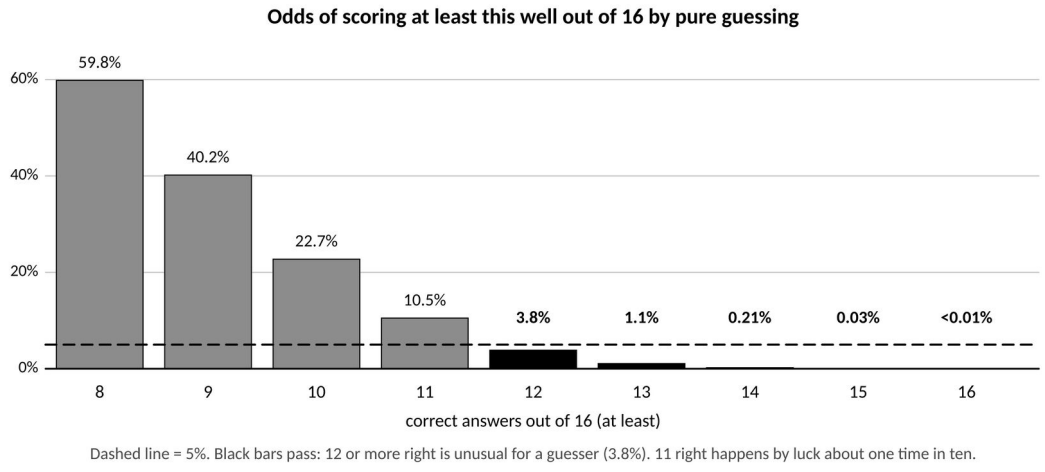


Figure 13.2: The odds of doing at least this well out of 16 tries by pure guessing, figured from simple 50-50 odds. Below the 5% line is a pass.

Repeat a pass before you believe it

If you pass, try it again on another day. Passing twice is much harder to do by luck. And keep in mind that if a whole room full of people takes the same test, a few will pass just by chance, which Winer also points out [7].

Some limits. A short ABX test is good at catching small differences in sound, but it can't measure how a guitar feels over months of playing. And if you fail, it doesn't prove there's no difference. It means you didn't detect one, under those conditions, on that day. A 16-trial test is also a blunt tool. Someone who gets 70% of trials right, a real but small ability, will still fail it about half the time, so if the answer matters, run more trials. A fail is still worth knowing before you spend money.

The player and the audience

Guitar players aren't just listeners. We're holding the thing.

Myth: The player feels the difference, so the audience hears it

> **The claim:** *I can feel this guitar resonate in my hands and against my body. It feels more alive, so it must sound better to everyone else too.*

You might ask, "So is feel just my imagination too?" No. Feel is real. The question is whether what you feel makes it out to the audience.

The best study I found on this used violins. Saitis and colleagues had 16 skilled violinists rate five violins, ranging from about $2,700 to $71,000 and made between 1914 and 2011, two ways: by playing them, and by listening to recordings of them [11]. Each player was about as consistent with themselves in both tasks. But players agreed with each other far more when they were playing than when they were listening to recordings. While playing, there was modest agreement between players; while listening, agreement fell to almost nothing [11]. Eleven of the 16 said their sense of a violin's richness changed when they only listened [11]. The authors suggest that touch and vibration give players cues that simply aren't in the recording.

Another violin study shows the same split from a different angle. Inta, Smith and Wolfe in Australia compared a violin that had been played regularly for three years with its twin kept in museum conditions. Panels of players (blindfolded in the later rounds) and listeners found no more significant differences across 48 comparisons than chance alone would produce. Yet the owner, playing blind, picked out his own violin in 20 of 24 trials [12]. He knew his instrument by how it played, even though nobody listening could hear a preference.

What about electric guitars? The only study I found looked at how guitarists talk, not what they hear. Researchers analyzed 370 passages of speech from 23 electric guitarists and found that 41.3% were about touch. Comments about the neck were tied to touch 91% of the time, and the authors conclude players feel vibration mostly through the neck and the fretting hand [13]. That tells us feel is a big part of how guitarists judge an instrument. It doesn't tell us whether those vibrations change what comes out of the amp.

For acoustic guitars, there's a well-known test that cuts the other way. According to a Lancaster University press release, Carcagno and colleagues had six guitars built that were identical except for the wood on the back and sides, from Brazilian rosewood to walnut [14]. Fifty-two guitarists rated them while playing in a dim room wearing welder's goggles, and the ratings came out similar across all six. In a separate blind test, 31 of those players couldn't easily tell the guitars apart by sound or by feel [14]. Chapter 4 covers that study in more

detail. A PhD thesis from the University of Edinburgh found experienced guitarists in a blind test couldn't reliably tell apart guitars that differed only in back-and-side wood when the woods had similar properties [15].

So here's where I land. A player gets information the audience never gets: vibration through the hands and body, how quickly a note responds, and sound from a few inches away instead of across a room. Two guitars can feel quite different to you and still sound the same to the crowd. And sometimes, as the Lancaster study shows, they're hard to tell apart even by feel once you can't see them.

Verdict: Partly true. Players really do sense differences in feel, response and vibration that listeners often can't detect. But "the player feels it" does not prove "the audience hears it."

Try it yourself: Record two of your guitars through the same rig, same settings, playing the same part. Have a friend play the recordings back to you in random order. Then do the same test by playing each guitar blindfolded. See whether the two results agree.

Where you stand

I covered the physics of this in Chapter 11: speakers beam their treble straight ahead, and the room adds reflections that change from spot to spot. The part that belongs in this chapter is the perception side. In the Harman blind tests I described earlier, moving a speaker to a different spot in the room clearly changed how listeners rated it, and that real difference almost vanished once they could see the speakers [2]. It's the same room physics that changes the sound as you walk around.

What about old wood and relic finishes?

You might expect a chapter about bias to take on vintage guitars, aged wood and relic finishes. Those myths lean hard on expectation, and the violin studies above are the closest thing we have to a blind test of "old is better." But they also involve real questions about how wood and finish change over time, so I cover them in Chapter 5, where we look at finishes, aging and "opening up."

What this means for your money

Your ears make the final call, and they come with a brain that's easily swayed. Here's how I'd put that to work.

- Never judge a purchase by a sighted, unmatched comparison. Price, looks and reputation all leak into what you hear.
- Match the volume before you compare anything. If one option is even a little louder, it has a head start it didn't earn.
- Before spending real money on a tone upgrade, run the blind test in this chapter. If you can't pick it out in 16 tries with the levels matched, think hard about whether it's worth the price.
- Feel counts. If a guitar or a part makes you want to play more, that's a legitimate reason to buy it. Just know that's what you're paying for.
- Dial in your amp from where the audience will be, or at least check it there. The sound beside your amp isn't the sound out front (Chapter 11 explains why).

Chapter 14 pulls these lessons together with the verdicts from the rest of the book into a priority list for spending your tone money.

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Chapter 14: Spending Your Tone Money Wisely

We've covered a lot of ground. Wood, necks, finishes, magnets, wire, pots, caps, cables, strings, picks, tubes, speakers, pedals and the ears on the side of your head. If you read straight through, you saw a pattern. The things players argue about the most are often the things that matter the least, and some of the things that matter the most are cheap, boring and hardly ever talked about.

This chapter puts it all in one place. It doesn't add any new research. Every claim here points back to the chapter where the evidence lives, so you can check my reasoning. Think of it as the conversation I'd have with you at the bench if you came in with a few hundred dollars and asked, "Where should I spend this to sound better?"

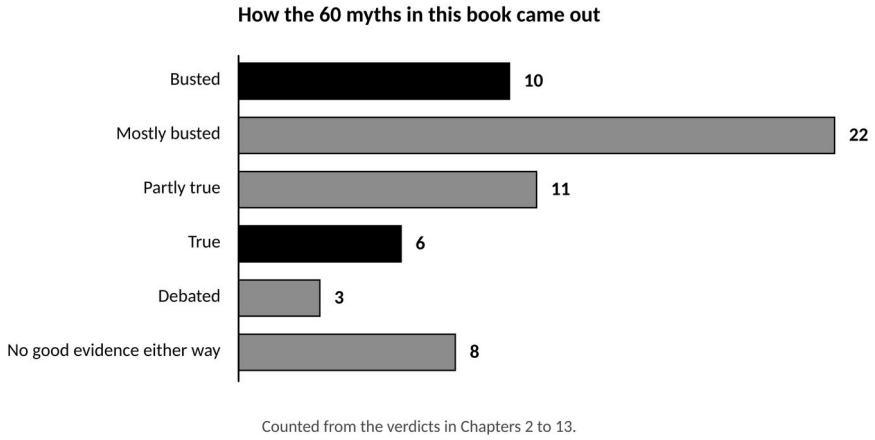


Figure 14.1: How the verdicts in this book came out. Busted and Mostly busted together are more than half.

Start with what's free

Before you buy anything, use the tools you already own. Most of them cost nothing.

- Your hands. Where you pick along the string, how hard you hit it, the angle of your pick and whether you use flesh, nail or plastic all change the sound in big, measurable ways (Chapter 9). Move your picking hand an inch toward the neck and listen. That's a free tone change, and you'll hear it right away.
- Your pickup height. Height changes level, brightness, sustain and even tuning. Too close, and the magnet can pull on the string enough to cause warble (Chapter 6). An hour with a screwdriver and your ears is time well spent.
- Your volume and tone knobs. The tone cap's value does real work when you roll the knob back (Chapter 7). A lot of players leave both knobs on 10 and never find out what the guitar can do.
- Where you stand. The speaker beams its treble straight ahead, and the room adds its own reflections. The sound at your ankles is not the sound your audience hears (Chapter 11). Before you blame the amp for being harsh or dull, walk around the room.
- Your amp's settings at matched volume. A louder setting tends to win a quick comparison, even when it isn't better (Chapter 13). Match the volume before you decide anything.

Then spend on what the evidence backs

Here's the order I'd spend in on an electric. Nobody has tested these upgrades against each other, so the order is my own judgment from the earlier chapters: cheapest and surest first, weighing what each one costs, how big its measured effect is and how solid the evidence is. If you play acoustic, the list is shorter: fresh strings (Chapter 8), a good setup with a well-fitted saddle (Chapters 4 and 9), and a solid top and body size you like from a good builder, chosen over a rare back wood (Chapter 4).

1. Fresh strings

Old wound strings lose their high partials far faster than new ones, while the low end barely changes. The main cause is grime packed into the windings (Chapter 8). A new set is the cheapest real tone upgrade you can buy. If your guitar sounds dull, start here. (My book *Guitar Care and Maintenance* covers how to change and care for them.)

2. A good setup

Action and relief decide when the string starts touching the frets, and fret contact adds treble, buzz and a squashed attack (Chapter 9). A setup won't turn one guitar into another, but that fret contact is a change you can hear. Higher action also lets you dig in harder before the frets get in the way.

3. The right cable, and the right length

Cable capacitance is part of your pickup's tone circuit. More capacitance means a lower, darker peak (Chapter 7). The number that matters is capacitance per meter, not price, plating or copper purity. Buy a cable with a stated low capacitance, and don't use 20 feet when 10 will do.

4. One good buffer, if your board is big

On a long chain of true bypass pedals with long cables, the cable capacitance adds up and your treble drains away. One well-placed buffer fixes that. If you play a vintage-style fuzz, it goes before the buffer (Chapter 12). If your rig is one cable into an amp, you don't need one.

5. Speakers

For many players this may be the biggest single change on the list, though nobody has measured it against the others. It sits fifth only because it costs more than the fixes above it. A guitar speaker is one of the most strongly coloring parts of the chain: it covers a narrow band, and the way the cone breaks up shapes the whole midrange and treble (Chapter 11). If you want a different voice from the amp you already like, try a different speaker before you buy a different amp. And if you want more volume, remember a speaker that's 3 dB more sensitive gives you as much as doubling your watts.

6. Pickups, chosen by their measurements

Pickups really do change the sound, but for different reasons than the ads say. What matters is where the resonant peak sits and how tall it is, and that depends mostly on inductance, the load and the cable. DC resistance alone, magnet grade and winding style matter far less than the catalogs claim (Chapter 6). If you can, compare pickups by resonant frequency and inductance rather than by adjectives. Then set the height before you judge them.

7. An amp or modeler that fits how you play

Tube amps compress, sag and clip in ways that feel good to a lot of players, and tube rectifiers add more sag (Chapter 10). On recordings, listeners in controlled tests mostly could not tell good models from the real amp, especially at crunch settings. So buy for feel, features, weight, volume and budget. The magic isn't locked inside one technology.

Where I'd save my money

Some upgrades have little or no evidence behind them. If you enjoy them, that's your call, and I won't argue with what makes you want to play. But if your goal is a better sound for the money, here's where I'd hold back.

- Tone capacitor upgrades for the sake of the cap type. Value matters, type doesn't (Chapter 7).
- Gold-plated, oxygen-free or boutique-priced cables. Check the capacitance figure instead (Chapter 7).
- Audiophile power cords and fuses for your amp. The measured difference was a fraction of a dB, even with a poor cord (Chapter 10).
- NOS or premium tubes bought to transform your tone. Tubes do differ by a few dB of gain, but the tests used only a few samples of each, and no blind test shows NOS tubes are reliably preferred (Chapter 10).
- Collector prices for a famous overdrive. The Klon's sound comes from a clever circuit, not rare parts, and a good clone measured nearly the same (Chapter 12).
- Paying extra for a neck-through or set neck, a nut or a heavy bridge to get more sustain on an electric. For most notes the string's own losses (air drag and friction inside the string) decide how long it rings. Of the energy the guitar does take, most leaves through the neck, not the bridge, and nobody has shown that a mass swap gives you sustain you can hear (Chapter 3).
- Paying extra for body wood alone on a solid-body electric. The differences measured so far are small, and no controlled test on real, matched guitars has shown players can pick the wood by ear (Chapter 2).
- Paying a premium for rare back and side woods on an acoustic. In the best blind test available, players could barely tell six back woods apart (Chapter 4). Spend on the top, the build quality and the body size instead.
- Paying extra for nitro over poly as a tone upgrade. On an acoustic, a thick finish of either kind adds damping, so thickness matters, not chemistry. On a solid-body, the finish has very little to work on (Chapter 5).
- Vibration devices that claim to open up your guitar. Controlled tests found no change beyond what untouched instruments did on their own (Chapter 5).
- Relic finishes for tone. Buy one if you love the look and feel, not for the sound (Chapter 5).

Where the jury is still out

Some questions don't have answers yet. Nobody has run a good blind test of solid against laminate acoustics of the same design, of one top species against another, of scalloped against standard bracing, of maple against rosewood fretboards, of old wood or a '59 Les Paul against a modern guitar, of phosphor bronze against 80/20, or of coated against uncoated strings (Chapters 2, 4, 5 and 8). Whether torrefied tops really sound like old wood is still debated and hasn't been tested blind, so don't pay extra expecting a vintage sound (Chapter 5). Analog against digital delay and germanium against silicon fuzz really do sound different, but which is better comes down to taste (Chapter 12). If one of these matters to you, test it yourself.

Run your own test

The method in Chapter 13 works for almost anything on this list. Get a helper. Match the volume. Hide which is which. Shuffle the order. Decide how many trials you'll do before you start, and keep score. If you can pick the expensive part 12 times out of 16, that score would be unusual for a pure guesser, so you're likely hearing something. If you land around 8, you're guessing, and you just saved yourself some money.

You might ask, "What if I fail the test but I still like the expensive one better?" Then buy what makes you want to pick up the guitar. Just be honest with yourself about why you're buying it. A part that inspires you is worth something. It just isn't the same thing as a part that changes the sound.

One last word

Most of the sound you love comes from your hands, your strings, your speaker and where you stand, and most of that costs little or nothing. When you do spend money, close your eyes and match the volume first.

Glossary

These are plain-word definitions of the technical terms used in this book. The chapter numbers in parentheses point to where each term is explained in more detail.

- *ABX test:* a blind test where you hear A, then B, then X, which is secretly one of the two, and you say which one X is. (Ch. 13)
- *Action:* how high the strings sit above the frets. (Ch. 9)
- *Active pickup:* a pickup with a small battery-powered preamp built in, so cables and pots affect it much less. (Ch. 6)
- *Aliasing:* false tones created when a sampled system can't keep up with high frequencies. (Ch. 12)
- *Alnico:* a magnet alloy of aluminum, nickel and cobalt (plus iron), used in many pickups. It comes in numbered grades such as Alnico II and Alnico V. (Ch. 6)
- *Beaming:* a speaker's habit of sending its higher frequencies in a narrow beam straight ahead, so the treble drops when you move off to the side. (Ch. 11)
- *Bias:* a tube's or transistor's resting point when no note is playing. Supply voltage and temperature can shift it. (Ch. 12)
- *Bucket-brigade device (BBD):* the chip in most analog delay pedals. It passes tiny samples of your signal down a chain of capacitors, one step per clock tick. (Ch. 12)
- *Buffer:* a small circuit that takes the weak guitar signal and drives the cable after it, so long cables don't drain the treble. (Ch. 7, 12)
- *Capacitance:* the ability to store electric charge. In a guitar rig it comes from the pickup coil, the cable and the tone cap, and it pulls the pickup's resonant peak lower. Measured in picofarads (pF) or nanofarads (nF). (Ch. 1, 7)
- *Ceramic magnet:* a magnet made from ferrite powder. The magnet itself doesn't conduct electricity, so it adds no eddy currents of its own, though steel pole pieces used with it can. (Ch. 6)
- *Class A / Class AB:* ways of running an amp's power tubes. In Class A the tubes draw roughly the same current all the time. In Class AB, a push-pull pair draws more current the harder you play, and near full power each tube shuts off for part of the wave. Sag shows up mainly in Class AB amps. (Ch. 10)
- *Clipping:* what happens when an amp or pedal is pushed past what it can deliver cleanly, flattening the tops of the wave and adding harmonics. This is the root of overdrive and distortion. (Ch. 10, 12)
- *Comb filtering:* the canceling of certain harmonics when a string is plucked, or sensed, at a particular point along its length. The pattern of dips looks like the teeth of a comb. (Ch. 1, 9)
- *Compliance:* how easily a speaker's suspension gives. More compliance lowers the speaker's resonance (fs). (Ch. 11)
- *Conductance (driving-point):* the part of a spot's give, when shaken at a given frequency, that soaks up energy instead of handing it back. A spot with high conductance takes energy from the string quickly. (Ch. 1, 2)
- *Cone breakup:* when parts of a speaker cone start moving on their own instead of as one piece. In guitar speakers it shapes most of the midrange and treble. (Ch. 11)
- *Damping:* anything that soaks up vibration energy, so a note dies faster or a resonant peak gets lower and broader. (Ch. 1)
- *Damping factor:* how tightly an amplifier controls the speaker's motion. Tube amps usually have a low damping factor, which lets the speaker shape the sound more. (Ch. 10, 11)

- *DC resistance (DCR):* the resistance of a pickup's coil measured with an ordinary meter. It tells you about the wire, not directly about how a pickup sounds. (Ch. 6)
- *Dead spot:* a note on the neck that dies much faster than its neighbors, because the neck resonates at that pitch and soaks up the string's energy. (Ch. 1, 3)
- *Decibel (dB):* the unit for comparing levels. A 3 dB change is a small step you can hear; a 10 dB increase sounds about twice as loud. (Ch. 1, 10, 11)
- *DI (direct) recording:* a dry recording of the guitar signal straight from the guitar, before any amp or pedal. (Ch. 13)
- *Double-blind test:* a test where neither the listener nor the person running it knows which item is playing. (Ch. 13)
- *Eddy currents:* small swirls of current induced in metal parts near a pickup, such as covers, magnets and pole pieces, that soak up energy and flatten the resonant peak. (Ch. 6)
- *fs:* a speaker's own resonance frequency, where its cone and suspension vibrate most easily. (Ch. 11)
- *Fundamental:* the lowest frequency of a note, the one that sets its pitch. (Ch. 1)
- *Gain:* how much a circuit amplifies a signal. (Ch. 10, 12)
- *Harmonics and partials:* the higher frequencies that ring along with the fundamental. Their mix is a big part of what we call tone. Strictly, a harmonic is a partial at an exact whole-number multiple of the fundamental; on real strings the partials run slightly sharp (see Inharmonicity). (Ch. 1)
- *Headroom:* how much louder a signal can get before the amp or pedal starts to clip. (Ch. 10, 12)
- *Helmholtz resonance:* the bass "air" resonance of an acoustic guitar, made by the air in the body bouncing in and out of the sound hole. (Ch. 4)
- *Hertz (Hz):* vibrations per second. 1 kHz is 1,000 Hz. (Ch. 1)
- *Humbucker:* a pickup with two coils wired so that hum cancels. It senses the string at two spots, which cancels some frequencies. (Ch. 6)
- *Impedance:* resistance to an alternating signal such as audio, which can change with frequency. Input impedance is how heavily a device loads whatever feeds it. (Ch. 6, 7, 10, 12)
- *Inductance:* a coil's tendency to resist quick changes in the current through it. It is one of the most important numbers for a pickup. Measured in henries (H). (Ch. 1, 6)
- *Inharmonicity:* how far a real string's partials drift from perfect whole-number multiples of the fundamental, caused by the string's stiffness. (Ch. 1, 8)
- *Laminate:* several thin layers of wood glued together with the grain of the middle layer running crosswise, like plywood. (Ch. 4)
- *Level matching:* setting two options to the same loudness before you compare them. (Ch. 13)
- *Load:* whatever a pickup or circuit has to drive, such as pots, cable and the amp input. (Ch. 7)
- *Mode:* one pattern of motion that a guitar top, body or neck can vibrate in, each at its own frequency. (Ch. 4)
- *Negative feedback:* feeding part of an amp's output back to its input to keep the amp accurate. (Ch. 10)
- *Node:* a point on a vibrating string that stays still for a given partial. Plucking or sensing a string at a node leaves out that partial. (Ch. 1)
- *NOS (new old stock):* tubes made decades ago that were never used. (Ch. 10)
- *Nut:* the slotted piece at the headstock end of the fretboard that the strings rest on. (Ch. 3)
- *Output transformer:* the part between a tube amp's power tubes and the speaker that matches the two. (Ch. 10)
- *PAF:* short for "Patent Applied For," the label on Gibson's original late-1950s humbuckers. (Ch. 5)
- *Passive pickup:* the ordinary kind of pickup, with no battery or preamp. The cable, pots and amp input all help shape its sound. (Ch. 6, 7)
- *Phase inverter:* the small stage in a push-pull amp that splits the signal so each tube of the pair gets its half. (Ch. 10)
- *Piezo pickup:* a pickup that turns pressure into an electrical signal, usually a strip under an acoustic guitar's saddle (an undersaddle pickup). (Ch. 4, 8, 9)

- *Pink noise:* a hiss with equal energy in each octave, handy for matching levels. (Ch. 13)
- *Potentiometer (pot):* the variable resistor behind a volume or tone knob. Common values are 250k and 500k ohms. (Ch. 7)
- *Potting:* soaking a pickup in hot wax so it fills the gaps in the coil and between the cover and the bobbin. (Ch. 6)
- *Preamp and power amp:* the two halves of a guitar amp. The preamp makes the pickup's tiny signal bigger and usually holds the gain and tone controls; the power amp makes enough power to move a speaker. (Ch. 10)
- *Push-pull:* a power amp design where pairs of tubes or transistors split the work. A balanced push-pull stage cancels much of its own even-order distortion. (Ch. 10)
- *Q:* how sharply something resonates. A high Q means a tall, narrow peak, and a note or vibration that rings a long time. (Ch. 5, 6)
- *Re-amping:* playing one recorded dry guitar track back through different gear, so the performance is identical every time. (Ch. 12, 13)
- *Rectifier:* the part of an amp's power supply that turns AC into DC. Tube rectifiers let the supply voltage drop more under load than solid-state ones. (Ch. 10)
- *Relief:* the slight forward bow in a guitar neck. (Ch. 9)
- *Resistance (ohms, kOhm):* how hard a part makes it for current to flow, measured in ohms. A kOhm is a thousand ohms. (Ch. 6, 7)
- *Resonance:* a frequency where something naturally rings and gives a boost. In a pickup circuit, it is the peak formed by the coil's inductance and the circuit's capacitance. (Ch. 1, 6)
- *Sag:* a temporary drop in an amp's supply voltage when you play hard, which adds compression. (Ch. 10)
- *Scale length:* the vibrating length of an open string, from nut to saddle. (Ch. 8)
- *Scatter winding:* laying pickup wire on the bobbin in a looser, less orderly pattern than a machine's neat layers. (Ch. 6)
- *Sensitivity:* how loud a speaker plays for a given input power, measured in dB at a set distance. (Ch. 11)
- *Sighted test:* a comparison where the listener knows which item is playing. Sighted tests are easily swayed by expectation. (Ch. 13)
- *Single coil:* a pickup with one coil. It senses a short stretch of string, about 1 cm wide, set by the magnet pole. (Ch. 6)
- *Spectral centroid:* roughly the "center of gravity" of a sound's frequencies. A higher centroid means a brighter sound. (Ch. 9)
- *Sustain:* how long a note keeps ringing. (Ch. 3)
- *THD (total harmonic distortion):* all the harmonics a circuit adds, rolled into one number and given as a percent of the signal. (Ch. 10)
- *Timbre:* the color or character of a sound, separate from its pitch and loudness. (Ch. 1)
- *Torrefied wood:* wood that has been heated in a low-oxygen oven to change its moisture behavior and stiffness. Sometimes called roasted wood. (Ch. 5)
- *Treble bleed:* a small capacitor across the volume pot that lets some highs slip past when you turn the volume down. (Ch. 7)
- *True bypass:* a pedal switching method that connects the input straight to the output when the effect is off, with no circuit in the path. (Ch. 12)

About This Book

This book puts the most common guitar tone claims to the test, one part of the rig at a time: wood, necks and hardware, finishes, pickups, pots and caps, strings, your hands and picks, amps, speakers, pedals, and your own ears. Each myth gets a plain verdict based on the best evidence available, from Busted to True, or an honest "we don't know" where nobody has tested it well.

The last chapter shows where your tone money does the most good, and a glossary at the back explains the terms. This edition adds 34 charts and drawings, from how a plucked string loses its partials to how a speaker beams its treble, plus a step-by-step home blind test with the odds worked out.