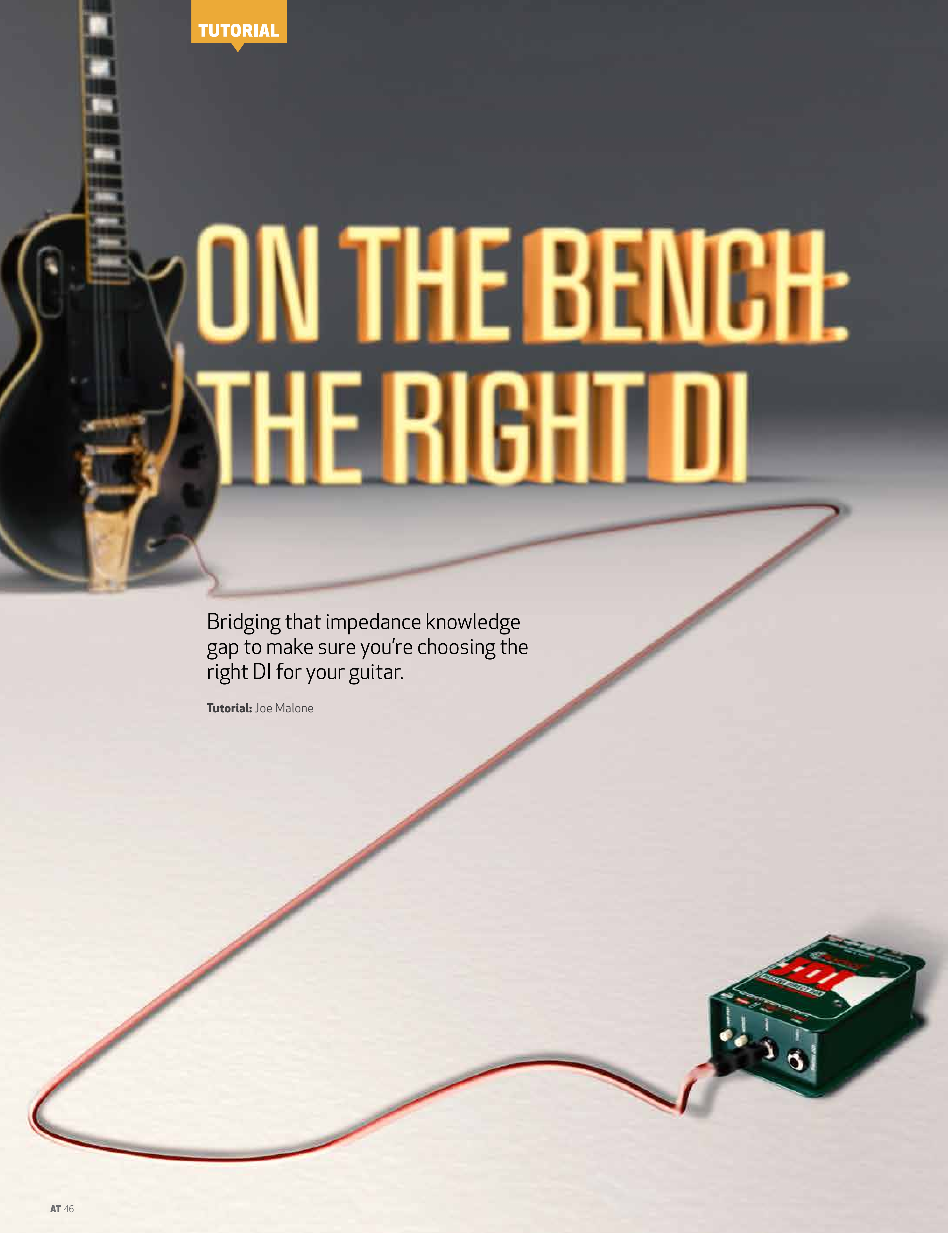


ON THE BENCH: THE RIGHT DI

Bridging that impedance knowledge gap to make sure you're choosing the right DI for your guitar.

Tutorial: Joe Malone

Have you ever thought about picking the 'right' DI? Or have you just been plugging into the closest available ¼-inch socket? I'm here to tell you that DIs aren't all created equal. I'm not selling you a load, but someone might be. Tech joke!

First off, what's a DI? Quick answer: It's an impedance buffer/converter usually with unbalanced to balancing conversion as well. Non-technical version: it helps interface instruments to your DAW without killing your tone.

Unfortunately, impedance is never what people think. It's a complex beast that's a measure of the opposition a circuit presents to a current when a voltage is applied. And it's all over the shop. If it wasn't all over the shop, they'd just call it resistance. And this here is the key to this whole DI conundrum. We're not sending a DC signal through a DI. It's not one straight line of voltage, it's a beautiful soundwave that represents a constantly changing voltage. Hence the impedance changes as your frequency does.

In electronics world, to keep pieces playing nicely, we play a matching game (it's actually called voltage matching, but forget that for now). The rules go something like this: the input impedance of the piece of gear that follows should be much bigger than the output impedance of the preceding piece of gear. Say, about three to 10 times the amount at least. While the number sounds high, it's actually putting a very *low* 'load' on the input, meaning all of that precious voltage gets through with very little current (electronic 'push') required.

A passive electric guitar pickup has a high impedance output of around 5-10kΩ at low frequencies to 50-70kΩ at high frequencies, give or take. This output is already loaded down, usually by a 250kΩ volume pot and 250kΩ tone pot in series with a 22-47nF tone cap. So even with the tone fully open, the high frequencies have a load of 125KΩ. To make sure its voltage gets through intact, we need an even higher impedance input. Which is why 90% of guitar amps — Fender, Marshall, you name it — have an input impedance of around 1MΩ!

So does that little box on the floor, or jack on your interface do the same thing? Let's find out.

PASSIVE PICKS

The most basic and passive way to make a DI is with a step down transformer, which offers a higher input impedance — usually 10kΩ to 100kΩ — with a lower 150-600Ω output impedance. The greater the impedance difference between the input and output, the greater the dB level loss, as the impedance conversion doesn't come for free.

The first thing you would have noticed is that a passive DI's input impedance is not the same as a guitar amp inputs. Furthermore, transformer DIs will sound completely different when driven by different guitars or loaded by different mic pres. So when people talk about liking the 'sound' of a transformer DI, what they often don't realise is its sound or tone will be greatly changed depending on the instrument feeding the input or the mic preamp attached to the output. Whatever happens on the output of the transformer DI is reflected back onto the input. Its frequency response doesn't remain the same.

We talk about impedances like it's going to hold 100kΩ from DC to 5MHz, but that 100kΩ is pretty much only in the lower audio range — it'll have bumps and lumps all throughout the spectrum as the impedance changes. At 50Hz the impedance might be down to 20kΩ, then as you go up to the midrange, it's 100kΩ, then over the top end, it'll load down because of the capacitance of the guitar cable.

If you use a transformer DI, it'll load your pickups in a way so your guitar doesn't sound anything like what it should. I went through all this with Kinman when we were working on his noiseless pickups. When we loaded the pickups like a guitar amp would with a 1MΩ impedance, you could see it push a lump in the Fender pickup design. If you went into a DI with an impedance higher than 1MΩ, that lump would either peak higher or flatten out and it'd have no bite or aggressive sound. And if you went into a transformer DI, it would push that lump way down into the low mid, so you'd get an almost muffled guitar.

Everyone loves the Radial passive DI, they say, 'it's got the best sound.' But it actually doesn't have a set 'sound'. Any changes to what's driving it or what's hooked to the output will completely change the frequency response and colour you get in between. A transformer does that because it's weak, basically. It gets pushed around; its frequency response changes, it gets bumps in the response, it can roll off early. Loading a passive bass with a transformer DI can completely change the sound of your bass, because of the way it reflects the load — often for the better. I usually love transformer DI on old synths as well.

I'm not saying transformer DIs aren't good. They'll either work for what you're doing, or they won't. Passive DIs have another great advantage in that they'll never have a flat battery.

ACTIVE LIFE STYLE

Active powered DIs — tube, transistor or op amp — on the other hand, *can* give you a fairly set 'sound'. Active DIs are a lot more constant, because they isolate the high-impedance input from the low-impedance output almost 100%. They don't see each other's value and react to that. It means that whatever the designer's intent for the device's tone — varying from pure to highly coloured — will be relatively fixed.

Greater impedance differences can also be achieved — 1MΩ-1GΩ input and 20-200Ω output — with no dB level loss due to active buffering and/or gain stages.

We make all of our DIs 1MΩ so your guitar thinks it's plugged into a Fender or Marshall amp. Everything will sound exactly as it should, which is important if you want to reamp. They run right before the mic preamp's input transformer so they keep the tone of the preamp. On some devices, like the API512, when you plug into the DI socket, you're actually behind the input transformer, so the major tonal element is removed from the chain.

WHEN TO GO TO GROUND

People always ask me when you lift it, and when you don't. It's dead easy. If it's 50 or 100Hz humming or buzzing really loudly, then flip the switch. If it was open, it might have needed the ground sent through, and if it was closed, it might need the ground lifted. It either doesn't have the ground at all, or it's got two coming from different places and it's making a loop. Flip the switch and one way will be quiet, it's that simple.

We use FET DIs because they're very simple and pure, with a very high input impedance. If you use transistors, you end up with more capacitance, which can roll off the top end. FET and valve DIs can load 1MΩ with very little capacitance to ground.

PIEZOS PREFER PLENTY

The circuit in a valve mic is essentially a super-high input impedance, phantom-powered DI. They just happen to make the DI input impedance 200MΩ to 1GΩ so the element can drive it. The amplifier is usually a FET with gain, and a stepdown output transformer working as a super-high input impedance DI.

When that's emulated in the outside world — pushing the input impedance up to 500MΩ or 1GΩ — it can really help take the bark out of piezo elements that have direct passive outputs. It's not so critical these days, because a lot of piezo pickups in guitars have onboard preamps performing that role. But when you add a piezo under a saddle, it has a very high output impedance, so even 1MΩ is a heavy load. Placing a really high impedance input up very close so there is no cable capacitance can make a piezo sound much better. They basically want to have super high input impedance so the element doesn't know it's driving the DI at all.

And that's the trick at the end of the day, picking a DI with the right impedance so it keeps your guitar sounding exactly the way it should. Maybe try something active, or look for something with switchable input impedances to give you a variety of tones. After all, it's the guitar that makes the sound, not the DI.

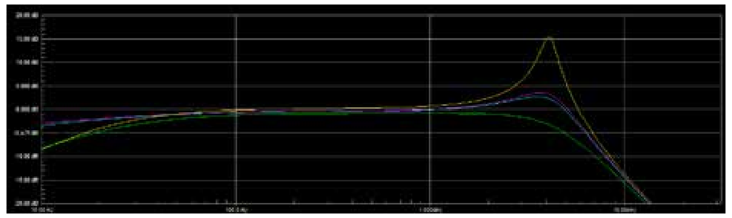
THE LEAD UP

Impedance in guitar amps is pretty pure, but your leads can have a big impact. The biggest rolloff in high end is to do with an unbalanced lead going to the DI. There's a certain capacitance in a 10-foot guitar lead that tunes your pickup in your guitar to a certain type of peak. The impedance of the pickups works with the cable capacitance to make an RC filter which will typically put a bump in the top end before rolling it off.

MEASURING IMPEDANCE

Measuring impedance is not easy, you have to graph it out with test gear. It's usually why active DIs are technically easier, because you know it'll work as advertised due to the isolation.

Here's a frequency graph I made to show you what a Fender Strat looks like when plugged into 100kΩ, 1MΩ and 1GΩ FET DIs, alongside a very cheap 100kΩ passive step-down transformer DI. The passive transformer in this case has a peak (yellow) but depending on the transformer and mic pre used, it could be anywhere between the 100kΩ resistive load rolloff (green) and this peak, or more. The graph was generated from a Strat pickup simulation with volume pot on full and tone pot wide open.



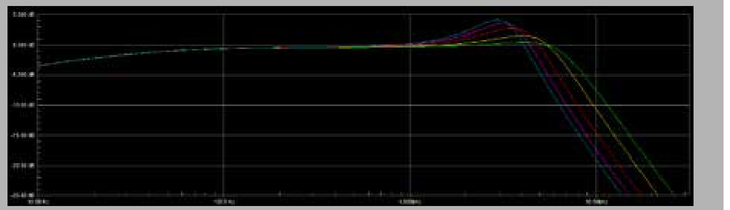
Strat guitar on single pickup emulation into load:

Green — 100kΩ resistive load

Blue — 1MΩ resistive load

Purple — 1GΩ resistive load

Yellow — 100kΩ impedance cheap isolation transformer load



CAPACITANCE CURVES

This graph shows five cable capacitance steps from flattest to highest peak — 220pF, 330pF, 510pF, 680pF and 820pF — to demonstrate how much your lead varies your pickup tone or EQ. The graph is generated from a Strat pickup simulation with volume pot on full and tone pot wide open.

Cable capacitance across Strat guitar on single pickup:

Green — 220pF

Yellow — 330pF

Red — 510pF

Purple — 680pF

Blue — 820pF

CONTROL YOUR CAPACITANCE

Guitar lead capacitance isn't a small influencer on your guitar tone; it's the secret sucker of your high end. Unfortunately, capacitance increases with the length of your guitar cable, so getting the most high end out of your guitar tone typically means standing at arm's width from your amp, or wearing your pedal board like a ball and chain.

When Eric Valentine discovered this capacitance phenomenon he became obsessed with changing guitar cables to find the right match. He's produced and engineered records for Slash, Queens of the Stone Age and Lostprophets, so is naturally a stickler for great guitar tones. So much so, he even built a robot to let him monitor his mic positioning from his control room.

He also owns Undertone Audio, a boutique audio electronics company that builds large format analogue consoles, EQs, preamps and compressors. One day, he was letting out his frustrations over having to constantly swap guitar cables to Larry Jasper, who does all the circuit design for Undertone. Jasper proposed a simple idea. Why not build a cable with variable capacitance?

Hey presto, the 10-foot long Undertone Audio Vari-Cap Instrument Cable was born. After a few years of trying different form factors the final product has Neutrik connectors, and a little box that sits towards one end of the cable with a simple knob for adjusting the cable's capacitance. You can vary the capacitance from an ultra-low 180pF (including the cable, connectors and circuit) to a heavy 1780pF in fifteen 100pF steps.

A good 'low-capacitance' guitar cable these days is usually around the 28pF/ft mark. So for a 10-foot cable, you're up around 300pF. Other cables can be closer to 800pF. Valentine: "180pF is a sound a lot of people have never heard before unless you've tried to plug your guitar in with a three-foot cable."

Valentine isn't necessarily advocating that the lowest setting is always going to be best. While it can open up the sound of some guitar tones, other times it can reveal too much high end and the result can be a microphonic mess. He's just saying that it's worth experimenting with, and hearing your guitar in a way you never have before is worth the price of a cable.

He used Slash as an example: "I was working with Slash around the time I first discovered the benefits of low capacitance cables. So I pulled out some of my great low-capacitance cable and plugged it in with his rig. But it didn't work at all! It just squealed out of control with super, high, feedback oscillation.

"It turned out he was using this particular Monster cable that had an extra-high capacitance to it — in the 1500pF range — and it's part of his sound. He has a modified Marshall head that has a ton of extra high gain blasted into it. The cable was compensating for that and giving him this mid-range push that is part of that scratchy attack he has in his rhythm guitar sound.

"At that time I made a little box that would add capacitance and he and I experimented with different amounts of capacitance for different guitar parts. There were some clean guitar parts where we would take all the capacitance away and all of a sudden his Les Paul would sound more like a Strat. Then you put it back and you have that cool, attacky, mid-rangey sound he uses for his gainy stuff. It's a big deal."

The Vari-Cap cable circuit is purely passive so you don't have to put batteries in the little cablewart. But there are some particulars worth noting. To get the capacitance really low, Undertone used a particular cable that's a tiny bit stiffer than your average guitar cable — not coax install stiff though. "I think people would find it a little too stiff to be walking around on stage and a little too short," said Valentine. "Short and stiff! Not super desirable." In the studio though, it could be your secret tone weapon.

You can grab the Vari-Cap cable from Undertone Audio's site for US$89.99.