FET Preamp Cable

J. Donald Tillman
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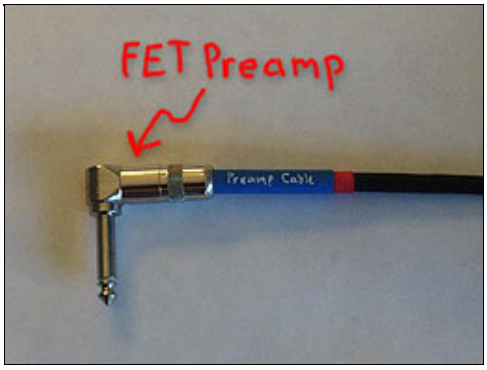
This article describes the Preamp Cable, my *Guitarist's Secret Weapon*. A Preamp Cable is a phantom powered discrete FET (Field Effect Transistor) preamp built into the plug of a guitar cable. It provides almost all the advantages of an on-board preamp with none of the disadvantages.



To the best of my knowledge I invented the Preamp Cable in 1992 and improved it in 1996, though it wouldn't surpise me if someone has done this before. I've built up a number of prototypes with subtle variations and have been using them ever since.

This article is a report about several interesting aspects of the project. It is not a set of step-by-step instructions for constructing a Preamp Cable, although it's close.

What does the preamp do?

While the voltage off an electromagnetic guitar pickup can be a healthy 2.0 Volts or so peak-to-peak if you're playing hard, the impedance of that signal varies greatly over the frequency spectrum and a high impedance signal can be damaged interfacing to the outside world. The load capacitance of a guitar cord can attenuate the high frequencies and lower the tuning of the resonant peak of the pickup. The input impedance of a guitar amp, mixer or effects boxes can attenuate or distort parts of the guitar signal. And because the guitar signal is not very robust, external noise sources and grounding can become serious problems. The guitar's volume control further increases the output impedance, multiplying the problems.

Piezoelectric pickups suffer similiar problems, though the exact mechanisms are different.

A preamp can address these problems by acting as a buffer, providing the guitar pickup with an optimal high impedance load and driving the cable, effects boxes, and amplifier with a robust signal. The sound is ballsier, brighter, and more responsive.

Why a Preamp Cable?

"It preamps anything it touches."

You can get most of the advantages of having a preamp installed in your electric guitars, basses, or piezo-equipped acoustic instruments

- without having to carve up the your favorite instrument (which can be important if it's an especially valuable vintage model)
- without having to install a bypass switch in case the preamp or battery fails
- without having to wear out the limited number of screw/unscrew cycles of the instrument's wood every time you replace the battery

- without having to build a seperate preamp into each of your instruments.

Additionally, it's easy to carry extra Preamp Cables as backups in case of failures.

(An interesting question comes up; are there circumstances where an on-board preamp has an advantage over the Preamp Cable? Sure; exotic pickup mixing or cases where you want to preamp the pickups individually before mixing them.)

FET Preamp

The preamp itself is a high quality, low noise discrete FET circuit described in my article A Discrete FET Guitar Preamp. The design allows the circuit to be split into two parts at the point where the FET is powered. The FET and a few associated parts can be built into a standard 1/4-inch phone plug on the near end of the cable while the remainder of the circuitry and the battery can be housed in a small MXR-sized box on the far end of the cable.

The preamp has a very high input impedance (3.0 M ohm), a reasonably low output impedance (6.0K ohm), and a slight voltage gain (around 3dB). It does not use opamps and therefore avoids several classes of distortions that I personally don't like.

Phantom power

The Preamp Cable is "phantom powered", meaning that the power to drive the preamp circuitry shares the same wire (the same piece of copper) as the audio signal. This removes the weight and the bulk of a battery and allows the preamp to be built into a standard phone plug.

An XLR connector is used on the far end because it has a more reliable connection for the dc current that will be present, so the Preamp Cable will not be confused with a regular guitar cable, and so the Preamp Cable can be connected to a standard phantom powered mic input.

The little midnight blue box contains a 9-volt battery to power the preamp as well as circuitry to split out the audio from the power. No power switch is necessary as plugging the Preamp Cable into the box effectively turns on the power. There is a second convenience "Auxiliary Output" jack for a tuner.

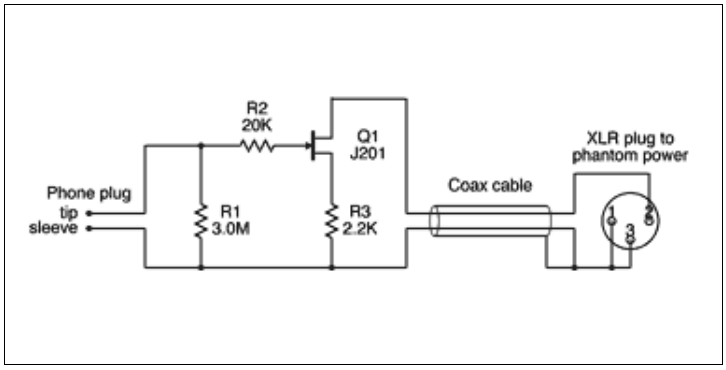
Battery life us six months or thereabouts, depending on use of course. (Long battery life is hard to measure.)

As an extra feature, it turns out that the Preamp Cable can just as well be used with standard phantom powered microphone inputs on a mixer (48 Volt, 6.8 Kohm, balanced). This is the way I typically use it.

Also, you can use a standard microphone cable to extend the length of a preamp cable.

Preamp Cable Construction

Here is the schematic and parts list for the Preamp Cable:



Preamp Cable parts list	
Q1	J201 N-channel JFET
R1	3.0 Mohm 1/8-watt 5% resistor
R2	20 Kohm 1/8-watt 5% resistor
R3	2.2K ohm 1/8-watt 5% resistor
P1	1/4-inch phone plug, Switchcraft 280 (straight) or 226 (right angle)
P2	3-pin XLR plug, Switchcraft A3M or Neutrik equivalent

1/8 watt resistors are necessary for the circuit to fit in the space inside the 1/4 inch phone plug.

The circuit is simliar to the left half of the circuit in my Discrete FET Preamp article. A 20 Kohm resistor has been added to the input for protection from static discharge as the plug will spend some time waving around in the breeze.

Obviously this is not the place for a cheap plug. I've used both the Switchcraft 280 straight 1/4-inch plug and the Switchcraft 226 1/4-inch right angle plug. The straight plug is preferable for the inset jack on a Fender Stratocaster while the right angle plug is preferable for most other instruments. Alternately a Neutrik plug can be used; the Neutrik plugs actually have a little more available space.

(Later note: I will definitely be using the larger Neutrik 1/4-inch plugs for future preamp cables. My eyes aren't what they used to be and the Neutrik models seem to have more working room. Also their large size suggests that this is not just a regular guitar cord.)

Due to FET manufacturing consistancy issues and power supply limitations, the FET needs to be hand selected for the best performance from this circuit. I recommend building up a breadboard version of the circuit and substituting FETs until the voltage at the drain is closest to 6.0 volts.

The circuitry is crammed into the space inside the plug. This is not an easy operation and a small-tipped low power soldering iron is essential. As is a lot of patience.

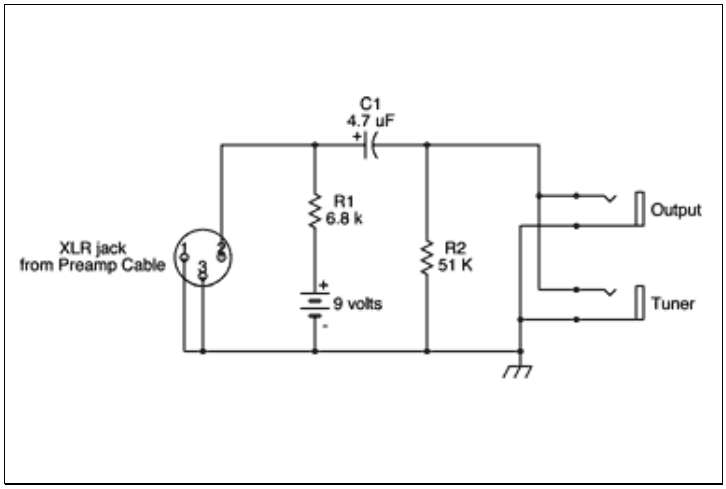
By itself the circuitry would be susceptable to mechanical strain from regular cord use, so the inside volume of the plug is filled with epoxy. Black electrical tape works well to hold the epoxy in place while it hardens as well as insulating any solder connections from the plug case. Additionally, heat shrinkable tubing helps to limit the mechanical abuse of the cable at the stress point. And labeling the cable is important.

The XLR connector wiring is somewhat compatible with the AES XLR spec:

XLR Connections	
XLR pin 1:	Ground
XLR pin 2:	Signal output
XLR pin 3:	Ground

Preamp Cable Phantom Power Box construction

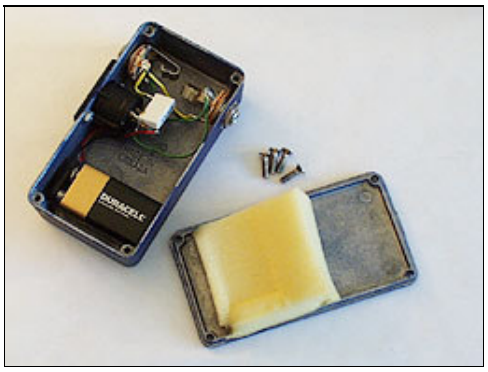
Here is the schematic and parts list for the Phantom Power box:



Phantom Power Box parts list	
R1	6.8 K ohm 1/4-watt 5% resistor
R2	51 K ohm 1/4-watt 5% resistor
C1	4.7 uF electrolytic capacitor

J1	Switchcraft D3F XLR jack
J2, J3	Switchcraft "11" 1/4-inch phone jacks

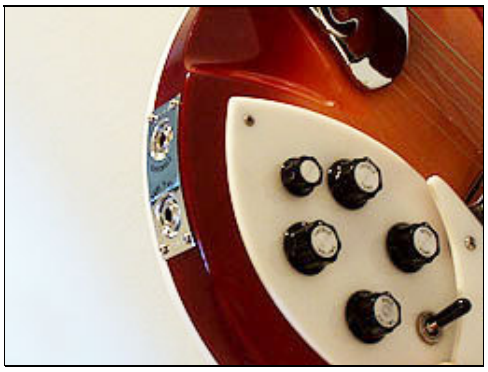
The enclosure is an off-the-shelf Hammond Manufacturing 1590-B die-cast aluminum box, 2.34 x 4.39 x 1.22 inch (60 x 112 x 31mm). Guitarists call it an "MXR box".



Stereo

"Anything worth doing is worth overdoing."

Not only is it possible to pack a preamp into a phone plug, it is also possible to pack two preamps in a phone plug.



I'm a big fan of Rickenbacker guitars, and many Rickenbacker models come with stereo wiring. On these models there are two separate output jacks; one labeled *mono* and one labeled *stereo*. Typically one uses the *mono* output, but the *stereo* output has the bridge pickup through the bridge volume and tone contols on the *tip* terminal and the neck pickup through the neck volume and tone controls on the *ring* terminal. Rickenbacker calls their stereo wiring "Rick-O-Sound".

The stereo wiring can be very useful. A stereo 12-string instrument sounds heavenly. A guitar can have a lot of space when one pickup goes through one effect while the other pickup goes through another. You can fade in effects with the volume controls. Or you can set up the neck and bridge pickups as separate presets and use the pickup switch to bop between them without physically being near a stompox.

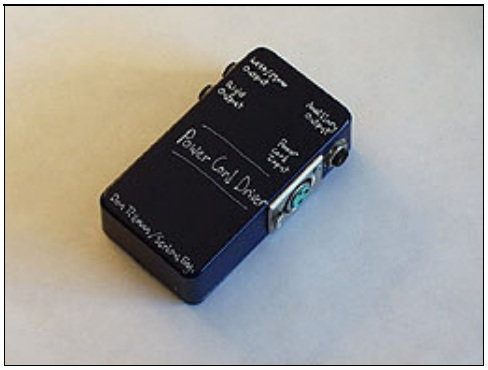
A Stereo Preamp Cable takes advantage of this.

The Stereo Preamp Cable uses a stereo (3 conductor) 1/4-inch phone plug. I've used the Switchcraft 236 (right angle), but the Switchcraft 297 (straight) or the Neutrik equivalents should work fine. As with the mono version, this is not the place for a cheap plug. The Preamp Cable circuitry is doubled, once for the *tip*, once for the *ring* contact. Construction is obviously more

difficult due to the physical size issues. Here in the photo some of the circuitry can be seen inside the epoxy potting.

It would be a good idea to hand-match the FETs for the stereo Preamp Cable.

A stereo version of the Phantom Power box doubles the circuitry of the mono Phantom Power box.



This table show the stereo wiring assignments from guitar to final outputs:

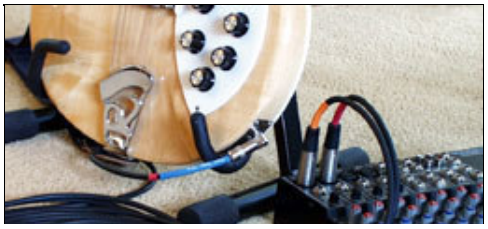
Stereo wiring assignments		
Guitar signal:	bridge pickup	neck pickup
Stereo phone plug:	tip	ring
XLR plug:	pin 2	pin 1
Output jacks:	"Left/Mono"	"Right"

An XLR Splitter Cable is required to run the stereo guitar directly into the phantom power mic inputs of a mixer. The Splitter Cable has a female XLR input plug and left and right maIe output plugs wired this way:

female XLR pin 1 to right male XLR pin 2

female XLR pin 2 to left male XLR pin 2

female XLR pin 3 to the remaining pins of the male plugs as well as the cable shield



My personal favorite approach combines a Rickenbacker 370 12-string with stereo outputs, a stereo Preamp Cable, an XLR splitter cable, and a Mackie mixer. This is what I used on all the 12-string guitar parts on the Tesseract album.

How can I get a Preamp Cable?

Until someone goes into production with it you have to build one yourself.

I've only built a handful of prototypes for myself and a couple of friends. I'm not in the Preamp Cable manufacturing business, so I'm not going to be making any more except to try out some improvements.

In the summer of 1996 I shopped the Preamp Cable around, showing it to various folks in the business, asking for advice and opinions, and searching for someone interested in manufacturing and distributing it. I was not successful, but I probably gave up too early. (Special thanks to John Hall of Rickenbacker, Roger Powell of Utopia, Bill Richardson of Gryphon Strings / StudioGuitar and the folks at Gelb Music for all the expertise and words of advice!)

Is the Preamp Cable patentable? Phantom powered preamps have been around for a very long time so the basic technology is not new, and this application is pretty much exactly what phantom power was designed for in the first place, but this specific implementation has some innovative details. Nonetheless, a patent must be filed within a year of public disclosure, and since I let the cat out of the bag years ago, a patent is not going to happen.

I would be happy to work with a company to make the Preamp an actual product. (Ah, the real reason for this article.)

Future improvements

If I were to build another batch of Preamp Cables I would make some improvements.

- Use an even lower noise FET.
- For more headroom, run the Phantom Power box at 18 Volts instead of 9 Volts, and optimize the FET circuit for that voltage.
- Use an FET differential amp to reduce hum and noise and also be more compatible with the AES XLR spec.
- Some other variations I'm still considering.

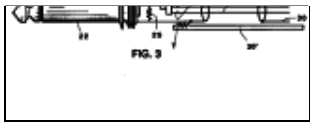
Later...

[This section was added later, June 2005.]

Jack Orman notes (Patents on Parade #3, Impedance Matching Cable System) that a patent was actually filed and issued for a preamp cable.

US Patent 5,585767:
Impedance Matching Cable System for Electronically Coupling Musical Instruments to Amplifiers

Thomas G. Wright, Jr.



Filed: 27 April 1995
Issued: 17 December 1996
US 5,585,767 at the USPTO
US 5,585,767 from pat2pdf.org

This uses an FET mounted in a phone plug, so in that sense it's similar to my circuit, but there are significant differences. This circuit is a source follower, and so it provides no voltage gain and has more headroom. It's only half phantom powered as it uses a separate wire for the positive supply to power the source follower and a negative phantom supply for the output. As such, it is not usable with a phantom powered mic input on a mixer.

I'm not convinced that my original 1992 Usenet post would suffice as prior art because, while the post does mention phantom powering the circuit, it doesn't actually describe building the circuit into a phone plug. Still, I'll claim this patent is not enforceable because remotely powered preamps have been used all over for many decades (condenser microphones, 'scope probes, hard disk drives, medical instrumentation, etc.) and the patent introduces nothing innovative.

And there are some weird issues with this patent. The author never once mentions cable capacitance, yet that is the primary reason for having a preamp near a guitar; it is the cable capacitance that loads down the pickup. He does refer to this as an "impedance matching" device, yet almost every guitar amplifier has a 1.0 Mohm or greater input impedance. What sort of amplifier input is he connecting a guitar to? In column 3 he mentions connecting to a "power amplifier", but only there.

There are a number of errors in the patent. The FET source and drain are inexplicably swapped throughout the text. (It is not a problem in practice as most FET's are completely symmetrical with no physical difference between the source and drain, but this is a gratuitious confusion to include in an explanatory document. I mean, we don't call it a "drain follower".) Neither the type of FET (junction, MOS, enhancement, depletion) nor the polarity (p-channel, n-channel) is specified. Figure 2 lists the resistor value in milliohms (m) instead of megaohms (M). Figure 3 is half mechanical drawing and half schematic, with the plug casing drawn to look like a schematic and with the threads of the plug casing drawn exactly as resistors. Claim 2 doesn't make any sense at all; I think two concepts got mangled together.

The patent specifies that a 3 pin XLR connector is to be used to connect the cable to the power supply. That is a good connector choice electrically and mechanically, but from a user interface standpoint it's a bad decision because it will be confused with microphone cables or balanced line audio cables and this circuit is not compatible with those applications.

He also missed an opportunity here -- in his design the plug pretty much only contains an FET, which means that besides connecting the FET as a source follower you also have the options of connecting it as a low gain preamp or a high gain preamp depending on the details of the power supply circuit.

So, if you want to go into production with a preamp cable, know that this patent exists and that you might have to do something to either prove prior art, be significantly different from the patent claims, or talk to the inventor. I don't believe my preamp cable circuit infringes on his patent as such, our circuits are different, and details described in the "claims" section are different than mine.

References

A Discrete FET Guitar Preamp, J. Donald Tillman, May 2001. The preamp circuit that the Preamp Cable is based on.

Hammond Manufacturing references:

Hammond 1590-B data sheet

Neutrik connectors

Switchcraft references:

Data sheet for Switchcraft 280 (mono) and 297 (stereo) 1/4-inch straight phone plugs
Data sheet for Switchcraft 226 (mono) and 236 (stereo) right angle phone plugs
Data sheet for Switchcraft A3M XLR plug
Data sheet for Switchcraft D3F XLR connector
Data sheet for Switchcraft "11" jack

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