A Discrete FET Guitar Preamp

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Introduction

I've been performing experiments with guitar preamps and on-board electronics since, oh, the Nixon adminstration or thereabouts. Sometime around 1990 I designed this preamp circuit, and have been using it mostly unchanged ever since. In 1992 I posted a schematic of the preamp to one of the Usenet groups and the circuit became somewhat popular.

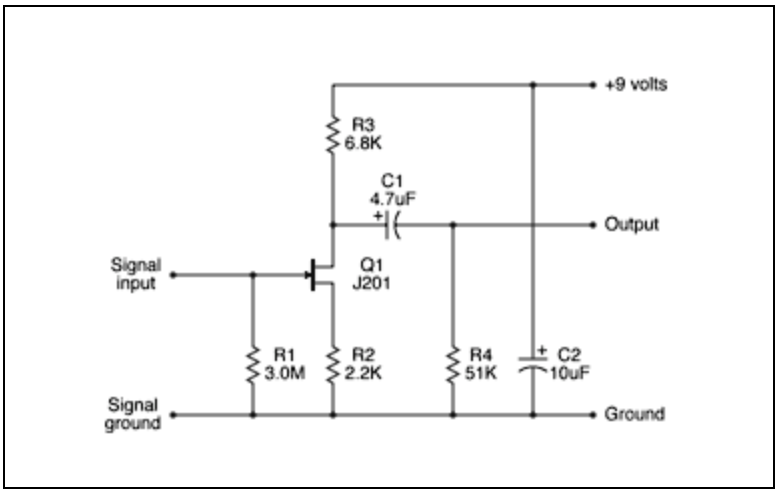
The goals of the preamp are:

- Sounds great. Of course.
- Discrete FET (Field Effect Transistor) design. Discrete because I don't like the sound of opamps, and FETs because the devices operate in a manner somewhat analogous to vacuum tubes.
- Runs off a 9v battery. In practice a decaying 9V battery, possibly as low as 8.0 volts.
- Very high (3.0 Mohm) input impedance. 1.0 Mohm is the minimal acceptable input impedance for a guitar device.
- Medium (6.0 Kohm) output impedance. There's no need for an especially low output impedance as we're only using the preamp to counter the effects of cable capactance and loading.
- 3 dB gain. You don't need much gain, and given the guitar signal level and the 9v supply voltage, there isn't room for much gain.
- Low noise.
- Graceful overload. Overload happens; the circuit should clip gracefully and recover gracefully.

The preamp can also be phantom powered and mounted in a phone plug. See my article "An FET Preamp Cable".

Schematic

Here is the schematic diagram:



FET Preamp Schematic

And the parts list:

FET Preamp Parts List	
Q1	J201 N-channel JFET
R1	3.0M ohm 1/4-watt 5% resistor
R2	2.2K ohm 1/4-watt 5% resistor
R3	6.8K ohm 1/4-watt 5% resistor
R4	51K ohm 1/4-watt 5% resistor
C1	4.7 uF electrolytic capacitor
C2	10 uF electrolytic or tantalum capacitor

Notice that some of the details are left to the reader's imagination because there are so many ways to use this preamp. For example:

- Mount it on-board the guitar, after the pickup selection switch, volume and tone controls.
- Use a separate preamp on each pickup.
- Mount the preamp on a belt or guitar strap.
- Use it for piezeoelectric pickups for violin, string bass, etc..
- Bypass R2 with a small value capacitor for a treble boost.
- Bypass R2 with a large value electrolytic capacitor for more gain.
- Phantom-power the preamp

Technical details

It's a simple unassuming common source FET stage that looks and performs somewhat like the first 12AX7 stage in a Fender preamp.

Q1 is a Siliconix J201 N-channel JFET. You can get a copy of the data sheet from the Siliconix

web site. My original design used a Motorola 2N5457 N-channel JFET, which also works well, but the J201 is a lower noise device.

R1 determines the input impedance and, for the case of open inputs, capacitively coupled inputs or piezoelectric pickups, references the FET gate to ground. R1 can be almost any value, and in some cases, such as if the preamp is connected directly to an electromagnetic pickup, can be eliminated entirely. I originally used 10 Mohm for this resistor, but more recently I've been using 3.0 Mohm so that there's less noise during switching transients.

R2 biases the FET at around 0.5 mA. This can compensate for some variation in FET characteristics -- if the FET is conducting too much current, the voltage across R2 will rise making the FET gate more negative with respect to the FET source, and thus reducing the current in the FET.

R3 is the FET drain load resistor. The value is chosen for roughly 6.0 volts at the FET drain. The value of R3 also determines the output impedance.

C1 is a coupling capacitor to remove DC from the output. R4 references the output to ground, and keeps the output from floating positive if left unconnected. C2 isn't really necessary, but depending on how the power supply is rigged it can reduce power on/off transients.

A note about FETs

I should point out that FETs in general suffer from a serious lack of manufacturing consistancy. The FET V_{GS} and I_{DSS}, the parameters that determine the bias point, can be anywhere over a 5-to-1 range and still be within spec. That's pretty awful, but such is life. It's an engineering accomplishment to design a circuit that can function exactly the same over a wide variation of component parameters. But I can't guarantee that in this situation; there's not enough supply voltage headroom.

The upshot is that while this preamp circuit is designed to work with typical J201 FETs, it will not work with all of them and it would be a good idea to try a handful of FETs and throw out any that don't bias correctly. An easy test is to measure the voltage at the drain of Q1 and if it's between 5.0 and 7.0 volts things are fine.

Why use a preamp?

While the voltage off an electric guitar pickup can be a healthy 2.0 Volts or so peak-to-peak if you're playing hard, the impedance of that signal is very high and the signal level, especially for the high frequencies, can be lost due to a long cable. As an experiment, try playing your instrument with a 20-foot cable direct into your amplifier, and then again with a 1-foot cable, and see if you can tell the difference.

Another advantage of a preamp is that the famous "loss of highs when you turn down the volume control" effect goes away. This is the effect that folks attempt to compensate for with a small capacitor across the volume control.

Additionally, a number of effects boxes have inappropriately low impedance inputs that can sap a significant amount of signal. And most mixer inputs are a factor of 100 too low an input impedance for guitar pickups.

Why avoid opamps?

I personally don't like the sound of circuits with opamps in the audio chain.

In an opamp the signal goes through a series of nonlinear transistor stages optimized for really high gain, and a large quantity of feedback is used to direct that gain to act as a servo mechanism to set the output voltage. "Compensation" is required for stability, so the amount of feedback changes with frequency.

If an opamp is driven into clipping, it does so ungracefully.

And in general, the distortions introduced by opamps are not musical.

Limitations of the preamp

The most serious limitiation of the circuit is that it can be overdriven by high output pickups. The input voltage limit is probably around 2.5 volts peak-to-peak, and with that the output voltage will be around 3.5 volts peak-to-peak, add an extra volt for biasing the FET, and you're getting pretty close to the power supply limit. Hand-selecting FETs might improve this a little.

Frequently asked questions

[this section was added later]

I've been getting a lot of email lately, often asking the same questions about this preamp. So let me answer them up front.

Can I purchase a preamp from you? Will you build me one?

No; I'm not in that business.

I don't know anything about electronics. Can I build your preamp?

(One guy even wrote, "*I am a moron; can I build your preamp?*")

I have no idea. It appears that electronics skills have been on a cultural decline over the last couple of decades, and the demise of Heathkit and several hobbyist electronics magazines as well as the lack of user-servicable products confirm this. I am not in the position to teach people electronics skills over email, so it's probably safe to say that if you are asking, then the answer is likely to be no. Also, the quality of the preamp is somewhat dependent on the builder's construction skills, and success at such a project would depend on what your acceptable level of quality is.

On the other hand, building a preamp is a really fine way to learn audio electronics. The goals and expectations would need to be different of course.

Where can I get the FET?

I can't keep track of which distributors carry it; they keep changing. First try your favorite mail-order electronics places. If that doesn't work you can always ask Siliconix.

Can I substitute another FET?

The circuit is only designed to work with the specified FET. Other FETs might be inappropriate, or may require some circuit changes to work. And note that the "replacement lines", like the NTE replacement transistors, are nothing like the orignal FETs.

I built the preamp and it's not working. Can you help me debug it?

No; I don't have the time. And people invariably send me very confusing descriptions of their symptoms. The most typical problems are misidentifying the pins of the FET, simple wiring errors, or the wrong value of a resistor.

Can you get me a schematic for a preamp like your design, but different?

No. The design is completely optimized for the application and all the part values interract, so any variation on the design means you pretty much have to tweak all the values up yourself.

Can I run the preamp off of 18 volts?

Yes, but the improvement in headroom would be tiny. The design would need to be adjusted for an especially improved performance at 18 volts.

History

In 1992 I participated in a discusion on the alt.guitar Usenet group. A fellow was asking about guitar preamps, someone had posted an opamp-style preamp schematic, and I suggested a discrete FET approach.

Here are the posts from my personal archive. Note that the circuit here is slightly different than the one above.

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Newsgroups: alt.guitar
From: Don Tillman
Subject: Re: Building your own (ONBOARD PREAMP!)
Date: 28 Sep 92 10:14:49


  Date: Thu, 24 Sep 1992 15:33:55 GMT
  From: pquince@blacks.jpl.nasa.gov (Peter Quince)
  Organization: Image Analysis Systems Group, JPL

  Along these lines (and I will reiterate this in a separate article),
  I have finished putting together the onboard preamp spec'd out in _The
  Guitar Handbook_.  A prelim wire up indicated that it does indeed work.
  In a couple few days I will do the jury rig hook up and fuss with the
  adjustment pot.  The big questions then will be:

    o what will the gain be? (which i asked myself as i started)

0.8 dB gain with the adjustment pot at minimum, 20.8 dB with the adjustment
pot at maximum.


    o is it noisy?
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Depends upon the opamp you use. For a TL071, somewhat noisy. For a 741, extremely noisy.

> o what kind of a whammy does it put on the signal?

It'll sound okay to lame depending upon the opamp used.

I personally don't like the sound of opamp-based preamp circuits. The noises and distortions they produce are annoying and umusical and when overdriven their clipping sounds very buzzy and recovery is ungraceful. For me a discrete FET circuit is the best way to go and, as a side effect, is only half the space (4 resistors, 1 fet, 1 cap, less wiring, add a cap and a pot if you need the gain adjustment).

-- Don

Date: 30 Sep 92 09:20:08
Newsgroups: alt.guitar
From: Don Tillman
Subject: Re: Building your own (ONBOARD PREAMP!)

> Date: Tue, 29 Sep 1992 14:38:56 GMT
> From: rstern@col.hp.com (Richard Stern)
> Organization: HP Colorado Springs Division
>
> Try this op-amp based pre-amp using the following circuit.

(Umm, proper engineering practice requires you to decouple the 9v supply and to bypass the lower 1Mohm resistor with a .1 uF (or so) cap, especially if you're driving a load.)

The design you present is nearly identical to the "Guitar Handbook" circuit that started this conversation, and suffers from the same problems -- high feedback, bad feedback topology, ungraceful overload and recovery, noise, and the signal has to go through a dozen non-linear devices inside the chip before it gets out. Exactly the sort of thing that gives solid-state amps a bad reputation!

> Date: Mon, 28 Sep 1992 13:15:11 -0500
> From: Kurt Taylor <kurt@istwok.ods.com>
>
> Please post a schematic of your fet pre-amp. (I have tried many op-amp based circuits with little success, unless you like BAD pre-amps :'))

> Date: Tue, 29 Sep 92 10:34:54 -0400
> From: tjs@godzilla.eecs.umich.edu (tim stanley)
>
> You mention your preference for FET based pre-amps. Can you give me any pointers to where I can lift a schematic of such a critter?

> Date: Tue, 29 Sep 1992 07:55:32 GMT
> From: chuck@spectrum.cs.unsw.oz.au (Mark Andrew Hawling)
>
> Can you post one of your FET designs that you think is good.

Well okay. Here's a nice design from the "op-amps are for weenies"

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school.  Low distortion, low noise, low feedback, graceful overload,
simple, elegant, inexpensive, etc.  This baby sings.  It has a transfer
characteristic somewhat similiar to the first 12AX7 tube in a Fender
amp.


                +-------------------------+--- +9v
                |                         |
                <                         |
                <  6.8k                   |
                <                         |
                |     5uF                 |
                +----||----+--- out       |
                |          |              |
              |-+          |              |
in ---+------>|            |              |
      |       |-+          |              |
      |         |          |              |
      < 10M     < 2.2k     < 51k         ---
      <         <          <             ---  10uF
      <         <          <              |
      |         |          |              |
      +---------+----------+--------------+--- gnd


The FET is a 2N5457.  The voltage gain is subtle, 3dB or so.  You can
substitute another low-Vdss FET if you know what you're doing.  Power
drain is about 0.5 mA, so a 9v batter will last a good long time.  It
does start to sound a little grubby when the battery sinks below 7v.

It's also trivial to add a high-boost switch if you'd like; have it
shunt the 2.2k resistor with a 0.05 uF (adjust to taste) cap.  Or shunt
the 2.2k resistor with a 10uF cap for more gain.

Obviously you want to wire it so it's powered off when the instrument
isn't plugged in -- it's far superior to use a switched jack instead of
the weenie approach of using the second connection of a stereo jack.

Also note that this design is easily phantom-powered, so you can even
get by without installing a battery.

-- Don
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The latter post was archived and placed on a number of guitar websites, including:

- Harmony Central Guitar FAQs
- On-Line Guitar Archives

Someone also drew out a pretty schematic of the preamp circuit as well as some other opamp-style preamps (which I have nothing to do with) and that page ended up on:

- Jamie "Leper" Heileman's Schematic Archive

(There have been others that have since disappeared from the web.) I'm pretty amazed how this circuit has been passed around.

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email: don@till.com

web page: http://www.till.com