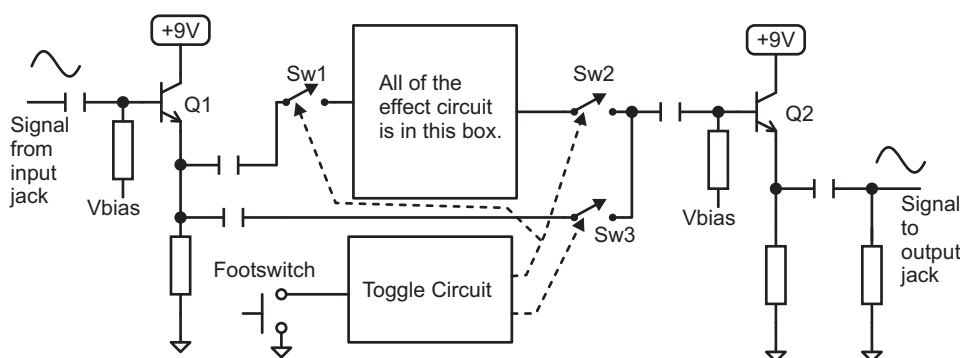


The Technology of JFET Switching in Boss and Ibanez Pedals

All Boss and Ibanez mass market pedals use a very similar switching setup. They use a buffered input and output, and JFETs applied as switches to route the signal through the pedal. There are good and bad things about this setup, but it is not mysterious in the least. Here's how it works.

The overall setup is shown below. All of these pedals use buffers at the input and output. Almost all of them use simple bipolars NPN transistors for the buffers, although you could use an opamp or JFET source follower, and I've seen some commercial pedals which use JFETs in these positions. Q1 and Q2 are the input and output buffers respectively. The input impedance is high enough to not cause a large treble loss, although it is usually about 220K to 470K, because the bias resistor on Q1 can't be much higher than that in most cases. Sometimes there will be a resistor in series with the output capacitor on the output of Q2. This is there so that an output short does not harm the pedal.



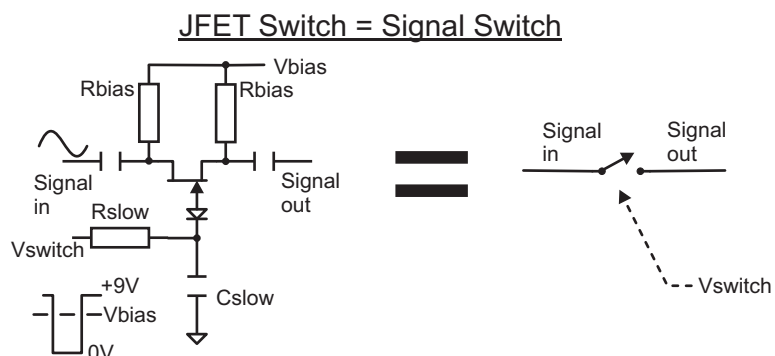
Here are some important things to note about the overall workings. Switches Sw1, Sw2, and Sw3 are what do the "bypassing" for the pedal. Sw1 and Sw2 are always on or off at the same time; that's what is meant by the arrow which runs from the toggle circuit and splits to go to both Sw1 and Sw2. Sw3 is open when Sw2 and Sw2 are closed, and vice-versa.

This switch scheme is the same from the stand point of where signals go and how they're switched as the "Most Basic True Bypass Scheme" illustrated in *The Technology of Bypass Switching* at http://geofex.com/Article_Folders/bypass/bypass.htm.

For our understanding, it's important to note that Sw3 does all of the "dry" signal passing, and Sw1/Sw2 do all of the effect signal passing. Effects hackers who have BUMS (Blind Urge to Mod Syndrome) often have the quandry about how they can convert a Boss/Ibanez switching scheme to be always on for an external true bypass. You now know all that's needed for this: you remove the JFETs that do Sw1, Sw2, and Sw3 from the board, and insert jumpers from source to drain where Sw1 and Sw2 used to be, leaving Sw3 out. All done.

So let's take a look at those JFET switches.

In the picture at the right, the JFET circuit on the left is conceptually equal to the simple switch on the right, but with the components needed to make it act like a switch included. N-channel JFETs are "on" in the switch sense, when there is zero volts between the gate and source. In practice, you can simply open the gate up, and the resistance between drain and source goes down to the lowest possible value.



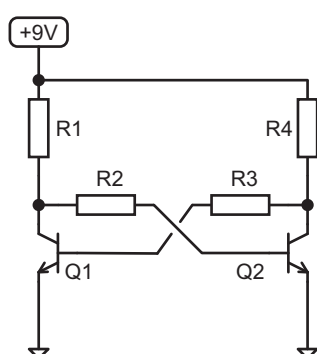
To make the JFET turn off - that is, not let signal through - you force the gate to be more negative than the drain and source. In a 9V-powered pedal, one way to do this is to bias the drain and source up above ground by some amount. The “on” condition is done by letting the gate float up to the same voltage as the drain and source. The “off” condition is done by pulling the gate close to ground, so it is several volts lower than the drain and source.

Since almost all 9V powered pedals use a bias voltage of about half the power supply (4.5V), it's simple to tie the drain and source to this +4.5V supply with high value resistors. These are shown as R_{bias} in the illustration above, attached to V_{bias} . The capacitors at the input and output side prevent the DC conditions before and after the JFET switch from preventing it working as a switch.

The switching signal V_{switch} is applied through R_{slow} and C_{slow} , which together prevent the JFET from switching in nanoseconds. This keeps the switch from popping audibly. V_{switch} must go down almost to 0V to turn the JFET off, and must go up enough for the gate to get to at least the V_{bias} voltage level of the drain and source. With the diode as shown in series with the JFET gate, V_{switch} *can* go higher, as high as 9V, and the diode prevents this from changing the switching operation of the JFET by not letting the higher voltage upset the gate-source voltage on the JFET.

Back in the first illustration, if we substitute in copies of the JFET switching setup for Sw1, Sw2, and Sw3, all we have to do to make bypass switching work is to feed Sw1 and Sw2 from one switch control signal that goes above V_{bias} and down to ground, and then arrange to feed Sw2 from an opposite signal, one that is at ground when the voltage controlling Sw1 and Sw2 is higher than V_{bias} , and alternately above V_{bias} when the voltage controlling Sw1 and Sw2 is at ground.

Here's how that works.



In the illustration at left, Q1 and Q2 are simple DC amplifiers. They are set up so they feed each other in a loop. If Q1 happens to be turned on, it will be pulling lots of current through R1, and its collector will be held nearly at ground. That pulls the end of R2 to ground, and prevents the base of Q2 from getting any drive signal to turn it on, and so the collector of Q2 is high, nearly 9V.

With the collector of Q2 off, a current goes through R4 and R3, providing current to the base of Q1 and keeping it on. So Q1 stays on as long as nothing else happens.

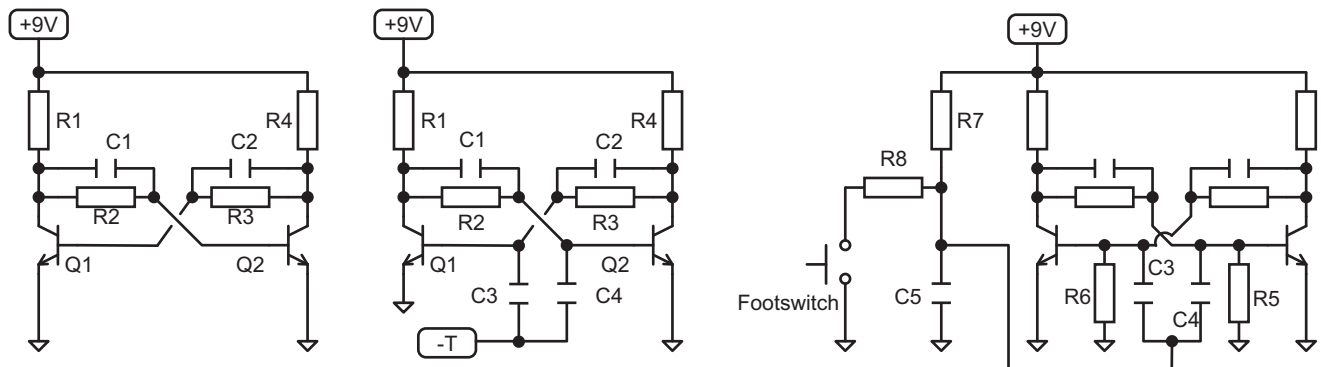
If we momentarily shorted Q1's base to ground, it would quit pulling current through R1 and holding the junction of R1 and R2 down.

That would let current flow through R2 to Q2's base, and turn on Q2, pulling down on R4 and R3, and robbing Q1 of base drive. We would now find that Q1 would stay off and Q2 would stay on. The two have exchanged conditions. Every time we turn off the active transistor, the other transistor comes on. It's a toggle circuit, flipping which collector is high every time we tell it to toggle.

That's exactly what's needed for running our JFET switches. The transistor that's on has its collector pulled to ground, and the transistor that's off has its collector nearly at 9V. So we can connect the collector of, say, Q1 to Sw1 and Sw2's V_{switch} , and the collector of Q2 to Sw3's V_{switch} terminal, and we have the alternating action which does the bypass switching we want.

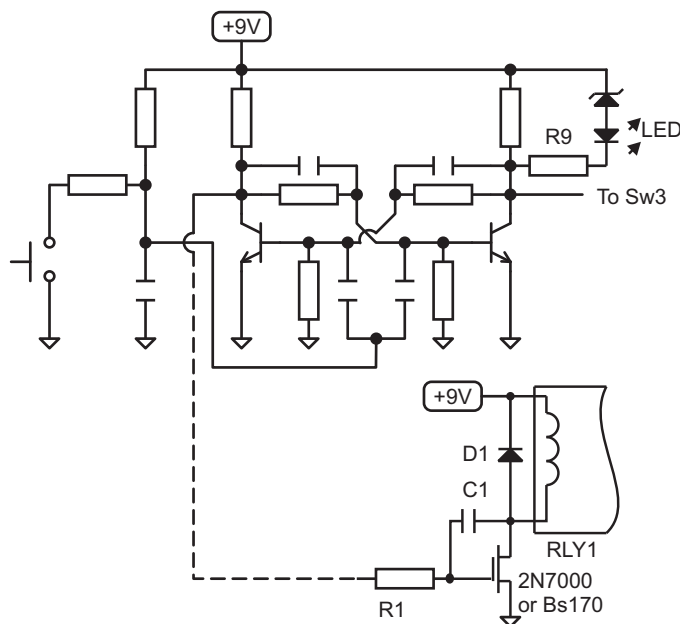
The rest of the junk associated with the Ibanez and Boss toggle circuits is to make it work with a single momentary contact for the footswitch and to operate reliably and quickly. In the illustration at left below, C1 and C2 are “speed up” capacitors which make the toggling action faster and surer

. In the illustration in the center below, I've added C3 and C4, which connect the bases of the transistors to the footswitch signal. Finally, on the right below, I've added the footswitch circuit which applies a negative going "blip" to both of the transistor bases. The transistor that's already off doesn't care about the blip, but the one that's on starts turning off, and that is enough to make them toggle into the other condition.



Which transistor collector connects to control Sw1/Sw2, versus Sw3? It doesn't matter. The flipflop/toggle does the same thing. It only matters when we put an indicator LED on it.

Notice that the transistor that's ON (that is, pulling its collector to ground) turns its switches OFF. So if we want the effect to be active, Sw1/Sw2's Vswitch signal is high, letting them conduct, and Sw3's Vswitch signal is low, turning it off. What the pedals do is to connect an LED and series resistor to the collector of the transistor that runs Sw3. The LED does not say "effect on". It says "effect NOT bypassed."



I've shown the LED setup at left. There is usually a zener diode and always a resistor (R9) in series with the LED. This lowers the loading on the transistor collector and prevents the LED from upsetting how the toggle circuit works.

At this point we get down to why you're probably reading this. The vast majority of people who are happy with what Boss and Ibanez switching does do not care how it works. Mostly people who don't like it want to know how it works so they can change it to be more to their liking. I mentioned this up front about how to replace Sw1/Sw2 with wires and remove Sw3. This makes the pedal always on, and lets you do an external true bypass box.

But you can use that built-in toggle circuit to run an internal true bypass circuit if you want.

The circuit is shown at left above. You need a DPDT relay which will run from 9V and is non-latching. You must make the Sw1/Sw2/Sw3 changes I noted, then wire up the relay switch contacts to do true bypass. Then you connect up a new MOSFET, resistor, diode and capacitor as shown. The resistor is large, maybe 100K, and connects to the collector that does NOT have the LED connected - that is, the one shown in the dotted line which used to connect to Sw1/Sw2.

When this signal goes high, it turns on the MOSFET and that clicks the relay in to un-bypass the effect. The LED comes on to indicate that the effect is on. C1 is noncritical, about 0.001uF, and D1 can be 1N4148. Mouser sells miniature low signal relays which work from 9Vdc now. But if you can't get a 9Vdc rated relay coil, you can use a 5V or 6V rated relay, and insert a resistor in series with the relay coil to eat up the extra voltage and not burn out the coil.

Mods

There's always something more to add. Here are some suggested mods.

1. Remote footswitch: Easy-peasey. Find a spot in the case where you can put a jack into it to connect a remote footswitch pedal. Something like a 3.5mm / 1/8th inch mono jack would work fine. Put in the jack, and run two wires from the jack tip and sleeve to the same place where the wires from the internal tactile switch from the footswitch in the enclosure connects. Plug in a remote cable to the jack going to a pedal with a momentary switch in it. Bingo, remote footswitch.

Notice that this can be an *electronic* remote footswitch too. You have to watch polarity, but you can sub in an NPN with its emitter going to the grounded side of the tactile switch and its collector tied to the more-positive side of the internal footswitch. Then you can blast the NPN base with a blip of current (limited, please! 1ma is more than enough) and it will make the bypassing flip states.

2. Always comes up in the same state. This is pretty easy if you want to mess with it. The two halves of the toggle circuit are always presented theoretically as identical; Q1 is EXACTLY the same as Q2, and all the symmetrical components are identical. If that were true, the toggle circuit would randomly come up in one state or another, because the two amplifiers would respond to power coming on in an identical fashion. They might actually stay exactly balanced for some time. But there is always noise, and eventually a noise blip would favor one side over the other, and the circuits would reinforce the offset until it settled on one side or the other. It's a bit like trying to balance a ball bearing on a razor blade - even if it's perfect, tiny air currents would eventually unbalance it. In practice, one transistor has more gain, or is hotter, or the resistor tolerances would be different, something. But you can pre-unbalance it.

Back on Page 3, the sample circuits show the two speed-up capacitors C1 and C2 and the two base-drive resistors R2 and R3. The two caps are supposed to be equal, and the resistors are supposed to be equal. But what happens if one cap is bigger than the other? In practice, the transistor with the bigger capacitor connected to its collector tends to come on (that is, collector low) all the time when the power supply comes on. The bigger the difference in the two caps, the more this tendency is expressed. 470pF is one value used in one Boss pedal. I got reliable startups on one side or the other making one 330pF and one the stock 470pF. Putting an extra 47pF to 100pF across one or the other should make that side come up reliably.