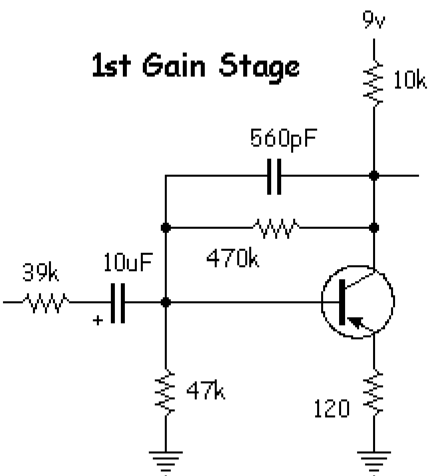
A Close Look at the Big Muff Pi

Along with the fabled Fuzzface, the Big Muff Pi from Electro-Harmonix has had a big influence on the sound of hard driving rock music. It's distinctive, over-the-top buzzy distortion sound has been featured in a number of classic rock tunes over the years.

I bought my first Big Muff (Part #EH-3003 $49.95 suggested retail) in 1976. I was working in a music store at the time and got the pedal for wholesale cost: $22.50. It is what is commonly called a Version 2 which has the 3 knobs in a row across the top of the front and the name screened in red in the middle. Since I'm the original owner, I know that no modifications or other changes have been made to the box. This article is based on reverse engineering that model and constructing clones from the design. The complete schematic of the Big Muff used in this article is available for download.

I've had a copy of an original E-H schematic (dated Oct 15, 1975) for years and always expected it to be the design that was in the pedal that I owned. It was certainly a surprize when I opened my Big Muff to find that it used 2N5087 PNP transistors while the schematic from E-H shows NPN transistors. There are numerous other differences between them as well although generally they are equivalent circuits. A redrawn version of the E-H NPN schematic is available at the end of this article.

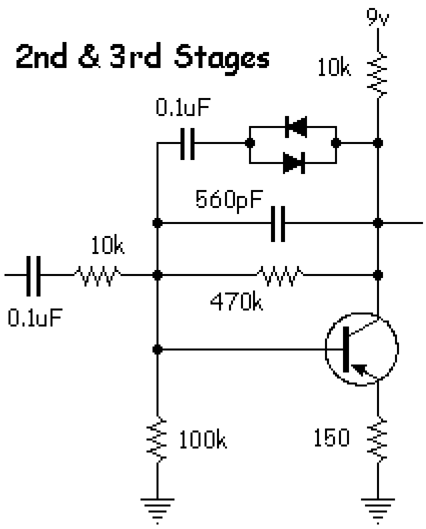
The Big Muff Pi (BMP) consists of 4 common emitter bipolar transistor gain stages with a simple passive tone control network between stages 3 and 4. One of the first things that you will notice is that the 4 stages appear quite similar, but on closer examination it is revealed that each has minor differences from the others. While diode clipping has been used to clip the guitar signal and generate distortion since the fuzzbox was invented, one major difference of the BMP from other designs is that it has 2 clipping stages (2 & 3) in series. This contributes to the buzzy sound of the box by severely clipping the highly amplified signal. Operation of the NPN version will be quite similar to that described below.



The input gain stage is a basic transistor amplifier with part of the base bias taken from the collector of the transistor instead of directly from V+. This is a commonly used method to control base current. The 39k resistor on the input increases input impedance and limits available gain which can never exceed 470k/39k (21.6 db). In this stage, it never quite reaches that level and measures out at 16.5db when driven by a 600 ohm signal generator and will be even less when connected to a high Z guitar pickup. The low frequency rolloff is flat well below the lowest guitar frequency. The 560pF capacitor that is in parallel with the 470k feedback resistor acts as a simple low pass filter. The -3db point is at 1k Hz. Since the 12th fret note of the high E string of a guitar is around 660Hz, the fundamental frequencies of the guitar are passed through while noise and upper harmonics are attenuated.

I'm not sure why the resistor from the base to ground is 47k since a 100k in this position would bias the transistor for largest possible undistorted voltage swing. However, considering the two clipping stages that follow, this probably makes very little difference in the final sound.

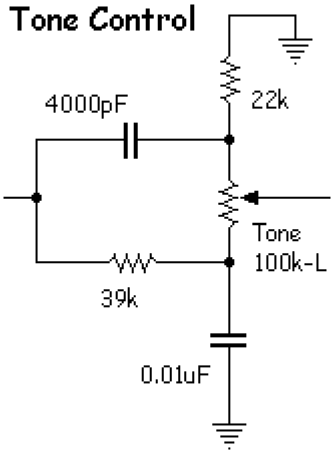
The ouput of the first stage goes to the "Sustain" control that has a small resistor between its lower end and ground, which prevents the signal from being completely cut off. (This prevents those clueless ones of us from having to figure out why the box isn't making any sound.)



The second and third gain stages have the same basic configuration as the first with minor changes. The input resistor is after the capacitor and smaller in value. This boosts available gain to 26db and also increases the low pass cutoff frequency to 1.5kHz. Because of the larger resistor on the collector of the third transistor, that stage has about 1db more gain and the frequency corner is 1.33kHz. Even more significantly is the addition of a pair of back-to-back diodes in the feedback loop. They limit the signal peaks to plus or minus 0.65v just as they would in the feedback loop of an inverting opamp. The 0.1uF cap blocks dc to prevent upsetting the bias of the transistor. Note that the third stage has a 1uF coupling capacitor in series with the diodes compared to 0.1uF on the second. I'm not sure what significant difference that provides - probably none and E-H was just using some 0.1uF ceramics that they had on hand.

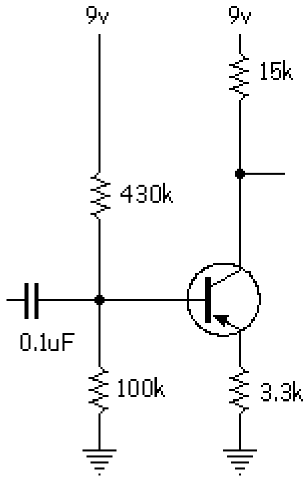
By putting two clipping stages in series, even a low level signal from the guitar is severely clipped. The waveforms from this type of circuit design are very sharp with near vertical sides. The 560pF feedback capacitors take some of the edges off the waves.

Tone Control



The tone control stage is a very basic design with simple R-C low pass and high pass filters driven by the third stage output. A 100k linear pot is used to mix the filter outputs being sent to the last amplifier. The overall blend of frequencies can be changed by rotating the pot to the left or right. With the tone control centered, there is an overall 7db loss through the filters and the corner frequencies are spaced so that there is a broad notch of about 6.8db (-13.8db total) at 1.2kHz.

The fourth gain stage is not configured the same as the previous stages. The base bias is different and there is no series input resistor. Since there is no capacitor in the feedback loop, response is flat across the audio band and gain is about 8.8db. This compensates for the 7db loss in the tone filter.



4th Gain Stage

Other Versions

Although I have not verified that the NPN schematic is correct, it shows the third stage as lacking a resistor from the base of the transistor to ground. This changes the bias of the transistor and sets the collector at 1.1v instead of 4.5v where it should be for best operation. However, with the clipping circuits limiting the output to +/- 0.65v swing, the bias should not effect the output much, if at all. A 100k resistor from the transistor base to ground would bias it much more into the linear range as is done with the PNP version.

Transistor Selection

The NPN and PNP versions of the Big Muff use 2N5088 and 2N5087 transistors respectively. These are good low noise choices for the circuit. A high gain MPSA18 was substituted in the NPN version and made no discernible difference in the sound. Other transistors have been noted in Big Muff's and it has been said that E-H used whatever transistors that could be bought readily and inexpensively.

Modifications

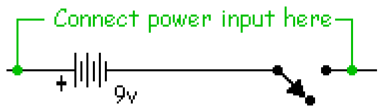
Big Muff's did not feature true bypass and a heavy-duty SPDT switch was used to select between the input and output signals. This leaves the input of the BMP across the guitar signal at all times and colors the sound even when the unit is bypassed. Conversion to true bypass is quick and easy and will improve the use of the Big Muff in modern effects chains. Check out the

AMZ true bypass switch diagram to see how this could be accomplished with a DPDT footswitch.

Another improvement would be to change the resistor from base to ground on the first PNP transistor from 47k to 100k to improve bias and raise the input impedance. On the NPN version, add the 100k base to ground bias resistor on the third stage, also for bias improvement.

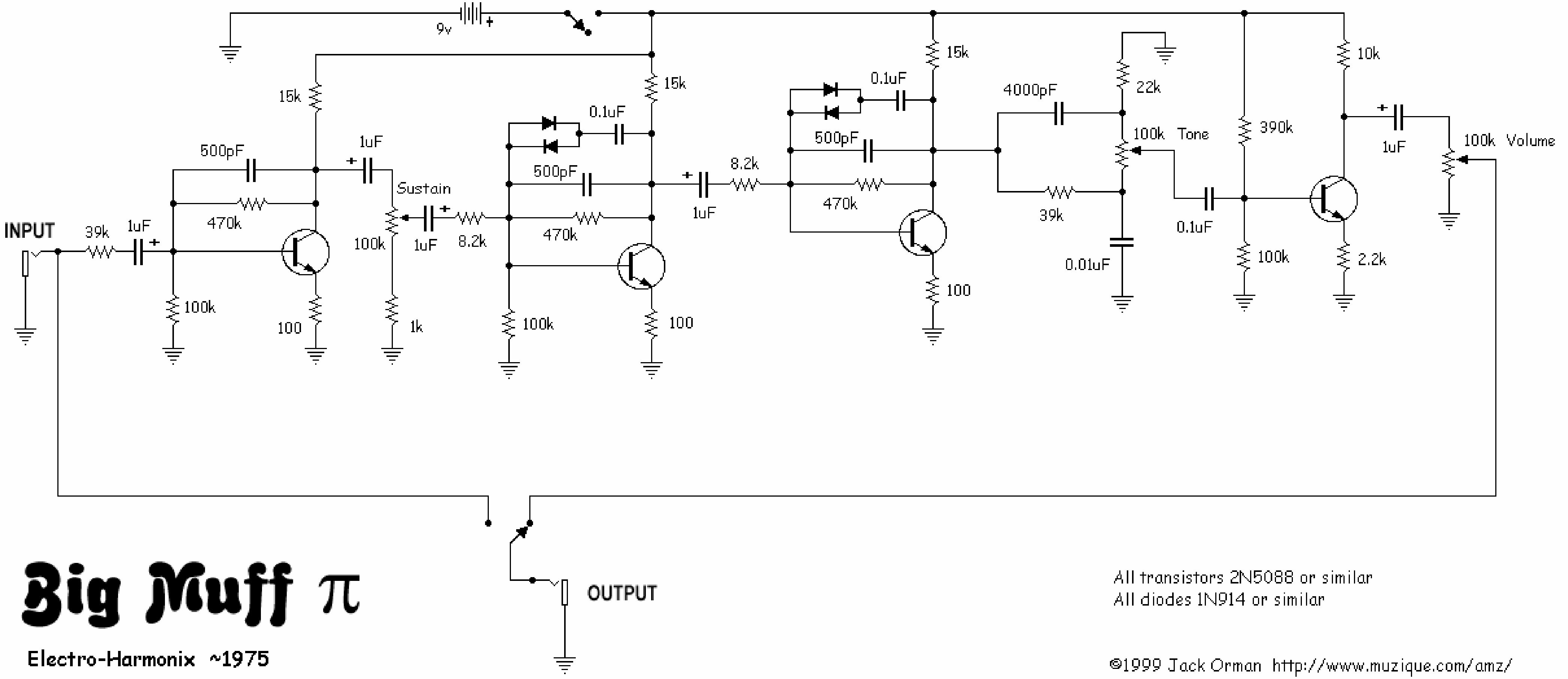
One modification that is sometimes mentioned is to change the clipping diodes to improve the sound of the BMP. It is much more productive to leave the first clipping stage alone and do the mods on the second clipper. As shown in the diagram, the silicon diodes that were used in the original can be replaced by 3 germanium diodes in series to provide softer clipping while producing a similar output level to the tone control. Replacing only one of the silicon diodes with three 1N34a will give a slightly different sound.

The tone control may be modified to alter the frequency response. Replace the 22k resistor to ground after the 4000pF cap in the tone control with a 100k to remove the notch in filter response. Other changes, such as 3300pF/100k and 33k/0.01uF pairs will move the corner frequency at which the filters overlap higher.



A final modification is to add a dc power jack to eliminate the need for replacing batteries. Although the BMP draws little current, if the switch is not turned off after use, the battery will be drained over time. I've wasted countless batteries in this fashion. Since the simple transistor gain circuits have poor hum and noise rejection, it is important that any source of dc power be clean and well filtered. The power leads should be connected to ground and to the side of the switch opposite from the battery. This allows the Muff to be operated from the external power with the battery switch turned off and prevents damage to the battery or possible leakage by reverse current flow into it.

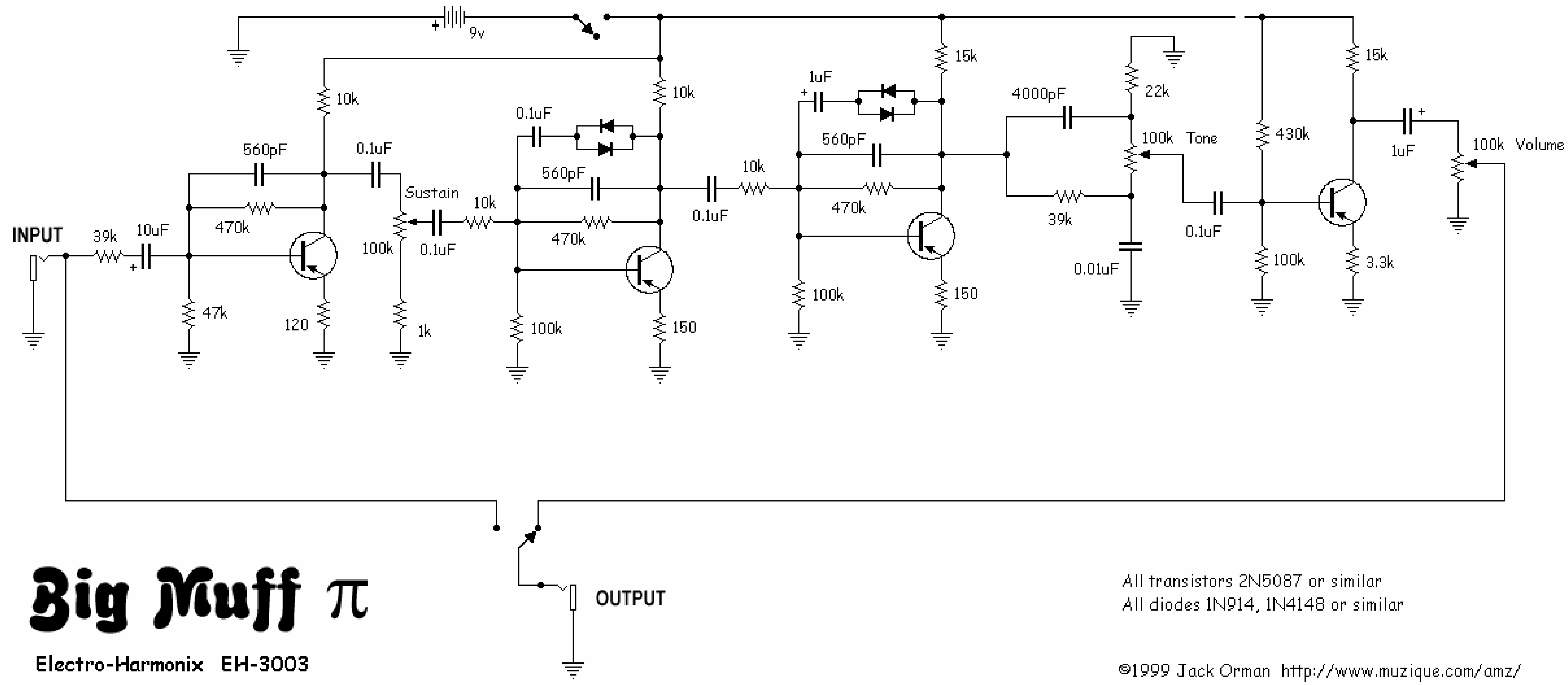
Note that the PNP version of the Big Muff requires a negative voltage supply. The dc adapter that is driving it should be used only for the Big Muff - do not try to power other effects from the same wall wart. An NPN Muff can be driven by a common dc power supply with most other effects because it uses a positive power supply (and therefore negative to ground).



Big Muff π

Electro-Harmonix ~1975

All transistors 2N5088 or similar
All diodes 1N914 or similar

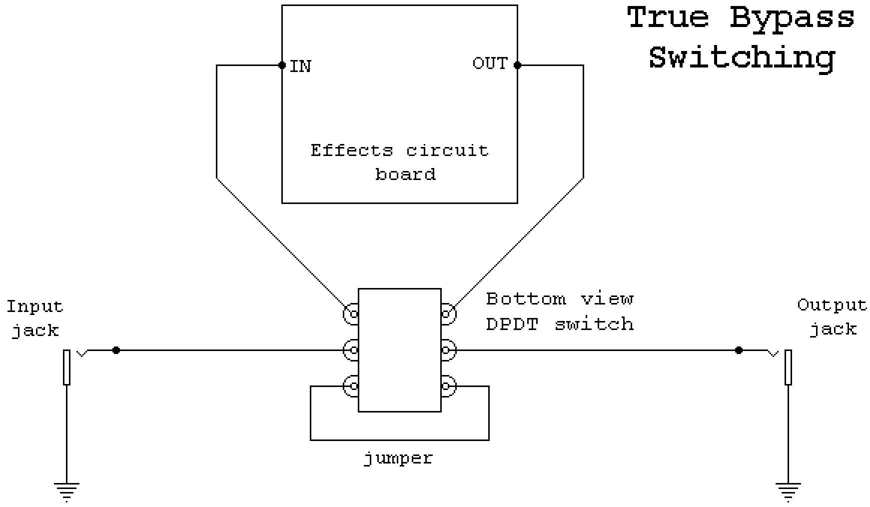


Big Muff π

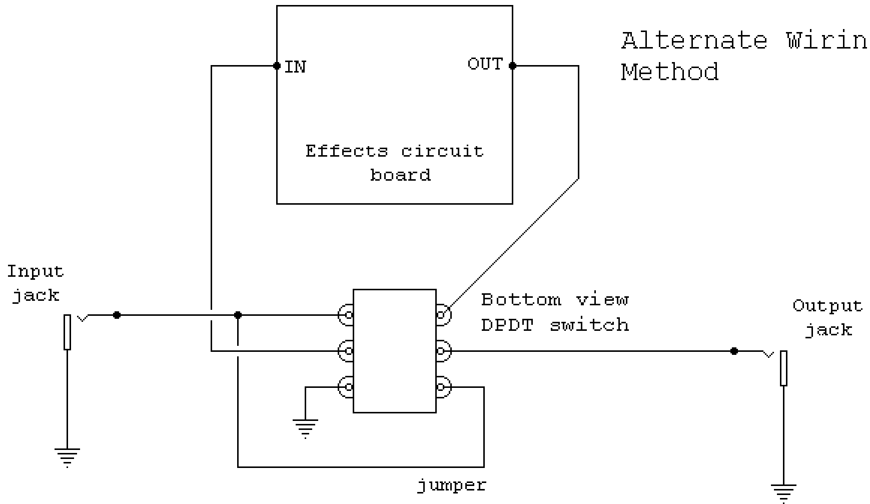
Electro-Harmonix EH-3003

All transistors 2N5087 or similar
All diodes 1N914, 1N4148 or similar

True Bypass Switching

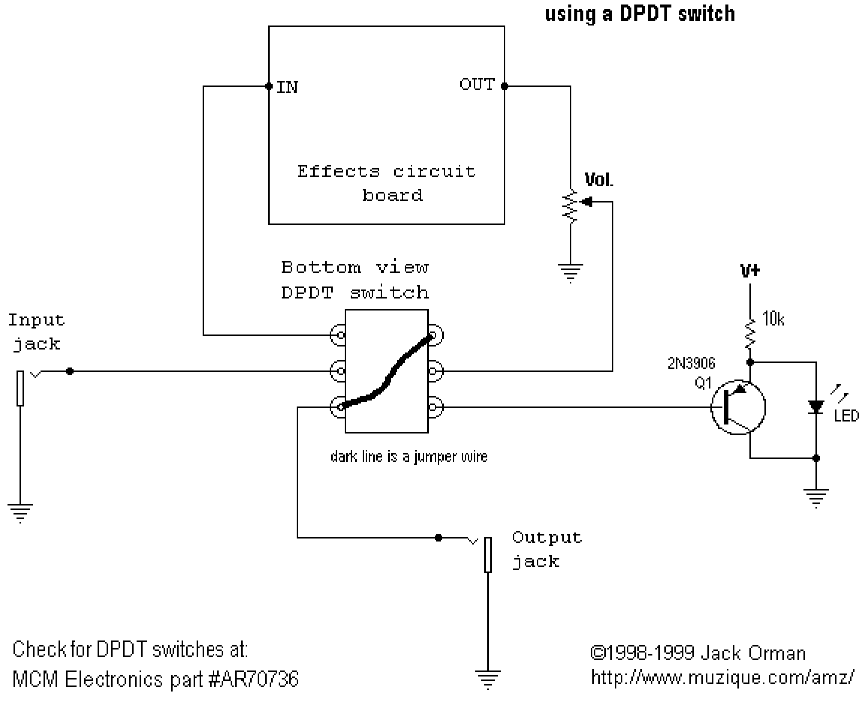


Alternate Wiring Method



Either of these wiring diagrams provides a true bypass of the effects circuit which will prevent the circuit from loading down the input when bypassed which could reduce frequency response.

True Bypass with LED indicator using a DPDT switch



Check for DPDT switches at:
MCM Electronics part #AR70736

http://www.muzique.com/amz/