Neutron Filter

A Mutron III Workalike

Build a clone of the classic effect
GEO Design 117
Version 1.01d

Neutron Filter, a Mutron III Workalike

The Mutron III was an envelope-controlled filter originally made by Musi-tronics. This filter could be set to be a low pass, high pass or band pass filter, the characteristic frequency of which followed the instantaneous loudness (or “envelope”) of a guitar signal. This means that the tone of a signal passed through the filter changed with the loudness of a note as it rose during the initial attack and then decayed. For the bandpass setting, the sound is very like having a wah pedal that automatically rocks the pedal with every note.

There are other envelope-controlled filters, but the Mutron was notable for having more flexibility of tone and sound quality. The Neutron is designed with the same technology as the original to allow you to get the same tone. The use of a tunable state variable filter is what makes this possible. That concept was patented in the early 70’s; the patent has now expired, so the concept is public domain.

The Neutron has controls for:

- Gain - how much or little the signal is amplified through the effect
- Peak – how resonant the filter is
- Sweep direction – whether the filter frequency goes up or down as the note gets louder
- Range – a coarse control of whether the filter frequency is in the top or bottom of the audio signal range.

How it works – looking at the schematic, the Neutron is composed of six operational amplifiers. These amplifiers implement three major functional blocks:

(1) a variable gain input amplifier (U1b), with the gain set by the “Gain” control;

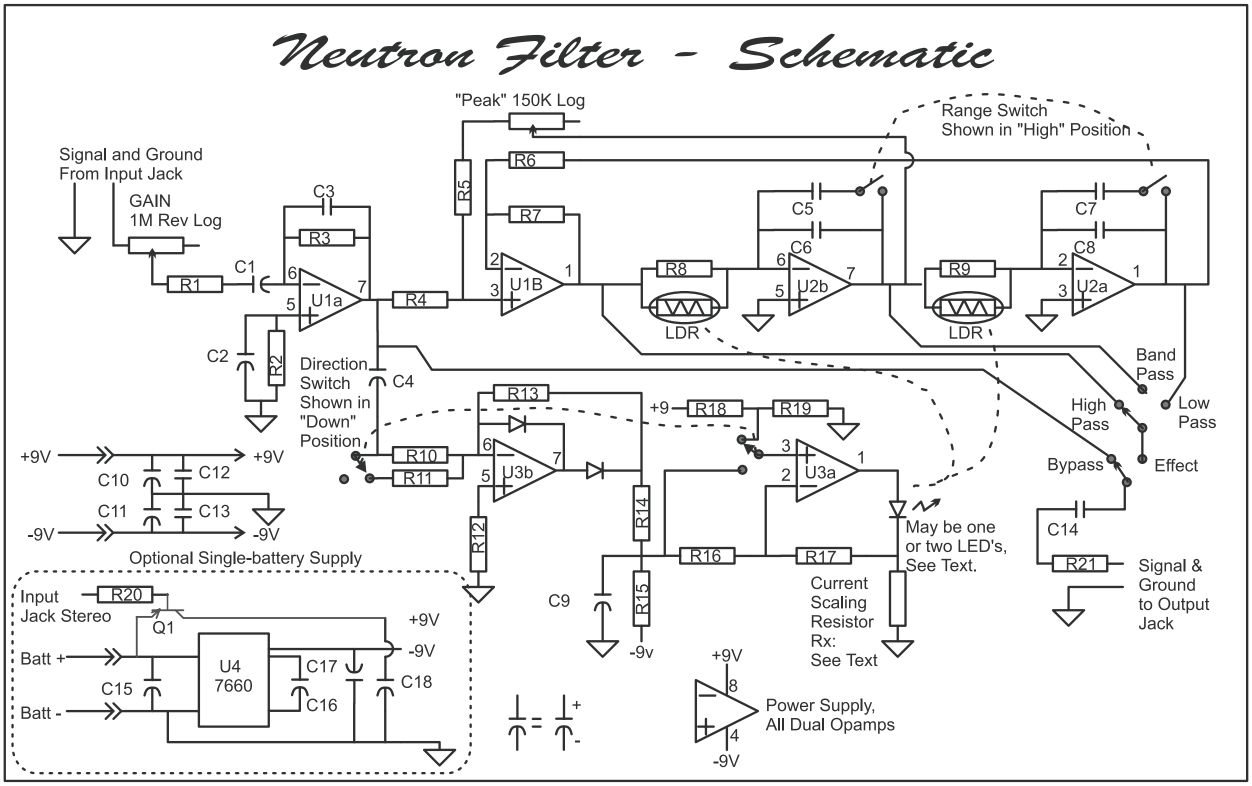
(2) a “state variable” filter that actually does the filtering work, made from three amplifier sections (U1a, U2b, and U2a); and

(3) a precision rectifier/filter (U3a and U3b) that detects the instantaneous loudness of the audio signal and uses this to control the filter center frequency.

Taking each section separately...

(1) The input amplifier is a fairly simple inverting amplifier. The gain of U1b is determined by R3 (120K) and by the series combination of R1 and GAIN. This resistance can be varied by the gain control from a gain of about 40 down to an attenuation of about 1/8, suiting a large range of guitar signals. The “bypass” signal is taken from the output of this stage as well.

Note that the “bypass” signal is inverted with respect to the input signal. This is generally recognized as a no-no today, but that’s what the Mutron did. You will probably not have any difficulty with this unless you split your signal into two parallel paths, one of which includes the Neutron, and then remix the two signals. Also note that the Neutron, like the Mutron, does not do true bypass, but instead does a buffered dry signal in the “bypass” mode. You have some options here - you can do the non-true bypass as in the original, or use a DPDT switch to do true bypass, or the same DPDT to do true bypass with an indicator as in the "Millenium Bypass". See http://www.geofex.com/~keen for how to do this.



(2) The state variable filter is an unusually flexible filter, allowing as it does simultaneous output of high, low, and band pass outputs. The control of the filter is also simple, with the filter frequency set by two resistors and two capacitors. In this case C6 and C8 (1.8nF, or 0.0018uF) capacitors in the feedback path of U2b and U2a and the variable resistances in parallel with R8 and R9 for those same amplifiers determine the frequency. The “Range” switch does a rough high/low adjustment of frequency by adding an extra 2.2nF (or 0.0022uF, C5 and C7) capacitor in parallel with each of the 1.8nF feedback capacitors when the range switch is in the “low” position. The variable resistances controlled by the envelope detector then sweep the filter frequency within the selected range. The “Peak” control adds a bit of positive feedback to the filter to allow the filter to be “peaked” at the filter frequency. This makes the bandpass higher gain and narrower, and also puts a sharp “peak” in the response of both the high and low pass outputs right at the cutoff frequency.

(3) The remaining two amplifiers detect the loudness of the signal and use it to drive the variable resistances that change the filter frequency. U3b has two diodes connected to it acts as a precision rectifier, allowing detection of even very small signals without the loss of the forward conduction voltage as a simple diode would do. The rectified signal is filtered into a variable DC voltage in C9 (4.7uF envelope capacitor) and then applied to the LED driver amplifier, U3a. This amplifier simply uses the detected envelope to drive a proportional current through the LED(s), which control the variable resistances and change the filter frequency. The “Up/Down” switch changes the “direction” of the envelope by changing the U3a from an inverter to a follower and changing its DC bias level to match. The LED is driven in current mode, with the current through it sensed by the resistor noted as **"Rx*"** on the schematic and parts diagram. This resistor adjusts the amount of drive current to suit the sensitivity of the specific LED; it must be adapted for the one you use. Start with about 560 ohms and work up until you get a value that makes your unit have about the right amount of sweep. This should be less than 4.7K.

I see the light - the opto-electronic module originally used in the Mutron III was unique, custom manufactured for them. It combined a single drive LED and two LDR’s in a single light-tight package. To the best of my knowledge, it is no longer available. However, you can get the same result four different ways, which are shown as options on the parts placement diagram. The same PCB layout is designed to accomodate all four ways to do the optoisolator, so select the one that suits your needs (and suppliers!) best.

Option 1 uses two H11F3 LED/photo-FET modules; Option 2 uses a single-LED/two LDR optoisolator similar to the original(which is also very hard to find, unfortunately); Option 3 uses two of the single LED/LDR optoisolators like the CLM6000 or the NSL32; Option 4 uses a single LED and two discrete LDR's mounted on a 14 pin component header, a kind of discrete version of the original opto module.

Option 1 sidesteps the difficulties of getting an LED/LDR module by using a linear LED/photo-fet module. These optoisolators are easily available by mail order and work well in the circuit by actual test. They even match one another tolerably well.

In Options 2, 3, and 4, you’re using or building a functional reproduction of the original LED/LDR circuit. Option 2 is the simplest, an LED/dual LDR module from a Japanese supplier. These, sadly, are only available in large quantity orders usually. You might try contacting C.J. Landry through his web site, cjlectronics, as he had some at one time. Option 3 uses a pair of LED/ LDR optoisolators like the VTL5C3, CLM6000, NSL32, or CLM600. These modules are moderately less rare than the original opto module, and you may well be able to find them. Option 4 is the simplest for most people, although it requires extra work. If you buy discrete LDR's and a high-brightness green LED, you can mount the parts on a 14pin component header so they connect to the right points on the PCB when the component header is soldered into the board. You will need a component header with a top cover; these are readily available from Mouser and other suppliers. Strictly speaking, the LDRs should be matched and track, but in practice this seems not to make too much difference to the sound. If you'd like to match the LDR's for optimum results, buy a few extra LDR's and measure the resistance under dim to moderate light conditions, holding the LDR's in as nearly the same orientation as you can, and select the LDR's with the nearest two resistances.

Power to the Package - the original Mutron III used a dual 9V battery and dual-voltage AC power supply. The Neutron has improved on this a bit by making single battery operation possible. The 7660 module with its accompanying three 10uF and one 100uF capacitors (C15, 16, 17 and 18) form a charge pump voltage converter. This converter uses a capacitor as a “charge bucket” to pump 9Vcharges into a –9V supply, so one battery can supply both + and – nine volts. The disadvantage is that the power is now coming from one battery instead of two, so the single battery drains twice as fast. However, this does make using an external DC power supply simple, as single voltage AC powered external supplies are very common, while bipolar ones are not. If you use the charge pump power option, populate the 7660 and capacitors, and insert the two jumpers leading from the charge pump circuit at the bottom of the board. If you use a dual battery or DC supply, leave all of these parts off.

Since the charge pump converter pulls pulses of current out of the battery at about 10KHz, you must be careful that the negative battery lead NOT be part of your signal ground; if you get the grounding wrong, you will get a high pitched whine in your sound. To prevent this, use the battery connections shown for the charge pump converter. In this version of the board, I have provided Q1 and R20. Attaching a wire to the input jack stereo lug from the pad attached to R20 will switch the power off and on through Q1. Do NOT use the old trick of using a stereo jack to switch the (-) lead to signal ground. This will guarantee that you get whine. The board layout is specifically designed to prevent whine from the converter from getting into the signal on the board, but as we know, reality has a way of intruding on designs. If you have wired the battery power correctly and still have a whine, you can insert chokes instead of the two jumpers at the bottom of the board in the power lines. This should clear up even hard cases.

If you elect to use dual batteries or a dual AC supply, simply leave off the 7660, the associated capacitors and the jumpers. Instead, power the effect at the pads marked (+9V), (-9V), and (Ground). The (Ground) connection serves as a star ground, and signal ground to the controls and jacks should be connected here as well.

Parts List and Suppliers

Designation(s)	Label-Value	Mouser Part Numbers	Qty	Expected Price ea.
Q1	2N3906	625-2N3906	1	0.10
U1,U2,U3	TL 072 Dual Opamp	511-TL072ACN	3	0.85
D1,D2	1N4148 diode	333-1N914	2	0.15
C1	4.7uF Tantalum	80-T350A475K010	1	0.39
C2	0.1uF axial ceramic	581-SA105E104M	1	0.12
C3	10pF	581-SA102A100J	1	0.19
C4	2.2uF	140-XLR16V2.2	1	0.05
C5,C7	0.0022uF (2N2)	581-SA101C222J	2	0.27
C6,C8	0.0018uF (1N8)	80-CK05BX182K	2	0.30
C9,C10,C11	4.7uF	140-XRL16V4.7	3	0.07
C12,C13	0.1uF ceramic	80-C315C104M5U	2	0.12
C14	15uF non polar	140-NPAL50V15	1	0.71
R1	3.3K	29SJ250-3.3K	1	0.07
R2,R3,R16, R17,R19	120K	29SJ250-120K	5	0.07
R4,R20	4.7K	29SJ250-4.7K	1	0.07
R5,R11	12K	29SJ250-12K	2	0.07
R8,R9	220K	29SJ250-220K	2	0.07
R10,R6,R7	22K	29SJ250-22K	3	0.07
R12,R13	1M	29SJ250-1M	2	0.07
R14	330	29SJ250-330	1	0.07
R15	47K	29SJ250-47K	1	0.07
R18	180K	29SJ250-180K	1	0.07
R21	560	29SJ250-560	1	0.07
GAIN	1M Rlog **	313-4000-1M	1	1.74
PEAK	150K log/audio pot**	313-4000-100k	1	1.74
Rx	150 to 4.7K, see text			
Optional Parts		Single Battery Option Parts		
U4	7660 power converter	570-ICL7660CPA	1	1.79
C15,C16,C17	10uF	140-XRL-25V10	3	0.07
C18	100uF	140-XRL-25V100	1	0.12
The usual stuff you'll need...				
Box	Hammond 1590DD	Digi-Key	1	~$12.00
Range, Direction	DPDT Toggle Sw.	10TC260	2	2.58
Mode	3PST Rotary Sw	10WW033	2	1.54
Bypass	SPDT or DPDT	Stomp Switch	1	* N/A

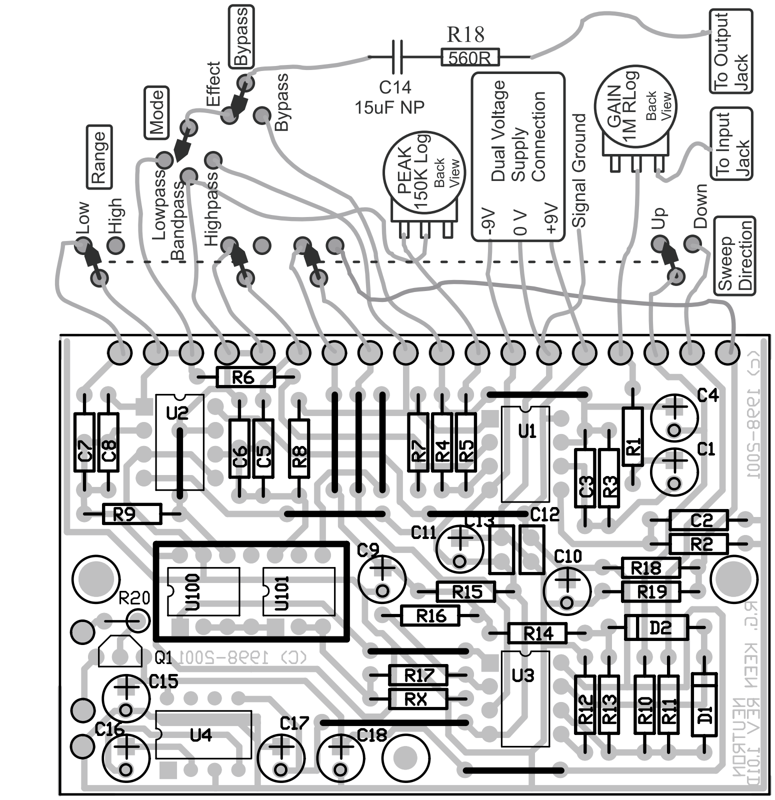
1/4” jack 1-ckt	Mono phone jack	502-111	2	1.88
1/4" jack 2ckt	Stereo phone jack	502-112B	1	1.96
Battery clip	9v battery clip	12BC092	1 or 2	0.38
Stranded wire	#22 - #24 AWG			
	Knobs			2

** The exact values, 150K and 1M reverse log are not readily available. The substitutes listed here will work; however, the “Peak” range is a bit restricted and the 1M is an audio taper, so must be wired and rotated counter-clockwise. You can use these values until you can locate the right ones. The 1M pot works, but simply has the reverse rotation. You could use a dual 100K audio pot for PEAK, but wire both sections in series. This will make for a 200K audio pot, very close to the real value.

Photocell Options Parts Lists

Option 1 Parts	Description	Mouser PN	$ ea.	Qty
U100,U101	H11F3 LED/photoFET	512-H11F3	2	1.65
Option 2 Parts	Description	Source	$ ea.	Qty
LED/dual LDR module	0805 replacement	C.J. Landry	12.00	1
Option 3 Parts	Description	Source	$ ea.	Qty
LED/LDR opto	CLM6000, CLM600 NSL32/32A VTL5C3	Hosfelt Electr. Silonex Newark Electr.	4.00 5.00 5.00	2
Option 4 Parts	Description	Mouser PN	M $	Qty
LED	Green LED, super bright	604-934SGC	0.21	1
LDR/photocell	Light variable resistor	338-76C59 or 338-54C79	1.56	2
14 pin header	Component header with cover, 0.41 high	151-314T3	0.78	1

Parts,Wiring, and Layout



Here's how to etch and wire it - and what to watch out for.

First, there are a bunch of jumpers. Sorry, that was the only way to get it on a single sided board. Make yourself a bunch of jumpers by first bending the resistor leads to the required spacing (they're all 0.4" wide) and them trimming off most of the excess. The excess is plenty long enough to make two jumpers, so you don't have to pre-cut many of them .bend the jumpers and install them first.

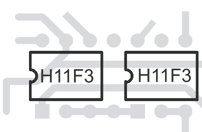
It's probably best to put in the jumper under U2 first so you don't forget about it. Jumpers under IC's are a layout no-no, but I figured you were up to it for something you make by hand.

Q1 and R20 are new with this rev. They are a transistor switch that lets you put a single battery on the board and still turn power on and off with the stereo input jack trick. R20 goes off to the stereo contact on the jack, and is pulled to ground when a plug is inserted. This turns on Q1, which lets power into the circuit. The battery remains attached to the battery pads.

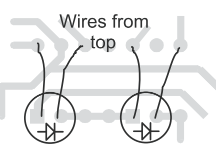
As noted in the text, decide what version of variable resistors you'll use. These diagrams show you how to stick in the version you want. People have built this with all of the optional ways shown, they all work.

If you use the single LED/component header, it helps if you glue a shiny aluminum foil layer to the inside top cover. Mouser has the headers and covers.

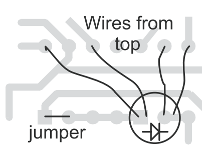
C14 and R18 are soldered between the bypass switch and the output jack, not on the PCB itself. This is not good practice, but it would make the wiring even more congested to put them on the PCB. It helps to put them both in a short length of heat shrink tubing.



Option 1: Photo-Fet optoisolators

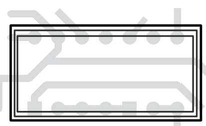


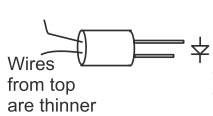
Option 3: CLM6000/ NSL32 LED/LDR's



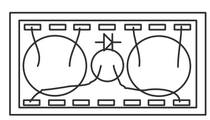
Option 2: LED/dual LDR optoisolator

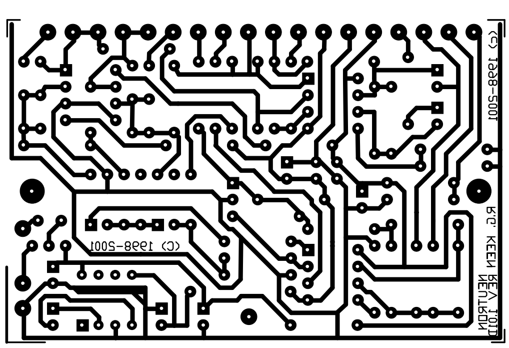
Option 4: two LDR's and one LED in 14 pin component header with cover.

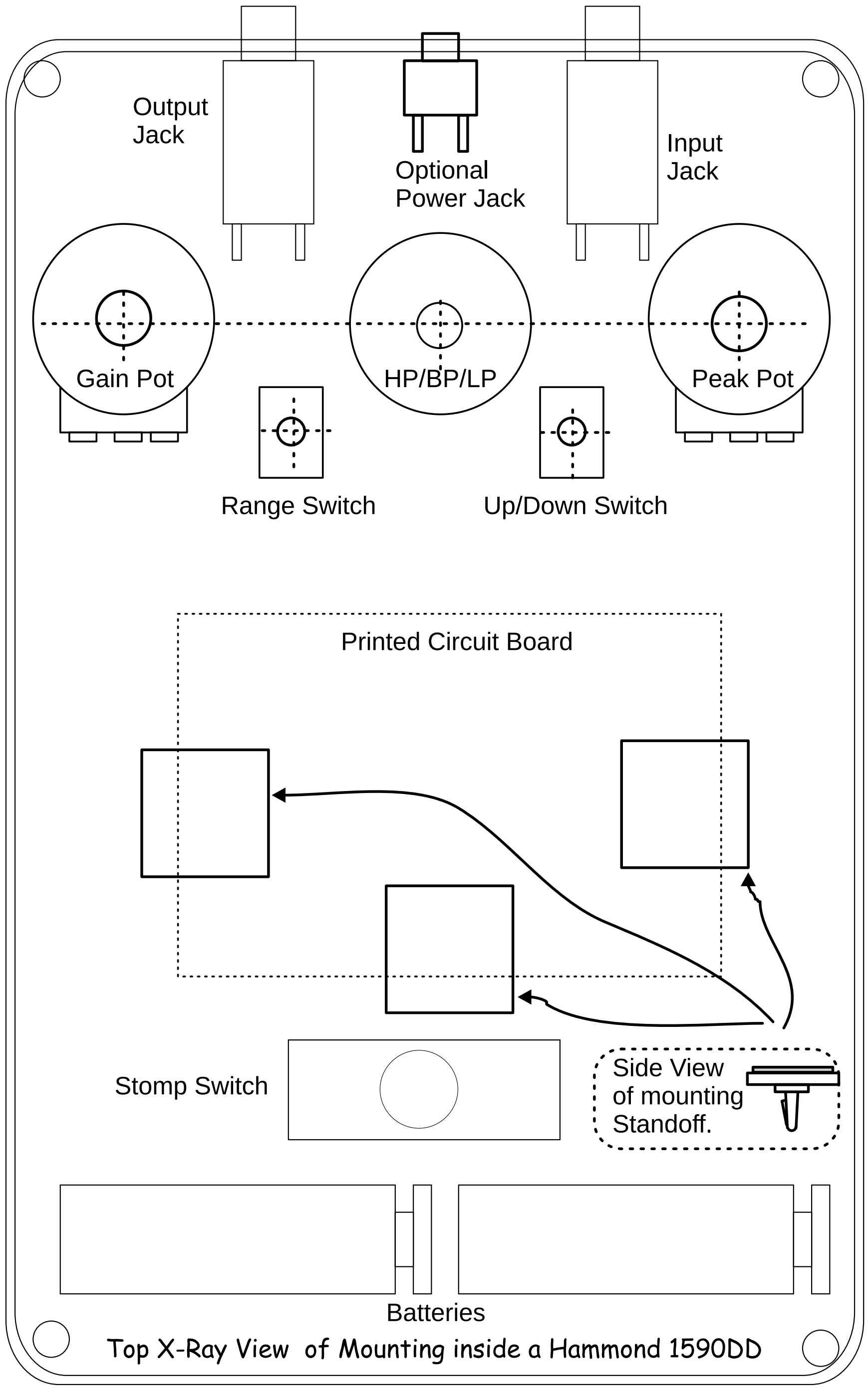




Wires under LDR's/LED to terminal locations devices point UP.






Output
Jack
Optional
Power Jack
Input
Jack
Gain Pot
HP/BP/LP
Peak Pot
Range Switch
Up/Down Switch
Printed Circuit Board
Stomp Switch
Side View
of mounting
Standoff.
Batteries
Top X-Ray View of Mounting inside a Hammond 1590DD