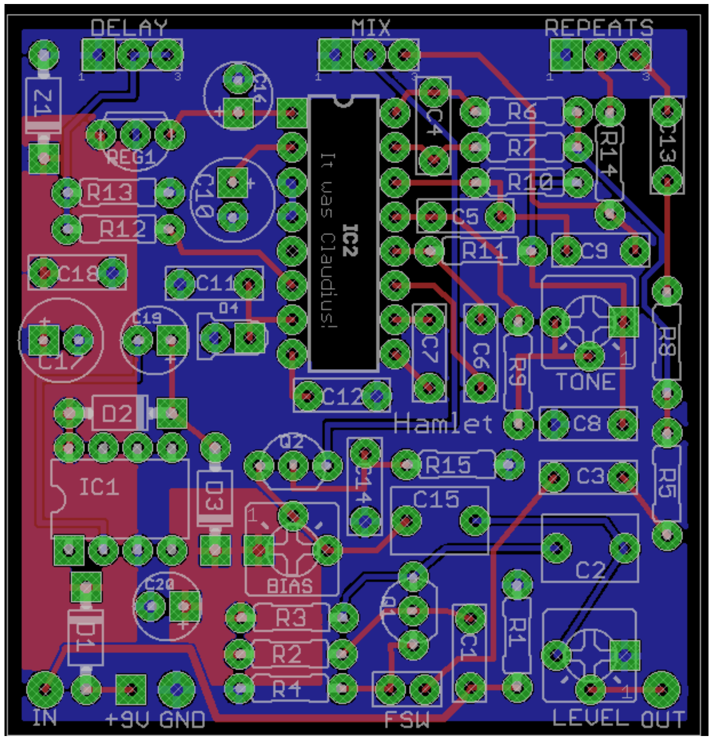
The Hamlet Delay: Preamp and Delay with Tails

by Jon Patton

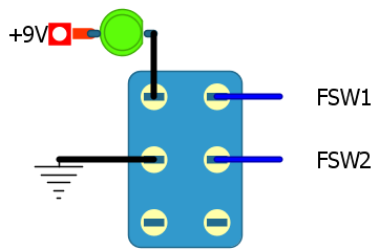


Resistors		**R14**	2.2K	**C12**	100nF	**Bias** (see notes)	10K trim
R1 (opt.)	4.7M	**R15**	470Ω	**C13**	100nF	**Level**	10K trim
R2	4.7M	**Capacitors**		**C14**	22nF	**Regulator**	
R3	4.7K	**C1**	100nF	**C15**	1µF poly	**REG1**	78L05
R4	1K	**C2**	1µF poly	**C16**	10µF	**Transistors**	
R5	10K	**C3**	220nF	**C17**	100µF	**Q1**	2N3904
R6	10K	**C4**	1nF	**C18**	100nF	**Q2**	2N5457
R7	10K	**C5**	1nF	**C19**	10µF	**ICs**	
R8	4.7K	**C6**	100nF	**C20**	10µF	**IC1**	LT1054
R9	10K	**C7**	100nF	**Potentiometers**		**IC2**	PT2399
R10	22K	**C8**	56nF	**Delay**	100KB	**Diodes**	
R11	10K	**C9**	47nF	**Mix**	25KB	**D1-D3**	1N5817
R12	1K	**C10**	47µF	**Repeats**	20KA	**D4**	3mm dif. LED

R13	150K	**C11**	100nF	**Tone**	25K trim	**Z1**	12V Zener

Notes, Mods, & Substitutes

The Hamlet Delay is my take on a PT2399 delay with tails. The dry path is an always-on preamp with available boost, very high input impedance and low output impedance. The delay line is switched on separately in parallel with the dry signal. A tone trimmer allows the user to fine-tune the repeats, going from bright digital to tape-like to darker narrow-bandwidth analog-style repeats. Unlike many PT2399 delays, there is very little treble filtering otherwise, and combined with some progressive bass loss, the repeats take on a shimmery, singing quality that is not readily found in other delays. The circuit also contains what is, to my knowledge at the time of this design, a unique method of limiting the signal in the PT2399 via a single LED, making it *impossible* to distort the delay chip.

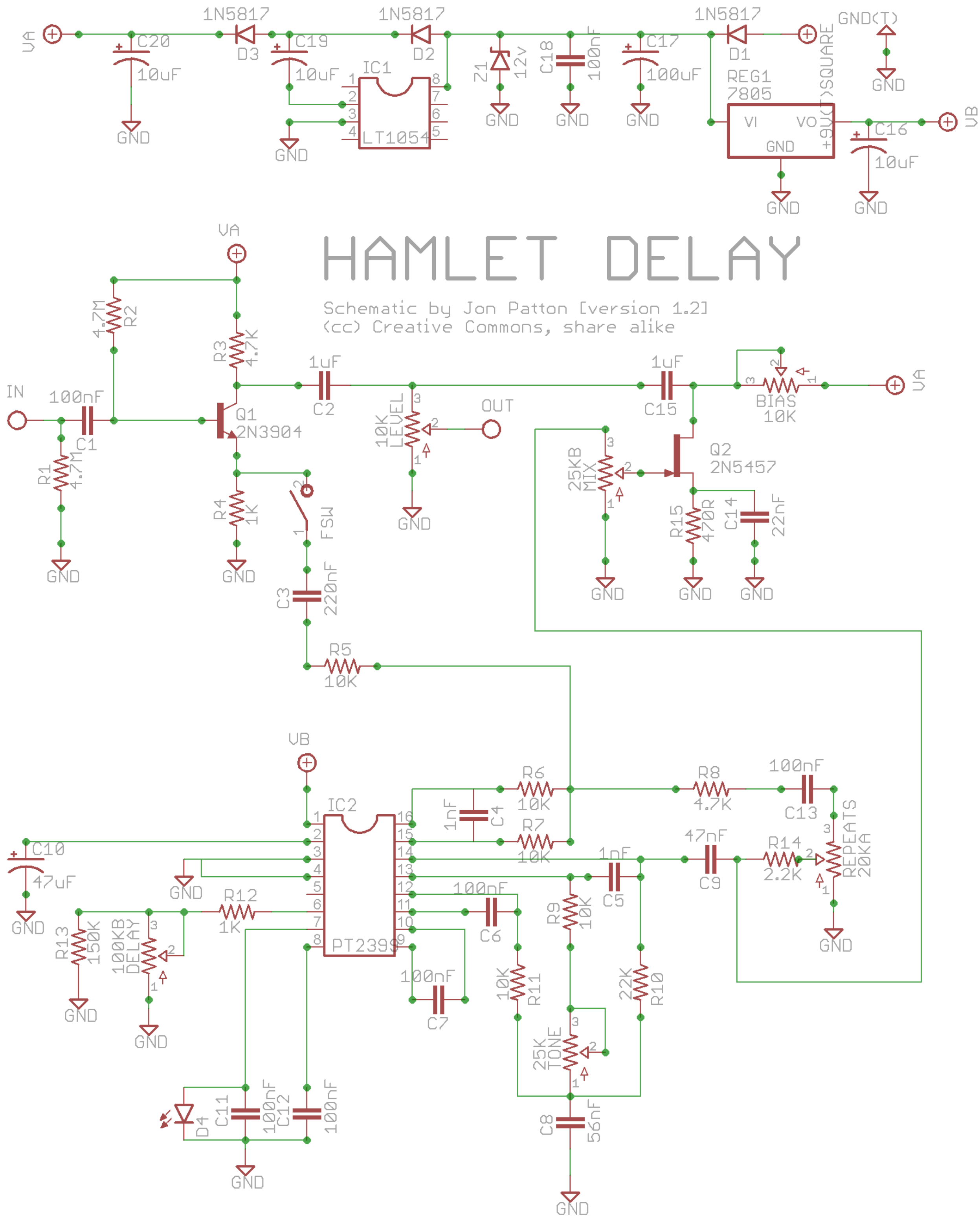


- **The footswitch wiring** is very simple and shown at left.
- **PT2399s**: Inevitably, and as many DIYers are aware, there is some noise on the longest delay times. This is and to be expected with any PT2399 design. This can't be avoided without making the repeats very dark or severely limiting the delay times. Still, some chips may have more white noise, "shhh" distortion, and/or motorboating than others, so I highly recommend using a socket.
- **Charge pump:** I recommend using an LT1054, which is much more robust than the MAX1044. If you use a MAX1044SCPA you must connect pin 1 of the charge pump to the 9V source. On the PCB, this is best accomplished by using the cathode lead from D1. You must also use a different Zener (10V is good) to protect the chip from overvoltage.
- **Q1:** You should use a medium-gain silicon. I preferred the humble 2N3904 for its tonal balance after trying more than a dozen different transistors of varying gain. Several other Si transistors with HFE ~200-500 also sounded very good. Avoid very high gain transistors (above 800 hfe) like darlington transistors. They will dull the highs and may cause problems in the delay line, such as uncontrollable oscillation.
- **Q2**: Biasing: Set your multimeter to 20V. Turn the mix pot all the way up. Place the black probe on ground and the red probe on the cathode of D3. Note the total supply voltage. Now probe the drain of Q2. Adjust the trimpot for 50% (usually about 9V) of the supply voltage as a starting point. Now adjust the bias to set the gain of the delay line to taste. My preference is 10.5V. You can use other JFETs in Q2, but you may need to use a larger trimpot. In my test unit, a J201 biased to 9v with a 10K trim, but just barely.
- **The tone cap in the delay line**, 56nF, is an unusual value. Although you can substitute any close value (e.g. 47nF), I preferred the frequency rolloff/knee of the 56nF, and it's part of the Hamlet's unique voicing.
- **Delay control**: You can use a 50K and omit R13 for a shorter maximum delay. R14 sets the minimum delay. You can increase it for a longer minimum delay.
- **Repeats control**: 20KA is an unusual value in the U.S. Tayda carries it, or you can use a 25KA. The log taper is critical. Do not use a linear or W taper -- the repeats will bunch up in the beginning of the rotation.
- **Pay close attention to the pinout of your regulator.** The mask shows the orientation of the 78*L*05, a TO-92 package with no heat sink. The pinout of the package with a heat sink is reversed.
- **R1** is an optional pulldown resistor for builders who wish to wire the effect for true bypass.
- **If you are wiring the effect for true bypass rather than tails**, be sure to jumper the FSW pads on the PCB.
- **If you do not have and cannot get any 1N5817 diodes**, another Schottky diode may be used to still achieve 18V. In a pinch, you can use 1N4001, but this will reduce the maximum voltage to ~15v.
- **C16** should be tantalum if possible. It has no effect on the sound, but may provide better power filtering.

- The trimpot pads are for 6mm trimmers, based on the Bourns 3306, but the small cheap blues ones (e.g. from Tayda Electronics) fit, too. The tone trim value is not critical, so just use the closest thing you can get..
- **D4** forms a crude limiter for the PT2399 (see “How It Works” below). A yellow or green diffused LED is best, red or orange work in a pinch. Blue and white have too high a Fv and will not work.

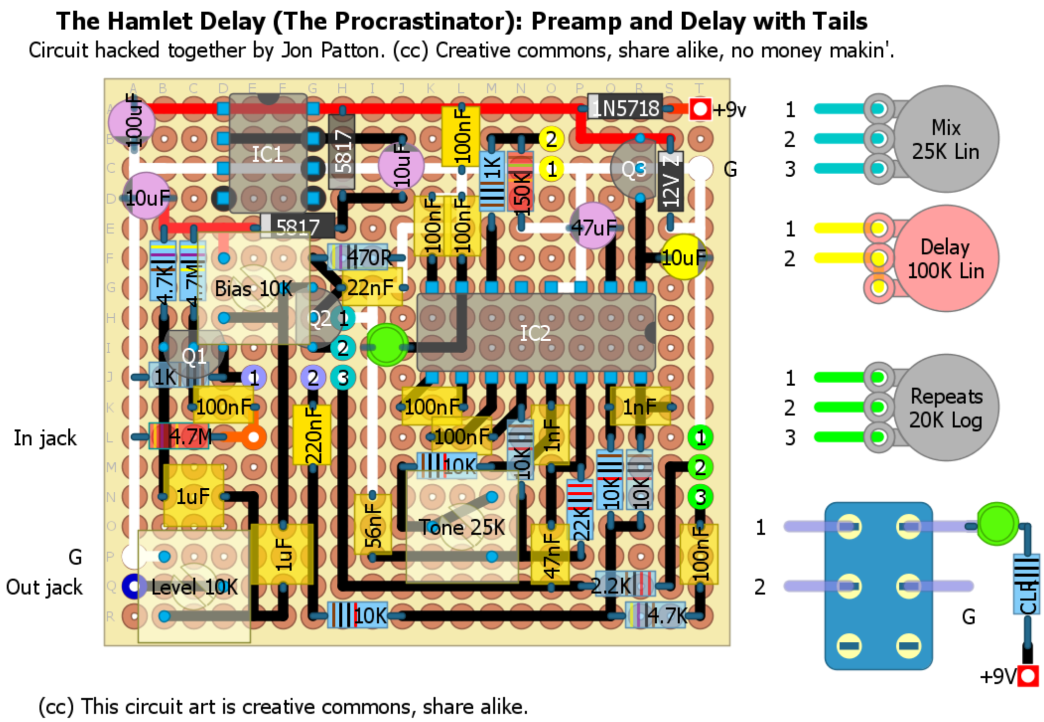
HAMLET DELAY

Schematic by Jon Patton [version 1.2]



Perfboard layout

This is how I like to build 'em!



Clip (or bend away from the socket) pins 1, 4, 5, 6, and 7 for LT1054 or pins 4, 5, 6, & 7 for a 1044.

Etched single-sided version

To ensure proper scaling, please download the layout file here:
https://dl.dropbox.com/u/9878279/Jon%20Patton%27s%20layouts/Hamlet/Hamlet%20delayout.pdf
Be sure to print the PDF without page scaling. The parts layout for the etched version is identical to the perfboard layout.

How It Works

Keep in mind that I am just a guy with a breadboard, ears, and a dream, not an electronics wizard. This is the best explanation I can offer for how the circuit works.

Power section

The first part of the power section contains our standard power supply filtering (C17 at C18) and polarity protection (D1). A zener diode protects our charge pump from overvoltage, like voltage spikes from an unregulated power supply and our own mistake when plugging in the wrong power supply (oops!). The 9v signal is tapped for two tasks: Providing 5v to the digital delay chip through Reg1 (a 5v regulator) and providing 18v to Q1 and Q2 through a basic charge pump arrangement. Additional power supply filtering post-regulator is provided by C16 and post-charge pump by C20.

Preamp section

After the input decoupling cap (there to protect our guitar's pickups from DC), a somewhat unusual thing happens at Q1: Our signal is amplified by the collector, where it passes through to the output cap and volume control, and also buffered by the emitter, which sends it to the delay section. There are several reasons for doing it this way, not least of which is that it was the only way to do it that the delay didn't oscillate uncontrollably! R4's small resistance to ground, which helps amplify the dry signal at the collector, also helps limit our wet signal. This will be important in a moment.

Q2 is a gain recovery stage for the delay signal. R15 limits the gain safely above the JFET's cutoff (it could be slightly smaller for more available gain, but 470Ω is a more common value than 330Ω or 270Ω, and the frequency response would be different). The 22nF bypass cap from source to ground maximizes the gain of frequencies in the upper midrange and treble. Increasing this cap would have provide a more full-range sound, but the PT2399 filters out treble and upper midrange frequencies, so the 22nF cap makes up for that loss. A 1µF decoupling cap follows Q2's drain, and from there, our preamp section is completed with a 10K trimpot for the output volume.

A final somewhat unusual result of this preamp setup is that the gain from Q2 provides a little bump to Q1. Therefore, adjusting the Q2 bias control also has a small effect on the sound of Q1 (mostly "sparkle"). This is part of why I prefer to bias mine to 10.5v; the slightly higher bias trimmed the treble on Q1 to be flatter.

Delay section

The bypass footswitch simply shunts the connection to the delay signal.

An input cap (C3) forms a high-pass filter for the signal into the delay. It's sufficiently large to pass our guitar's frequencies from the buffered signal created by the emitter of Q1. Next up is a resistor (R5) that further attenuates the signal into the delay and, based on my experience on the breadboard, prevents weird things from happening with the repeats pot.

The delay chip's circuitry is fairly standard for a PT2399, minus some common filtering capacitors. It's designed to avoid treble filtering of the repeats except at Pin 13 (a low-pass filter), where our Tone trimmer resides. Pin 13 is the stage immediately preceding the low pass filter out that connects to the repeats (pin 14), which is connected to the same tone cap. By increasing the resistance between the 56nF cap and pin 13, *more* treble from of the repeats signal is filtered. R9 sets the lower limit of the tone pot. More filtering means less harmonic distortion in the repeats, yay!

The Repeats control is a standard voltage divider, limited in its connection to pin 14 *and* the mix pot by R14. C9 provides some final high-pass filtering. Increasing it will retain some additional bass and subharmonic frequencies, but no fundamental guitar information is lost even with a comparatively small capacitor in this position.

The mix pot at the end of the audio section is a simple voltage divider (volume control) connected directly to the gate of our FET amplifier make-up gain stage. Because our delay signal is going to be re-amplified, 25k provides enough input even though it's half the size of the mix pot in most delays. Our repeats can even get well above unity.

On the other side of the chip (pins 1-8), there is some power filtering, our chip's ground connections, and the delay control, a 100K pot in parallel with a 150K resistor (for a maximum resistance of 62.5, and about 650 ms of delay). R12 prevents the delay chip from locking up and also sets the minimum delay time.

Then we find something extremely unusual and, to my knowledge, unique to the Hamlet: an LED from pin 7 to ground.

A brief discussion of an issue present in most PT2399 delays is in order. The Rebote, Deep Blue Delay, and countless other DIY and boutique delays use the inverting pin of the op amp for the input and for feeding the PT2399 a buffered signal. With an unboosted signal from a single coil guitar, this means you get a nice clean delay with no distortion. It can sound very, very good, too -- the 1776 Effects Multiplex uses this same setup and is a great pedal. But if we pull out our multimeter and measure the delay chip, we find that the audio pins are all biased to about 2.4 volts. The whole delay chip only runs on 5v. Here's what happens in the words of RO Tyree (from DIYStompboxes):

> Humbuckers typically push out about +/-1V, maybe a bit more, so a gain of 2 at the input buffer sends the total to over +/-2V which [overloads] the PT2399. The output buffer/mixer has a gain of 0.5 to reset the levels so Vin = Vout. The designer did this so that weaker signals from single-coils get boosted going in, so noise added by the PT2399 is small(ish) compared with the signal going through it and then is reduced by half in the mixer. It's not the best method, by any means, but it's better than a poke in the eye with a sharp stick.

This problem only gets worst when running a boost or distortion pedal in front of a PT2399 delay. Not only can the delay chip distort, but the low input impedance of Pin2 of the op amp is more likely to create op amp distortion (the op amp distortion will usually happen before the PT2399 distorts). Solving the distortion issues was a major design goal for me. The op amp distortion was easier to solve: the simple transistor stage running on 18v won't be distorted by any 9v pedal I own (including the MOSFET booster, which provides as much as 30db of gain).

As far as the PT2399 distortion goes, originally I was content to merely attenuate the size of the signal going into the PT2399, then boost it later, like a faux compander. Unfortunately this was missing the real "compression" half of that equation. I could get up to about a 15db boost without distorting the signal, but it didn't do anything to limit signals above that point. If I was going to claim that a pedal had lots of headroom, I couldn't really be satisfied with this performance. So I started poking around on the delay chip while strumming a guitar fed into a cranked booster, looking for voltage spikes. I found them on pins 7 and 8 of the PT2399, which are labeled "CC" in the datasheet, with no accompanying explanation, but my theory was it stood for "current control."[1] With just a guitar, or just mild boost, I was seeing maximum voltages around 1.5v. But with full boost, the voltage spiked as high as 2.5 or even 3v. The result when it got that high?: Bladt. Distortion.

I started brainstorming some ways to handle this, and the first thing that came to mind was diodes to cut the signal. Then I thought about a zener diode. Zeners conduct in reverse under specific conditions: when the voltage exceeds their rating. (E.g. 9.1v, 12v). The response is non-linear, and it would work to siphon off excess voltage at a known value. Unfortunately, a zener diode with a low enough voltage rate (2v) is rare (especially as a through-hole part) and I certainly didn't have one on hand. I poked around a bit and found that diodes from pin 7 (but not pin 8) to

---

[1]Merlin Blencowe has some good notes that give clues to the interior connections if pin 7, and Rob Strand on DIYStompboxes had this to say about Pins 7 and 8 years ago:

> "pins 7 and 8 are used to smooth the a biasing supply inside the modulator (MOD) and demodulator (DEM) blocks. There's no reason to mess with these pins, or the caps on it. (Initially I thought this was part of the ADM slope control but it's not)."

ground did indeed limit the voltage to the Fv of the diodes. But general purpose diodes on pin 7 made the signal too quiet. Fortunately, I stuck with it, and after some experimentation and consulting with the folks on DIYstompboxes, I found that a single yellow or green LED with its cathode to ground worked perfectly. Well, almost perfectly, because like most things in electronics, there's a tradeoff. Although the LED has no effect until the signal size exceeds the diode's forward voltage of 1.8v, the signal also *can't* exceed that limit. The gain recovery stage of Q2 can only give us so much extra output. So with an input signal around +20db, we lose the ability to have repeats above unity, and somewhere around +25db, the dry volume will be noticeably higher than the repeats volume (even with the mix control cranked). But despite this shortcoming, the headroom of both the dry and delay paths is astounding, more than sufficient for the Hamlet to be run in-line with any boost or overdrive effect, rather than in an amp's effects loop.

This was quite an adventure. I hope everyone has as much fun building the Hamlet as I had designing it.

Credits: This circuit was inspired in part by the Madbean Fatpants and the 1776 Multiplex Echo Machine. The tone control is similar to the one originally suggested by CultureJam. Thanks as always to the many, many knowledgeable people on the forums who willingly share their knowledge of electronics to help solve all the little problems that crop up in the design process.