HD130 Preamp

Builder's Guide

Version 1
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Revision History

Version	Changes
0	Draft Copy
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Contents

1 Introduction

This document contains a guide for assembling the HD130 Preamp by Electronic Audio Experiments. This PCB is based on a schematic that we originally shared in 2017 as an open source project. This version was also available in a fully assembled form thanks to our friend Brad at Nerd Knuckle Effects. In January 2024 we released The Bard, which is a streamlined take on the HD series preamp. We decided to share this version as a separate project alongside it. The Bard and the DIY HD130 have several differences which are outlined below in Section 1.3.

1.1 Background

The Music Man HD series amps were among the earliest hybrid amps, combining a solid state preamp with a tube power amp. These were produced from 1974 until 1984 when Music Man was sold in an asset sale to Ernie Ball, who discontinued their production. These amps were commercially unsuccessful, but have since developed a cult following for their high headroom cleans and uniquely trashy overdrive. While few famous guitarists are known for using this amp, I have seen them countless times at small clubs and DIY shows. As far as dollars per watt goes, the HD130 and its siblings are one of the best deals on the vintage amp market.

This pedal is a simplified take on Channel 1 of the original amp, which is the channel that does not have reverb or tremolo. The preamp resembles a classic Fender circuit, but with op amps used in the place of tubes. The op amps in the original amp are operated at ±16V. In this adaptation we designed around a ±9V bipolar power supply, using a charge pump to derive the negative rail. The gain can be rescaled or you can use the reduced headroom to achieve extra distortion relative to the original.

To get into some specifics, there two versions of the HD130 bearing the 2100-130 chassis designator. The earlier version has an all tube power amp consisting of four 6CA7 power tubes, with one half of a 12AX7 serving as a driver and the other as a cathodyne phase splitter[1]. This version is considered by some to be superior due to this extra tube, but the phase inverter has so much negative feedback that the power amp stays clean until the amp is turned up to ear-splitting levels.

The later version is a partial redesign of the power amp, with the driver tube replaced by an op amp phase splitter (not unlike a balanced line driver) and an interesting (read: over-engineered and unreliable) cascode configuration using power BJTs driving the 6CA7 tubes from their cathodes. This is a very linear configuration with similar high headroom to the previous version. However, the preamp gain was also scaled up significantly[2], which is the source of the trashy overdrive that makes this amp special. Because this overdrive originates entirely in the preamp, we felt it reasonable to omit the power amp.

[1] For more reading see here: `https://www.valvewizard.co.uk/cathodyne.html`

[2] If it weren't for all the negative feedback in the earlier version, I would assume that this is to compensate for the lack of the extra output driver tube.

1.2 Operation

The controls are as follows:

Volume Self explanatory. Can get quite loud. Equivalent to the master volume on the original amp.

Gain Sets the gain of the circuit near the input. Low settings are very clean, higher settings can get pretty aggressive. Equivalent to the volume control on the original amp.

Bass Low frequency adjust. Fairly subtle, but interactive with the other controls.

Mid Mid frequency adjust. Has a fairly "scooped" character at most settings.

Treble High frequency adjust. The most powerful of the tone controls, since this thing can get very bright.

The Bass, Mid, and Treble controls form a a classic FMV (Fender, Marshall, Vox) tone stack, with some impedance scaling to better work with op amps (more on that later). This type of tone stack has a slightly mid-scooped character. There is also an optional Bright switch that can be added. This adds extra treble at lower Gain settings.

One important thing to note about this circuit is that the tone controls are placed before the gain stage that clips the most when the amp is overdriven. This means you can emphasize particular frequency bands for more or less gain.

1.3 Comparison to The Bard

In The Bard circuit, we made a few changes to streamline the design.

- The Bard's power supply is 9V unipolar. On the DIY version, there is a bipolar 9V supply for added headroom. (Note that the original amp runs at 16V bipolar.)
- We decided to do away with the Mid control. When running this pedal into a guitar amp, we found it usually sounded best with the Mid control at max.
- The Bard has a moderate amount of gain on tap. On this version, you can choose component values for significantly more gain if so desired.
- We optimized The Bard to accommodate both Bright and Normal modes. On this build, the Bright switch is optional and you can implement a suitable middle ground.

Comparing the two, the DIY version has more versatility but is less user-friendly as a traditional overdrive pedal. The Bard is optimized to work in a typical pedal chain in front of an amp.

1.4 Before You Start

This board is recommended for moderate level to experienced builders. This guide assumes you have some familiarity with:

- Sourcing your own parts via Mouser, Digikey, etc. using a bill of materials
- Soldering a PCB from a parts list
- Drilling your own enclosure using a provided template
- Pedal assembly using PCB-mounted 16mm potentiometers
- Soldering jacks and switches with off-board wiring

This document includes a parts list, schematic, and drill template. It also includes a broad analysis of the circuit and some suggested modifications. For generic assembly tips, please refer to the Appendix.

1.5 Disclaimers and Licensing

> ⚠ **Caution:** EAE is not responsible for the outcome of your build and cannot offer direct support or troubleshooting beyond this document.

2 Parts List

The following parts list assumes a build in the stock configuration. Parts marked with an asterisk (*) have additional information in Section 7, where you can also find suggested mods. We recommend reading this section before you begin.

Resistors, Potentiometers, Trimpots

Qty	Value	Ref #s	Description
2	10kΩ Audio	GAIN, VOL	Potentiometer, 16mm PCB Mount Right Angle
1	25kΩ Audio	BASS	Potentiometer, 16mm PCB Mount Right Angle
1	25kΩ Linear	TREB	Potentiometer, 16mm PCB Mount Right Angle
1	5kΩ Linear	MID	Potentiometer, 16mm PCB Mount Right Angle
1	1M	R1	Resistor, Metal Film 1/8W
1	100R	R10	Resistor, Metal Film 1/8W
3	4.7K	R11, RX1, CLR	Resistor, Metal Film 1/8W
1	68K	R2	Resistor, Metal Film 1/8W
1	220K	R3	Resistor, Metal Film 1/8W
3	100K	R4, R7, R8	Resistor, Metal Film 1/8W
2	10K	R5, R6	Resistor, Metal Film 1/8W
1	22K	R9	Resistor, Metal Film 1/8W
1	330K	RX2	Resistor, Metal Film 1/8W

Capacitors

Qty	Value	Ref #s	Description
1	3.3n	C10	Capacitor, Box Film 5mm LS
1	220n	C11	Capacitor, Box Film 5mm LS
1	470n	C13	Capacitor, Box Film 5mm LS
2	1u	C14, C16	Capacitor, Box Film 5mm LS
3	100n	C6, C9, C12	Capacitor, Box Film 5mm LS
1	15n	CX1	Capacitor, Box Film 5mm LS
2	100u	C2, C5	Capacitor, Elec 6.3mm dia 2.5mm LS 25V min
3	100p	C7, C8, CX2	Capacitor, MLCC NP0 25V min 5mm LS
1	33p*	CX3	Capacitor, MLCC NP0 25V min 5mm LS
6	100n MLCC	C1, C3, CB1, CB2, CB3, CB4	Capacitor, MLCC X7R 25V min 2.5mm LS
1	10u MLCC	C4	Capacitor, MLCC X7R 25V min 5mm LS

Discrete Semiconductors

Qty	Value	Ref #s	Description
1	1N5817	D1	Diode, Shottky

Integrated Circuits

Qty	Value	Ref #s	Description
1	RC4558	IC1	IC, Op Amp Dual
1	LM307†	IC2	IC, Op Amp Single
1	ICL7660S‡	IC3	IC, Charge Pump

* Select CX3 based on desired compensation cap for IC2.

†LM307 is the default value but not readily available. See Section 7 for additional notes regarding op amp selection.

‡Solder JP1 if using ICL7660S. See Section 7 for details about charge pump selection.

Off-Board Parts

Qty	Value	Ref #s	Description
1	Enclosure	N/A	125B or equivalent
2	1/4” Mono Jack	IN, OUT	Switchcraft 111x or equivalent
1	DC Jack	9V	2.1mm barrel connector
1	3PDT	BYP	3PDT Footswitch, solder lug
4	Knob	N/A	1/4” shaft w/ set screw
1	3PDT Daughterboard	N/A	Included w/ PCB
1	LED	N/A	Any 3mm or 5mm LED
1	Ribbon Cable	N/A	6 conductor ribbon cable, prestripped

3 Wiring

The wiring diagram is shown in Figure 1. For overall assembly instructions please refer to the Appendix. Wire pads on the board are listed in Table 1. For convenience, pads make connections to hardware located in close proximity. Note that the LED is mounted on the reverse side of the footswitch PCB, or can be wired off-board using a bezel. If you are using a 3PDT daughterboard, a 6-pin ribbon cable may be used. If you are not using a daughterboard, refer to Figure 2. You may use another scheme provided the input is grounded in bypass.

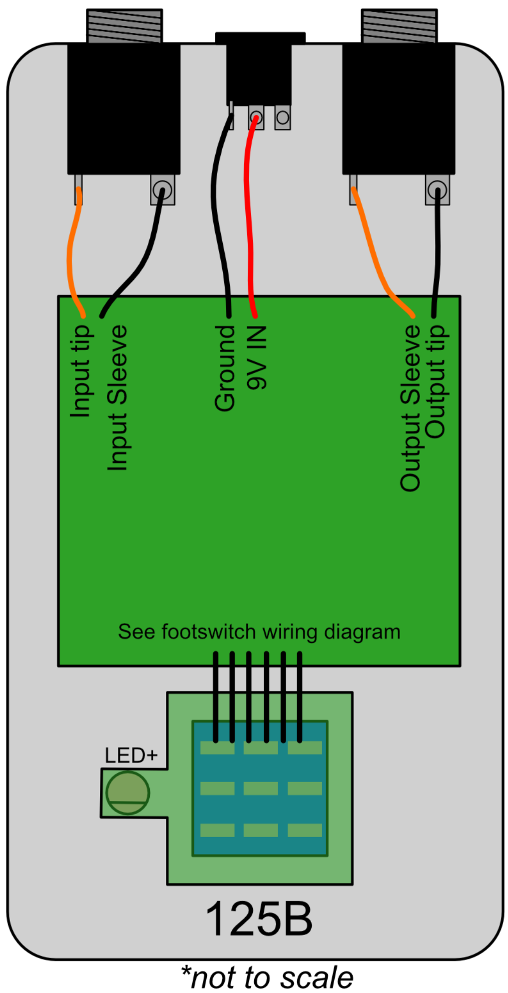


Figure 1: Wiring diagram. This view is looking into the enclosure from below. Note that this figure is for illustrative purposes only and is not drawn to scale. Tip/sleeve pads may be swapped on certain boards.

Pad	Function
I	Input Jack Tip
O	Output Jack Tip
G1, G2	Jack Sleeve Connections (Ground)
[+]	9V input (DC jack)
[-]	DC jack ground
JI	Bypass footswitch connection to input jack
L+	LED + to footswitch
L-	LED/Footswitch ground
S	Send/Input to effect
R	Return from effect
JO	Bypass footswitch connection to output jack

Table 1: List of wire pads and functions.

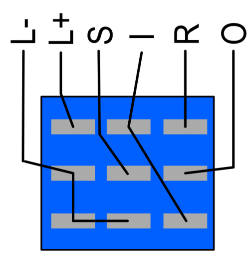
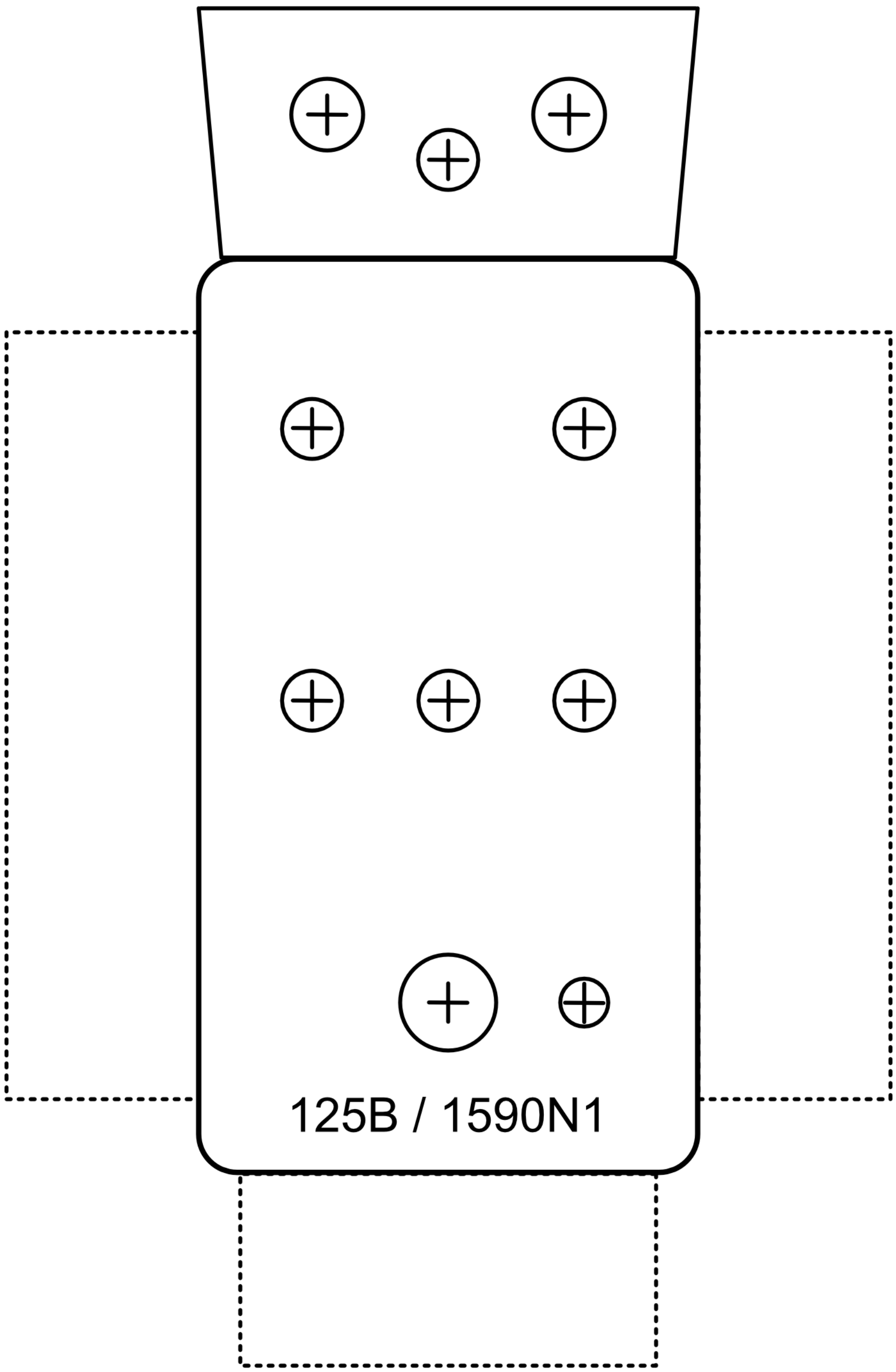


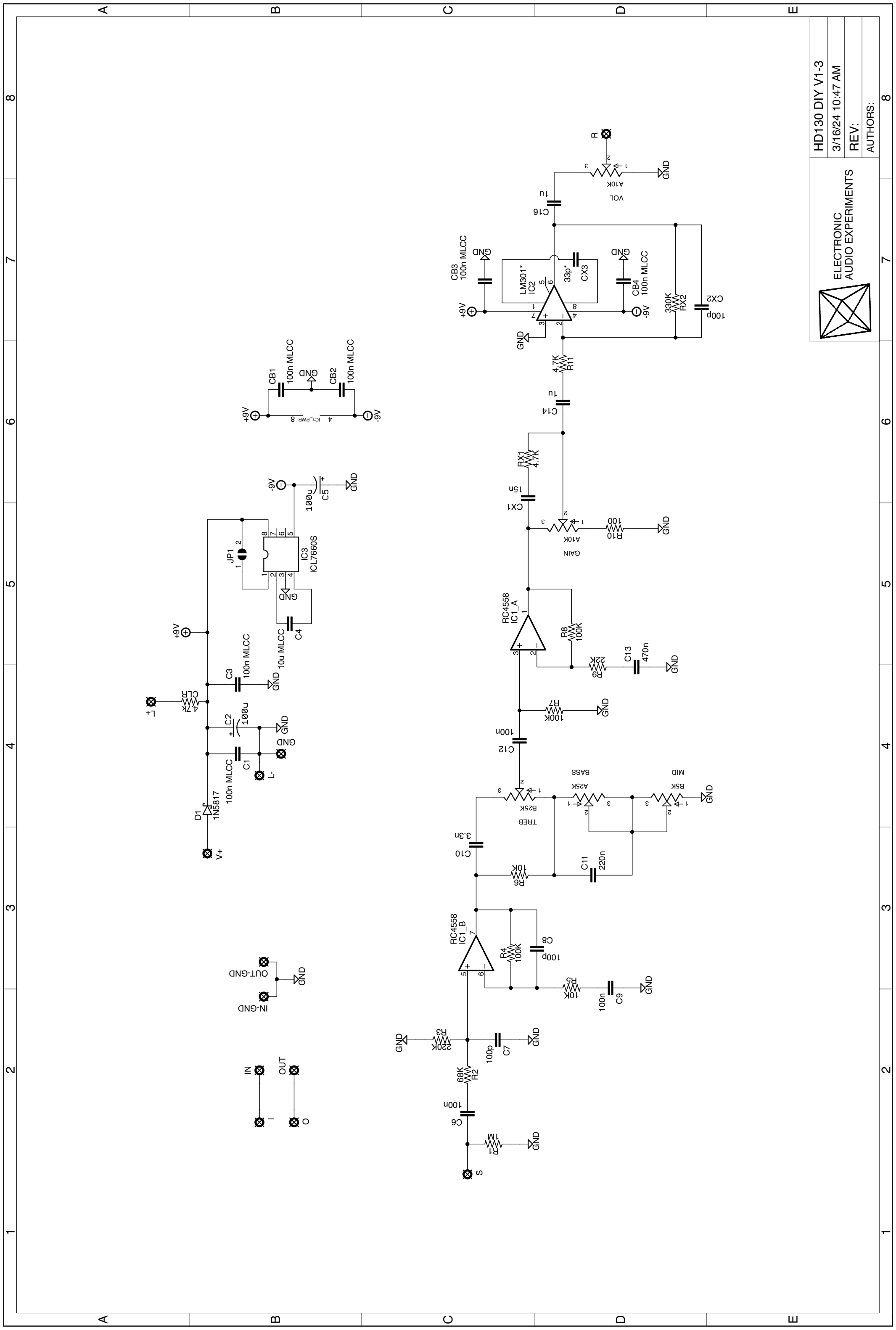
Figure 2: 3PDT Wiring Diagram. Note horizontal orientation of solder lugs.

4 Drill Template

Print this page out using 1:1 settings on your printer and fold to form the drill template. We recommend drilling pilot holes first to check alignment.



5 Schematic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AUDIO EXPERIMENTS

6 Circuit Analysis

6.1 Signal Path

The HD130 preamp consists of three cascaded op amp gain stages with passive attenuation and filtering in between. What distinguishes this circuit is the unusual approach to gain adjustment. In most op amp preamp/drive circuits, variable negative feedback is used to set the gain based on ratios of resistors. In this circuit, each of the op amp stages is fixed and the gain is controlled by attenuating between stages.

The signal path is a direct translation of a typical Fender-style tube amp. First is a gain stage, followed by a tone stack and volume control, then by a recovery gain stage that typically goes right to the power amp with a master volume typically placed after the recovery stage. Placing the tone stack early in the signal chain has a significant impact on the overdriven character. Rather than sculpting the overall output, the tone controls determine the relative gain of particular frequency bands.

The first gain stage, formed by IC1B, is a non-inverting amplifier with a passband gain of 11, or about 21dB.[3] The 100nF capacitor C9 means that this stage has a shelf cut below about 150Hz[4]. This keeps bass frequencies from getting too flubby. C8 forms a low pass filter with a cutoff frequency at about 15kHz, which is less about overall sonics and more about keeping the output stable.

Immediately following is the tone stack, which follows the classic FMV (Fender, Marshall, Vox) configuration. Notice that the component values have been scaled relative to typical tube amp values. The resistors (or potentiometers) are all 1/10 their usual value, and the caps are all 10x the usual value. Since the ratios between resistors and capacitors are the same, the frequency response is also the same. Using lower resistances is a good thing because for any resistor, more resistance equals more noise.[5] A neat side effect is that the capacitor typically found between the treble and bass pots has been reduced to a wire, saving a part.

After the tone stack is IC1A, another non-inverting amplifier which has a gain of about 4.5x, or 13dB. Since C13 is 470nF, the high pass cutoff is now about 33Hz, which is effectively full range. The only job for this stage is to overcome the losses of the tone stack.

Next is where things start to get interesting. Ignoring the gain pot for now, we see that the next amplifier stage, IC2, is an inverting op amp configuration with a gain

[3]Recall that the passband gain of a non-inverting op amp is $1 + R_f/R_s$, where R_f is the feedback resistor connected from the output to the inverting input, and R_s is the shunt resistor going to ground or virtual ground.

[4]This is why I use the term "passband gain." A capacitor looks like an open circuit at very low frequencies, which means that the impedance of R9 plus C9 will increase at low frequencies, thus reducing gain at those frequencies—relatively speaking, a low shelf cut.

[5]This is a fundamental law of physics. For more information, look up Johnson Noise.

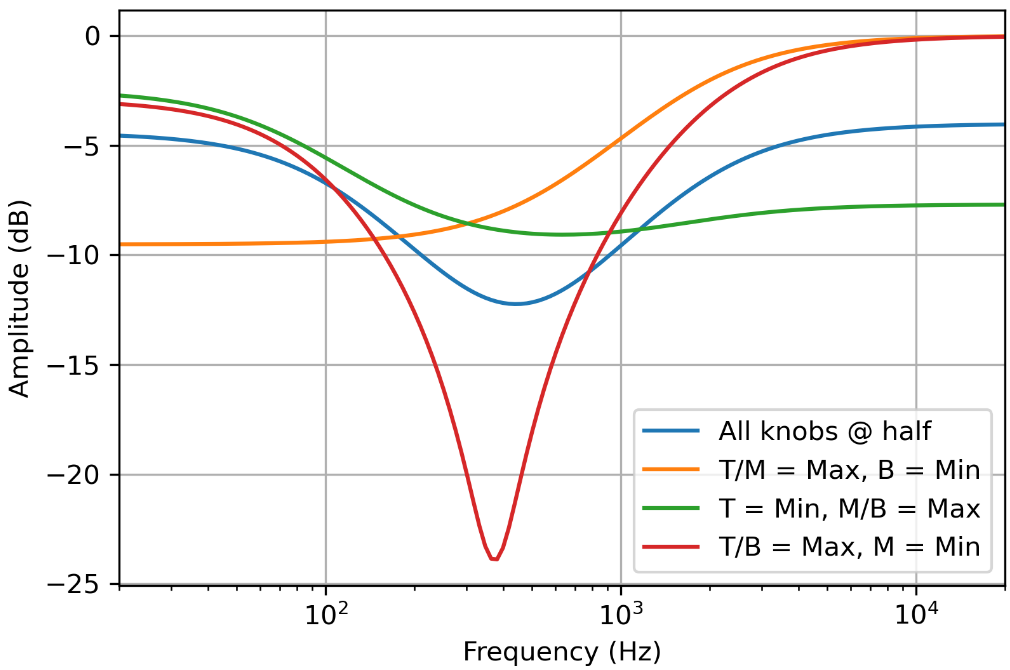

Figure 3: Some representative frequency sweeps of the tone stack.

of 330kΩ/4.7kΩ = 70, or about 37dB.[6] This stage contributes the bulk of the gain and distortion. With a gain of 70, even very small signals are going to drive the op amp into clipping. The capacitor C15 forms a low pass filter with a corner frequency of 4.8kHz, which helps filter out any overly harsh harmonics produced by overdriving the op amp.

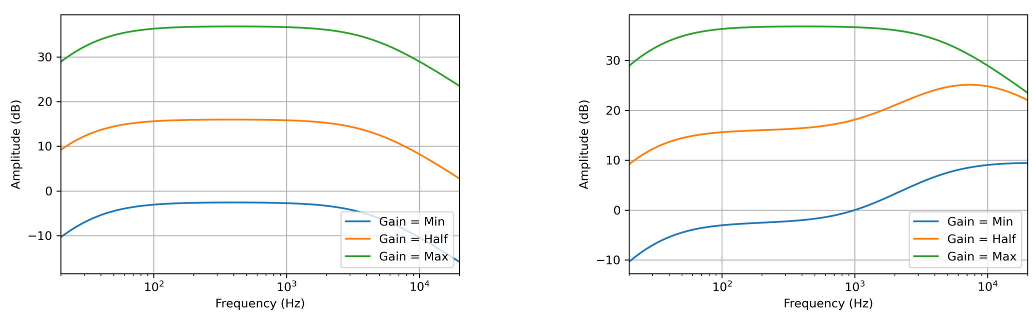

Figure 4: Comparison between the output clipping stage in the normal (left) and bright (right) modes. (In this example, RX1 = 0.)

The Gain pot is used to passively attenuate the input of IC2. The Bright switch

[6]Recall for an inverting op amp, the passband gain is equal to $-R_f/R_i$, where R_f is the feedback resistor and R_i is the input resistor. The negative sign indicates that the phase is flipped.

places a treble bleed on this pot, which boosts high frequencies at low gain. This gives the low gain sounds a more sparkly, jangly sound. For a comparison between the normal and bright cap modes at various Gain settings, see Figure 4.

In the clipping stage (IC2), the op amp selection has a significant impact on the sound. The clipping of an op amp with no diodes in the feedback loop depends on the type of of op amp (BJT, FET, CMOS, etc) as well as its slew rate and gain-bandwidth product, which are parameters expressing how the op amp is able to reproduce high-frequency signals. The original amp uses the LM307, which is a low speed BJT op amp with a slew rate of 0.4V/μs—which is incredibly slow by modern standards. If you use a (relatively) newer op amp such as the TL071, with a slew rate of 13V/μs, the clipping response will be much more sizzly and harsh. For suggested alternative parts, refer to Section 7.1.

Finally, the signal path ends with a simple passive volume control to set the output level.

6.2 Brief notes on the power supply

I think the power supply here merits a few points of discussion. First, this circuit uses a bipolar supply, which means that there are two equal and opposite supply voltages which are symmetrical around 0V. In this circuit, it is approximately +9V and -9V. But, what are the actual merits of a bipolar supply? It comes down to a few reasons:

1. **Extra headroom:** If you have an easy way to create a negative supply voltage, you double your headroom. After all, $9-(-9)=18$V.

2. **Ground is 0V:** In many traditional pedal circuits, half the supply voltage (typically 4.5V) is used as a voltage reference so that the audio signal is sitting at the exact midpoint of its minimum and maximum limits. Generating a stable DC reference can be tricky. In a bipolar supply, ground (0V) is the midpoint. And while good grounding requires care, you generally have far less to worry about.

3. **Easy DC coupling:** The term *DC coupling* is often used when amplifiers are connected without DC blocking caps between them. This is often easier to do on a bipolar supply.

Bipolar power supplies are very handy for op amps because op amps are naturally fairly symmetrical. So, for this pedal, to generate a negative voltage we use a device called a charge pump. These are fairly popular in guitar pedals, but can be misunderstood. Charge pumps can double or invert a voltage by charging and discharging a capacitor using FET switches. In this case, we are creating an inverted copy of the incoming 9V power supply. Charge pumps are great, with one caveat: we now have a switching signal to contend with. This means we have to take some high-speed layout precautions. The charge pump itself should be selected for a switching frequency greater than 20kHz so that switching is not audible in the output signal.

The TC7660SCPA and similar specify a higher switching frequency for this purpose. The actual charge pump switching lines (in this case, going to C4) should be short PCB traces to keep inductances low and prevent ringing. C4 itself is a low ESR, non-polarized multilayer ceramic capacitor which eliminates the polarity concerns and limited lifetime of electrolytic capacitors. And finally, we use 100nF MLCCs for local decoupling of each IC as well as at the input of the circuit, which ensures the op amps are performing at their best (particularly in terms of stability and transient response) and further eliminates switching noise from the charge pump. Local decoupling is so often omitted in guitar pedals, even ones with charge pumps, but it can make a big difference.

7 Modifications

⚠**Caution:** Modifications should not be attempted unless you have the means to troubleshoot changes beyond the base configuration.

7.1 Swapping Op Amps

Because this circuit relies on op amp clipping, swapping op amps will have a significant impact on the drive character. The original HD130 uses the LM307, which is a slow BJT op amp that is akin to the LM301, but with an internal 30pF compensation capacitor.[7] However, the LM307 is fairly hard to find (a new metal can package part is a whopping $15) so it's worth exploring alternatives.

Since IC2 is the primary clipping stage, we decided to make it a single op amp and include pads for a compensation cap, CX3. If you're lucky enough to source an original LM307, it's a great fit here and you can omit CX3. An LM301 (or even an LM308) would be a great choice as well. You can also try an NE5534 here, but note that its pinout is slightly different. When using an NE5534, the compensation cap has to go between pins 5 and 8, and can be easily tack soldered on the back of the PCB.

7.2 Charge Pump Selection

For IC3, we recommend using the ICL7660SCPAZ, which has a 30kHz switching frequency to keep noise out of the audio range. If using this part, solder the jumper JP1 on the back of the PCB. You can also use an LT1054, in which case JP1 does not need to be soldered. We also recommend installing a socket in case the charge pump is damaged through the use of an incorrect external power supply.

7.3 Gain adjustment

Because each op amp stage has a fixed amount of gain, the set values play a huge role in the overall sound. The values on the schematic are based on the later version of the HD130. The resistor RX2 has the greatest impact. 330kΩ is the original value and has quite a lot of gain. With this amount of gain, IC2 clips very aggressively on a 9V bipolar supply. To scale for the same relative headroom as the original amp, try decreasing it to 150K and doubling CX2 to 220pF to compensate.

This part of the circuit can accommodate some other modifications as well. For example you can also adjust CX2 independently (increase to darken the tone) or even put a pot in series with it to make an effective tone control. You can also use the CX2 pads to install a clipping diode network. We like 2x 1N4148s in either direction, with a 10kΩ resistor in series. Zener diodes (two 3.3V diodes end to end) also make great clippers.

[7] External compensation is familiar to those of you who have built a Rat style pedal with an LM308, which also traditionally has a 30pF compensation cap.

Finally, the resistors R4 and R8 provide additional opportunities for adjusting the gain of the other two fixed-gain stages. If you get excessive clipping at low gain, try R4 = 47kΩ.

7.4 Bright Cap

We have included pads for a bright cap (CX1) and accompanying series resistor (RX1). The role of a bright cap (also referred to as a treble bleed) is to shunt high frequencies “around” the gain pot. This makes lower gain sounds more bright and clear, but has a diminishing effect as the gain pot is turned up. On the original amp there is a switch to connect or disconnect the bright cap. To recreate this behavior, use the RX1 pads to wire an SPDT switch off board. You can also install RX1 to operate between the normal and bright modes. We recommend 4.7kΩ as a starting value. Additionally, you can try different values for CX1.

For IC1, the op amp choice is not as critical. In our testing, most BJT op amps sound similar here. We like the RC4558 and NE5532. You can use a TL072 here but you may get some extra phase reversal distortion due to the high gain of the first two stages.

7.5 Tone Stack Mods

Any modifications that you would normally try on an FMV tone stack can go here. For a handy calculator, check out `https://www.guitarscience.net/tsc/info.htm`. To account for the “missing” capacitor try 1uF or greater and the simulation will get you in the right ballpark.

A Generic Assembly Guide

This is a fully general pedal assembly procedure that applies to all EAE open source projects. Note that minor details can vary between PCBs. But this will serve as a quick reference for those already familiar with this type of assembly.

1. Populate and solder the PCB per the parts list. Do not solder in enclosure-mounted components such as pots, indicator LEDs, and/or toggle switches. Ensure that all leads are trimmed to 0.1" or less.

2. Drill the enclosure per the template. Use a center punch first to mark holes for accuracy. If you have one, a stepper bit is very convenient here. If you are unsure about any hole sizes, check using the appropriate hardware.

3. Solder pots and toggle switches (if present) to the PCB using the enclosure as a jig to hold the hardware in place. We recommend using potentiometers with dust covers. If the pots are not insulated, ensure they are not making contact with the back of the PCB.

4. Install PCB mounted LED on the reverse side of the board. Gently bend the legs to hold it in place, but do not solder yet.

5. Install flying wires on the board. These go to the jacks and footswitch(es).

6. Insert PCB into enclosure and tighten all hardware. Fit LED(s) into place, solder, and trim the leads.

7. Solder flying wires to the appropriate pads. Refer to the wiring diagram or table for the specific pedal in question.

8. Pedal is ready for testing!