PROJECT NAME

AMETHYST

aion
DIY GUITAR EFFECTS

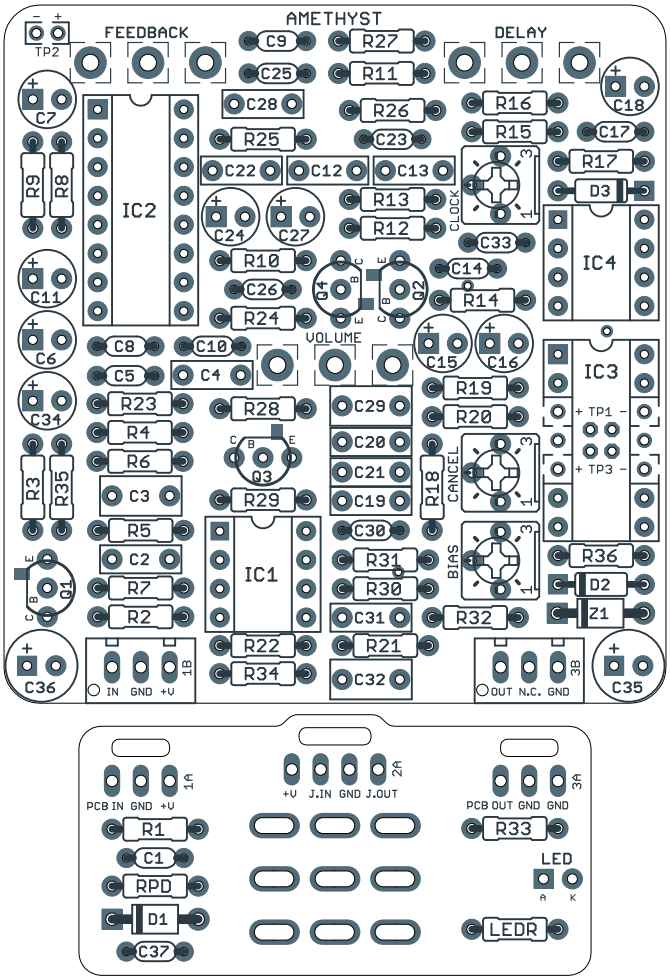
BASED ON
BOSS® DM-2 Delay

BUILD DIFFICULTY
Advanced

EFFECT TYPE
Analog delay

DOCUMENT VERSION
1.0.2 (2025-01-05)

PROJECT SUMMARY
One of the first analog delay effects to use a bucket brigade chip, and still widely considered among the best analog delays ever designed.



Actual size is 2.3” x 2.42” (main board) and 1.78” x 0.91” (bypass board).

IMPORTANT NOTE

This documentation is for the **PCB-only** version of the project. If you are building the full kit from Aion FX, please use the kit build documentation instead. The instructions are more detailed and may differ in some areas due to the specialized parts and assembly methods used in our kits.

TABLE OF CONTENTS

INTRODUCTION

The Amethyst Analog Delay is based on the BOSS DM-2, which was originally released in 1981 and is still widely considered to be one of the best delay pedals ever made.

The DM-2 circuit uses the MN3005 bucket-brigade delay (BBD) chip, which has 4,096 stages and makes the unit capable of around 300ms of delay time when properly calibrated. It also uses a NE570 compander to significantly improve noise performance for the delay line.

In 1982, Boss updated the circuit to use the MN3205, which has better audio specifications at the expense of lower maximum voltage and headroom. This is called the "Second Edition" or DM-2 V2. There are no actual changes to the audio portion of the circuit, but the BBD and clock run on inverted power so the PCB had to be modified slightly to accommodate either version.

For many years, the DM-2 V1 was out of reach for most DIYers due to the scarcity of the MN3005 and MN3101. However, with the Xvive reissue of the MN3005 released in 2015 and Cabintech's CT3101 clock released in 2023, the classic circuit is once again convenient (if not cheap) to build.

The Amethyst PCB has jumper pads so you can choose either the MN3005/MN3101 or the MN3205/MN3102 chipset depending on availability. Otherwise, it is a direct adaptation of the original DM-2 with no modifications or substitutions.

The PCB also includes space for a few extra components so that you can build the Way Huge Aqua Puss, which is a slightly modified clone of the DM-2 from the mid-1990s. See build notes for more info.

USAGE

The Amethyst has three controls:

- **Delay** (called "Repeat Rate" on the DM-2) sets the delay time, longest at minimum and getting shorter as you turn it up. It seems backwards, but it matches the rotation on the original DM-2.
- **Feedback** (called "Intensity" on the DM-2) sets the number of repeats. Due to anti-alias filters, each successive repeat has degraded treble content, resulting in an ambient wash that doesn't conflict with the dry signal. The upper end of the range can get into self-oscillation or infinite repeats.
- **Level** (called "Echo" on the DM-2) sets the volume level of the delay signal. The dry signal is unaffected and always unity gain.

PARTS LIST

This parts list is also available in a spreadsheet format which can be imported directly into Mouser for easy parts ordering. Mouser doesn't carry all the parts—notably potentiometers—so the second tab lists all the non-Mouser parts as well as sources for each.

View parts list spreadsheet →

PART	VALUE	TYPE	NOTES
R1	10k	Metal film resistor, 1/4W	
R2	470k	Metal film resistor, 1/4W	475k for Aqua Puss.
R3	10k	Metal film resistor, 1/4W	
R4	10k	Metal film resistor, 1/4W	
R5	47k	Metal film resistor, 1/4W	47.5k for Aqua Puss.
R6	47k	Metal film resistor, 1/4W	47.5k for Aqua Puss.
R7	10k	Metal film resistor, 1/4W	
R8	10k	Metal film resistor, 1/4W	
R9	10k	Metal film resistor, 1/4W	
R10	10k	Metal film resistor, 1/4W	
R11	10k	Metal film resistor, 1/4W	
R12	10k	Metal film resistor, 1/4W	
R13	10k	Metal film resistor, 1/4W	
R14	100k	Metal film resistor, 1/4W	
R15	10k	Metal film resistor, 1/4W	100k for Aqua Puss.
R16	18k	Metal film resistor, 1/4W	
R17	22k	Metal film resistor, 1/4W	
R18	100k	Metal film resistor, 1/4W	
R19	100k	Metal film resistor, 1/4W	
R20	10k	Metal film resistor, 1/4W	
R21	10k	Metal film resistor, 1/4W	
R22	10k	Metal film resistor, 1/4W	
R23	10k	Metal film resistor, 1/4W	
R24	10k	Metal film resistor, 1/4W	
R25	10k	Metal film resistor, 1/4W	
R26	10k	Metal film resistor, 1/4W	
R27	22k	Metal film resistor, 1/4W	
R28	47k	Metal film resistor, 1/4W	47.5k for Aqua Puss.
R29	47k	Metal film resistor, 1/4W	47.5k for Aqua Puss.
R30	10k	Metal film resistor, 1/4W	
R31	47k	Metal film resistor, 1/4W	47.5k for Aqua Puss.
R32	470R	Metal film resistor, 1/4W	150R for Aqua Puss.

PARTS LIST, CONT.

PART	VALUE	TYPE	NOTES
R33	100k	Metal film resistor, 1/4W	
R34	10k	Metal film resistor, 1/4W	
R35	10k	Metal film resistor, 1/4W	
R36	22R	Metal film resistor, 1/4W	BBD power supply filter resistor.
RPD	1M	Metal film resistor, 1/4W	Input pull-down resistor.
LEDR	10k	Metal film resistor, 1/4W	LED current-limiting resistor. Adjust value to change LED brightness.
C1	(omit)	MLCC capacitor, NP0/C0G	470pF MLCC for Aqua Puss.
C2	47n	Film capacitor, 7.2 x 2.5mm	
C3	1uF	Film capacitor, 7.2 x 3.5mm	10uF electrolytic for Aqua Puss.
C4	6n8	Film capacitor, 7.2 x 2.5mm	
C5	100pF	MLCC capacitor, NP0/C0G	
C6	10uF	Electrolytic capacitor, 5mm	
C7	10uF	Electrolytic capacitor, 5mm	
C8	100n	MLCC capacitor, X7R	
C9	220n	MLCC capacitor, X7R	
C10	100pF	MLCC capacitor, NP0/C0G	
C11	10uF	Electrolytic capacitor, 5mm	
C12	6n8	Film capacitor, 7.2 x 2.5mm	
C13	82n	Film capacitor, 7.2 x 2.5mm	100n for Aqua Puss.
C14	330pF	MLCC capacitor, NP0/C0G	
C15	1uF	Electrolytic capacitor, 4mm	
C16	10uF	Electrolytic capacitor, 5mm	
C17	100pF	MLCC capacitor, NP0/C0G	
C18	1uF	Electrolytic capacitor, 4mm	
C19	2n2	Film capacitor, 7.2 x 2.5mm	
C20	33n	Film capacitor, 7.2 x 2.5mm	
C21	1n	Film capacitor, 7.2 x 2.5mm	
C22	39n	Film capacitor, 7.2 x 2.5mm	
C23	330pF	MLCC capacitor, NP0/C0G	
C24	10uF	Electrolytic capacitor, 5mm	
C25	220n	MLCC capacitor, X7R	
C26	100pF	MLCC capacitor, NP0/C0G	
C27	1uF	Electrolytic capacitor, 4mm	10uF electrolytic for Aqua Puss.
C28	100n	Film capacitor, 7.2 x 2.5mm	220n for Aqua Puss.
C29	1uF	Film capacitor, 7.2 x 3.5mm	10uF electrolytic for Aqua Puss.
C30	100pF	MLCC capacitor, NP0/C0G	
C31	6n8	Film capacitor, 7.2 x 2.5mm	

PARTS LIST, CONT.

PART	VALUE	TYPE	NOTES
C32	1uF	Film capacitor, 7.2 x 3.5mm	10uF electrolytic for Aqua Puss.
C33	(omit)	MLCC capacitor, X7R	100n MLCC for Aqua Puss.
C34	47uF	Electrolytic capacitor, 5mm	Power supply filter capacitor.
C35	220uF	Electrolytic capacitor, 6.3mm	Power supply filter capacitor.
C36	220uF	Electrolytic capacitor, 6.3mm	Power supply filter capacitor.
C37	100n	MLCC capacitor, X7R	Power supply filter capacitor.
Z1	(omit)	Zener diode, 500mW, 8.2V	Use 1N5237B (8.2V zener) for MN3205 version.
D1	1N5817	Schottky diode, DO-41	
D2	1N914	Fast-switching diode, DO-35	Jumper for MN3205 version.
D3	(jumper)	Fast-switching diode, DO-35	1N914 for MN3205 version.
Q1	2N5088	BJT transistor, NPN, TO-92	MPSA18 for Aqua Puss.
Q2	2N5088	BJT transistor, NPN, TO-92	MPSA18 for Aqua Puss.
Q3	2N5088	BJT transistor, NPN, TO-92	MPSA18 for Aqua Puss.
Q4	2N5088	BJT transistor, NPN, TO-92	MPSA18 for Aqua Puss.
IC1	JRC4558D	Operational amplifier, dual, DIP8	LF353N for Aqua Puss.
IC1-SOCKET	DIP-8 socket	IC socket, DIP-8	
IC2	NE571	IC socket, DIP-8	Coolaudio v571 is a current substitute.
IC2-SOCKET	DIP-16 socket	IC socket, DIP-16	
IC3	MN3005	Bucket-brigade delay, 4096 stages	Can also use MN3205 or v3205. See build notes.
IC3-SOCKET	DIP-14 socket	IC socket, DIP-8	
IC4	MN3101	Clock driver for bucket-brigade delay	See build notes for sourcing.
IC4-SOCKET	DIP-8 socket	IC socket, DIP-8	
DELAY	1MB	16mm right-angle PCB mount pot	Called "Repeat Rate" on the original DM-2.
FEEDBACK	50kA	16mm right-angle PCB mount pot	Called "Intensity" on the original DM-2.
VOLUME	50kB	16mm right-angle PCB mount pot	Called "Echo" on the original DM-2.
BIAS	22k trimmer	Trimmer, 10%, 1/4", Bourns 3326P	Can substitute 20k or 25k.
CANCEL	10k trimmer	Trimmer, 10%, 1/4", Bourns 3326P	
CLOCK	1M trimmer	Trimmer, 10%, 1/4", Bourns 3326P	
LED	5mm	LED, 5mm, red diffused	
IN	1/4" mono	1/4" phone jack, closed frame	Switchcraft 111X or equivalent.
OUT	1/4" mono	1/4" phone jack, closed frame	Switchcraft 111X or equivalent.
DC	2.1mm	DC jack, 2.1mm panel mount	Lumberg NEB/J 21 C or equivalent.
FSW	3PDT	Stomp switch, 3PDT	Available from Aion FX.
ENC	125B	Enclosure, die-cast aluminum	Can also use a Hammond 1590N1.

BUILD NOTES

BBD selection

The original bucket-brigade delay chips used in the DM-2 have been discontinued for many years and old-stock chips are difficult to find and expensive. Fortunately, reproductions of both the MN3005 and the newer MN3205 are available along with the corresponding clock driver, and they perform just as well as the original devices in this circuit.

The original DM-2 v1 used the MN3005 (reproductions available from Xvive), while the second version used the MN3205 (reproductions available from Coolaudio as the v3205). The Amethyst project is set up to allow either type to be used by soldering two jumpers in one configuration or another.

So which should you use? The MN3205 has slightly better noise specs, but a lower maximum operating voltage, which means lower headroom. When running it at 9V, the maximum voltage doesn't make much of a difference, so the added expense of the MN3005 probably outweighs any advantage. But, provided you know what you're doing and have the correct external adapter, the MN3005 version DM-2 can be made to run at 12V or 15V.

The parts list and schematic show the MN3005 version. If building the MN3205 or v3205 version, you will need to make the following changes:

- Z1: omit → 1N5237B or other 8.2V zener (prevents BBD chip damage from overvoltage)
- D2: 1N914 → jumper
- D3: jumper → 1N914

You will also need to ensure the jumpers are set for the type of BBD and clock as described below.

Setting the jumpers

Underneath IC3, there are four jumper pads arranged in a square pattern. The MN3005 and MN3205 have their positive and negative supply pins inverted from each other, so the jumpers need to be set to route the supply voltages to the correct pins.

The underside of the PCB has a legend on the silkscreen showing which way the jumpers should be soldered. If using a MN3005, both jumpers should go horizontally. If using a MN3205 or v3205, the jumpers should go vertically.

The MN3101 and MN3102 clock drivers have the supply pins reversed internally, so these two chips are cross-compatible and IC4 does not require any of its own jumpers.

Clock selection

The MN3101 clocks are only compatible with the MN3005, and the MN3102 and v3102 clocks are only compatible with the MN3205 and v3205.

In late 2023, Cabintech made a discrete version of the MN3101 that acts as a drop-in replacement in DIP-8 format. These perform just as well as the originals, so it's recommended to use them in conjunction with the MN3005.

We do not recommend trying to source old-stock MN3101s due to the risk of fakes or damaged parts.

Biasing & calibration

The DM-2 circuit has three different trimmers that need to be adjusted for optimum performance. Before you begin, set all three trimmers to the center (12:00) position.

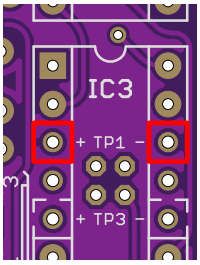
If you're more of a visual learner, here is an in-depth video showing the calibration of a Way Huge Aqua Puss clone. The procedure and target specifications are identical to the DM-2, only the part names are different. You'll just need to mentally translate a few of the part names and positions to this project.

Otherwise, here's a full description of the adjustment process. Note that the trimmer settings are based on the supply voltage, so during calibration it's recommended to power the pedal with the exact supply you plan on using in your rig. If you use a bench supply or something else, the difference in supply voltage may cause the calibration to change.

Clock frequency

This step requires a multimeter with frequency measurement, sometimes called a frequency counter.

1. Set the Delay (repeat rate) knob to minimum, the longest delay setting. Feedback and Volume can be set anywhere.
2. Connect the multimeter to the pads marked "TP1", which is on the right side of the PCB immediately below pins 2 and 7 of IC3. The positive lead should connect to the left side and the negative lead to the right side. If you used a DIP-14 socket for the BBD, you can insert leftover resistor leads into these empty sockets and attach the multimeter leads to them while testing.
3. Adjust the CLOCK trimmer until you read a frequency of 6.8kHz.



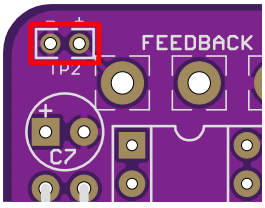
If you have an oscilloscope but not a frequency counter, you can use a scope to visualize the clock signal waveform on TP1. Adjust the CLOCK trimmer until one full square-wave cycle is 146µs (in other words, the time between the start of one positive cycle to the start of the next positive cycle).

If you do not have either an oscilloscope or a way to measure frequency, then adjust the trimmer until you hear a high-pitched squeal or whine, and then back off slightly until it goes away.

BBD bias

For this step, you will need a signal generator and an oscilloscope. For the generator, you can use an application like ARTA, or even a phone app as long as you verify that the output level matches the spec.

1. Set the Feedback to minimum and Delay to maximum. Volume can be set anywhere.
2. Set the signal generator for a 200 Hz sine wave at 0dBm. Connect this to the input jack of the effect, making sure it's in effect mode.
3. Connect the oscilloscope to the pads marked "TP2", which are located in the upper-left corner of the PCB. You can solder leftover resistor leads to these pads to make them easier to reach if everything is already installed to the enclosure. Note that the positive pad is on the right, the reverse of TP1 & TP3.



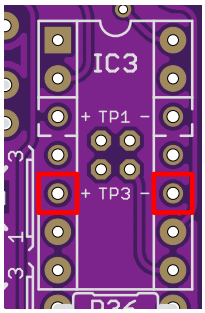
4. Adjust the BIAS trimmer until the waveform has the minimum amount of distortion or clipping, aiming for symmetry on the top and bottom halves. If you don't see any distortion on the waveform, you can increase the level of the test signal until it appears.

If you do not have an oscilloscope or signal generator, then you'll have to use your ears. Adjust the trimmer until the delay signal has the lowest amount of audible distortion.

Clock cancellation

For this step, you will need an oscilloscope.

1. Put the effect in bypass mode to ensure there is no input signal.
2. Set Delay and Feedback to minimum. Volume can be set anywhere.
3. Connect the oscilloscope to the pads marked "TP3", which is on the right side of the PCB immediately above pins 3 and 6 of IC3. The positive lead should connect to the left side and the negative lead to the right side. If you used a DIP-14 socket for the BBD, you can insert leftover resistor leads into these empty sockets and attach the oscilloscope leads to them while testing.
4. Adjust the CANCEL trimmer until the two clock signals have converged with the closest amount of overlap.



If you don't have an oscilloscope, just leave the trimmer at the halfway (12:00) position.

Now, test all three knobs across the full range. If you notice any distortion, artifacts, or squealing, you'll need to go through the calibration steps again.

Delay knob orientation

The DM-2's Delay knob works backwards from what is typically viewed as the standard today. In the original pedal, they call it "Repeat Rate", and the rate or speed increases as you turn it up, meaning the short slapback delay is found at the upper end of the range.

The control label is consistent with the function, and it makes sense on paper, but when you actually use it, it feels counterintuitive. We more often think of it as a "Delay" knob where the amount of delay increases as it is turned up—or in other words, the rate or speed decreases.

We intended to reverse this for the Amethyst project, but as it turns out, the DM-2's factory schematic is wrong and has the pot orientation labeled backwards. So in reversing the direction of the pot from the schematic, we inadvertently made it exactly like the original pedal.

This will be updated in a future revision of the Amethyst. For the initial release, if you want the delay to get longer as you turn up the knob, you will need to reverse lugs 1 and 3 of the Delay pot.

The easiest way to do this is to use a PCB-mount pot, but clip the outer legs partway down and just leave the center one intact. Then, solder the outer wires in an "X" pattern, from lug 1 to pad 3 and from lug 3 to pad 1. The center lug will anchor the pot to the PCB.

Way Huge Aqua Puss variant

The Way Huge Aqua Puss is a very near clone of the DM-2 v1, first released in late 1997 and most notably used by John Mayer. The Aqua Puss was eventually reissued by Dunlop in 2008 after they acquired Way Huge, but today the pre-Dunlop versions sell for $2,000 or more.

To build the Aqua Puss, make the following component substitutions.

- **C1:** omit → 470pF MLCC
- **C3:** 1uF → 10uF electrolytic (positive leg in right pad)
- **C13:** 82n → 100n
- **C27:** 1uF → 10uF electrolytic
- **C28:** 100n → 220n
- **C29:** 1uF → 10uF electrolytic (positive leg in right pad)
- **C32:** 1uF → 10uF electrolytic (positive leg in left pad)
- **C33:** omit → 100n MLCC
- **R2:** 470k → 475k
- **R5-6, R28-29, R31:** 47k → 47.5k
- **R15:** 10k → 100k
- **R32:** 470R → 150R
- **IC1:** JRC4558D → LF353N
- **Q1-4:** 2N5088 → MPSA18

The full schematic showing Aqua Puss values can be found on page 11.

IC2 compander bias & troubleshooting

If you're getting clean signal but no delay, you can add a 22k or 30k resistor across pins 4 and 12 of IC2 and see if that changes anything. This will raise the bias voltage of the compander's output stage, and in a very small number of cases it has fixed the problem. It will have no detrimental effects, and many DIY analog delays such as the Anamorph from Madbean use this resistor by default.

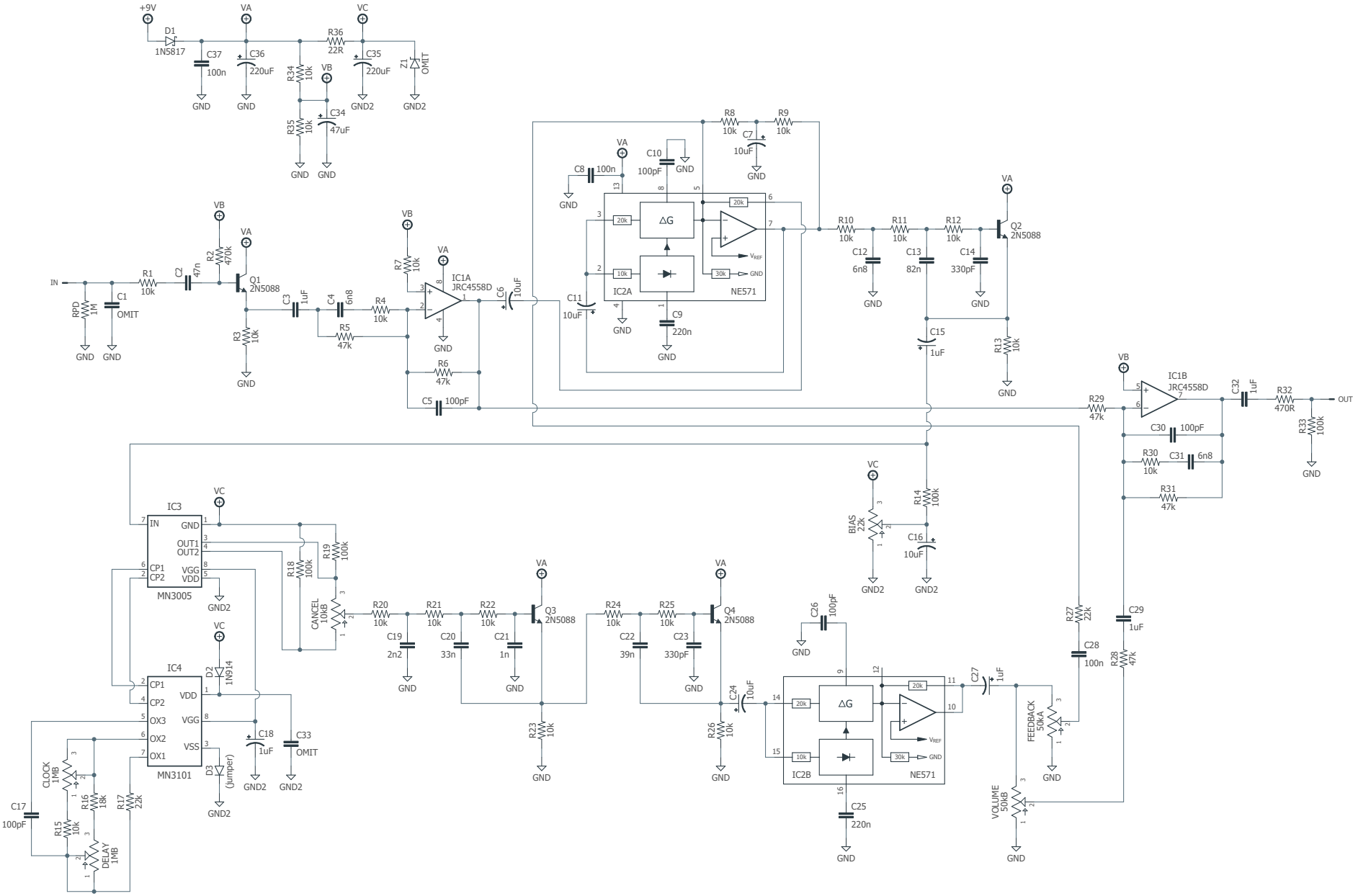
It's safest to add this resistor on the underside of the PCB, but if you're careful, you can solder it directly to the legs of the IC and piggyback the resistor over the top.

However, it's very rare that this solves the problem, and it's still the case that the most likely issue is that the BBD is not biased correctly. For this circuit, most build failures are actually calibration issues. There is a very narrow voltage range where the BBD will pass signal, and one of the symptoms of improper calibration is no delay signal at all.

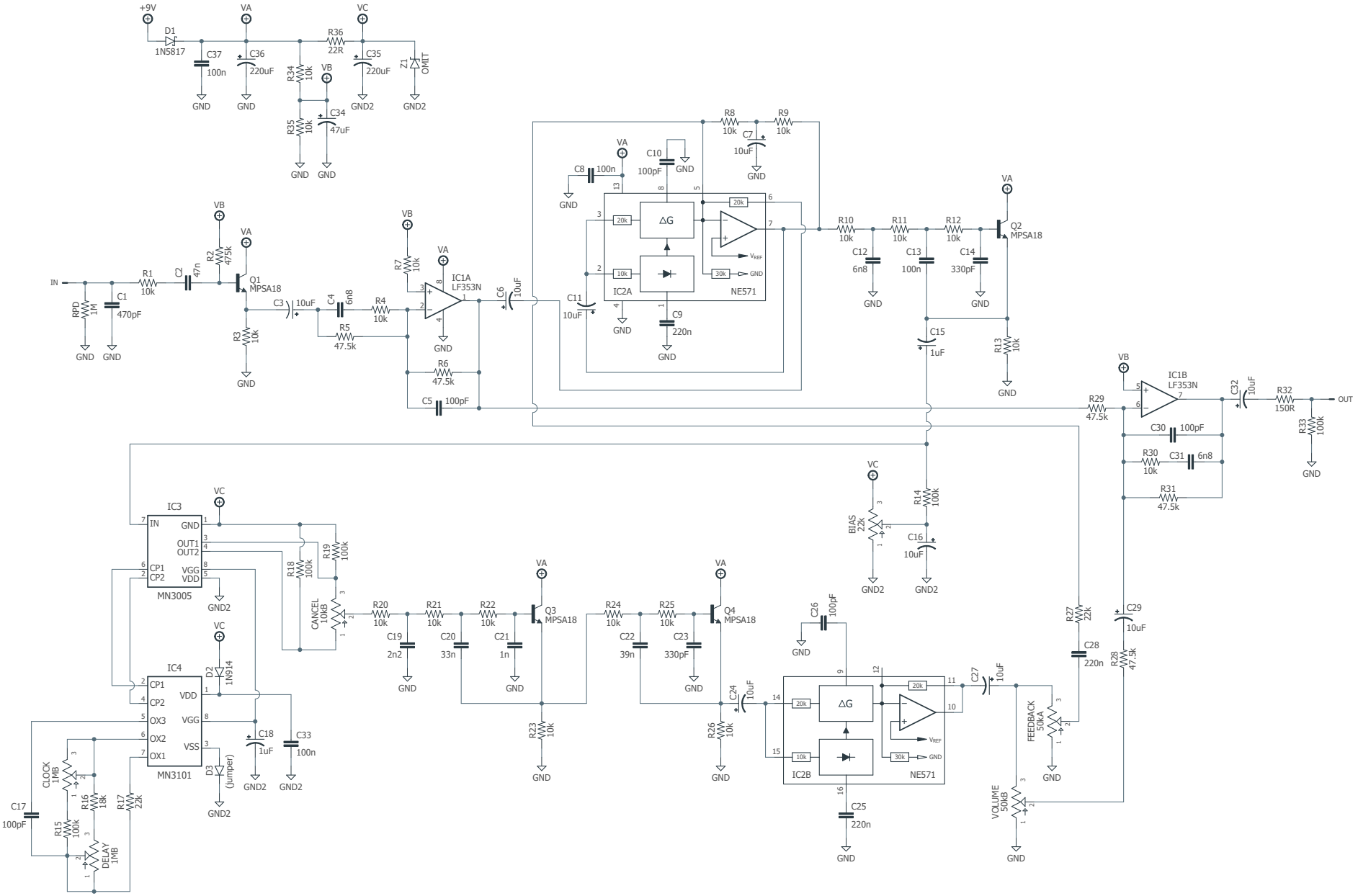
Feedback potentiometer

As in the original DM-2, the Feedback control is very sensitive and the pedal goes into self-oscillation at around the 12:00 position. We recommend changing the 50k Feedback pot from "B" (linear) to "A" (audio) taper. It will have the same range of control, but the onset of self-oscillation is more gradual.

SCHEMATIC (DM-2)



SCHEMATIC (AQUA PUSS)



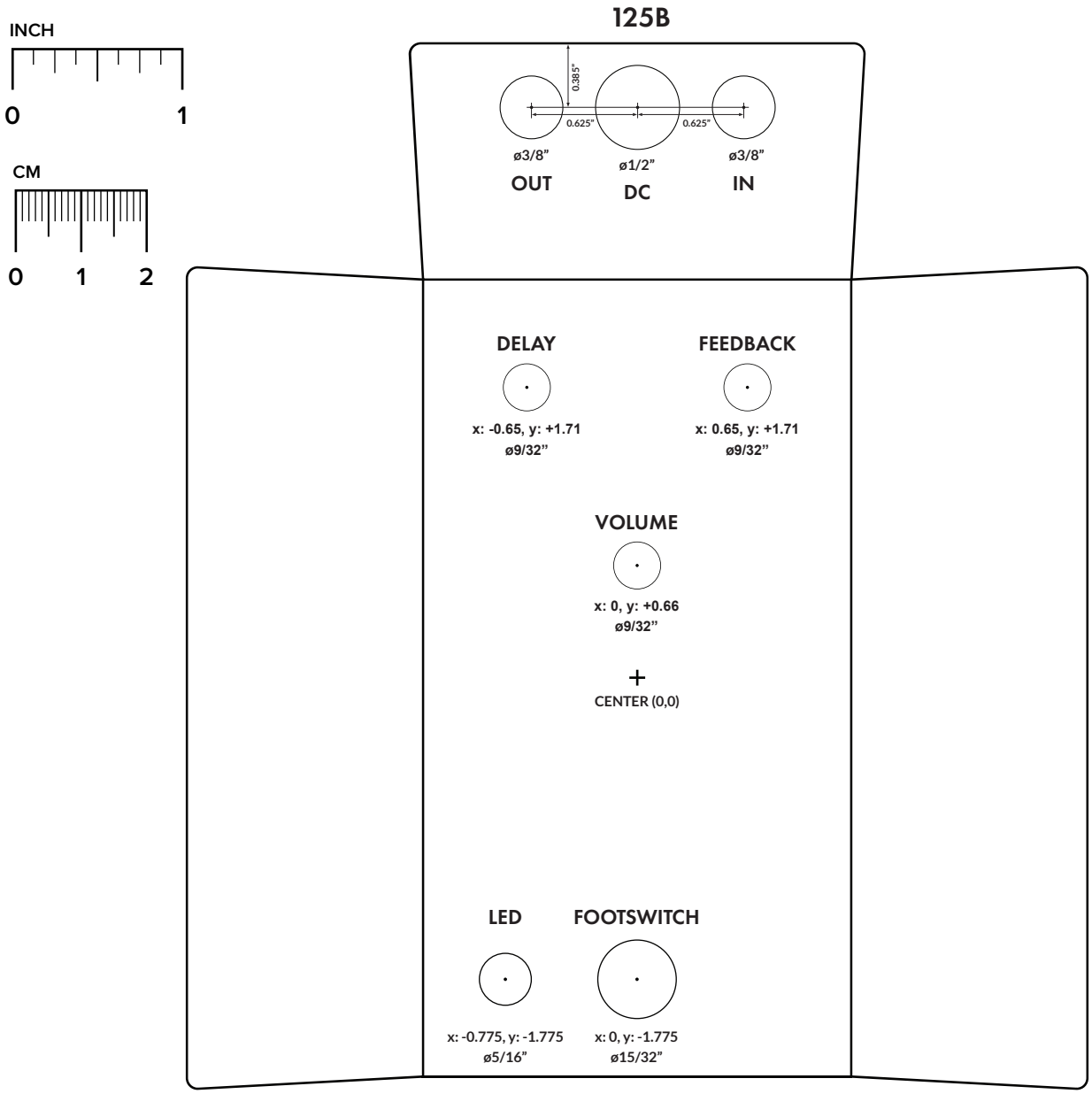
DRILL TEMPLATE

Cut out this drill template, fold the edges and tape it to the enclosure. Before drilling, it's recommended to first use a center punch for each of the holes to help guide the drill bit.

Ensure that this template is printed at 100% or "Actual Size". You can double-check this by measuring the scale on the printed page.

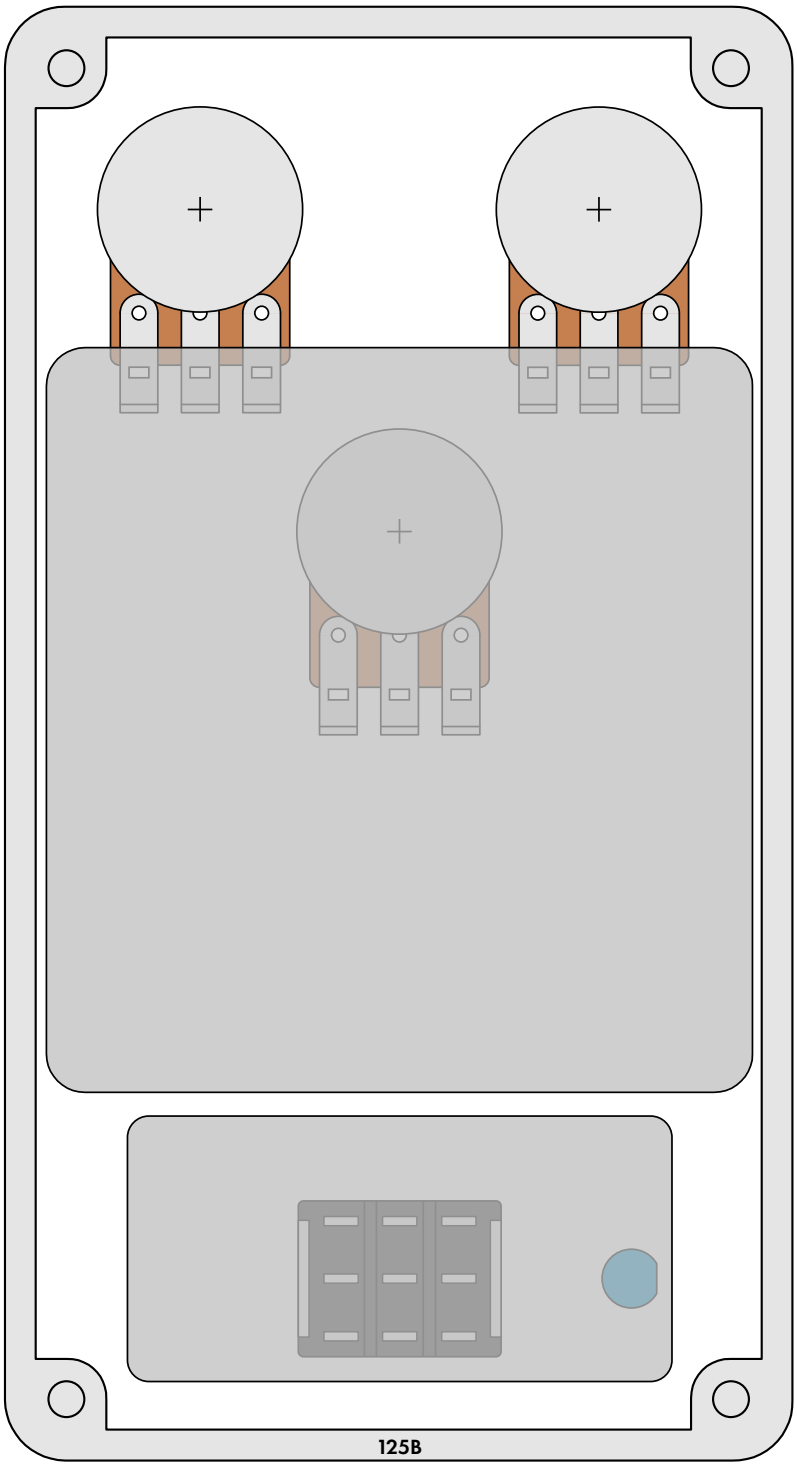
Top jack layout assumes the use of closed-frame jacks like the Switchcraft 111X. If you'd rather use open-frame jacks, please refer to the Open-Frame Jack Drill Template for the top side.

LED hole drill size assumes the use of a 5mm LED bezel, available from several parts suppliers. Adjust size accordingly if using something different, such as a 3mm bezel, a plastic bezel, or just a plain LED.

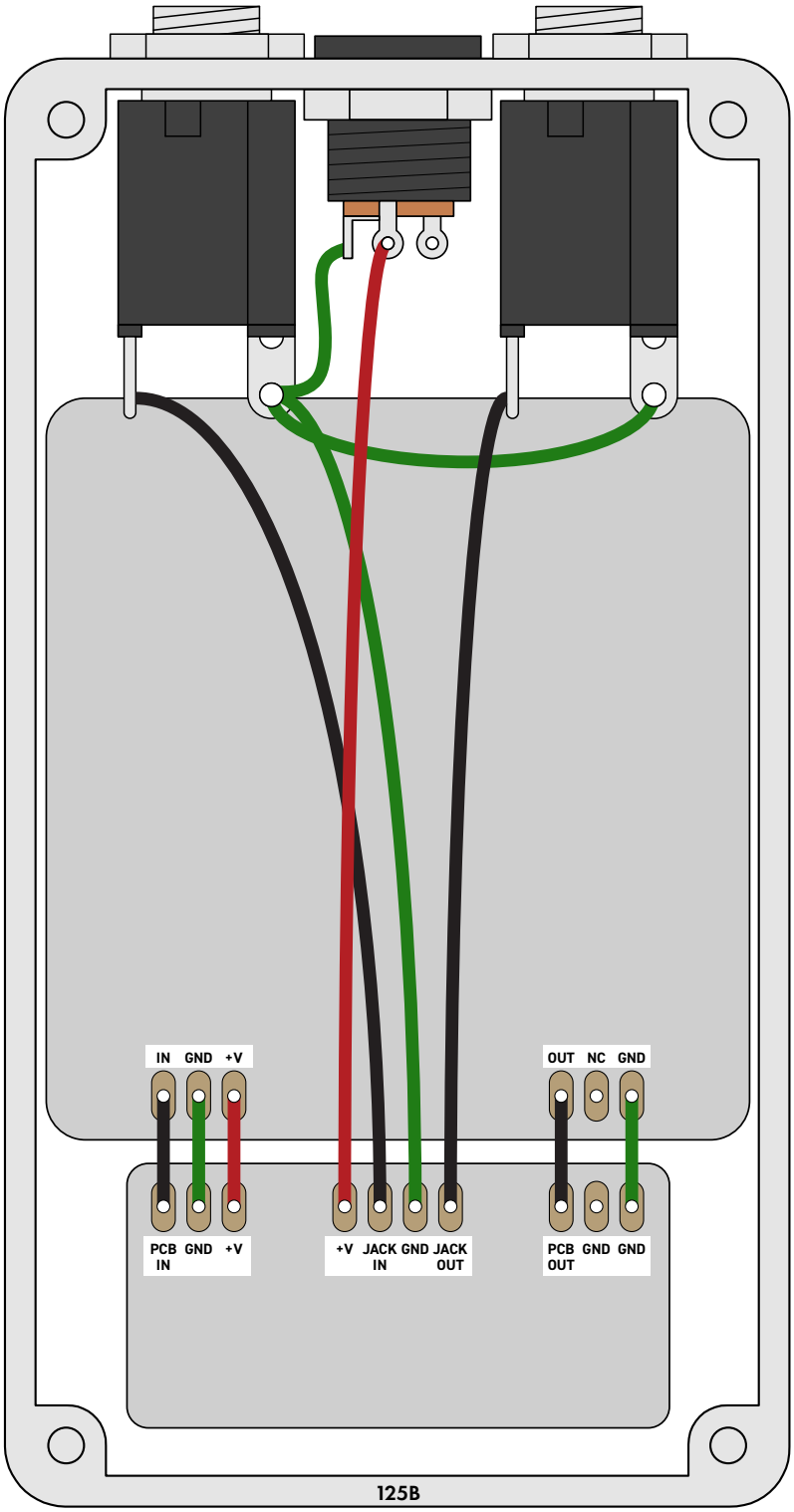


ENCLOSURE LAYOUT

Enclosure is shown without jacks. See next page for jack layout and wiring.



WIRING DIAGRAM



LICENSE & USAGE

No direct support is offered for these projects beyond the provided documentation. It's assumed that you have at least some experience building pedals before starting one of these. Replacements and refunds cannot be offered unless it can be shown that the circuit or documentation are in error.

All of these circuits have been tested in good faith in their base configurations. However, not all the modifications or variations have necessarily been tested. These are offered only as suggestions based on the experience and opinions of others.

Projects may be used for commercial endeavors in any quantity unless specifically noted. No attribution is necessary, though a link back is always greatly appreciated. The only usage restrictions are that **(1) you cannot resell the PCB as part of a kit without prior arrangement**, and **(2) you cannot "goop" the circuit, scratch off the screenprint, or otherwise obfuscate the circuit to disguise its source**. (In other words: you don't have to go out of your way to advertise the fact that you use these PCBs, but please don't go out of your way to hide it. The guitar effects industry needs more transparency, not less!)

DOCUMENT REVISIONS

1.0.2 (2025-01-05)
Changed Feedback pot from 50kB to 50kA so that there is a greater range of control before the self-oscillation begins.

1.0.1 (2024-12-05)
Added notes to page 9 about compander troubleshooting.

1.0.0 (2024-04-19)
Initial release.