PROJECT NAME

SAPPHIRE

DIY GUITAR EFFECTS

BASED ON
BOSS® BD-2 Blues Driver

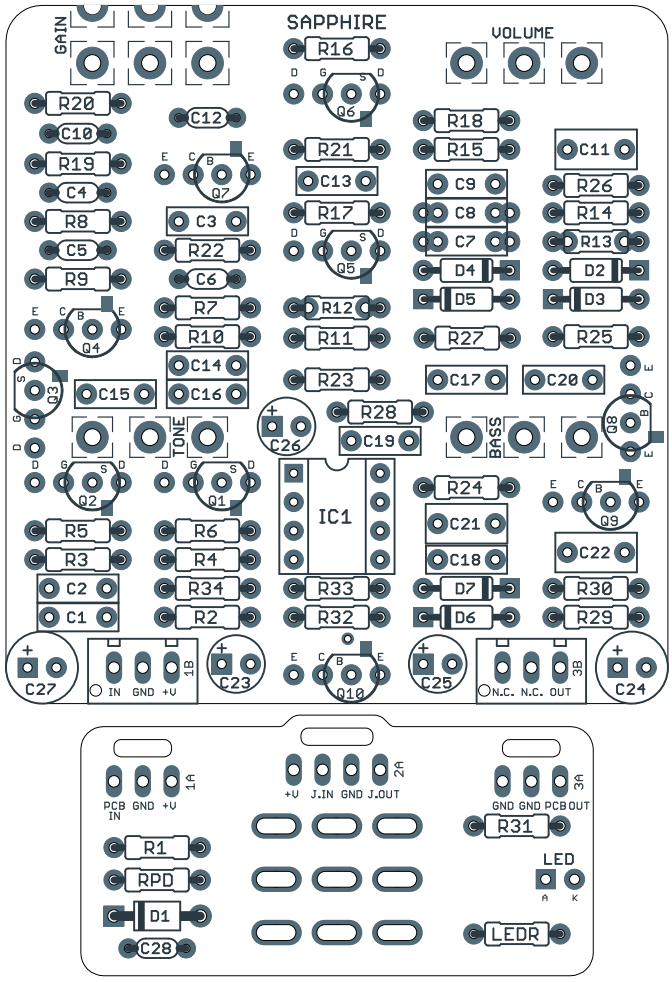
BUILD DIFFICULTY
Intermediate

EFFECT TYPE
Amp-like overdrive

DOCUMENT VERSION
1.0.1 (2024-08-08)

PROJECT SUMMARY

One of the most popular pedals in the BOSS lineup, it uses their distinctive “discrete op-amp” topology to deliver an amp-like drive resembling vintage Fender tweed or blackface amps.



Actual size is 2.3” x 2.42” (main board) and 1.78” x 0.86” (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.

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INTRODUCTION

The Sapphire Amp Overdrive is based on the BOSS® BD-2 Blues Driver, one of their most popular pedals in continuous production since it was first released in 1995. It's been used by a wide variety of artists including Mike McCready (Pearl Jam), Robert Smith (The Cure), Tom Morello, and even Prince.

The Blues Driver bears many similarities to the OD-2 Turbo Overdrive from 1988. This was the first appearance of Boss's "discrete op-amp" circuit topology that uses two JFETs and a PNP transistor to create a variable gain stage that can be controlled like an op-amp but clips gracefully when overdriven. The Blues Driver starts with a circuit very similar to the OD-2, and then adds a slight bass boost to the end to give it the signature fullness, along with some clipping diodes and a fixed-position Fender tonestack for shaping the tone.

Despite its overwhelming popularity, the BD-2 is not without its flaws. On higher gain settings, the note decay has been described as "fizzy" or "splatty". And while the bass-heavy EQ is distinctive, it's not as flexible as other more transparent drives. Because of this, it's one of the most frequently modded pedals out there, with Keeley's and Analogman's mods being the most popular.

Another notable one is the Galaxie Mod from Machine Head Pedals, which is documented in the build notes on page 7 and is strongly recommended. It's an extensive mod that replaces half of the passive components, completely transforming the pedal into something new.

The Sapphire is based on the stock BD-2 circuit converted to true bypass. The bass boost has been made variable, so it can be adjusted between the stock value and the Galaxie value.

The original BD-2 uses the 2SK184-GR JFET, a low-cutoff type similar to J201, but no longer made in through-hole format. 2SK209-GR is the SMD version that is still in production and will perform exactly the same as the originals. Each of the JFETs have extra pads for soldering SMD parts, but if you don't feel confident in your SMD skills, Aion FX sells 2SK209-GR pre-soldered to adapter boards to be used in through-hole applications.

USAGE

The Sapphire has four controls:

- **Drive** is a dual-gang control that simultaneously increases the gain of both discrete op-amp stages.
- **Tone** is a passive treble cut after the second gain stage.
- **Bass** is an active bass boost at the end of the circuit.
- **Volume** sets the overall output of the effect signal.

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	1M	Metal film resistor, 1/4W	
R3	10k	Metal film resistor, 1/4W	
R4	220k	Metal film resistor, 1/4W	
R5	4k7	Metal film resistor, 1/4W	
R6	2k2	Metal film resistor, 1/4W	
R7	1k5	Metal film resistor, 1/4W	Galaxie mod: 10k. See build notes for full mod.
R8	22k	Metal film resistor, 1/4W	
R9	510k	Metal film resistor, 1/4W	Omit if using 250kA drive pot.
R10	2k2	Metal film resistor, 1/4W	
R11	330k	Metal film resistor, 1/4W	Galaxie mod: omit (leave empty). See build notes for full mod.
R12	100k	Metal film resistor, 1/4W	Galaxie mod: 22n CAPACITOR. See build notes for full mod.
R13	1M	Metal film resistor, 1/4W	Galaxie mod: 6n8 CAPACITOR. See build notes for full mod.
R14	15k	Metal film resistor, 1/4W	Galaxie mod: JUMPER. See build notes for full mod.
R15	1M	Metal film resistor, 1/4W	Galaxie mod: 100k. See build notes for full mod.
R16	4k7	Metal film resistor, 1/4W	
R17	2k2	Metal film resistor, 1/4W	
R18	2k2	Metal film resistor, 1/4W	Galaxie mod: 10k. See build notes for full mod.
R19	33k	Metal film resistor, 1/4W	
R20	510k	Metal film resistor, 1/4W	Omit if using 250kA drive pot.
R21	2k2	Metal film resistor, 1/4W	
R22	5k6	Metal film resistor, 1/4W	Galaxie mod: 2k2. See build notes for full mod.
R23	470k	Metal film resistor, 1/4W	
R24	6k8	Metal film resistor, 1/4W	
R25	1k2	Metal film resistor, 1/4W	
R26	10k	Metal film resistor, 1/4W	
R27	470k	Metal film resistor, 1/4W	
R28	100k	Metal film resistor, 1/4W	
R29	10k	Metal film resistor, 1/4W	
R30	100k	Metal film resistor, 1/4W	
R31	1k	Metal film resistor, 1/4W	
R32	2k2	Metal film resistor, 1/4W	

PARTS LIST, CONT.

PART	VALUE	TYPE	NOTES
R33	10k	Metal film resistor, 1/4W	
R34	10k	Metal film resistor, 1/4W	
RPD	2M2	Metal film resistor, 1/4W	Input pulldown resistor. Can be as low as 1M.
LEDR	10k	Metal film resistor, 1/4W	LED current-limiting resistor. Adjust value to change LED brightness.
C1	47n	Film capacitor, 7.2 x 2.5mm	
C2	100n	Film capacitor, 7.2 x 2.5mm	Galaxie mod: 10n. See build notes for full mod.
C3	150n	Film capacitor, 7.2 x 2.5mm	Galaxie mod: 39n. See build notes for full mod.
C4	47pF	MLCC capacitor, NP0/C0G	Galaxie mod: 100pF. See build notes for full mod.
C5	47pF	MLCC capacitor, NP0/C0G	
C6	220pF	MLCC capacitor, NP0/C0G	Galaxie mod: omit (leave empty). See build notes for full mod.
C7	100n	Film capacitor, 7.2 x 2.5mm	Galaxie mod: 10k RESISTOR. See build notes for full mod.
C8	47n	Film capacitor, 7.2 x 2.5mm	Galaxie mod: 100k RESISTOR. See build notes for full mod.
C9	2n2	Film capacitor, 7.2 x 2.5mm	Galaxie mod: 47n. See build notes for full mod.
C10	100pF	MLCC capacitor, NP0/C0G	Galaxie mod: 220pF. See build notes for full mod.
C11	1uF	Film capacitor, 7.2 x 3.5mm	Galaxie mod: 68n, 82n or 100n. See build notes for full mod.
C12	100pF	MLCC capacitor, NP0/C0G	
C13	6n8	Film capacitor, 7.2 x 2.5mm	
C14	5n6	Film capacitor, 7.2 x 2.5mm	
C15	18n	Film capacitor, 7.2 x 2.5mm	Galaxie mod: 33n. See build notes for full mod.
C16	18n	Film capacitor, 7.2 x 2.5mm	Galaxie mod: 22n. See build notes for full mod.
C17	47n	Film capacitor, 7.2 x 2.5mm	
C18	2n2	Film capacitor, 7.2 x 2.5mm	Galaxie mod: omit (leave empty). See build notes for full mod.
C19	56n	Film capacitor, 7.2 x 2.5mm	
C20	56n	Film capacitor, 7.2 x 2.5mm	
C21	1uF	Film capacitor, 7.2 x 3.5mm	
C22	1uF	Film capacitor, 7.2 x 3.5mm	
C23	47uF	Electrolytic capacitor, 5mm	Power supply filter capacitor.
C24	100uF	Electrolytic capacitor, 6.3mm	Power supply filter capacitor.
C25	47uF	Electrolytic capacitor, 5mm	Reference voltage filter capacitor.
C26	47uF	Electrolytic capacitor, 5mm	Reference voltage filter capacitor.
C27	100uF	Electrolytic capacitor, 6.3mm	Power supply filter capacitor.
C28	100n	MLCC capacitor, X7R	Power supply filter capacitor.
D1	1N5817	511-1N5817	
D2	1N914	512-1N914	Galaxie mod: omit (leave empty). See build notes for full mod.
D3	1N914	512-1N914	Galaxie mod: omit (leave empty). See build notes for full mod.
D4	1N914	512-1N914	Galaxie mod: omit (leave empty). See build notes for full mod.
D5	1N914	512-1N914	Galaxie mod: omit (leave empty). See build notes for full mod.

PARTS LIST, CONT.

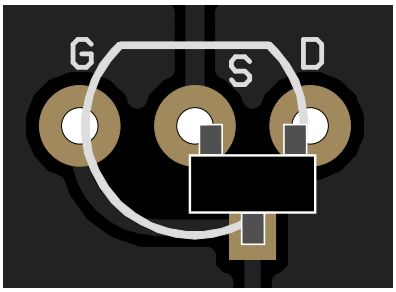
PART	VALUE	TYPE	NOTES
D6	1N914	Fast-switching diode, DO-35	Galaxie mod: omit (leave empty). See build notes for full mod.
D7	1N914	Fast-switching diode, DO-35	Galaxie mod: omit (leave empty). See build notes for full mod.
Q1	2SK209-GR	JFET, N-channel, SOT-23	Original uses 2SK184-GR. 2SK209-GR is the SMD equivalent.
Q2	2SK209-GR	JFET, N-channel, SOT-23	Original uses 2SK184-GR. 2SK209-GR is the SMD equivalent.
Q3	2SK209-GR	JFET, N-channel, SOT-23	Original uses 2SK184-GR. 2SK209-GR is the SMD equivalent.
Q4	2N3906	BJT transistor, PNP, TO-92	Substitute. Original uses 2SA1335-GR.
Q5	2SK209-GR	JFET, N-channel, SOT-23	Original uses 2SK184-GR. 2SK209-GR is the SMD equivalent.
Q6	2SK209-GR	JFET, N-channel, SOT-23	Original uses 2SK184-GR. 2SK209-GR is the SMD equivalent.
Q7	2N3906	BJT transistor, PNP, TO-92	Substitute. Original uses 2SA1335-GR.
Q8	2N5088	BJT transistor, NPN, TO-92	Substitute. Original uses 2SC2459-GR.
Q9	2N5088	BJT transistor, NPN, TO-92	Substitute. Original uses 2SC2459-GR.
Q10	2N5088	BJT transistor, NPN, TO-92	Substitute. Original uses 2SC2459-GR.
IC1	JRC4558D	Operational amplifier, DIP8	Substitute. Original uses M5218AL (SIL-8).
IC1-S	DIP-8 socket	IC socket, DIP-8	Substitute. Original uses 2SA970-GR.
GAIN	500kA dual	16mm right-angle PCB mount pot	Substitute for 250kA in original. Use 510k for R9 and R20 to drop the value to 250k. Omit these resistors if using an actual 250kA pot.
BASS	25kB	16mm right-angle PCB mount pot	
TONE	10kB	16mm right-angle PCB mount pot	
VOLUME	100kA	16mm right-angle PCB mount pot	
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	Mouser 163-4302-E or equivalent.
FSW	3PDT	Stomp switch, 3PDT	
ENC	125B	Enclosure, die-cast aluminum	Can also use a Hammond 1590N1.

BUILD NOTES

Using SMD JFETs

The 2SK184-GR JFET is no longer available in through-hole format. This PCB uses a hybrid through-hole/SMD outline for each JFET. An extra “G” (gate) pad is included to accommodate surface-mount devices without the need for adapters.

SMD JFETs should be oriented as follows:



All surface-mount JFETs use the same pinout, so this configuration will fit any type that we’re aware of. However, always check the datasheet if you’re uncertain—they’re difficult to desolder.

Using through-hole adapters

If you’re not confident in your ability to work with surface-mount parts, Aion FX offers 2SK209-GR JFETs (the SMD version of 2SK184-GR and 2SK117-GR) that come pre-soldered to adapters for use in through-hole designs. These are from the same manufacturer as the ones used in the original BOSS pedals and will perform identically.

Using old-stock transistors

Toshiba has not manufacturered through-hole transistors and JFETs in many years, but it’s still possible to find the 2SK184-GR as well as the four types of BJT transistors used in the original. However, be aware that these follow the Japanese pinout conventions, whereas the PCB layout is set up for USA conventions since there are a lot more widely-available substitutes in this format.

For those using original Toshiba through-hole JFETs or BJTs, an extra pad has been added to the left of the transistor outline (drain for JFETs, emitter for BJTs) so that the Japanese pinout can be easily used without needing to twist the legs around. In both cases, the transistor should be rotated 180 degrees from the silkscreen and shifted by one pad, as shown:

Galaxie Mod

The Galaxie Mod created by Keith Aviles of Machine Head Pedals (known as 11 Gauge on the TDPRI forums) is without question the most extensive BD-2 mod that has been developed. This modification—or more accurately, major surgery—changes out about half of the components to completely restructure the pedal. It lowers the gain and fully eliminates the fizz while improving the tone control's usefulness.

For a few of the parts, capacitors are replaced with resistors and vice versa. To accommodate this, some of the component footprints on the Sapphire PCB are composites that allow either 0.2" film capacitors or 0.3" resistors to be used, so the pads look like a sideways number 8. The PCB silkscreen shows the components from the stock BD-2.

The parts list includes alternate values for the mod, but for completion's sake, here is the full list.

PART	STOCK VALUE	MOD VALUE
C2	100n	10n
C3	150n	39n
C4	47pF	100pF
C6	220pF	Omit (leave empty)
C7	100n	10k resistor
C8	47n	100k resistor
C9	2n2	47n
C10	100pF	220pF
C11	1uF	68n, 82n or 100n *(see note)*
C15	18n	33n
C16	18n	22n

PART	STOCK VALUE	MOD VALUE
C18	2n2	Omit (leave empty)
R7	1k5	10k
R11	330k	Omit (leave empty)
R12	100k	22n capacitor
R13	1M	6n8 capacitor
R14	15k	Jumper (bare wire)
R15	1M	100k
R18	2k2	10k
R22	5k6	2k2
R24	6k8	*see note*
D2-D7	1N914	Omit (leave empty)

C11: This value can be tailored to your preference. The original mod uses 100n, but Keith suggests that 82n or 68n may be better alternates if you have them.

R24: In the Galaxie Mod, this resistor is changed to 33k. However, the Sapphire's bass control is a variable resistor in series with R24, and at max rotation it's nearly 33k in value (6.8k + 25k = 31.8k). It's recommended to leave R24 as the stock 6.8k, but you could increase it to 8.2k if you want full clockwise rotation to be closer to 33k.

Gain pot value

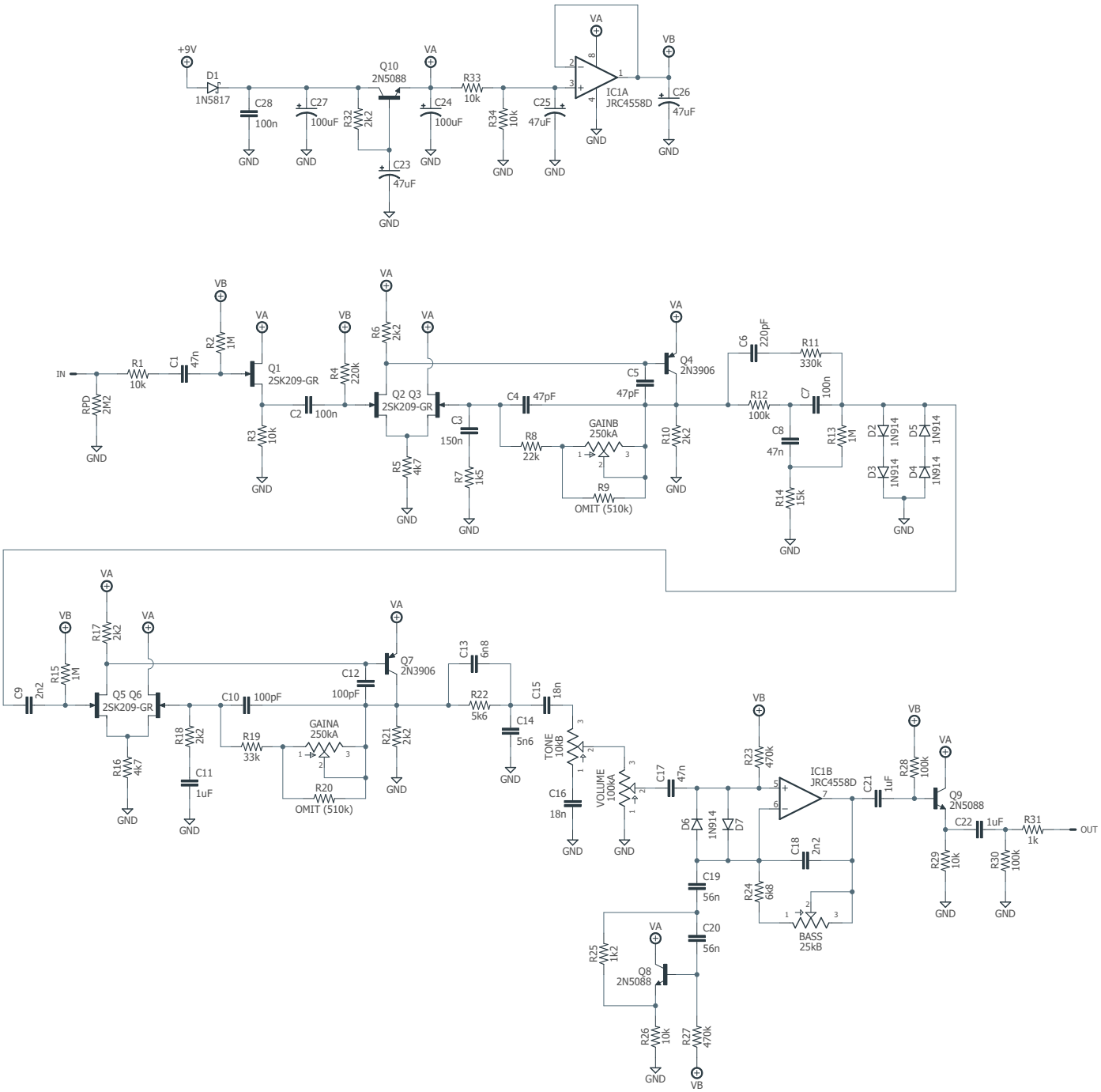
The original BD-2 uses a 250kA dual-gang potentiometer. These are not available from any of the usual suppliers except for Tayda Electronics, who carries a straight-pin knurled-shaft type. These can be made to fit the Sapphire PCB with some effort, but it's much easier to just use a 500kA dual potentiometer which is readily available in the right-angle format used in this project.

Parallel resistors (R9 and R20) have been added to each half of the gain control to drop the 500k value down to an effective value of 250k. The taper is affected slightly, but it's not noticeable unless you're doing an A/B test against an original and trying to match knob positions. If using the stock 250kA value, omit R9 and R20.

Q2/3 and Q5/6

It has been suggested that Q2/3 and Q5/6 (the JFET differential pairs that make up the two discrete op-amp gain stages) should be matched in their $V_{GS(off)}$ value for for best performance.

This may be true in theory, but we took meas urements of the JFETs in an original Blues Driver and the two pairs were not matched any more closely than any of the other non-paired JFETs, which suggests they were chosen at random. It doesn't appear that BOSS used any sort of matching in the manufacture of the Blues Driver and so it's not something we recommend giving any consideration.


+9V
D1
1N5817
C28
100n
C27
100uF
Q10
2N5088
R32
2k2
C23
47uF
VA
C24
100uF
R33
10k
R34
10k
C25
47uF
IC1A
JRC4558D
VB
C26
47uF
GND
IN
R1
10k
RPD
2M2
C1
47n
R2
1M
Q1
2SK209-GR
R3
10k
C2
100n
R4
220k
Q2 Q3
2SK209-GR
R5
4k7
R6
2k2
C3
150n
R7
1k5
C4
47pF
R8
22k
GAINB
250kA
R9
OMIT (510k)
C5
47pF
Q4
2N3906
R10
2k2
C6
220pF
R11
330k
R12
100k
C7
100n
C8
47n
R13
1M
R14
15k
D2
1N914
D3
1N914
D4
1N914
D5
1N914
C9
2n2
R15
1M
R16
4k7
Q5 Q6
2SK209-GR
R17
2k2
R18
2k2
C11
1uF
C10
100pF
R19
33k
GAINA
250kA
R20
OMIT (510k)
C12
100pF
Q7
2N3906
R21
2k2
C13
6n8
R22
5k6
C14
5n6
C15
18n
TONE
10kB
C16
18n
VOLUME
100kA
C17
47n
D6
1N914
D7
1N914
R23
470k
IC1B
JRC4558D
C18
2n2
C19
56n
R24
6k8
BASS
25kB
C20
56n
R25
1k2
Q8
2N5088
R26
10k
R27
470k
C21
1uF
R28
100k
Q9
2N5088
C22
1uF
R31
1k
OUT
R29
10k
R30
100k

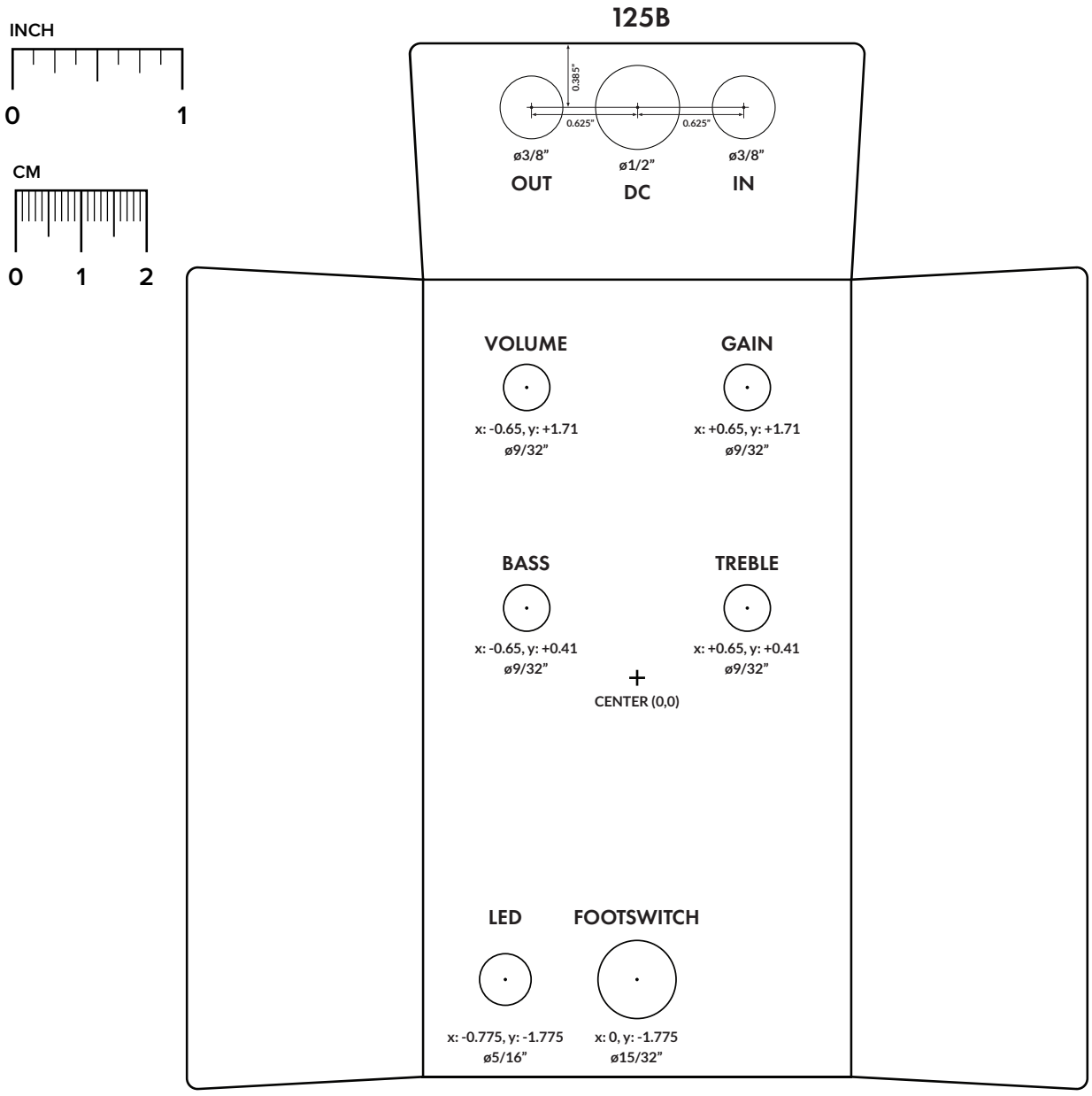
DRILL TEMPLATE

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.

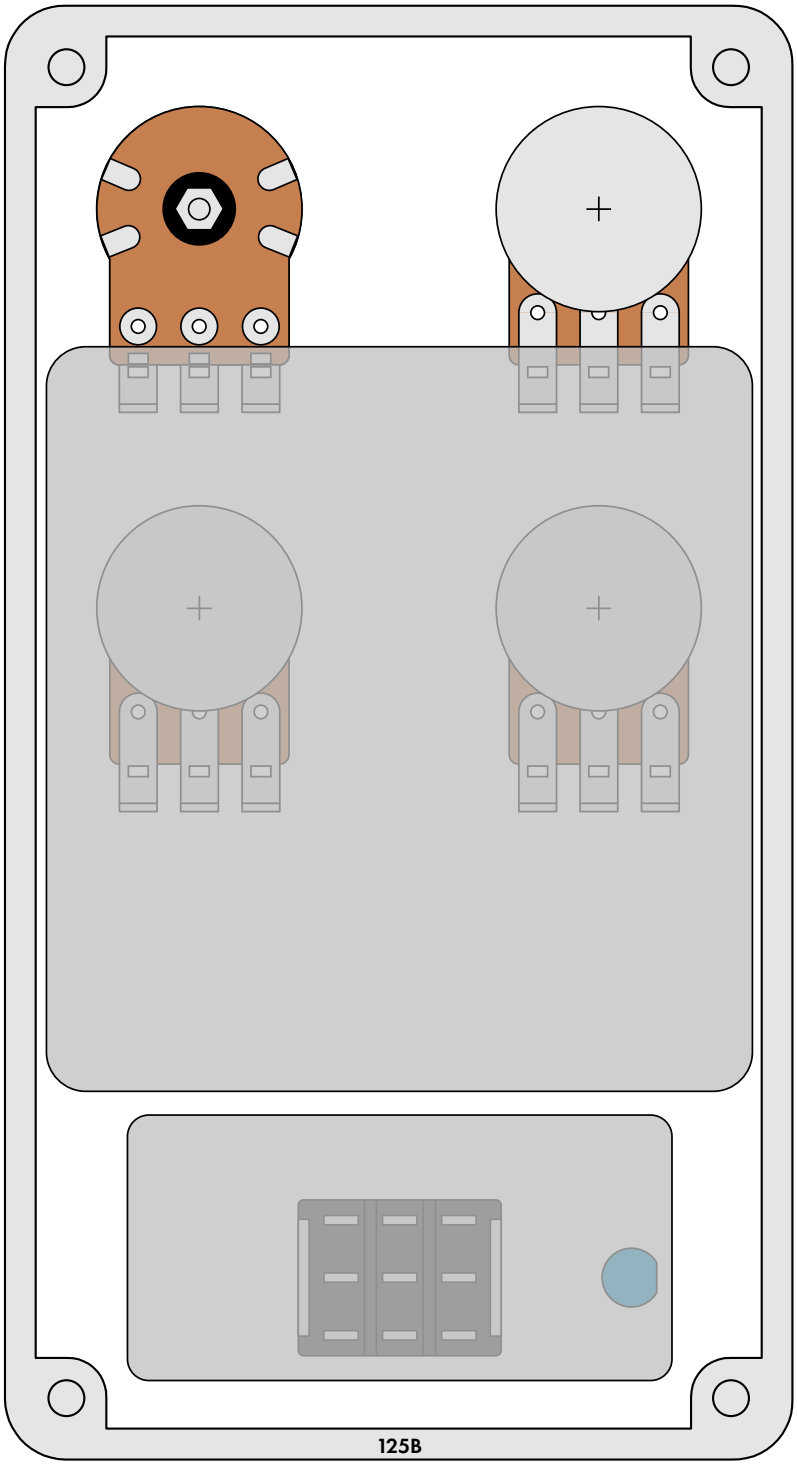
LED hole drill size assumes the use of a 5mm LED bezel, available from several parts suppliers. Adjust size accordingly if using something different, such as a 3mm bezel, a plastic bezel, or just a plain LED.



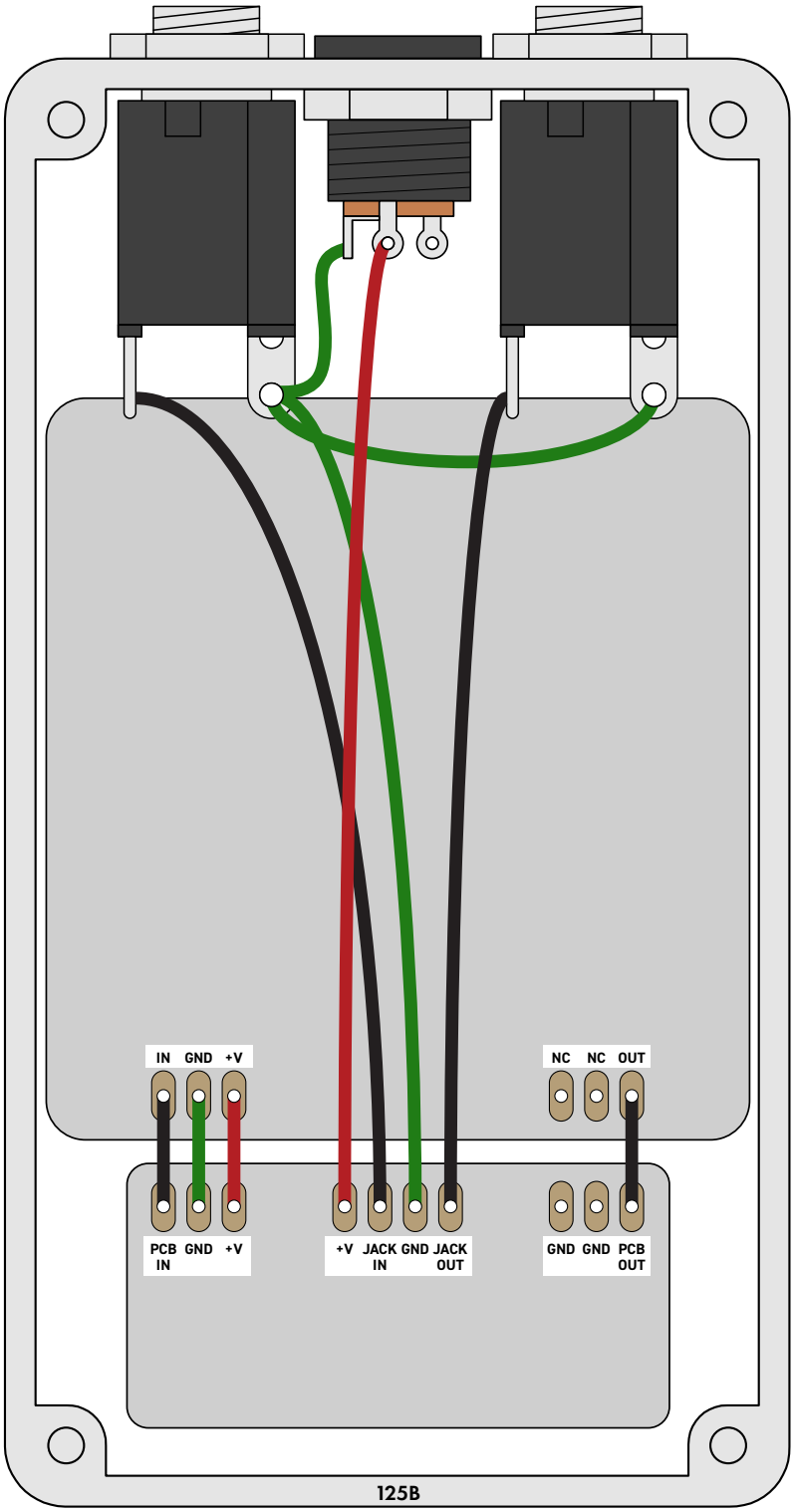
ENCLOSURE LAYOUT

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

Note: The upper pads for the dual-gang gain potentiometer appear to be cut in half. **This is intentional!** It's called a *plated half-hole* or *castellated hole*, and it's used so that the PCB can lay flat across the pots instead of angling upward for the dual pot. Solder it like you would if they were normal pads, but bend the top pins forward slightly so they make contact with the edge of the pads.



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 cannotbe 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

1.0.1 (2024-08-08)
Changed LEDR to 10k so it works better with a wide variety of LEDs.

1.0.0 (2021-11-26)
Initial release.