A Universal Shunt Regulator for Audio Applications

Walter G. Jung

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This document describes a *Universal Shunt Voltage Regulator*, as optimized for positive and negative audio power supply use. It includes a high performance current source, adjustable up to 100mA of current. In a given application, a common form of shunt voltage regulator circuit is used for both POSitive and NEGative outputs. Jumpers configure the current source as is applicable for a given output polarity. In essence, the circuit functions as a high power zener diode with voltage adjustability and a very low output impedance. Two such circuits, one set for POSitive and the other for NEGative provide a bipolar (±) shunt regulated supply system.

The new circuit, having been frozen on 12/27/2014, is thus so named. It has been optimized further from a previously published version, which appeared within the Walt Jung *AudioXpress* interview of 10/12 (Figure 1 therein). It has all of the general merits of that version, but with more flexibility and higher performance.

Figure 1 shows a POSitive out version of the regulator, while Figure 2 is the NEGative counterpart. Several key points should be noted between these two figures. Note that the rightmost portion is the same between Fig. 1 and Fig. 2. The salient differences lie in how current source M4 is connected. It appears in the unregulated POS input leg in Fig. 1, and in the unregulated input NEG leg in Fig. 2. The jumpers, along with the grounding/COM connections, determine whether a negative or positive output results.

Note that within this setup it is assumed that *the Vunreg raw DC sources are fully floating*. This is easily achieved with two independent transformer windings of similar AC secondary voltages, and two corresponding full wave rectifiers and smoothing filters. Details of this will not be described here, except to note that sufficient voltage headroom must be provided to correctly operate current source M4.

The headroom required for current source M4 will typically be 8Vdc or more than Vout, i.e., ~22V for Vunreg if you are building a 13.8V regulator as shown, or ~20V for Vunreg if you are building a 12V regulator. Your mileage may vary here. It is because of this headroom issue that a cascode setup for a pair of DN2540's isn't generally recommend. Nevertheless, the single MOSFET source shown can still provide excellent results. An input RFI filter is used before M4, preferably with a low inductance capacitor type for C1.

Some subtle but important changes within the regulator and shunt driver have been made, vis-a-vis the *AudioXpress* version as cited above. The small value emitter resistor R6 linearizes Q2, and a 10mA driver is used (Q1), for high bandwidth and linearity within the shunt path. A RED LED is used as the level shift voltage between the op amp and Q1, which centers the dynamic range for output voltages as low as 5V. A useful factor here is that the RED LED specified is virtually noiseless, vis-a-vis a zener used for the level shift function.

An optional RC network (C5 - R15) around the op amp rolls off AC response, and may be useful if/when instability is encountered. It should not be found necessary for most applications. Obviously, R15 must be used in all instances, but C5 can be treated as an option.

Specific Component Recommendations:

Resistors - SMD types are OK for most positions, but R1/R2 are more critical, and these parts should be of high quality, such as Dale/Vishay RN60 types.

Capacitors – C1 should be a stacked film or similar low inductance type. C5 is an NP0 ceramic (if used). Electrolytics C2 - C4 aren't critical in value, and can be either 100 or 120µF units. These should *not* be ultra low ESR, but rather more general purpose units. Nichicon VR series is OK here.

RED LED (D1) – Lite-On LTL-4221N was used in circuit development, and is strongly suggested for lowest noise.

Transistors – Fairchild types recommended for Q1, Q2, Supertex for M4. Q2 and M4 are TO-220 packaged power units, and will need heat sinks.

Op Amp (U3) – The ADI AD817N is recommended, and will work down to 5V. This circuit has been built, tested and simulated with the AD817. Other types can work, but substitute at your on risk. Even an ancient 741 can work within this circuit, according to simulations. But that's a historical note, not a usage recommendation!

Voltage Reference (D4) – Lots of possible options here. Take careful note of the **Table 1** arrangement of Vref devices. In terms of noise, they are worst to best, from top to bottom.

- The National / TI LM329 (Vref = 6.9V) is used for a 13.8V output within these examples. An LM329 is lower noise than a bandgap type, and has an advantage of operating at currents below 1mA. Higher current will *not* improve the noise, alas (see **Table 1** for suggested R13 values).
- A very simple one-part sub is a Fairchild 1N5235B, with a Vref = 6.8V. This can also be used, and can potentially provide lowest noise. A key note here: *this low noise will only be true if the D4 device is run at substantially higher current, i.e., 3-5mA.* So with the 1N5235B, adjust R13 accordingly (see **Table 1** for suggested R13 values).
- A preferred setup is with the "PM829" connection, which is a back-back combination of 6.2V 1N5234B diodes, and this provides close to 6.9V for Vref, with the bonus of lower TC as well as lowest noise. (see **Table 1** for suggested R13 values).
- For a 5V output, a TL431C or LM336-2.5V can be used for D4 (Vref = 2.5V), with R13 adjusted for a 1mA reference current. Note however that these two references are *not* low noise parts.

In all cases, note the final output noise can be limited by the op amp, and the AD817 and AD825 are *not* lowest noise devices.

Vendors: From many years of good personal experiences, both Mouser and Digi-Key are recommended for the above parts. Their prices are reasonable, and the service is excellent.

Preliminary Setup Steps:

1) ***Select a R5 value for M4, so that 1V appears across a temporary load of 10Ω. This will set the current source for 100mA. This should be done* before *connecting the remainder of the circuit (U3 etc).***

2) ***Select D4 and an op amp suitable to the target output voltage according to Table 1 below. Resistances are in standard 1% values. Note: the AD817 works for all voltages shown.***

Table 1: Output Voltages and R1, R2, R13 Values

Vout = (1 + R1/R2) * Vref

Vref (V)	Vout (V)	D4 Vref / Device	R1	R2	R13 (for noted Iref)
2.5	5	2.5V / TL431C	1kΩ	1kΩ	2.49kΩ / 1mA
6.9	12	6.9 V / LM329D	750Ω	1kΩ	4.99kΩ / 1mA
6.9	13.8	6.9 V / LM329D	1kΩ	1kΩ	4.99kΩ / 1.4mA
6.8	13.6	6.8 V / IN5235B	1kΩ	1kΩ	1.82kΩ / 3.8mA
6.9	13.8	~6.9V / PM829	1kΩ	1kΩ	1.82kΩ / 3.8mA

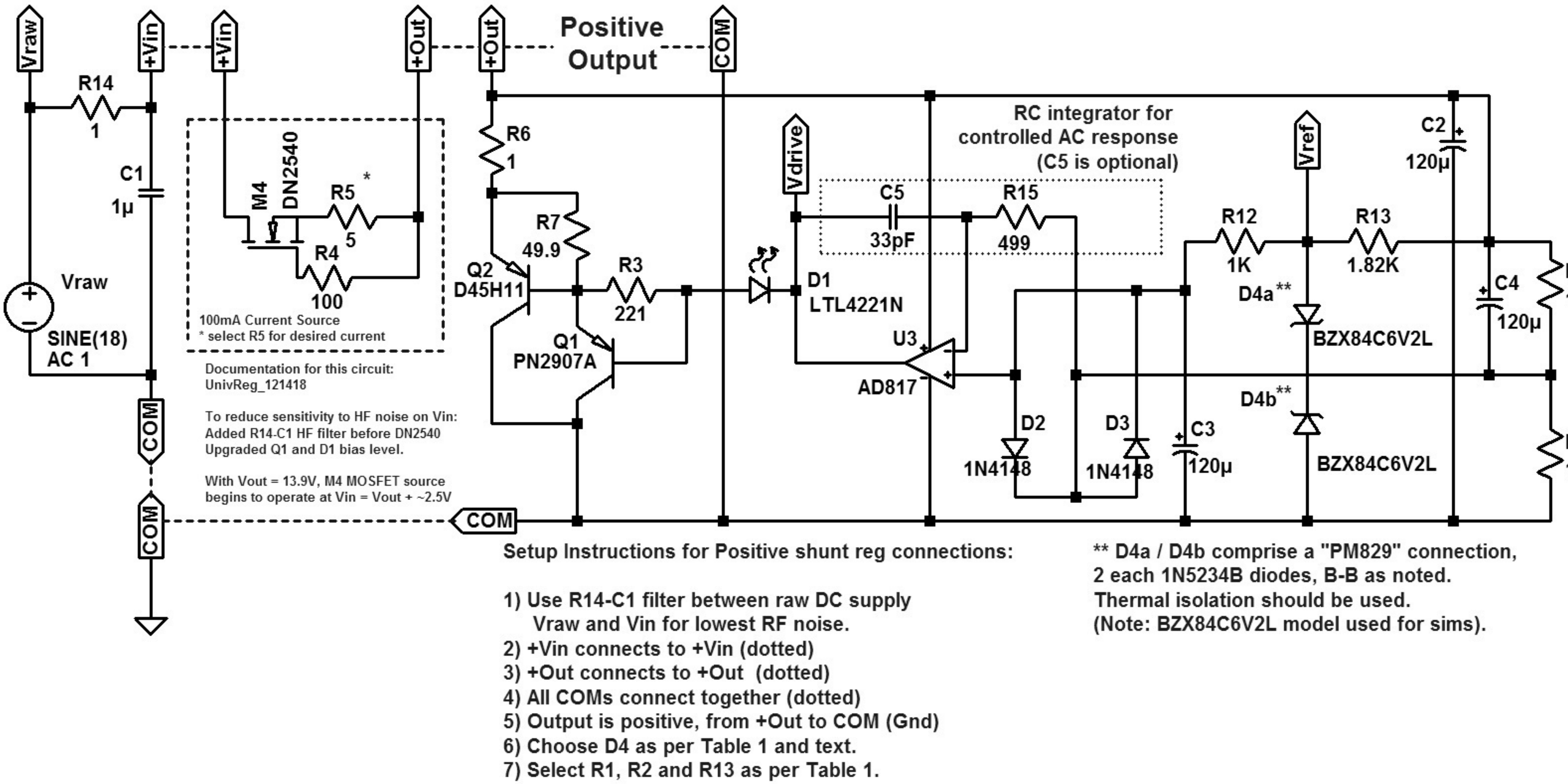

Figure 1: A Universal Shunt Regulator Setup for Positive 13.8V Output(s).

Unregulated source Vraw is floating (i.e., FW bridge rectifier).
R14 / C1 form optional RF filter.
R5 is selected with a given M4 MOSFET, for 100mA (or lower) current.
Use adequate heat sinking on M4 and Q2.
See text for component selections.

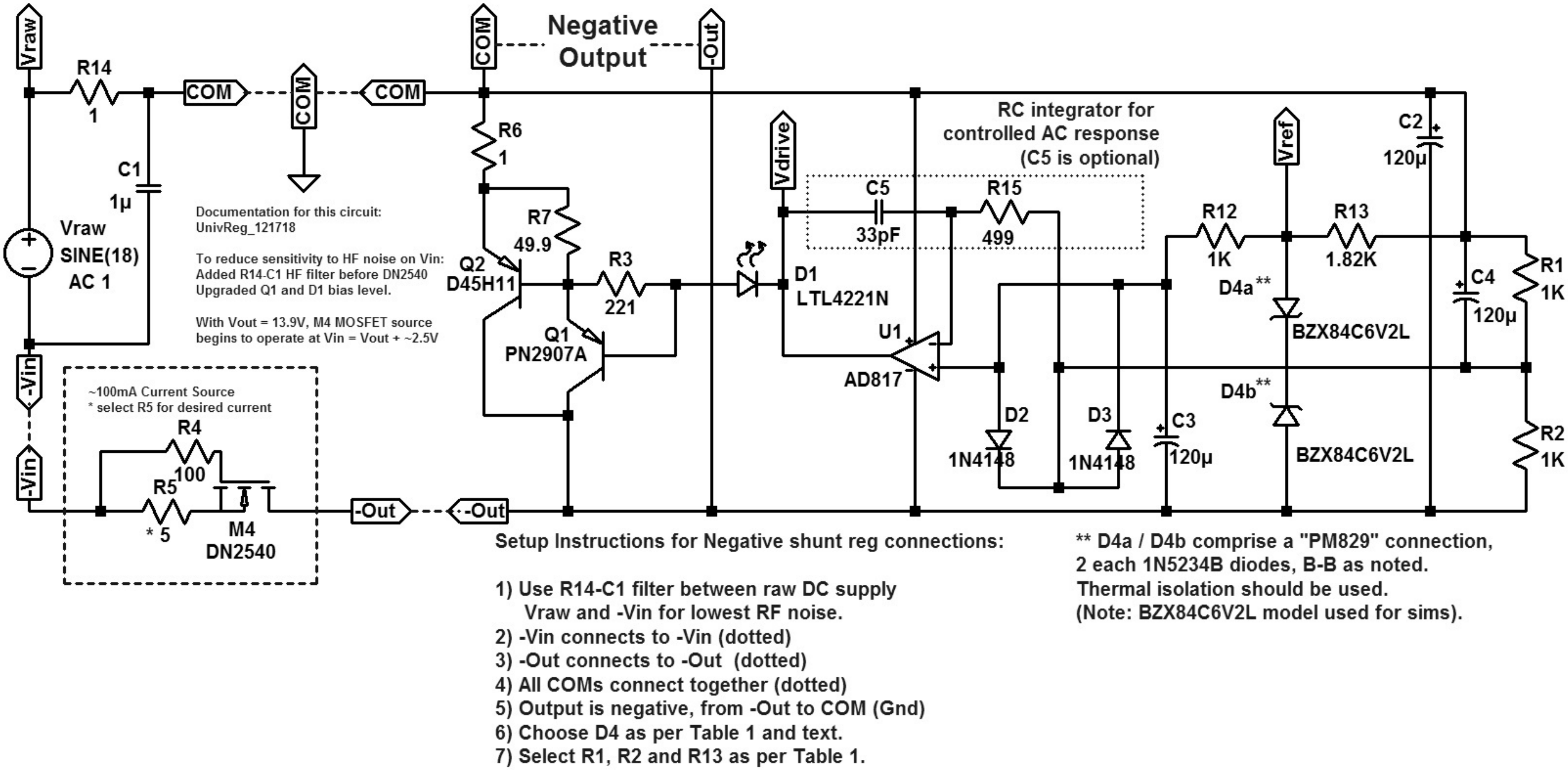

Figure 2: A Universal Shunt Regulator Setup for Negative 13.8V Output(s).

Unregulated source Vraw is floating (i.e., FW bridge rectifier).
R14 / C1 form optional RF filter.
R5 is selected with a given M4 MOSFET, for 100mA (or lower) current.
Use adequate heat sinking on M4 and Q2.
See text for component selections.

3) Install the remaining parts of the circuit, but without the final load(s). Verify (a) that the proper output voltage appears as per Table 1. Verify (b) that the proper output voltage also appears as per Table 1, when the final load is connected. Note: the regulator itself consumes ~25mA, so the current available to a load will be 75mA or less.

This *Universal Shunt Regulator* circuit is presented here in "As-is" fashion. While it has been built successfully in a great many different formats, it is simply not possible to anticipate all of the potential uses out there. Or, to entertain the inevitable questions of "Can I change x or y?" that might arise. Most questions can be answered by carefully reading the regulator articles found on the same website page as this article.

Feedback on the *Universal Shunt Regulator* circuit is welcome, and will be monitored via a special mailbox. See the "Making Web Comments" page of this website. Then, if you do choose to comment, indicate whether it is for publication, or a more general one. Such comments can provide a path for any future updates.

I suggest building the *Universal Shunt Regulator* first just as shown, and get it working correctly. That will be fun, and in the end, very likely rewarding. Good luck!