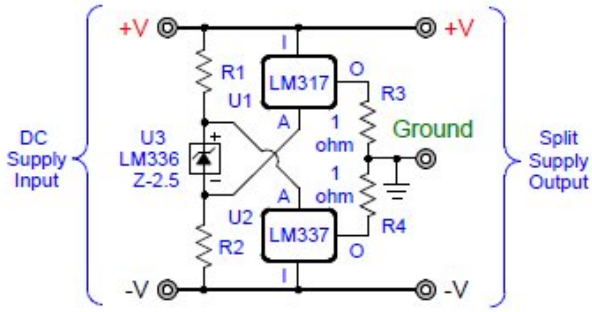
Virtual Ground Circuits from Voltage Regulators

These circuits enable two-conductor DC power supplies (including DC wall adapters, 9V and 12V batteries, etc.) to function as **split supplies** with three conductor outputs (i.e., positive, negative AND ground). They are called "Virtual Grounds" or "Rail Splitters".

Adjustable Voltage Regulators

The inexpensive LM317/LM337 circuits below are capable of delivering up to +/-18V at more than 1.5 amps, 75 times the current of a TLE2426 rail splitter chip. The DC Supply Input can be from 7.5VDC to 40VDC. The TO-220 voltage regulators are each rated for 20W. However, they can handle a watt or more without heatsinks - example: Output = +/- 9VDC @ 60mA.

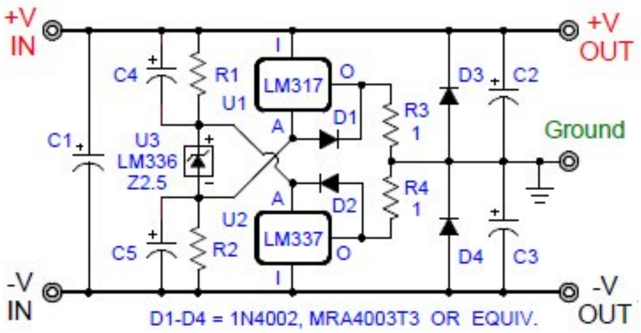
Both the LM317/LM337 **Basic** and **VG1 Circuits** below draw quiescent current of only 4 or 5 milliamps - great for battery use!



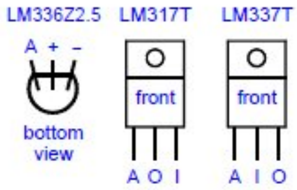
Basic Virtual Ground Circuit with Adjustable Voltage Regulators

How it works: The LM317 (positive) and LM337 (negative) adjustable voltage regulators operate in parallel with their outputs tied together through small resistors to create a virtual ground. The LM336BZ-2.5V voltage reference compensates for the LM317's (+1.25V) internal reference and the LM337's (-1.25V) internal reference. So when the LM317/LM337 adjust pins are connected inside the R1/R2 voltage divider as shown, each voltage regulator output voltage becomes 1/2 of whatever the rail-to-rail voltage happens to be. Thus, together, the voltage regulators "split the rails", creating a "rock solid" virtual ground.

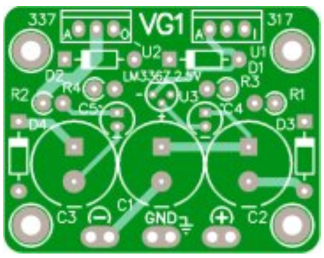
> Although a simple and inexpensive virtual ground solution, some audio designs sound better when using it. For example, when powering a headphone amplifier, the bass notes may sound clearer and more life like. This could be due to how the voltage regulators hold the ground point firmly in place.

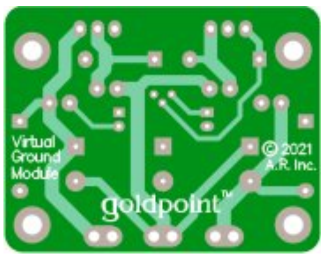


DC Supply	As Split Supply	R1, R2
7.5 VDC	+/- 3.75V	866
9 VDC	+/- 4.5V	1.62K
12 VDC	+/- 6V	2.32K
18 VDC	+/- 9V	3.90K
24 VDC	+/- 12V	5.36K
30 VDC	+/- 15V	6.81K
36 VDC	+/- 18V	8.00K



VG1 Virtual Ground Circuit





VG1 PC Board (Top) **(Bottom) 1.4" x 1.8"** **similar earlier version**

VG1 PC Boards are available for **$5** each. **P/N = VG1** Above, at right, an assembled earlier version.
PC Board size: 1.4" x 1.8" Mounting holes are for 4-40 screws, spaced 1.0" x 1.5".

All parts are redily available and easy to find - and can be ordered from Mouser.com or Digikey.com.
Resistor and capacitor values are not critical - you can substitute near or alternate values.

VG1 Parts List:	notes:
R1, R2 - see VG1 schematic chart	1/4W or 1/2W
R3, R4 - 0.75 ohm to 1 ohm	1/4W or 1/2W
C1 - 470uF/50V**	Panasonic P/N EEU-FM1H471
C2, C3 - 1000uF/25V**	Panasonic P/N EEU-FM1E102
C4, C5 - 22uF/50V	Panasonic P/N EEU-FM1H220
D1 - D4 - 1N4002 (or similar)	for SMD: MMRA4003T3
U1 - LM317T	TO-220 package Digi-Key, etc.
U2 - LM337T	TO-220 package Digi-Key, etc.
U3 - LM336Z2.5	2.5V voltage reference (Fairchild)

NOTES:

1) The values for R1 and R2 shown in the chart above yield about 2mA of current through the LM336BZ-2.5V. The formula used to determine the values is: **R1 or R2 = (Vrr - 2.5) / .002 / 2**. For example with a 12V power supply: (12 - 2.5) /.002 / 2 = 2375. So use a 2.37K resistor for R1 & R2. Also: **I = (DC supply - 2.5) / (R1+R2)**.

2) The adjust pin on the LM336 voltage reference is not used, so leave it unconnected;
only connect the "+" and "-" pins.

3) Reducing component count: When using a battery for the DC source, such as a 9V battery in a low current application, you can skip installing C1 - C5 and D1 - D4 altogether and simply use the **Basic Circuit** as shown at the top of this page. However, when powering low-noise audio circuitry and if your DC power supply is plugged into an AC source, you should install all of the capacitors. C1 - C3 can be 2,200uF - 10,000uF more. This necessitates installing all of the diodes to protect the voltage regulators from the large discharging capacitors at turn-off.

4) A test of the **VG1 Circuit** was done with an Eveready Gold 9V alkaline battery as the DC supply, the R1/R2 resistors were each 1.62K, and there was no load on the output of the circuit. The 9V battery itself actually measured 9.3V. Results: The ground remained perfectly centered (+/- 4.65V), while the total current being drawn was only about 4.5mA. This shows that with 2mA through the voltage divider section, the rest of the circuit was consuming only an

additional 2.5mA. And that says if we add a 20mA load to the output, and if the 9V battery could supply 350mAH to 550mAH, the battery would last about 12 to 20 hours or more of continuous use.

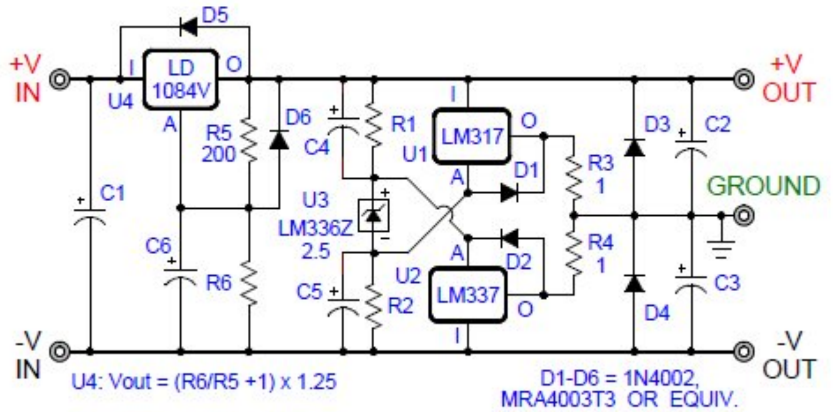
5) You may be able to reduce the size of the 1 ohm output resistors to 0.75 ohm or less by minimizing the current through the LM336BZ-2.5 (by using larger value R1/R2 resistors). A small ground point voltage offset, if it happens, is usually acceptable. An LM336BZ-2.5V can operate with 0.5mA to 10mA of forward current.

6) The LM317/LM337s require about 1.5 to 6mA of load current to maintain regulation - and they will continue to regulate with an Input voltage as low as 3.7 volts.

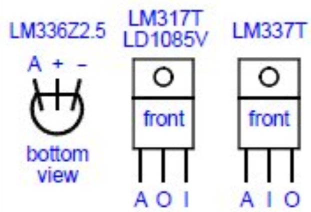
7) Increasing the size of C1, C2 and C3 can be sonically advantageous. They can be 220uF to 12,000uF, (or as much as you can afford or have room for.) Generally, electrolytic capacitor rated voltages should be at least 30 percent higher than whatever their power supply voltage is.

If you are using the virtual ground with an audio circuit and your DC power supply has an AC source, adding another voltage regulator in front of the rail splitter section can further improve sound quality. An **LD1085V**, 3A LDO (Low Dropout Voltage) voltage regulator sounds better for this purpose than others I've compared by listening tests. When using this additional voltage regulator (U4), be sure that your DC Supply (input voltage) is always 1.5V (or more) higher than your desired LM317/LM337 rail-to-rail voltage - because the LD1085V needs at least 1.3V across it to stay in regulation. note: The maximum DC Input Voltage for a LD1085V is 30VDC. (This three regulator circuit draws twice the current (or more) compared to the **VG1 Circuit**, so it may not be as well suited for battery use.)

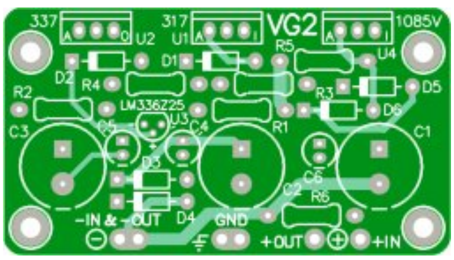
The following circuit makes a good phono preamp power supply (for use with a high-quality opamp):



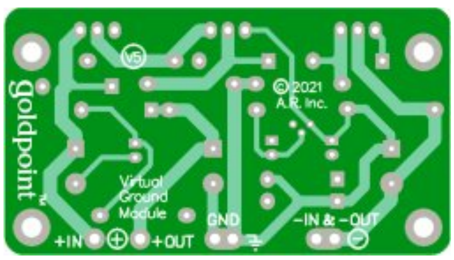
DC Supply	R6	U4 Output	As Split Supply	R1, R2
7.5 VDC	806	6.29V	+/- 3.14V	953
9 VDC	1.00K	7.5V	+/- 3.75V	1.30K
12 VDC	1.43K	10.19V	+/- 5.09V	2.00K
18 VDC	2.37K	16.06V	+/- 8.03V	3.32K
24 VDC	3.32K	22.0V	+/- 11.0V	4.75K
30 VDC	4.12K	27.0V	+/- 13.5V	6.49K
36 VDC	5.11K	33.19V	+/- 16.6V	7.87K



VG2 Enhanced Virtual Ground for Low Noise Audio Applications



VG2 PC Board (Top)



VG2 PC Board (Bottom)

VG2 PC Boards are available for **$8** each. - **P/N = VG2**
PC Board size: 1.4" x 2.55" - Mounting holes are for 4-40 screws, spaced 1.0" x 2.25".

All parts are redily available and easy to find - and can be ordered from Mouser.com or Digikey.com. Resistor and capacitor values are not critical - you can substitute near or alternate values.

VG2 Parts List:	notes:
R1, R2 - see VG2 schematic chart	1/4W or 1/2W
R3, R4 - 0.75 ohm to 1 ohm	1/4W or 1/2W
R5 - 200 ohm	1/4W or 1/2W
R6 - see VG2 schematic chart	1/4W or 1/2W

C1 - 470uF/50V**	Panasonic P/N EEU-FM1H471
C2, C3 - 1000uF/25V**	Panasonic P/N EEU-FM1E102
C4, C5, C6 - 22uF/50V	Panasonic P/N EEU-FM1H220
D1 - D6 - 1N4002 (or similar)	for SMD: MMRA4003T3
U1 - LM317T	TO-220 package Digi-Key, etc.
U2 - LM337T	TO-220 package Digi-Key, etc.
U3 - LM336Z2.5	2.5V voltage reference (Fairchild)
U3 - LD1084 or LD1085	TO-220 package Digi-Key, etc.

Development Credits:

Arn Roatcap: (Founder of Goldpoint Level Controls goldpt.com) - Prior to the LM317/LM337 circuits, built virtual grounds using fixed value voltage regulators (see circuits below). Integrated new ideas, constructed all of the prototypes and performed extensive listening tests.

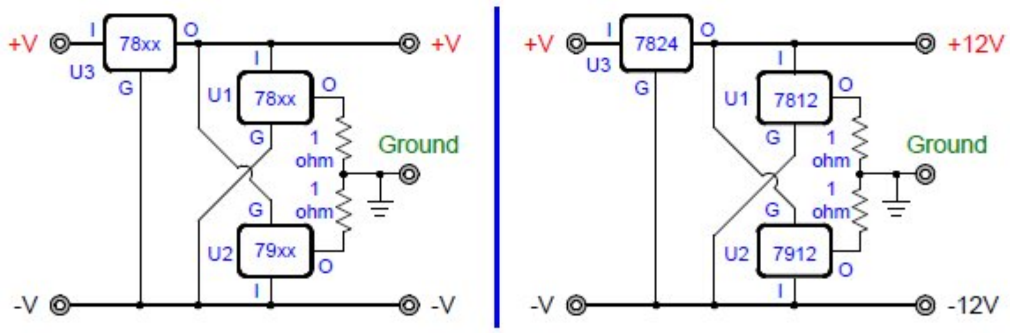
John Broskie: (GlassWare glass-ware.com and Tube CAD tubecad.com) - Suggested many virtual ground circuit ideas from 2006 to 2013. Directed the use of 1 ohm output resistors on the rail splitter voltage regulators.

Kim Laroux: (head-fi.org forums) - Had the ingenious idea to offset the LM317/LM337 internal voltage references by using a single 2.5V zener diode.

KT88: (head-fi.org forums) - Contributed the key idea to use a LM336 voltage reference, instead of a zener diode, to compensate the LM317/LM337 internal voltage references.

Fixed Voltage Regulators

Shown here because of their simplicity, the following two circuits use **fixed value voltage regulators** to split the rails. They *MUST* have a third voltage regulator (U3) to keep the U1/U2 rail-to-rail voltage from going up or down. *S*ome possible fixed value U3/U1/U2 voltage regulator combinations are:
[+10V, +5V, -5V], [+12V, +6V, -6V], [+18V, +9V, -9V], [+24V, +12V, -12V].



Basic Virtual Ground Circuit with Fixed Value Voltage Regulators

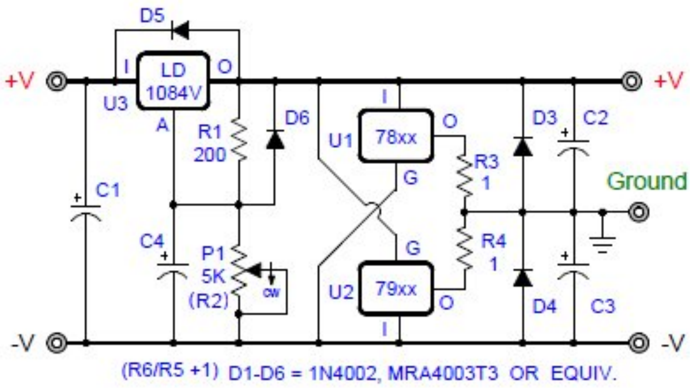
When a "complimentary pair" of fixed value voltage regulators are used to create a virtual ground this way, the absolute values of their output voltages are each 1/2 of the rail-to-rail voltage. And the rail-to-rail voltage must remain at a set, unvarying voltage which is the sum of the absolute values of both of the rail splitter regulators output voltages. You therefore must use the third voltage regulator (U3).

Without U3, the rail-to-rail voltage could go up or down with load changes, battery drain, as the AC line voltage went up or down, etc. And if the rail-to-rail voltage went up or down, the two fixed value regulators would begin to compete with each other to establish different ground points, one or both constantly wasting current (and possibly overheating or burning up). So U3 is essential to ensure that fixed value regulators U1 and U2 do not interact with each other.

The output of U3 needs to be close to the value of U1 added to the absolute value of U2. As the output voltages of common fixed value voltage regulators vary by as much as 5% from their rated values, buying extra ones and pre-testing them to find their actual output voltages lets you select them to meet the desired **U3 = U1 + |U2|**.

Because U3 consumes twice as much power compared to U1 or U2, a good choice for it is an *adjustable voltage regulator* such as a 3 amp LD1085V or a 5 amp LD1084V. This also gives the advantage of allowing the use of *any* fixed value voltage regulators for U1 and U2. With an adjustable regulator for U3, the virtual ground point does not have to be centered between the rails. For example, you can make a +5V/-12V power supply by setting a variable voltage regulator U3 to 17V, selecting U1 as a 7805 (+5V), and U2 as a 7912 (-12V).

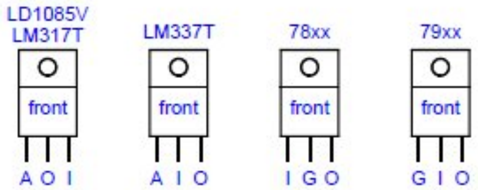
However, it is still a good idea to pre-test U1 and U2 to find their actual output voltages - then adjust the output voltage of U3 (via P1) to meet the the desired **U3 = U1 + |U2|** before powering up.



Virtual Ground With Fixed Value Voltage Regulators for Rail Splitter Section Only

An alternate way of setting P1 above to the correct voltage is as follows:
1) Set the ammeter on a high scale, such as the 10A scale.
2) Insert the ammeter in-line between the DC supply and the +V input.
3) Turn on the DC power supply.
4) Quickly adjust P1 to give the lowest quiescent current. If it reads below 2A, change to the 2A scale.
If it is then seen to be below 200mA, (you're aiming for perhaps 5mA to 50mA), switch to the 200mA scale.
5) Then use a voltmeter to test the output voltages relative to the ground point.

Alternatively, you can replace P1 above with a fixed resistor (R2). This is even recommended - if you already know the exact voltages of U1 and U2. **U3 = U1 + |U2|**. The U3 output voltage = (R2/R1 +1) x 1.25.



A 12V fixed value regulator could operate as low as 11.5V or as high as 12.5V.

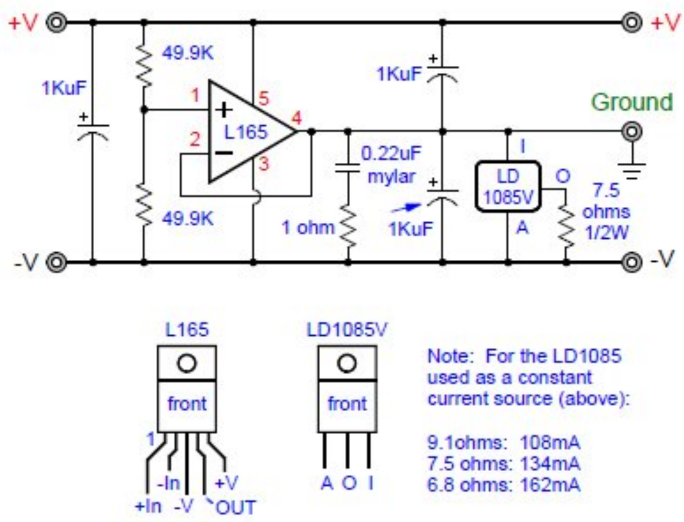
LD1085V: Inexpensive ($1), adjustable, (1.25V to 28.5V), 3A positive, Low Dropout Voltage (LDO)

78xx / 79xx (fixed) and LM317 / LM337 (adjustable): Inexpensive (about $0.25) and commonly available.

A Power Op-Amp Virtual Ground Circuit

Here is a rail splitter virtual ground circuit which "works", but is a second or third choice sonically. While it does center the ground point perfectly, it requires a constant current source (the LD1085V) hung on its output to sound any good when powering audio circuits. The constant current source forces the power op-amp to run in class A mode. As both the L165 and the LD1085V require heat sinks, this circuit is not good for battery use (too much wasted power).

The L165 comes in a five lead TO-220 package, and is rated for up to 3 Amps at +/-18V.



Power Opamp Virtual Ground Rail Splitter

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