# Voltage Reducer for Lithium-ion Polymer Four-Cell Batteries

## Power your rig with LiPo batteries!

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Lithium-ion polymer batteries (often informally referred to as “LiPo” batteries) are popular with radio controlled model enthusiasts due to their high energy density. This advantage has not been lost on radio amateurs seeking to lighten portable radios. However, much of Amateur Radio equipment has been designed to accept a 13.8 V external supply, and the use of these batteries presents something of a Goldilocks conundrum — at 16.8 V, the voltage of a fully charged four-cell battery (termed “4S”) is too high for most portable radios, like my Elecraft KX3 and the nominal voltage of 10.8 V of a three-cell battery (3S) is too low for many QRP transceivers operating at full power.

My plan for taking advantage of LiPo batteries was to use a four-cell battery followed by a regulator to bring the voltage within spec for portable Amateur Radio equipment. However, I did not want the complexity or RF hash generated by a switching regulator, so I opted for the simple solution of inserting two diodes in series with the battery supply, to create a nominal 2 V voltage drop.

Leaving the diodes in the supply line throughout the battery’s discharge cycle would be inefficient, so I added a bypass relay to short the diodes out once the battery voltage dropped past a certain level. The relay is powered and the diode bypass contacts are held open only during the first part of the discharge cycle. Once the threshold voltage is passed, power is removed from the relay and the normally closed contacts then short the diodes, providing full battery voltage to the load.

### Circuit

The schematic for the voltage reducer is shown in Figure 1. Diodes D1 and D2 are connected in series with the battery’s positive (+) terminal and serve to drop the voltage supplied to the radio by a freshly charged battery by approximately 2 V. Two paralleled normally closed (NC) relay contacts bypass the diodes and are held open by activating relay K1. The relay is controlled by NPN transistor switch Q1. The base of the transistor is connected to the BATTERY supply through a 100 Ω current-limiting resistor R2 in series with a 14.3 V Zener diode D5. While the BATTERY voltage is greater than the sum of the 14.3 V Zener diode drop plus the 0.7 V base-emitter drop of the transistor, current is supplied to the transistor base keeping the transistor on and the relay powered, which in turn, keeps the bypass contacts open.

As the LiPo battery discharges, the voltage on the BATTERY terminal will eventually drop below 15 V (ie, 14.3 V + 0.7 V), which will turn Q1 off and deactivate the relay. This will in turn complete the bypass circuit formed by the relay’s paired NC contacts (each contact rated at 3 A) and supply full BATTERY voltage to the XCVR.

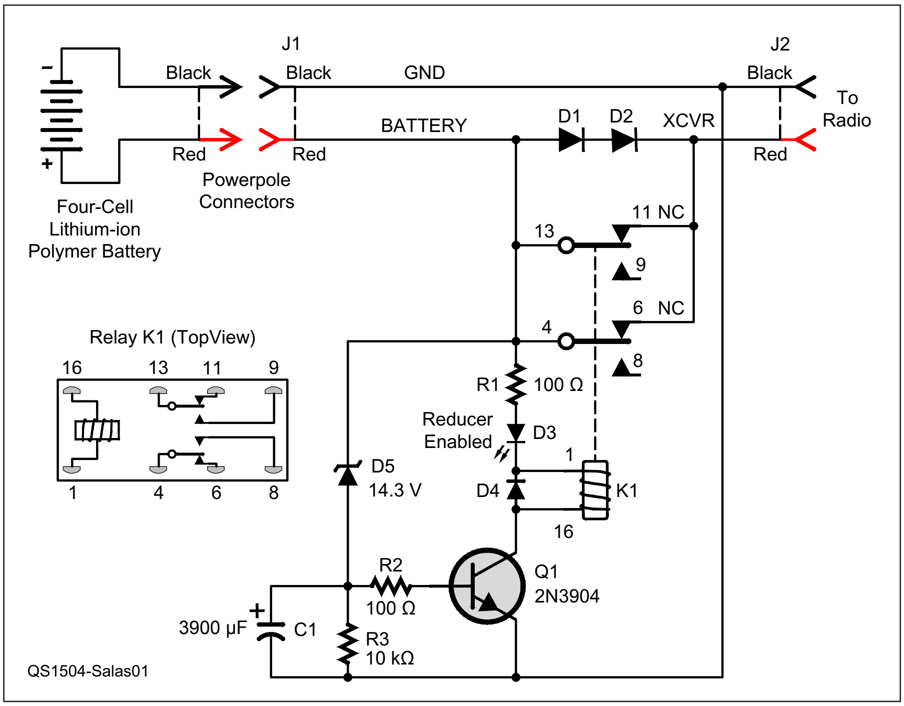


**Figure 1** — Schematic diagram of the voltage reducer. Mouser (**www.mouser.com**) part numbers in parentheses.

C1 — 3900 µf 2.5 V electrolytic capacitor (647-PLG0E392MDO1)
D1, D2 — 1N5401 Schottky diode (821-1N5401)
D3 — Red high brightness 5 mm round LED (638-MV8114)
D4 — 1N4001 Si diode (512-1N4001)
D5 — NZX14C,133 14.3 V Zener diode (771-NZX14C,133)
J1, J2 (Black) — Anderson Powerpole black connector and contact (879-1330G4)
J1, J2 (Red) — Anderson Powerpole red connector and contact (879-1330)
K1 — 12 V, 3 A DPDT relay (655-V23105A5003A201)
R1, R2 — 100 Ω ¼-W resistor (660-MF1/4DCT52R1000F)
R3 — 10 kΩ ¼-W resistor (660-MF1/4DCT52R1002F)
Q1 — 2N3904 Si NPN transistor (610-2N3904)
2 ea — Powerpole mounting bracket (879-1462G1)
1 ea — Hammond plastic box 3.3 × 2.2 × 1.4 inches (575-199316)
1 ea — 16-pin socket for relay (546-1591LS-BK)
Q1 — 2N3904 Si NPN transistor (610-2N3904)
2 ea — 4-40 x ¼ inch threaded standoff (636-160-000-006R032)
2 ea — 4-40 x 9/16 inch screws with nuts and lockwashers
1 ea — circuit board (Contact author for availability of printed circuit boards or ExpressPCB layout files. A few fully built assemblies may also be available.)

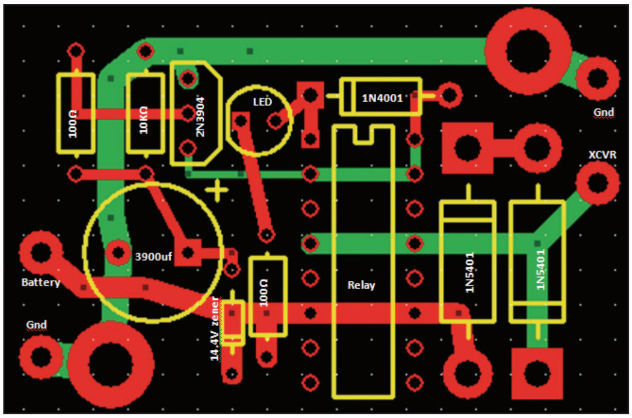


**Figure 2** — Voltage reducer PC board layout. The LED/D3 anode (long lead) is closest to the 2U3904.

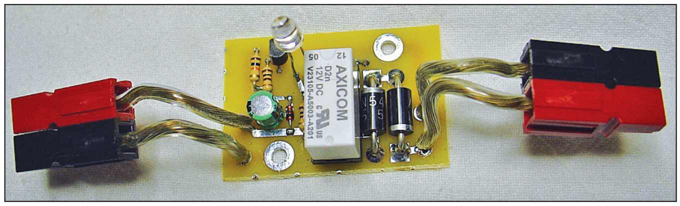

**Figure 3** — Voltage reducer prior to installation in case. The Powerpole input and output connectors are wired to the PC board with 1½-inch #16 AWG stranded wire pigtails.

A high-brightness LED D3 and a 100 Ω resistor R1 are wired in series with the relay coil. The LED illuminates when the relay is activated, indicating that the voltage to the BATTERY input is still above the 15 V threshold and that the voltage to the XVCR output will be reduced by the two voltage-dropping diodes D1 and D2. Diode D4 suppresses kickback voltage from the relay coil when the relay is deactivated. The 3900 μF electrolytic capacitor C1 provides noise and ripple immunity. The 10 kΩ resistor R3 guards against leakage current and ensures that Q1 turns off completely.

The relay control circuit does require some power to operate: 26 mA is drawn by the circuit for a LiPo battery voltage of 16.8 V, dropping to 19 mA at 16 V and 10 mA at 15 V just before the relay drops out. No current is drawn by the circuit once the relay drops out. Operation is completely automatic, and the voltage to the radio is not interrupted when the relay switches. At the beginning of the LiPo battery's discharge cycle, when the voltage is being reduced, some power is dissipated by diodes D1 and D2. For my KX3 running at 10 W and drawing about 2 A, the diodes will dissipate about 4 W during this phase. However, this drops to zero once the 15 V threshold is passed and the relay is deactivated.

This design has a number of advantages over a solid state solution. It is simple, inexpensive, and easy to build. The relay has intrinsic hysteresis, as it requires more current to enable it than to keep it enabled (typically 10 mA to enable and 0.6 mA to keep it enabled). There is essentially no voltage drop across the relay contacts, and no current is drawn when the relay drops out (a saturated power transistor has some voltage drop and requires constant base current while saturated). A switching regulator requires filtering and/or shielding and normally draws current all the time. Finally, this sealed relay is very reliable (the lifetime is specified at 500,000 operations typical in this application), but it is easily replaced should it ever fail.

## Construction

The circuit layout and construction technique are not critical. While I could have easily built the circuit on perforated circuit board, I anticipated that I would need more than just a single unit, so I decided to lay out a printed circuit (PC) board. Figure 2 shows the component locator for my layout. Contact me for PC board availability. I even have a few full PC board assemblies, or I can provide the ExpressPCB layout if you wish to make your own board.

The voltage reducer is housed in a 3.3 × 2.2 × 1.4-inch plastic box. I originally considered combining the battery and voltage reducer in a common box, but decided that would be too battery-specific, so I opted to use Anderson Powerpole™ connectors for the voltage reducer's input and output to simplify the insertion of the unit between the battery and radio.[1]

Prepare the Powerpole connectors by attaching 1½-inch #16 AWG stranded wires to the connector pairs. The Powerpole connectors slide into slots that are 0.6 inches wide by 0.4 inches deep, nibbled into the left and right sides of the box and are held firmly in place by the box cover. Alternatively, you can use the Powerpole mounting brackets called out in the parts list.

Solder the LED D3 to the PC board so that its base is 0.9 inches above the board's surface. When the PC board is mounted with the ¼-inch standoffs and in the box called for in the parts list, D3 will just poke through a hole in the top cover. Figure 3 shows the assembly ready for mounting in the box and Figure 4 shows an internal view of the completed voltage reducer.

Figure 5 is an external view of the voltage reducer next to the 4S2P 5200 mAh LiPo battery I use (4S2P stands for four cells in two packs). Incidentally, as you can see in Figure 5, this LiPo battery pack has "standard" Anderson Powerpole connectors. Many of these battery packs come with RC (radio control) connectors. Replacing RC connectors with Powerpole connectors can be dangerous due to the very high current output capability of these batteries. Unless you really know what you are doing, build or buy an adapter cable.

I used Casio white-on-clear tape to label the box. You could also mark the box with a silver Sharpie® permanent marker pen.

## Changing Output Voltage

While the voltage reducer circuit was designed for my Elecraft KX3, which has a maximum external dc input voltage of 15 V, it is easily changed to comply with different maximum voltage limits. For example, the new TEN-TEC 539 QRP transceiver has a maximum input voltage specification of 14 V dc. For this radio, change the 14.3 V Zener, D5, to a 13 V Zener and replace the two series diodes, D1 and D2, with three 1N5401 diodes to drop the fully charged 4S LiPo voltage from 16.8 V to under 14 V. If you are using the same printed circuit board described in the Construction section, replace one of the horizontally mounted 1N5401 diodes with two vertically mounted 1N5401 diodes and solder their open leads together.

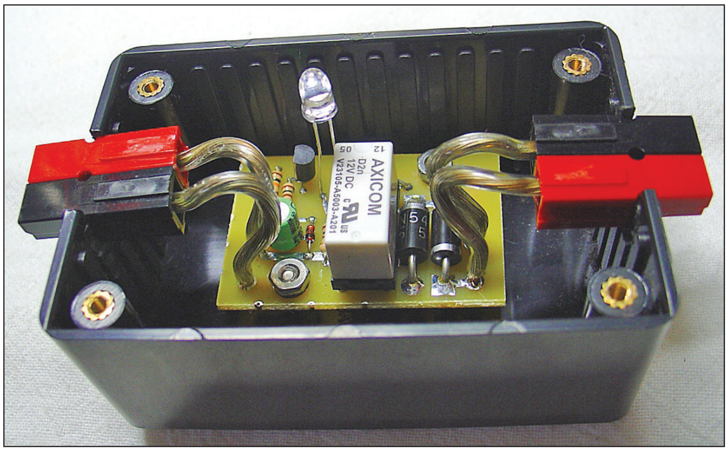


**Figure 4** — The voltage reducer mounted in a Hammond plastic box with Powerpole connectors slid into slots made with an inexpensive nibbling tool. The Reducer Enabled LED stands above the PC board to just poke through a hole in the box's top cover.

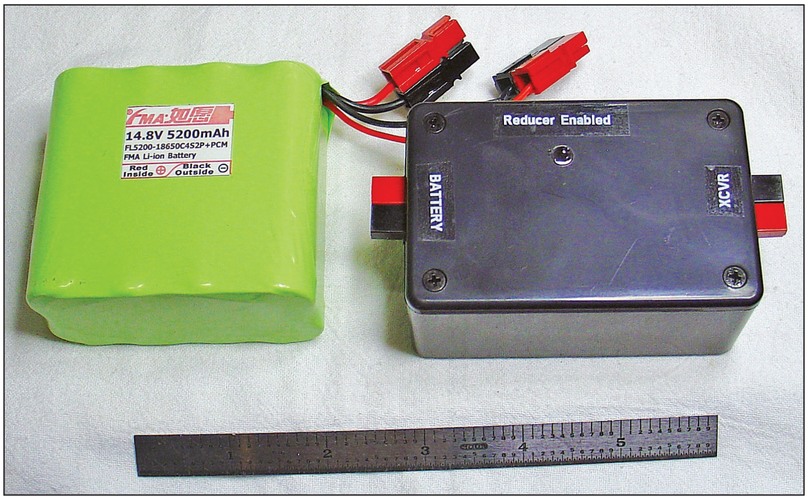


**Figure 5** — The assembled voltage reducer alongside a four-cell 5200 mAh LiPo battery. Even though the battery label lists 14.8 V, a freshly charged four-cell LiPo battery will have a voltage of 16.8 V, which is too high for most portable radios.

## Operation

The voltage reducer is simple to use: first connect a fully charged four-cell LiPo battery to the BATTERY input Powerpole connector and then connect the unit to be powered to the XCVR output Powerpole. With a 14.3 V Zener diode, the relay will activate at exactly 15 V, as indicated by the Reducer Enabled LED. For LiPo battery voltages below 15 V, the relay will open and full battery voltage will be applied to the load. Again, when the relay opens, no current will be drawn by the circuit.

## Test Results

I made some voltage measurements with the automatic voltage reducer connected in-line between a fully charged 5200 mAh 4S2P LiPo battery and my Elecraft KX3 transceiver. The KX3 output power was set to 10 W and the dc current was nominally 2 A. The KX3 power supply voltage was monitored by the KX3 internal voltmeter. The results were as follows: LiPo battery voltage 16.8 V; KX3 (receive) 14.9 V; KX3 (transmit, key up) 14.6 V; and KX3 (transmit, key down) 14.1 V.

I continued to monitor the battery voltage over time. When the LiPo battery voltage dropped below 15 V, the reducer automatically shorted the diodes. Just before this occurred, the transmit-key-down voltage was 13 V. Finally, even though LiPo batteries have a low-impedance, high-current output there was some battery voltage variation under keying conditions. However, the hysteresis of the relay along with the filtering provided by the 3900 μF capacitor prevented relay chatter during keying even as the battery voltage passed the voltage reducer trip point. While there was a 400 mV peak-to-peak ripple on the battery output voltage under the 2 A keying load, there was almost no ripple on the base of the 2N3904 relay control transistor.

## Conclusion

New battery technologies continue to improve the ease and convenience of portable operation, especially for the QRP operator. Of course, there are usually trade-offs when any new technology is implemented. The voltage reducer circuit described here automatically overcomes potential over-voltage problems when using some lithium-ion battery packs with existing 12 V QRP transceivers.

[1]An article describing a unitized version of the voltage reducer and LiPo battery built into a single case is available on the author's website at **www.ad5x.com**.

Photos by the author.

Amateur Extra class license holder and ARRL Life Member Phil Salas, AD5X, has been licensed since 1964. His early Amateur Radio interests led to BSEE and MSEE degrees from Virginia Tech and Southern Methodist University respectively, followed by a 33-year career in microwave and light wave telecom design and management. Now retired, Phil, a frequent *QST* contributor, is busier than ever, tinkering with electronics, playing with his grandsons, but mostly enjoying time with his wife Debbie, N5UPT, who is also his best friend. You can reach Phil at **ad5x@arrl.net**.

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