# UNDERSTANDING AND USING 723 VOLTAGE REGULATORS

# Simple circuits for chargers through test bench use

# ΡΗΟΤΟ Α



All units use the 723 voltage regulator. Left-13.8 volt power supplies. Center-On top of the 28 A 13.8 volt power supply are two quick/trickle chargers. Right-On the bottom is a bench power supply. Above, battery charger (black meter) and to its right a 1.6 A 13.8 volt power supply.

have read many articles on voltage regulation and power supplies and always learn something new from each one. I built my first-regulated, current limited power supply over 10 years ago. Since that time I have built quite an assortment of low-voltage dc power supplies. **Photo A** shows a few of them. In fact, not everything in the photo is a "power supply" — I'll explain that later.

Everything in **photo A** has one thing in common, the "723" voltage regulator (LM723CN,  $\mu$ a723CN, or equivalent number). It's adjustable from 2 to 37 volts, and has foldback current limiting. These features make it extremely versatile. This is basically an article on applications, but you'll still need an understanding of the circuit used with the 723 regulator (**fig. 1**).

# basic components

The projects focus on three items: R2, the voltage adjustment; R4, the current limit resistor; and Q1, the pass transistor. By varying these three things you can construct some interesting and useful equipment.

R2 is used to vary the voltage (fig. 1) from about 7 to 37 volts, less if  $V_{in}$  is less than 40 volts. (A different circuit for the 723 is required for voltages from 2 to 7 volts and will not be discussed here.)

R4 is a current limit resistor. The 723 regulator limits the flow of current through Q1 when it senses a voltage drop (on pins 2 and 3 of U1) of approximately 0.65 volts across R4. If R4 is 1 ohm, the current limit is 650 mA; 10 ohms for R4 gives a 65-mA current limit and 0.1 ohm gives a 6.5-A current limit.

Pass transistor, Q1 in **fig. 1**, handles the desired current load. Most sources rate the 723 regulator at 150 mA but I've seen it rated at 50 mA. Although the 723 regulator is protected by thermal shutdown, I've found that it can only stand a couple of shutdowns before failure. Because most of the uses for the 723 regulator require more than 150 mA, the pass transistor or multiple-pass transistors are used to handle the desired maximum current. My experience shows that the 723 regulator likes loads well under 50 mA.



The 2N3055 in a TO-3 case is a good choice for the pass transistor. It is an inexpensive power transistor rated at 15-A and 115-watts dissipation. I never push the 15-A rating but would rather use several pass tran-

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Use of "Darlington pair" (Q2, and Q3) for pass transistor reduces load on the 723 regulator.



sistors in parallel and let each one handle about 5 or 6 A. You must also consider power dissipation, and adequate heat sinking is required. A single 2N3055 for Q1 requires about 17-mA drive for a 0.5-A output and about 100-mA drive for a 2-A load on Q1. As you can see, the 723 regulator's output capacity can be quickly exceeded just to drive a single-pass transistor.

# safely loading the regulator

A good way to handle the required drive to the pass transistor without overloading the 723 regulator is to use a "Darlington pair". **Figure 2** shows Q2 and Q3 in a Darlington configuration. Q2 is the driver for Q3. I didn't show a Q1 in this diagram because I want you to think of Q1 as being mounted on the voltage regu-

# FIGURE 4



parts list	
C1	100 to 500 pF
C2	2.2 μF tantalum
C3,C4	0.05 to 10 μF
C5	100 μ <b>F</b>
C6	0.01 μF
CR1	15 v 1 watt zener diode
Q1	2N3055
Q2	SCR to suit current wax
R1,R3,R5	1k ohms
R2	5k potentionmeter
R6	220 ohms
R7	10k ohms
R8	1.5k ohms 1 watt
U1	LM723CN regulator
R4	Current limit resistor 0.1 ohm
	5 watt wire wound for 6.5 A
	limit; 10 ohms for 65 mA limit.
C3 and C4	are only used if needed to
eliminate 1	riggering of SCR by transients.

lator circuit board. With the high gain of the Darlington pair, the drive to Q2 from the 723 regulator is only 0.7 mA for a 2-A load and 1.5 mA for a 3-A load. The 723 regulator is now barely loafing.

Now let's look at a "super duty" current, maybe 30 A. **Figure 3** shows a circuit with two drivers and three or more pass transistors (Q3, Q4, and Q5). The 0.1ohm 5-watt emitter resistors are important because they make the multiple pass transistors share the load. The 22-ohm resistor attached to the base of each pass transistor also helps equalize load, but these resistors are not absolutely necessary.

Another important design feature is the overvoltage protection or "crowbar". A crowbar is typically a circuit which detects voltage exceeding a fixed value and fires an SCR to short circuit the input supply to the regulator circuit and blow a fuse. The term crowbar probably comes from the use of brute force to blow the fuse and stop the overvoltage condition. Don't try to blow a 35-A fuse with a 6-A SCR!

A common crowbar circuit is shown in **fig. 4**. Capacitors C3 and C4 help prevent false triggering of the SCR by transients and spikes. But it's really not false triggering at all; the crowbar is doing exactly what it is supposed to do. If you connect an oscilloscope to the output of your power supply and turn the power switch off and on a few times, I think you may be surprised at the spikes. These spikes are a real nuisance and can be very difficult to suppress.



Overvoltage circuit<sup>1</sup> using the MC3423 overvoltage sensor.



28-A power supply. Note switch for 2-speed fan.

An excellent article on overvoltage protection using an MC3423 overvoltage sensor specifically designed to fire a crowbar was written by VK5IK.<sup>1</sup> The MC3423 circuit is shown in **fig. 5**.

**Photo A** shows two mini-boxes on top of the 28-A power supply. These are battery chargers for an HT. The box with the black-faced meter is a NiCd battery charger with two outputs — one with adjustable current and one with fixed output. The bench supply on the lower right has both adjustable voltage and current capability.

Let's take a closer look at how the 723 voltage regulator is used in some of this equipment. The high ampere power supply in **photos B**, **C**, and **D** was used



Back of 28-A power supply. The "driver" is the transistor at the lower left. At the lower right is a 35-A fuse holder. The other six transistors are 2N3055 pass transistors.



28-A power supply wiring. Voltage regulator board is at upper left. The crowbar is on the separate board at the lower left. Note the five 0.1 ohm 5 watt current limit resistors soldered to the two buss wires.

for several years with my TR7A and several Atlas transceivers. You can keep a two-speed fan on low for any current under 10 A continuous and all SSB operation. The heat-sinked full-wave bridge at the lower right of **photo D** comes from diodes "liberated" from the horseshoe rectifier assembly of a 65-A automotive alternator. These rectifier assemblies contain six diodes and usually only one fails.

My latest power supply is shown in **photo E**. The meters were hamfest specials, both 0-1 mA with shunt or series resistors as needed. This is the first time I have made and used a pc board. I "married" the VK5IK overvoltage circuit to my 723 circuit. To reduce unwanted triggering of the SCR, I found it necessary to increase C2 of the VK5IK circuit to 0.047  $\mu$ F.



12 A power supply with "matched" meters for 0-20v and 0-10 A.

The two-output battery charger in **photo A** (box with black meter) uses two separate 723 circuits from the same dc input source. The fixed output is limited by R4 to 15 mA to trickle charge AA NiCds. The voltage is set to perhaps 24 volts, plenty for a dozen or more AA cells at a time. Because the current limit is fixed, it doesn't matter whether one or a dozen AA cells are on trickle charge; no adjustment is necessary. I did place an LED in this output to show when current is flowing — this eliminates the need for a meter.



The second output is current adjustable from about 12 mA to 300 mA by the use of a fixed resistor in series with a potentiometer (**fig. 6**). Again the voltage is set high enough to charge a large number of cells at one time. The charge rate remains constant until you change the adjustment.



The 0 to 1-A bench supply shown at the lower right in **photo A** is another variation of the battery charger described above, with R2 mounted on the front panel for convenient voltage adjustment. (Well, that's almost how I did it!) I found that the minimum voltage adjustment using the 5k pot with the 1k resistors (R1 and R3) was just under 8 volts. I tried to get the lowest possible voltage and changed R1, R2, and R3 as shown in **fig. 7**. The change didn't do everything I wanted (remember the circuit used for the 723 has a lower limit of 7 volts), but because I had already added the second potentiometer to the panel I didn't change it. Replacing the 2.2-ohm resistor in **fig. 6** with a 0.65ohm 1-watt resistor (actually a couple of resistors in



Battery charger for HT uses voltage doubler on left half with 723 circuit on right half.

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#### **FIGURE 9**



Component side of the basic 723 regulator PCB showing component location (enlarged view).

# **FIGURE 10**



parallel) allowed me to attain the 1-A current limit. I use this bench supply primarily as a battery charger.

I then made a battery charger for an HT (**photo F**) which will both quick and trickle charge. I selected R4 to limit the current to 150 mA (I have also used 450-



mA limit). I adjust the voltage with a fully charged battery pack and a milliammeter in the circuit so that the charger will float across the battery pack at 15 mA. I even keep the charger connected while using the HT. The quick charge is not quite as good as more sophisticated circuits which maintain a maximum rate until a set point and then switch to the low rate. The 723 circuit starts out at maximum charge but tapers off as the voltage of the battery pack increases with the level of charge. The quick charge is effective to about 60 percent of full charge before it passes through a normal rate and finally to the 15 mA trickle rate. It's not





fancy but it sure beats the charger supplied with the HT.

The charger in **photo F** has a voltage doubler. It was originally built to use with a TR2400 with an 8cell battery pack. I used the charger in the car, but found that the car's electrical system voltage wasn't high enough to charge the HT battery pack unless the motor was running and the car's voltage was about 14.1 volts. I added the voltage doubler circuit<sup>2</sup> and it solved the charge problem. But this little device puts out a lot of RFI. It seems to be a broad-banded frequency sweeping RFI on any hf frequency. I'm not sure how it would work if enclosed in a shielded minibox.

I built another HT battery charger without the voltage doubler for use in the shack. I now have an HT with a 7-cell battery pack so I can use the car's electrical system, a 13.8-volt power supply, or a wall-type dc module.

I have included several circuit board designs. Figure 8 is the basic 723 voltage regulator circuit. The component side is shown in fig. 9. The pc board has provision for the on-board driver. If the driver is mounted on the board, E1 (not B) goes to the base of the pass transistor or the second driver. The collector voltage to the on-board drive is supplied by C1. The same pc board is shown in fig. 10 with a conventional crowbar circuit added; figure 11 shows the component side. A 4 to 6-A SCR can be mounted directly on the board, but SCRs for higher current applications should be mounted remotely (no heat sink required) and R7 connected directly to the SCR.

Figure 12 shows the 723 circuit "married" to the VK5IK circuit. Figure 13 has multiple 723 circuits from a common supply so you can have multiple outputs and charge NiCds or gel-cells from the same supply simultaneously.

#### references

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Article G

# HAM RADIO

