AUTO VIM: PART 2

Part II: Smart power supply for every bench

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Current Monitor

Although voltage monitoring circuits are growing more common in bench supplies, there's still little useful current monitoring. A single meter for gross current measurement provides little help for monitoring low current circuits, while a sensitive meter pegs long before the supply nears its maximum rated output. Automatic monitoring of both positive and negative current drain appears only in expensive industrial and lab equipment in the $2,500-and-up class. A simple, reliable, and effective current monitoring circuit, however, has long had a place in the data books.

The current monitor in Auto-VIM owes much to National Semiconductor's Linear Databook circuit for routinely converting current drain to a voltage output without resorting to ultra-precise resistor matching.

The sensor circuits in Figure 4 use different op amps to sense positive and negative current flow. The TL081 (or LF351) Bi-FET op amp uses P-channel inputs which work with input voltages close to the positive supply value, but fail as the input voltage approaches the negative supply voltage. By contrast, the newer TI NFET op amp, the TL091, with its N-channel inputs, shows precisely the opposite characteristics. Between the two, we obtain separate but parallel sensors for positive and negative supply currents.

The transistors, whose base current is controlled by the op amp output, control the voltage seen at the 3.3kΩ resistor. In fact, the circuits provide an output voltage per mA of line current equal to .001 times the product of R1 and R3 divided by R2. The circuit shown provides .0033V per mA, or 1.65V at 500 mA. Sensor circuit output is positive for the TL081/2N3904 combination and negative for the TL091/2N3906 duo. Although most data book circuits show FETs rather than transistors used with the FET input op amps, the bipolar transistors work better at the 5V end of the power supply range. Note the 10-turn trimmer pots marked Rb, which will receive attention during circuit calibration.

A DC amplifier follows each sensor to increase the voltage to a level desired for measurement. As with the voltage monitor, the negative amplifier inverts while the positive does not, thus yielding positive voltages for the bilateral switch. Each amplifier has a gain of 6.7 so that the metering circuit will see 12V at 500 mA, which is within the linear range of the op amps and within the switching range of the 4066. Each section of the LF353 includes an offset balancing circuit to decrease errors introduced by remnant voltage outputs.

The 4066 bilateral switch operates just as in the voltage monitor, switching in time with the positive and negative readings according to the signals from the flip-flop. One section performs another chore, that of shorting and unshorting part of the meter resistor chain as the current rises above or falls below 50 mA at the sensors. A section of a 339 comparator causes the output to change whenever the inverting input passes 1.2V. The resistor chain includes separate calibration trimmers, Rm, for each range. A 50 mA meter from Radio Shack with an internal resistance of about 2150Ω forms the base from which the other resistor values were calculated. The 1N914 and the 1.5V Zener provide meter protection.

Two of the remaining 339 sections control indicator lights which tell the user which range the meter uses. With the values shown, the circuit flips to the high range just as the needle passes the 50 mA mark, and returns at about 45 mA. The difference derives from the introduction of a small amount of hysteresis (the 5MΩ feedback resistor) to obtain good switching action with slowly changing voltages. The circuit is more than fast enough to protect itself when going from nearly no current on one polarity to nearly full current on the other. It's much faster than any mechanical or heating effects upon the meter.

Output for a digital voltmeter emerges directly from pins 4 and 1 of the 4066. If the digital meter has a three or three and a half figure readout, the builder can omit the autoranging feature and the indicator lights. This option permits using one 4066 for both monitors, since each 4066 has four independent switches per package. Set the gain of the DC amplifiers to a level giving the desired voltage per mA for the digital metering circuitry.

As with the voltage monitor, construction is not critical, and the parts fit on a 3 x 3 ½-inch perfboard backed against the voltage monitor board with four ¾ inch pillars. The squeeze is a bit tighter due to the larger sensor resistors (.22Ω at 3 watts) and the number of trimmers. Again, be sure all trimmers are accessible for later adjustment.

Calibrate the current monitor in sections, starting with the sensors. In fact, I added input and output pins for the sensors and DC amplifiers (shown as small circles in Figure 4), only connecting them together after initial adjustments. The TL081/091 op amps require careful balancing, hence the use of 10 turn pots.

Circuit output with no current load on the supply will go to zero and jump to a few volts of the opposite polarity. Set the value as close to zero as possible. Check the balance across

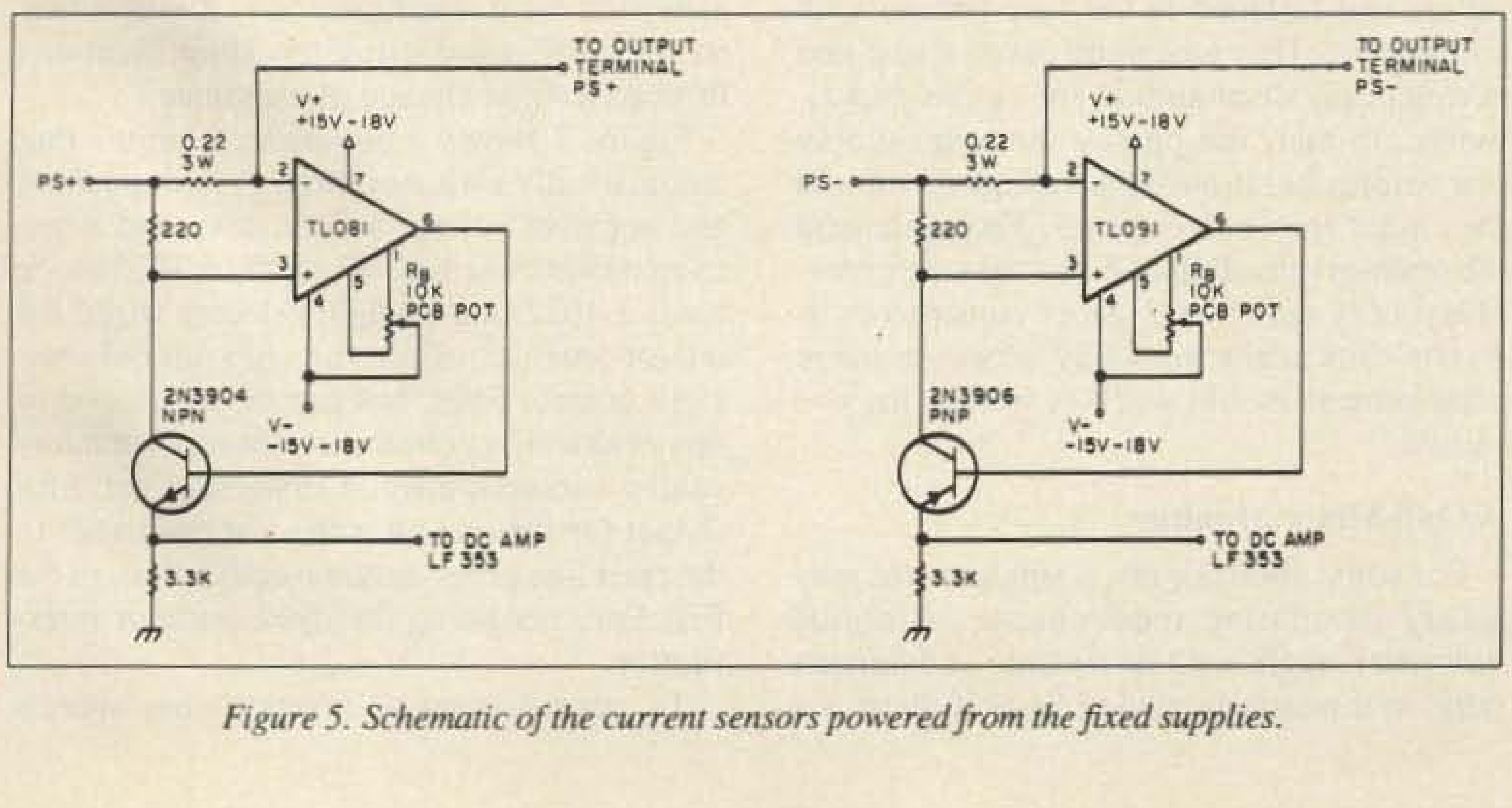

Figure 5. Schematic of the current sensors powered from the fixed supplies.

the full power range, as the remnant voltage will vary according to how well the positive and negative lines track each other. Be sure it never changes polarity for any voltage in the power supply range. Figure 5 shows a slight variation in the sensor circuits, with op amp power derived from the fixed supply. This method yields lesser remnant voltages as the power supply changes voltage, but is limited by the fact that the fixed supply and the upper limits of the variable supply are so close together. The sensor goes nonlinear as the variable supply approaches the fixed supply.

For this circuit, an 18V dual fixed supply for the sensor circuits would be ideal, although this value would exceed the limits on the CMOS chips. Hence, for the bench supply shown, powering the TL081/091 sensors from the variable supply provided more accurate readings, with a maximum remnant reading of under 2 mA at the meter.

Separately balance the DC amplifiers by grounding their input resistors and adjusting the balance trimmers, Rb, for no output. Connect the sensor outputs and adjust the gain of each amplifier, using some standard high wattage resistors to set calculable loads. A 1000Ω, 5W resistor, for example, will provide a load of 5 mA at 5V, 10 mA at 10V, and 15 mA at 15V, while a 250Ω, 5W resistor will quadruple all values. Set the comparator trimmer, Rt, for an input of about 1.2V.

Using a small load, adjust the 2kΩ meter trimmer for accurate reading at or near full scale. Using a larger load (just being sure that the meter shifts from the 50 to 500 mA scale), adjust the 20kΩ meter trimmer for accurate readings. Now monitor changing loads to be sure the meter shifts range as desired, and check that the LEDs indicate the proper range.

Although the calibration procedure is somewhat complex as such things go, it permits the building of an auto-polarity, autoranging circuit with common, inexpensive components. In my view, spending ham time instead of family money makes good sense.

Final Assembly

The entire supply and control circuitry fits into a cabinet 3 inches high by 5 inches deep by 8 inches wide. All controls, fit on the front panel. The fit is close, but more than adequate. The meters obviously take up the most space. For convenience, even the fuse has its front panel space.

Between the front panel and the boards, there is about an inch and a half of space for panel components and their leads. This eases final assembly, which requires a considerable number of connections to the panel and from one board to another. For low current connections, I used ribbon cable for ease of handling and the built-in color coding that reduces wiring errors. Wherever possible, I connected one end of each wire set before final assembly, taking careful notes on which color wire connected to which other terminal.

The power supply section mounts horizontally on half-inch pillars, and occupies most of the cabinet space. The monitor boards mount vertically back-to-back, separated by

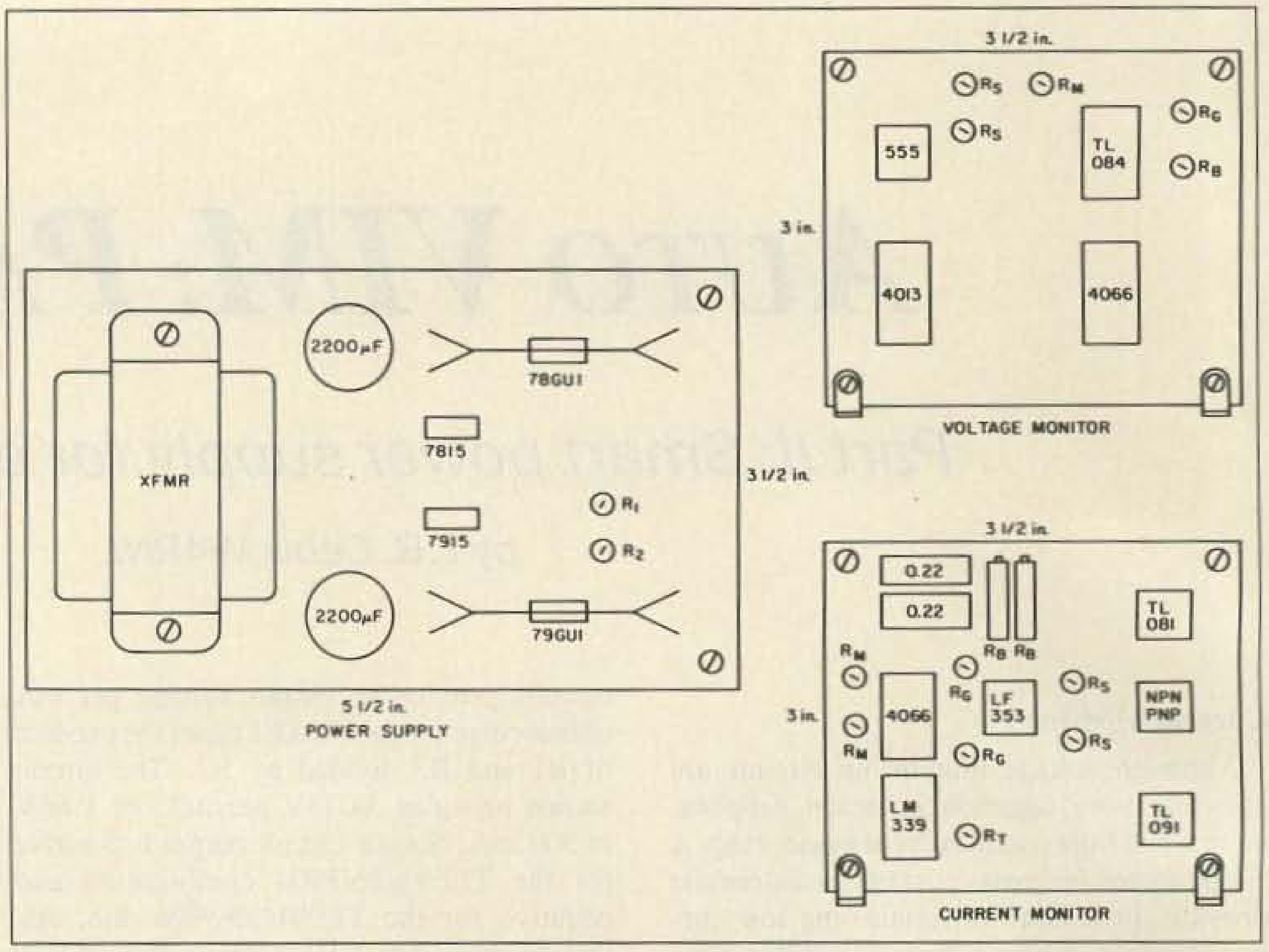

Figure 6. Board layout sketches for AUTO-VIM.

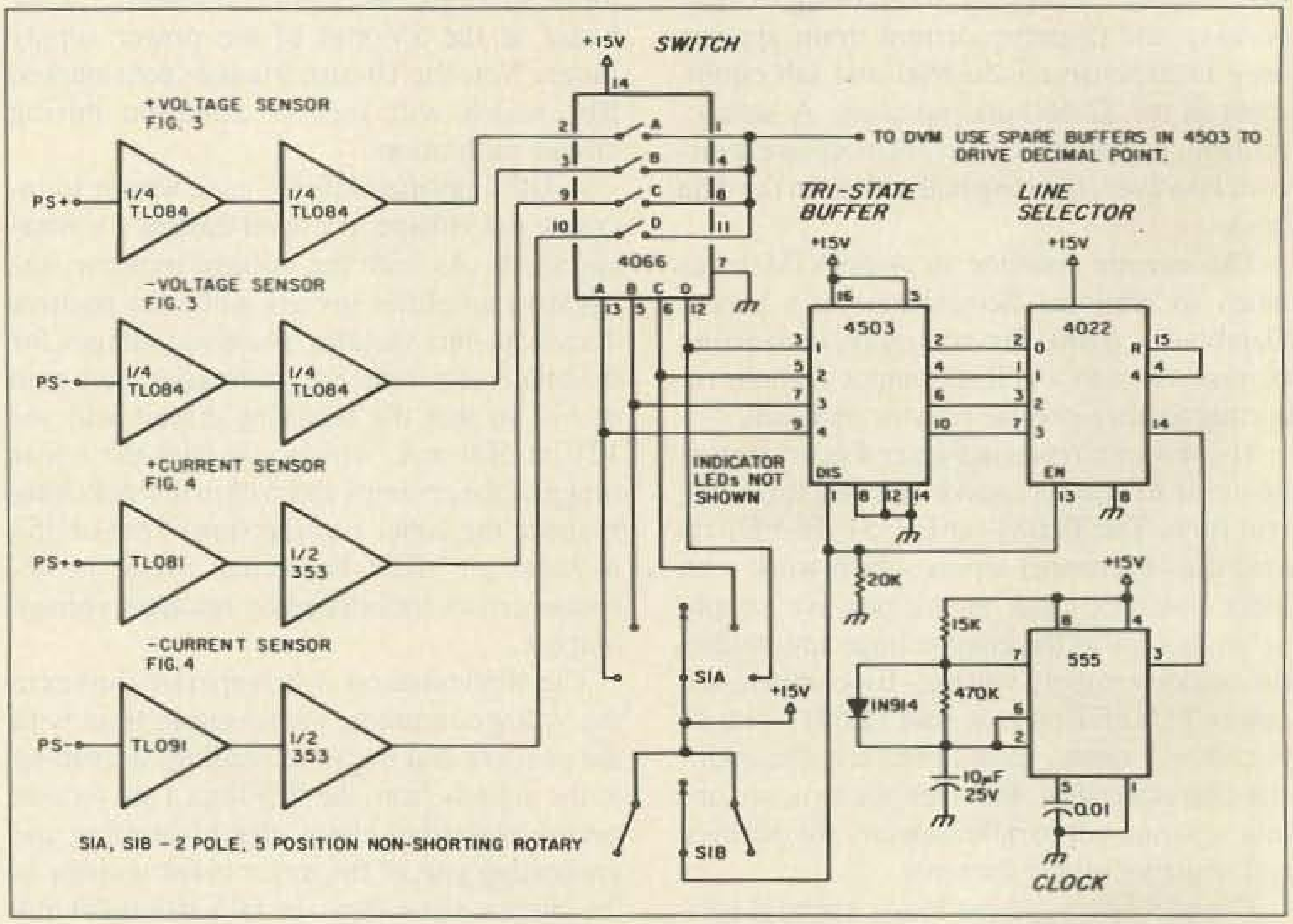

Figure 7. Schematic diagram of a one meter (DVM) auto-polarity voltage and current monitor.

pillars and fastened to the case bottom with L-brackets. This technique saves space and permits easy dismounting for circuit experiments. In fact, the photos show the supply just before alteration of the voltage monitor to the circuit shown in Figure 3. To supplement the photographs, Figure 6 sketches the general layout of each board. Since construction is so non-critical electronically, any convenient arrangement should work as well as the one shown.

A One-Meter Monitor

For some applications, a single meter may satisfy monitoring requirements. A digital voltmeter might well do voltage and current duty on a regularly cycled basis if there is a provision for manual override. A single meter permits some circuitry simplifications through a slight change of technique.

Figure 7 shows a one-meter monitor that automatically switches through both positive and negative voltage and positive and negative current readings. The 555 or 7555 clock feeds a 4022 one-of-eight selector wired for one-of-four use. Since the chip not only has eight control lines, but can be sequenced to others as well, cyclical monitoring over many values becomes easy. Connecting the fifth output (or the one after the last one used) to the reset line gives instantaneous return to the first line, restarting the cycle without interruption.

To permit manual override, the signals

from the selector pass through a tri-state buffer, the 4503. Normally, the selector enable pin (13) and the buffer disable pin (1) are at ground (through a 20kΩ resistor). Under these conditions, the meter cycles automatically. The two-pole, five-position non-shorting rotary switch establishes these conditions in its center position. At any other position, the disable and enable pins go High, interrupting the cycle. The switch also sends the desired 4066 switch control pin High, thus holding the meter on this reading until the switch is returned to the center position. The 4503 outputs will also support indicator LEDs with 1.5kΩ series resistors without further buffering.

The sensors appear only in outline form, since they are identical to those in Figures 3 and 4. Since the TL084 and the LF353 are quad and dual op amp versions of functionally the same circuitry, one can interchange positions for all but the two current input sensors. For this application, separate DC amplifiers for each of the voltage sensors are preferable, since they permit separate calibration of both positive and negative voltage monitors. The 4066 output can drive any analog or digital meter. The only necessary variations will be in amplifier gains to supply acceptable signal levels to the metering circuits.

The monitoring circuits we have looked at are expandable in many directions to serve a large number of monitoring needs. Adding current monitoring to the more common voltage monitoring provides an especially helpful dimension to the average bench supply in the ham shack. Since the whole supply should cost no more than about fifty dollars, including a case and two meters (almost half the cost), there's no good reason why every ham shack should not have a supply with all the benefits of automatic voltage and current monitoring. AUTO-VIM will certainly earn its keep. Having used it for only a few months, I have already recovered its cost in parts I did not burn up. I can now spot trouble before my nose tells me it is too late. ■

[Part 1, including Figures 1–4, was published in the August issue.]

PARTS LIST

Dual Power Supply

Quantity	Part	Source
1	18V, 2 amp transformer	All Electronics
1	½ amp fuse and holder	RS 270-364
1	SPST toggle switch	RS 275-662
1	Line cord	
6	1N4001 50 PIV diode	RS 276-1101
1	78GU1 variable positive voltage regulator	Circuit Specialists
1	79GU1 variable negative voltage regulator	Circuit Specialists
1	7815 +15V regulator	Circuit Specialists
1	7915 −15V regulator	Circuit Specialists
2	2200 µF, 35V electrolytic capacitor	RS 272-1020
2	.1 µF, 35V tantalum capacitor	Digi-Key
1	.22 µF, 35V tantalum capacitor	Digi-Key
2	1 µF, 35V tantalum capacitor	Digi-Key
1	2.2 µF, 35V tantalum capacitor	Digi-Key
1	2 section linear potentiometer, 10kΩ /section	Circuit Specialists
2	500 Ω PC board trimmer pot	Digi-Key
2	1.5kΩ, ¼W resistor	
1	2kΩ, ¼W resistor	
1	4.2kΩ, ¼W resistor	
2	4.7kΩ, ¼W resistor	
2	5.6kΩ, ¼W resistor	
1	LED and panel mount	Jameco
2	Heatsinks for TO-202/TO-220 cases	Digi-Key
1	Cabinet: 3 ½ x 7 ⅛ x 5 ¾ inches	RS 270-269
	Perfboard	
	Mounting posts and hardware	
	T46 or similar connection pins	

Voltage Monitor Parts

No.	Part	Source
1	TL084 quad BiFET op amp	RS 276-1714
1	4066 bilateral switch	Digi-Key
1	4013 dual D-type flip-flop	Digi-Key
1	555 or 7555 (CMOS) timer	Digi-Key
1	0 to 15 voltmeter with external series resistor	RS 270-1754
3	.01 µF, 50V disc capacitors	Jameco
1	2kΩPC board trimmer pot	Digi-Key
2	10kΩPC board trimmer pot	Digi-Key
2	100kΩPC board trimmer pot	Digi-Key
1	100 Ω, ¼W resistor	
2	1kΩ, ¼W resistor	
1	9.1kΩ, ¼W resistor	
3	15kΩ, ¼W resistor	
2	20kΩ, ¼W resistor	
2	75kΩ, ¼W resistor	
6	100kΩ, ¼W resistor	
1	150kΩ, ¼W resistor	
1	470kΩ, ¼W resistor	
2	LED and panel mount	Jameco
1	SPDT Center off toggle switch	RS 275-664
1	8 pin DIP socket	
3	14 pin DIP socket	
-	Perfboard	
-	Posts and hardware	
-	T46 connection pins	
-	Ribbon cable	

Current Monitor Parts

No.	Part	Source
1	TL081 P-channel BiFET op amp	RS 276-1716
1	TL091 N-channel NFET op amp	RS 276-1745
1	LF353 dual BiFET op amp	RS 276-1715
	4066 bilateral switch	Digi-Key
1	LM339 quad comparator	RS 276-1712
1	2N3904 NPN transistor or equivalent	RS 276-1603
1	2N3906 PNP transistor or equivalent	RS 276-1604
1	1N914 silicon diode	RS 276-1122
1	1.5V Zener diode	Digi-Key
1	50 microammeter	RS 270-1751
1	5kΩ PC board trimmer pot	Digi-Key
1	10kΩ PC board trimmer pot	Digi-Key
2	10kΩ, 10 turn trimmer pot	Jameco
1	20kΩ PC board trimmer pot	Digi-Key
4	100kΩ PC board trimmer pot	Digi-Key
2	.22 Ω, 3W 5% resistor	All Electronics
2	100 Ω, ¼W resistor	
2	220 Ω, ¼W resistor	
2	1.5kΩ, ¼W resistor	
2	3.3kΩ, ¼W resistor	
1	7.5kΩ, ¼W resistor	
3	10kΩ, ¼W resistor	
1	20kΩ, ¼W resistor	
1	91kΩ, ¼W resistor	
10	100kΩ, ¼W resistor	
1	220kΩ, ¼W resistor	
1	510kΩ, ¼W resistor	
1	620kΩ, ¼W resistor	
1	5 M Ω, ¼W resistor	
4	8 pin DIP sockets	
2	14 pin DIP sockets	
	Perfboard	
	Posts and hardware	
	T46 connection pins	
	Ribbon cable	

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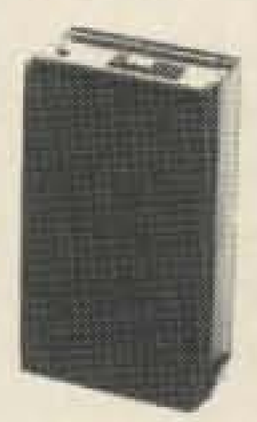

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