Elegant Rotating

K9AZG did it right. W4RNL makes it better. For sightless and sighted hams alike, this update to a 1982 article will be revealing.

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A simple and elegant solution to setting beam headings for both blind and sighted hams is the K9AZG automatic beam aimer (*73*, November, 1982). With a few voltage comparators, transistors, and relays (plus the usual passive and power-supply components), the device controls CDE and similar rotator control boxes so that by setting a single potentiometer, the operator can step back and relax as the beam turns to the desired heading and stops. Sightless hams now have an easy way to determine beam headings reliably, while the sighted ham can use the beam-turning time for tune-up, logging, and other activities.

The original automatic beam aimer used two sections of an LM339 quad voltage comparator to detect the desired change of direction, as shown in Fig. 1. (Fig. 1 is redrawn from the original to show the individual comparators.) Each comparator controls a transistor switch and relay which in turn control the clockwise and counterclockwise switches of the CDE box. Like any good idea, we can improve upon the original and overcome some potential problems. This article describes some improvements which will prevent a few problems that some CDE rotator owners may encounter with the original design.

The Basic Idea

The basic idea behind the

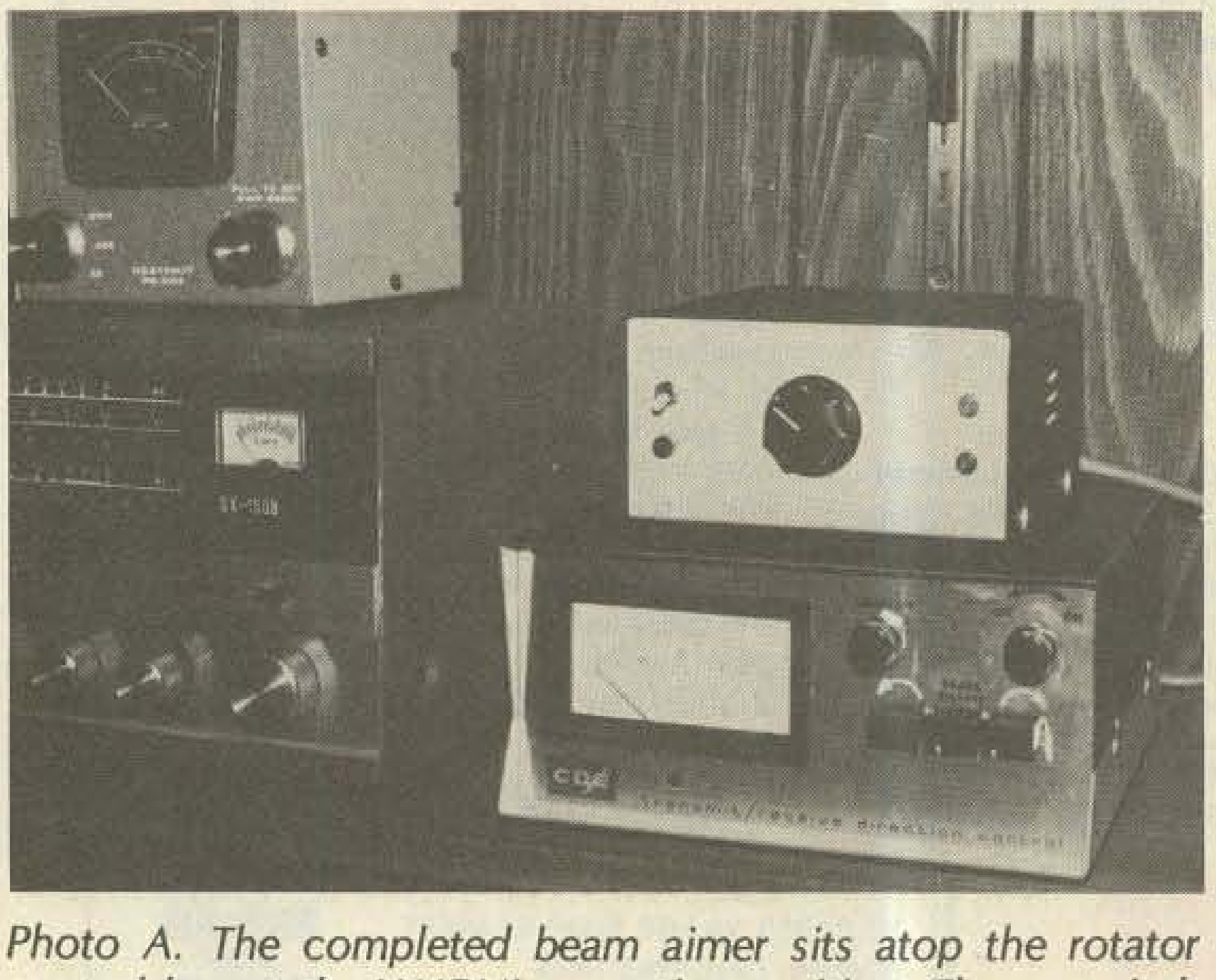


Photo A. The completed beam aimer sits atop the rotator control box at the W4RNL operating position. The ac switch and power LED are to the left and the clockwise and counterclockwise LEDs are to the right. The center knob is the direction control prior to the addition of calibration markings.

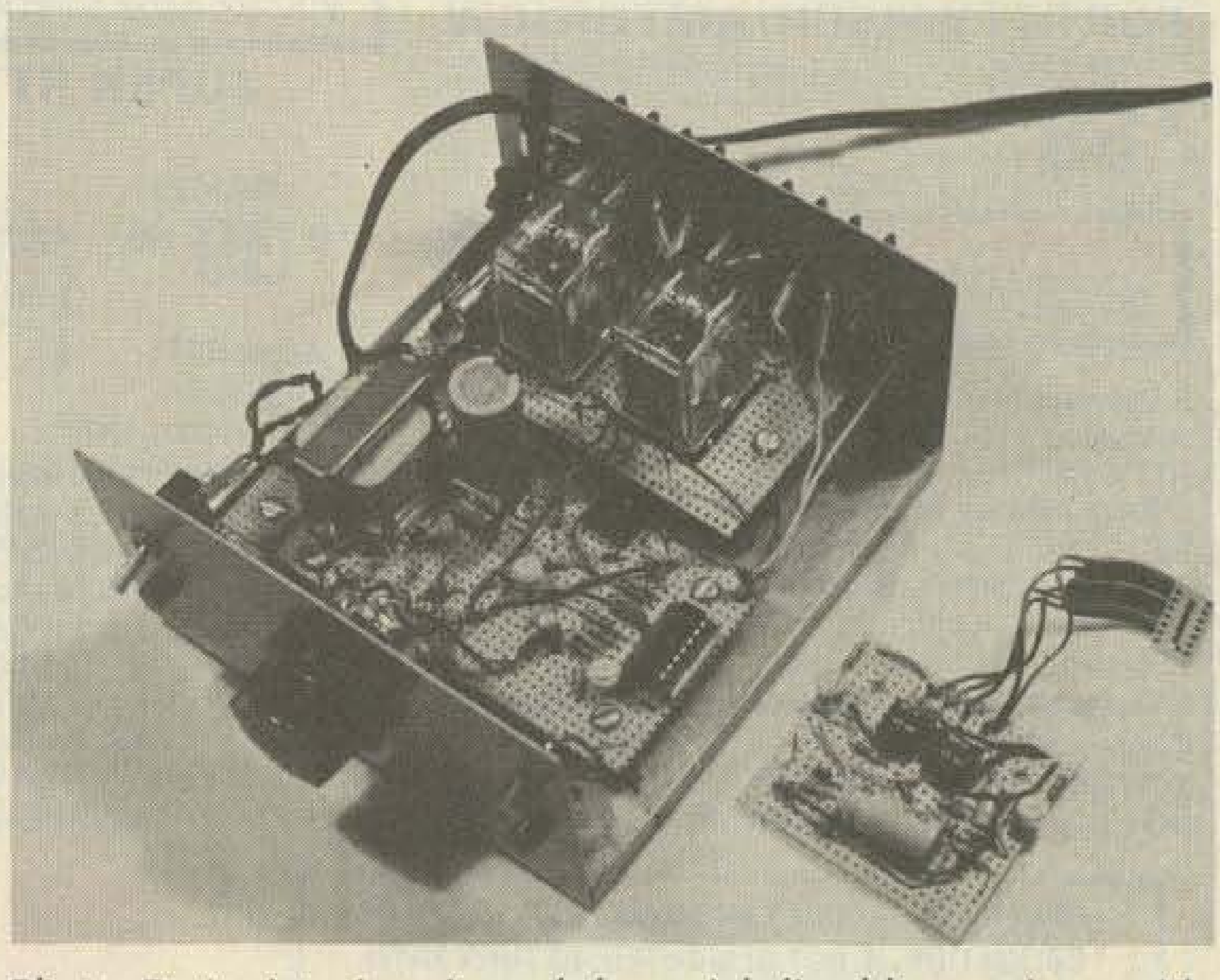


Photo B. An interior view of the quick-fixed beam aimer with the improvement board to the right. The front perfboard contains the power supply and circuitry, while the rear board contains the relays (only two needed for the CD-44).

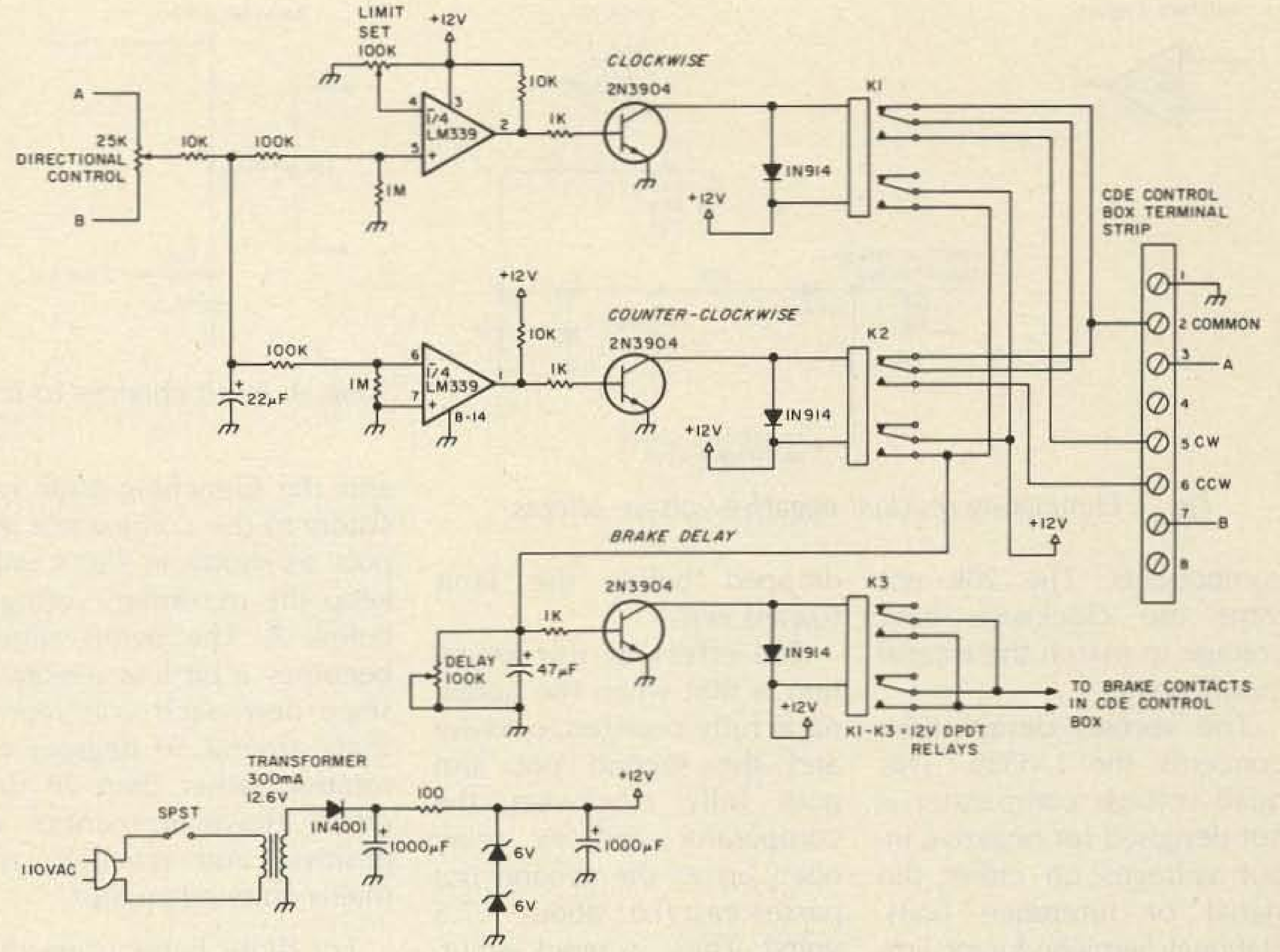


Fig. 1. The original K9AZG automatic beam aimer (redrawn).

automatic beam aimer appears in Fig. 2. The 500-Ohm potentiometer in the rotator head changes value with direction, standing at mid-scale when the beam points north and at one of the extremes as the beam points south. Fed by an ungrounded 13-volt supply, the rotating arm creates a ground, thus changing the voltage across the left and right legs of the pot as the beam moves. From extreme point A to center we get a negative voltage; from point B to center we get a positive voltage; and the absolute values of the two add up to 13 volts.

A second potentiometer across the rotator pot (say, about 25k) will read 13 volts across its extremes. More significant for beam aiming, the voltage between the moving arm and ground will be zero when the arm and the rotator pot arm are equal percentages away from the same extreme point. If the beam points north and the second pot is mid-scale, the voltage at the second pot arm will be zero. If we move the second pot counterclockwise, leaving the beam north, we will show a positive voltage. We get a negative voltage if the second pot arm is clockwise with respect to the beam heading. Together, these voltages allow us to turn on one of two relays that close in parallel to the CDE switches, thus activating the rotator. That is the function of the K9AZG circuit.

The maximum voltage that the comparators in Fig. 1 can see is either plus or minus 13 volts. When the antenna is counterclockwise south and we move the second pot arm clockwise to the other extreme, the arm shows −13 volts to ground. In the opposite condition, when the antenna is clockwise south and the pot is fully counterclockwise, the arm shows +13 volts. If both the antenna and the second pot are at either extreme, the pot arm ideally shows zero volts.

Design Limits and Quick Fixes

Unfortunately, only sometimes can we achieve the ideal conditions noted above. There are two design limits to the original beam aimer that may present problems to some hams. First, the CDE rotators have limit switches to shut off either clockwise or counterclockwise rotation at the south heading. Among other functions, the limit switches serve to keep us from wrapping antenna cables like vines around the rotator and mast stub. The limit switches may leave some residual voltage at either end of the scale. Imagine that the limit switches cut off the rotator at positions X and Y in Fig. 2. If the second pot is at its extreme, some small voltage will exist and the relay will not open. K9AZG counters this at one end of the scale with a calibration pot, but the other end of the scale goes to ground.

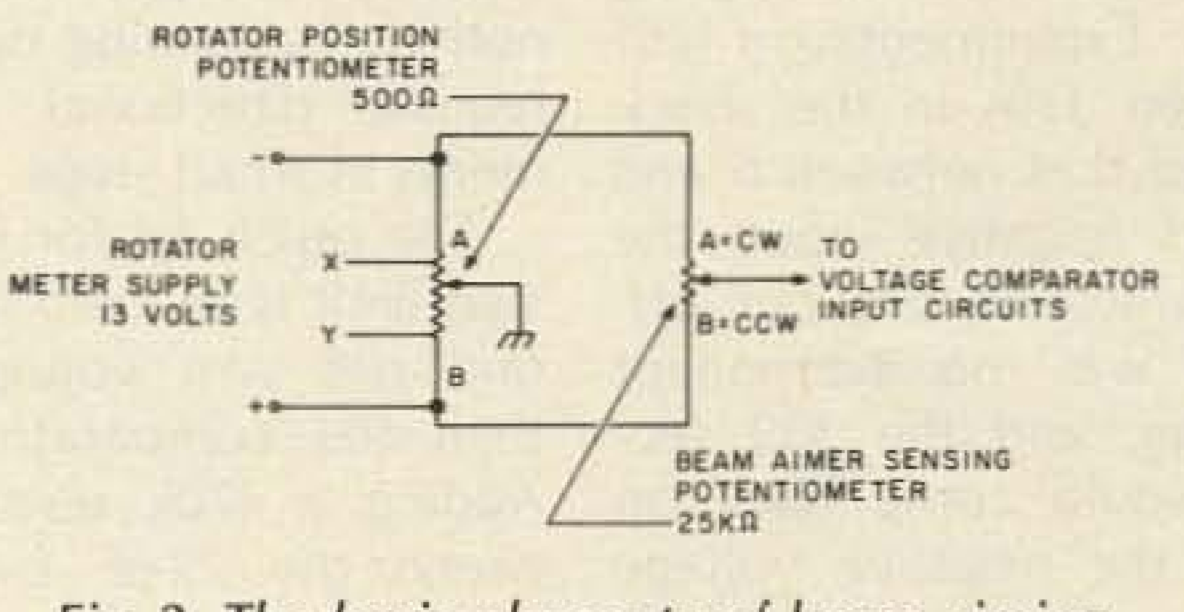


Fig. 2. The basic elements of beam aiming.

The quick fix for this problem is the substitution of a low negative-voltage circuit to replace the ground connection of pin 7 of the LM339. Fig. 3 shows a suitable circuit using minimal

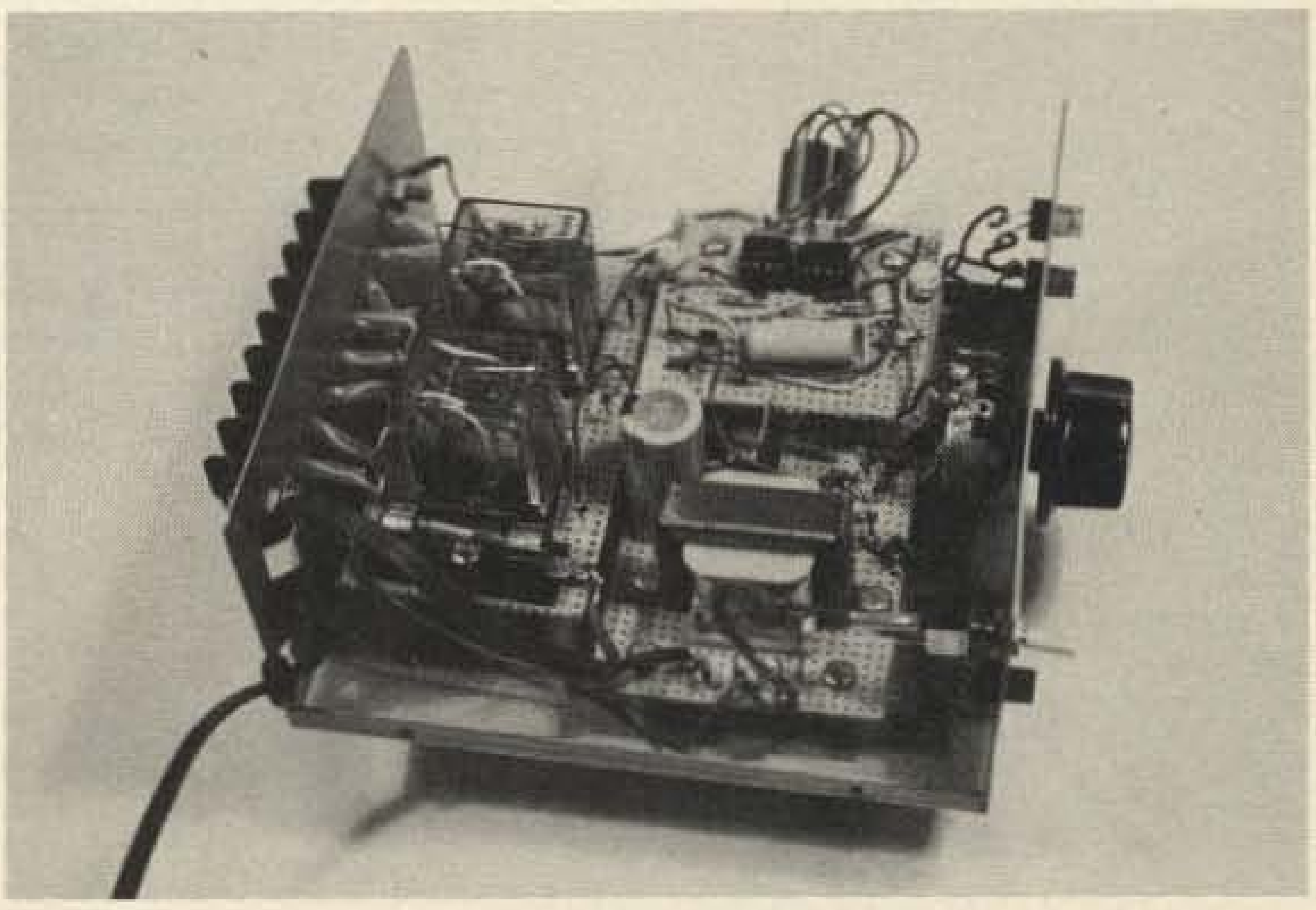


Photo C. An interior view of the improved beam aimer shown from the opposite side of the case. The new input board stands on half-inch pillars over the LM339 socket and transistors. The feedthrough barrier strip for rotator-control-box connections is visible at the rear of the cabinet.

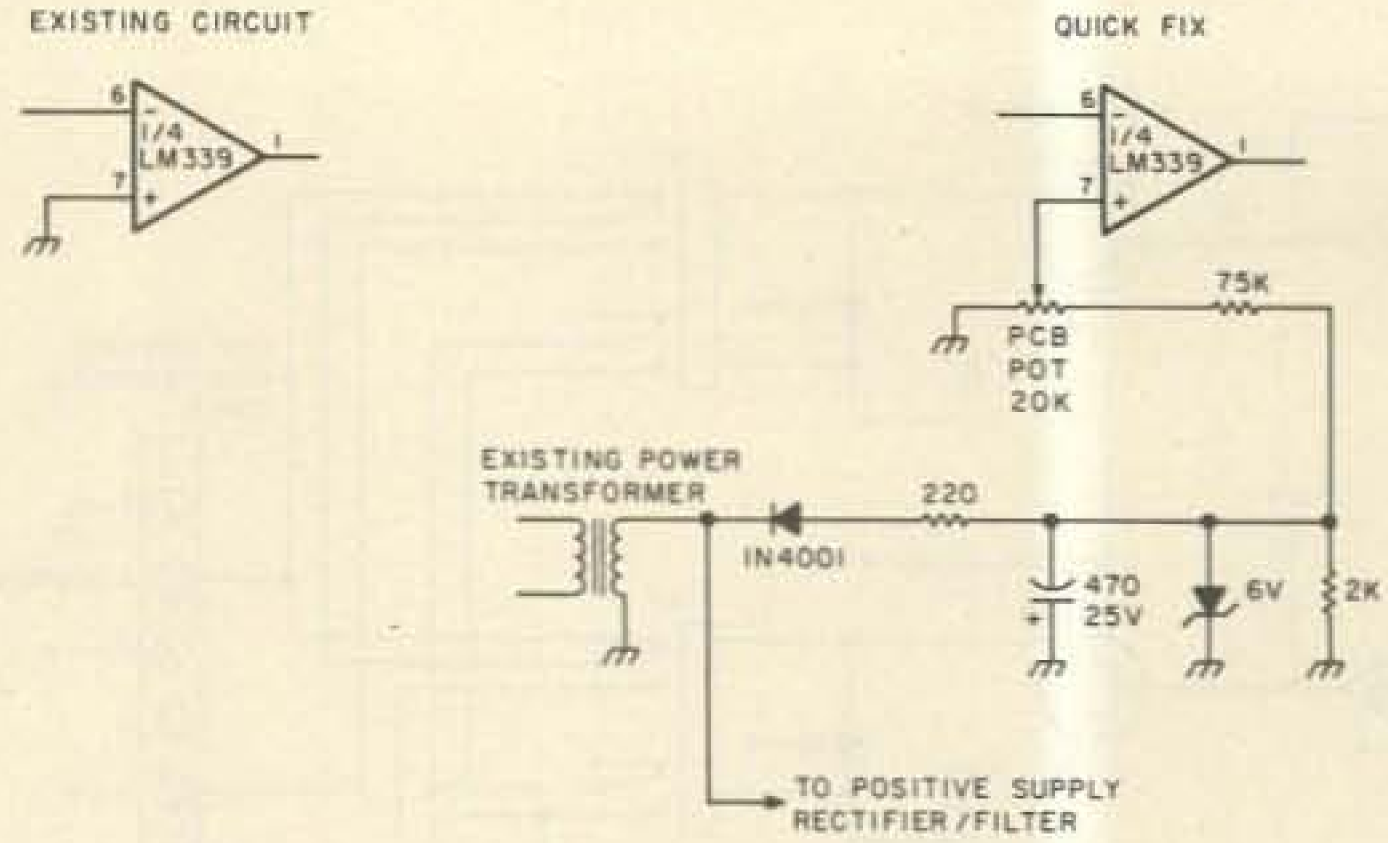


Fig. 3. Eliminating residual negative-voltage effects.

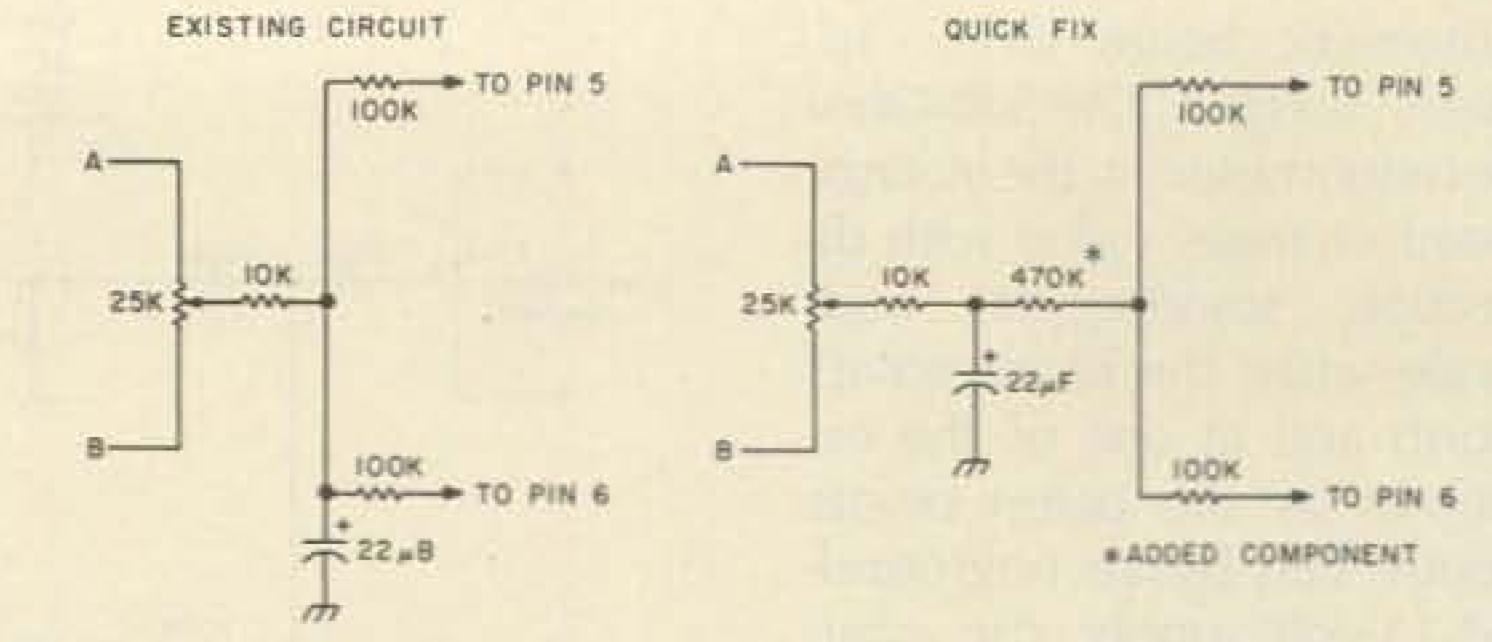


Fig. 4. Input changes to reduce excessive negative voltage.

components. The 20k pot trims the clockwise limit voltage to match the rotator cutoff point.

The second design limit concerns the LM339. This quad voltage comparator is not designed for negative input voltages on either the signal or reference lines. National Semiconductor limits its negative excursions to −0.3 volts in their rating sheets. Experiments on half a dozen 339s in the shack showed that between 6 and 8 volts negative input, the comparator would cut off. There was no permanent damage, and the 339 section would come back on when the negative voltage dropped below the limit toward zero.

The effect of this limitation is that when the antenna is fully counterclockwise and the second pot arm goes fully clockwise, the comparator and its relay open up as the second pot passes east (i.e., about −7.5 volts). Thus, a rapid excursion from southwest to southeast might result in nothing happening or might require directional adjustments in small steps.

The quick fix for this design limit is to keep the second pot arm voltage less than the comparator limit. Adding a 470k resistor between the 22-μF capacitor and the branching 100k resistors to the comparator inputs, as shown in Fig. 4, will keep the maximum voltage below 7. The beam aimer becomes a bit less sensitive since now each volt represents around 50 degrees of rotation rather than 28 degrees. However, control is positive, and precision remains quite adequate.

For those hams using the CD-44 and similar rotators, the third relay in the K9AZG design is unnecessary since there is no separate brake-solenoid circuit to control and no required delay between the direction switch and brake-switch release. To discover whether your rotator requires the third relay, check the rotator schematic in the operator's manual. If pin 2 in the rotator is not connected to a brake circuit, then the unit uses an automatically-engaging disc brake. For this class of rotator, the extra relay contacts in the clockwise and counterclockwise switch relays may be connected in parallel and used to control directly the "brake" switch, which actually is a master ac switch for the rotator. Use K9AZG's precautions of bringing the ac to a female socket on the CDE control box rear panel and then to the beam-aimer cabinet.

Fig. 5 shows all the modifications combined in a unit that works well with the CD-44 rotator. These quick fixes, however, are not the best possible design for the beam aimer.

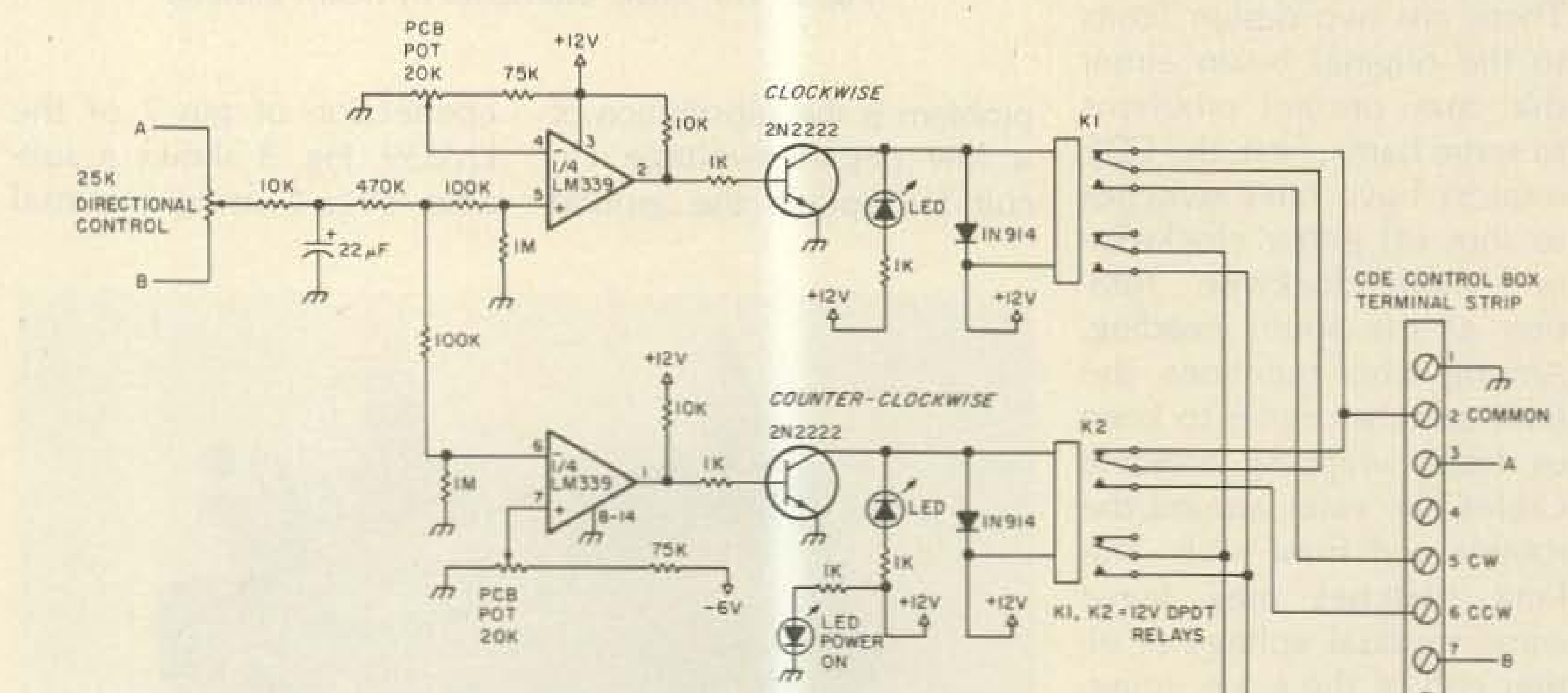


Fig. 5. A simplified beam aimer for the CD-44 and similar rotators.

Improving the Beam-Aimer Design

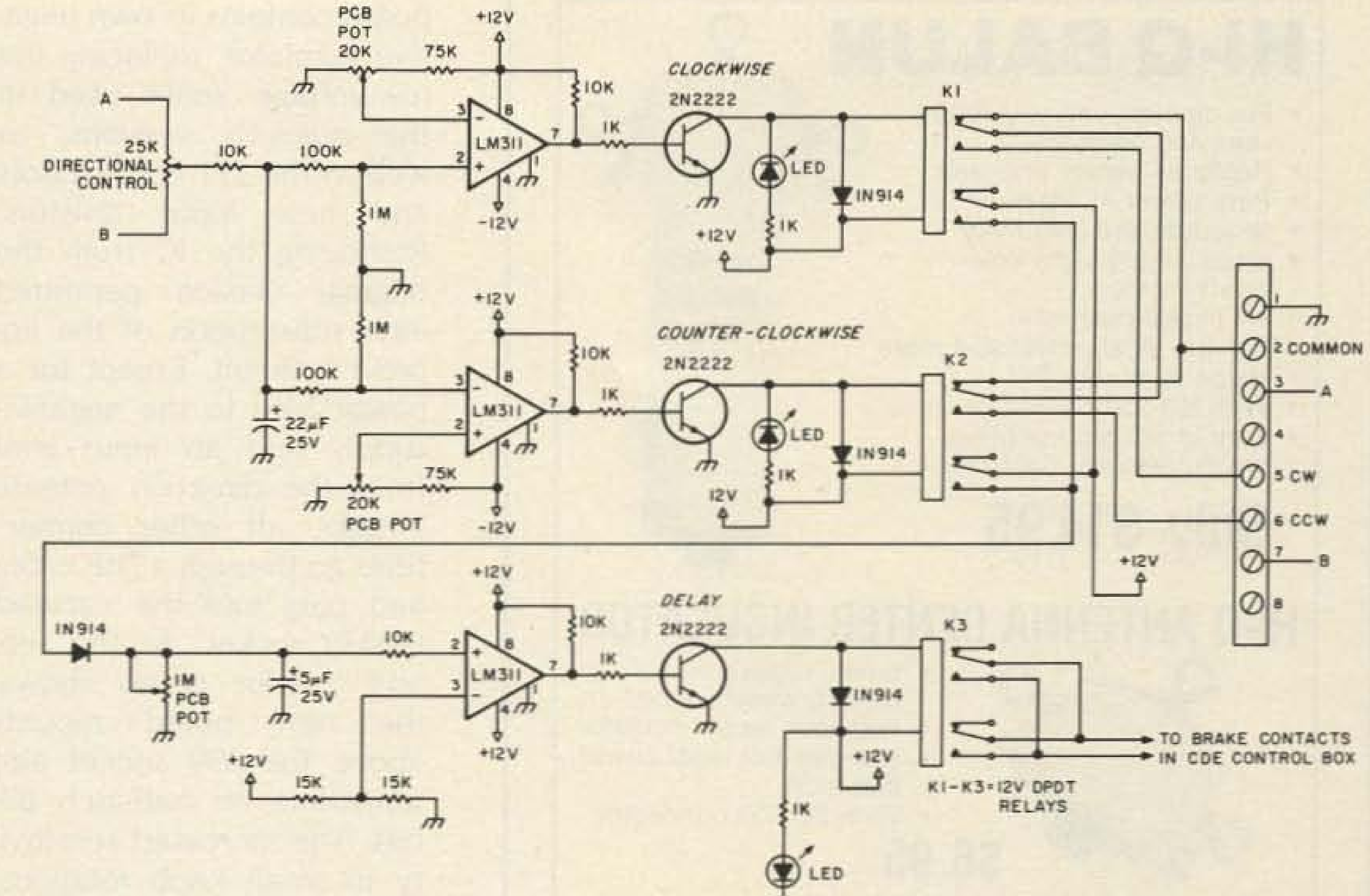
The automatic beam aimer can be more generally improved by a little redesign. Fig. 6 shows the full set of improvements. First, using LM311s with a dual supply from one 12-volt transformer is simple enough, and it provides for both positive and negative trimming of the voltage-comparator reference lines as well as permitting the 311 to accept a +13- to −13-volt excursion. The uncommitted collector of the 311 output allows for a zero-to-positive output swing to control the switching transistors. This design thus overcomes both limitations of the original.

Second, a slight redesign of the delay circuit for the brake control (which is needed for larger rotators using brake solenoids) will overcome a further potential problem. The slow decay of the base voltage in the orginal brake-relay circuit can create contact chatter and possible arcing as the coil voltage drops in the transistor-collector circuit. Additionally, the transistor may draw an excessive load while the base voltage drops through the linear range toward cutoff. To create a very positive switching action, we need add only one more LM311, using it to set the delay. Its output switches rapidly, turning the transistor on and off with equal speed. In addition, we can add a variable delay to the 311 circuit and choose a value with the printed-circuit-board pot during initial adjustment.

Construction

Construction of the beam aimer in any version is straightforward and well covered by K9AZG. Perfboard works well for prototypes, although printed-circuit-board versions would make an excellent club project. The photos show the W4RNL layout. In both photographs, the rear board containing the relays for a CD-44 rotator is mounted a full inch above the case bottom to clear the socket pins. For the CD-44, the delay circuitry was omitted. The forward board containing the power supply and comparator circuit rests on half-inch pillars to ease front-panel connections. Almost any other configuration will work as well. Follow K9AZG's cautions with respect to ac connections to the rotator-control-unit brake switch, whether or not it actually controls the brake in your unit.

One photograph shows the beam aimer with quick fixes prior to modifications for the LM311 comparators. To one side of the LM339 board is the LM311 circuitry board which supplanted the quick-fix version of the aimer in the case. The new



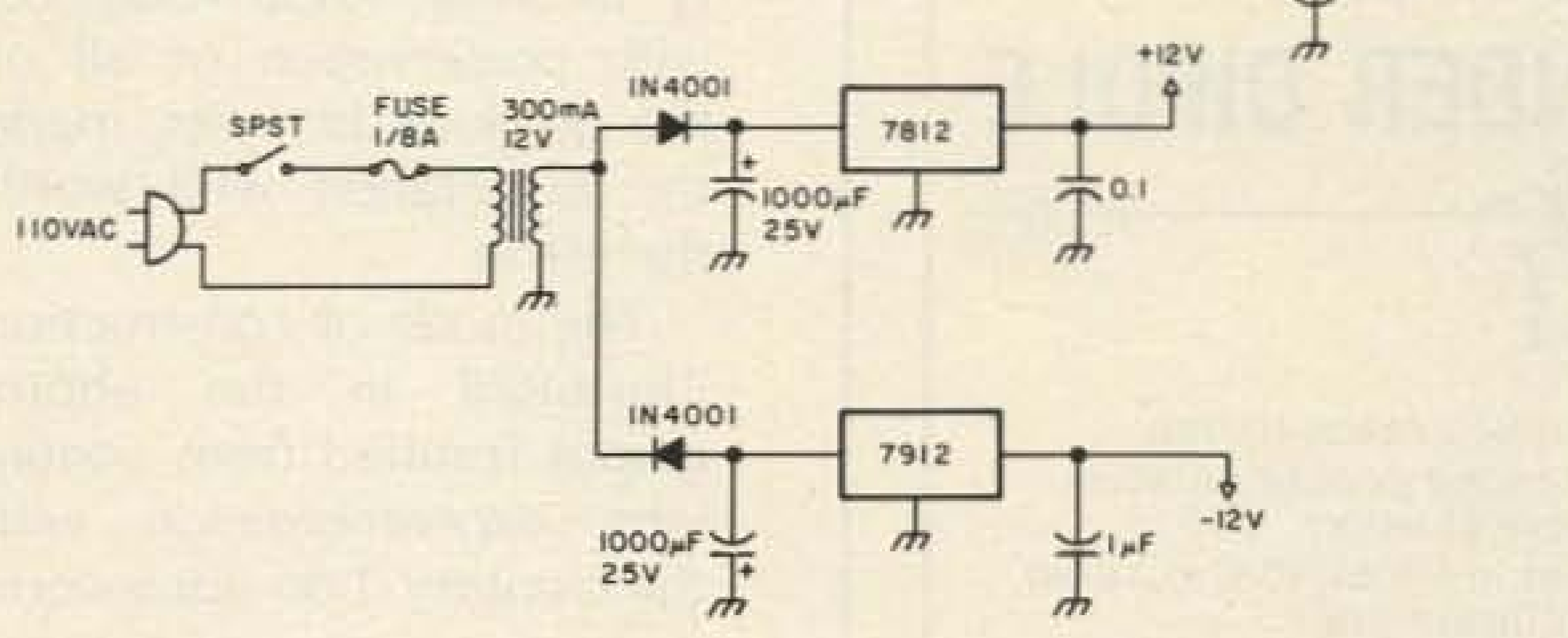


Fig. 6. An improved automatic-beam-aimer design.

Parts List

Part	Quantity Fig. 5	Quantity Fig. 6	Radio Shack Number
Transformer, 12 V, 300 mA	1	1	273-1385
Ac switch, SPST toggle	1	1	275-612
Fuse, 3AG, 1/8 to 1/4 A	1	1	170-1270
Fuse holder, clip-in	1	1	270-739
1N4001, 50-piv power diode	2	2	276-1101
7812 12-V regulator	1	1	276-1771
7912 – 12-V regulator		1	*
6-V zener diode, 1 W	1		276-561
1000-µF, 25-V electrolytic capacitor	1	2	272-1032
470-µF, 16-V electrolytic capacitor	1		272-1030
22-µF, 16-V electrolytic capacitor	1	1	272-1026
5-µF, 16-V electrolytic capacitor		1	272-1024
1-µF, 50-V tantalum capacitor	1	1	*
.1-µF, 50-V tantalum capacitor		1	*
LM339 quad comparator	1		276-1712
14-pin DIP socket	1		276-1999
LM311 voltage comparator		3	*
2N2222, NPN switching transistor, TO-92	2	3	276-1617
8-pin DIP socket	2	5	276-1995
1N914 silicon signal diodes	2	4	276-1620
LEDs, colors to suit	3	3	276-1622
Relay, 12-V, 75-mA coil, DPDT 3-A contacts, socket	2	3	275-206
Terminal strip, barrier or feedthrough, 8 contact	1	1	274-653
25-kilohm potentiometer, panel mount, and knob	1	1	*
20-kilohm PCB potentiometer	2	2	217-336
1-megohm PCB potentiometer		1	217-338
220-Ohm, 1/4-W resistor	1		
1-kilohm, 1/4-W resistor	5	6	
2-kilohm, 1/4-W resistor	1		
10-kilohm, 1/4-W resistor	3	5	
15-kilohm, 1/4-W resistor		2	
75-kilohm, 1/4-W resistor	2	2	
100-kilohm, 1/4-W resistor	2	2	
470-kilohm, 1/4-W resistor	1		
1-megohm, 1/4-W resistor	2	2	
Case, about 5" wide, 6" deep, 3" high	1	1	270-253
Perfboard (cut from 4½" by 6", or make PCB)	1	1	276-1394

Miscellaneous wire, rotator cable, solder, terminal pins, ac cord, grommet, etc.

*Note: Parts not listed with R.S. numbers are available from DigiKey, Jameco, and other mail-order sources; or experiment with the nearest available value.

Total estimated cost with new parts: $25 to $35.

board contains its own negative regulator, replacing the low-voltage zener used in the quick-fix versions, as well as the 311 comparators and new input resistors. Removing the IC from the original version permitted easy substitution of the improved circuit. Except for a power lead to the negative supply and an input lead from the direction potentiometer, all other connections go through a DIP cable and plug into the vacated LM339 socket. As the second interior photo shows, the new board mounts above the 339 socket and transistors on half-inch pillars. The increased sensitivity to small knob rotations, with preservation of all of the quick-fix benefits, made the installation well worth the effort.

The mode of construction illustrated in the photographs resulted from continuing experimentation with the circuitry. I do not recommend it except as an example of how noncritical dc circuits are with respect to layout. Any convenient layout will do, including possible installations inside the CDE rotator cabinet.

These design improvements are slight overall but they may serve to keep a first-time builder from growing discouraged in the process of trying the automatic beam aimer. Without knowing where to look for clues, the source of anomalies can be frustrating. However, K9AZG's basic idea is both sound and elegant in its simplicity. So too were his motives. If you know a sightless ham who needs a better way to control his or her beam direction, follow K9AZG's lead and build a version of the automatic beam aimer. The satisfaction of helping a fellow ham get additional fun out of operating will more than repay the small investment in easily-available components. ■