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Set it and forget it. W4RNL shows us how to automate our HD-73 rotator.

An Automatic Beam-Aimer For The HD-73 Antenna Rotator

BY L.B. CEBIK*, W4RNL

With its modest price and sizable load capability, the Alliance HD-73 has been very popular with amateurs. Alliance no longer manufactures or markets the HD-73. Recently the rights to the HD-73 were sold to Philips ECG, who will now manufacture and market the rotator. I would expect to see them once again on dealers' shelves by the time you read this. Like many rotators in its class, it requires manual operation. The operator holds down the switch until the beam reaches the desired heading. Having built and used an automatic beam-aiming accessory for an old CD-44, I longed for the convenience of a similar item for the HD-73. In addition, if there are sightless amateurs using HD rotators, they could benefit from an easy-to-use and reliable rotator control with tactile calibration markings.

The completed unit now has the following features:

- A single "set-and-forget" directional control;
- Relatively simple, reproducible circuitry using common components;
- A safety interlock with the HD-73 to prevent improper operation of the rotator;
- Noncritical construction; and
- Minimal modification of the HD-73 control unit.

The Circuit Idea

Set-and-forget automatic rotator controls are not new. The least expensive TV antenna rotators use electro-mechanical systems to achieve this goal. Heavier rotators such as the HD-73, the CD-44/45, and the Ham-M/IV use switches that the operator must hold down until the beam reaches its proper direction. There must be a better way!

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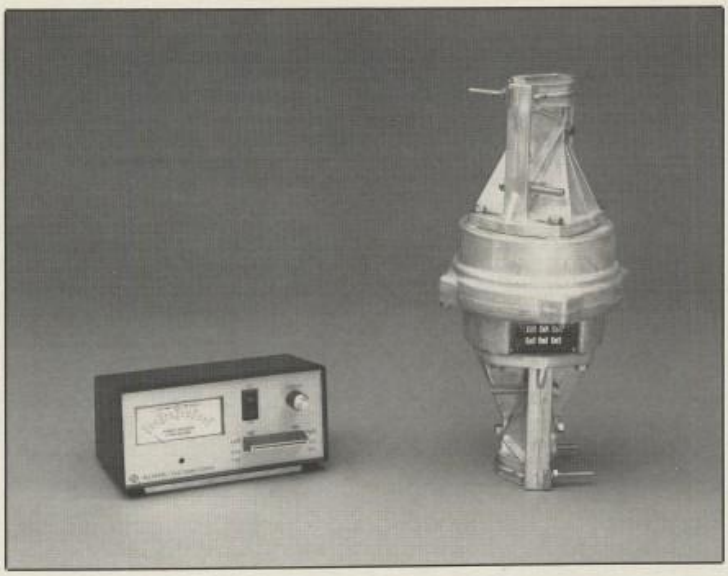

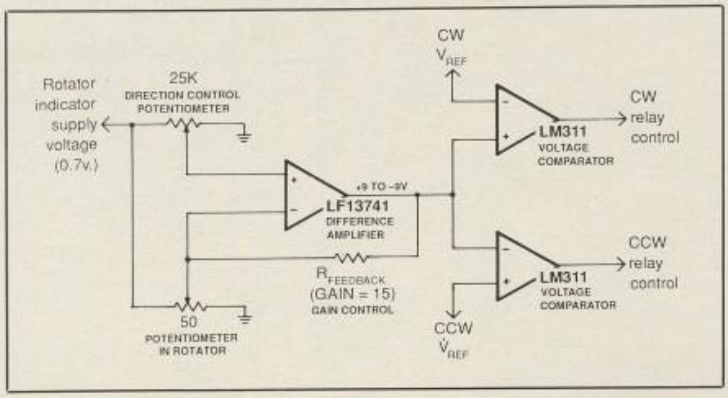

Fig. 1– A simplified schematic of the Alliance beam-aimer circuit idea.

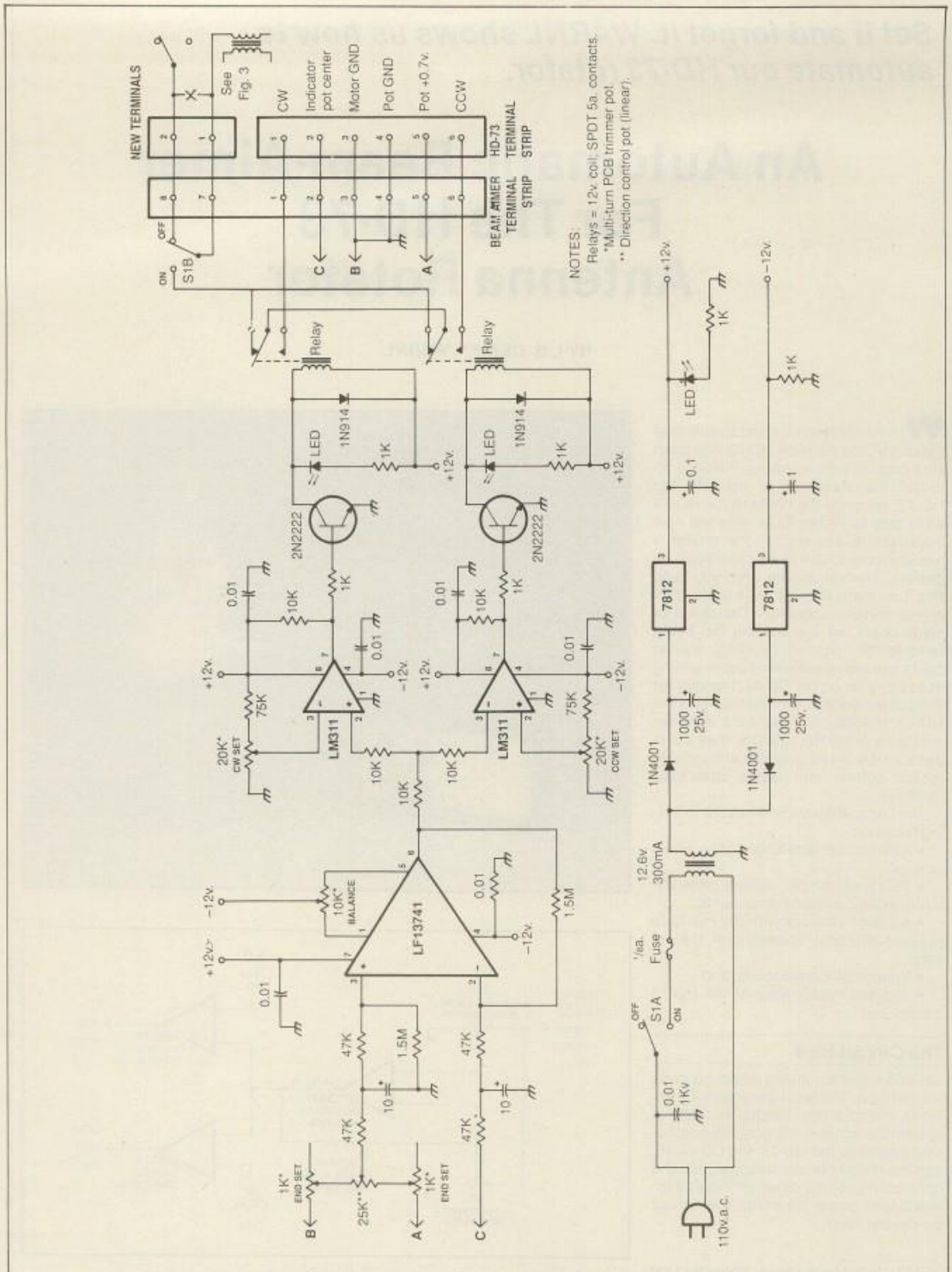

Fig. 2– Schematic diagram of the beam-aimer and power supply.

A few years ago, K9AZG and I developed a reliable automatic control for the CD-44/45 and HAM-M/IV rotators.[1] The basic principle of these beam-aimers is to sense the difference in voltage at the taps of two potentiometers. One pot (50 to 75 ohms) is in the rotator motor unit. Its terminals are on the rotator control unit terminal strip for easy access. The second pot (about 25 K ohms) is tied across the end terminals of the rotator pot. Its tap voltage will equal that of the rotator pot tap only if the two are equal in rotation. If the operator moves the tap on the 25 K ohm pot, a differential voltage appears between the two taps.

Routing the differential voltage to a pair of voltage comparators yields the possibility of controlling two relays: one operates the rotator clockwise, the other operates it counterclockwise. The CD-type rotator is ideally set up for this type of control. When the two pots are coincident, the voltage at the direction control pot tap is zero. Positive voltages at this tap swing the beam in one direction while negative voltages send it the other way.

The HD-73 rotator differs from the CD-series in several respects. First, it uses an AC-driven motor that requires no separate braking circuit. That factor simplifies the auto-aimer somewhat, since no brake timing circuitry is required.

Second, the HD-73 indicator system uses positive voltage only for its 1 mA full-scale directional meter. Moreover, the maximum voltage across the rotator pot is about +0.67 volts, too low for sensitive, small movements of the beam.

The solution to these design variations, as shown in the simplified schematic in fig. 1, lies in a simple op amp difference amplifier input stage. Instead of driving the voltage comparators with voltages from the pot taps, we can send these voltages to an op amp which will both sense the difference and multiply it. A DC amplifier with a voltage gain of 10 to 15 will yield positive and negative voltages of 6 to 9 volts at maximum difference between the two pots. When the pots are coincident, the op amp output is zero.

The Beam-Aimer Circuit

Fig. 2 shows the full schematic of the beam-aimer. The differential amplifier has a gain of 15 and a noninverting input impedance of about 1.6 M ohm. The high input impedance is required so that the input circuit will not significantly affect the voltage at the direction pot tap. The direction control pot is itself of high resistance so as not to materially affect the voltage at the tap of the rotator pot. The high input impedance requires an FET-input op amp, such as the LF13741, the TL-081, or similar units.

The series resistance to each input is split to permit a 10 mF tantalum filter capacitor. This capacitor tends to smooth jumps in the tap voltage during pot rotation. In addition, the series resistor and parallel capacitor add a small time delay in voltage increases and decreases. As the voltage from the rotator indicator pot meets and cuts off either of the voltage comparators, there is a very slight overshoot. The indicator pot voltage thus ends up at the center of the dead zone in which neither voltage comparator is on.

The direction control pot has trimmer pots at each end to equalize the effects of the resistance in the rotator cable on the rotator pot. A 1 ohm resistance in the line, typical for 65 to 100 foot cable runs, amounts to 1.5% of the total pot resistance. Multi-turn 1 K ohm PCB trimmers allow the end voltages to be matched precisely, after the difference amplifier has been balanced with the 10 K ohm multiturn trimmer.

The remainder of the control circuitry is identical to earlier beam-aimers. The industry-standard LM311 provides a control voltage for the 2N2222 relay drivers. Directional LEDs indicate when the unit is working. The relays are wired so that if, by some quirk, both relays activate simultaneously, no voltage reaches the rotator motor. Each 311 has a rotation-limit trimmer to permit precise cut-off of the relay just as the motor reaches the limit of its rotation.

The power supply is a simple, dual 12-volt unit regulated with 7812 and 7912 three-terminal ICs. Note that the power switch is a DPDT toggle switch, half of which is used to provide an equipment safety feature.

HD Modifications

The HD-73 control unit requires only one simple modification. The motor voltage line must be run to the beam-aimer unit to permit the relays to activate the rotator. All other connections are made to the existing terminal strip on the rear of the HD control unit.

We could bring a single "hot" line to the beam-aimer, but bringing a return line also allows an important safety and convenience feature. With just a hot line, we might accidentally set the beam-aimer to provide motor voltage for one direction and then hit the control-unit manual bar switch to supply voltage for opposite rotation. The second half of the power switch routes the hot line only to the relays whenever beam-aimer power is on. When power is off, the hot line is routed back to the HD-73 control unit for normal manual operation.

Modifying the HD-73 control unit requires breaking the lead between the transformer and the manual switch, as shown in the partial schematic in fig. 3.

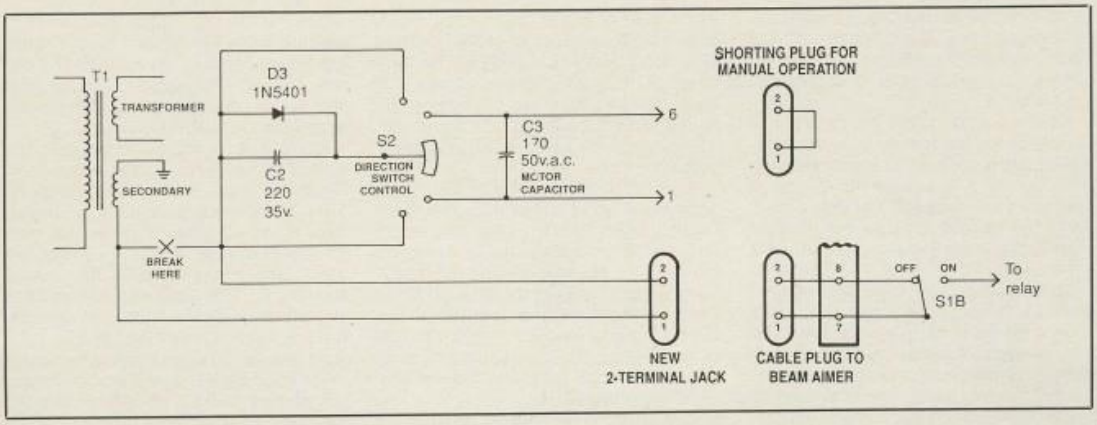

Fig. 3– Partial schematic of the HD-73 control unit to show necessary modifications.

This lead (a red wire in my unit) has a spade terminal that fits a spade lug on the switch. Simply clip off the terminal from the wire and route it to a new pair of rear terminals. Install a new spade terminal on a second piece of wire and route it from the new terminals to the switch.

There is room on the back panel of the HD control unit for a pair of terminals just to the right of the cable clamp lug. I used an old FT crystal socket because it was compact and fit the space and because a couple of old FT-241A crystals made handy plugs. Drilling for the socket installation should be done carefully with a slow-speed drill to prevent damage to the transformer about ½ inch behind the panel. Be sure to note carefully which socket hole is hot and which is the return line.

I made a shorting bar for one FT-241A crystal case (with the old crystal assembly removed). With the shorting plug in place, the HD control unit operates independently of the beam-aimer. The second FT-241A crystal case became a plug for two wires of the 8-wire cable connecting the HD control unit to the beam-aimer.

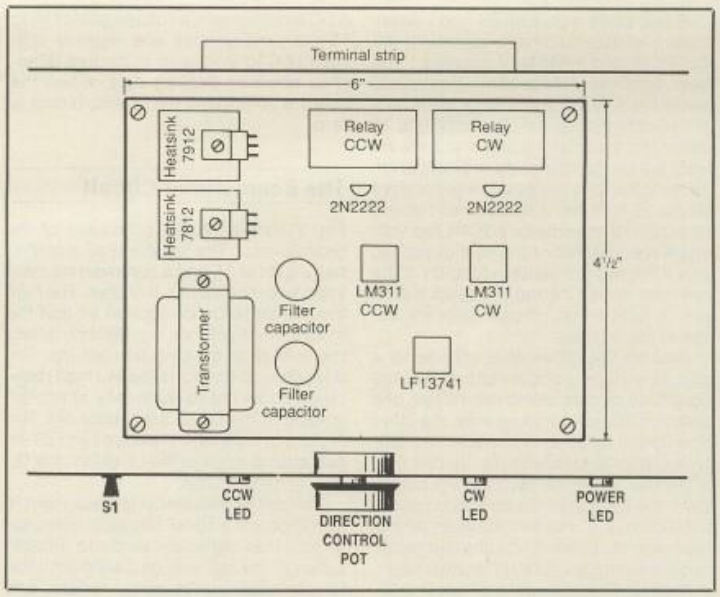

Fig. 4– A sketch of the beam-aimer circuit perfboard showing general layout of parts.

Construction and Alignment

Construction is largely noncritical, since all the circuits are DC. As fig. 4 shows, the entire unit fits on a 4½ inch by 6 inch piece of perfboard with room to spare. Use small heat sinks for the regulators, since the beam-aimer can draw over 100 mA during beam rotation. Keep all AC line connections isolated from the remainder of the circuitry for safety during testing and maintenance.

The difference amplifier requires only that some care be used to keep input and output leads and components well-separated—that is, on opposite sides of the op amp. Be sure to bypass the plus and minus supplies of both the 13741 and the 311s close to the body of the op amps. Also be sure that each 311 has a common ground point near the comparator; that measure helps prevent the unit from oscillating as the two input voltages pass each other.

Keep the leads to the 2N2222s short. Bypass all the hot terminals on the terminal strip to ground either inside the case or externally. Also bypass the AC line at the case entry using 1 KV ceramic capacitors. DC circuits can be sensitive at close range to the RF fields that surround a transmitter.

The parts list shows the source of most of the parts. Radio Shack carries virtually everything except the op amp, the 311s, and the negative regulator. Jameco, Digi-Key, and similar outlets are good sources for the missing items. The circuit on its perfboard fits nicely into a 2 by 8 by 6 inch case with rub-on panel markings covered

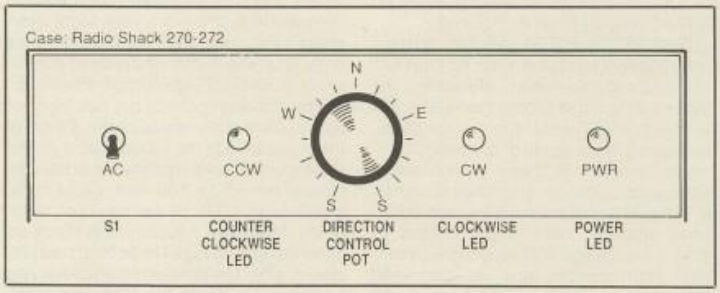

Fig. 5– A sketch of the front-panel layout of the beam-aimer.

with a coat or two of clear spray. Fig. 5 shows the general layout of the front panel, with its power switch and LED, the turn-direction LEDs, and the direction pot. The case size was selected because it fits neatly under the original HD control unit.

Tuning up the beam-aimer is a three-stage operation.

1. After building and smoke-testing the circuit and while it is outside the case, balance the LF13741. Use jumpers to temporarily ground the inputs at a point between the pot taps and the outer 47 K ohm resistors. Adjust the 10 K ohm balance trimmer until the amplifier shows 0.00 volts at the junction of the three 10 K ohm resistors. I used an analog meter to get into the ball park and did the final tweaking with a DVM.

2. With the perfboard installed in the case, connect the cable between the aimer and the HD control unit. For now, omit terminals 1 and 6, and use the shorting plug rather than the cable plug at the new HD terminal socket. This permits setting the direction pot end trimmers while controlling the rotator manually.

Run the beam and the aimer direction control all the way clockwise. Adjust the 1 K ohm clockwise trimmer until the difference amplifier shows 0.00 volts output. Repeat the adjustment at the 1 K ohm counterclockwise extreme, using the other end trimmer. With the values shown in fig. 2, you should read about 9 to 10 volts op amp output (positive or negative, depending upon the relative positions of the pots) when the direction pot is at the opposite extreme from the rotator pot. Repeat the adjustment of the end trimmer pots to account for the slight interaction between the pots.

Parts List

Quantity	Part	Source
1	LF13741, TL-081, or similar op amp	D-J*
2	LM311 voltage comparator	D-J
2	2N2222 or equiv. NPN switching transistor	RS*
1	7812 + 12 volt regulator	RS
1	7912 – 12 volt regulator	D-J
2	12 volt, 5 amp contacts, SPDT relay	RS 275-219
2	1N4001 50 PIV, 1 A diode	RS
2	1N914 or equivalent signal diode	RS
3	LED, color to suit taste	RS
1	25 K ohm linear potentiometer	RS
1	10 K ohm multiturn PCB trimmer pot	D-J
2	1 K ohm multiturn PCB trimmer pot	D-J
2	20 K ohm multiturn PCB trimmer pot	D-J
4	47 K ohm, ¼ watt resistor	RS
2	1.5 M ohm, ¼ watt resistor	RS
2	75 K ohm, ¼ watt resistor	RS
5	10 K ohm, ¼ watt resistor	RS
6	1 K ohm, ¼ watt resistor	RS
2	0.01 mF, 1 KV ceramic capacitor	D-J
6	0.01 mF, 50 volt ceramic capacitor	RS
2	1000 mF, 25 volt electrolytic capacitor	D-J
1	0.1 mF, 25 volt tantalum capacitor	D-J
1	1 mF, 25 volt tantalum capacitor	D-J
2	10 mF, 25 volt tantalum capacitor	D-J
1	perfboard, 4½ inches by 6 inches	RS
1	case, 1 $^{15}/_{16}$ by 8¼ by 6¼ inches	RS 270-272
1	8-terminal lug strip	RS
1	2-terminal strip/jack and matching plug	
3	8-pin DIP sockets	RS
2	TO-220 heat sinks	RS
1	DPDT toggle switch	RS
1	12.6 volt, 300 mA transformer	RS
1	¼ A fuse and holder	RS
	Miscellaneous hardware, knob, wire, line cord, etc.	

*Table I– Parts list for the automatic beam-aimer. (*Note: RS = Radio Shack; D-J = Digikey, Jameco, and other mail-order sources.)*

3. During the early adjustments, you may see one or even both LED relay indicators on. The final adjustment sets the "dead zone" and the end-of-rotation position. Finish connecting all eight lines of the aimer cable before beginning this adjustment.

Use the beam-aimer to turn the beam counterclockwise. Set the 20 K ohm trimmer in the counterclockwise circuit until the relay stops just as the beam reaches south. (*Note:* If the relay always cuts off before the beam reaches south, adjust the counterclockwise direction pot trimmer so that the beam reaches south before the relay cuts off. Then readjust the 20 K ohm trimmer for relay cut-off.)

Turn the beam fully clockwise and repeat the adjustment in the clockwise circuit. (*Note:* Preadjust the clockwise direction trimmer if the beam never reaches clockwise south before relay cut-off.)

The adjustments just made create a dead zone of 5 to 10 degrees in which both relays are off. This dead zone is just about right for HF beams, with their 30 degree or greater beam angles. If the dead zone is larger, readjust both the direction pot trimmers and the 311 trimmers until it shrinks. The object is to have a zone in which the operating relay shuts off without starting the other relay in both directions and everywhere throughout the direction pot range.

The beam-aimer is now ready for use. Its convenience will quickly show itself as you find yourself making more small beam direction adjustments than with the manual HD control unit. With tactile calibration of the direction pot scale, sightless hams can accurately track the stations they wish to work simply by setting the pot and listening for the relay to click off. One way or another, the HD beam-aimer is a satisfying project for a dead-band weekend.

Notes

1. L.B. Cebik, W4RNL, "Elegant Rotating," *73*, June 1984, pp. 60–64; see also Guy Slaughter, K9AZG, "Automatic Beam Aimer," *73*, November 1982, pp. 22–24.