Building a "Poor-Man's" Amateur Radio Satellite Ground Station Part II: Inexpensive Manual/Computer-Controlled Rotator Controller

by Gordon Gibby KX4Z

Others have pointed out that you just "don't have enough hands" to adjust everything simultaneously as a satellite arcs overhead in a 3D orbit, with constantly changing Doppler effects as well. A really helpful improvement for my poor-man's satellite ground station efforts was developing computer-controlled aiming of my antenna system. There are commercially available options. These include a Yaesu G-232B controller box retailing upwards of $649.99 (https://www.dxengineering.com/parts/ysu-gs-232b) , and a really slick multi-function system by CSN Technologies for much less, $275. (See: https://www.dxengineering.com/parts/atn-sat-tracker) Many hobbyists have been successful using off-the-shelf commercial systems.

Much Cheaper HomeBrew System

However, Anthony Good K3NG many years ago wrote Arduino code to interface between freely-available satellite tracking software, and almost any manner of rotator, from commercial to any number of homebrew rotators. His somewhat confusing but highly advanced software handles one- or two-axis control and a vast array of potential motors and sensors.

When I considered using his well-developed software, I found good examples of others who had done so, but **no currently available printed circuit board to make this easier**. I dislike "bailing-wire" contraptions; I prefer to have a solid printed circuit board project if possible. So I enlarged his basic Arduino schematic to utilize a Nano (which requires careful choices of software due to its memory limitations), built-in manual push-buttons, and potential pulse-width modulation and control of off-the-shelf relay boards to reverse direction.

This resulted in Gerbers for an inexpensive interface board that turned out to be quite successful. The schematic and a photo of a working prototype board are presented below. The printed circuit design is an offshoot of earlier circuits I've built, and places the Nano and components on one side of the board, and uses the reverse side for the 2-line LCD display and user-interface buttons. This reduces the size and cost of the board.

This project has been "shared" on pcbway.com and can be accessed easily: https://www.pcbway.com/project/shareproject/K3NG_Rotator_Dual_Axis_Controller_Board_fd759cc2.html Zipped GERBER files suitable for submission to pcbway.com are also available at: https://www.nf4rc.club/how-to-docs/gerber-files-for-k3ng-rotator-printed-circuit-board/

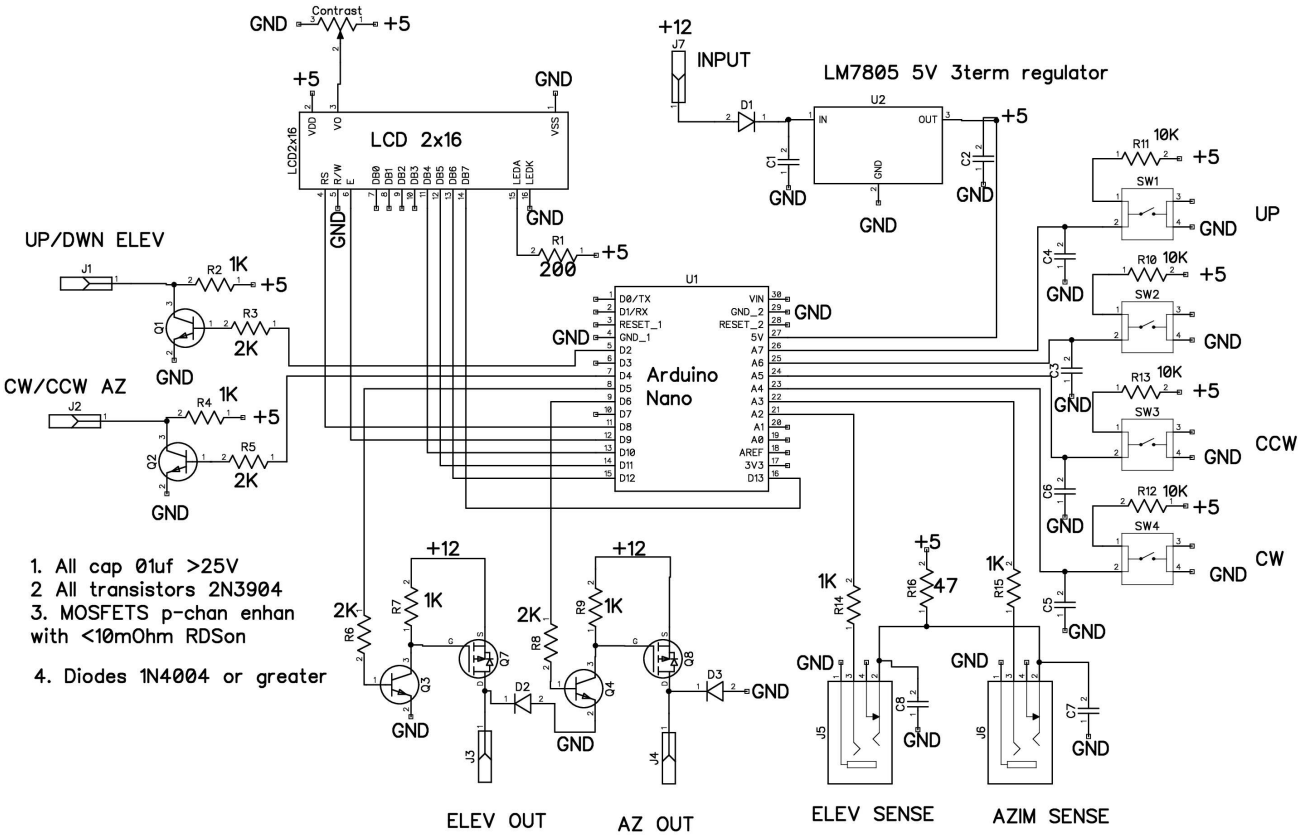

Figure 1: Schematic Diagram for the Rotator Controller

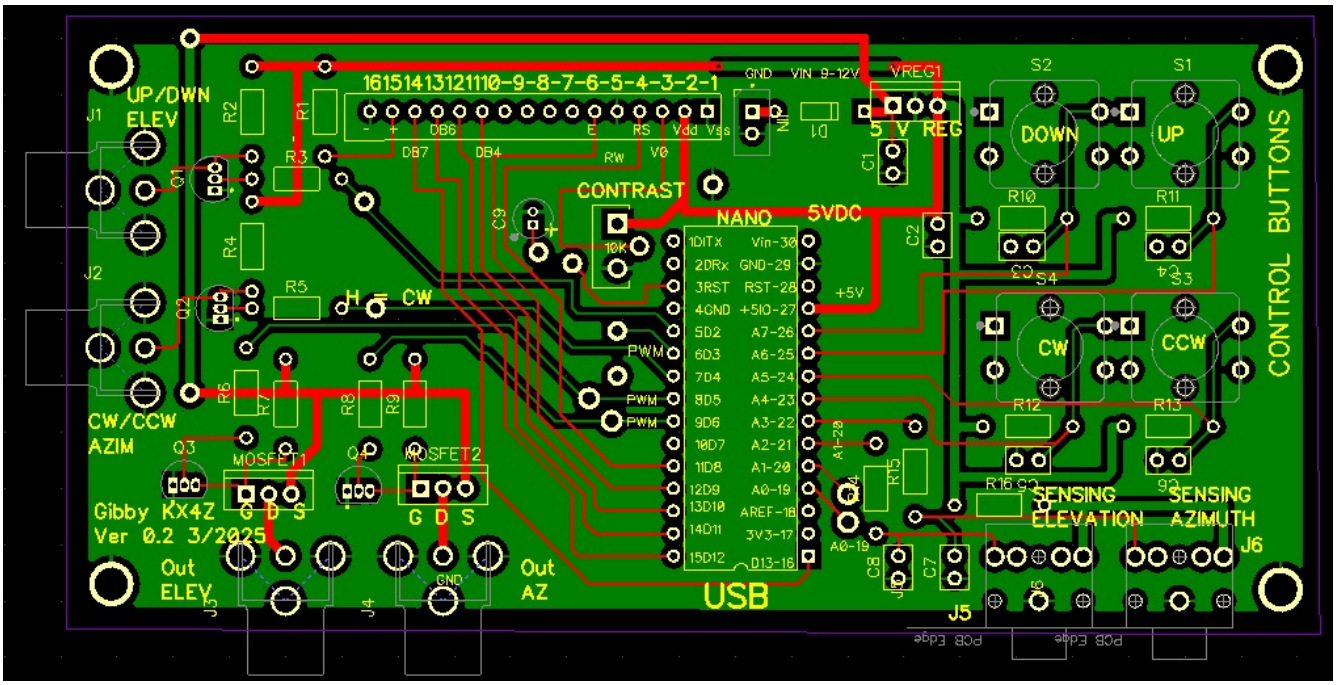

Figure 2: Screenshot of board (top traces RED, bottom traces GREEN) from DipTrace software.

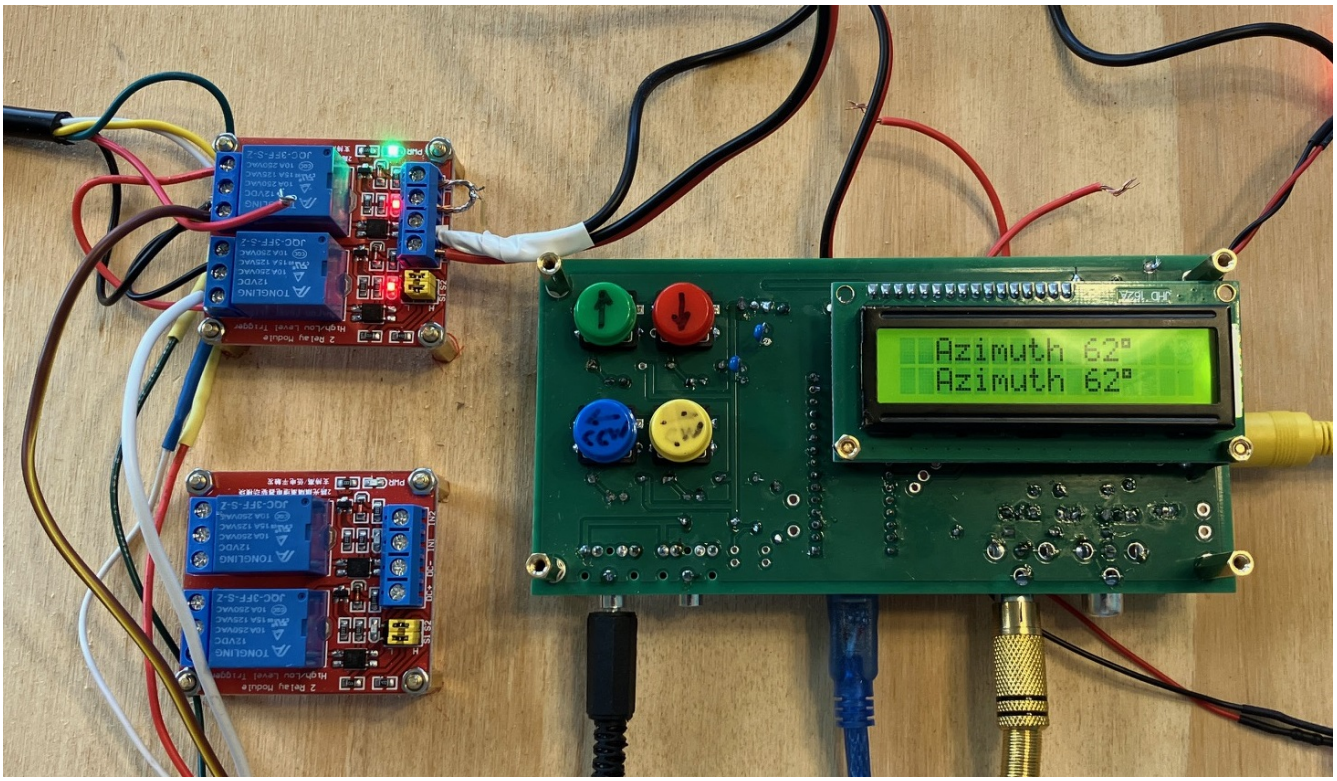

Figure 3: Photo of prototype build, on simple plywood. 4 buttons for up/down left/right are shown. The component side is downwards, where connectors are also mounted. The two orange wires are to connect a 10uF anti-erase capacitor which seems to be unnecessary. In this photo, the elevation inputs and outputs have not yet been added, so the controller displays only azimuth rotation.

SOFTWARE To Drive Board

With minor alterations to the basic K3NG software (available at: https://github.com/k3ng/k3ng_rotator_controller), this board works quite well, providing both manual and computer-controlled operation of one or two rotators. It can be used directly with Yaesu commercially available DC-motor rotators such as the G-450ADC. In fact it can simply replace the manual rotator that comes in such rotator packages, with the addition of a DC power supply.

The K3NG source code and alterations, settings will be discussed in a future article. The modified source code for my implementation will be provided in that article. A solution for 2-axis rotator control will also be provided in a subsequent article, as will information on homebrew antennas. This is truly a low-cost way to get into satellite communications!

BILL OF MATERIALS		
Designation	**Specification**	**Notes**
U1	Arduino Nano, 30-pin DIP package headers installed	

U2	LM7805 5V 3terminal 1A regulator	
D1, D2, D3	1N4004, 1N4005, 1N4006 or 1N4007 1-Amp silicon diode	
Q1, Q2, Q3, Q4	2N3904 NPN transistor (or any similar small signal transistor, hfe>50	
Q7, Q7	P channel enhancement MOSFET, Vds >=50V, Rdson <=10milli-ohm	
C1, C2, C3, C4, C5, D6, C7	0.1 uF ceramic capacitor, 50V or higher.	0.01uF may also be used.
R1	200 ohms, 1/4W	Sets the brightness of the LED back light of the LCD display
Contrast	10K trimmer potentiometer, 1/4 watt	
R2,R4, R7, R9, R14, R15	1K 1/4 watt resistor	
R3, R5, R6, R8	2K 1/4 watt resistor	
R10, R11, R12, R13	10K 1/4 watt resistor	pull up resistors for manual buttons
R16	47 ohm 1/4W resistor	Serves as a current limit and "fuse" for the potentiometer sensing system as a protection against short circuits
External relay board	2 SPDT relays, each independently controllable by 0/5V logic voltages	Both relays on each board are driven in sync so that the + and - leads to the DC rotator motor can be reverse in polarity to reverse direction. The board relays are powered by 12V (same as the rotators) while their logic inputs are optically isolated and controlled by 0V/5V logic LOW/HI inputs (very convenient for the Arduino Nano outputs). (If necessary these could be used to make proper connections to reverse direction of an AC motor) https://www.amazon.com/dp/B085N49S79?ref_=ppx_hzsearch_conn_dt_b_fed_asin_title_1&th=1
External Relay Board	Amazon https://www.amazon.com/	See photo and schematic for wiring details

	dp/B085N49S79	
RCA Phono jack	Mouser part number: 490-RCJ-012 https://www.mouser.com/ProductDetail/Same-Sky/RCJ-012?qs=WyjlAZoYn53isKUFZudEAg%3D%3D	Printed circuit board is made for this part.
3.5mm stereo jack	Mouser part number: 490-SJ1-3545N https://www.mouser.com/ProductDetail/Same-Sky/SJ1-3545N?qs=WyjlAZoYn53N5dGhOxE1Xw%3D%3D	Printed circuit board is made for this part
Pushbuttons	12x12x7.3 mm printed circuit board mounted pushbuttons, package of 25. https://www.amazon.com/dp/B01E38OS7K	Plenty for your club!
2x16 LCD display with header	(package of 2) https://www.amazon.com/gp/product/B00HJ6AFW6 Extra long header pins: https://www.amazon.com/gp/product/B09G5RF3H6	Remember that this mounts on the "BACK" side of the board, which faces the user, while the microcontroller and components end up on the "bottom" I supported the far end of the LCD with a small standoff so it wouldn't be exposed to bending stress.
Arduino Nano	(Package of 3 -- you can find individuals also) https://www.amazon.com/gp/product/B07G99NNXL	Be very careful soldering this in. Use slender solder as the pins are very close!
Optional LED indicators (12V)	OPTIONAL https://www.amazon.com/dp/B0757YNM1D	See discussion Just to help me observe what is happening, or to impress onlookers
Optional USB adapter	Accepts normal "printer" type B USB plug and adapts to the Mini USB on the Nano. https://www.amazon.com/dp/B0DDHDQK4B	Optional but you may prefer the sturdier USB B for the external connection

External Relay Boards

Rather than create more custom printed circuit board circuitry, I elected to use 3rd party logic-controlled relays for the final polarity control to the rotators. The power signal is optionally pulse-width modulated by power MOSFETS, which dissipate very little power because they are either OFF or fully ON, but the polarity reversal is accomplished by the external relay boards. That makes it easier to replace the relays if they should ever fail, and reduced the amount of custom construction.

Use one relay board if you are only controlling azimuth; use two if you are controlling azimuth and elevation; each board controls the polarity of the DC power signal sent to a single rotator DC motor.

The board requires +12VDC and GROUND power input. This powers the relays and also the "black box" internal control logic. The control logic can be set to respond to either HI (5VDC) or LOW (0VDC) logic inputs. Both inputs are connected together and driven by the same Arduino output, either CW/CCW (for azimuth) or UP/DWN (for elevation).

Each relay has normally open (NO), normally closed (NC) and common (COM) output terminals. The relays are wired so that they can pass or invert the polarity of the power signal coming from the controller board MOSFETs.

If you end up with a rotator moving "backwards" to what you wanted, just swap the COM outputs going to the DC motor on the rotator, to fix your problem!

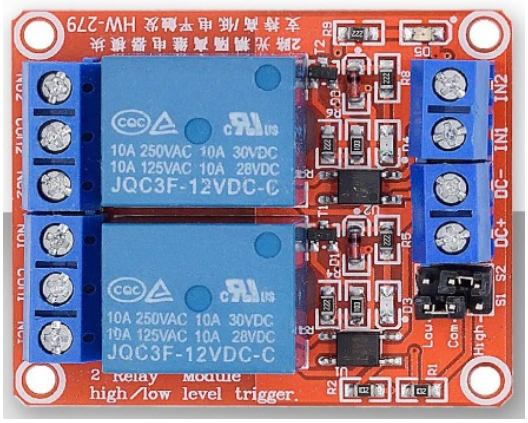

Figure: 3rd party logic-controlled relay board. If you are controlling both azimuth and elevation (as I am) you will need TWO of these. If you have an AC-based rotator, you can use these to provide the proper connections; wiring for that not discussed in this article.

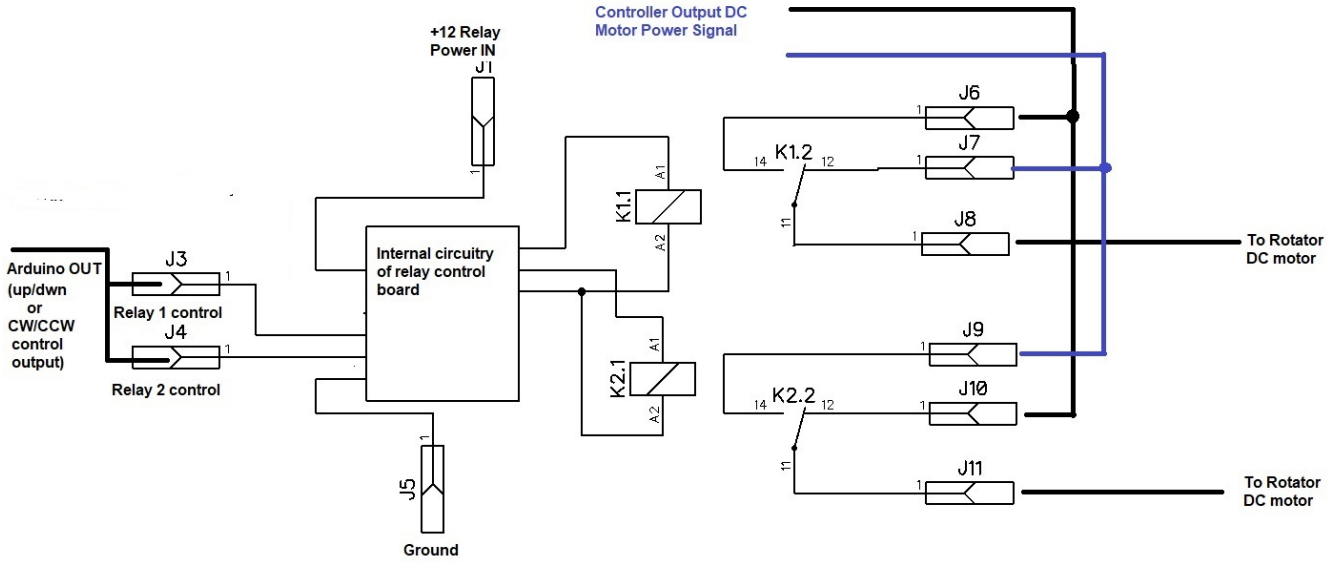

Figure: Schematic of how ONE external relay board is integrated with the controller board to allow polarity reversal to the rotator DC motor.

Optional LED Indicator Lamps

Some time back I purchased a gaggle of 12-V LED indicator lamps and never really used them. These already include the dropping resistor, so they need 12V or so to properly illuminate, and they were too dim for the original plan. However, they ended up working quite well as optional indicators on this project. I simply soldered them to any connector for which I wanted a visual indication of voltage. For example, I added one to the power-input connector so I could verity input power. I added one to the "AZ OUT" azimuth rotator power output, and it makes it obvious when power is going to the rotator (in either direction). These are cheap and you can add them wherever you wish.

Power Requirements

I was very surprised to find that even the Yaesu G-450ADC rotator draws relatively little power-- I see only a small needle movement on my MFJ 25-Ampere ham power supply. A 2-ampere power supply would probably work quite well. You could use a spare 12V laptop power supply for example. This drives the Yaesu G-450ADC at a slower, but acceptable speed. I get one full rotation in about 90 seconds. Be cautious about upping the voltage -- the 3terminal regulator will need a heatsink and the linear actuator that I used, is rated for 12V.