Remote Antenna Switch and Controller Build

Several months back – in April of 2023 – I got tired of looking for a reasonably-priced remote antenna switch that was weather-sealed and could accommodate at least four antenna outputs. What with me being me, I decided to build it myself, so I started hunting for ideas. What I came across was a starting point for this project. Let me explain a little bit just what my needs were.

Figure 1 - Switch unit front panel

My antenna farm, when it is finally finished, will consist of antennas in two separate areas – out back behind my garage, and up on the roof of my house. Out back will be the bulk of the HF antennas, including a Hustler 5BTV vertical, a 6-band hex beam, a three-band fan diploe, and a 6-meter Hen Delta. All of these antennas will be fed via a single coaxial cable, which will carry the switching control as well as the RF output. The actual switching unit used here is a Heathkit® HD-1481 Remote Coax Switch. I found that unit NIB on ebay.com, and built it according to the manual. It is a two-piece setup, with the remote switch head being mounted out at the antenna field, and the controller in the shack. The coaxial cable used will be the Davis RF *BuryFlex*™ LM-400 specification cable.

Figure 2 - Switch unit rear panel

The house rooftop will also hold a small array of antennas, primarily VHF/UHF, though there will be one HF antenna up there. The VHF/UHF antennas include an Arrow 146-4 four-element 2-meter Yagi on a rotator on a chimney mount, with an Ed Fong DNBJ-2 J-pole in its 250W version above the Yagi, a Comet CX-333 tri-band vertical on a non-penetrating roof mount bracket over the roof peak, and a home-brew 1.25-meter copper pipe J-pole on an arm on the NPRM bracket. All of these antennas will be fed via a single coaxial cable feed. There will be a second coaxial line going to the roof, however, because I also plan on an end-fed 40-meter sloper that will run from the house roof to my garage roof. All of the VHF/UHF antennas will be selected by this new remote switch gear that I had decided to build. It is, of course, also a two-piece system, but this one does not impose the control signals onto the RF in the coaxial cable. Instead, a pair of four-wire cables will connect the controller in the shack with the switching head up on the roof.

I will describe each of the two units separately, starting with the switch unit (Figures 1 and 2), as its design drove the design of the control unit. I had started out by doing some online research into antenna switch systems, to see what other folks had designed and built. I started out by looking for a relatively low-cost way to implement a four-antenna remote switch for the antennas that are going on my rooftop. I did not want to run multiple coaxial cables from the rooftop into the shack, so I was really working on a solution to this issue, when I came upon the KO4NR

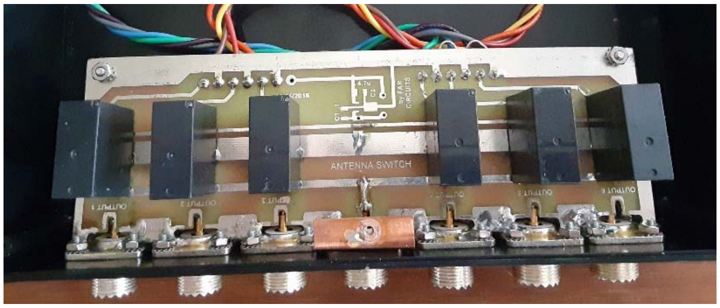

Figure 3 - Switch unit PCB installed in enclosure

Low-Cost Antenna Switch article in the online supplemental material to the *ARRL Handbook 100*, in the *Station Accessory Projects* chapter. This switch unit uses a half dozen relays to provide switching for up to six antennas, and is wired so as to ground the antennas not in use at any given time. I read the article, thought about the design a while, and then I ordered the printed circuit board (Figure 3) from FAR Circuits (https://www.farcircuits.net/) of Dundee, Illinois. Then I started to gather parts to build the unit. In addition to the American Zettler AZ755-1C-12DE relays, the switch unit consists of some very basic parts, namely six 0.001µF ceramic capacitors, six 1N4001 diodes, a pair of Phoenix 1729050-02 terminal strips, and seven SO-239 flange-mount jacks. When purchased from FAR Circuits, the PCB is shipped with the above relays and also with some grommets intended to improve relay connectivity to the PCB.

A few words are in order regarding the PCB from FAR Circuits. The board is of relatively low quality and required some modification and repairs in order to be made usable for its intended purpose. I was quite disappointed when I received and unpacked the board. To begin with, the board is a modification, *i.e.,* a second version of the board described in the original ARRL article, with no advance warning of the change. Among the changes are the fact that the capacitors on the board are now surface mount devices, which were included with the board. However, the anti-spike diodes were omitted in this version of the board. I ended up adding them in directly across the relay coil pins. Also, although the board maker includes brass grommets meant to improve the relay contact pin connections to the board, an insufficient number of these grommets were shipped, necessitating a call to FAR Circuits to remedy the situation. In addition to that, one of the six relays included was an incorrect type, in that the shipment mistakenly had one Form A type (DPST) instead of a Form C (DPDT) relay.

Figure 4 - Switch unit PCB showing areas of trace repairs

It is obvious that the resist masking used to manufacture the PCB was rather leaky. The PCB traces are, in general, weak and poorly defined. One of the PCB traces from the input terminals to the relay coils was missing a section of the trace, leaving insufficient trace area for the current to be carried. I repaired this by overlaying some wire along the trace (Figure 4). At another location, one of the relay positions had five of the relay contact pin holes drilled to accept the grommet, while the sixth was not so drilled. I ended up drilling the hole to the proper size to accept the grommet. This is necessary because the brass grommets are used to carry signal current through the board to the traces on the other side, as the board holes are not through-plated. Finally, the PCB trace areas where the SO-239 connectors attach to the edge of the

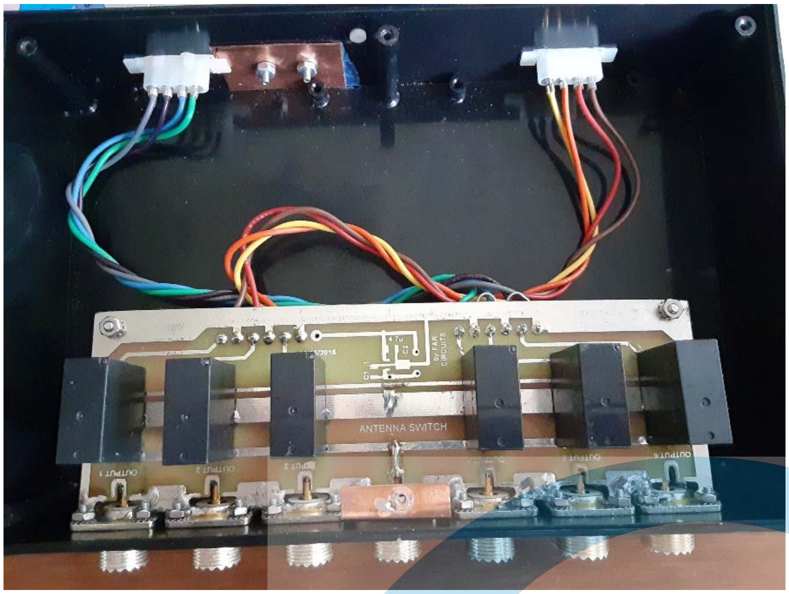

Figure 5 - Inside of enclosure - wires are not yet fully seated in connector bodies

PCB were flimsy and undersized, and a poor fit to *any* of the SO-239 variants that I tried to fit, including the expensive Amphenol connectors cited in the original article. I ended up bridging the gaps with some flat copper braid or some bare wire from the shell of each SO-239 to the PCB traces. Another problem is that the PCB installation provisions for the Phoenix 1729050 6-circuit terminal strips are rather poorly prepared. On one side of the PCB, there are pads for one of the terminal strips, but not for the second strip. In any event, the pads are largely worthless, as the holes themselves are not through-plated. The board design prevents the builder from installing the terminal strips on the “component side” of the PCB. This is not a big deal other than the fact that with this installation location, it becomes necessary to connect the switch control input wires to the terminal strips before installing the PCB into the enclosure. Let the buyer beware!

This version of the board is designed to provide for active low or active high control of the relays, using a three-pin header with a shorting cap to make that selection. I opted to simply install a jumper wire between the PCB holes instead of using the jumper setup. The board also includes traces and pads for a 12V three-pin SMT voltage regulator for use in instances where the builder is supplying a higher voltage, like 24VDC, to the relay board. This regulator position also includes pads for a 4.7µF capacitor in conjunction with the regulator. None of that was needed in my build, so I simply ignored that whole area of the board.

To round out the switch unit construction, I decided to install the whole thing into a black ABS plastic 2-piece enclosure. The board measures 7.5” x 2.4”, and the SO-239 connectors are mounted along the long edge of the board. The enclosure that I used was one that I had on hand, and it measures 9.5” x 6.35” x 2.4”, more than large enough to do the job. Along one of the long faces of the lower section of the enclosure, I laid out and drilled the holes for the seven SO-239 connectors. There are seven such connectors because one of them – the center connector – is the RF input to the switch unit. The remaining six connectors are the various antenna RF outputs from the switch. Any unused SO-239 connectors are covered with weather-tight threaded caps on chains.

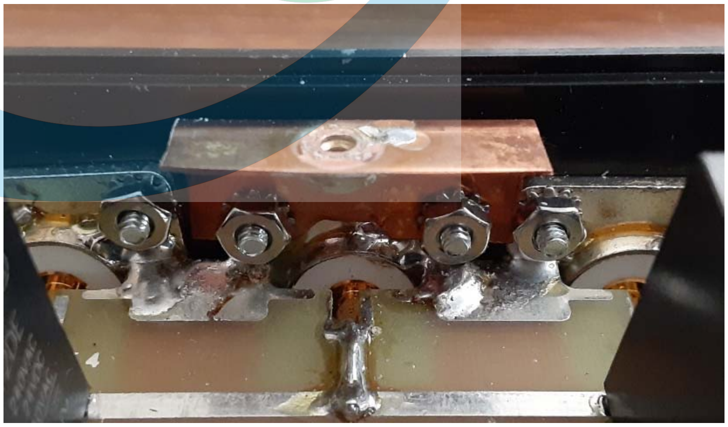

Figure 6 - Copper sheet metal securement fixture

Once the holes were drilled, I dry-fitted the assembled board to the enclosure and marked out the two holes for the inner edge support of the PCB within the enclosure. Then I laid out and cut the two holes for the Molex four-pin connector bodies (Figure 5) to be mounted to the opposite long face of the enclosure lower section. As it turns out, I made a small error in actually cutting one of these openings, making it about three-eighths of an inch longer than it should have been. As a result, the Molex shell mounted at that location is secured by a small piece of copper sheet metal mounted to the enclosure on the inside of the enclosure. To prevent cross-connection of the two cables from the controller, one of these Molex connectors has male pins while the other one has female sockets. The same arrangement was used on the controller unit rear panel, making it impossible to cross-connect the control cables. Inside the enclosure, each of the Phoenix connectors on the PCB are carried out to the reap panel Molex connectors by color-coded hook-up wire.

Switch Head Parts List			
Description	**P/N**	**Qty**	**Supplier**
Printed Circuit Board	KO4NR	1	FAR Circuits
Relay 12VDC DPDT Form 1C	AZ755-1C-12DE	6	Mouser
Diode	1N4001	6	Mouser
Connector Plug Body, Male Molex 0.093" Standard	538-03-09-2041	1	Mouser
Connector Receptacle Body, Female Molex 0.093" Standard	538-03-09-1041	1	Mouser
Crimp Terminal, Molex 18-24 ga. 0.093" Male Pin	538-02-09-2103	4	Mouser
Crimp Terminal, Molex 18-24 ga. 0.093" Female Socket	538-02-09-1104	4	Mouser
Duck Bill Vent	B07TKRM2JS	2	Amazon
SO-239 Connector, Teflon-Insulated	721405422371	7	www.w5swl.com
Terminal Strip	1729050-02	2	Mouser
Capacitor 0.001µ 50V 0805 SMT Ceramic	C0805F102K5RACTU	6	Mouser
Enclosure, Serpac 9.5" x 6.35" x 2.4"	094BK	1	Digikey

Table 1 - Switch head parts list

The upper section of this enclosure is secured to the lower section via six screws, one in each corner and one centered along each of the long edges of the enclosure. As it turns out, one of those two center bosses onto which the cover securement screws would be inserted had to be cut away to accommodate the installation of the PCB along that face of the enclosure. This would have made the enclosure less weather-tight as there would be a loose area and a hole where the missing screw should have been. To solve that problem, I cut a small piece of copper sheet metal, laying out and drilling three holes in it, and then bending it so that it could be mounted to the upper two screws on the center SO-239 connector shell, placing a hole directly underneath the screw hole for the missing retaining screw (Figure 6). I then soldered a brass nut to the copper sheet underneath that hole, making a fastener into which a 4-40 machine screw could be driven to secure the enclosure upper section properly all the way around its periphery. With all of the openings in the enclosure completely filled – I sealed the Molex connector shells to the enclosure with hot glue – the enclosure was now air tight. However, I wanted to vent the enclosure so as to allow for seasonal temperature and pressure changes without leaving openings for water or insects to get into the enclosure. To that end, I drilled two small holes and then installed a duck-bill vent into each of these two holes,

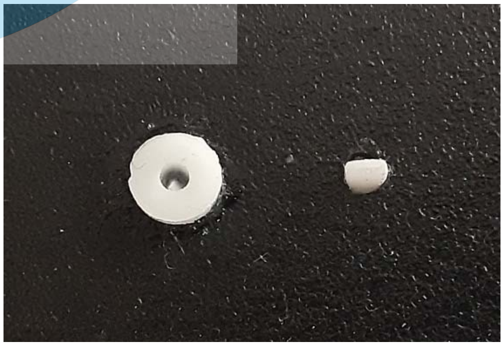

Figure 7 - Duck bill vents installed

facing in opposite directions (Figure 7). Thus, one vent breathes in while the other breathes out, and the enclosure remains sealed against water or insect entry.

Once all was ready, I installed the PCB into the enclosure lower section, securing each SO-239 connector with four 4-40 x 3/8” machine screws with lock washers and hex nuts. The inner edge of the PCB is supported by stand-offs mounted to the floor of the enclosure, and the wires from the Phoenix connectors were inserted into their proper ports in the Molex connector shells. The enclosure upper section was installed to the lower and secured with the six screws intended for that purpose.

Figure 8 - Controller front panel

The switch unit is the business end of the system. It requires a controller (Figures 8 and 9) in order to operate, and that controller is the subject of the next part of this article. I designed and built a simple but effective and relatively low-cost controller that can provide the requisite voltage and current to operate the switch unit relays despite some voltage drop in the connecting control cable assembly.

The heart of the controller is a common LM317 adjustable three-pin voltage regulator, rated for one ampere continuous current output at some adjustable regulated voltage. The switch unit uses 12VDC relays for its switching members. The relay coil current demand is on the order of 158mA at 68°F, so the one ampere capacity of this regulator should be more than adequate even in worst-case conditions. The LM317 was chosen instead of the simpler to deploy LM7812 because I wanted the ability to adjust the circuit output voltage up a bit to compensate for any control cable voltage drop, thus providing the ability to maintain the optimal 12 volts to the relay coils. While it is true that the relays will operate at lower voltages, I wanted to design for best operating conditions.

Figure 9 - Controller rear panel

Power to the controller is 115VAC, input through a 500mA 5mmx20mm glass cartridge fuse and a SPST toggle switch, and then into a Hammond 166L16 16VAC center-tapped step-down transformer. Of course, the center tap is cut short and heat-shrink covered, as it is not used.

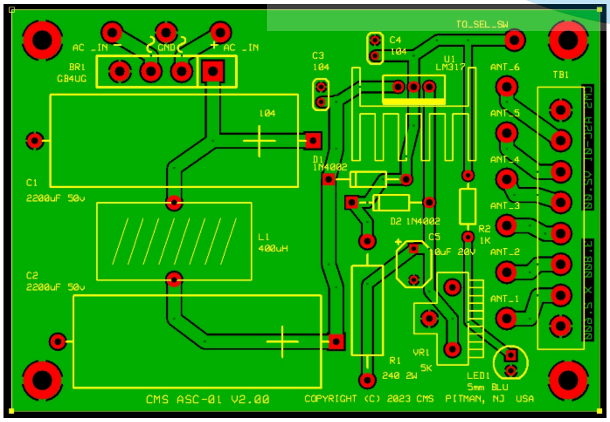

Figure 10 - Controller PCB design

I decided on a hefty GBU4G bridge rectifier (because I had some on hand) and a more-than-usual post-rectifier filter to provide the truest DC input to the regulator that was possible while still maintaining a relatively inexpensive design. This filter uses a pair of 2200µF 50V axial electrolytic capacitors with a 400µH toroidal inductor in a *pi* configuration. I could have used radial capacitors, as I also had them on hand, but I wanted to keep the height profile down and I had the board real estate to fit the axial variety, so I did so.

The voltage regulator IC has 0.1µF ceramic capacitors to ground at both its input and output, and is protected by a pair of 1N4002 diodes connected as per the LM317 datasheet. The LM317 *adjust* pin is bypassed to ground via a 10µF 20V tantalum capacitor. The adjustment circuit includes a 240Ω 2W resistor (again what I had on hand) and a 5kΩ trimmer pot to provide proper adjustment range.

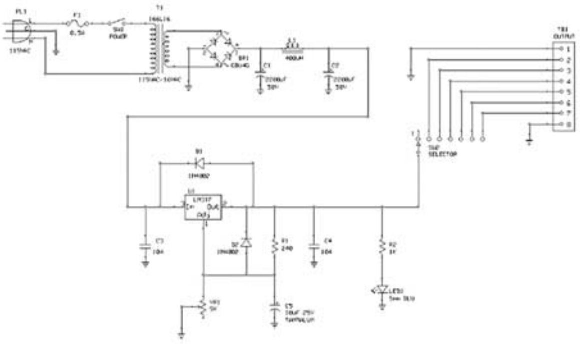
Figure 11 - Controller schematic diagram

A blue 5mm LED, current limited via a 1kΩ 250mW resistor, is connected from the voltage regulator output to ground, and serves as a power-on pilot lamp, being panel mounted near the power switch.


Figure 12 - Controller interior view

A 12-position rotary switch with position-limiting capability is used as the selector switch, connected to the custom PCB via a total of seven 18AWG wires. The switch is locked in at seven positions at 30°radial intervals, as is suitable for the six-relay complement in the switching unit, with its first position being an *"OFF"* position at which none of the relays will be energized. The output to the control cable is through an eight-position Phoenix 1729076 terminal block. The two end wire positions are ground positions, while the remaining six are for the antenna switch relay inputs.

As was hinted at above, I designed a custom printed circuit board for the controller, and had the boards manufactured by *jlcpcb.com*. The 2.6" x 3.8" PCB is illustrated in Figure 10, while the associated circuit schematic is shown in Figure 11.

The controller is housed in a two-piece aluminum enclosure from Jameco Electronics (*www.jameco.com*), p/n 208911, and was labeled using self-adhesive white vinyl label stock. The label designs were created in *CorelDraw!* and printed on my color laser printer. The labels were affixed to the enclosure's front and rear panels and then the required holes were drilled through the labels and the panel. Figure 12 illustrates the interior view of the controller unit.

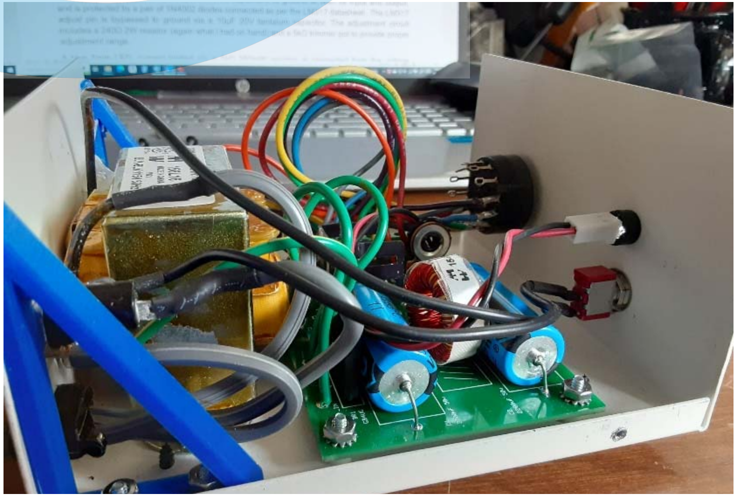
Figure 13 - Controller side view, showing supports and LED connection

The power cord is a flat three-wire 16AWG AC power cord three feet long with a NEMA 5-15P three-prong plug at one end, having its entry into the enclosure made through a Heyco 1814 strain relief. The strain relief required the drilling of a 7/16" hole that was then elongated to achieve an overall dimension of 7/16” X 5/8”, appropriate for the loaded strain relief. A pair of custom-designed and printed panel supports were installed to prevent inward flexing of the rear panel when the cables are plugged into their rear-panel connections. These supports can be seen in Figure 13, as can the means of connecting the front panel LED to the PCB.

Controller Parts List

Description	P/N	Qty	Supplier
Transformer, 115VAC/16VAC CT Hammond 166L16	546-166L16	1	Mouser
Power Cord, 16AWG 3C NEMA 5-15P 3’ long	9732SW8809	1	Southwire
Strain Relief, SR302-1 Black Heyco 1814	836-1814	1	Mouser
Switch, SPST Miniature Toggle 5A/125VAC	76523	1	Jameco
Fuse Holder, Panel Mount 5x20mm	150464	1	Jameco
Fuse GMA-type 5x20mm 0.5A Glass	102041	1	Jameco
Full Wave Bridge Rectifier, GBU4G 400V 4A	512-GBU4G	1	Mouser
Capacitor, 2200µF 50V Axial AL Electrolytic	598-228TTA050M	2	Mouser
Inductor, 400µF Toroidal Hammond 1540M08	546-1540M08	1	Jameco
Capacitor, 0.1µF MLCC	25523	2	Jameco
IC, LM317T Voltage Regulator	23579	1	Jameco
TO-220 Heat Sink Low-Profile Hat Section 1.75” x 0.70” x 0.38”	2155022	1	Jameco
TO-220 Heat Sink Installation Kit	2227284	1	Jameco
Capacitor, 10µF 20V Radial Tantalum	80-T355E106K020AT-TR	1	Mouser
Diode, General Purpose 1N4002	76961	2	Jameco
Resistor, 240Ω 2W 5% Metal Film	594-5083NW240R0J	1	Mouser
Potentiometer, 5kΩ Thumb Wheel	94706	1	Jameco
Resistor, 1kΩ 250mW 5% Carbon Film	690865	1	Jameco
LED, T1-3/4 (5mm) Blue Water Clear	2239023	1	Jameco
Terminal Strip, Phoenix 1729076-02	651-1729076	1	Mouser
LED Holder, 5mm LED Panel Mount	23077	1	Jameco
Connector Receptacle Body, Molex 0.100” KK-series	234798	1	Jameco
Crimp Terminal, Molex KK-254 22-24 ga.	736595	2	Jameco
Switch, 1P12T Rotary 350mA/30VDC Solder Lug	576501	1	Jameco
Knob, Pointer with White Line, 1/4” Shaft with Set Screw	102788	1	Jameco
Enclosure, 5.9” W x 5.3” L x 3.0” H with rubber feet	208911	1	Jameco
Connector Plug Body, Male Molex 0.093” Standard	538-03-09-2041	1	Mouser
Connector Receptacle Body, Female Molex 0.093” Standard	538-03-09-1041	1	Mouser
Crimp Terminal, Molex 18-24 ga. 0.093” Male Pin	538-02-09-2103	4	Mouser
Crimp Terminal, Molex 18-24 ga. 0.093” Female Socket	538-02-09-1104	4	Mouser
Interconnect Cable to Switching Unit	(4) 18AWG/4C Cable, PVC-jacketed x 32 feet long		
Connector Plug Body, Male Molex Mini-Fit Jr.	538-39-012-041	2	Mouser
Connector Receptacle Body, Female, Molex Mini-Fit Jr.	538-39-012-045	2	Mouser
Crimp Terminal, Molex 18-24 ga. Male Pin	538-39-000-041	8	Mouser
Crimp Terminal, Molex 18-24 ga. Female Socket	538-39-000-039	8	Mouser
PCB - Custom	Supplied by author, available for purchase		
Enclosure Panel Support - Custom	(2) Supplied by author, available for purchase		
Hardware for mounting PCB and Transformer	(4) 4-40 x 1/2” and (2) 6-32 x 3/8” sets with KEPS nuts		
PCB Mounting Spacers	(4) #4 x 3/16” white nylon tubular spacers		
Ground Connection	8-32 x 1” machine screw with flat washers, KEPS nuts, and wing nut		

Table 2 - Controller parts list

The PCB measures 3.8” x 2.6”, and the transformer has a footprint of 3.25” x 2.00” with 2.81” between the holes in its mounting flange. With the enclosure measuring 5.9” wide and 5.3” long, it is relatively simple to position the PCB and the transformer next to each other on the floor of the enclosure. The power entry and fuse holder are installed to the enclosure rear panel, while the power switch, pilot LED, and selector switch are all on the front panel. The three-inch height of the enclosure provides plenty of headroom for the two-inch transformer height. The transformer is secured to the enclosure floor via 6-32 x 3/8” hardware including toothed lock washers and hex nuts. The PCB is installed using 4-40 x 1/2" hardware including toothed lock washers and hex nuts, and sits on #4 x 3/16” tubular nylon spacers.

The LED pilot lamp is installed, as mentioned, into the front panel near the miniature SPST toggle-type power switch. I used a two-piece mounting bushing that is installed into a 1/4" hole, with the two parts heat-welded together via the tip of a soldering iron. The LED snaps into the bushing. I chose to use a Molex KK-series 0.100” two-position female socket to connect the LED to the PCB (Figure 13), but wire leads could be soldered directly to the LED instead, and then covered with heat-shrink tube.

The leads to the power switch *must* be heat-shrink tube sealed due to the high voltage available there, as are the leads at the fuse holder. This is purely a matter of safety and common sense. As the schematic shows, the fuse and switch are in the transformer primary winding circuit; the secondary winding leads go directly to the PCB.

A ground lead from the PCB to the chassis (enclosure) rear panel provides for affirmative grounding of the PCB. That ground wire is attached to an 8-32 x 1" machine screw that projects through the rear panel of the enclosure and accepts the ground connection to the shack single-point ground system, securing it there via an 8-32 wing nut. The ground lead from the incoming AC power cord is also connected at that point.

The output cabling is handled via a pair of parallel 4-conductor 18AWG sheathed cables, routed through a pair of snap-in Molex standard 0.093” 5.03mm-pitch connectors. I drilled a pair of adjacent holes at each connector location on the rear panel, and then squared the holes off to their final sizes. The controller parts list includes some Molex connector body and terminal pin numbers for extending the lengths of the output cables if single-length cables are unavailable or are cost-prohibitive.

I prepared a pair of short (three-foot) output cables for testing purposes, and I found that the system works as designed. The RF throughput is good for the entire VHF and UHF portions of the radio spectrum in which I am interested, specifically from 1.25 meters through the upper end of the 70-centimeter band. Throughput loss is negligible, with a maximum 1.025:1 VSWR measured at about 442 MHz.

While the specs are good on the switch head relays, and while they are rated for continuous duty, it remains to be seen how they will actually stand up to real-world working conditions. I am fully confident in the design and operation of the controller. The purpose of the 5kΩ potentiometer on the controller PCB is to allow final adjustment of the output voltage, so as to derive a full 12 volts at the relays with the unit installed and the output cable voltage drop in circuit. I have spoken with two other hams who have built antenna switch units based upon the PCB used in my design, and both report at least “acceptable” performance. I have agreed to build a controller for one of these folks, as he is not happy with the control solution that he is currently using.

All things considered, this was a rewarding project and one that can be undertaken by most hams with a little bit of soldering and construction know-how. The unit will do the job for which it was designed, and the controller looks good in the shack. While the switch unit could have been more compact, space was not a consideration for this outdoor item. The controller, however, is quite compact and would be easily fitted into almost any shack environment.