antenna relay sequencing

Use one basic protection circuit for normal switching or full break-in

Antenna relays are very expensive, and while bargains can sometimes be found on the surplus market and at swap meets, it takes time to find them.

Running 1500 watts into 50-ohm coax means that more than 5 amperes of rf current flows at almost 300 volts. Coax relays, with their contacts and spacing kept relatively small to preserve the impedance match, are definitely not designed to hot-switch this kind of rf power. If you try using them for this, you'll burn out the contacts; in fact, Murphy's Law ensures that transmit contacts will burn out completely just as you hear the rare DX country or VHF grid square you've been looking for.

Another form of antenna relay failure that's as common as burning out the contacts is arcing from the transmitter connector to the relay shell. This is caused by abnormally high rf voltage output from a high-power amplifier under open-circuit conditions.

A power amplifier also needs protection from any open-circuit condition, even for just a fraction of a millisecond. If a tube-type amplifier sees an open load at any time, either at the beginning or the end of a transmission, plate circuit arcing and damage to the components may occur. In solid-state amplifiers, an open load can destroy the transistors instantly.

The need for sequencing a mast-mounted VHF preamplifier is well known. GaAsFETs certainly aren't designed to handle several hundred watts, even for the few milliseconds it takes for a relay to switch.

This article discusses the most common case of a power amplifier and an ordinary coaxial antenna relay. The same basic circuit is used for full break-in with vacuum relays; in such a situation, the delay periods will simply be shorter. The same circuit can also be used to sequence mast-mounted VHF preamplifiers, together with an interface circuit to delay the exciter.

design criteria

To protect the relay and amplifier when the push-to-talk (PTT) line is closed, the amplifier turn-on should be delayed long enough for the relay contacts to close — and, most important, to have settled down after bouncing. To protect the relay and amplifier when the PTT line is opened, the relay contacts should be held in long enough for the amplifier output to have dropped to zero.

Each unit should, as much as possible, "take care of itself." This means, for example, that the relay should not depend upon a certain capacitor in the exciter or amplifier for a delay. Because you might want to use a different exciter or amplifier later on, the sequencing circuit should be treated as an integral part of the antenna switching mechanism.

circuit specifications

The timing functions of amplifier hold-off at the beginning of a transmission and relay hold-in at the end of a transmission are separated, greatly simplifying the selection of timing capacitors.

The control line for the circuit conforms to the following standards, which I've adopted for all the equipment in my shack: the open-circuit voltage on the control line is negative, and does not exceed −1 volt; the closed-circuit current on the control line does not exceed 1 mA; and the control line is diode-isolated. The first two standards ensure that the control line may be easily controlled by other such circuits, using inexpensive, easily obtainable, low-voltage PNP transistors, without the need for complicated interface circuits or relays. The result is that everything in the shack (except the antenna and other rf circuits) is controlled by solid-state switching. The final standard al-

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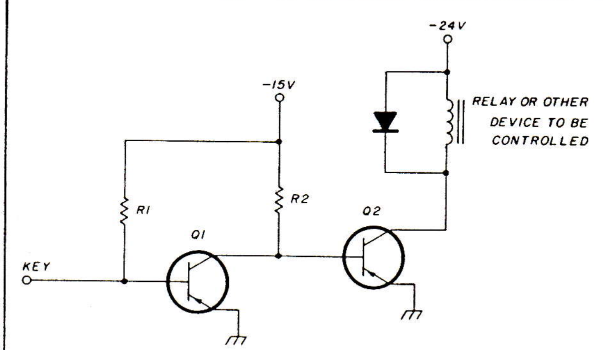

fig. 1. Basic two-transistor PNP switch.

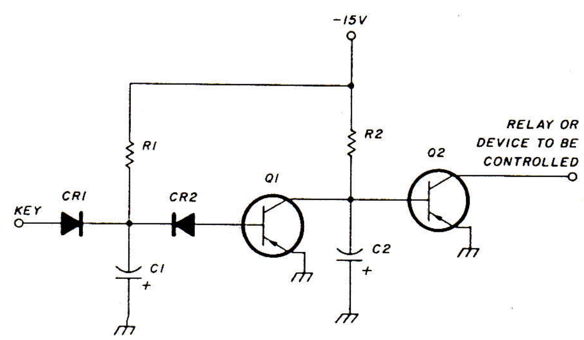

fig. 2. Basic switch with diode isolation and timing capacitors added.

lows the control lines of any number of such relay circuits, power amplifiers, drivers, transverters, preamplifiers, or other items to be tied in parallel, with no interaction. If the exciter's PTT line conforms to these standards, or is fitted with an appropriate interface circuit so that it does conform, it may be tied in parallel with the control lines of any number of other pieces of equipment, along with the PTT switch on the mike stand and the foot switch. A master band switch on the operating bench allows you to select which amplifiers, transverters, or antennas are to be tied in at the same time.

Since my exciter has a negative voltage on the PTT line, and my tetrode amplifiers use negative bias standby switching, I've used negative relay supplies and PNP switches for everything in the shack. However, this circuit can also be used with positive supplies by merely substituting NPN transistors and flipping over all the electrolytic capacitors.

A basic two-transistor PNP switch is illustrated in **fig. 1**. I use dozens of these switches in my shack. Most of the transistors are available for about ten cents. The relay drivers (which must handle high current) and the tetrode amplifier bias switches (which must handle high voltage) cost a bit more. I've used this circuit to convert all the gear I've built with relays over the last 40 years to solid-state switching; none has ever failed.

circuit description

The switching operation shown in **fig. 1** is very simple. Were it not for Q1, resistor R2 would supply enough base current to saturate Q2. This lowers the collector voltage to a very low value, which energizes the relay and enables the amplifier or other circuits. In the unkeyed state, resistor R1 supplies enough base current to saturate Q1, lowering the voltage at the collector of Q1 to about −0.1 volts, much lower than the −0.6 volts needed at the base of Q2 to turn it on. Thus, in the normal state, Q1 is on and Q2 is off. Now what happens when the key is closed?* Keying the circuit grounds the base of Q1, turning it off. This removes the grounding (by the collector of Q1) from the base of Q2, allowing R2 to turn it on. Now the collector of Q2 drops to about −0.1 volts, enabling the relay or other device. Having the top of the relay coil always hot is one clue to the simplicity of this circuit. The transistors all have their emitters grounded and are either on or off, so their collectors either present a ground to the next stage or do not. Everything in the shack is enabled by simply grounding a terminal. There's no need for making two-wire connections when you want to apply a voltage to something.

The basic circuit shown in **fig. 1** needs only diode isolation and timing to become a full working device. These features have been added in **fig. 2**.

diodes provide isolation

Diode isolation is provided by inserting CR1 in the key line. If two or more of these switches have their key lines all tied together, the diodes CR1 in each switch will prevent any current flow between switching circuits. There's only one problem: with CR1 in the key line, closing the key reduces the voltage at the low end of R1 only to the forward voltage drop of the diode, which is just about the same as the −0.6 volts required to turn on the base-emitter junction of Q1. Thus, Q1 may or may not turn off, depending on the characteristics of the diodes and transistors, the temperature, and other such details. Diode CR2 saves the day by producing a 0.6-volt drop between the low end of R1 and the base of Q1. Now the voltage at the low end of R1 must be about −1.2 volts to turn on Q1. Closing the key drops it to −0.6 volts, and Q1 goes off with absolute certainty. Thus CR2 fixes the problem caused by the isolating diode, CR1.

*"Key" is a generic term used here for the point in any solid-state switch, relay circuit, exciter, or amplifier which is grounded in order to enable the device. Only in a CW keying circuit would "key" indicate a real telegraph key, and even then we'd usually be referring to the output of an electronic keyer. In this antenna relay sequencing circuit, the PTT line connects to the "key" terminal of the switch.

Figure 2 shows the general form of the switch, with two timing capacitors, although we use only one capacitor in each of the separate antenna relay and amplifier switching circuits. (Both capacitors could be used in certain applications, when both turn-on and turn-off delays are desired.) Capacitor C2 provides a turn-on delay (which we will use for the amplifier), while capacitor C1 provides a turn-off delay (which we will use for the relay). When the key is closed, C1 discharges immediately through CR1, and Q1 turns off. This allows R2 to turn on Q2, but not instantaneously. It must charge C2 up to about -0.6 volts, and this takes a bit of time. Thus C2 provides a turn-on delay, but C1 doesn't affect the turn-on. Now when the key is let up, this allows R1 to turn on Q1 — but, again, not instantaneously. It must charge C1 up to about -1.2 volts, and this provides the turn-off delay. As soon as Q1 turns on, its collector discharges C2 immediately, so C2 doesn't affect the turn-off time.

separate relay and amplifier switching

It's the clean separation of functions between C1 and C2 that makes the use of two separate switching circuits — for relay and amplifier — well worth the few extra parts. In the relay switching circuit, there's no C2 and the turn-off delay capacitor C1 doesn't delay the turn-on. In the amplifier switch, there's no C1 and the turn-on delay capacitor C2 doesn't delay the turn-off. Although there may be circuits that will do all this with one transistor, the adjustment of turn-on and turn-off times is much more complicated, there's no isolation (so key lines can't be tied together), and hot two-wire connections are often required. The sequencing could also be done with timer ICs, but this circuit seems simpler and may be less susceptible to rf pickup problems. Instead of comparators and timer thresholds, this circuit simply uses the base-emitter junctions of the transistors, which have sharp thresholds at about 0.6 volts with hard turn-on currents, resulting in a very sharp positive action. Timer IC circuits would still need the timing capacitors, transistors for relay drivers, and transistors or relays in interface circuits to match PTT lines and amplifier control lines.

selection of bias resistors

The basic switching circuit shown in **fig. 1** doesn't show the values of the bias resistors R1 and R2. These depend on the load current to be switched. Take first an antenna relay switch. A typical 24-Vdc antenna relay draws about 80 mA — let's say no more than 100 mA. We don't need the exact relay coil current, but rather just an upper limit for design purposes; our circuit will work well with any relay drawing less than this limit. To ensure that Q2 turns on hard at this collector current, a good rule of thumb is to provide a base current of about 10 percent of the collector current. This is like asking the transistor to have a gain of 10; the transistors we'll be using have typical gains in the 50 to 200 range, so this is quite a conservative rule. For Q2 to turn on hard means that with the 100-mA collector current, the collector voltage should drop quite low, to about 0.1 or 0.2 volts. This is not to ensure that the relay coil will get the full 24 volts (it will probably work fine at only 20 volts), but instead to keep the Q2 collector dissipation low. At 0.2 volts this will be only 0.02 watts, but if Q2 doesn't turn on hard, and the collector voltage drops only to 4 volts, the dissipation will be 0.4 watts, more than the rating of a typical ten-cent transistor. So for a 100-mA collector current, we'll provide a base current of 10 mA. The bias resistor R2 should then have the value $R = E/I = 15/0.01 = 1500$ ohms. The power in R2 will be $P = I^2R = (0.01)^2 \cdot 1500 = 0.15$ watts, so a 1/2-watt resistor will be satisfactory.

Q1 has to sink the 10-mA current in R2 in order to keep Q2 off until we push the PTT button. The collector voltage of Q1 should be as low as 0.1 to 0.2 volts, well below the 0.6 volts required by the base of Q2, so that Q2 will stay off. We apply the same rule of thumb as before; Q1 needs only 1-mA base current in order to sink 10 mA in the collector circuit. Thus for R1 we need a value of $R = 15/0.001 = 15$ k. Of course, the voltage across R1 isn't the full 15 volts, because of the small voltage drop in CR1 and the base-emitter junction of Q1. But there's no need here for mathematical precision. The power in R1 will be only 0.015 watts, so we'll use a 1/4-watt resistor. (Whenever the required current comes out less than 1 mA, I always provide 1 mA anyway; this avoids unusually low currents, thereby lessening any possibility of problems from leakage in the PTT line or rf pickup, and ensures that the output transistor in any switch, even if built to switch only another 1-mA line, will sink at least 10 mA, and will thus switch several 1-mA lines simultaneously if necessary.)

The current gain of the two transistors together is the product of the individual gains. Thus, to be safe, we assume a combined gain of 100, although 10,000 would be a more typical value. It's this gain of at least 100 that allows the 100 mA relay coil to be controlled with only 1 mA on the PTT line.

The amplifier switch bias resistors are even easier to select. If the amplifier bias switching circuit follows the standards listed above, you'll need to sink only 1 mA on the amplifier control line. So 15-k, 1/4-watt resistors will be acceptable for both R1 and R2. We'll leave the bias switching problem to the amplifier itself. This will keep the bias, up to -300 volts, off our control lines and out of our station band switch. The bias switch will be discussed below.

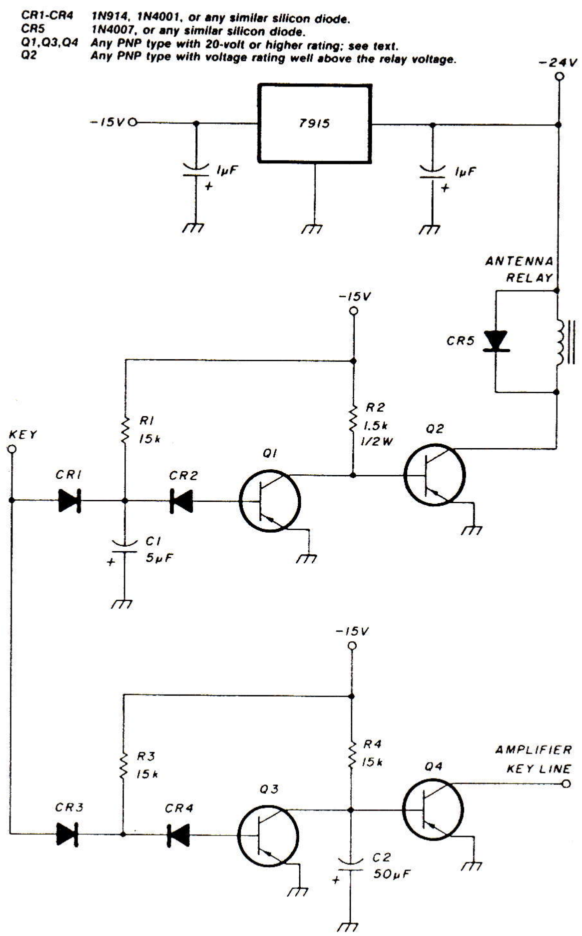

fig. 3. Complete sequencing circuits. Component values shown are for a typical 24-volt antenna relay; for other relays, see text. Not shown is rf filtering on all lines that lead outside the box, and disc ceramic bypass capacitors from base to emitter of each transistor. This filtering with rf chokes and bypass capacitors follows standard practice; actual values of the components will depend upon the frequency of operation.

selecting the timing capacitors

Figure 3 shows a typical complete sequencing circuit — in this case, for a 24-volt relay. The −24 volt relay supply is further dropped to −15 volts for the timing circuits. Since the voltage used affects the timing, this ensures that if the relay is changed to one with a different coil voltage, the timing circuits need not be readjusted.

Because of variations in the actuating time of different relays, it won't be sufficient to merely provide component values; the method of calculation must be explained. The time constant formula T = RC is usually used to choose circuit values in an R-C timing circuit, as in **fig. 4**. The units are seconds, ohms, and farads, but if kilohms and microfarads are used for R and C, the formula conveniently gives the time, T, in milliseconds (ms). The time constant, T, is the time required to charge the capacitor to about 63 percent of the applied voltage, V. In the circuit used here, however, the capacitors never charge beyond about −0.6 or −1.2 volts. To find the exact time to reach this voltage requires a complicated exponential-growth formula. But in this situation the level of charge is less than 10 percent of the applied voltage, so a much simpler formula will suffice:

$$v \approx \frac{t}{T} V \qquad (1)$$

This is a straight-line approximation to the exact voltage. Here, V is the applied voltage, v is the voltage reached after time t, and T is the time constant. The formula indicates a simple proportionality between the time and the voltage. Thus, in a circuit with a time constant, T = 500 ms, and an applied voltage of V = 15 volts, the capacitor will charge to about v = −0.6 volts (4 percent of the applied voltage) in about t = 20 ms (4 percent of the time constant). For a 10-ms antenna relay, this delay would be enough to hold off the amplifier while the relay closes.

Once we have the required time constant, it's easy to find the value of the capacitor needed in each bias circuit. With a 20-ms relay, we may wish to delay the amplifier for 30 ms, in order to allow for contact bounce. Using the relationship

$$t \approx \frac{v}{V} T \qquad (3)$$

with the values v = 0.6 volts and V = 15 volts, we find we need a time constant of

$$T \approx \frac{15}{0.6} \cdot 30 = 750 \text{ ms} \qquad (3)$$

The delay capacitor C2 is on the base of Q4. If the switching circuit in the amplifier follows the standards

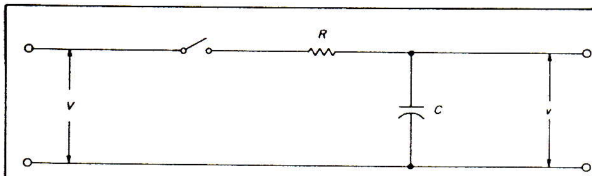

fig. 4. RC timing circuit. The time constant of this circuit is defined by T = RC, which is the time required for the voltage v on capacitor C to reach about 63 percent of the applied voltage V. The exact time required for the voltage on capacitor C to reach a specified voltage v is given by t = −T ln (1 − v/V). However, it is not necessary to use such a precise formula. The approximate time required for the voltage on capacitor C to reach a low specified voltage v is given by: $t = \left(\frac{v}{V}\right) \cdot T$. This approximation is within 6 percent of the exact time, as long as v is less than 10 percent of the applied voltage V.

CR1,CR2	1N914, 1N4001, or any similar silicon diode.
R2	For higher R3 current drain, the value of R2 is lowered, as described in the text.
R3	Bias adjustment potentiometer in existing amplifier.
R4,R5	Voltage divider to provide about −15 volts to the switching transistors. The current required depends on the value of R2. R4 can be the bleeder resistor in the existing bias supply. The lower end of R4 is lifted from ground and R5 is inserted.
Q1	Any PNP type with 40 V or higher rating; see text.
Q2	Any PNP type with 300 V or higher rating, see text.

(part of fig. 7)

CR1,CR2	1N914, 1N4001, or any similar silicon diode.
Q1	2N4401 or any similar NPN type.

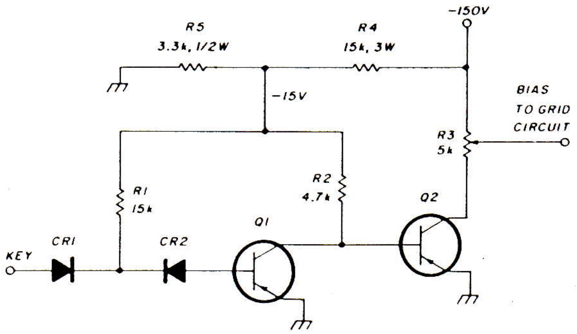

fig. 5. Tetrode amplifier bias switch. Values shown are typical for an amplifier of about −150 volts standby bias, such as a 4CX1000A. Rf filtering should be added, as noted in fig. 3.

listed above (for example, the circuit shown in **fig. 5**), the bias resistor R4 will have the value 15 k. Thus, we obtain

$$C = \frac{T}{R} = \frac{750\ ms}{15\ k} = 50\ \mu F \qquad \textbf{(4)}$$

Although one could calculate all this precisely, the final adjustment is best made empirically with an oscilloscope, as described below.

Now that we have the amplifier delay timing capacitor chosen, we can work on the antenna relay hold-in timing. On voice, one usually stops talking a fraction of a second before letting up the PTT switch. The delay is provided by our human reaction time, which is pretty slow compared to the speed of the electrons we're pushing up to the antenna. Still, one might release the PTT button in the middle of the last syllable, or take the foot off the foot switch while keying, and we have to provide for any such possibility. A good exciter continues to transmit for 3 to 5 milliseconds after the key is let up; this allows gradual decay of the keying waveform and prevents key clicks. If the antenna relay opens during this time, arcing will result, and in the case of QSK operation, key clicks will be generated.

For these reasons we provide a short delay in opening of the antenna relay when the PTT line is opened. In **fig. 3**, this is done with C1 at the base of Q1 in the relay switching circuit. When the PTT line is opened, Q1 won't turn on until C1 charges through R1 up to about −1.2 volts. This is 8 percent of the applied −15 volts, so we need a time constant T = RC about 12.5 times the required delay. For a 6-ms relay hold-in time, T = 75 ms will be about right. If R1 is 15 k, C1 will need a value of C = T/R = 75 ms/15 k = 5 μF.

antenna relays

Since the best bargains for coaxial relays on the surplus market, or at swap meets, are 24-volt dc types, **fig. 3** shows the circuit for these. The dc relays offer the advantages of quiet operation, solid-state control, and the convenience of using the relay supply to power the sequencing circuit. However, the circuit is easily adapted for an ac antenna relay by adding a small reed relay as shown in **fig. 6**. The reed relay switching time is quite small compared to that of the coax relay. We can add a few milliseconds to our computations, or just let it be absorbed in the final scope test.

Because of the high cost of antenna relays, I've followed the old-fashioned custom of using only one relay, at the amplifier output, with the receiver antenna line running to a separate jack on the exciter. This minimizes losses on VHF and alleviates the need for double

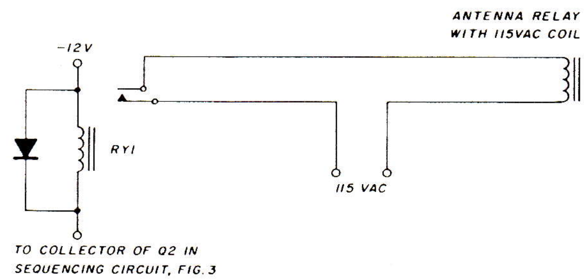

fig. 6. Interface for ac-operated antenna relay. RY1 is a 12-volt reed relay; other coil voltages may also be used.

relays on every preamplifier, attenuator, transverter, and driver down the line. This method is also highly recommended by some GaAsFET preamplifier manufacturers for safest operation. However, if you want to use two relays, switching the input and output simultaneously, just connect the coils in series or parallel, depending on the operating voltage available.

In the complete sequencing circuit shown in **fig. 3**, both the relay switch and amplifier switch are limited to 1-mA closed-circuit current, but the circuit as a whole requires the PTT line to sink 2 mA. The design standards can be implemented a bit loosely; in fact, the 1-mA limit was chosen for just this reason. If each individual circuit conforms to this limit, then any reasonable number of such circuits can be tied in parallel, and the total current will remain small.

In one of my relay sequencing circuits, extra protection is provided by inserting one set of the coax relay auxiliary contacts at the input to the amplifier delay circuit at the base of Q3 in **fig. 3**, and the other set at the output at the collector of Q4. This keeps the amplifier disabled in the event of failures such as an open relay coil or a shorted or open transistor. This also provides some mechanical delay so that C1 need provide delay only during the bounce time. However, this mechanical method doesn't eliminate the need for the amplifier sequencing circuit. Oscilloscope tests on typical antenna relays show considerable antenna contact bounce times, continuing long after the auxiliary contacts close. Incidentally, the "hot-shot" method (providing double the coil voltage for about 50 ms) often seems to make the bounce worse!

amplifier switching

For tetrode amplifiers with negative grid bias standby switching, amplifier switching is done with a separate switching circuit installed in the amplifier, as shown in **fig. 5**. In principle, the amplifier bias adjustment control could be connected directly to the collector of Q2 in the sequencing circuit of **fig. 3**, but this would have several disadvantages. The voltage rating of Q4 would have to be high enough to handle the full standby bias of the amplifier, as high as −300 volts or more. This high voltage would be on the cable between the amplifier and the sequencing circuit, violating the standards set forth at the opening of this article. If the control lines of both the driver and final amplifier are tied together at Q4, the −300 volts from the amplifier would appear at the driver switching circuit and in the station band switch. The isolating diodes would have to be the high-voltage type and there would be dangerous voltages in unexpected places. I much prefer to have the bias switching circuit inside the amplifier, even though it may seem a bit strange to find four transistors between the PTT switch and the amplifier bias circuit. All but the last one — a required high-voltage type — are inexpensive.

For amplifiers with screen voltage standby switching, a small reed relay with a solid-state driver can be installed in the amplifier. For zero-bias triode amplifiers, the solid-state interface circuit shown in **fig. 7** may be used.

connection to the exciter

The PTT jack on the sequencer can be connected in parallel with the PTT line of the exciter if the exciter PTT line is also negative and isolated. If the exciter PTT line is negative but not isolated, isolation can be easily provided by using the basic circuit of **fig. 2**, with no timing capacitors. If the exciter PTT line is positive, and you want to use negative switching for most gear in the shack, the interface circuit shown in **fig. 7** can be used. For full break-in, the exciter can be delayed using another two-transistor switching circuit.

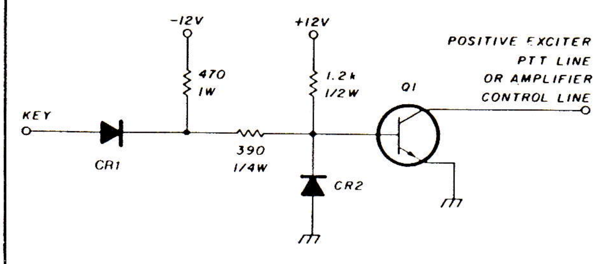

fig. 7. Interface for positive switching. This circuit will enable the negative switching sequencing circuit to control a positively-switched triode amplifier bias standby circuit, an exciter positive PTT circuit, or a relay energized with a positive voltage. It will sink more than 100 mA. Rf filtering should be added as noted in the caption for fig. 3. To reduce the current and voltage on the keyline, to conform with the standards suggested in the text, insert the basic circuit of fig. 2, without timing capacitors, in place of diode CR1.

testing and adjustment

The antenna relay can be tested to determine the actuating and bounce time before building the sequencing circuit, but it's easier to build the circuit using estimates of the delays required and then test the whole system afterwards. An amplifier delay of 50 ms and a relay hold-in time of 10 ms would be good figures to start with.

One possible test setup using a dual-trace triggered scope is shown in **fig. 8**. Although this illustration shows a battery, any available voltages from test supplies can be used. The antenna relay is controlled by the sequencing circuit, but the amplifier isn't used for the test. The external scope trigger connection, connected to the PTT line, is used. Thus the left edge of the scope trace represents closing of the PTT line. A foot switch, straight key, or push-button on the PTT line is convenient for repeated, manually triggered tests. The closing and opening transitions can be observed separately by changing the trigger polarity. One trace is used for the antenna relay contacts, and the other for the amplifier switching circuit. The testing is done with very small voltages and currents, so no damage results while you try different timing capacitors or parallel combinations of whatever capacitors are on hand in an effort to obtain the desired delays.

The timing capacitors should be selected so that the amplifier switch doesn't turn on until about 5 ms after the relay contacts cease bouncing and the contacts remain closed until about 10 ms after the amplifier shuts down. After initial adjustment, the antenna relay contact test current can be increased to several amperes; more bounce sometimes appears.

A single-trace scope can be used to see what's happening at two or more different places simultaneously, although it requires the special test circuit shown in **fig. 9**. A triggered sweep is still needed. The battery and the resistors establish various voltages, which the relay contacts and the amplifier switching circuit alter in such a way that can be observed on the scope. With the PTT line open, −9 volts will be seen on the scope. It stays at −9 volts while the relay contacts close. As soon as the relay closes, it climbs to −6 volts, then to −3.6 volts when the amplifier switching circuit turns on. If the amplifier switch turns on before the antenna relay closes, the trace will climb to −4.5 volts without going through the −6 volt stage, indicating that more amplifier delay is needed. Contact bounce before the amplifier switch turns on is seen on the scope as a fluctuation between −9 and −6 volts. Contact bounce after the amplifier switch turns on (to be avoided!) is seen on the scope as a fluctuation between −3.6 and −4.5 volts. Now when the PTT line opens, the amplifier switching circuit turns off instantly; the trace drops to −6 volts and stays there while the relay holds in, then drops back to the full −9 volts.

obtaining components

Inexpensive PNP transistors are available from the suppliers listed below.** For most circuit positions the 40-volt, 200-mA 2N3905 will do well. A good 24-volt relay driver is the slightly more expensive 120-volt 2N5400. Rated at 600-mA collector current, it will handle a 100-mA relay coil current with a nice safety factor. For higher coil current, such as we'd have with relays in parallel or 6-volt relays, the MPS-U57 (rated for 2 amperes) can be used. For tetrode amplifier bias switching in the circuit shown in **fig. 5**, the 300-volt MPS-A92 is available from BCD Electro.** These choices of transistor types are quite arbitrary; any available PNP types can be used as long as you check the manufacturer's ratings and compare these with the circuit voltage and current requirements.

For the timing capacitors, it's essential to use only tantalum electrolytics rather than ordinary filtering types. Tantalum will remain stable, with negligible leakage, over a very long time. Tantalum electrolytics usually have a 10 percent tolerance, which is satisfactory for sequencing purposes. On the other hand, the ordinary aluminum types often have tolerance ratings such as −20 percent to +100 percent. Because of this, and their leakage and unreliability, they are unusable in this application. Notice that in these circuits the capacitors never see more than 1.2 volts, so inexpensive 6-volt units may be used. One source for tantalum electrolytics is, again, BCD Electro.**

performance

For several years I've used two of these units with two homebrew amplifiers. One uses a 4CX1000A on 1.8 through 50 MHz; the other uses push-pull 4-400A's at 144 MHz. There's no arcing at the contacts, and I believe the antenna relays will last a long time.

Many antenna relays have an inspection port at one end, with a snap-in cover, for checking the contacts and connectors, which can be cleaned or replaced if necessary. It's interesting to remove this cover, turn off the shack lights, and watch for arcing. Without the sequencing circuit, the arcing can be seen clearly

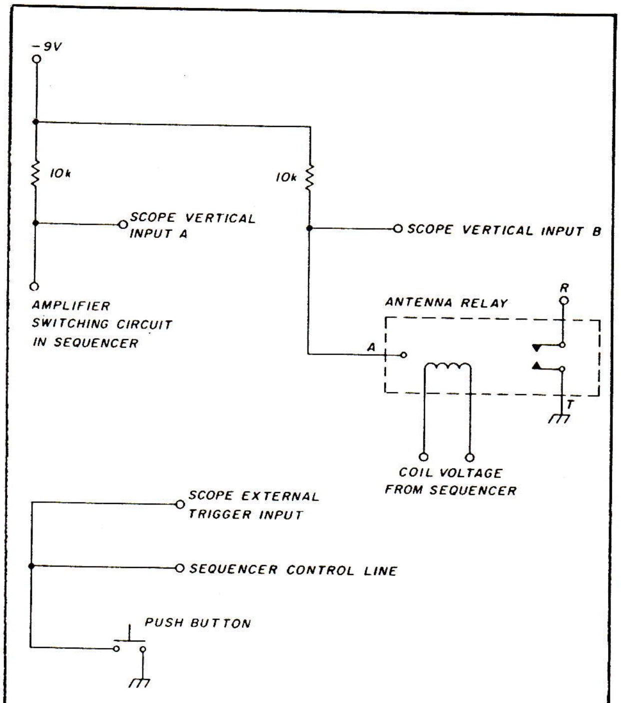

fig. 8. Test setup with a dual-trace scope.

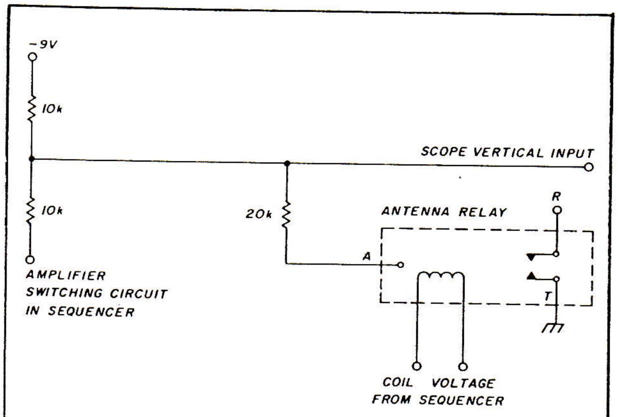

fig. 9. Test setup with a single-trace scope. Not shown is the trigger and PTT connection, which is the same as shown in fig. 8.

** BCD Electro, P.O. Box 830119, Richardson, Texas 75083. Parts also available from Circuit Specialists, P.O. Box 3047, Scottsdale, AZ 85257.

every time you push or let up the PTT button. (For this test I ran low power to avoid burning the contacts too badly.) The dark-shack visual method provides a good final check on the sequencing circuit; this was how I found out how important it was to allow for the contact bounce time.

The sequencing circuit will protect the relay against contact arcing as long as there's a proper load on the antenna terminal. If a proper load is absent because of high SWR, antenna failure, feedline failure, or parasitics, the rf voltage could reach a high level and arcing could result between the transmit contact and the grounded relay shell. To protect against this, rf voltage limiting can be used with the circuit shown in reference 1. This circuit senses the rf voltage from the relay terminal to ground and uses the exciter ALC system to keep the amplifier output level below the arcing point. If the relay and sequencing circuit are built into the amplifier, all these protection circuits can be combined on one circuit board with an ALC circuit from reference 2 or 3.

references

1. M. Mandelkern, KN5S, "High SWR Protection for Transceivers and Amplifiers," *CQ*, May, 1980, pages 63-65.
2. M. Mandelkern, KN5S, "ALC for Class AB_1 Amplifiers," *QST*, July, 1986, pages 38-39, 47.
3. M. Mandelkern, KN5S, "ALC for Triode Amplifiers," Technical Correspondence, *QST*, December, 1986, pages 46-47.

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