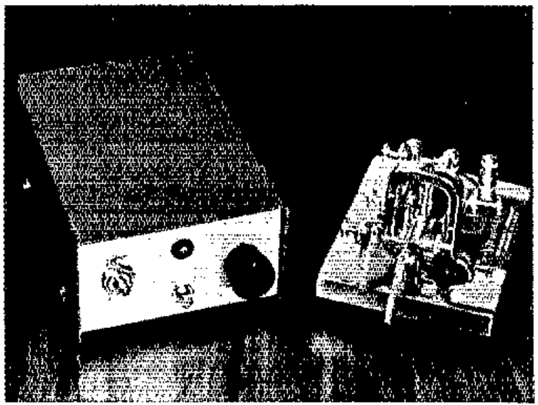
An Integrated

KEYER/TR SWITCH



BY JAMES H. FOX,* WA9BLK

THE AUTHOR has always preferred to work full break-in cw, which, once used, is never forsaken voluntarily. However, the usual problems with electronic T-R switches, signal suck-out and other ills, have led to other solutions. The excellent article in *QST* of July, 1964,[1] outlining the use of reed relays, forms the basis for the switching functions described here.

In addition, a desire to go to an electronic keyer after several years off the air led to a perusal of the article by W0ZHN and K0UXQ in *QST*.[2] While similar in spirit, the keyer that evolved does not much resemble that one, in that more readily available TTL instead of RTL integrated circuits are used here, necessitating a complete redesign of the circuit. However, the original features of the W0ZHN/K0UXQ keyer, including self-completing characters and exact dot/dash/space timing, have been preserved. More important, a dot memory has been added, after a brief period of operation using a keyer without this feature convinced the author of its desirability. Best of all, the final unit uses mostly parts that are readily available at Radio Shack stores throughout the country.

Basic Keyer Circuit

As shown in Fig. 1, the keyer itself consists of four sections: a timing circuit (U1), a dot generator and output stage (U2A), a dot memory (U2B), and a dash generator (U3A and U3B). U1 is a 74121 monostable multivibrator, while U2 and U3 are 7473 dual *J-K* flip-flops. This design provides for simple construction, a stable time base, and complete freedom from the double-dot problem often associated with dot-memory keyers.

The heart of the keyer is the timing circuit, which generates a continuous series of pulses so long as either the dot or dash lever is pressed. As shown in Fig. 2A, the basic timing interval consists of a timing pulse followed by a reset pulse. When the key is pressed, the 74121 monostable multivibrator (U1) generates the timing pulse, its length determined by the timing circuit R1-C1, where R1 is the speed control of the keyer. The output of the multivibrator is coupled back to the input by C2, producing the reset pulse which retriggers the circuit so long as the key remains closed. R2 is included to prevent loading down the Q output of U1, while CR1 serves to discharge C2 between reset pulses. In effect, we thus have a free-running multivibrator.

It is a tendency of keyed timing circuits to have a first pulse that is either longer or shorter than the following pulses. This is because the timing components need a period of transition between the static and dynamic operating states. In this circuit, CR1 very quickly discharges C2 during the timing pulse, so that it has reached its steady-state operating condition before the end of the first timing pulse. Further, the reset pulse occurs relatively slowly, as C2 recharges through R2 and the input circuit of U1. This gives C1 time to recharge between timing pulses, so that the second timing pulse sees essentially the same charge on C1 as the first timing pulse. As a result, the pulse-width stability at all keying speeds is better than 5% (typically half this amount) between the first and all following pulses. (In the author's opinion, a difference less than 10% is negligible.)

The $\bar{Q}$ output of U1 is coupled to the clock inputs of U2A and U3A. The Q output of U3A in turn is coupled to the clock input of U3B, forming the dash generator. When a dot is sent, U3B is held in the clear state ($\bar{Q}$ output high) through R3. This allows U2A to change state on every negative-going clock-pulse transition, creating equally spaced dots

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[*] 1 Lt., USAF, 2187 Comm. Gp. (AFCS), PSC Box 815, APO NY 09293. U. S. address, 200 Kewanna Dr., Jeffersonville, IN 47130.

[1] "A Keyed Antenna Relay," *QST*, July, 1964, p.29.

[2] Halverson and Stordahl, "An Integrated Circuit Electronic Keyer," *QST*, April, 1968, p. 22.

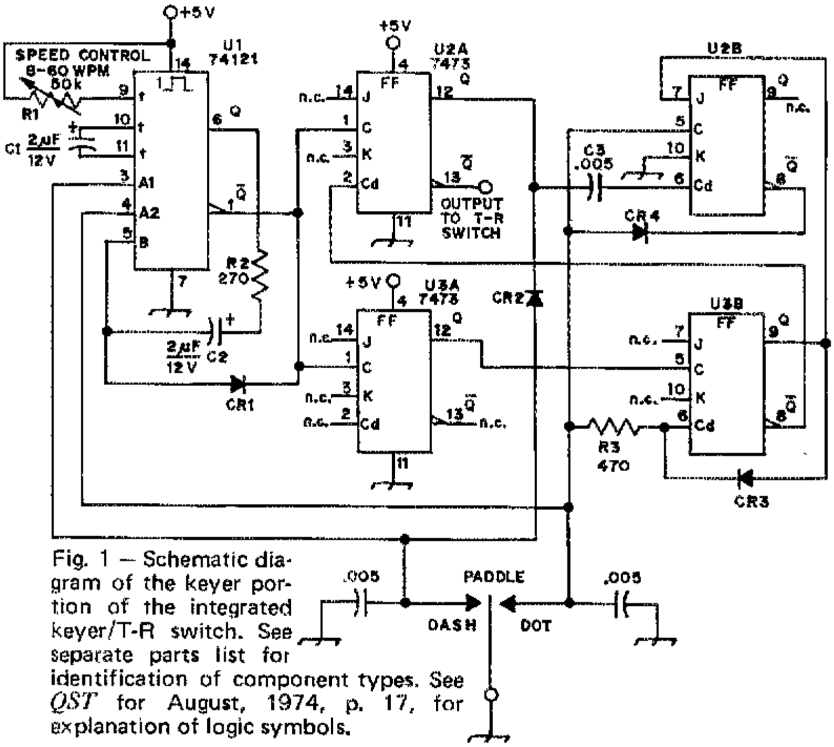


Fig. 1 — Schematic diagram of the keyer portion of the integrated keyer/T-R switch. See separate parts list for identification of component types. See *QST* for August, 1974, p. 17, for explanation of logic symbols.

and spaces so long as the dot lever is pressed; see Fig. 2D. Note that although U3A is also being triggered at this time, U3B is not allowed to be triggered, so that the dash section is not active at this time.

However, when a dash is sent, U3B is allowed to be triggered also, since it is no longer being held in the clear state. The result is that U3B is triggered every other time that U3A is triggered; see Figs. 2B and 2C. By holding U2A in the clear state through the $\bar{Q}$ output of U3B, we thus create a dash exactly three times the length of a dot, followed by a space exactly one dot interval long. Thus, perfect character timing is obtained; see Fig. 2D. CR3 holds the clear input of U3B at a high voltage state (uncleared) while a dash is being sent. This prevents keying of a dot during this time from clearing U3B, so that the dash can complete itself.

The Q output of U2A is in the low voltage state whenever a character is being sent. This is fed back to the timing generator U1 through CR2, so that the generator keeps running until the character is completed. Thus, all characters are self-completing, once triggered. The $\bar{Q}$ output of U2A forms the output of the keyer, and is fed to transistor Q1 of the T-R switch to drive the switching circuitry.

Dot Memory

The fourth section of the keyer, U2B, is the dot memory. This allows one to key a dot at any time, even if a dash has not yet completed. The dot is held in memory, and keyed out automatically after the dash completes itself. Without the memory, the dot would be lost unless the key were held in the dot position until the dot actually started. This greatly facilitates the sending of letters which have a single dot at the end, or a dot surrounded by dashes. The lack of this feature may explain why so many choppy CQs are heard, as the operators have learned to pause slightly before starting the dots.

The operation of the dot memory can be outlined as follows. If a dash, or a space following a dash, is being sent, U2B will be triggered from the clock input if the dot lever is pressed then, placing the dot in memory. However, if no dash were being sent when the dot lever was pressed, the dot would not be put in memory, but would be keyed out immediately. If a dot is put in memory, the $\bar{Q}$ output of U2B is low, which keeps the

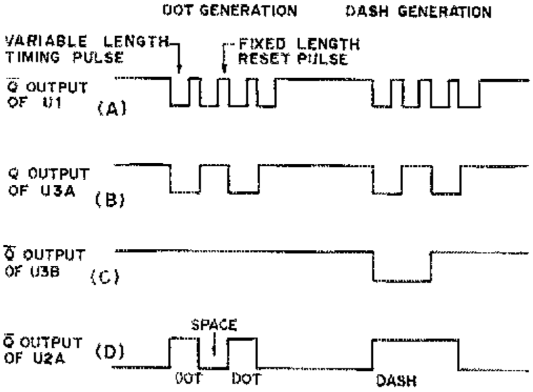


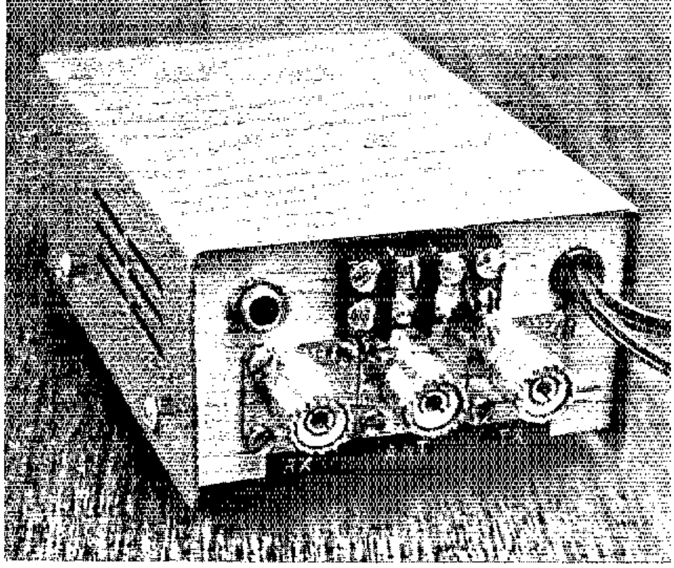
Fig. 2 — Timing waveforms of the keyer. See text.

timing circuit running through CR4. Through R3, this also holds pin 6 of U3B low, assuring that the next character will be a dot. The memory is cleared by a negative pulse through C3 as the dot starts, returning $\bar{Q}$ to the high voltage state.

This method was adopted after considerable experimentation with other designs, which often erroneously put dots into memory and produced double dots at the output. As with most other dot memories, these earlier designs put a dot in memory every time the dot lever was pressed. Then a pulse was applied to clear the dot memory as the dot began. However, if the contacts on the key bounced after the clear pulse had passed, another dot would be put in memory, creating two consecutive dots at the output. The usual cure for this is simply to delay the clear pulse until all the contact bounce is over. However, this still leaves the door open to bounce as the contacts break, since no amount of delay can compensate for this. With ICs that switch in only 20 nanoseconds, any bounce at all would cause problems, so another method had to be found.

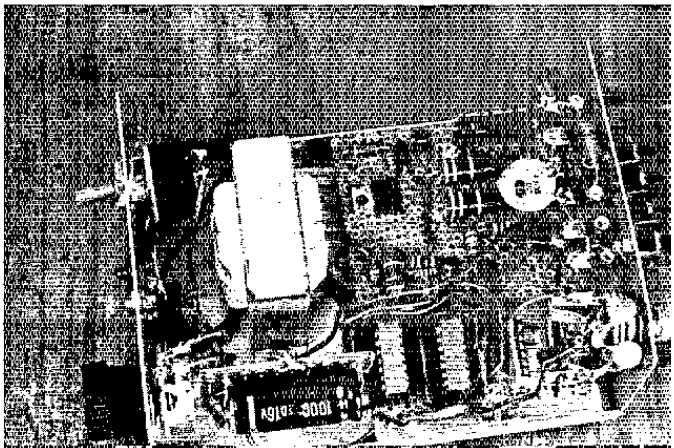
It was then noted that double dots can occur only when the contacts bounce while a dot is being sent, since the clear pulse has already passed. Bounce on the dot contacts during a dash is no problem, as the clear pulse does not come until much later, when the dot actually starts. This is fortunate, since a little thought will reveal that the only time it is necessary to put a dot in memory is when a dash, or the space following, is being sent. At all other times, dots should be prevented from being put into memory. Then, the dot contacts can bounce all they want, without producing double dots.

To understand how this is accomplished in this memory, it is first necessary to understand some of the peculiarities of the 7473 IC, which is a master-slave type of flip-flop. In addition to the usual rules of operation for *J-K* flip-flops, the 7473 has the interesting feature that the *J* or *K* inputs can effectively be set to the low state only when either the clock or clear input is low. For instance, if the *J* input is high while both the clock and clear are high, simply grounding the *J* input will not cause it to go to the low state internally. Then, if a clock pulse comes along, the flip-flop will obey the appropriate switching rule as though *J* were still high. This holds for only the first clock pulse however, since a clock pulse will put the clock input in the low voltage state. The *J* input is then set internally low for all following clock pulses, until the external *J* input goes high again.



On the back of the unit are mounted the rf connectors, external keying terminals, and key jack. The ac power line and transmitter keyed line pass through the grommet at the right.

This feature allows us to realize the goal of allowing dots in memory only during dashes or their spaces in a particularly simple manner. Referring again to Figs 1 and 2C, note that when a dash starts, the *J* input of U2B is put in the high state by *Q* of U3B. (Note that *K*, being grounded from the start, always stays in the low state.) The external *J* input goes low in the midst of the dash, but that is no matter: *J* will internally remain high until either the clock or clear input goes low. Thus, if a dot is keyed anytime after the start of a dash, U2B will be triggered from the clock input, and a dot will be put in memory ($\bar{Q}$ output goes low). If the dot is keyed during the dash or its space, the dot will remain in memory until the dot actually starts. However, if the dot is keyed *after* the space following the dash, the dot will effectively be blocked from memory. This is because the *J* input will go low internally (it is already low externally) a few nanoseconds after the clock input is keyed low. Also, the clear input is held low for several microseconds as C3 recharges through the clear input of U2B. This combination assures that any contact bounce is locked out of memory until the next dash comes along.



On the circuit board are mounted the T-R switch circuitry at the top, and the keyer circuitry at the bottom. The .01-μF rf bypass capacitors are mounted on the rear terminal strip, and the .005-μF capacitors on the key jack. (See text for proper placement of ICs on the circuit board.)

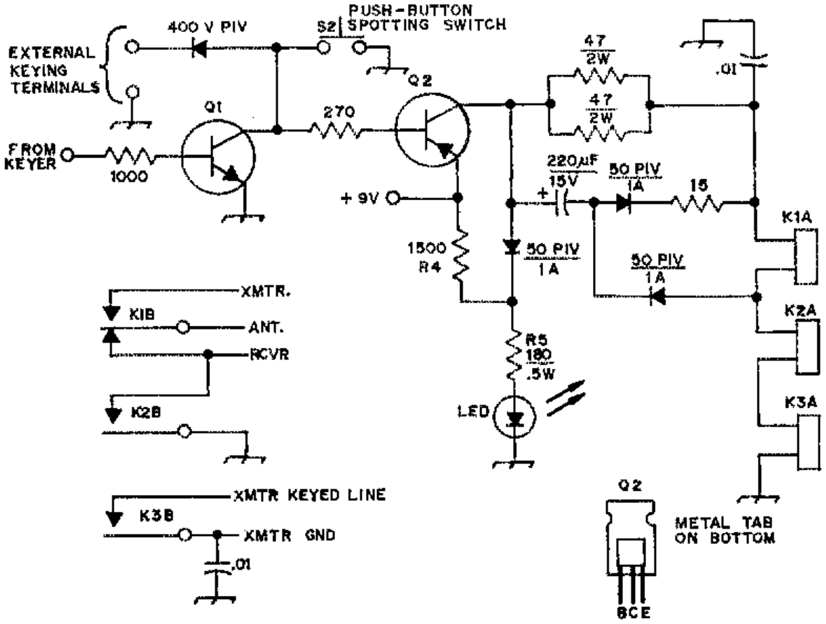


Fig. 3 — T-R switch of the integrated keyer/T-R switch. See separate parts list for identification of component types. Relay coil-winding data, for No. 32 enam. wire:
K1 — 400 turns, pull-in current 140-150 mA.
K2, K3 — 120 turns, pull-in current 140-150 mA.

It seems that every new keyer that comes along claims some new keying characteristic, requiring a descriptive name. This keyer is simply an improved version of the basic dot memory keyer, in which the logic of the circuit completely eliminates double dots due to contact bounce. Thus, after a wholly impartial search for a name, I have decided to call this technique BounceLess Keying, or BLK for short.

T-R Switch

The T-R switch consists of driver transistors Q1 and Q2, and reed relays K1 through K3; see Fig. 3. This circuit not only switches the antenna from the receiver to the transmitter with relay K1, but grounds the receiver input with relay K2, and keys the transmitter with relay K3. Both grid-block and cathode-keyed transmitters can be used, as the contacts on K3 are rated at 500 mA. If a grid-block transmitter with a large capacitance on the keyed line is used, some authors recommend the use of a 220-Ω resistor in series with the relay contacts to prevent sticking contacts. However, I have not found this necessary with my rig.

The coil turns for each relay are wound directly on its glass case, and covered with a coat of epoxy cement for protection. After some sad experiences with mounting the relays on the perforated board along with the rest of the components, the technique of soldering them to terminal strips evolved so as to protect the delicate leads. To bend the leads, be sure to grasp them with a pair of long-nose pliers between the bend and the glass case. When soldering the No. 32 enameled wire, simply heat it first with the iron to burn off the insulation.[3] These terminal strips are then mounted on the back of the chassis, with K1 as close to the coax connectors as possible.

An oscilloscope check of the current in the relay coils shows that it reaches the switching threshold in much less than a millisecond after keying. Thus, the speed is limited only by the mechanical characteristics of the relays, which are quite fast. No speed limitations should be encountered for any practical keying speeds.

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[3] **[EDITOR'S NOTE: This technique may be used with some of the newer types of enamel-coating material, but older types may require that the insulation be sanded or scraped off before the wire can be soldered.]**

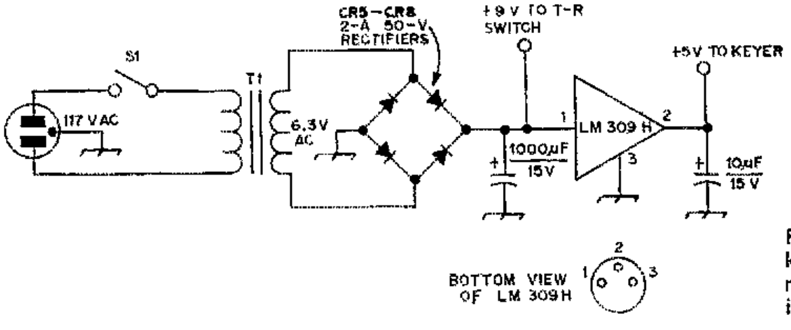
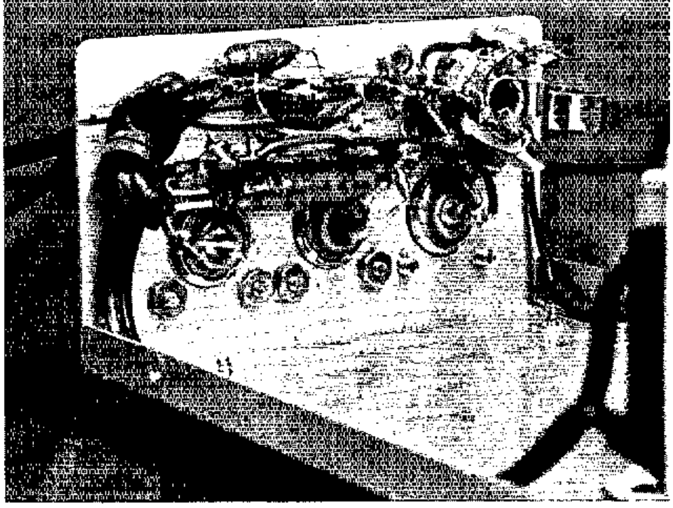


Fig. 4 — Power supply for keyer/T-R switch. See separate parts list for component identification.

Details of the relay placement show how K1, the antenna relay, is mounted on the bottom terminal strip between the transmitter and antenna coax connectors. The transmitter keying relay, K3, is mounted on the top terminal strip, while the receiver grounding relay, K2, is soldered directly to the receiver coax connector at right. *(All photos by author)*



One word of caution: when I had the antenna relay K1 originally mounted alongside the keyer integrated circuitry, rf from the transmitter interfered with the keyer at power levels above a few watts. With K1 mounted at the coax connectors, and the windings bypassed with a .01-μF capacitor, this problem was solved. However, the rf leads to K1 should be kept *short*, on the order of 1/2 inch, and should be soldered to the relay right at the glass body. It would also be wise to mount the integrated circuits on the side of the circuit board away from the antenna relay, with the transistors and T-R circuitry between them. The increased spacing should eliminate any further possibility of RFI in the ICs.

As other authors have emphasized, it is necessary to switch the antenna relay on just before the transmitter is keyed, and delay it from turning off until slightly after the transmitter is turned off. This is necessary to prevent keying hot rf in the antenna relay, which would produce key clicks. In this circuit, antenna relay K1 turns on so quickly that the delay through K3 and the transmitter prevents keying hot rf in K1. This has been checked using two samples of K1, and two of K3, which shows that the results are reproducible. However, an oscilloscope check showed that antenna relay K1 tended to shut off at the end of a character before the transmitter output dropped to zero, cutting off the "tail" of the keyed rf waveform. This was easily solved with the 220-μF capacitor, which delays the turn-off of K1 about 10 milliseconds. A further scope check showed no change to the leading or trailing edge of the waveform with or without K1. Thus, if your transmitter doesn't have clicks now, this won't add them.

Power Supply

The power supply, shown in Fig. 4, is a conventional full-wave bridge circuit with capacitive filtering for the T-R switch circuitry. An LM309H integrated-circuit regulator provides the correct voltage for the IC keyer. This device gives truly outstanding regulation, assuring highly stable keying, and is internally protected from overcurrent conditions or overheating. However, if you should encounter unusually low line voltages, below about 105 volts, it would be a good idea to add another 1000-μF filter capacitor at the input of the LM309H. This will assure proper regulating action down to line potentials well below 100 volts, should this be necessary. At the output of the LM309H is a capacitor to prevent switching spikes generated by the TTL ICs from interfering with the proper operation of the keyer. Any capacitor of 5 μF or greater value will work here, so use what you have on hand.

Other Circuitry

The two terminals of the barrier terminal strip mounted on the rear of the chassis permit keying the T-R relays from an external switch, such as transmitter relay contacts when on phone. They can also be connected directly across the coil of this relay, or across a push-to-talk switch. The 400-volt diode in series with these contacts protects transistors Q1 and Q2 from any voltage present in the external circuit, such as switching spikes across a relay coil. The push-button switch on the front panel also keys the T-R relays, and is used for tuning or spotting the transmitter. The light-emitting diode is used as a keying monitor. When the ac power is applied, it glows dimly; when a character is keyed, it glows more brightly. The resistors shown are optimized for the FLV100 LED; if you use the MV5020, reduce the value of R4 to 1000 Ω, and the value of R5 to 100 Ω.

If you prefer, as I do, to monitor your own signal off the air, the T-R switch is complete as shown. The signal attenuation provided by relay K2 during transmission will allow a receiver with a good agc circuit to monitor without overload. However, if you wish to add additional muting circuits or key an audio monitor, more relays can easily be added. Simply wind them the same as K2 and K3, and connect them in series with the windings on K2 and K3.

Of course, if you wish to build just the keyer itself, you need just one keying relay. As shown in Fig. 5, this can be accomplished with just one transistor, if you wind twice the number of turns on the relay as before. A commercial relay could also be used if you don't wish to wind your own. However, due to their much higher inductance, you will need to add a diode (1N914 or similar) across the relay windings to assure quick turn-off of the relay. Connect the anode to the

Parts List

RS = Radio Shack *PP = Poly Paks*

All resistors in schematic diagrams are 1/4 watt unless otherwise noted. Capacitors are in µF; those marked with polarity are electrolytic.

U1	74121 monostable multivibrator	RS 276-1814 or PP SN74121
U2, U3	7473 dual *J-K* flip-flop	RS 276-1803 or PP SN7473
CR1-CR4	1N914 silicon switching diodes	RS 276-612 or PP 50U143
Q1	Npn silicon type (as 2N2222) I_c: 250 mA min.; beta: 30 min.	RS 276-2009 or PP 2N2222
Q2	Pnp silicon power type (as 2N6109) I_c 1 A min.; beta: 15 min.	RS 276-2025 or PP 92CU1446
K1	Spdt reed switch, 3" long	RS 275-202 or PP 92CU1257
K2, K3	Subminiature spst reed switch, 1" long	RS 275-033 or PP 87U655
LED	Light-emitting diode, type FLV100 or MV5020	RS 276-026 PP 92CU1339
T1	6.3 volt ac transformer, 1.2 A	RS 273-050
S1	Ac toggle switch	RS 275-602
S2	Miniature push-button switch	RS 275-1547
—	Metal case 4 × 2-3/8 × 6"	RS 270-252
—	14-pin IC sockets	RS 276-027 or PP 92CU1308
—	No. 32 wire	RS 278-011
—	5-volt regulator, LM309H	PP LM 309H

Miscellaneous: 50-kΩ timing pot (see text), SO-239 chassis connectors, two-terminal barrier strip, perforated circuit board, 6-lug terminal strips, two-conductor phone jack, metal standoff spacers, rubber grommets, knob, minor hardware. (All available at Radio Shack if you don't have them in your junk box.)

47-Ω-resistor side of the coil, and the cathode to the +9 V side.

Conversely, the T-R switch only can be built, and keyed through the external keying circuit. For use with a transistor output keyer however, increase the value of the base resistor of Q2 to 390 Ω to limit the external current to a safe 16 mA.

Operation

The antenna relay has been used with a 150-watt input (85-watt output) transmitter for several months with no ill effects. This level will be quite adequate for the average barefoot exciter running up to a couple of hundred watts, and can probably be exceeded if the SWR isn't too high. However, I would not recommend a kilowatt into this unit. See the articles in *QST* of December 1964[4] and February 1973[5] for details of higher power operation.

The 50-kΩ timing pot allows operation from about 8 to 60 wpm. However, I find a speed range greater than about 3 to 1 somewhat critical to adjust. Therefore, I actually use a 22-kΩ pot in series with a 3300-Ω fixed resistor, giving a more tractable range of 12 to 35 wpm. You can adjust these values to suit your taste.

If you use dual paddles, dots will take precedence over dashes. Thus, with the dot memory, you can insert a single dot between dashes by merely touching the dot lever.

(Continued on page 52)

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[4] "High Power Version of the Keyed Antenna Relay," *QST*, December, 1964, p. 20.

[5] Lawson, "High-Speed Break-In via a Keyed Vacuum Relay," *QST*, February, 1973, p. 13.

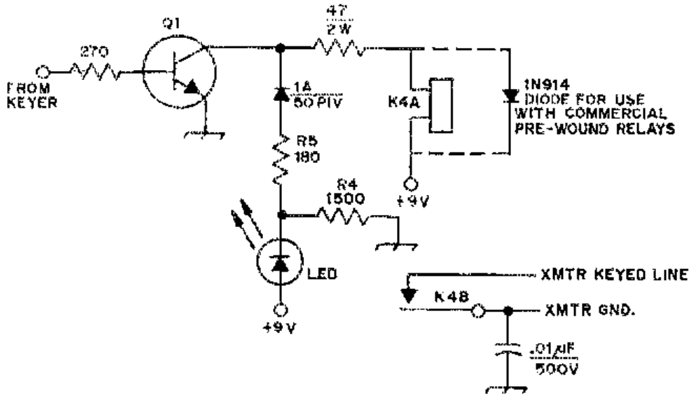

Fig. 5 — Circuit for keying transmitter if T-R switching is not desired. See separate parts list for component identification. K4 coil-winding data: 225 turns No. 32 enam. wire, pull-in current 75-80 mA.