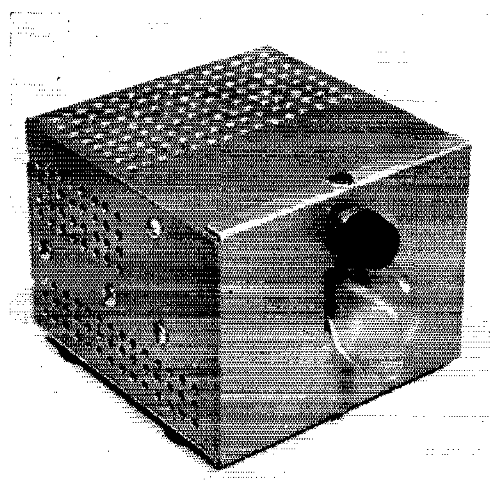
The All-Electronic "Ultimatic" Keyer

Part I — Construction and Handling

BY JOHN KAYE,* W6SRY

The selection two years ago of "Ultimatic" as a name for "a key with a memory" was a bit premature.[1] Reversion to the hoary twin-lever key and the addition of sequence "seizure" now eliminates most of the back-and-forth motion normally associated with code transmission, carrying the principle much closer to the ultimate.

The new sequencing function provides leeway for key release corresponding to, and greatly exceeding in time, the leeway for key closure provided by advance storage in the memory circuits. It also reduces the maximum back-and-forth motion of the hand to *once per letter*, and that at a greatly reduced rate. On most letters the rocking motion is completely eliminated. By obviating the fight against the hand's inertia, the effort expended for any given speed is greatly reduced. Besides relieving the operator of *virtually all timing responsibilities*, and most of the labor, the compound leeway does away with all sensation of being chained to an inexorable time base.



Here is an all-electronic version of the "key with a memory," the "Ultimatic." Several improvements over the multiple-relay version have been incorporated in this newer version.

The time base, memory, and interlocked-sequencer circuits handle automatic spacing and advance storage of marking characters in a manner functionally identical to the relay model. (The original article is recommended rereading in conjunction with a detailed study of this improved model.) With twin keys and the new seizure circuitry, continuous closure of one key generates that type of character until the opposite key is also closed. After completion of the character in progress, the output switches to the opposite type, even with both keys closed. Release of either key provides output corresponding to the still-closed key. With one key held closed, a single opposite-type character can be injected by a closure (as short as 2 microseconds) of the opposite key at any time after the start of a desired preceding character.

* 2296 West Nicolet, Banning, Calif.

[1] Kaye, "The 'Ultimatic'—a Key with a Memory," *QST*, February, 1953.

Multiple intermediary opposite-type characters within a letter are obtained by holding one key closed throughout the entire letter while operating the opposing key long enough in the middle of the letter to get the desired string. When both keys are released together, the terminal character(s) is determined by the lastly-closed key. When the keys are released independently, the terminal character(s) is selected by the still-closed key.

Using the Key

One can, of course, attack the keyer as if it were an ordinary bug or start-stop automatic key, or with any intermediate technique up to that realizing full usage of all functions. Since a given key need not be released to permit selection of an opposite-type character, the motions on the keys may be as careless as the mood dictates, with all kinds of overlap. The *one* and *only* requirement is that the two keys be closed in the proper order for the letter being sent. The output comes up straight and perfect.

A few specific examples of full sequencor usage are in order; otherwise an operator might never discover the really easy way to make a CQ, a numeral or, for that matter, any of the combinations. For the call "W1AW," both keys may be *squeezed* together four times, each time allowing the dot side to close at least a few microseconds before the dash side. They are both held at least until the last dash of each letter starts, and they are necessarily released between letters only long enough to establish automatic interletter spacing. "W6BJ" calls for similar technique, with the dash key making first contact on the "6" and the "B."

A question mark results most easily from continuous closure of the dot key for the entire duration, with the dash key operated any time during the second dot. The dash key is released anywhere from the start of the second dash up to due time for the first terminal dot. The reverse procedure gives a comma. A numeral such as "3" is made by holding dots throughout the number, closing up the dash side any time after the third dot starts. Both keys may be released together any time after the beginning of the second dash, or independently.

That bearcat "CQ" is a pushover: continuous closure of the dash key throughout each letter, with the dots flicked in indiscriminately, taking full advantage of the memory leeway. The "C" can be started with the "squeeze" technique, or it can be made with two quick squeezes just long enough to trip the memories. This is true for *any* combination whose first two characters are of opposite type. In context, a given letter will normally be manipulated differently between different preceding and following combinations, to minimize seesaw motion. All code combinations

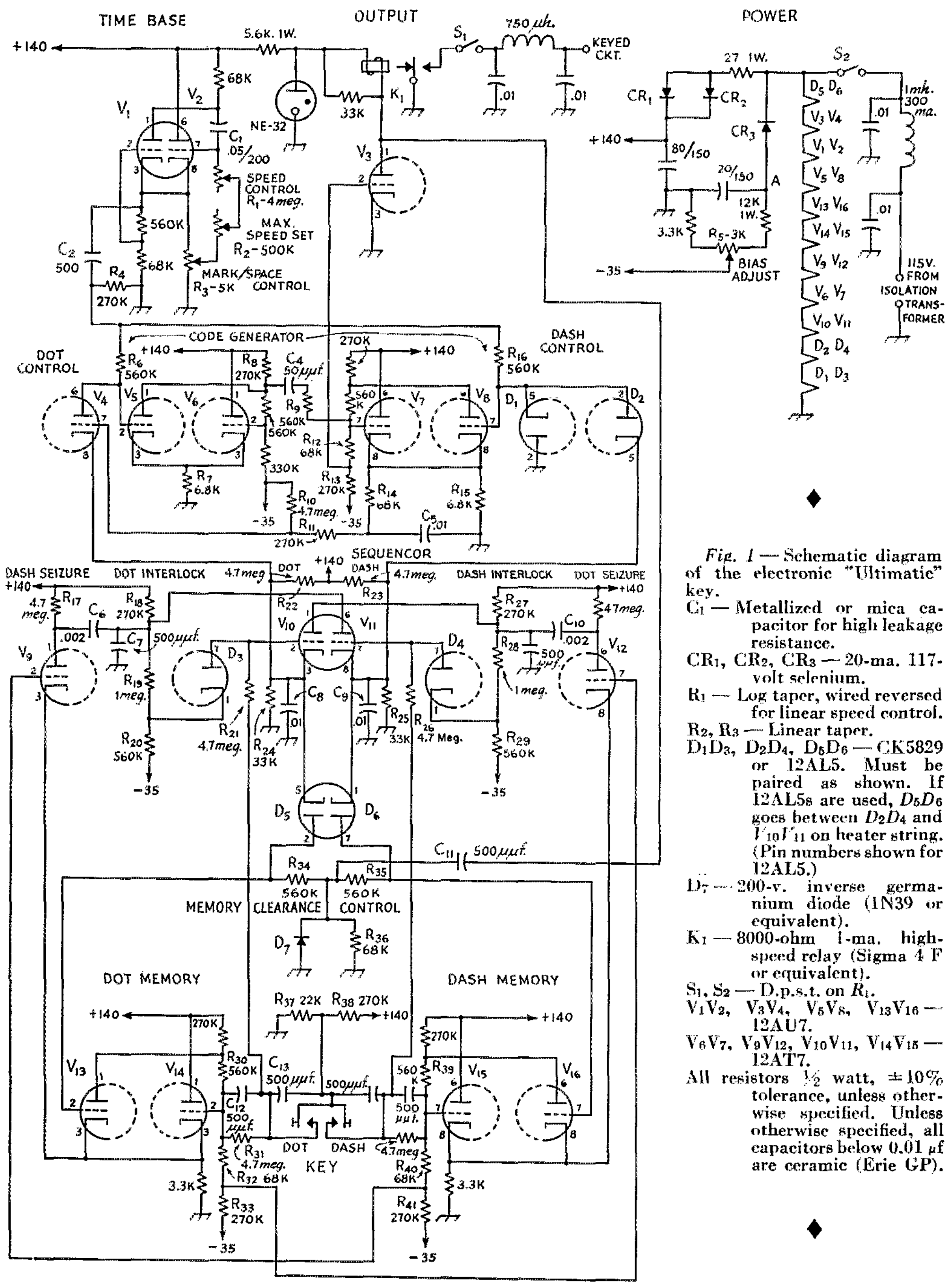


Fig. 1 — Schematic diagram of the electronic "Ultimatic" key.

C_1 — Metallized or mica capacitor for high leakage resistance.

CR_1, CR_2, CR_3 — 20-ma. 117-volt selenium.

R_1 — Log taper, wired reversed for linear speed control.

R_2, R_3 — Linear taper.

D_1D_3, D_2D_4, D_5D_6 — CK5829 or 12AL5. Must be paired as shown. If 12AL5s are used, D_5D_6 goes between D_2D_4 and $V_{10}V_{11}$ on heater string. (Pin numbers shown for 12AL5.)

D_7 — 200-v. inverse germanium diode (1N39 or equivalent).

K_1 — 8000-ohm 1-ma. high-speed relay (Sigma 4 F or equivalent).

S_1, S_2 — D.p.s.t. on R_1.

V_1V_2, V_3V_4, V_5V_8, $V_{13}V_{16}$ — 12AU7.

V_6V_7, V_9V_{12}, $V_{10}V_{11}$, $V_{14}V_{15}$ — 12AT7.

All resistors ½ watt, ±10% tolerance, unless otherwise specified. Unless otherwise specified, all capacitors below 0.01 µf are ceramic (Erie GP).

other than those made up of straight series of like characters (I, S, H, 5, M, O) follow one of these illustrations in full or part, or they can be made by any intermediate motion down to that used on a Vibroplex. And with perfect results, regardless of fumbling!

General Circuit Data

As the circuit diagram [2] in Fig. 1 shows, power is derived from line-type rectifiers. The tube heaters are in series across the line. Alternatively, the heaters can be fed in parallel or series-parallel from a suitable transformer. The plate and bias voltages are obtained from a 117-volt 40-ma. winding, or they can be borrowed from an available source via VR tubes. The NE-32 maintains constant relay current for stable mark-to-space ratio at all line voltages. An isolation transformer is, of course, mandatory unless the station is designed for "hot-line" operation throughout, through the use of appropriate safety grounding.

For long tube life, maximum plate current in most tubes runs around 3½ ma., although some tubes draw less than ½ ma. The pulse peak in V_2 hits 6 ma. The keyer is completely stable with line voltages from 80 to 135, but it goes berserk if too much r.f. gets back to it through external leads. Voltages mentioned for various points in the circuit, as measured with a v.t.v.m., obtain with average tubes and 10-per-cent-tolerance components at 113 line volts and −33 volts bias.

Construction

This particular unit was built in a Channel-Lock box cut down to 4 by 4 by 3 inches. The mounting plate fastened to the front panel section provides ⅞ inch below for components and 2¹⁄₁₆ inches above for tubes. All surfaces except the front are perforated with ⅛-inch ventilation holes on ¼-inch centers, with additional ⁵⁄₁₆-inch access holes in the bottom for R_3 and R_5.

To minimize bulk, the CK-5829 subminiature diodes and the NE-32 are wired direct without sockets. If 12AL5s are substituted for the expensive subminiature diodes, with relay output, the housing depth requirement is 4¾ inches for another row of tubes. With electronic output instead of the relay, the two additional potentiometers can be stacked above R_3 and R_5, with top-side access, and the NE-32 can be eliminated. It is entirely feasible, of course, to provide room for three 12AL5s by reducing the size of the keys. Subminiature potentiometers would then occupy the space below the chassis vacated by the CK5829s.

Further reduction of over-all size is not recommended. The thing already runs hotter than the proverbial two-buck pistol, with the present amount of compression. On the contrary, one should really spread it out in a big box or rack mounting, bringing out the key and

[2] Copies of the enlarged schematic diagram are available for 50 cents from ARRL's Technical Information Service, 38 La Salle Road, West Hartford, Conn.

• Two years ago, W6SRY described his "key with a memory," which made it possible to send perfect code without perfect manipulation by the operator. The one stumbling block for some constructors was the multiplicity of relays used in the circuit. We are pleased to present the all-electronic version, which not only eliminates the need for critical relays, but makes for still greater handling ease by the operator.

The length of the article requires that it be published in two parts. We depart from custom in presenting the circuit and constructional details before the circuit explanation, to better serve the many amateurs who have written to the author requesting details on this key. Part II (next month) will explain how the circuits work and how the output relay can be eliminated.

speed-control leads in separate shielded and pi-section r.f.-filtered pairs. Speed-control lead r.f. by-pass capacitors should not exceed 0.001 μf. each side of 750-μh. r.f. chokes. The key-lead r.f.

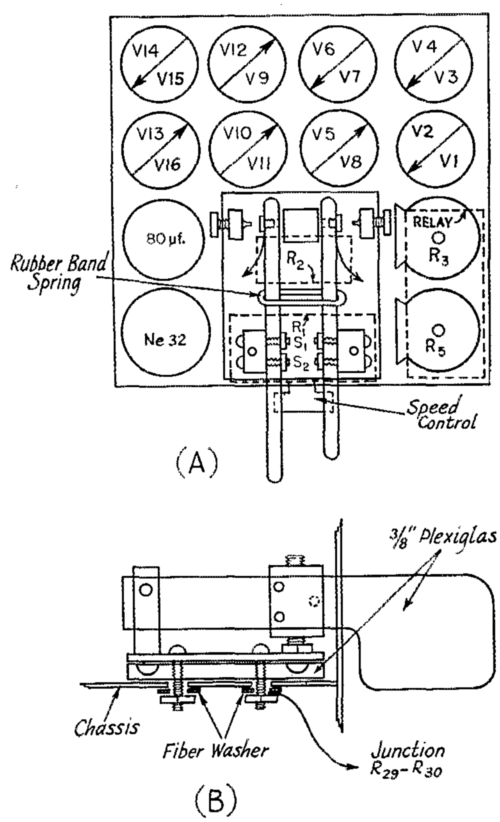
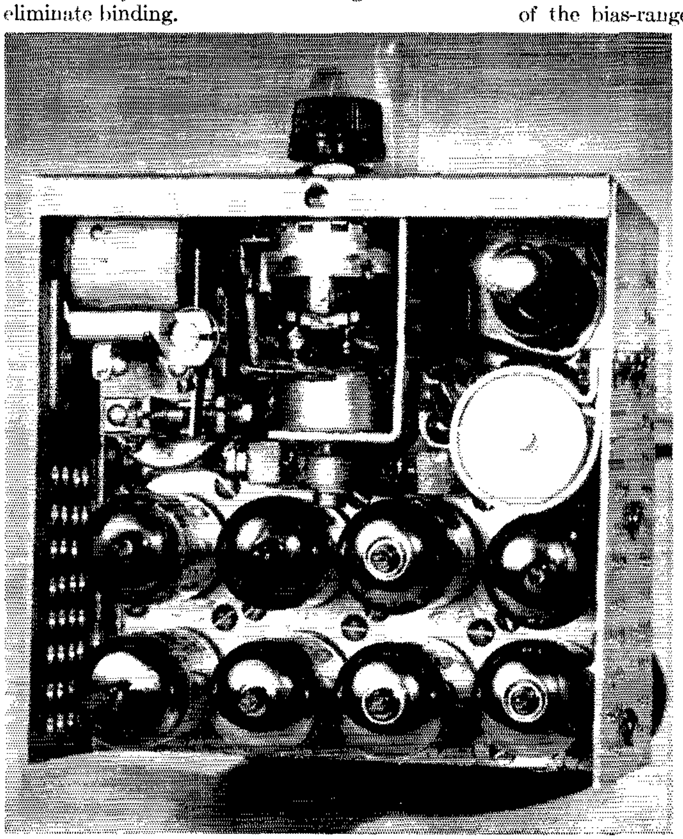


Fig. 2 — (A) Top view of a suggested tube-socket and control arrangement for the Ultimatic key. Arrows point in direction of pin gap. (B) Details of the key-lever construction. The screws are 8-32.

by-pass capacitors should make up the total 500 μμf. of C_{13} and its corresponding capacitor on the dash side.

Fig. 2A and a photograph show the top view of a socket orientation providing optimum component dress, with resistors mounted on and between the sockets. All No. 9 pins and center shields were removed to provide more room for parts. With the heaters connected in parallel for 6.3-volt operation, the No. 9 pins should be bent over and soldered to the mounting rings. If the series heater connection is used, the heater leads should be dressed very tightly against the chassis, to minimize a.c. fields.

Fig. 2B shows a side view of the key levers. Although a cone pivot bearing is definitely superior, the threaded bearing pivots in this unit proved surprisingly good, and they can be readily built with a minimum of effort. The keys are assembled on a 1½ ×2× 1/16-inch metal plate, insulated from the chassis by ⅜-inch Plexiglas levers and threaded on the 8–32 pivot bolts. (Metal pivot blocks, tapped for 8–32, are bolted to the ⅜-inch Plexiglas.) The pivot bolts are secured to the key plate with nuts, as shown. The "spring" tension is adjusted by sliding the rubber band to an appropriate position. This method of supplying spring tension absorbs most of the sloppiness that might result from too loose a thread fit in the pivot screws, a condition apt to arise from filing threads to eliminate binding.



This top view shows why the author does not recommend building the key into a small volume.

During construction of the many miniaturized models preceding this one, it was found wise to wire subcircuit by subcircuit, performance checking each subcircuit before going on. Nothing is so exasperating as finding a bonehead error buried under three layers of resistors massed together with ⅛-inch leads. Ask me — I know!

Trigger & Bias Adjustment

The sole adjustment procedure consists of running the bias up and down at R_5 with various line voltages between 80 and 135, to find the range of stable operation for each functional circuit. At each test setting, check over-all operation and each circuit individually with a v.t.v.m., in accordance with the functional summaries.[3] Observation of circuit performance can be greatly simplified by slowing things down to a walk with 0.25 μf. (metallized, to minimize leakage) shunted across C_1 of Fig. 1, so that the v.t.v.m. needle stands still long enough to be read. Approximate expected voltages are given in the circuit description. Others are readily calculated from the divider strings, bearing in mind grid-loading effects. With normal-tolerance components, it is to be anticipated that one or two of the subcircuits may turn up with a bias range centering somewhat off the median value. The addition of a 2- to 4-megohm shunt across the appropriate element of the resistance string will pull the range center to median. The final setting of R_5 is at the average of the bias-range midpoints for all the subcircuits at expected nominal line voltage.

Tube and component aging is compensated at R_5, though readjustment will not be required until prolonged aging has drastically shifted the tolerance midpoints. The model shown here tolerates a ±5-volt bias shift from the −33-volt median established at a nominal 113 line volts.

Mark-Space Adjustment

With 0.004- to 0.01-inch relay armature travel and continuous 15-w.p.m. dots, R_3 is set for half-scale reading of an ohmmeter connected across

[3] Given in Part II.

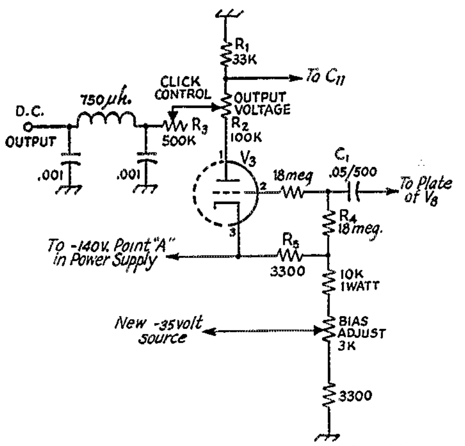


Fig. 3 — Optional output circuit for the Ultimatic. If this circuit is used, the heaters of V_3V_4 must be moved to the ground end of the heater string in Fig. 1. C_1 — Metallized capacitor.

the output terminals. Then at the desired maximum dot speed the relay spring tension is adjusted for midscale on the ohmmeter. Steady dashes should read one-quarter scale. The two adjustments interact a bit, so two or three runs may be necessary to establish a constant mark/space at all speeds. Since R_3 affects the top speed, R_2 is set last, with R_1 at minimum, for the desired top speed.

With electronic output, R_1 of Fig. 3 is set, on spacing output, for slightly more than cut-off for the vacuum-tube keyer to be used. R_3 of Fig. 1 is then set, on 30-w.p.m. dots, for the desired mark/space ratio as indicated by final-amplifier plate current. R_2 of Fig. 1 is trimmed for the top speed.

Test Equipment

It must be remembered that the *only* test equipment that can possibly be used to read many of the voltages in the Ultimatic is a v.t.v.m. with an input impedance on the order of 30 to 50 megohms, or an equivalent cathode-follower device. Even with a 1-megohm isolating resistor in the probe, the triggers will sometimes be tripped by capacity as contact is made. To determine which way a circuit is stabilized, it is best to read across the cathode resistor, touching the grid-plate strings only for an actual voltage.

Learning To Use the Key

Trial runs on guinea-pig operators indicate that it takes a little time to reëducate one's reflexes so that at high speed one can take full advantage of all of the sequencing functions and leeway tolerances. Full use of the seizure function calls for a considerable departure from standard techniques. However, the new tricks are readily acquired because they demand much less effort. One who has never used anything but a pump handle has a nice advantage and can master the gadget much faster because he has no cortical synapses to disconnect, nothing to unlearn. However, and this is the beauty of the thing, whatever technique is being used on the present bug or start-stop autokey will produce perfect results at usual sending speeds after 5 minutes of practice. Mastering the tricks simply calls for experimentation, using the functional summaries and specific examples as guides. Every operator will acquire his own personal technique, equally good but possibly different. Initial practice should be at low and moderate speeds to facilitate study of the relationships between the Selector-memory-sequencor, the time base, and the hand.

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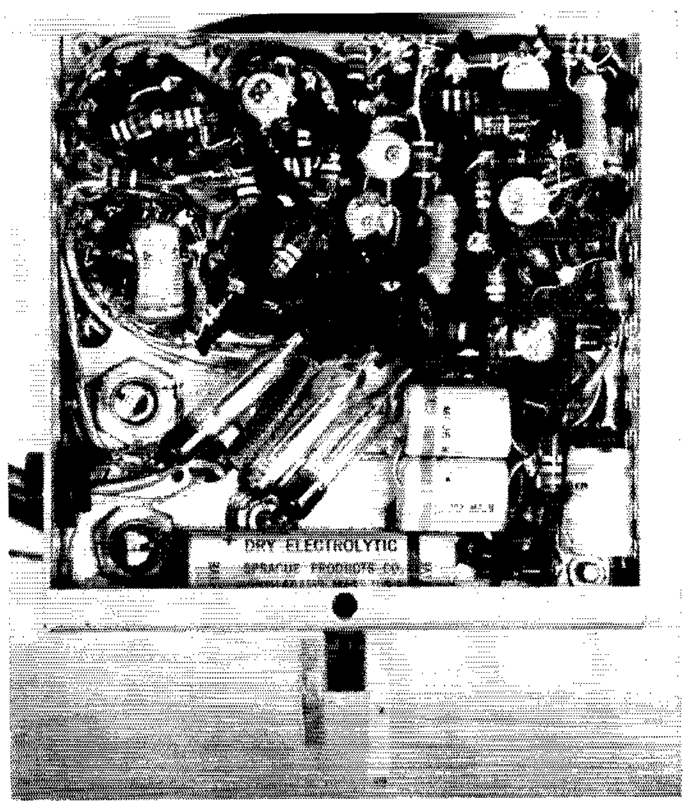

A bottom view of the key clinches the argument for allowing more room for the circuit components.

The All-Electronic "Ultimatic" Keyer

Part II — How It Works

BY JOHN KAYE,* W6SRY

• Part I (*QST*, April, 1955) of this article described what the key does and how it can be built. Here is the explanation of the circuits and pertinent test data. Part I is required, since it carries the circuit diagram.

The electronic Ultimatic is best considered as two separate units, a code generator and a selector-memory-sequencor (SMS). The generator is composed of a time base, two character-generating triggers, and a relay-control tube or an optional d.c.-output tube for direct control of vacuum-tube keyers. The SMS comprises a twin-lever key, two memories, two interlocked-sequencor circuits, two multiple-character holding circuits, and two sequence-seizure circuits. This SMS structure is completely symmetrical. One side only will be discussed. Each paragraph concerning it can also serve to describe the other side by substituting "dot" for "dash" and vice versa and considering the corresponding circuit components. Refer to Part I for the circuit diagram. To extend the stability range, grid-current loading is used in several places. For this reason, some of the voltages to be cited will differ from those calculated from straight voltage-divider action of resistor strings.

Time Base

The multivibrator, V_1V_2, generates a sufficiently-square wave at its cathodes from which C_2R_4 differentiates alternate positive and negative pulses for operation of the generator triggers. The "mark/space" ratio of this type of oscillator has been found to be substantially independent of plate voltage over a wide range, and consequently, no voltage regulation is required. The elevated grid return of V_1 provides a mark/space ratio of 45/55 with R_3 at ground, increasing to 90/10 before failure as the arm is moved toward the cathodes. A capacity of 0.05μf. at C_1 gives a minimum speed below 5 w.p.m. and a maximum above 100. Heaven forbid anyone turning it loose on me!

Relay Output

During spacing, the relay is energized because the grid of V_3 is held at ground potential at the junction of R_{12} and R_{13}. The normal "back" contact is used to key the external circuit. On "mark" the junction of R_{12} and R_{13} drops to -15 volts, cutting off V_3. Relatively heavy spring tension on the relay minimizes armature travel time. When the grid of V_3 returns to ground potential for spacing, the current through V_3 is sufficient to open the contact promptly. Slower armature travel at this time, caused by the stiff spring, is of no consequence. With 0.004-inch armature travel, this method of relay operation results in practically zero variation in the mark/space ratio to, fantastic as it may sound, well above 100 w.p.m.

*2296 West Nicolet, Banning, Calif.

Idle Code Generator

V_5V_6 and V_7V_8 are cathode-coupled triggers, with V_6 and V_7 conducting in the idle condition. Voltages of +15 and +12 stand on R_7 and R_{15}, respectively. When the output is to remain spacing, both sequencors, V_{10} and V_{11}, are cut off, with cathodes held at +1.7 and +.9 by R_{22} and R_{23}, to compensate for the negative contact potentials in the control clampers D_1, D_2 and V_4. Positive pulses from C_2R_4 are clamped at +.9 to the grid of V_8 by D_2 and R_{16}. The junction of R_{10} and R_{11} holds the grid of V_4 at its cathode potential of +1.7, clamping positive pulses to the grid of V_5 at +2.2 volts. These pulse amplitudes are too low to affect the triggers. Negative pulses are not affected by the dot control V_4R_6, but are grounded out by D_1R_{16}.

Dot Generation

When the output is to be a dot, V_{10} is made conductive by SMS action, establishing +10 volts at R_{24}. This effectively cuts off V_4, whose grid does not rise above +8 volts at $R_{10}R_{11}$. The first succeeding positive pulse from C_2R_4 rises to +10 volts at the grid of V_5 to transfer conduction to that tube. The resultant drop across R_8 transmits a 60-volt negative pulse toward the grid of V_7 via C_4 and R_9. This cuts off V_7 and transfers conduction to V_8. The junction $R_{12}R_{13}$ stabilizes at -15 volts to cut off V_3, releasing the relay for marking output.

The following negative pulse cuts off V_5 and returns conduction to V_6. As V_5 cuts off, a positive pulse is transmitted via C_4 to the grid of V_7, to return conduction to that tube. The junction of R_{12} and R_{13} returns to ground potential, and V_3 pulls up the relay for spacing output.

Even if the key is held closed, with a constant +10 volts standing on R_{24}, the output cannot again go to marking until the next positive timing pulse, ensuring a full half cycle of spacing output to complete the dot.

Dash Generation

When the output is to be a dash, V_{11} is made conductive by SMS action, and +10 volts stands on R_{25}. The first positive pulse from C_2R_4 rises to +10 volts at the grid of V_8, transferring conduction from V_7 to V_8 and the output to marking. The following negative pulse toward the grid of V_8 is grounded by D_1, and V_8 remains conductive.

Conduction in V_8 reduces the potential at R_{15} to +2.2 volts. The voltage at the junction of R_{10} and R_{11} drops to −0.5 to cut off V_4, whose cathode now stands at +0.9 volts. (The cut-off voltage is low because the plate voltage is only about 10 volts.) C_5R_{14} delays this drop until well after the first positive pulse has decayed at the grid of V_5. The second positive pulse can now trip V_5V_6 to V_5 conduction. V_8 continues to conduct, of course. The second negative pulse cuts off V_5, which returns conduction to V_7 and the output to spacing. The output cannot again go to marking until the next positive pulse, ensuring the half cycle of spacing to complete the dash after 1½ cycles of marking output.

When conduction is first transferred from V_7 to V_8, a 19-volt negative pulse is transmitted from the grid of V_7 toward the plate of V_5 via C_4, but R_9 limits it to insufficient amplitude to upset stable conduction in V_6. If SMS action has transferred sequencor conduction to V_{11} by the time of the second positive pulse in the dash, the elevation of the cathode of V_4 is only incidental, since the drop at $R_{10}R_{11}$ has already cut off V_4.

Automatic Spacing Characters

As in the relay model, interletter and interword spacing characters are obtained by allowing one or two positive pulses to go by. Closure of a key at any time following a passed-up positive pulse produces marking output beginning at the next positive pulse.

Memory Actuation

The dot-memory trigger $V_{13}V_{14}$ idles with V_{13} conducting. This is the opposite tube of the pair from that in the code generators, facilitating the use of readily-derived positive memory-clearance pulses and a simple sequencing structure. While idle, C_{12} discharges and C_{13} charges through R_{31}. Closure of the dot key lifts the grid of V_{14} on charging current to C_{12} to the +10-volt value standing at $R_{37}R_{38}$. C_{13} discharges immediately and ensures C_{12} action despite a possibly scratchy contact at the key. The comparatively slow (2 millisecond) charge rate of C_{13} through R_{31} prevents unwanted memory actuation from contact scratch as the key is released. The grid of V_{14} rises from −13 volts and stablizes at +10 volts with V_{14} conducting. The key may be immediately opened and the dot selection will be stored in the actuated trigger until cleared by appearance of the dot at the output.

Memory Clearance

The dot memory is cleared under control of D_3R_{34} by a positive pulse to the grid of V_{13}, generated by $C_{11}R_{36}$ from the V_3 plate swing as the output goes to marking. To prevent spurious memory retrip, D_7 grounds the negative pulse generated as the output goes to spacing.

Only one sequencor tube can conduct at a time. If the output character following the time of dot storage is to be a previously-selected dash, V_{11} conducts and only +1.7 volts stands at R_{24}. The clearance pulse toward the dot memory is clamped to that amplitude by D_5R_{34}, insufficient to clear the memory. When V_{10} is conductive for dot output, the pulse is allowed to rise to +10 volts at the grid of V_{13} and return conduction to V_{13} to clear the memory. The dash memory $V_{15}V_{16}$ behaves identically, with clearance under the control of $V_{11}D_6R_{35}$.

Sequence Interlock

When the dot memory is idle and the dot key is open, the junction of R_{30} and R_{32} applies −13 volts to the grid of V_{10}, via R_{21} and R_{31}, to cut off the tube. Tripping of the dot memory applies +10 volts from $R_{30}R_{32}$ toward the grid of V_{10}. If V_{11} is being held conductive by a positive selection potential from the dash memory or key, its plate current through R_{18} lowers the potential at $R_{19}R_{20}$ to −7 volts. The positive potential directed toward the grid of V_{10} by a dot selected under this condition is clamped by D_3R_{21}, and the grid of V_{10} is held below cut-off. This guarantees prior transmission of an earlier selected dash. C_7 stabilizes the negative interlock voltage against spurious releases by plate voltage fluctuations caused by line-voltage changes and distributed capacitive couplings. This is necessary at very low line voltages, where the interlock potential drops to around −3 volts.

With the dash memory clear and the dash key open, V_{11} is cut off by −13 volts at $R_{39}R_{40}$, and $R_{19}R_{20}$ stands at +12 volts. This allows the +10-volt dot selection potential to reach the grid of V_{10} via R_{21}. The cathode of V_{10} rises to +10 volts to start a dot on the next positive time-base pulse, and permits the memory clearance pulse to reach the grid of V_{13}. Conduction through V_{10} and R_{27} lowers $R_{28}R_{29}$ to −7 volts, to clamp at D_4R_{26} any subsequently selected dash until after the dot starts. Additionally, by thus locking out V_{11} and holding R_{25} and the cathode of D_6 at +0.9 volts, clearance of the dash memory (when actuated after dot storage but before that dot starts) is prevented.

For a series of dots, the key is held closed and +10 volts from R_{37} R_{38} holds V_{10} conductive via R_{21} (and V_{11} locked-out) after the dot memory clears at the start of the first dot, until the key is released or the sequencor is "seized" by subsequent actuation of the dash memory. The similar structure of the dash sequencor behaves identically under interlock control of the dot sequencor, to provide single or multiple dashes.

Sequence Transfer

Assume a dot and a dash, selected in that order before any output starts, and the keys

(*Continued on page 122*)

In the preceding paragraphs considerable emphasis has been placed on minimizing distortion. Low-distortion test signals are especially important when testing phasing types of transmitters because distortion on the test signal produces sideband components in the region of desired sideband suppression.

Another point which is worthy of consideration when evaluating the performance of the phasing-type exciter is the absolute phase shift in the 90-degree audio phasing network at the two test frequencies used. Reference (5), which discusses a typical phasing network, indicates a possible variation of about ±1.3 degrees phase shift over a frequency range of 225 to 2750 c.p.s. For best results it is therefore desirable to select two test frequencies such as to produce equal phase shift; this results in equal suppression at each frequency and minimizes any slight ripple modulation which would otherwise be superimposed on the two-tone envelope output. Slight variation in components of one of the two oscillators may be made in this case so as to obtain a pair of frequencies fulfilling the above requirement.

The two-tone test generator is simple and inexpensive to construct and is believed to be a very worth-while addition to the test equipment used by the s.s.b. and a.m. man.

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2) Reque, "Linear R.F. Amplifiers," *QST*, May, 1949.
3) Ehrlich, "How To Test and Align a Linear Amplifier," *QST*, May, 1952.
4) ARRL *Handbook*.
5) Norgaard, "SSB Jr.," *GE Ham News*, Nov.-Dec., 1950.

Keyer

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released. V_{10} conducts and $R_{28}R_{29}$ is negative. The dash selection potential is clamped by D_4R_{26}. The dot memory clears as the dot starts. V_{10} cuts off on −13 volts from $R_{30}R_{32}$. $R_{28}R_{29}$ rises to +12 volts to pass the dash selection to V_{11}. Conduction in V_{11} establishes +10 volts at R_{25} for a dash on the next positive time-base pulse, and drops $R_{19}R_{20}$ to −7 volts to lock out any new dot selection made before the dash starts. The reverse transfer actions are obtained through circuit symmetry.

With their interlocks and activation circuits, V_{10} and V_{11} comprise effectually a tri-stable system. Either one or the other tube may be conductive, but never both. However, both tubes may be nonconductive. The three conditions correspond to selection of dot, dash, and spacing characters. By itself, this structure guarantees that a given character will be held in storage if an opposite type character(s) has been priorly selected, and it will not be released until that prior character(s) has been transmitted.

C_8 and C_9 delay the rise of sequencer cathode voltages. When control is transferred from one

(Continued on page 124)

side to the other this delay guarantees that both memories are not cleared by the same clearance pulse and that both generating triggers are not tripped by the same time-base pulse. Without capacitive delay this would occur, since generator trip, memory clearance and sequence transfer are virtually simultaneous.

Sequence Seizure

Thus far, a given sequencor tube cannot be activated by its associated memory or key until the opposite sequencor is released by both its key and memory, because of the interlock function. V_9 and V_{12} generate seizure pulses to override the interlocks in such a manner that the output exactly follows the order of selection, regardless of subsequent key manipulations or holdings. The crisscross grid and cathode connection to the memories results in nonconduction in both tubes if both memories are clear or if both memories are actuated, and conduction in one of the tubes when the memory associated with its grid is actuated and the other memory is clear. This obtains from the following potentials in the memories: actuated — cathodes +11 volts, junctions $R_{32}R_{33}$ and $R_{40}R_{41}$ +1 volt; clear — cathodes +1.3 volts, $R_{32}R_{33}$ and $R_{40}R_{41}$ −17 volts. When both memories are actuated, $R_{32}R_{33}$ and $R_{40}R_{41}$ rise to +3 volts as the grid-current loading in V_9 and V_{12} is removed.

Assume the dot and dash keys closed in that order before any output starts, with only the dot key held closed. Without seizure the closed dot key would hold the sequencor after the first dot on +10 volts from $R_{37}R_{38}$ for continuous dot output, and the stored dash would not appear in the order of selection. However, when the dot memory clears, its cathode (and that of V_9) drops to +1.3 volts and V_9 conducts as a result of the +1 volt on its grid from the actuated dash memory. C_6, slowly reverse charged by R_{17}, charges through V_9 and R_{18}. This momentarily reduces $R_{19}R_{20}$ from +12 to −7 volts, to cut off V_{10} by pulling down the dot-holding potential at D_3R_{21}. Junction $R_{28}R_{29}$ momentarily rises to +12 volts while V_{10} is cut off. The positive selection potential from the actuated dash memory seizes V_{11} via R_{26} while $R_{28}R_{29}$ is positive, and conduction in V_{11} permanently holds $R_{19}R_{20}$ at negative interlock potential to isolate the closed dot key. Thus sequence control has been transferred to the dash side despite the closed dot key, and the next output character will be the dash. When the dash memory clears, the still-closed dot key will reëstablish V_{10} conduction for dot output. If both keys have been held closed, the dash hold potential will retain control of the sequencor, since the dot memory is now clear and no pulse will be generated by $V_{12}C_{10}$ when the dash memory clears in the presence of an already-cleared dot memory.

Assume that the dash key is not closed until after the first dot (or any dot of a series) has started. The dot memory will be clear at this time with V_{10} conducting on the +10 volts from the closed dot key. The cathode of V_9 stands at

(Continued on page 126)

+1.3 volts and that tube will conduct immediately when the dash memory is activated, seizing the sequencor as before.

In both cases, with both keys held closed, the subsequent output is a series of dashes until either the dash key is released or the dot key is released and reclosed. After clearance of the dash memory, release of the dash key applies −13 volts to the grid of V_{11} and initiates a simple sequencor transfer to the +10 volts from the closed dot key. Opening and reclosing the dot key with the dash key still closed actuates the dot memory for a $V_{12}C_{10}$ seizure, and the output switches to dots. The opposites of these seizure actions obtain from symmetry.

Summary of SMS Functions

1) Momentary closure of a key actuates the associated memory. The memory directs an activating potential toward the associated sequencor.

2) Continued closure of a key directs an independent holding voltage toward the associated sequencor. This hold potential is effective only after the associated memory has assumed or seized control of the sequencor.

3) Actuation of a memory with the opposite key and memory idle *assumes* control of the sequencor, isolating the opposite memory and hold potentials.

4) Actuation of a memory *seizes* control of the sequencor over continuously closed opposite key hold potential, if the opposite memory is clear.

5) Actuation of a memory does not take control of the sequencor over an actuated opposite memory.

6) Clearance of a memory whose key is closed allows an actuated opposite memory to seize control of the sequencor over the hold potential from that closed key.

7) Clearance of a memory whose associated key is closed does not relinquish control to an opposite closed key whose associated memory is not actuated.

8) In the absence of any actuated memories, release of one key after both keys have been held closed places the sequencor under control of the still-closed key.

Summary of Actions of the Keys

1) A single character is generated by momentary or prolonged closure of a key. The character is held by the memory for a positive time-base pulse if the key is released prior to that pulse.

2) Successive like characters are generated by constant closure of a key.

3) When one memory is already actuated, closure of the opposite key before generation of the first-stored character activates the opposite memory. The firstly actuated memory retains control of the sequencor until one character of its type is delivered at the output. The secondly actuated memory then assumes control of the sequencor (as the first key is open or still closed) and the next output character is of the second type.

(Continued on page 128)

4) Continued closure of this second key maintains control of the sequencor after the transfer action, and the output is a series of the second type until that key is released. This obtains even with the first key still closed.

5) Release of the second key, with the first key still closed, causes the output to revert to the first character type.

6) Release and reclosure of the first key (just a flick!) reactuates the first memory and seizes control of the sequencor — the second key closed all the while — and the output reverts to the first character type until that first key is again released or until the opposite type character is flicked in by the second key. At least one character of the first type is guaranteed by the memory.

7) In recapitulation, any closure of a key guarantees at least one character of that type, transmitted in correct relationship to the order of closure, regardless of intervening selective motions. Whenever a key makes contact, the output subsequent to the character in progress corresponds to that key until the other key makes contact or the first key is released.

With automatic spacing, perfect characters, and memory and seizure leeways, all the operator has to do is spell. With a few more tubes, the keyer might be tied in to a dictionary.

D.C. Output

To eliminate the one relay, the circuit modification of Fig. 3 (Part I) can be applied. With this circuit, V_3 conducts during spacing and its plate stands 120 volts negative with respect to ground. Cut-off voltage from −30 to −120 is available at the arm of R_2, for control of a vacuum-tube keyer. R_3 protects the memory clearance junction R_1R_2 from loading effects by connected equipment and also serves as the key-click filter resistance.

The plate of V_8 drops 60 volts on marking, transmitting a 60-volt negative pulse via C_1 to the grid of V_3. The C_1R_4 time constant is sufficiently long to hold V_3 cut off for a 2-w.p.m. dash. With V_3 cut off the output load stands at ground potential, marking condition for the standard vacuum-tube keyer.

Heavy line surges can produce as much as 10 volts negative swing across R_4. The 24-volt positive grid return of V_3 to R_5R_6 ensures that these surges do not appear in the output. Since the generator and SMS trigger configurations are quite independent of source voltage, they are stable in the presence of any surge short of complete outage. Use of this output circuit demands that V_3V_4 be at the absolute ground end of any heater strings. Even though the 12AU7 heater-cathode insulation is rated at 180 volts, the maximum point is approached in V_3 when the line voltage exceeds 125.

(Scramble in Part I, April, 1955, *QST:* Page 14, left-hand column, in last paragraph, the text should read: ". . . insulated from the chassis by 3/8-inch Plexiglas. Metal pivot blocks, tapped for 8–32, are bolted to the 3/8-inch Plexiglas levers and threaded on the 8–32 pivot bolts. The pivot bolts are secured. . . .")