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TRANSISTORIZED FREQUENCY STANDARD

The obvious advantages of transistor circuitry in certain types of test instruments have been listed many times in this journal and in other places and need no repetition here. One instrument which is particularly aided by transistorization is the portable secondary frequency standard.

Earlier constructional articles have described transistorized frequency standards but these instruments usually have contained only an oscillator stage. The utility of a frequency divider in conjunction with the oscillator is well known to users of frequency standards, and its absence from many transistorized circuits is critical. The instrument described in this article accordingly provides a 10-kc multivibrator in addition to a 100-kc crystal oscillator.

This instrument circuit has been chosen for simplicity, fewest components, low d-c power drain, operation from inexpensive batteries, and use of inexpensive transistors. Whereas the volume of the instrument is the same as that of a standard volt-ohm-milliammeter, no attempt was made to miniaturize the layout. Undoubtedly, however, the instrument can be built smaller, if the reader so desires. The completely self-contained frequency standard measures 7" long, 5" high, and 3" deep, and weighs 1½ pound. Its total current drain is approximately 6 milliamperes dc from two 1½-volt,

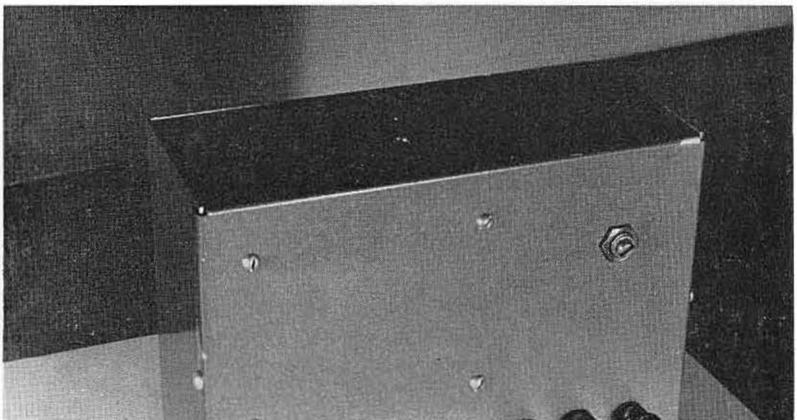

Fig. 1. Completed Frequency Standard. Measuring only 7" x 5" x 3", this transistorized instrument weighs 1½ lb. and operates from two self-contained flashlight cells. See Fig. 8 for identification of components.

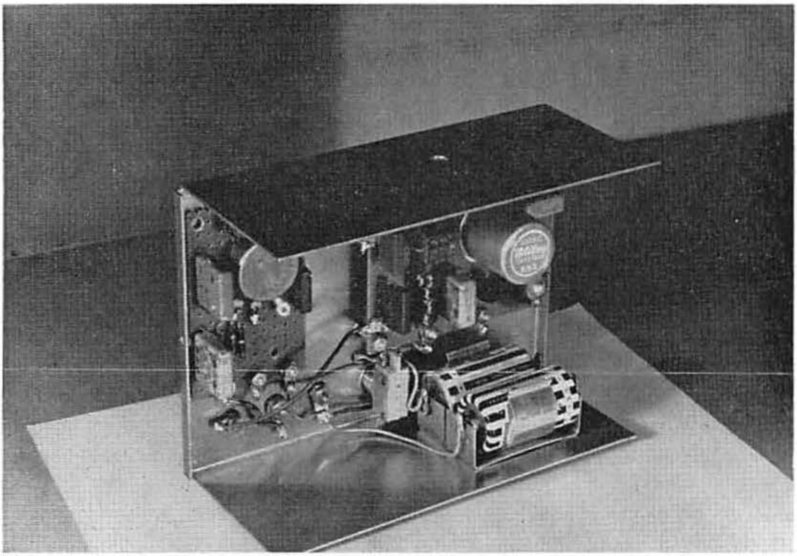

Fig. 2. Inside the Instrument.

Size-C flashlight cells connected in series.

Figure 1 shows the external appearance of the finished instrument. Binding posts are provided for 10- and 100-kc output. (See lower right-hand edge of the front panel.) A hole is provided in the top of the case for insertion of a screwdriver or alignment tool to set the oscillator frequency when standardizing against WWV broadcasts. A screwdriver-adjusted potentiometer in the upper right-hand area of the front panel is provided for setting the multivibrator frequency. Figure 2 shows the inside of the completed instrument.

Instrument Circuit

Figure 3 shows the complete circuit schematic. The oscillator is based upon a miniature 100-kc crystal (Bliley KV3) and is tuned by adjusting the slug screw of the collector inductor, L. The latter has an adjustment range of 4 to 30 millihenries and is set to approximately 13 mh for 100-kc resonance. The exact inductance setting required depends upon the actual capacitance of C_2. However, this is not an extremely critical adjustment, since tuning is rather broad. Fine adjustment of the slug permits zero beating with standard frequency radio signals. 100-kc output is provided at terminal T_1 by capacitance coupling through C_4. Similar output for synchronization of the multivibrator is supplied via capacitance coupling through C_5. The base resistor, R_1, may require some alteration in value for particular transistors. The single oscillator transistor, Q_1, is a 2N107.

The multivibrator employs a conventional cross-coupled circuit utilizing two 2N107 transistors, Q_2 and Q_3. In this circuit, R_2 and R_5 should be matched in resistance. These two resistances might require some alteration with individual transistors, to obtain exact 10-kc operation. Also, C_6 and C_7 should be matched in capacitance. One base resistance, R_4, is made variable for adjustment of the multivibrator frequency. 10-kc output is provided at Terminal T_2 by capacitance coupling through C_8. 100-kc energy for synchronization of the multivibrator is injected into the base of Transistor Q_2, through Capacitor C_5.

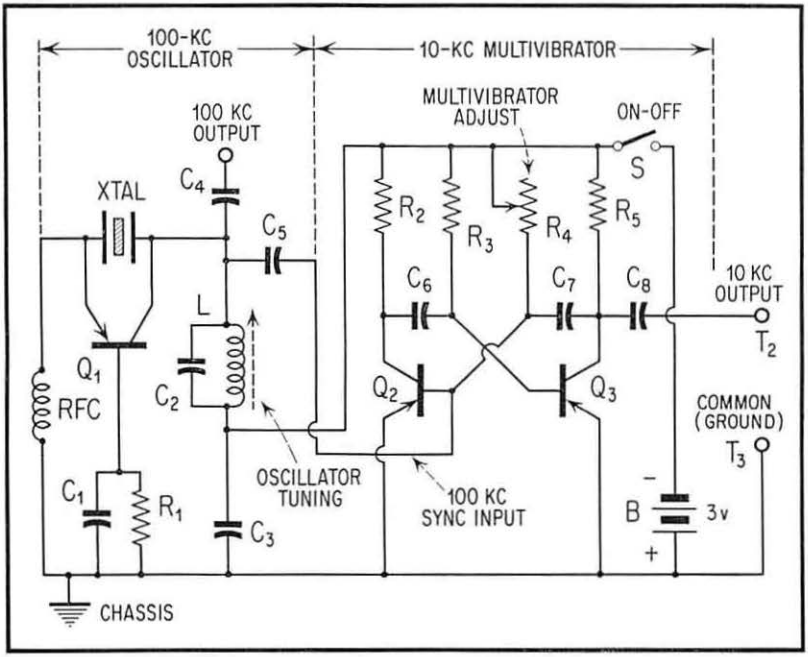

Fig. 3. Complete Circuit of the Frequency Standard.

The 100-kc output of the instrument will contain 10-kc markers as well, as a result of inherent coupling within the circuit. Generally, this is no disadvantage, since the space between any two successive 100-kc points will thus be divided automatically into ten equal spaces by the nine intervening 10-kc points. However, should the reader desire to disable the multivibrator, this can be done by means of a separate spst switch. Connect one terminal of this switch to B-minus and connect the B-minus ends of R_2, R_3, R_4, and R_5 to the other terminal of the switch instead of to Switch S. When this additional "10 KC" switch is opened, the multivibrator will be

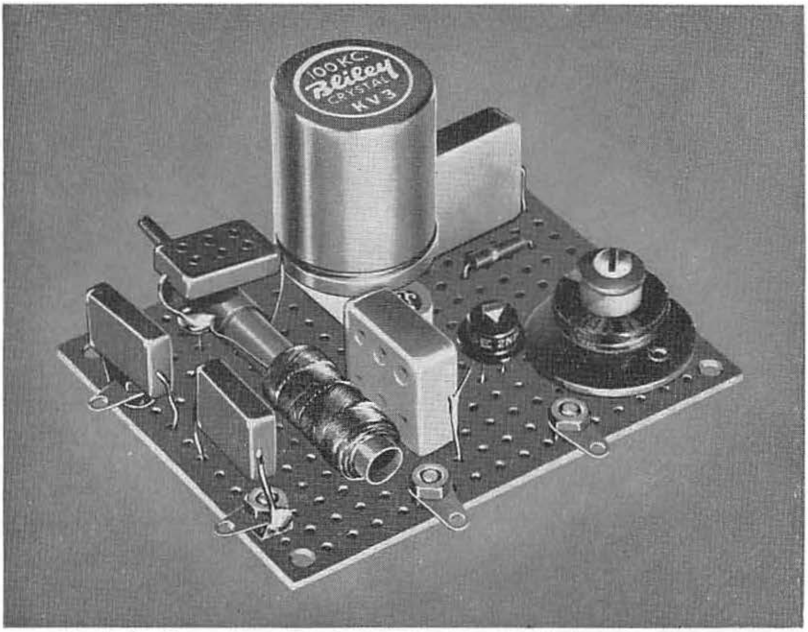

Fig. 4. Oscillator Circuit Board. See Fig. 5 for identification of components.

switched off. Switch S will still be connected to the lower end of Inductor L, as shown in Figure 3, and will become the separate "100 KC" switch. To switch the entire instrument off, both switches then would have to be thrown to their open position.

An examination of Figure 3 shows that the configuration of this circuit does not differ materially from that of the comparable tube circuit. The main difference, of course, is in the size of the instrument and its power supply and in generated heat. The transistor circuit is cool in operation and requires no warmup period; it is ready for instant operation. Moreover, it is not troubled by microphonics and internally-generated hum. A technician familiar with the tube version of this frequency standard will have no trouble in shifting to use of the transistorized instrument.

Mechanical Construction

Figures 1, 2, 4, 5, 6, 7, and 8 show constructional details of the frequency standard.

The aluminum box (LMB No. 145) which houses the instrument is 7" long, 5" high, and 3" deep. There is ample "breathing space" inside the case, and considerable miniaturization is possible if such is required. Figures 1 and 8 show details of the front panel and its few components.

Both the oscillator and multivibrator are assembled on small panels of 1/16"-

thick perforated phenolic stock. The pigtails of the capacitors, resistors, and transistors are passed through the tiny holes in the panels and are connected together underneath. This arrangement provides some of the compactness of the printed circuit without the complexity of the latter's manufacture. The Editors employed separate circuit boards for the oscillator and multivibrator. But there is nothing sacred about this arrangement; an individual builder may use a single board for both circuits if he is so inclined.

The oscillator circuit board is shown in Figures 4 and 5. This board is 3½" x 3" in size. The crystal socket is fastened to the board with a pair of 4-40 screws, the neck of Inductor L is gripped by a miniature fuse holder fastened to the board with a 6-32 screw, and the r-f choke is mounted with a single 6-32 screw. Solder lugs along two edges of the board are provided for 100-kc output, sync output to the multivibrator, and for connection to B-minus and ground. The oscillator circuit board is held to the front panel by four 1½"-long 6-32 screws. These allow the board to be moved back for clearance, so as to prevent panel-grounding of the wiring under the board. A 5/16-inch clearance hole is drilled in the top of the case (visible in Figure 1) just above the slug screw of Inductor L. This per-

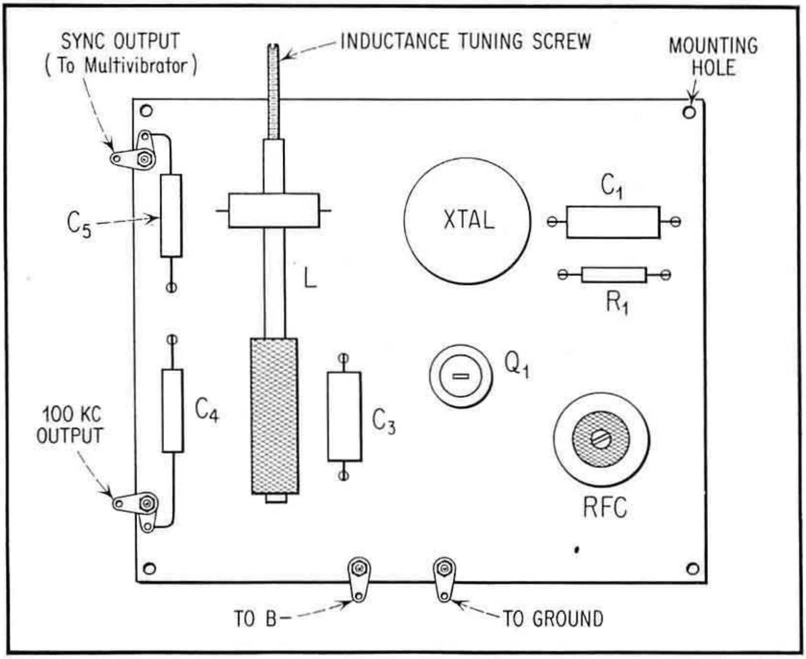

Fig. 5. Layout of Oscillator Circuit Board.

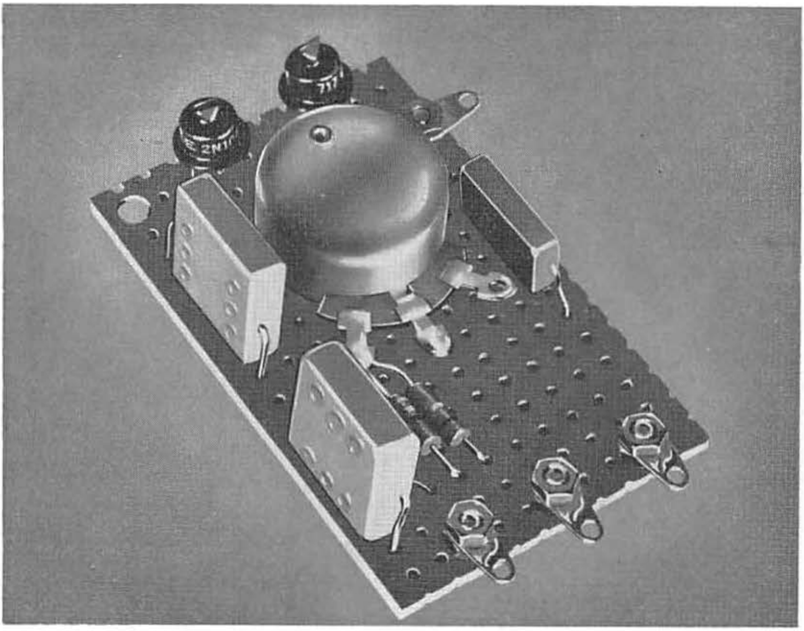

Fig. 6. Multivibrator Circuit Board. See Fig. 7 for itentification of components.

mits insertion of a screwdriver or alignment tool to trim the inductance.

The multivibrator circuit board is shown in Figures 6 and 7. This board is 2″ by 3″ in size. The potentiometer, R_4, is mounted through a clearance hole in the board and serves to hold the multivibrator circuit board to the front panel, but far enough behind the latter to prevent short-circuiting of the wiring under the board. The potentiometer has a slotted shaft for screwdriver adjustment, since this control is not often operated and a knob or dial might be accidentally twisted. A shaft lock on this potentiometer will protect it from tampering. Solder lugs along two sides of the multivibrator circuit board are provided for 10-kc output, sync input from the oscillator, and for connection to B-minus and ground.

Terminals T_1, T_2, and T_3 are insulated binding posts. Coaxial or concentric connectors employing output cables, while neat in appearance, are not recommended, since cable capacitance tends to bypass many of the desired harmonics in the output signals.

Figure 2 shows the internal construction and interwiring of the instrument. The circuit boards are clearly visible in this photograph, as are also the ON-OFF switch, output terminals, and battery. The two small cells of the battery are clipped into a battery holder (Keystone 174) mounted on the floor of the instrument box.

The parts must be mounted as solidly as possible. Use plastic-covered, flexible hookup wire for the connections. Keep all signal leads well away from the metal panel to reduce capacitance effects, and do not use shielded wire, since the capacitance of such wire will bypass useful harmonics of 10 and 100 kc. An example of a signal lead "in the clear" is seen in Figure 2. Here, the 100-kc lead from the output binding post to the oscillator circuit board lug is seen pulled well away from the panel, in the lower left section of the photograph.

Initial Adjustment

After construction is completed and all wiring has been checked, insert the crystal into its socket and the cells into the battery holder. Then, proceed to adjust the instrument in the following manner.

(1) Using a reliable all-wave radio receiver, tune-in WWV standard frequency transmissions on 2500 or 5000 kc. (2) Connect the instrument to the receiver; Terminal T_1 to the antenna terminal of the receiver, and Terminal T_3 to the receiver ground terminal. (3) Set Switch S to its ON position. (4) Adjust the slug of Inductor L for exact zero beat with WWV. Do this during an unmodulated interval of the WWV signal. (5) Next, disconnect the receiver antenna, so that no stations will be picked up, but leave the frequency standard connected to the antenna and ground terminals as before. Switch the receiver to the standard broadcast band and place it into oscillation (BFO switched on). (6) Near the low end of the band, locate two successive 100-kc signals from the frequency standard,

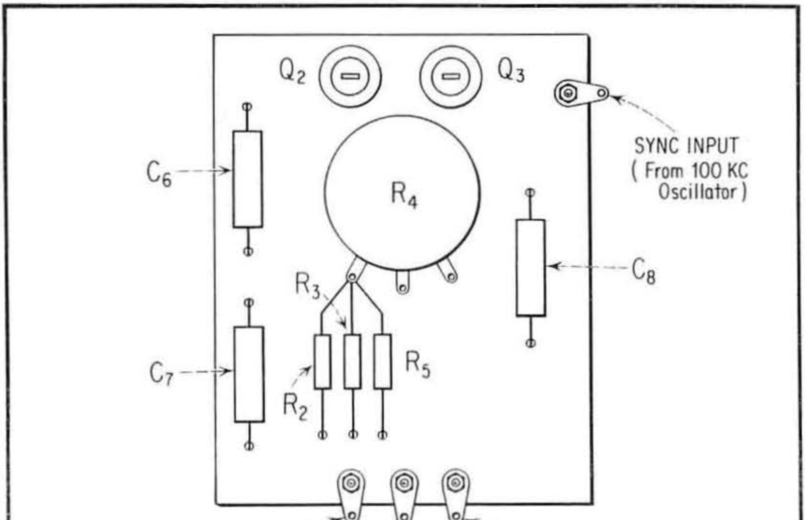

Fig. 7. Layout of Multivibrator Circuit Board.

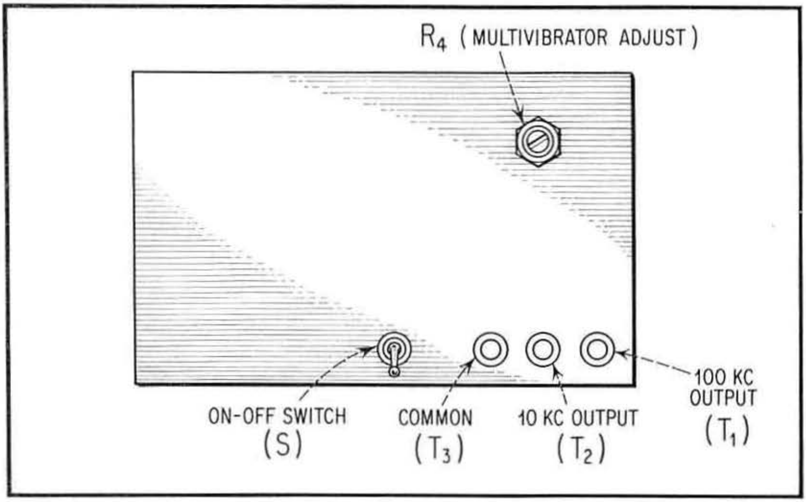

Fig. 8. Front Panel Layout.

and note the corresponding points on the receiver dial. (7) Tuning the receiver slowly, count the number of weaker spot signals (due to the multivibrator) between these two points. (8) Adjust Potentiometer R_4 in the multivibrator until exactly nine intermediate signals appear between the adjacent 100-kc points. When this is done, the multivibrator frequency is set exactly to 10 kilocycles.

Routine Operation

The transistorized frequency standard is used in the normal manner in all applications to which a tube-type instrument commonly is applied.

The instrument should be checked occasionally against WWV. The multivibrator frequency may be checked either with a receiver, as explained in the preceding Section, or with an electronic audio frequency meter connected to Terminals T_2 and T_3.

Parts List for Figure 3.

B—3-volt battery (2 Size-C flashlight cells connected in series)

C_1, C_3,—0.01 ufd mica — (C-D 1D5S1)

C_2—200 uufd mica — (C-D 22R5T2)

C_4, C_5, C_8—27 uufd mica — (C-D 22R5Q27)

C_6, C_7—0.003 ufd mica — (C-D 1W5D3)

L—4-30 mh tunable inductor — (Miller 6315)

Q_1, Q_2, Q_3—PNP transistors — (General Electric 2N107)

R_1—0.75 megohm ½ watt

R_2—1000 ohms ½ watt

R_3—0.22 megohm ½ watt

R_4—25,000-ohm potentiometer with slotted shaft

R_5—1000 ohms ½ watt

RFC—2½ mh radio-frequency choke — (Miller 853)

S—Spst toggle switch

T_1, T_2, T_3, T_4—Output terminals (binding posts, insulated)

XTAL—100-kc quartz crystal — (Bliley KV3)

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