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R-F Transistors

Their Characteristics and Applications

Part: 1

By the Engineering Department, Aerovox Corporation

SINCE the introduction of the commercial transistor, one of the most serious hindrances to its wide application in electronic circuits has, to many minds, been its limited frequency response. From time to time, press releases have disclosed that special laboratory transistors have performed satisfactorily at radio frequencies but no promise could be made regarding their general availability. At this writing, however, several types of junction r-f transistors have become commercially available and should open new avenues for the transistorization of electronic equipment. This article will review the important characteristics and typical applications of these transistors.

Of the six available types, all are germanium. Two are NPN, three PNP, and one surface barrier. The electrode polarities of the latter type are identical with the PNP type; that is, collector negative and emitter positive. All are hermetically sealed.

The accompanying Tables show the characteristics of these transistors which are important to the high-frequency circuit designer. Table 1 gives the maximum ratings for each type, and Table 2 shows typical characteristics. Where blanks appear in these tables, the missing data were not obtainable from the transistor manufacturer.

Each of the r-f-type transistors is metal-encased and its three pigtail leads may be soldered, welded, clip-

TABLE 1. MAXIMUM RATINGS

Type	2N94	2N94A	SB—100	CK760	CK761	CK762
Class	NPN	NPN	Surface Barrier	PNP	PNP	PNP
Manufacturer	Sylvania	Sylvania	Philco	Raytheon	Raytheon	Raytheon
Collector Voltage (dcv)	20 (a)	20 (a)	—4.5 (b)	—10	—10	—10
Collector Current (dc ma)	5.0	5.0	—5.0	—5.0	—5.0	—5.0
Emitter Current (dc ma)				5.0	5.0	5.0
Collector Dissipation (mw)	30 (c)	30 (c)	10 (d)	30 (e)	30 (e)	
Ambient Temperature (°C)				50	50	50

FOOTNOTES FOR TABLE 1.
(a) Collector-to-base voltage.
(b) Collector-to-emitter voltage.
(c) Total dissipation at 25°C. Derate 0.6 mw per °C rise in ambient temperature.
(d) At 40°C
(e) At 30°C

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ped, or plugged-in into the circuit. These transistors may be mounted and operated in any position. Aside from high alpha cutoff frequency, a particular feature of the high-frequency transistor is its low collector capacitance.

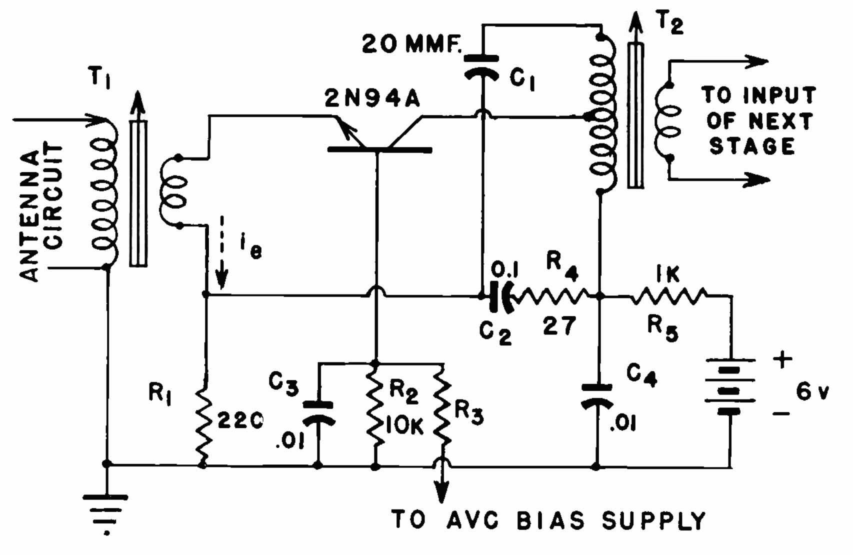
TYPICAL APPLICATIONS

With the advent of the commercial r-f transistor, equipment heretofore not readily transistorized will be adaptable to tubeless operation. This includes amplifiers, oscillators, control devices, and radio receivers. The accompanying schematics show several typical applications.

Radio-Frequency Amplifier. Figure 1 shows the circuit of a radio-frequency amplifier originally due to Sylvania. This is a neutralized, common-base circuit for the 2N94A transistor.

While this circuit was intended primarily for operation in the standard broadcast band (0.54 to 1.6 Mc), it has been tested at frequencies up to 5 megacycles with suitable selection of T_1 and T_2 for the frequency bands covered.

In the common-base configuration, the 2N94A in the circuit of Figure 1 exhibits an input impedance of 80 ohms (resistive) and an output impedance of 15,000 ohms. When amplifier stages are cascaded, the interstage transformers (such as T_2) must handle this step-down impedance ratio.



RADIO FREQUENCY AMPLIFIER
FIGURE 1

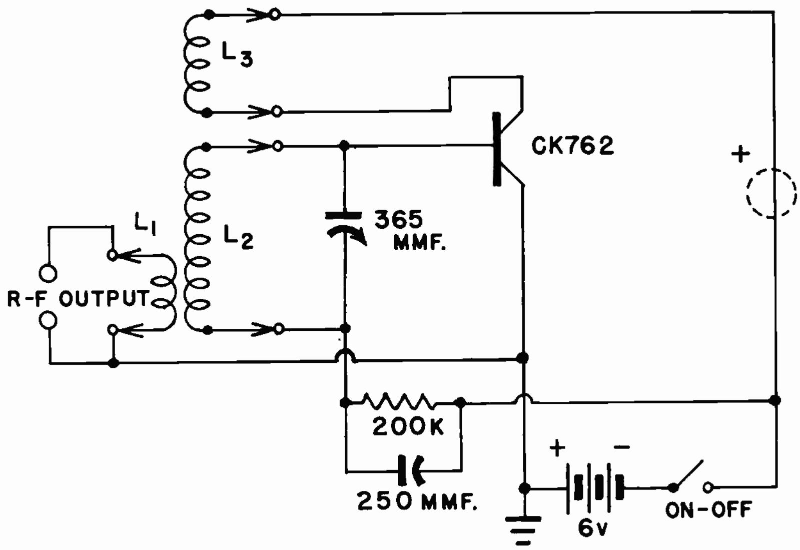
In the original tests of the r-f amplifier, the power gain per stage was measured as 20 db at 1000 kc and this includes 3 db loss in the transformers and neutralizing circuit. Bandwidth at the —3 db points is 25

TABLE 2. TYPICAL CHARACTERISTICS

Type	2N94	2N94A	SB—100	CK760	CK761	CK762
Collector Voltage (dcv)	6.0	6.0	—3.0	—6.0	—6.0	—6.0
Cutoff Current (dc μa)	3.0 (a)	3.0 (a)	—0.5	—1.0	—1.0	—1.0
Emitter Current (dc ma)				1.0	1.0	1.0
Input Impedance (ohms)	100 (b)	100 (b)	70 (e)	600 (g)	600 (g)	
Output Impedance (ohms)	150,000	150,000	400,000 (e)	25,000 (g)	250,000 (g)	
Collector Resistance (megohms)	2.0	2.0				
Extrinsic Base Resistance (ohms)	150	150		75	75	75
Collector Capacitance (μμfd)	10	10	3.5	14	14	14
Alpha (is greater than)	0.95	0.95				
Base Current Amplification Factor	40	40	20	40	45	65
Power Gain (db)	25 (c)	25 (c)		32	33	
Collector-Base Time Constant (sec)	1500 (d)	1500 (d)	800 (f)			
Maximum Oscillation Frequency (Mc)			45			
Alpha Cutoff Frequency (Mc)	3.0	6.0		5.0	10	20

FOOTNOTES FOR TABLE 2.

(a) At collector voltage = 10 v dc.
(b) Single-tuned, neutralized common-base circuit at 456 kc.
(c) Gain per stage (stage as in footnote b, above)
(d) Ohms × μμfd.
(e) Common-base circuit
(f) micro-microseconds
(g) At 455 kc, common-emitter circuit



SELF-EXCITED R-F OSCILLATOR
FIGURE 2

kc at 1 Mc.

Capacitance C_2 and resistance R_4 often require adjustment for optimum performance of the circuit with individual transistors. When the amplifier is part of a complete receiver or instrument circuit from which it receives avc bias, the zero-signal bias current (i_e) is adjusted to a level between 0.5 and 1 milliampere.

Self-Excited R-F Oscillator. The high-frequency transistor is an especially good oscillator. Oscillation may be obtained at frequencies somewhat beyond that of alpha cutoff.

Transistors will oscillate satisfactorily in many types of circuits. Figure 2 shows a tickler feedback circuit in which the transistor is connected in the common-emitter configuration. With the CK762, the circuit will oscillate up to 25 Mc. Vigorous individual transistors will reach 30 Mc.

The plug-in coil set (L_1-L_2-L_3) can be of the manufactured variety intended for use in all-wave regenerative receivers. Or these coils may be wound, following the data obtained from the nomographs found in the practical radio handbooks or from coil-winding slide rules. The tuning capacitance range is assumed to be 25 to 365 μμfd. For any frequency band, L_3 has approximately ⅓ the number of turns in L_2 and is wound over the top end of L_2 from which it is insulated. The pickup coil, L_1, consists of 3 to 5 turns wound over the lower end of L_2 and insulated from it.

A 0-1 d-c milliammeter in position M converts the oscillator into a dip meter similar in operation and use to the familiar vacuum-tube grid-dip meter.

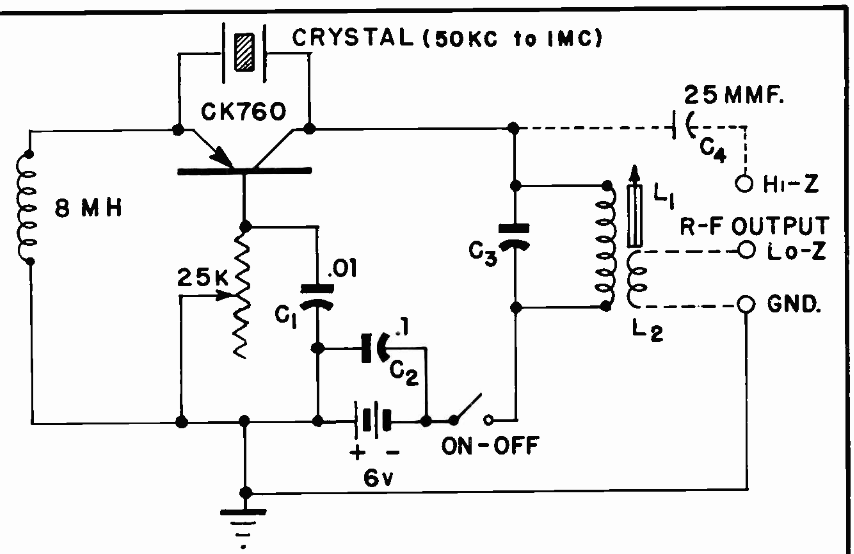
Standard-Frequency Crystal Oscillator. Like the tube-type, the transistor oscillator is improved by quartz crystal control. A natural application of the transistorized crystal oscillator is as a secondary frequency standard, since it can be operated economically from a self-contained battery and needs no warmup time.

Figure 3 is the circuit of a standard-frequency oscillator which can employ any crystal frequency between 50 and 1000 kc to which standard-frequency crystals usually are ground. This is a common-base circuit in which the crystal supplies the feedback path from collector to emitter of the CK760 transistor.

The tuned circuit is composed of fixed capacitor C_3 and a small slug-tuned inductor, L_1. With a 350-μμfd silvered mica capacitor for C_3, a 4-30-millihenry tuned inductor (J. W. Miller No. 6315) will tune from 50 to 140 kc. With $C_3 = 100$ μμfd, a 2-18-mh inductor (Miller No. 6314) tunes from 120 to 350 kc. With $C_3 = 150$ uufd, a 0.55-2.3-mh inductor (Miller No. 6197) covers 270 to 600 kc. And with $C_3 = 400$ μμfd, a 0.054-0.245-mh inductor (Miller No. 6196) tunes from 500 to 1200 kc. These LC combinations thus provide coverage on all standard-frequency crystal frequencies from 50 kc to 1 Mc.

High-impedance r-f output coupling may be obtained by means of the 25-μμfd capacitor, C_4. There is some objection to this type of coupling, however, since a low-impedance load easily could disable the oscillator. Low-impedance output is obtained by means of a pickup coil, L_2, which consists of 5 to 10 turns wound around the lower end of L_1.

The 25,000-ohm rheostat in the base circuit of the transistor is adjusted for easy starting of oscillation immediately upon closing the battery switch. This adjustment will be somewhat different for individual transistors.



STANDARD-FREQUENCY CRYSTAL OSCILLATOR
FIGURE 3

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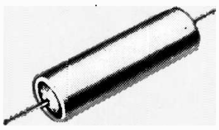
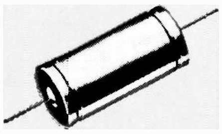
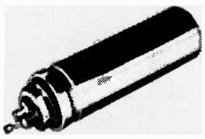
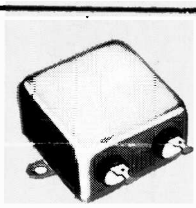
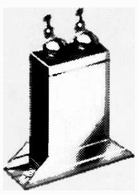
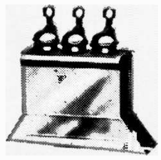
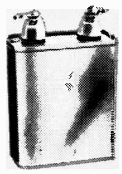
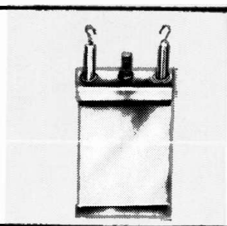
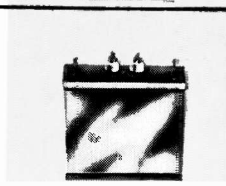
CP04 – CP05 – CP08 – CP09 – CP10 – CP11 –		Ratings 100-600 VDCW, available with insulated bodies, tangential brackets and threaded terminal mountings.
CP25 – CP26 – CP27 – CP28 – CP29 –		Ratings 200-1500 VDCW, insulated bodies, radial and tangential mounting brackets available.
CP40 – CP41 –		Ratings 600-1500 VDCW, grounded or insulated case construction.
CP53 – CP54 – CP55 –		Ratings 100-1000 VDCW. Available with terminals on top, bottom or side.
CP61 – CP63 – CP65 –		Ratings 400-1500 VDCW. Available with removable mounting brackets or with soldered mounting brackets for top or bottom terminal mounting.

MIL-C-25A NO.	CASE STYLE	REMARKS
CP67 – CP69 –		Ratings 600-1000 VDCW. Available with top or bottom channel mounting brackets.
CP70 –	 	Available in ratings from 600-12,500 VDCW. Type CP07 .mounting brackets available.
CP75 – CP76 – CP77 – CP78 –		Available in ratings from 250-600 VDCW. All units supplied with machine screw stud mounting.
CP80 – CP81 – CP82 –		Available in ratings from 400-1500 VDCW. All units supplied with machine screw stud mounting.

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