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DYNAMIC TEST SET FOR TRANSISTORS

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Approved

Stuart Wm Seeley

Dynamic Test Set for Transistors

Introduction

The test set described in this bulletin provides a wide variety of information about transistors: power gain at 4,000 cycles, approximate matching impedance and current gain over a wide range of bias conditions and power levels; d-c volt-ampere characteristics (point by point) and an estimate of linearity (by oscilloscopic observation). The circuit may be switched to provide either a base input amplifier or an emitter input amplifier. Source impedance and output load impedance may be adjusted in order quickly to select matching values or to evaluate operation under any arbitrary condition. Throughout all of these circuit changes the biases remain unchanged and the output meter indicates directly the power gain in db. Biases are supplied to the emitter and collector from supplies which may be set to deliver either constant current or constant voltage. The emitter bias may be of either polarity but the collector bias is suitable only for p-n-p junction transistors or n-type point-contact units. Both biases are continuously adjustable over a wide range. The current gain may also be easily determined by setting to a high input impedance and a low output impedance.

Principle of the Measurement

A signal generator and resistive attenuator supply a constant and known amount of "available" power to the input of the transistor although the source impedance is adjustable over a wide range. The power dissipated in an adjustable output load is measured. The general principles involved in the measurement will be explained with reference to Fig. 1.

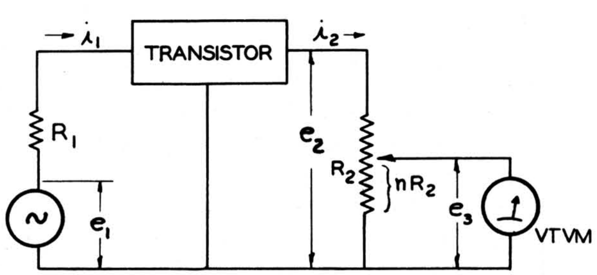


Fig. I – Schematic of test arrangement.

The input and output impedances R_1 and R_2 may be independently varied. The relationship between input power, output power and power gain are as follows:

$$\frac{e_1^2}{4R_1} = P_1 = \text{available input power.}$$

This is held constant by an appropriate change in e_1 as R_1 is varied. A matching T section in the test set accomplishes this automatically.

$$\frac{e_2^2}{R_2} = P_2 = \frac{e_3^2}{n^2 R_2} = \text{output power absorbed in load.}$$

(n is the fraction of R_2 between the tap point and ground).

By holding n^2R_2 constant as R_2 is varied, P_2 is measured by e_3^2.

Then, gain $= \frac{P_2}{P_1} = \frac{4R_1}{e_1^2} \cdot \frac{e_3^2}{n^2 R_2} = Ke_3^2$

A calibration switch permits adjustment of K (via e_1) to equal some power of 10. Now gain can be measured easily as $10^m e_3^2$. With a meter which has a "db" scale, such as the Ballantine, Model 300, the power gain is indicated directly in db.

The Input Matching Network

The source impedance presented to the input of the transistor is adjusted by switching in one of nine different resistive T sections. These networks all have the same attenuation (20 db) and all present 500 ohms to the signal generator. They will provide nine values of source impedance between 20 ohms and 10,000 ohms so that the mismatch inaccuracy is less than 2 db to any impedance between these values. Since these networks all have the same attenuation, the power available to the transistor remains constant regardless of the position of the matching switch. Therefore, optimum match is indicated by adjusting the matching switch for maximum gain. A similar adjustment is provided for the load resistance, which can be optimized in the same way (see below).

An audio signal generator having a 500-ohm output impedance, such as the Hewlett-Packard generator, Model 205A, is used to supply an input signal which can be adjusted over a wide range of levels. However, any audio signal generator may be used since the mismatch between the output impedance of the generator and the 500 ohms of the T section is constant for all the T sections, and this discrepancy is automatically eliminated in calibration.

The Output Matching Network

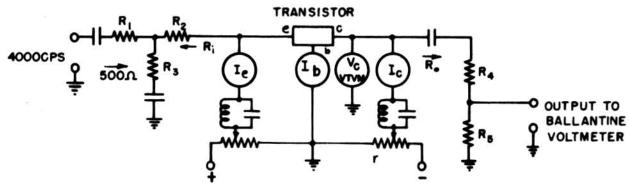
The output of the transistor is terminated by any of ten loading resistors, ranging in value from 50 ohms to 100,000 ohms. These loading resistors are made in the form of voltage dividers. An output meter of the Ballantine type is placed between the tap point and ground. The position of the tap point on each load is such that the voltage between the tap point and ground remains constant for any given amount of power absorbed in the load, regardless of the size of the load.

Calibration

A simple means of calibration is provided for use in initially adjusting the power output of the signal generator and for monitoring this adjustment. A voltage divider with a total resistance of 500 ohms is connected by a switch directly across the signal generator. Simultaneously, the tap point on this divider is connected to the output voltmeter. The position of the tap point is such that the calibration circuit is the electrical equivalent of the measuring circuit matched to an amplifier of unity gain. If a meter with a db scale (such as the Ballantine Model 300) is used to measure output power, calibration is performed by switching in the calibrating network and adjusting the output of the signal generator until the output meter reads zero db. When the circuit is returned to the operating position, the meter will indicate the gain of the transistor directly in db.

DC Biasing

Provision is made for introducing d-c biases to the transistor. For emitter input these biases are shunt fed through two tuned chokes to the emitter and collector electrodes as shown in Fig. 2. Built-in meters measure the d-c currents and voltages, the collector voltage being measured by a built-in vacuum-tube voltmeter which exhibits a very high shunting impedance. If the small error in d-c bias voltage introduced by the choke resistance can be tolerated, ordinary d-c voltmeters may be used if they are connected to the low side of the tuned circuits. A nearly constant current bias of either polarity can be supplied to the emitter by switching a high resistance in series with the emitter bias supply. A negative bias can be supplied to the collector either

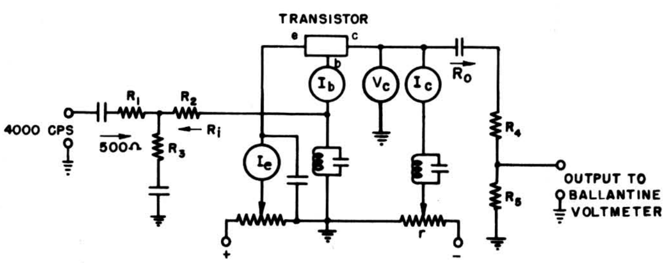


R_1, R_2, R_3 simultaneously adjusted for approximate match of input impedance.

R_4, R_5 simultaneously adjusted for approximate match of output impedance.

Fig. 2 - Simplified diagram of dynamic test set for measuring transistor performance with emitter input.

as a constant voltage through the tuned circuit or as a constant current through a current regulating pentode. In the latter case the collector supply does not involve the tuned circuit. The present test set was designed for transistors made of n-type germanium for the base region. If a positive constant-voltage bias is desired for the collector it can be obtained by a slight alteration in the present equipment involving switching potentiometer r to a supply of an opposite polarity and reversing the polarity of the meters in the collector circuit. When the transistor is tested as a base input amplifier the input signal is impressed across the tuned circuit which is switched between the base and ground. This condition is illustrated in Fig. 3. A switch permits the interchanging of the transistor connections with a minimum of inconvenience.



R_1, R_2, R_3 simultaneously adjusted for approximate match of input impedance.

R_4, R_5 simultaneously adjusted for approximate match of output impedance.

Fig. 3 - Simplified diagram of dynamic test set for measuring transistor performance with base input.

The measurements are made at 4000 cycles per second which is the resonant frequency of the tuned circuits. Measurements at any other frequency can be made if the resonant frequency is shifted to that frequency. The test set can also be adapted for measurement with emitter input under constant current bias conditions at any frequency, or while the frequency is swept. This can be done by series feed of the biases through either the matching resistors or a large shunt resistor eliminating the tuned circuits. Care must be taken to avoid capacitive feedthrough of the input signal.

Measurement of Current Gain

The test set is well adapted for measuring the current gain, α_{21} of the transistor as is demonstrated below in conjunction with Fig. 1.

$$\alpha_{21} = \frac{i_2}{i_1}$$

$$i_2 = \frac{e_2}{R_2}$$

If R_1 is made very large compared to the input impedance of the transistor, then:

$$i_1 = \frac{e_1}{R_1}$$

$$\alpha_{21} = \frac{R_1 e_2}{R_2 e_1}$$

During calibration of the test set e_1 has been adjusted for zero db corresponding to, say, 10 millivolts on the output meter. R_1 and R_2 can now be chosen such that α_{21} is some power of 10, times e_2. Hence α_{21} can be directly read on the voltage scale of the output meter.

Two values of current gain are associated with the transistor depending on whether the input signal is applied to the emitter or to the base. The emitter input current gain α_{ce} is the change in collector current per unit change in emitter current, the collector voltage being kept constant. The base input current gain α_{cb} is the change in collector current per unit change in base current, also at constant collector voltage. α_{cb} is related to α_{ce} by the expression:

$$\alpha_{cb} = \frac{\alpha_{ce}}{1-\alpha_{ce}}$$

In the present test set R_1 and R_2 have been so chosen that when the measured voltage,

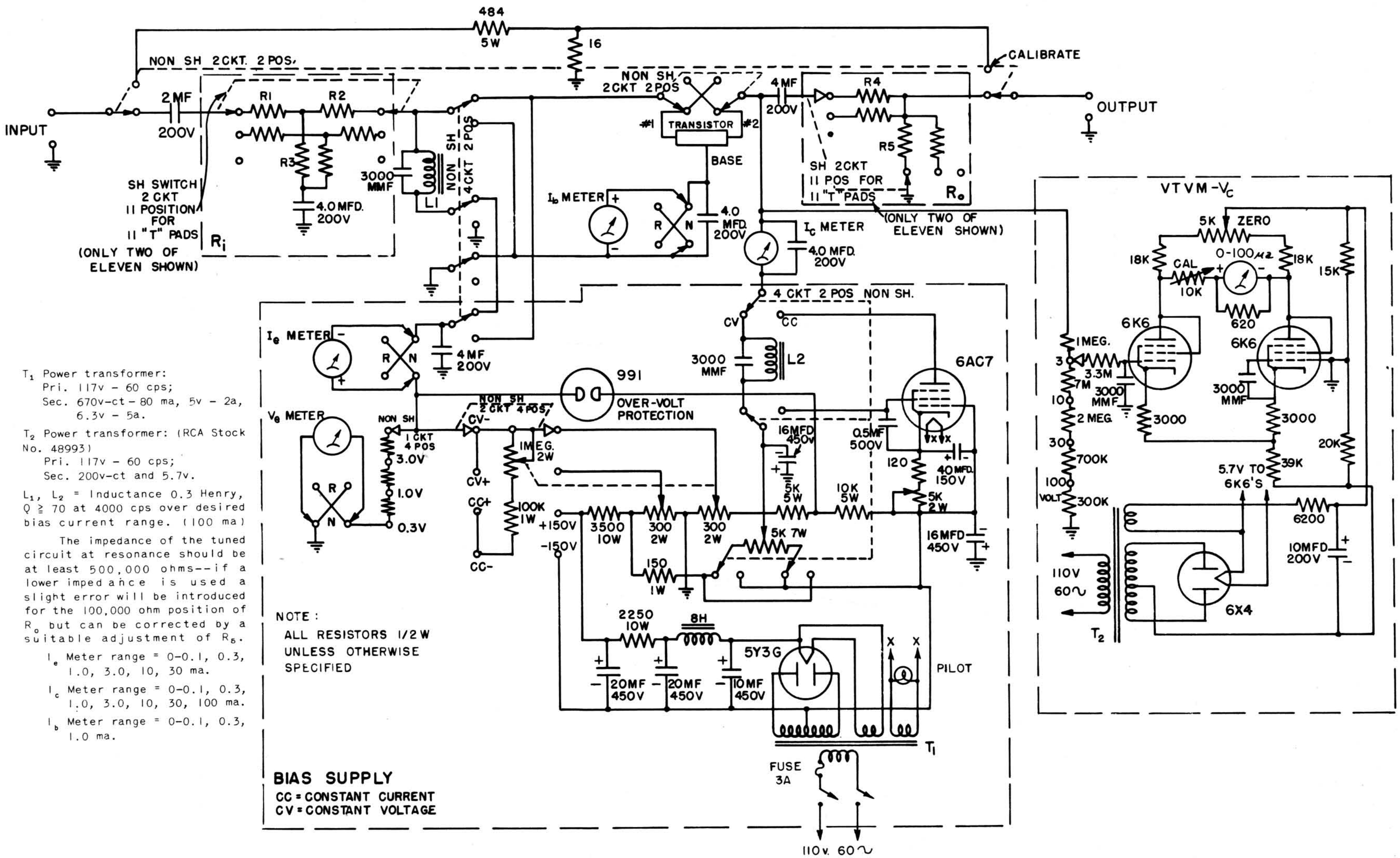


Fig. 4 – Schematic of dynamic test set for transistors.

T_1 Power transformer:
Pri. 117v – 60 cps;
Sec. 670v-ct – 80 ma, 5v – 2a, 6.3v – 5a.

T_2 Power transformer: (RCA Stock No. 48993)
Pri. 117v – 60 cps;
Sec. 200v-ct and 5.7v.

L_1, L_2 = Inductance 0.3 Henry, $Q \geq 70$ at 4000 cps over desired bias current range. (100 ma)

The impedance of the tuned circuit at resonance should be at least 500,000 ohms--if a lower impedance is used a slight error will be introduced for the 100,000 ohm position of R_o but can be corrected by a suitable adjustment of R_6.

I_e Meter range = 0–0.1, 0.3, 1.0, 3.0, 10, 30 ma.

I_c Meter range = 0–0.1, 0.3, 1.0, 3.0, 10, 30, 100 ma.

I_b Meter range = 0–0.1, 0.3, 1.0 ma.

Table I
INPUT NETWORK

R_i	R_1	R_2	R_3
20	470	0.4	18
50	470	20	30
100	470	56	47
200	430	150	62
500	430	390	100
1000	360	910	150
2000	300	1800	200
5000	200	4700	300
10,000	62	10,000	430
α_{ce}	0	10,000	500
α_{cb}	0	100,000	500

Table II
OUTPUT NETWORK

R_o	R_4	R_5	N
50	0	51	1
100	30	75	1.4
200	100	100	2
500	330	160	3.1
1000	750	220	5
2000	1600	300	6.3
5000	4300	470	10
10,000	9100	680	15.8
30,000	30,000	1300	24.5
100,000	100,000	2200	50
α_{ce}, α_{cb}	0	330	1

$$N' = \frac{\text{actual a-c voltage across load}}{\text{measured a-c voltage}}$$

All resistors 1 watt and 5 per cent tolerance.

$e_3 = e_2$, is equal to the calibration voltage, $\alpha_{ce} = 1$ and $\alpha_{cb} = 10$.

Tables I and II list the values of the resistors forming respectively the input and the output matching networks, as well as the values of the resistors used when the current gain is being measured.

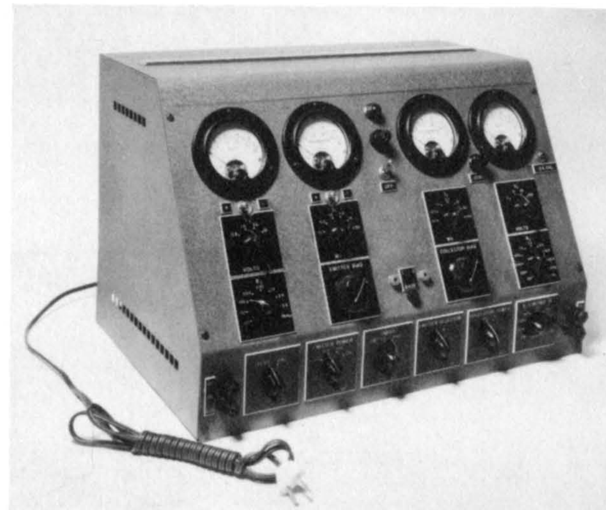


Fig. 5 – Photograph of complete unit.

The detailed schematic of the test set is shown in Fig. 4 and a photograph of the complete unit is shown in Fig. 5. For this particular model an external meter, not shown in the photograph, is used to measure the base current.

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