

RADIO PHYSICS

I. PHYSICAL ELECTRONICS

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A. METER PROTECTION CIRCUIT

An interesting property of a silicon transistor has been investigated by first making careful measurements of a Fairchild¹ NPN transistor of the type 2N1613. The circuit

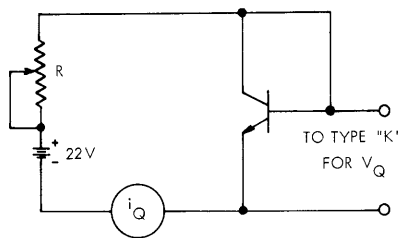


Fig. I-1. Measurement circuit for test of silicon NPN transistor, Type 2N1613 (Fairchild Semiconductor).

used for the first study is illustrated by Fig. I-1. The current that passed through the circuit was controlled by the variation of the resistance R . The current was measured on a calibrated meter, and the voltage difference between the emitter and the common lead that joins the collector to the base was measured with the type "K" Leeds and Northrup potentiometer. The result is best displayed by the graph in Fig. I-2. The relation between the voltage and current over nearly four orders of magnitude can be expressed by

$$i_Q = 10^{\frac{V - 0.796}{0.064}} = e^{\frac{V - 0.796}{0.0288}} \text{ A.} \quad (1)$$

The first point of interest illustrated by Eq. 1 is that a change in V_Q of only 64 mv corresponds to a change in current of a full order of magnitude. With this equation expressed as an exponential of base e , the number 0.0288 may be interpreted as the voltage equivalent of the temperature which is computed to be 334°K. Since the room temperature at the time when the transistor was measured was approximately 303°K (86° F), the discrepancy in absolute temperature was only 10 per cent, thereby indicating that the transistor was operating practically as an ideal diode.

This fact suggests at once that it would serve an extremely useful function as a meter-protecting device. The basic circuit is shown in Fig. I-3. This transistor is particularly useful for protecting meters with a full-scale sensitivity of 1 ma, or less. The procedure to be followed is derived from an application of Eq. 1. Assume that the full-scale deflection of the meter is I_m and that at full scale less than 1 per cent shunt

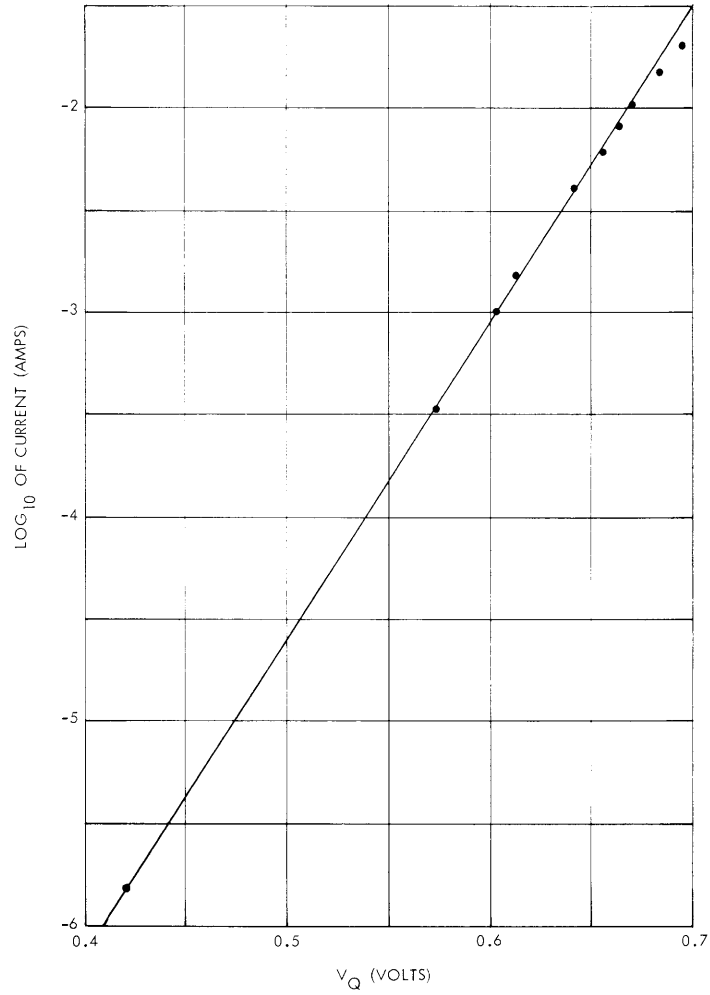


Fig. I-2. Relation between current i_Q (amp) and V_Q of Fig. I-1. Slope, 0.064 volt per decade. Equivalent temperature, 334°K; actual temperature, 303°K.

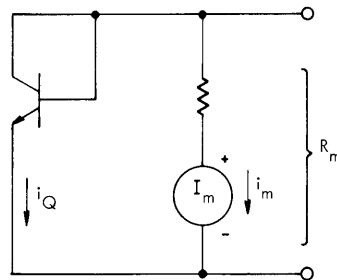


Fig. I-3. Basic circuit for meter protection. Meter current i_m ; transistor current i_Q ; full-scale meter current I_m ; total resistance including the meter R_m .

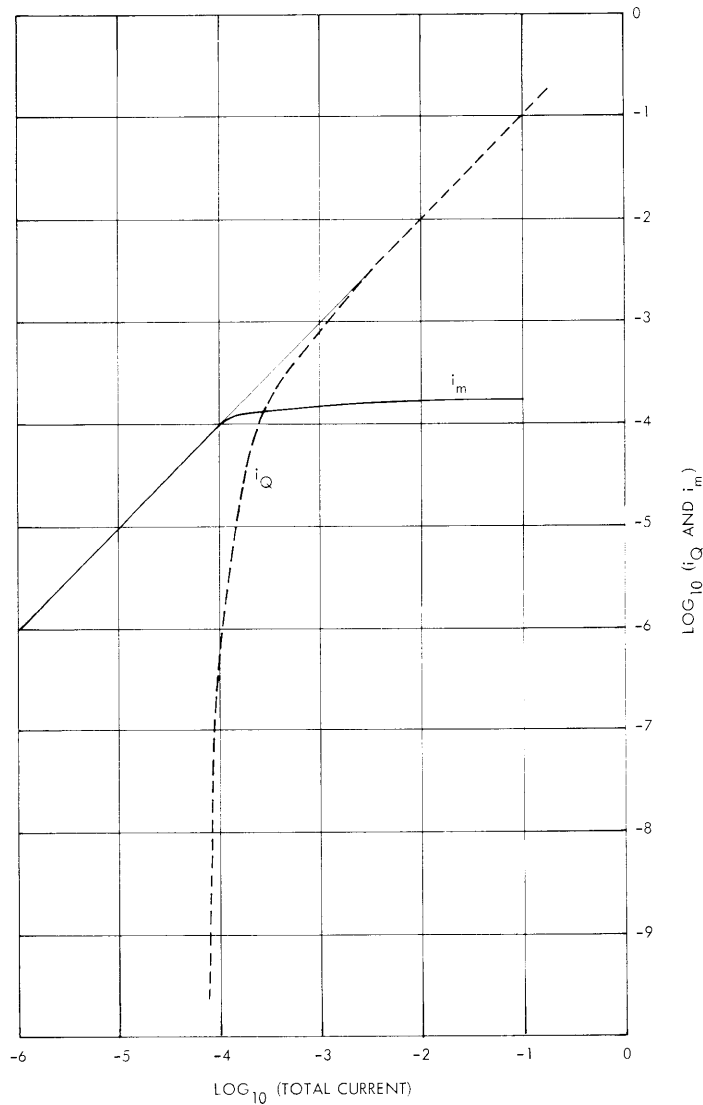


Fig. I-4. Meter current i_m (heavy solid line) and transistor current i_Q (dashed line) as a function of the total current (light solid line) (amp) on scales of \log_{10} .

current is permitted to pass through the transistor. Let this particular value of i_Q be designated I_Q , and let it be related to the maximum meter current as

$$I_Q \leq I_m \times 10^{-2} \text{ A.} \quad (2)$$

This relation may be combined with Eq. 1 to establish a maximum value of the total resistance R_m in Fig. I-3.

$$R_m \leq \frac{0.796 + 0.064(\log_{10} I_m - 2)}{I_m}. \quad (3)$$

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For a 100- μ a full-scale meter, this equation yields the value 4120 ohms for the maximum total resistance. This result indicates that a 4000-ohm total resistance would satisfy the requirement. A similar calculation that is applicable to a 1-ma meter gives 476 ohms; thus a 450-ohm total resistance would result in a shunting of less than 1 per cent at full scale.

The curves of Fig. I-4 illustrate graphically the effectiveness of this system of meter protection as applied to a 100- μ a meter. The abscissa is the logarithm of the total current passed through the meter and the transistor shunt. The solid line in Fig. I-4 represents the logarithm of the current passing through the meter, and the dashed line the logarithm of the current passing through the transistor. Note that up to 100 μ a the current through the transistor is negligible, and yet when the total current is practically 10 times full scale the meter is overloaded only 50 per cent. A still more extreme condition is evident when the total current is 300 times the full-scale meter reading, under which condition the meter is overloaded only 75 per cent.

In order to obtain full protection for both positive and negative overload, we use the

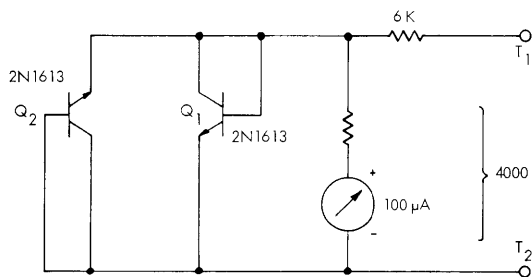


Fig. I-5. Circuit designed to protect a 100- μ a meter with a terminal voltage $T_1 T_2$ of 1 volt for full scale of the meter. Maximum safe terminal voltage at least 200 volts.

circuit shown in Fig. I-5. Normally, full-scale deflection of the meter occurs with a 1-volt difference in potential at terminals T_1 and T_2 . The external application of as much as 200 volts across these terminals will result in a maximum current flow through the meter of 180 μ a. All microammeters with which we are familiar are not damaged in any way by the application of an 80 per cent overload which results from an application of a terminal voltage 200 times that required for full scale.

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References

1. Courtesy of Dr. Robert Noyce, Fairchild Semiconductor Corporation, Mountain View, California.