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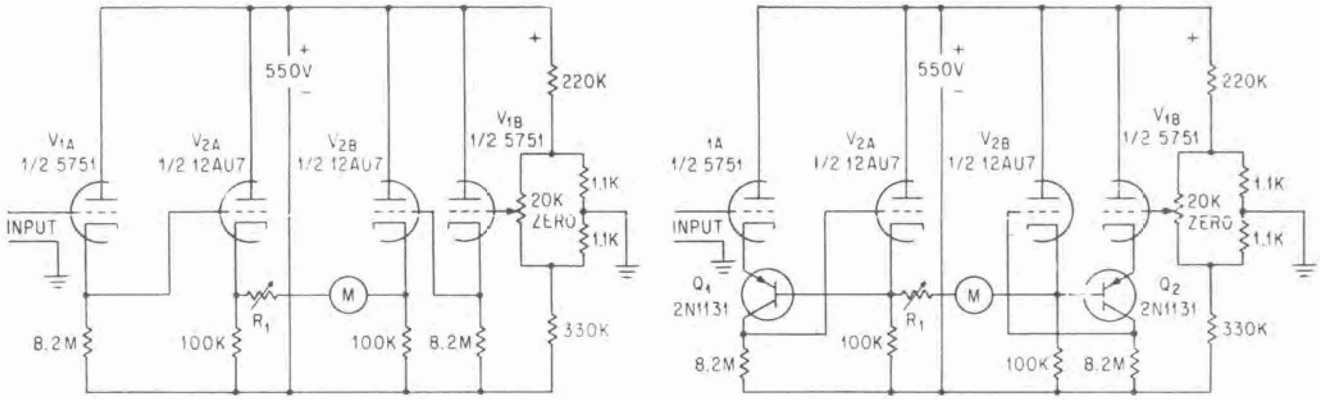

IMPEDANCE of meter drive circuit (left) depends on tube g_m and is subject to aging; hybrid circuit (right) uses transistors for below-1-ohm drive impedance, achieving independence from g_m variation

HYBRID VOLTMETER Avoids Aging Errors

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Technique stabilizes drive circuits against changes in tube transconductance

A 112 HYBRID VM.

ONE REASON why most vacuum-tube voltmeters require calibration at regular intervals is the aging, or change in transconductance, of the vacuum tubes. In this, a balanced vacuum-tube voltmeter uses transistors to bring vacuum-tube output impedances down to a small fraction of an ohm. The resulting performance is virtually independent of changes in tube g_m, and consequently the vtvm rarely if ever requires recalibration.

The balanced vtvm circuit, before modification, is shown in the left-hand illustration. Tube V_1 operates at low plate current to keep grid current small; V_2 is operated at normal conditions to drive the meter circuit. Resistor R_1 is switched to different values for various voltage ranges. The long-term stability of this circuit depends on constancy of voltage gain and on the output impedance of each side of the circuit. Voltage gain of V_1 is highly stabilized at $\mu/(\mu + 1)$ because of the large load resistance (8.2 megohms). The open-circuit voltage gain of V_2 is also stabilized for the same reason, but its output resistance (approximately $1/g_m$) increases steadily with life as g_m decreases.

Example—For a 1.5-volt range and with a 1-ma meter, the total multiplier resistance is a little smaller than 1,500 ohms. This is composed of the output resistance of each half of V_2 (about 360 ohms each), the meter internal resistance, and R_1. Aging of the tubes to half their original g_m would double their output resistances and cause the meter to read 30 percent low on that range.

The addition of a transistor in each side of the circuit (right) reduces output impedance to a small fraction of an ohm. A decrease in the g_m of V_2 to half its original value is now no longer important since the output impedance of each side of the circuit is still less than an ohm. The voltage gain of V_1 is unaffected by the addition of the transistor because the input impedance at the emitter remains substantially unchanged. Voltage gain of the $Q_1 - V_2$ combination is close to unity, and is highly stable.

Transistor requirements are modest. Base-to-collector voltage is simply the cathode-to-grid bias of V_2, a maximum of 6 volts. Collector current of Q_1 and plate current of V_1 are equal and quite low. There is no stiff requirement for current gain, so the transistor is used in what is effectively a grounded-base connection.

This hybrid circuit converts a normal good-quality voltmeter into a highly stable instrument, which should not require recalibration even at the normal end of life (half g_m) of the vacuum tubes.

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