PB-26
March 20, 1958

TRANSITRON APPLICATIONS IDEAS

A NEW LOOK
AT
MODULATOR QUADS

Engineers for years have designed DC amplifier systems using modulator quads to convert the low level DC signal into AC for easy amplification. This approach can result in a system with inherently high stability, since the AC amplifier gain can be stabilized with feedback. The stability of this system depends, of course, on the stability of the forward and inverse characteristics of diodes used in the modulator quads.

Ten years ago the designer could choose between only selenium diodes, copper oxide diodes, and point contact germanium diodes. None of these were desirable because of their high inverse leakage (particularly at high temperatures). A substantial reduction in inverse leakage accompanied the development of the silicon diode. Now further development has resulted in a new modulator diode having high temperature leakage no greater than the room temperature leakage of ordinary silicon diodes. In addition, careful matching insures a smaller unbalance on the input voltage than previously available.

MODULATOR QUAD APPLICATIONS

The uses of modulator quads can be separated into two general categories (see Fig. 1):

I. High Impedance - over 500K load impedance (generally constant current sources).

II. Low Impedance - less than 500K load impedance (generally 1 to 100 ohms source impedance).

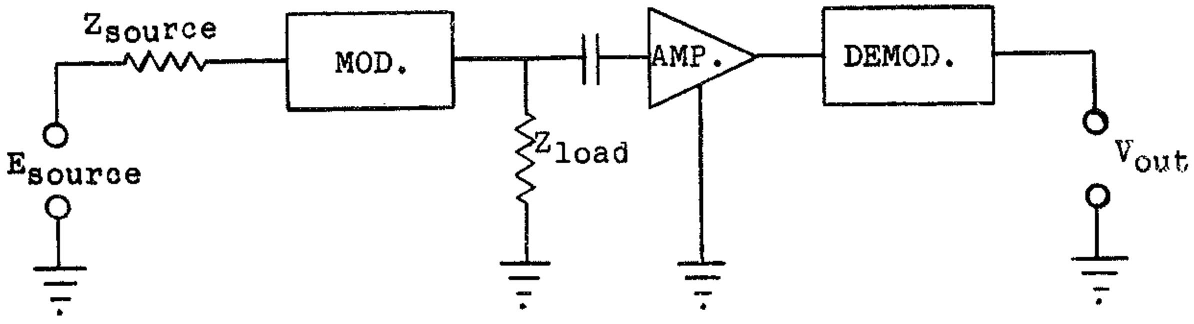

Fig. 1.

I. High Impedance

The critical factor in high impedance applications is the unbalance of the inverse leakage current. The best way to insure a low unbalance of leakage current is to require a low maximum leakage current for each diode. This is done at room temperature for the Q-31, and over the range of -65°C to +100°C for the Q-32 quad. Since the load impedance is high, the small unbalance of the forward characteristics will be negligible.

The modulator quad is superior to both silicon and germanium transistor modulators in high impedance applications. This is because its leakage current is significantly lower than the I_{CO} of available transistors. It is superior to mechanical choppers due to the absence of stray fields, reduced size and weight, as well as elimination of moving contacts.

II. Low Impedance

The critical factor in low impedance applications is the stability of the null voltage. The Q-31 has very good null voltage stability when operated in a restricted temperature range. Typically, it will be stable within ±50 microvolts for 1 hour of operation, or ±150 microvolts for 1 day of operation at 25°C ±1°C. Operation over a broad temperature range will, of course, cause the unbalance voltage to change. The unbalance of the Q-32 quad will not exceed 10 millivolts over the -65°C to +100°C temperature range. With a small load impedance, the unbalance due to inverse leakage will be negligible.

In the milliampere range, the modulator quad is superior to silicon transistor modulators in low impedance circuits because of the high series collector resistance found in small signal silicon transistors. Germanium transistor modulators, however, have less unbalance than modulator quads in low impedance circuits when the temperature is maintained at a low value. At temperatures above 75°C, the I_{CO} problem becomes large enough to consider the use of the Q-32 instead. Mechanical modulators have excellent electrical characteristics in low impedance circuits, but may be ruled out because of size, weight, shock, or vibration problems.

MODULATOR QUAD CIRCUITS

Two of the circuits frequently used with modulator quads are:

A. The Half-wave Modulator (Bridge Modulator)

B. The Ring Modulator

Transitron modulator quads are wired so that use in either circuit is practical.

A. The Half-wave Modulator:

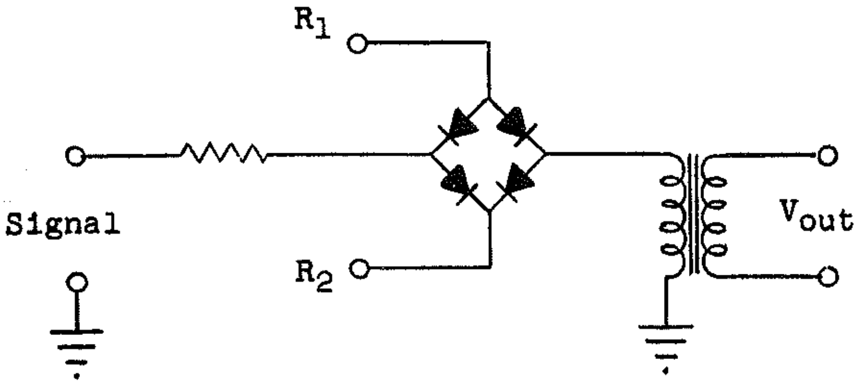

Fig. 2

The half-wave modulator allows operation with single-ended loads and sources. Its output is a square wave with an RMS amplitude equal to one-half of the signal input voltage.

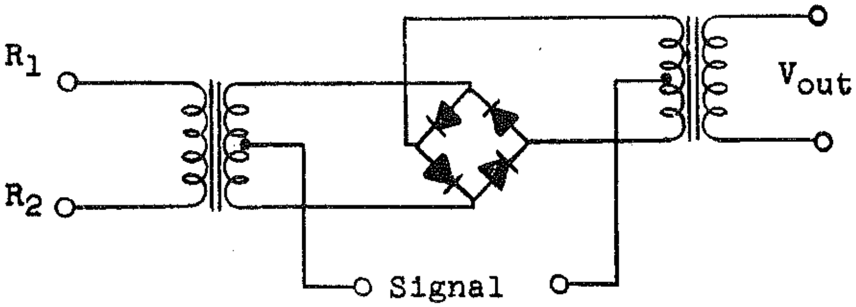

Fig. 3

B. The Ring Modulator:

The ring modulator is frequently used where balanced loads are possible. Its full wave operation results in greater circuit efficiency. Its output is a square wave with an RMS amplitude equal to the signal input voltage.

In both circuits, the modulator quad is switched back and forth by a drive voltage applied to terminals R_1 and R_2. Although a reasonably good output null can be obtained using a sine wave drive, optimum performance may be realized by using a square wave drive. The square wave should supply approximately 1.0 milliamperes through each diode in the forward direction, and not more than 6 volts in the inverse direction. A suitable square wave can be generated with a zener diode clipper (Fig. 4) or with a transistor clipper (Fig. 5) driven by a sine wave.

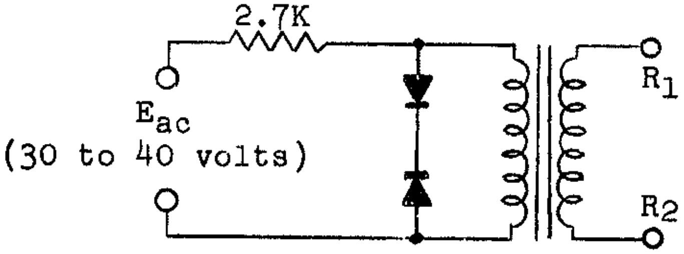

Fig. 4

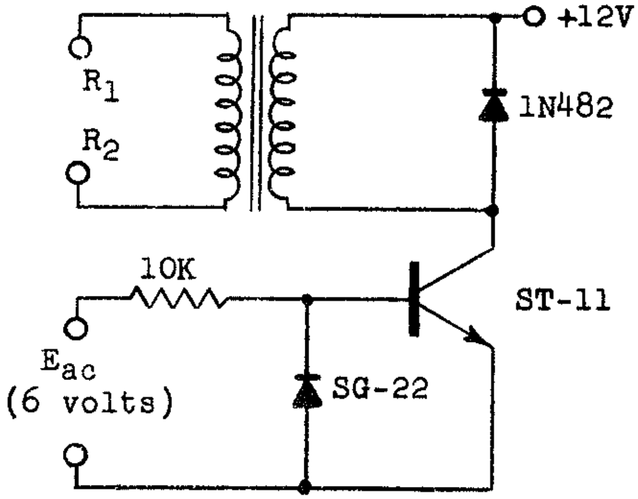

Fig. 5

The null voltage under controlled temperature conditions, with square wave drive, is extremely small at frequencies of 1000 cps or less. This null voltage is limited to 50 microvolts maximum for the Q-31 when measured in the prescribed circuit. Null voltage at higher frequencies is determined largely by the characteristics of the transformers used. Figure 6 indicates the average null voltage as a function of frequency.

The modulator voltage gain also is dependent on the transformers used. Figure 7 indicates how it can drop off with frequency with a typical transformer combination.

TYPICAL NULL VOLTAGE CHARACTERISTIC

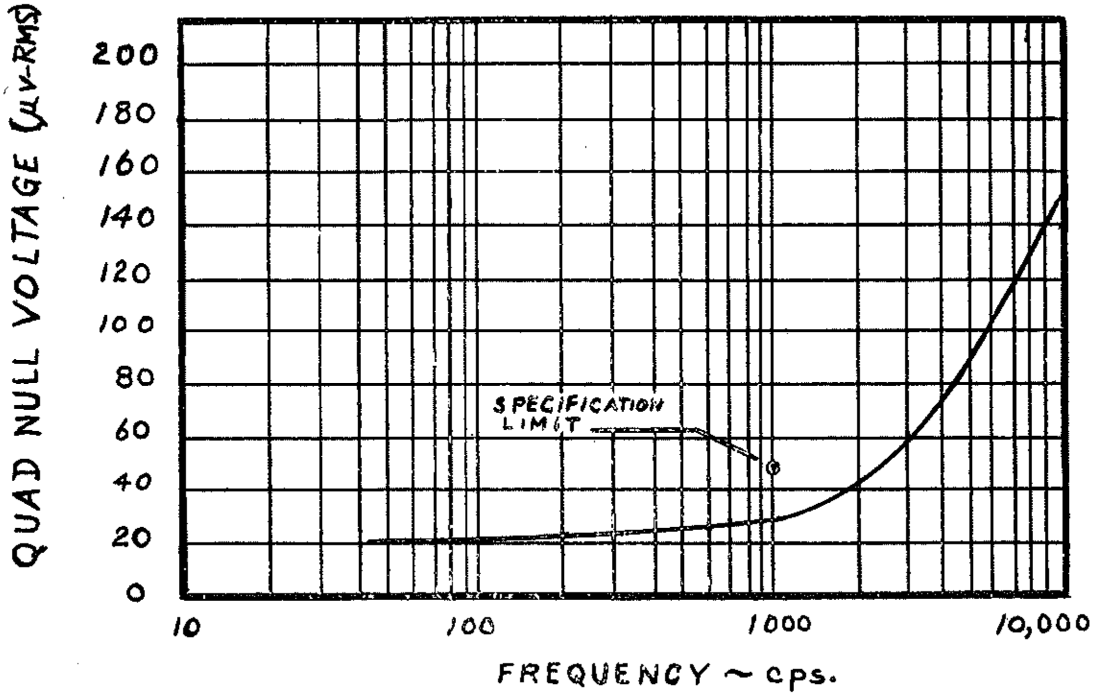

FIGURE 6

TYPICAL MODULATOR VOLTAGE GAIN

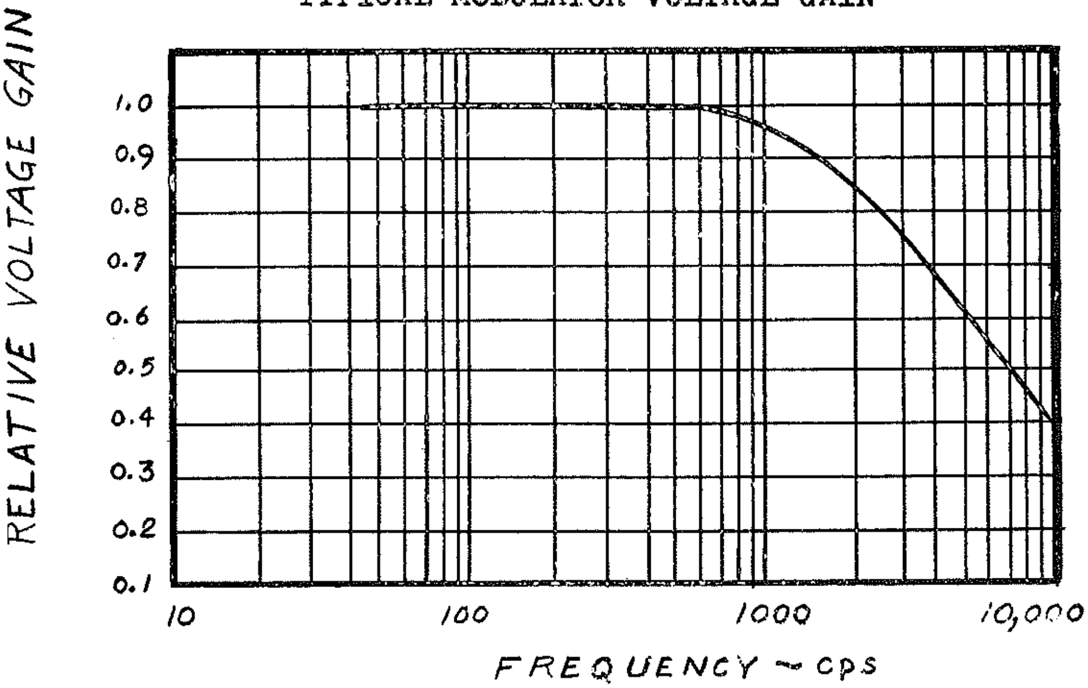

FIGURE 7

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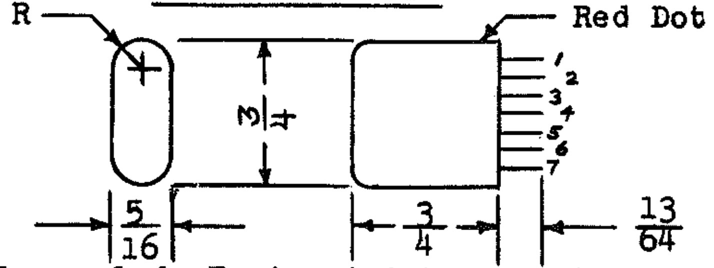
TRANSITRON

MODULATOR QUADS

TYPE	Q-31	Q-32
Voltage Unbalance at 1 ma		
at 25°C	2 mV max.	10 mV max.
at 100°C	---	10 mV max.
at -65°C	---	10 mV max.
Null Voltage at 1 ma (See ckt below)		
at 25°C	50 uV RMS max.	---
Inverse Current at -6V		
at 25°C	.001 uA max.	---
at 100°C	---	.030 uA max.
Operating Temperature Range	25°C Design Center	-65°C to +100°C
Maximum Inverse Voltage (per arm)	6V	6V
Maximum Forward Current (per arm)	25 ma	25 ma

See other side for Mechanical Data, Wiring Diagram, and Null Voltage Measurement Circuit.

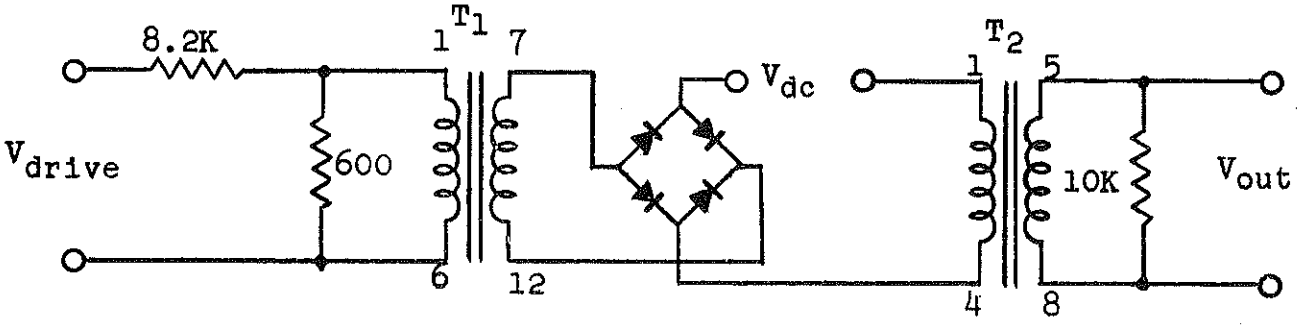
MECHANICAL DATA



Hermetically sealed, 7-pin miniature package.
Socket: Miniature 7-pin in-line type, Cinch #2H7 or equivalent.

WIRING DIAGRAM

NULL VOLTAGE MEASUREMENT CIRCUIT



NOTE: $V_{null} = \dfrac{V_{out}\ \text{min.}}{17.7}$

T_1 - UTC Type LS-33

T_2 - Triad Type G-2

Null voltage measured with Ballantine Model 310A or equivalent.

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PB-27 (Revision)

TRANSITRON APPLICATIONS IDEAS

LOW-DRIFT STRAIGHT D.C. AMPLIFIERS

By making use of the ST1026 silicon transistor, which retains considerable gain at extremely low collector currents, straight d.c. amplifiers can be constructed which have a very small equivalent input drift for variations in ambient temperature. The ST1026, which is specified in Bulletin TE-1353H, also features a particularly low I_{CO}.

For typical percent changes in transistor parameters, the absolute changes at these low levels will be small. However, amplifier drift can be reduced still further by careful choice of bias conditions, and, where extreme stability is required, by the use of simple compensating circuitry.

Three types of amplifier have been considered--one designed to reduce equivalent input current drift, another, somewhat more complex, to reduce voltage drift, and a third intermediate type which is basically the current amplifier with some degree of voltage compensation.

This bulletin contains details of typical circuits, the principles of their operation, results achieved, and a general discussion of the merits of these amplifiers as compared to vacuum tube and other semiconductor types.

Typical Circuits

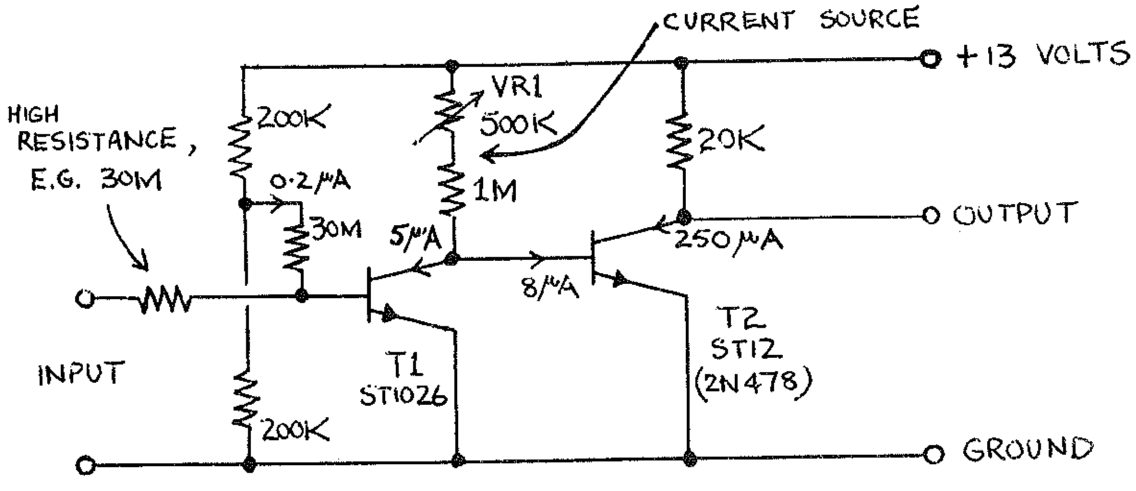

Fig. 1 - Compensation for current drift.

Catalog No. 80.33.14(8-58)

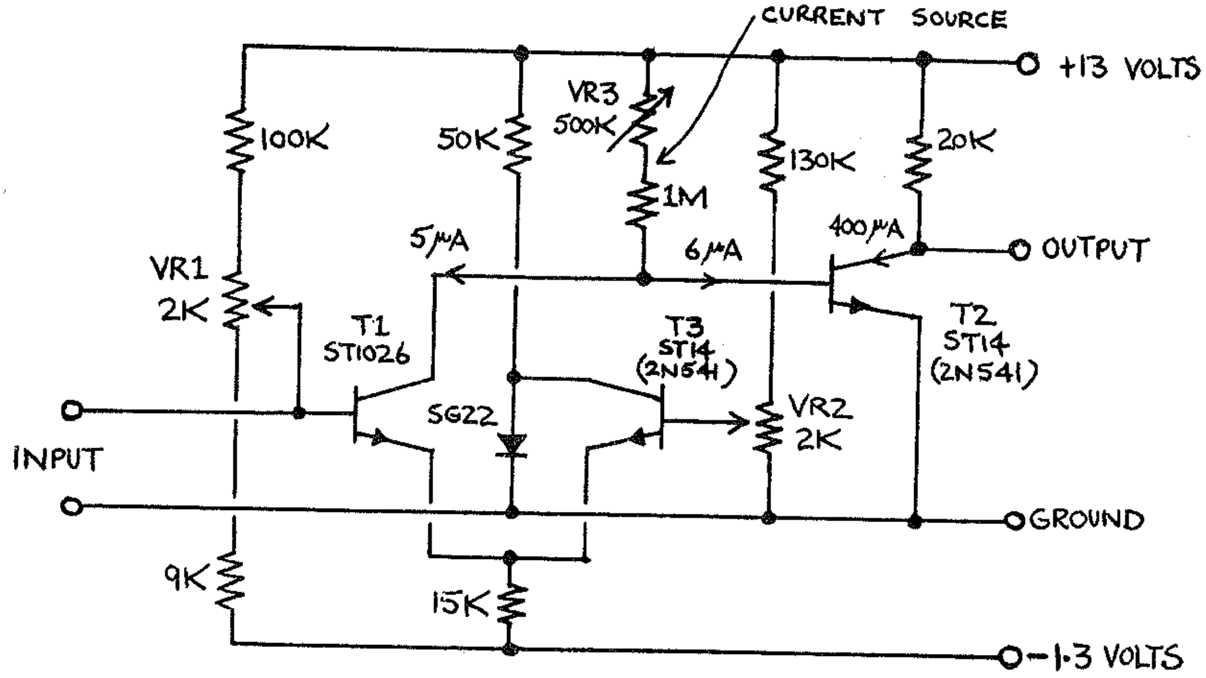

Fig. 2 - Compensation for voltage drift.

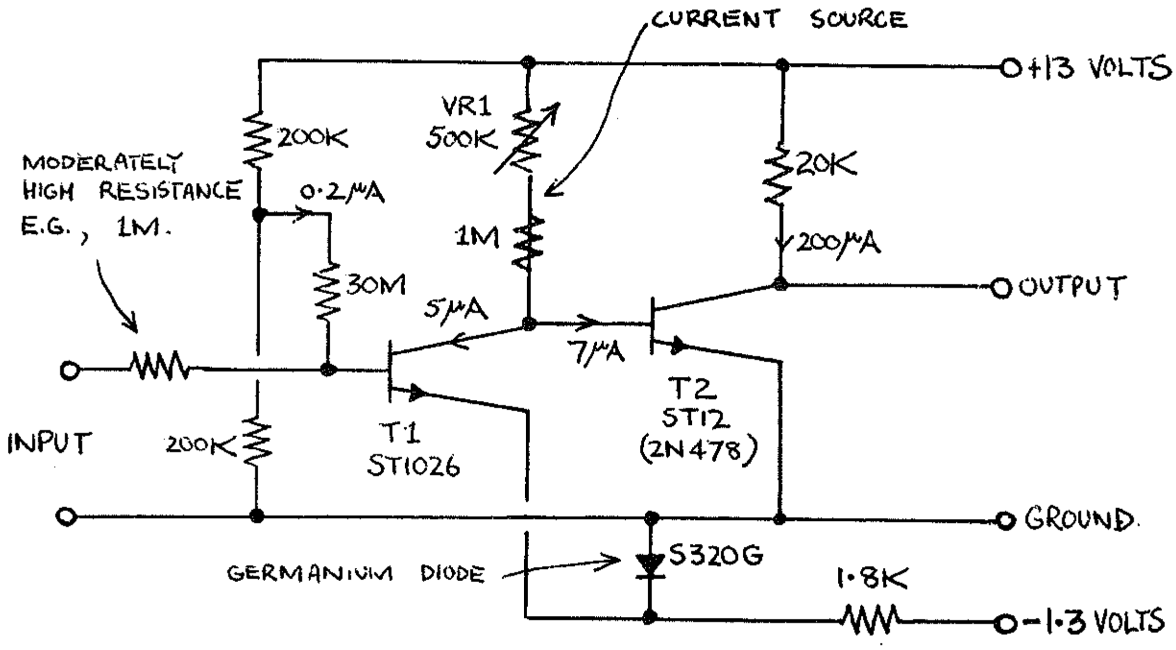

Fig. 3 - Compensation for current drift, with approximate compensation for voltage drift.

Principles of Operation

Current compensation of the type illustrated in Fig. 1 is basic to all these straight d.c. amplifiers. In that circuit the base bias current of the first transistor is very little dependent on temperature, being derived through a high resistance from a voltage much higher than the transistor base-emitter voltage. However, any increase of ambient temperature causes an increase in the collector current of T1 due to the temperature coefficient of its d.c. beta. This collector current I_{c1}, and I_{b2}, the base current of T2, are drawn from another current source, VR1 and its associated fixed resistor. Accordingly, if I_{c1} increases, I_{b2} must decrease by an equal amount. The bias conditions are arranged so that this decrease in I_{b2} and the increase with temperature of the d.c. beta of T2 result in as little change as possible in the collector current (I_{c2}) of that transistor.

Knowing parameters of the two transistors such as beta temperature coefficients, dependence of the betas on collector current, etc., it is possible to calculate for a chosen I_{c1}, the value of I_{b2} necessary to achieve these balance conditions. Fairly good agreement has been found between theory and practice.

Alternatively, with the selected value of I_{c1} fixed by the large resistor in the base lead of T1 (Fig. 1), the desired I_{b2} can be determined experimentally, using VR1 for adjustment.

In the voltage amplifier (Fig. 2), the differential transistor, T3, is used to balance to a large extent the V_{be} temperature coefficient of T1. In practice, to maintain gain T3 is run at about 60 uA, which presents a relatively low impedance to the emitter of T1, this latter transistor being run at 5 uA or so. Since this amplifier is to be used with a low impedance source which fixes the input voltage, the effect of deliberately unbalancing the V_{be} temperature coefficients is to induce a change with temperature in I_{c1}, the collector current of the first stage. This is compensated for by offsetting in the appropriate direction the current balance described in the section on current amplifiers (Fig. 1), which explains the slightly different ratio of I_{b2} to I_{c1}.

The current amplifier, with approximate voltage compensation (Fig. 3), is based on the same principles as the two other types. It uses a germanium diode to provide a simpler, but less accurate balancing out of voltage temperature drift.

Equivalent Input Drifts Achieved

	Per °C	Per Day
Current amplifier (Fig. 1)	±0.05 muA (0.00005 uA)	±0.5 muA (0.0005 uA)
Voltage amplifier (Fig. 2)	±40 uV	±250 uV

Applications and Advantages

The system using two transistors, which is primarily designed to have low current drift, is particularly suitable as a current amplifier with source impedances above one megohm.

Use of a third transistor results in an amplifier primarily designed to have low voltage drift, which is generally superior to a vacuum tube system for source impedances below ten kilohms.

When the third transistor is replaced by a germanium diode, a simpler but less accurate means of voltage drift compensation results.

In these amplifiers wide bandwidth can be obtained without modulation or separate channels, the system is insensitive to shock and contains no source of hum.

Finally, if drift must be reduced to the very smallest proportions, the important semiconductor elements will fit comfortably into a small crystal oven.

Any further inquires should be addressed to:

Transitron Electronic Corporation
168 Albion Street
Wakefield, Massachusetts

Attn: Applications Section

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March 20, 1958

TRANSITRON APPLICATIONS IDEAS

High Gain Servo-Amplifier

The amplifier shown was designed for high reliability making use of the excellent stability and reliability of silicon transistors.

The use of silicon transistors in servo-amplifiers has many advantages over the use of tubes...reduction in equipment size and power requirements...operation at lower voltages giving better component reliability...high efficiency resulting in low dissipation giving low temperature rises.

No special emphasis has been placed on miniaturization in the amplifier shown.

Design Features

1. High reliability and long life.
2. Excellent long term gain stability and freedom from drift.
3. Performance is independent of the change of transistor parameters.
4. Performance is independent of temperature changes between -65°C and 100°C and supply voltage variations of ±20%.
5. Output power 5 watts over an ambient temperature range of -65°C to 100°C.
6. Sensitivity is adjustable from 10 uV to 100 uV for full power output.
7. Will operate from a 60 c/s or 400 c/s signal and supply voltage.

Circuit Description

The amplifier is a 5-stage amplifier, the first three stages giving current gain and the last two stages power gain. The stages are coupled by transformers and stabistors. The use of stabistors greatly simplifies the biasing of the transistors while it also reduces to two the number of capacitors used in the circuit.

Excellent stability has been achieved as a result of three feedback loops. With the DC stabilizing loop from emitter of the driver transistor to the base of the input transistor decoupled by a 60 uf tantalytic capacitor, the -15 volt supply serves as a reference and keeps the emitter voltage of the driver within 10% of the nominal value of 1V over the full temperature range. The second feedback loop is from collector of the driver to the emitter of the input transistor. The feedback factor can be adjusted over a 10 to 1 range with a