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COMPENSATION OF EMITTER-BASE VOLTAGE
VARIATIONS WITH OPERATIONAL AMPLIFIERS*

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August 1969

ABSTRACT

Low cost operational amplifiers can replace temperature compensating devices and trimmer potentiometers in direct-coupled pulse amplifiers and discriminators. Better temperature and long term stability without adjustments can be achieved with this technique than with conventional means.

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The temperature dependance of the emitter-base voltage and the sample variations of this voltage often present problems in the design of direct-coupled pulse circuits. Commonly used methods of coping with this problem are not always satisfactory:

The compensation of the temperature walk with another semiconductor only provides first-order compensation. It implies critical selection of the compensating device and requires good thermal contact between the transistor to be compensated and the compensating device. Dual transistors lessen these difficulties, but restrict the choice of available transistors.

Sample variations are compensated by providing trimmer potentiometers. These are space consuming and require adjustment for each individual circuit.

A low cost operational amplifier can effectively compensate for temperature variations, and it permits to exactly predetermine the operating point of the transistor. This is illustrated for a common-base transistor stage as shown in fig. 1. However, the principle being outlined can be adapted for many other configurations.

In this circuit the emitter voltage U_e is determined by the reference voltage U_{ref} . It can be easily verified that nearly any low cost operational amplifier will give satisfactory results. For instance a MC1712 with its relatively low gain and high temperature dependence of the offset voltage has been successfully used. Its price is about the same as the price of a quality trimmer potentiometer previously needed to adjust U_e .

The circuit of fig. 1 has one big shortcoming: it regulates the operating point of the transistor in such a way that the geometric mean of the emitter voltage is kept equal to U_{ref} . But in nearly all applications the baseline voltage rather than the geometric mean of the emitter voltage needs to be kept constant. For low duty cycles this does not matter, since in this case the geometric mean is a good approximation of the baseline voltage. However, high duty cycles will make the baseline shift. (The reason is that the AC signal developed across the input resistance of the transistor is integrated as it is applied to the inverting input of the operational amplifier. This integrated voltage - the mean value of the emitter voltage - is compared with U_{ref} .)

The addition of a simple AC-compensating network will provide almost perfect compensation, even at very high duty cycles as shown in fig. 2.

The essential point in this circuit is that an integrated sample of the input voltage is added to the reference voltage. The compensation will be accurate if the integrating time-constants at both inputs to the operational amplifier are equal, and if the fraction of the input voltage added to the DC-reference voltage and the integrated voltage appearing at the other input of the operational amplifier are equal. Therefore, the voltage divider formed by R_1 and the parallel network $R_2 - R_3$ must have the same attenuation as the voltage divider formed by R_{in} and the input resistance of the transistor.

An example where this technique is very helpful is a 50- Ω input stage to a pulse discriminator as shown in fig. 3.

This stage must meet two requirements: (1) low input offset voltage - the emitter voltage must be exactly 0 V in order to avoid drawing DC current from the signal source, and (2) well defined DC-collector current, since the collector current is DC coupled into the triggering device. Both requirements are met to a far better degree than with conventional means (compensating diode or transistor and trimmer potentiometer).

The same principle can be used for the overall DC stabilization of pulse amplifiers - the single transistor stage being replaced with a DC-coupled amplifier (as in the "Nanoamplifier" by Chronetics.)

The stability achievable with this technique is limited by the open-loop gain and by the stability of the operational amplifier. However, in most circuits this limit will not be significant since other influences will prevail and will determine the stability.

A second order effect limits the accuracy of the compensation for high duty cycles: good compensation requires matching of the attenuation at both inputs of the operational amplifier. But since the input impedance of a common base stage depends on the emitter current, one leg of the attenuator at the inverting input depends on the input pulse height. Therefore the match of the attenuation, and consequently the compensation, will be only good for a limited range of input pulse heights. But normally the error caused thereby may be neglected.

FOOTNOTE AND REFERENCES

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FIGURE CAPTIONS

Fig. 1. DC - Stabilization for a common-base stage.

Fig. 2. DC - Stabilization for a common-base stage with compensation for high duty cycles.

Fig. 3. DC - Coupled 50- Ω input stage.

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Fig. 1 DC - stabilization for a common-base stage

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Fig. 2 DC - stabilization for a common-base stage
with compensation for high duty cycles

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Fig. 3 DC - coupled 50- Ω input stage

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