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Linear-Log Counting-Rate Meter Uses Transconductance Characteristics of a Silicon Planar Transistor

The problem was design of a counting-rate meter capable of compressing a wide range of data values, or decades of current. Prior methods employed the log-conversion properties of thermionic and solid-state diodes; neither type of diode provided an accurate log relation between current and voltage for more than a few decades of current. Furthermore, if the diode was used in the feedback loop of an operational current amplifier, any variation in the virtual ground potential or reference voltage appeared unattenuated in the output.

Now a silicon planar transistor, operating in the zero collector-base voltage mode, can be used as a feedback element in an operational amplifier to obtain the log response (*1*). The basic counting-rate meter (Fig. 1) consists of a diode pump and a current amplifier. An input pulse of either polarity, but at least 2.5 v in amplitude, is applied to the standardizing amplifier. The amplifier-output pulse is differentiated and fed to the pulse shaper, which provides the diode pump with a positive voltage pulse having constant amplitude and width; therefore the diode-pump output current is proportional to the average counting rate n. Feeding of the diode-pump output current to the virtual ground of the current amplifier, and through the feedback element, produces an output voltage proportional to n.

With the transistor in the feedback loop, the amplifier-output voltage is equal to the transistor's emitter-base voltage, and the collector current is equal to the diode-pump output current. The emitter-base voltage is related to the collector current according to the expression

$$V_{eb} = (kT/q) \times \ln(I_c/K) \quad (1)$$

where k is Boltzmann's constant, T is the absolute temperature, q is the charge of an electron, and K is a constant. Since $V_{eb} = \bar{e}_0$ and $I_c = \bar{i}$,

$$\bar{e}_0 = 2.3(kT/q) \times \log(\bar{i}/K) \quad (2)$$

Since $\bar{i} = C_f V \bar{n}$,

$$\bar{e}_0 = 2.3(kT/q) \times \log(\bar{n} C_f V/K) \quad (3)$$

Equation 3 thus shows that the transistor's emitter-base voltage is logarithmically proportional to the average counting rate $\bar{n}$.

Over the collector-current decade from 10^{-3} to 10^{-2} amp, the slope, or volts per collector-current decade, increases because of the bulk resistance of the emitter and base; consequently it is in error by approximately +40% at a collector current of 10^{-2} amp. This error is compensated by introduction of the proper amount of dead time in the pulse shaper; thus the diode-pump output current is reduced as a function of $\bar{n}$.

Reference:

1. J. J. Eichholz, *ANL-6968* (Argonne National Laboratory, Argonne, Ill., June 1966); the report is available from the Clearinghouse for Federal Scientific and Technical Information, Springfield, Va. 22151, at $3.00 (microfiche, $0.65).

Notes:

1. The linear feedback elements are metal-film resistors; the log element is a silicon planar transistor, type 2N2219.
2. The instrument has nine linear ranges which cover from 10 to 10^5 pulses per second, full scale.
3. The log scale covers the range from 1 to 10^6 pulses per second.

(continued overleaf)

4. Inquiries concerning this innovation may be directed to:

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Reference: B69-10191

Source: J. J. Eichholz
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Patent status:

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