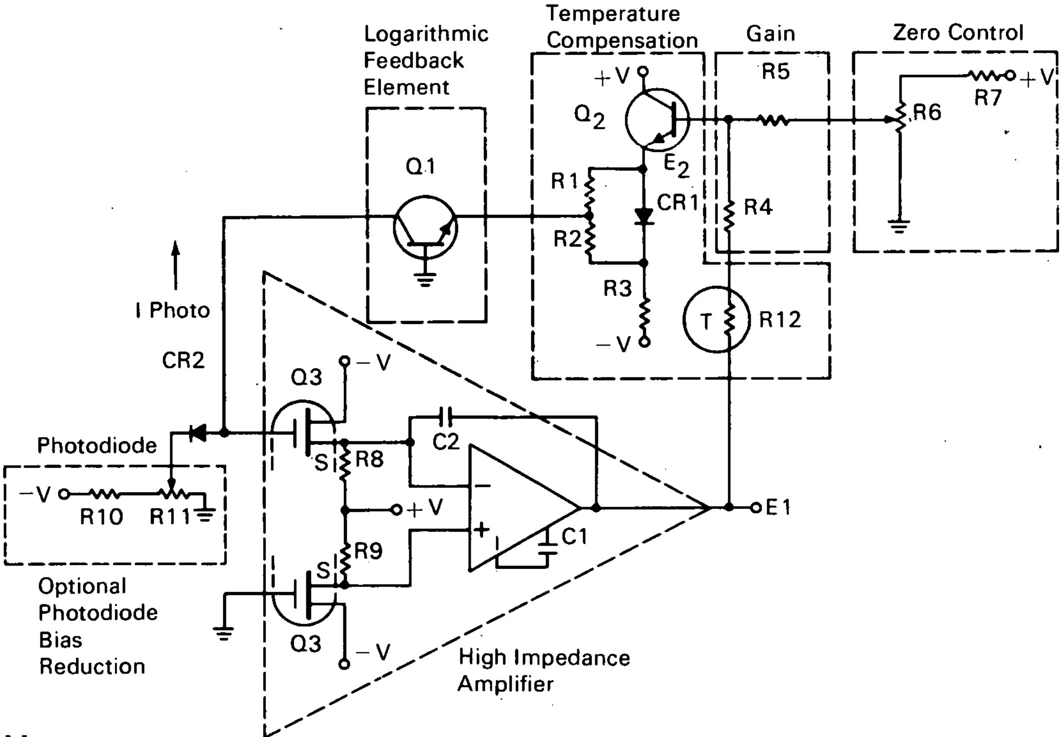
NASA TECH BRIEF

A New Solid-State Logarithmic Radiometer



The problem:

To provide a very small, lightweight, temperature-compensated radiometer, with no moving parts, to detect spectral intensities encompassing more than three decades over a range of at least 300 to 800 nanometers at power levels as low as 10^{-6} W/(cm^2).

The solution:

A combination of temperature-compensated logarithmic amplifiers and specially prepared PIN photodiodes operating in a zero-bias mode.

How it's done:

The PIN photodiode used as the sensor for the radiometer is biased at a constant, low voltage to provide an output current that bears a linear relationship to the incident radiation and is relatively free of distortion, insensitive to environmental conditions, and has low 1/f noise. Operation at bias levels near zero voltage also provides a low effective dark current, and permits the use of simple circuitry to compensate for the effects of temperature. However, this mode of operation leads to an increase in noise current, a decrease in quantum efficiency by a few percent, and a factor of five reduction in speed.

The amplifier used in connection with the PIN photodiode consists of a high-gain, integrated circuit, operational amplifier with a high-impedance

(continued overleaf)

matched-pair MOSFET input stage; a transistor in the amplifier's feedback loop provides the requisite logarithmic output, and a diode-transistor combination inserted in the feedback loop provides temperature compensation for the logarithmic feedback element.

The circuit operates as follows: The emitter voltage of Q1 is related logarithmically to the photodiode current; with operational amplifiers of very high gain, the photocurrent is identical to the current in the feedback element. Since the cathode of the photodiode is near ground, its anode is held at approximately this voltage by the operational amplifier; thus the photodiode is held at a potential near zero bias. Moreover, the collector-base diode of Q1 must also be operated near zero bias to minimize leakage current in this element and to extend its logarithmic response at low current levels. The temperature coefficients of Q2 and CR1 are similar to those of Q1; to oppose and cancel base-emitter temperature variations in Q1, the circuit elements R1, R2, CR1, and Q2 are arranged as shown in the diagram. The ratio of R1 and R2 establishes the net effective temperature coefficients of the combination of CR1 and Q2 to match that of Q1.

The output voltage obtainable from Q1 is limited to about 0.5 V (an inherent property of silicon semiconductors), but the additional gain is obtained by the ratio of (R4 + R12) to R5. The zero control segment of the circuit permits adjustment of zero conditions by applying a small voltage to the R5 terminal that ordinarily would be grounded.

Additional temperature compensation is provided by thermistor R12 and the voltage divider R11 which reduces the residual bias across the photodiode and thereby reduces its temperature-sensitive leakage current.

Notes:

1. The radiometer has a ±10% reading accuracy throughout the 5-decade dynamic range while operating over a temperature interval of 0° to 45°C.
2. The output noise of the radiometer is less than 20 millivolts at 10^{-9} watt, and operation at frequencies down to dc is therefore possible; however, the decay response is such that about a tenth of a second is required for the output to become zero in complete darkness. The frequency response is limited by C1, C2, and the effective resistance of Q1.
3. Requests for further information may be directed to:

   Technology Utilization Officer
   Ames Research Center
   Moffett Field, California 94035
   Reference: TSP70-10633

Patent status:

Inquiries about obtaining rights for the commercial use of this invention may be made to:

Patent Counsel
Mail Code 200-11A
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