Low-cost logarithmic amp works over one decade

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If extremely high precision is unnecessary and if the required dynamic range spans no more than one decade of input voltage, then this logarithmic amplifier will serve the application well. Use of a simple exponential generator, which is ultimately required to convert a voltage into its base-10 logarithmic equivalent, makes it possible to build the amp for a mere $3 to $4.

The overall system is shown in (a), with the schematic of the exponential generator shown in (b). Voltage divider R_1–R_2 applies 0.5 volt to RC combination R_3C_1 through op amp A_2 on power-up in order to initialize the exponential growth process. As C_1 charges, the output of A_2 increases as shown in the curve until the Schmitt trigger, A_3, which has a switching threshold of 10 V, fires, turning on field-effect transistor Q_1 and discharging C_1 to about 1.0 V. The process then repeats, with switching occurring at a rate, τ, determined by C_1 and R_2. The op amp must have a minimum slew rate of:

$$dV_o(t)_{max}/dt = (1/\tau)\, e^{t/\tau}\big|_{t=\tau} = (10 \log_e 10)/\tau = 23.03\, f_s$$

where f_s is the switching frequency. Thus at a switching frequency of 10 kilohertz ($C_1 = 0.01\ \mu F$, $R_1 = 4.32\ k\Omega$) the slew rate must be at least 0.23 V/microsecond.

During each switching cycle, the exponential output is compared at A_1 to the instantaneous input voltage, V_c, that is to be converted into its corresponding logarithm. A_1's on time, D_{V_p}, is thus related to input voltage V_c by:

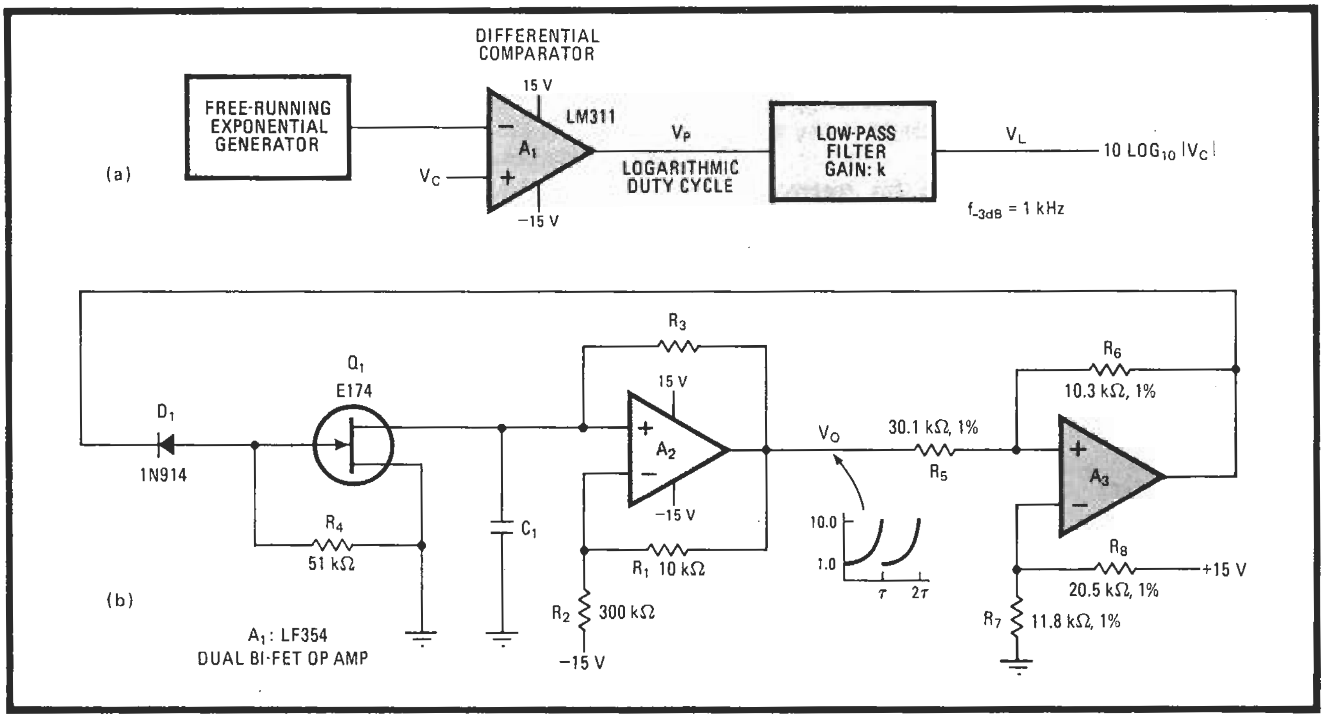
$$D_{V_p} = (t_{on}/\tau)\, 100 = \tau \log_e|V_c|/\tau = 0.434 \log_e|V_c|$$

where output voltage V_p corresponds directly to D_{V_p}, ignoring a scale factor.

The active low-pass filter of gain k that follows, which should be at least a third-order type for the best results, then finds the average value of V_p from:

$$V_L = \overline{V_p} = k(0.434) \log_e|V_c|$$

Choosing k such that $k(0.434) = k(V_{p\,max}/\log_e 10) = 4.34$, it is seen that $V_L = 10 \log_{10}|V_c|$ for $1 \le V_c \le 10$. □



Naturally. Low-cost generator provides exponential waveform of sufficient accuracy in amplifier that takes logarithms over one decade of input voltage. Filter averages pulse-width–modulated equivalent of V_c produced by differential comparator, A_1, for $V_L = 10 \log_{10} V_c$.