HP-67/97 program performs current-mirror analysis

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Analysis of the dc parameters of a current mirror—that is, a slaved current generator that tracks a reference—is difficult because the equations governing the circuit are nonlinear. Using an iterative technique, however, this HP-67/97 program permits easy solution of a complex 11-variable equation and enables the mirror, which is used extensively in monolithic operational amplifiers and in numerous discrete circuits, to be designed at either a fraction of the time (if charts and nomographs are used) or cost (if a computer is used).

The program allows design of the basic mirror circuit shown in the figure, where I_M, the mirrored current, can be made either equal to or some multiple of I_S, the reference current. This arrangement may be understood if the base-to-emitter junction of transistor Q_3 and resistors R_{B1}, R_{B2}, R_{E1}, and R_{E2} are replaced by shorts. Q_1 thus acts as a diode, and because its base and emitter leads are at the same potential as the corresponding leads of Q_2, I_M is made equal to I_S.

The loop equation describing the general circuit shown in the figure and analyzed by the program is:

$$\Delta V_{BE} + V_T \ln \frac{\beta_2(\beta_1+1)SI'}{(\beta_2+1)I_M} + I'[R_{E1}(\beta_1+1)+R_{B1}] - \frac{I_M}{\beta_2}[R_{E2}(\beta_2+1)+R_{B2}] = 0$$

where:

ΔV_{BE} = the measured mismatch between V_{BE1} and V_{BE2} when $I_{E1} = I_{E2}$

V_T = 0.026 volt at 298 K (25°C)

S = a scaling factor given by the ratio between Q_2's and Q_1's emitter area

β_i = the current gain of the i[th] transistor.

I′ is given by:

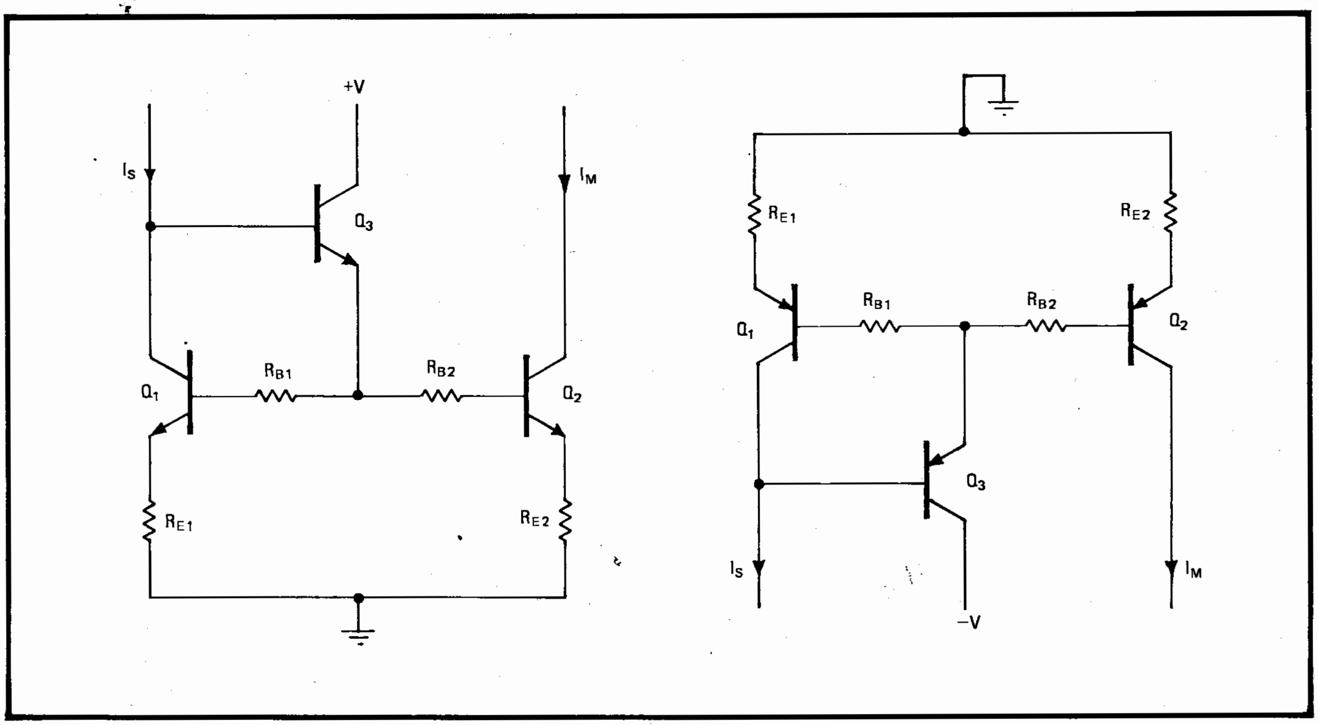
$$I' = \frac{I_S(\beta_3+1) - I_M/\beta_2}{\beta_1(\beta_3+1)+1}$$

Given any 10 parameters and an initial estimate of the remaining (unknown) quantity, the program determines the value of this last quantity by performing a Newton-Raphson iterative algorithm. In addition, it performs sensitivity analysis between any two parameters.

The program's usefulness may be seen in an example in which must be found, first, the value of R_{E2} that makes I_M = 25 microamperes when I_S = 250 μA at V_{BE} = 0, and when $\beta_1 = \beta_2 = \beta_3 = 100$ and S = 1; second, the sensitivity of I_M to a 1% change in R_{E2}; and third, the new value of I_M if V_{BE} = 1 millivolt.

Keying the appropriate quantities expressed in volts, amperes, or ohms, as the case may be, into their registers (note that $R_{E1} = R_{B1} = R_{B2} = 0$), and pressing f, b (see the instructions), yields R_{E2} = 2,371 Ω. Pressing 1, ENTER, 6, f, e, reveals that there is a −691.6% change in I_M for a 1% change in R_{E2}. Pressing 1, EEX, CHS, 3, E, B, indicates that, if ΔV_{BE} = 1 mv, I_M = 25.29 μA.

All parameters may be altered as functions of temperature with the aid of a companion program (not shown). Additional information on both programs may be obtained either from the author or the HP-67/97 Users' Library, 1000 N. E. Circle Blvd., Corvallis, Ore. 97330. Request program library numbers 2000 and 2001. □



Tracking. Program analyzes standard pnp or npn current mirror quickly and accurately. Checks of circuit sensitivity between any two circuit parameters are also performed. Setting β_3 = 0 is permitted in order to reduce the circuit to the basic two-transistor mirror.