Single Amplifier Current Sources

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The high gain and low offset drift of present day differential operational amplifiers permit their use in circuits which approach the performance of an ideal current source. High open loop gain results in a very small potential or a "virtual short" between the amplifier's input terminals. In this manner, a control voltage (E_I) may be applied across a resistor (R_I) which, due to amplifier nulling action, will result in the flow of a proportional load current (I_L) elsewhere in the circuit.

The circuits shown at right take advantage of the near short circuit (null) that exists between the amplifier input terminals. Except for the Howland circuit which utilizes positive feedback to approach infinite output impedance, the circuits are self-explanatory. (For more details on fundamental op amp theory request copies of Analog Device's "Operational Amplifiers, Parts I, II and IV.")

In each figure, the equations for load current vs. input and for amplifier output voltage and current are given to enable design within the amplifier's output limitations.

The circuits of Figures 3, 4, 5 and 6 are subject to common mode error which is dependent on input voltage level. For E_I greater than 5 volts common mode error may be substantial; but for a fixed reference voltage, the resulting error can be viewed as a gain error which can be calibrated.

Input offset voltage will add algebraically with E_I. The ratio of the maximum input offset voltage over the temperature range of interest to E_I offers a direct method of calculating voltage offset errors.

By the same token, input offset current will, in general, add algebraically with the input current I_I, (E_I/R_I). The same ratio as above but in terms of offset current and input current yields the error due to this factor. It is important that the source impedance of E_I for the non-inverting configurations of figures 3 and 4 be low since the input offset current flows through the source impedance producing an additional input voltage offset error.

The illustrations presented are working circuits, but the chief intent has been to offer numerical examples as guide lines. The circuit values can be changed over a considerable range.

FLOATING LOAD, INVERTING

ADVANTAGES
1. Simplicity
2. No common mode error

DISADVANTAGES
1. Input source must supply current equal to load current
2. Floating load

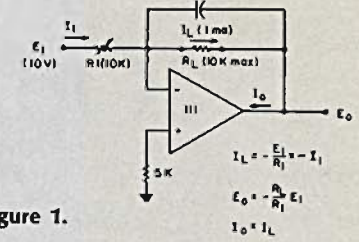

Figure 1.

FLOATING LOAD, INVERTING, WITH CURRENT GAIN

ADVANTAGES
1. Circuit exhibits current gain; hence source current may be much less than load current
2. Remote adjustment capability via R_3
3. No common mode error

DISADVANTAGES
1. Increased drift gain
2. Load is floating

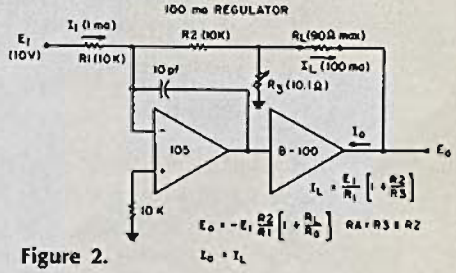

Figure 2.

FLOATING LOAD, NON-INVERTING

ADVANTAGES
1. Simplicity and ease of adjustment
2. Input Source (E_I) very lightly loaded

DISADVANTAGES
1. Common mode errors must be considered
2. Load is floating

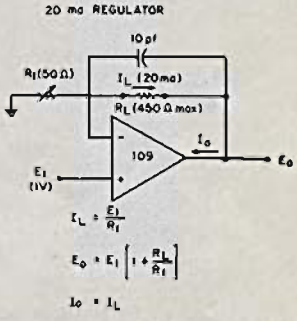

Figure 3.

"INBOARD" EMITTER FOLLOWER

ADVANTAGES
1. Same as Figure 3
2. Large output current at low cost

DISADVANTAGES
1. Load impedance floating and output is uni-directional
2. Common mode errors must be considered

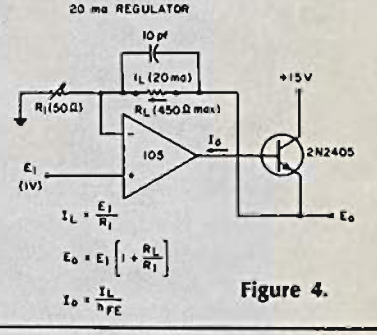

Figure 4.

HIGH IMPEDANCE, GROUNDED LOAD, FLOATED REFERENCE

ADVANTAGES
1. Simplicity and ability to supply high impedance loads
2. Load is grounded
3. Larger percentage of output voltage across load than Figure 6

DISADVANTAGES
1. Separate floating reference supply required
2. Common mode errors must be considered

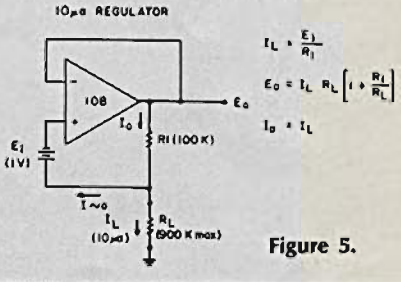

Figure 5.

HOWLAND CIRCUIT, GROUNDED LOAD AND GROUNDED REFERENCE

ADVANTAGES
1. Grounded load
2. Circuit has current gain so that $I_I < I_L$ for $K > 1$

DISADVANTAGES
1. Somewhat more complex
2. Common mode errors must be considered
3. Available load current less than Figure 5

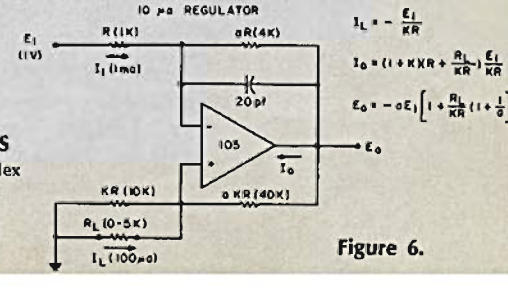

Figure 6.