Constant Current Power Supplies

Theory

A constant current supply functions as a regulated current source. It requires a change in thinking, to look at a supply that puts out a constant flow (current) regardless of the pressure (voltage).

A Few Basics

A theoretically perfect voltage generator would have zero internal impedance. A perfect current equivalent would have infinite internal impedance. If the source internal resistance, Rg, is very low when compared to the load, then it is said to be “stiff” and approximates a pure voltage source. Voltage drop across Rg is negligible underload .

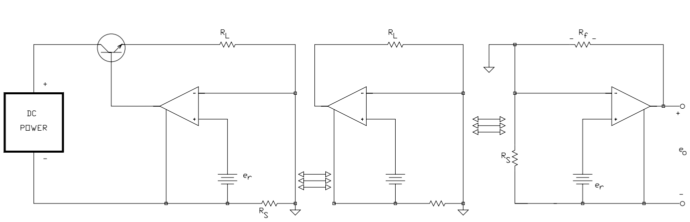
If Rg is very large compared to the load resistance RL, and the source voltage is increased, a changing load resistance will have very little effect on load current. This is because the load current is mainly determined by the source voltage Eb and the internal resistance Rg and is independent of load resistance. Practically, the situation is valid for RL < Rg/10, where RL is the load resistance in series with Rg. Achieving useful outputs with sources like batteries and resistors is not very practical, but does illustrate which parameters must be controlled in order to build true constant current (and constant voltage) supplies.

Practical Supply

A constant current power supply can be represented as a four terminal active device. The input represents a DC voltage source for basic current regulators, and it represents AC line voltage for those supplies which are complete with rectifiers and filters. To characterize the supply, definitions must be established.

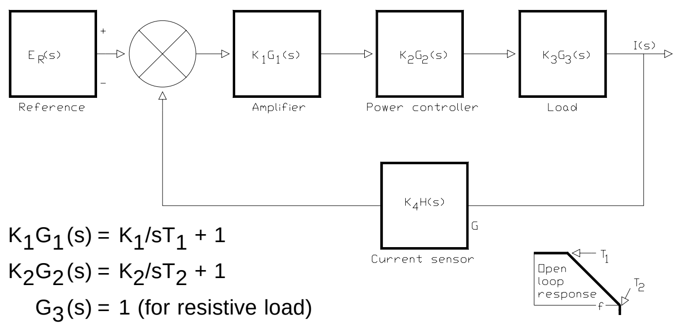
In a practical system, a transformer, rectifier and filter is included in each case in order to produce DC power. The power controller is added after this stage.

A constant current power supply consists of a DC power source that drives a series pass transistor which is controlled by a high gain op amp. The feedback signal is obtained from a shunt resistor Rs. In constant voltage the feedback comes from a voltage driver. The pass transistor operates as an emitter follower with a voltage gain of unity. Both the DC power source and transistor can be replaced by a single op amp which has a DC output capability equal to the combination. The resulting circuit can be redrawn in the form of a simple non-inverting op amp. The op amp is considered an ideal amplifier with infinite gain, and infinite input impedance, and amplifies the input voltage e_r, by the ratio of the feedback and gain resistors. In a constant current supply, the load resistance is the feedback resistor for the op amp. Since the supplies are isolated or floating, the output common can be any point desired. In a constant current supply, the output common is at a slightly different potential than the DC power source negative terminal because of the voltage drop across the shunt, Rs.



$$e_o = \frac{R_L + R_S}{R_S} e_r \qquad i_L = \frac{e_L}{R_L} = \frac{e_S}{R_S} = \frac{e_r}{R_S}$$

FIGURE 1.



$K_1G_1(s) = K_1/sT_1 + 1$

$K_2G_2(s) = K_2/sT_2 + 1$

$G_3(s) = 1$ (for resistive load)

$H(s) = 1$

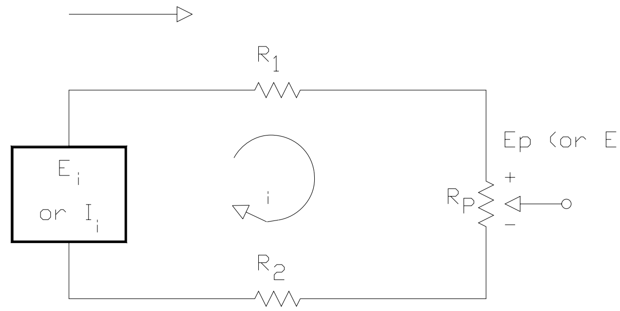
FIGURE 2.

A constant current supply is a relatively simple loop. The load is part of the loop and loop stability can be affected by the load. The time constant of the power amplifier T2, is very short for fast response. The amplifier transfer function is chosen to provide the dominant pole of the system (T1 is made large), because it is the easiest to control. Open loop gains on the order of 10,000 are necessary to achieve ±0.01 percent regulation. Loop stability is a problem. Care must be taken by power supply designers so that the unit meets stability requirements under all normal conditions of line, load and external environment.

Linear Scaling Easy

Constant current is a convenient way to build linear scaled systems using potentiometric transducers or position indicators. In a simple example, a 10 turn 1k potentiometer is supplied with a constant 10 mA of current which results in a ten volt output with one volt per turn. This can be read out directly on a DVM (digital voltmeter). By simply changing the current level the calibration can be easily adjusted to any value. This allows voltages directly proportional to degrees, pressure, acceleration, and so on, to be scaled and read directly on meters.

Another advantage of constant current is when the transducer is remotely located requiring long leads. Normally, with constant voltage, changes in line resistance would directly affect the accuracy of the measurement. The voltage across the potentiometer Rp is reduced by the sum of iR1 + iR2 and this will change as the temperature changes. The value of i = Ep/(R1 +R2) changes as R1 and R2 change, further complicating the problem. Constant current eliminates all of these error components since current through the potentiometer remains constant. Fluctuations in lead resistance between the supply and potentiometer do not affect the results.



For E_i : $Ep = E_i - i (R_1 + R_2)$

For I_i : $E_L = iRp$

FIGURE 3.

Performance Characteristics	Constant Current	Constant Voltage
Output	Constant current (adj.)	Constant voltage (adj.)
Compliance	Maximum output voltage	Maximum output current
Output Impedance	High	Low
Automatic Crossover	Adjustable voltage limiting	Adjustable current limiting
Output Ripple	RMS current Ripple	RMS voltage ripple
Temperature Coefficient	Change in output current versus temperature	Change in output voltage versus temperature
Slew Rate	Maximum rate of change of output current	Maximum rate of change of output voltage
Transient Response	Current response to step function change in load or reference	Voltage response to step function change in load or reference
Regulator Stability	Subject to loop oscillations if load is too inductive	Subject to loop oscillations if load is too capacitive