Application Note 19

Simple Current-Limiting Power Supply

by Jerry Kmetz

Just three ICs are required to build this adjustable-voltage, adjustable-current-limit power supply that operates like a laboratory supply. It offers an output voltage range of 0V to 25V and a current limit range of about 10mA to 1.5A. The Micrel MIC29152 LDO Regulator has a ground-referred bandgap (reference) voltage. Other adjustable regulators with ground-based reference voltages should also work.

Voltage-Control Circuitry

The lab supply schematic is shown in Figure 1. Amplifiers A1 and A2 implement output voltage control. The output voltage adjustment functions by controlling the ground reference potential of the feedback voltage divider. The internal bandgap reference voltage is sensed via V_{ADJ} by A1 and is used to provide adjustability down to 0V. The voltage at the adjust pin of the regulator remains constant when the closed-loop system is in regulation. Using this technique facilitates output voltage adjustability down to 0V without using an external reference voltage. In this design example, the voltage gain required of A1 is determined as follows:

$$A_V = 1 + \frac{R4}{R3} = 1.05$$

When R5 is adjusted so the input to voltage follower A2 is taken from the high side of the potentiometer, the gain of A1 will bias voltage divider R1 and R2 so that summing junction voltage V_{ADJ} will equal V_{REF} when V_{OUT} is 0V. For the MIC29152, V_{REF} is 1.24V. Note that the direction of current flow in voltage divider R1 and R2 is in the reverse direction from normal operation. The direction of current flow changes to "normal" when $V_{OUT} \geq V_{REF}$.

Conversely, when R5 is adjusted to provide ground (0V) at the bottom of R2, the regulator output voltage is the designed 25V maximum. Rotation of R5 results in a smooth variation of output voltage from 0V to the upper design value, as determined by R1 and R2. The following relationship specifies the highest output voltage:

$$V_{OUT(max)} = V_{REF}\left(1 + \frac{R1}{R2}\right)$$

Different maximum output voltages are readily achievable; first calculate new values for R1 and R2, then simply set R3 = R1 and R4 = R2.

Current-Control Circuitry

Amplifier A3 provides the adjustable current-limit capability; it amplifies the voltage dropped by current-sensing resistor R_S. For $I_{OUT(max)} = 1.5A$ and $R_S = 0.2\Omega$, the differential input signal to A3 (pin 2) is +0.3V. Lower gain settings for A3 correspond to higher output currents; higher gains correspond to the lower output currents. The design approach is as follows:

$$A_{V(min)} = \frac{V_{REF}}{V_s(1.5A)} = \frac{1.24V}{0.3V} = 4.13$$

$$A_{V(min)} = \frac{R10}{(R6 + R7)} = \frac{620k\Omega}{151k\Omega} = 4.11$$

$$A_{V(max)} = \frac{V_{REF}}{V_s(10mA)} = \frac{1.24V}{2.0mV} = 620$$

$$A_{V(max)} = \frac{R10}{R7(R6 \text{ set at } 0\Omega)} = \frac{620k\Omega}{1k\Omega} = 620$$

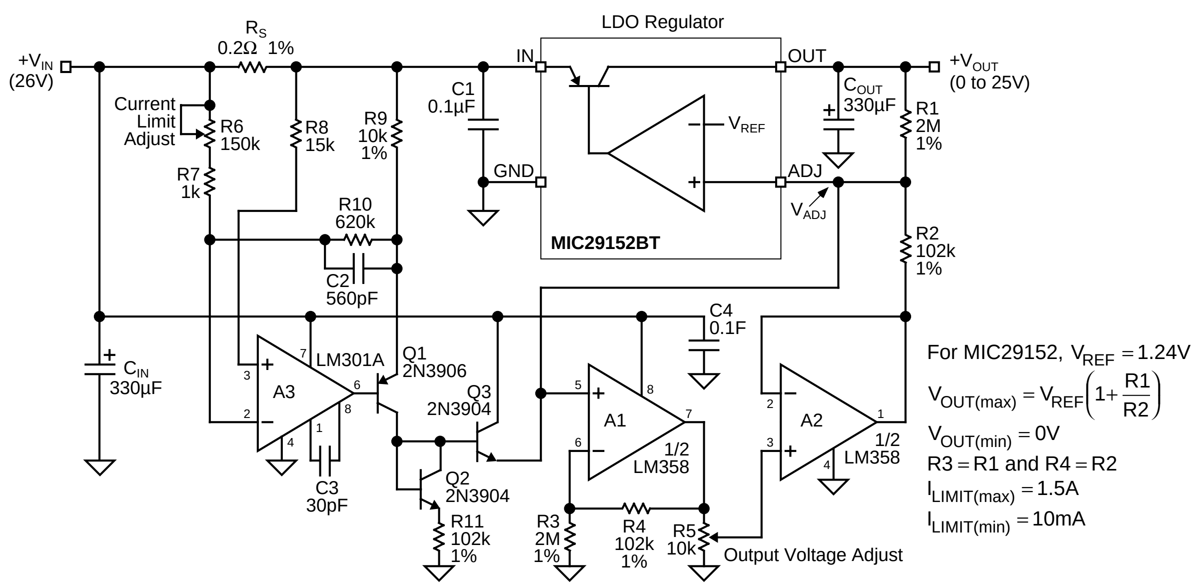

Figure 1. Adjustable-Voltage, Adjustable Current-Limit Power Supply

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The current-sense amplifier output signal is the voltage developed across R11; Q1 is used to produce the ground-referenced voltage required for feedback control of the MIC29152. Because the function of the current-limit circuitry is to reduce regulator output voltage, its output signal is essentially diode-coupled to the regulator loop summing junction by emitter follower Q3. Diode-connected Q2 provides first-order temperature compensation for the V_{BE} of Q3.

Figure 2 shows the accuracy of the current limit function. The voltage extends only to 24V because in the circuit breadboard resistor tolerances limited the maximum output to about 24.6V; 24V was the closest whole number convenient for making measurements. The vertical grid lines represent ideal current limiting. The graph shows actual performance; measured data is given in Table 1.

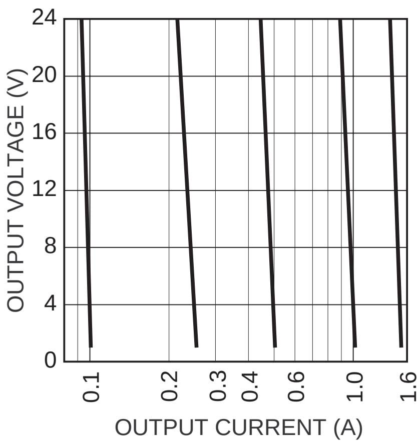

Figure 2. Current-Limit Accuracy vs. Output Voltage

Voltage (V)	Actual Measured Current (A)				
24	0.093	0.215	0.445	0.892	1.38
20	0.098	0.243	0.486	0.972	1.47
15	0.099	0.248	0.495	0.990	1.49
10	0.100	0.250	0.500	1.000	1.50
5	0.101	0.250	0.503	1.005	1.51
3	0.101	0.252	0.504	1.013	1.52
1	0.101	0.254	0.505	1.017	1.52

Table 1. Current-Limit Performance

Additional Considerations

Because of the wide input-to-output voltage range and current capability of this design it is difficult to provide sufficient heat sink to remain within the safe operating area (SOA). An efficient heat sink is very important. The thermal shutdown capability of the MIC29152 will prevent destruction, but it is a nuisance to encounter shutdown in use. Figure 3 indicates the safe operating area associated with using this circuit at an assumed maximum ambient temperature and two possible system thermal impedances.

A 35°C maximum ambient temperature allows for a 90°C junction temperature rise. Maximum allowed junction temperature for the regulator is 125°C. The 5°C/W and 6°C/W system θ_{JA} shown in Figure 3 are practical, but represent large (extruded) heat sinks. The θ_{JC} of a MIC29152BT (TO-220 package) is 2°C/W. Since θ_{CS} is typically 1.0°C/W, θ_{SA} must be 2°C/W or 3°C/W, respectively.

When building this circuit, care should be taken to minimize lead lengths associated with the gain-setting resistors (R6, R7, and R10) and the stabilization capacitor (C2). For the lowest current-limit setting the high gain (55dB) of this amplifier can make it susceptible to 60Hz pickup. Stabilizing the current-sensing amplifier circuit can be temperamental; it may be necessary to adjust the value of C2.

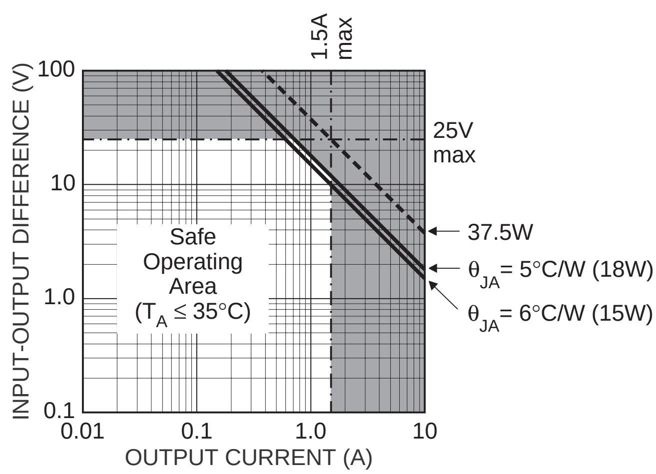

Figure 3. Safe Operating Area

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