LINEAR TECHNOLOGY
DESIGN NOTES

Power Op Amp Provides On-the-Fly Adjustable Current Limit for Flexibility and Load Protection in High Current Applications

Design Note 298

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Introduction

Many power operational amplifiers offer a built-in current limit where the limit is fixed or programmable through an external resistor. This offers the most basic measure of protection for the load circuitry, and the amplifier itself, under fault conditions. Sometimes, though, there is a need for *on-the-fly* current limiting to satisfy the requirements of different loads. For example, automatic test equipment (ATE) systems use multiple pin drivers to deliver test voltages across a wide range of loads, including faults, to a unit or board to test for continuity or functionality. To protect the load circuitry, the ATE must precisely control the maximum current delivered to each pin. Ideally the maximum current can be controlled on the fly, to accommodate the different loads at each pin.

Introducing the LT1970

The LT®1970 op amp can supply ±500mA of output current, with a precise, easy-to-implement current limit. Current limit control is via two simple 0V–5V voltage inputs, V_{CSRC} (for sourcing current) and V_{CSNK} (for sinking current), that set the maximum output current anywhere from 4mA to 500mA. Even at 500mA, the accuracy of the output current limit is guaranteed to a tight 2% (10mA) tolerance. The output current is continuously sensed by a small valued resistor, R_S, connected in series with the load as shown in Figure 1. The maximum output current is a function of the control-input voltage and the sense resistor according to the following expression:

$$I_{OUT(LIMIT)} = \frac{V_{LIMIT}}{10 \bullet R_S}$$

By simply changing the voltage between 0V and 5V at the control input, say through a D-to-A converter, the output current limit quickly changes to a new level.

For example, Figure 2 shows the output waveforms of the LT1970 driving a 1µF capacitive load in parallel with a 100Ω resistor. The current limit is set to 500mA sourcing (V_{CSRC} = 5V) and 50mA sinking (V_{CSNK} = 500mV). To charge the load capacitance, the amplifier current limits until the output voltage reaches its proper

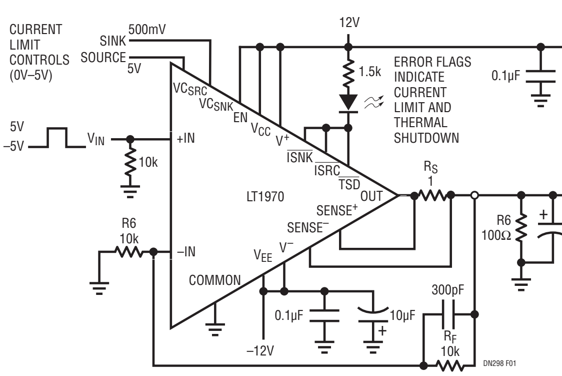

Figure 1. The LT1970: Easy to Use as an Op Amp with an Adjustable Output Current Power Stage

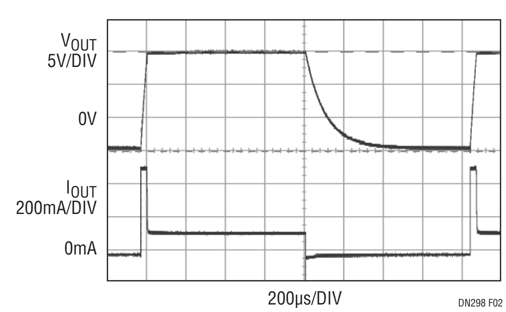

Figure 2. 500mA Source Current Limit and 50mA Sink Current Limit Control Output Response Characteristics

closed loop value. Then, while swinging negative, the sinking current limit prevents the output from going less than –5V.

The LT1970 also features open-collector error flags. These three outputs indicate that the amplifier is in current limit, either sourcing or sinking, and that the amplifier is in thermal shutdown. Additionally, the Enable input can be used to turn off the amplifier, thus putting the output into a high-impedance, zero output current state. This same input can also be used to simultaneously apply a new set of voltage and current settings to the load. The LT1970 is available in a small 20-pin TSSOP package with exposed underside metal for heat dissipation.

Boosted Output Current with "Snap-Back" Current Limiting

The LT1970 has separate supply pins for the input stage and the power output stage. Only load current flows through the output stage power supplies (V^+ and V^-). These pins can provide gate or base drive to external power transistors to boost the output current capability of the amplifier. A simple power stage, shown in Figure 3, increases the output current to ±5A. The same 0V to 5V inputs now set the output current limits a factor of ten higher (to 1A/V) by the use of a smaller current sense resistor, $R_S = 0.1\Omega$.

Externally connected gain setting resistors allow Kelvin sensing at the load. By connecting the feedback resistor right at the load, the voltage placed on the load is exactly what it should be. Any voltage drop across the current sense resistor is inside the feedback loop and thus does not create a voltage error. Figure 3 also shows a unique way to use the open-collector error flags to provide extra protection to the load circuitry. When the amplifier enters current limit in either direction, the appropriate error flag goes low. This high impedance to 0V transition can provide a large amount of hysteresis to the current limit control inputs, forcing a drastic reduction in output current. Resistors R1, R2 and R3 set the current limit control feedback at 2V max and 200mV min. Should the load current ever exceed the predetermined maximum limit, the output current snaps back to the min level. The output current remains at this lower level until the signal drops to a point where the load current is less than the minimum set value. When the signal is low enough, the flag output goes open and the current limit reverts to the maximum value. This action simulates an automatically resettable fuse to protect a load. Figure 4 shows the action of this feedback with a maximum current limit of 2A snapping back to 200mA when exceeded in either direction.

Conclusion

The LT1970 is a versatile and easy to use power op amp with a built-in precision adjustable current limit, which can protect load circuitry from damage caused by excessive power from the amplifier. This feature is particularly useful in ATE systems where the load is variable (and possibly faulty) at each tested node. Tight control of the output current in these systems is important to prevent damage to the tested unit.

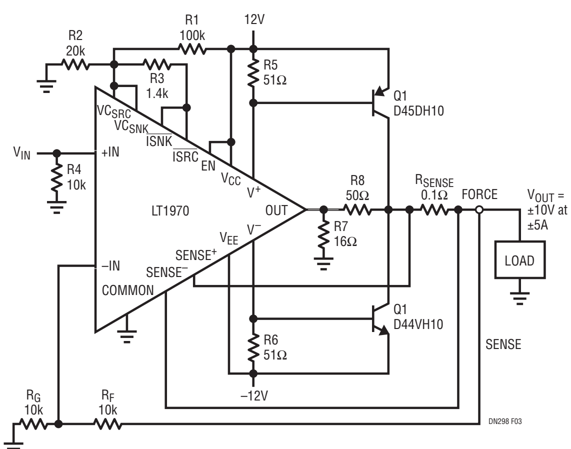

Figure 3. Easily Adjusted Current Limit for a ±5A Boosted Output Current Stage

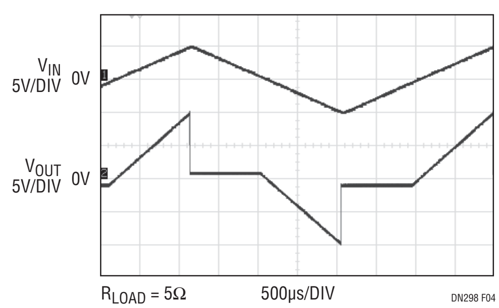

Figure 4. "Snap Back" Current Limiting with Both Source and Sink Current Limit Controlled by a Simple Resistor Network

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