

# 3A Linear Regulator Can Be Easily Paralleled to Spread Power and Heat

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The basic 3-terminal regulator has been a building block in designer tool kits for over thirty years without any significant change to its basic architecture. Using a fixed voltage reference, a resistor divider boosts the output voltage to the desired level. These are easy to use devices, hence their popularity, but there are some inherent downsides to this simple architecture.

One drawback to using a traditional linear regulator is that the minimum output voltage is limited to the reference voltage of the regulator. Another is that it is not easy to increase the available output current or spread power dissipation by paralleling devices. To distribute the load between multiple regulators, one must either add large ballast resistors, which incur load regulation errors, or balance

the load with complicated schemes of input sense resistors and op amp loops, which inevitably cancels out the promise of simplicity originally offered by using the ostensibly simple linear regulator.

But what if the voltage reference is thrown out and replaced with a precision current source? The resulting device is deceptively simple, as shown in the block diagram of Figure 1; a precision current source connects to the noninverting input of an amplifier and the output drives a large NPN pass element and connects to the inverting input to give unity gain. This small change to the venerable linear regulator device yields enormous gains in versatility and performance.

Now, in this new architecture, connecting each of the SET pins together when paralleling regulators provides a common reference point for *all* the error amplifiers, making it possible to balance any device-to-device offset variations with mere milliohms of ballast. Suddenly it is easy to spread power dissipation between as many devices are needed, and likewise scale the output current as necessary. The beauty of this architecture is that a single resistor generates the reference point for all of the regulators, whether one, ten or one hundred regulators are used. Additionally, the architecture allows zero resistance to equal zero output—there is no longer a fixed reference voltage to limit the bottom end of the usable output voltage range.

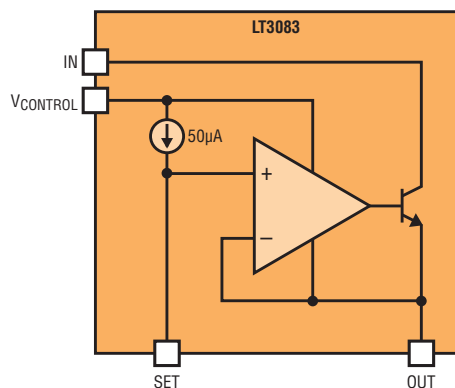


Figure 1. LT3083 block diagram

## BENEFITS OF A NEW ARCHITECTURE

The LT®3080 1.1A linear regulator was the first linear regulator to use a precision current source architecture, making it possible to produce high current, surface mount power supplies by paralleling any number of LT3080s. The LT3083 follows in the footsteps of the LT3080 with similar high performance specifications, but with an increased 3A output current capability. The performance advantages offered by this new architecture are numerous.

### Frequency Response and Load Regulation are Fixed

With traditional linear regulators, gain and bandwidth change as the output voltage is changed via resistor divider. Bypassing the feedback pin of the regulator affects loop response. Load regulation is not a fixed value, but a fixed percentage of the output as the resistor divider gains up any voltage deviation. Furthermore, reference voltage noise is gained up by the same resistor divider.

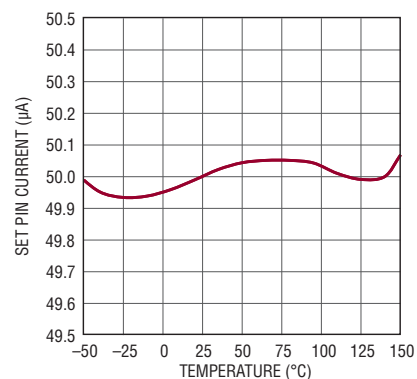


Figure 2. Reference current temperature characteristics

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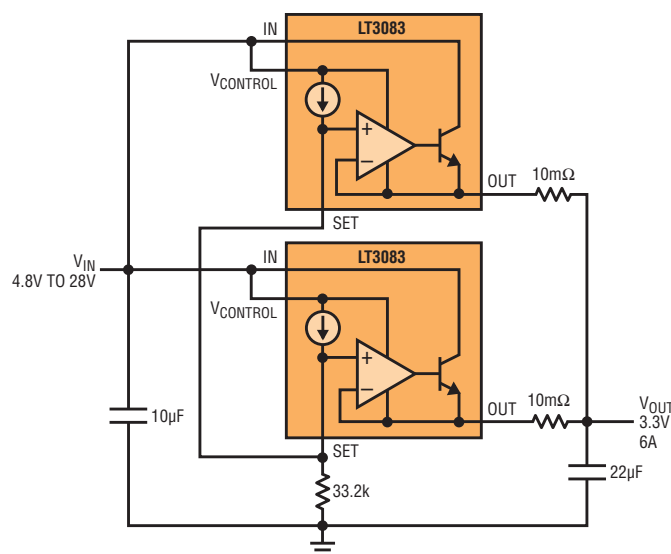


Figure 3. Paralleling regulators for higher current and heat spreading

Using a current source and unity-gain buffer eliminates these downsides. Since the error amplifier is always in unity gain, frequency response does not change as a function of output voltage or with the use of bypassing across the reference point. Load regulation is now a fixed value, regardless of output voltage. Since bypassing does not affect loop response, two noise sources can be eliminated: the reference current noise and resistor shot noise are quieted using a single capacitor. This leaves only the error amplifier noise at the output, and again, that stays at a fixed level, no matter the output voltage.

#### Top Notch DC Characteristics

DC characteristics of the LT3083 are the same as the original LT3080. The LT3083 separates out the collector of the NPN pass device to minimize power dissipation. Load regulation is typically below 1mV for the error amplifier, and nearly immeasurable on the 50μA reference current. Line

regulation for the reference current is less than 0.0002%/V, and is typically 2μV/V for the error amplifier offset. Temperature characteristics of the reference current are excellent, typically staying within 0.2% across the full operating junction temperature range, as shown in Figure 2.

The LT3083 also provides all of the protection features that Linear Technology parts are known for: current limit with safe operating area protection protects

the device from damage during short-circuit conditions and thermal limiting keeps the part safe during conditions of excessive power dissipation.

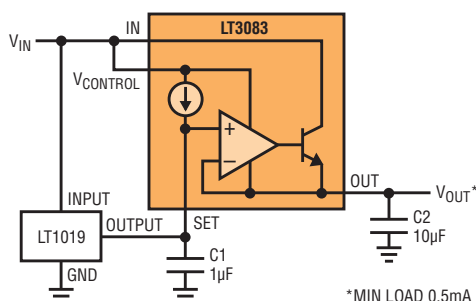
#### Top Notch AC Characteristics

Don't think that the AC characteristics of the LT3083 were sacrificed in an effort to achieve high DC performance. Transient response is excellent with as little as 10μF of output capacitance. Small ceramic capacitors can be used without the addition of ESR. Using a bypass capacitor across the reference resistor provides a slow-start function; the output voltage follows the RC time constant created by the SET resistor and bypass capacitor. Paralleling devices also provides advantages in noise performance. Paralleling multiple LT3083 regulators lowers the output noise in the same way that paralleling  $n$  op amps lowers noise by a factor of  $\sqrt{n}$ .

#### APPLICATIONS

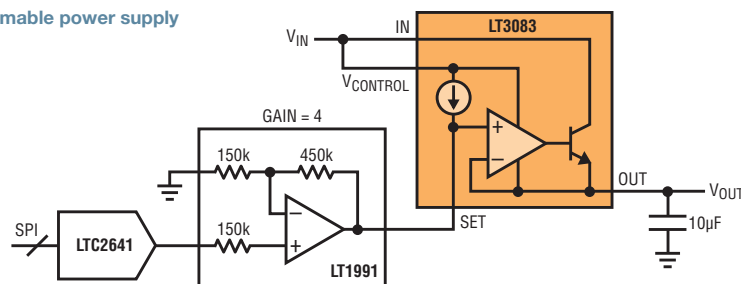
The LT3083's deceptively simple architecture and high performance parameters make it powerful building block for applications beyond the basic linear regulator. It can be easily paralleled to increase output current and spread heat. Actively driving the SET pin is perfectly acceptable; the low offset and high output current allow for highly accurate reference supplies at high power levels. Digitally programmable supplies are achieved by driving the SET pin with a DAC. Accurate current sources are realized without tremendous difficulty. The possibilities are only limited by the creativity of the user.

Figure 4. High current reference buffer



The LT3083 is easily configured as a 2-terminal current source, simply by adjusting the ratio of the external resistors and adding compensation.

Figure 5. Digitally programmable power supply



### Parallel Regulators Increase Current and Spread Heat

Figure 3 shows how to parallel multiple LT3083s to increase output current and spread heat. Note the minimal ballast needed to balance the load amongst the regulators. It's possible to produce quiet and accurate high current surface mount supplies simply by adding more LT3083s. Power dissipation is spread evenly across the paralleled regulators, but thermal management is still necessary. With as little as 0.5V drop across the regulator, a 3A load translates to 1.5W of power dissipation, pushing the thermal capabilities for surface mount designs.

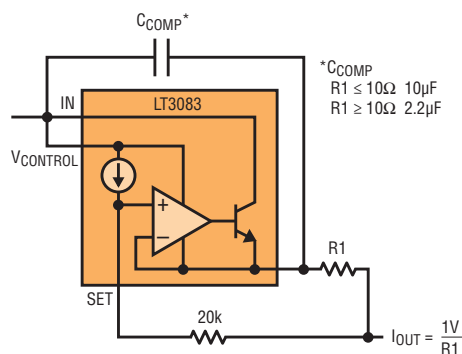
### High Current Reference Buffer

Creating a high current reference buffer takes very little effort, as shown in Figure 4. In this circuit, an LT1019-5 output connects to sink the 50µA reference current of the regulator. This reference provides 0.2% accuracy across temperature, or 10mV. With a maximum offset voltage of 4mV in the LT3083, output accuracy stays within 0.3%. The accuracy of the reference current in the LT3083 is not a factor in the output tolerance, and there are no resistors to present potential tolerance variations.

### Digitally Programmed Output

Programming the output voltage digitally simply takes the addition of a DAC to drive the SET pin. Figure 4 highlights how a DAC programs the LT3083 output to anywhere from zero to over 16V within 1.5LSB. In this circuit, an LTC2641-12 using a 4.096V reference drives the SET pin of the LT3083 through the LT1991 (configured for a gain of four).

Again, the tight specifications of the LT3083 allow for such excellent performance. Keep in mind that the minimum load current requirement must be met when operating at minimum output voltages—less than 500µA loading is required when operating at low input voltages, much less than traditional linear regulators that require 5 to 10mA.



### Easy 2-Terminal Current Source

Current sources can be very difficult to implement in certain applications. Some must be ground referenced, others must be referenced to a positive rail, while the most difficult designs require floating, 2-terminal devices. The LT3083 is easily configured as a 2-terminal current source, simply by adjusting the ratio of the external resistors and adding compensation as shown in Figure 5. The current source can be ground referenced, referenced to a positive rail or fully floating without concern.

### CONCLUSION

Hiding behind the simple architecture shown in the block diagram of the LT3083 is a high performance, highly versatile, groundbreaking building block device. The LT3083 combines the architectural leap forward of the LT3080, excellent AC and DC characteristics and increased current to easily solve problems that a traditional 3-terminal or low dropout regulator cannot touch. It can be used for supplies that operate all the way down to zero volts, paralleled for high current and heat spreading, or driven dynamically. High current linear power supplies are now available for surface mount boards without sacrificing performance. ■

Figure 6. 2-terminal current source