FEATURES
- Extended Safe Operating Area
- Maximum Output Current: 800mA
- Stable with or without Input/Output Capacitors
- Wide Input Voltage Range: 1.2V to 36V
- Single Resistor Sets Output Voltage
- Output Adjustable to 0V
- 50µA SET Pin Current: 1% Initial Accuracy
- Output Voltage Noise: 27µVRMS
- Parallel Multiple Devices for Higher Current, Heat Spreading and Lower Noise
- Pin Compatible Upgrade to LT1117
- Reverse-Battery and Reverse-Current Protection
- <1mV Typical Load Regulation Independent of VOUT
- <0.001%/V Typical Line Regulation
- 3-Lead SOT-223, 3-Lead DD-Pak, 8-Lead 3mm × 3mm DFN Packages

APPLICATIONS
- All Surface Mount Power Supply
- Rugged Industrial Power Supply
- Post Regulator for Switching Supplies
- Low Output Voltage Supply
- Intrinsic Safety Applications

DESCRIPTION
The LT®3088 is an 800mA low dropout linear regulator designed for rugged industrial applications. A key feature of the IC is the extended safe operating area (SOA). The LT3088 can be paralleled for higher output current or heat spreading. The device withstands reverse input and reverse output-to-input voltages without reverse current flow.

The LT3088’s precision 50µA reference current source allows a single resistor to program output voltage to any level between zero and 34.5V. The current reference architecture makes load regulation independent of output voltage. The LT3088 is stable with or without input and output capacitors.

Internal protection circuitry includes reverse-battery and reverse-current protection, current limiting and thermal limiting. The LT3088 is offered in the 3-lead SOT-223, 3-lead DD-Pak, and an 8-lead 3mm × 3mm DFN package.

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```
VIN +
IN
OUT
+1.5V
300mA
750Ω
10µF
OPTIONAL
3.01k
50µA

I_{OUT} = 2mA

V_{IN}

I_{LOAD} = 2mA

TEMPERATURE (°C)

SET PIN CURRENT (µA)

51.0
50.8
50.6
50.4
50.2
50.0
49.8
49.6
49.4
49.2
49.0

-75
-50
-25
0
25
50
75
100
125
150
175

SET PIN CURRENT (µA)

51.0
50.8
50.6
50.4
50.2
50.0
49.8
49.6
49.4
49.2
49.0

-75
-50
-25
0
25
50
75
100
125
150
175

TEMPERATURE (°C)

51.0
50.8
50.6
50.4
50.2
50.0
49.8
49.6
49.4
49.2
49.0

-75
-50
-25
0
25
50
75
100
125
150
175

TEMPERATURE (°C)
```
**LT3088**

**ABSOLUTE MAXIMUM RATINGS** (Note 1) All voltages Relative to $V_{OUT}$

- IN Pin to OUT Pin Differential Voltage: $\pm 40V$
- SET Pin Current (Note 6): $\pm 25mA$
- SET Pin Voltage (Relative to OUT, Note 6): $\pm 10V$
- Output Short-Circuit Duration: Indefinite
- Operating Junction Temperature Range (Note 2)
  - E-, I-Grades: $-40°C$ to $125°C$
  - H-Grade: $-40°C$ to $150°C$
  - MP-Grade: $-55°C$ to $150°C$
- Storage Temperature Range: $-65°C$ to $150°C$
- Lead Temperature (Soldering, 10 sec)
  - M, ST Packages Only: $300°C$

**PIN CONFIGURATION**

**ORDER INFORMATION**

<table>
<thead>
<tr>
<th>LEAD FREE FINISH</th>
<th>TAPE AND REEL</th>
<th>PART MARKING*</th>
<th>PACKAGE DESCRIPTION</th>
<th>TEMPERATURE RANGE</th>
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</thead>
<tbody>
<tr>
<td>LT3088EDD#PBF</td>
<td>LT3088EDD#TRPBF</td>
<td>LGSZ</td>
<td>8-Lead (3mm x 3mm) Plastic DFN</td>
<td>$-40°C$ to $125°C$</td>
</tr>
<tr>
<td>LT3088IDD#PBF</td>
<td>LT3088IDD#TRPBF</td>
<td>LGSZ</td>
<td>8-Lead (3mm x 3mm) Plastic DFN</td>
<td>$-40°C$ to $125°C$</td>
</tr>
<tr>
<td>LT3088HDD#PBF</td>
<td>LT3088HDD#TRPBF</td>
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<tr>
<td>LT3088EST#PBF</td>
<td>LT3088EST#TRPBF</td>
<td>3088</td>
<td>3-Lead Plastic SOT-223</td>
<td>$-40°C$ to $125°C$</td>
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<tr>
<td>LT3088IST#PBF</td>
<td>LT3088IST#TRPBF</td>
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<tr>
<td>LT3088HM#PBF</td>
<td>LT3088HM#TRPBF</td>
<td>LT3088M</td>
<td>3-Lead Plastic DD-Pak</td>
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<tr>
<td>LT3088MMP#PBF</td>
<td>LT3088MMP#TRPBF</td>
<td>LT3088M</td>
<td>3-Lead Plastic DD-Pak</td>
<td>$-55°C$ to $150°C$</td>
</tr>
</tbody>
</table>

Consult LTC Marketing for parts specified with wider operating temperature ranges. *The temperature grade is identified by a label on the shipping container. For more information on lead free part marking, go to: [http://www.linear.com/leadfree/](http://www.linear.com/leadfree/)
For more information on tape and reel specifications, go to: [http://www.linear.com/tapeandreel/](http://www.linear.com/tapeandreel/). Some packages are available in 500 unit reels through designated sales channels with #TRMPBF suffix.
**ELECTRICAL CHARACTERISTICS** The ● denotes the specifications which apply over the full operating temperature range, otherwise specifications are at TJ = 25°C. (Note 2)

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>CONDITIONS</th>
<th>MIN</th>
<th>TYP</th>
<th>MAX</th>
<th>UNITS</th>
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</thead>
<tbody>
<tr>
<td>SET Pin Current</td>
<td>I_SET</td>
<td>2V ≤ VIN ≤ 36V, 2mA ≤ I_LOAD ≤ 800mA</td>
<td>49.5</td>
<td>50</td>
<td>50.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2V ≤ VIN ≤ 36V, 2mA ≤ I_LOAD ≤ 800mA</td>
<td>49</td>
<td>50</td>
</tr>
<tr>
<td>Offset Voltage (VOUT – V_SET)</td>
<td>V_DS</td>
<td>VIN = 2V, I_LOAD = 2mA</td>
<td>–1.5</td>
<td>0</td>
<td>1.5</td>
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<td></td>
<td></td>
<td>VIN = 2V, I_LOAD = 2mA</td>
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<td>0</td>
<td>3.5</td>
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<td>I_SET Load Regulation</td>
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<td>∆I_LOAD = 2mA to 800mA</td>
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<td></td>
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<td>V_DS Load Regulation (Note 7)</td>
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<td>∆I_LOAD = 2mA to 800mA</td>
<td>DD Package</td>
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<td>–3</td>
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<td></td>
<td></td>
<td></td>
<td>M, ST Packages</td>
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<td>–4</td>
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<td>Line Regulation</td>
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<td>∆VSET</td>
<td>∆VIN = 2V to 36V, I_LOAD = 2mA</td>
<td>1.5</td>
<td>0.001</td>
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<td></td>
<td>∆VIN = 2V to 36V, I_LOAD = 2mA</td>
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<td>Minimum Load Current (Note 3)</td>
<td></td>
<td>2V ≤ VIN ≤ 36V</td>
<td>0.4</td>
<td>2</td>
<td></td>
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<td>Dropout Voltage (Note 4)</td>
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<td>I_LOAD = 100mA</td>
<td>1.21</td>
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<tr>
<td></td>
<td></td>
<td>I_LOAD = 800mA</td>
<td>1.35</td>
<td>1.6</td>
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<tr>
<td>Current Limit</td>
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<td>VIN = 5V, V_SET = 0V, V_OUT = –0.1V</td>
<td>0.8</td>
<td>1.2</td>
<td></td>
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<td>Reference Current RMS Output Noise (Note 5)</td>
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<td>10Hz ≤ f ≤ 100kHz</td>
<td>5.7</td>
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<td></td>
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<tr>
<td>Error Amplifier RMS Output Noise (Note 5)</td>
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<td>I_LOAD = 800mA, 10Hz ≤ f ≤ 100kHz, C_OUT = 0µF, C_SET = 0.1µF</td>
<td>27</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ripple Rejection</td>
<td></td>
<td>f = 120Hz</td>
<td>75</td>
<td>90</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>f = 1kHz</td>
<td>75</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>f = 1MHz</td>
<td>20</td>
<td></td>
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<tr>
<td>Thermal Regulation, I_SET 10ms Pulse</td>
<td></td>
<td>0.003</td>
<td></td>
<td></td>
<td>%/W</td>
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</tbody>
</table>

**Note 1:** Stresses beyond those listed under Absolute Maximum Ratings may cause permanent damage to the device. Exposure to any Absolute Maximum Rating condition for extended periods may affect device reliability and lifetime.

**Note 2:** Unless otherwise specified, all voltages are with respect to V_OUT. The LT3088 is tested and specified under pulse load conditions such that TJ = TA. The LT3088E is tested at TA = 25°C and performance is guaranteed from 0°C to 125°C. Performance of the LT3088E over the full –40°C and 125°C operating temperature range is assured by design, characterization, and correlation with statistical process controls. The LT3088I is guaranteed over the full –40°C to 125°C operating junction temperature range. The LT3088MP is 100% tested and guaranteed over the –55°C to 150°C operating junction temperature range. The LT3088H is tested at 150°C operating junction temperature. High junction temperatures degrade operating lifetimes. Operating lifetime is degraded at junction temperatures greater than 125°C.

**Note 3:** Minimum load current is equivalent to the quiescent current of the part. Since all quiescent and drive current is delivered to the output of the part, the minimum load current is the minimum current required to maintain regulation.

**Note 4:** For the LT3088, dropout is specified as the minimum input-to-output voltage differential required supplying a given output current.

**Note 5:** Adding a small capacitor across the reference current resistor lowers output noise. Adding this capacitor bypasses the resistor shot noise and reference current noise; output noise is then equal to error amplifier noise (see Applications Information section).

**Note 6:** Diodes with series 400Ω resistors clamp the SET pin to the OUT pin. These diodes and resistors only carry current under transient overloads. During normal operation, keep the OUT-to-SET differential voltage below 2V.

**Note 7:** Load regulation is Kelvin sensed at the package.

**Note 8:** This IC includes overtemperature protection that protects the device during momentary overload conditions. Junction temperature exceeds the maximum operating junction temperature when overtemperature protection is active. Continuous operation above the specified maximum operating junction temperature may impair device reliability.
TYPICAL PERFORMANCE CHARACTERISTICS

\( T_J = 25^\circ C \) unless otherwise specified.

---

**SET Pin Current**

\( I_{\text{LOAD}} = 2\, mA \)

---

**Offset Voltage**

\( N = 2994 \)

---

**Offset Voltage (\( V_{\text{OUT}} - V_{\text{SET}} \))**

\( I_{\text{LOAD}} = 2\, mA \)

---

**Load Regulation**

\( \Delta I_{\text{LOAD}} = 2\, mA \) TO 0.8A

---

**Minimum Load Current**

\( V_{\text{IN}} - V_{\text{OUT}} = 36V \)

---

**Dropout Voltage**

\( T_J = -50^\circ C, 25^\circ C, 125^\circ C \)
TYPICAL PERFORMANCE CHARACTERISTICS

T<sub>j</sub> = 25°C unless otherwise specified.

**Dropout Voltage**

- Dropout Voltage vs. Current Limit
- Dropout Voltage vs. Temperature

**Current Limit**

- Current Limit vs. Voltage
- Current Limit vs. Temperature

**Linear Regulator Load Transient Response**

- Linear Regulator Load Transient Response vs. Current vs. Voltage
- Linear Regulator Load Transient Response vs. Current vs. Time

**Current Source Line Transient Response**

- Current Source Line Transient Response vs. Current vs. Voltage
- Current Source Line Transient Response vs. Current vs. Time

For more information www.linear.com/LT3088
TYPICAL PERFORMANCE CHARACTERISTICS

Current Source
Line Transient Response

Linear Regulator
Turn-On Response

Linear Regulator
Turn-On Response

Current Source
Turn-On Response

Current Source
Turn-On Response

Residual Output Voltage with Less Than Minimum Load

Ripple Rejection

Ripple Rejection

Output Impedance

TJ = 25°C unless otherwise specified.
TYPICAL PERFORMANCE CHARACTERISTICS  

**Ripple Rejection (120Hz)**

- **$V_{IN} = V_{OUT(NOMINAL)} + 2V$**
- **RIPPLE = 500mVp-p**
- **$f = 120Hz$**
- **$I_{LOAD} = 0.1A$**
- **$C_{OUT} = 2.2\mu F$**
- **$C_{SET} = 0.1\mu F$**

**Ripple Rejection (10kHz)**

- **$V_{IN} = V_{OUT(NOMINAL)} + 2V$**
- **RIPPLE = 500mVp-p**
- **$f = 10kHz$**
- **$I_{LOAD} = 0.1A$**
- **$C_{OUT} = 2.2\mu F$**
- **$C_{SET} = 0.1\mu F$**

**Ripple Rejection (1MHz)**

- **$V_{IN} = V_{OUT(NOMINAL)} + 2V$**
- **RIPPLE = 500mVp-p**
- **$f = 1MHz$**
- **$I_{LOAD} = 0.1A$**
- **$C_{OUT} = 2.2\mu F$**
- **$C_{SET} = 0.1\mu F$**

**10Hz to 100kHz Output Voltage Noise**

- **$V_{OUT} = 50\mu V/DIV$**
- **$C_{SET} = 0.1\mu F$**
- **$C_{OUT} = 4.7\mu F$**
- **$I_{LOAD} = 800mA$**

$T_J = 25^\circ C$ unless otherwise specified.
PIN FUNCTIONS

IN: Input. This pin supplies power to regulate internal circuitry and supply output load current. For the device to operate properly and regulate, the voltage on this pin must be between the dropout voltage and 36V above the OUT pin (depending on output load current, see Dropout Voltage Specifications).

OUT: Output. This is the power output of the device. The LT3088 requires a 2mA minimum load current for proper output regulation.

SET: Set. This pin is the error amplifier’s noninverting input and also sets the operating bias point of the circuit. A fixed 50µA current source flows out of this pin. A single external resistor programs VOUT. Output voltage range is 0V to 34.5V.

Exposed Pad/Tab: Output. The exposed pad of the DD package and the tab of the M and ST packages are tied internally to OUT. As such, tie them directly to OUT at the PCB. The amount of copper area and planes connected to OUT determine the effective thermal resistance of the packages.

NC: (DD Package Only) No Connection. No connect pins have no connection to internal circuitry and may be tied to IN, OUT, GND or floated.

BLOCK DIAGRAM
APPLICATIONS INFORMATION

Introduction

The LT3088 regulator is easy to use and has all the protection features expected in high performance regulators. Included are short-circuit protection, reverse-input protection and safe operating area protection, as well as thermal shutdown with hysteresis. Safe operating area (SOA) for the LT3088 is extended, allowing for use in harsh industrial and automotive environments where sudden spikes in input voltage lead to high power dissipation.

The LT3088 fits well in applications needing multiple rails. This new architecture adjusts down to zero with a single resistor, handling modern low voltage digital ICs as well as allowing easy parallel operation and thermal management without heat sinks. Adjusting to zero output allows shutting off the powered circuitry.

A precision “0” TC 50µA reference current source connects to the noninverting input of a power operational amplifier. The power operational amplifier provides a low impedance buffered output to the voltage on the noninverting input. A single resistor from the noninverting input to ground sets the output voltage. If this resistor is set to 0Ω, zero output voltage results. Therefore, any output voltage can be obtained between zero and the maximum defined by the input power supply is obtainable.

The benefit of using a true internal current source as the reference, as opposed to a bootstrapped reference in older regulators, is not so obvious in this architecture. A true reference current source allows the regulator to have gain and frequency response independent of the impedance on the positive input. On older adjustable regulators, such as the LT1086 loop gain changes with output voltage and bandwidth changes if the adjustment pin is bypassed to ground. For the LT3088, the loop gain is unchanged with output voltage changes or bypassing. Output regulation is not a fixed percentage of output voltage, but is a fixed fraction of millivolts. Use of a true current source allows all of the gain in the buffer amplifier to provide regulation, and none of that gain is needed to amplify up the reference to a higher output voltage.

Programming Linear Regulator Output Voltage

The LT3088 generates a 50µA reference current that flows out of the SET pin. Connecting a resistor from SET to ground generates a voltage that becomes the reference point for the error amplifier (see Figure 1). The reference voltage equals 50µA multiplied by the value of the SET pin resistor (Ohm’s Law). Any voltage can be generated and there is no minimum output voltage for the regulator.

A precision “0” TC 50µA reference current source connects to the noninverting input of a power operational amplifier. The power operational amplifier provides a low impedance buffered output to the voltage on the noninverting input. A single resistor from the noninverting input to ground sets the output voltage. If this resistor is set to 0Ω, zero output voltage results. Therefore, any output voltage can be obtained between zero and the maximum defined by the input power supply is obtainable.

The benefit of using a true internal current source as the reference, as opposed to a bootstrapped reference in older regulators, is not so obvious in this architecture. A true reference current source allows the regulator to have gain and frequency response independent of the impedance on the positive input. On older adjustable regulators, such as the LT1086 loop gain changes with output voltage and bandwidth changes if the adjustment pin is bypassed to ground. For the LT3088, the loop gain is unchanged with output voltage changes or bypassing. Output regulation is not a fixed percentage of output voltage, but is a fixed fraction of millivolts. Use of a true current source allows all of the gain in the buffer amplifier to provide regulation, and none of that gain is needed to amplify up the reference to a higher output voltage.

Table 1 lists many common output voltages and the closest standard 1% resistor values used to generate that output voltage.

Table 1. 1% Resistors for Common Output Voltages

<table>
<thead>
<tr>
<th>VOUT (V)</th>
<th>RSET (kΩ)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>20</td>
</tr>
<tr>
<td>1.2</td>
<td>24.3</td>
</tr>
<tr>
<td>1.5</td>
<td>30.1</td>
</tr>
<tr>
<td>1.8</td>
<td>35.7</td>
</tr>
<tr>
<td>2.5</td>
<td>49.9</td>
</tr>
<tr>
<td>3.3</td>
<td>66.5</td>
</tr>
<tr>
<td>5</td>
<td>100</td>
</tr>
</tbody>
</table>

For more information www.linear.com/LT3088
APPLICATIONS INFORMATION

With the 50µA current source used to generate the reference voltage, leakage paths to or from the SET pin can create errors in the reference and output voltages. High quality insulation should be used (e.g., Teflon, Kel-F); cleaning of all insulating surfaces to remove fluxes and other residues is required. Surface coating may be necessary to provide a moisture barrier in high humidity environments.

Minimize board leakage by encircling the SET pin and circuitry with a guard ring operated at a potential close to itself. Tie the guard ring to the OUT pin. Guarding both sides of the circuit board is required. Bulk leakage reduction depends on the guard ring width. 50nA of leakage into or out of the SET pin and its associated circuitry creates a 0.1% reference voltage error. Leakages of this magnitude, coupled with other sources of leakage, can cause significant offset voltage and reference drift, especially over the possible operating temperature range. Figure 2 depicts an example guard ring layout.

If guard ring techniques are used, this bootstraps any stray capacitance at the SET pin. Since the SET pin is a high impedance node, unwanted signals may couple into the SET pin and cause erratic behavior. This will be most noticeable when operating with minimum output capacitors at full load current. The easiest way to remedy this is to bypass the SET pin with a small amount of capacitance from SET to ground, 10pF to 20pF is sufficient.

Using the LT3088 as a Replacement for the LT1117

The LT3088 can be used as an upgrade or replacement for the LT1117 regulator. The LT3088 offers superior performance over the LT1117, including extended input voltage range, lower output voltage capability, extended safe operating area, and protection features such as reverse voltage/current protection. Figure 3 shows how the LT1117 is used as a basic adjustable regulator. Two methods are shown in Figures 4 and 5 to change from the LT1117 to the LT3088. The first method (shown in Figure 4) requires no changes to existing board layouts: replace the LT1117 with the LT3088, change resistor R2 to set the desired output voltage, and do not stuff resistor R1 (the minimum load requirement of 2mA for the LT3088 must still be met). The second method is shown in Figure 5: a 25k resistor is...

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For more information www.linear.com/LT3088
added in series with the SET pin of the LT3088 and uses the same existing resistor divider. This technique can be used to easily satisfy the LT3088’s 2mA minimum load current requirement.

Configuring the LT3088 as a Current Source

Setting the LT3088 to operate as a 2-terminal current source is a simple matter. The 50µA reference current from the SET pin is used with one resistor to generate a small voltage, usually in the range of 100mV to 1V (200mV is a level that rejects offset voltage, line regulation, and other errors without being excessively large). This voltage is then applied across a second resistor that connects from OUT to the first resistor. Figure 6 shows connections and formulas to calculate a basic current source configuration.

Again, the lower current levels used in the LT3088 necessitate attention to board leakages as error sources (see the Programming Linear Regulator Output Voltage section).

Selecting RSET and ROUT in Current Source Applications

In Figure 6, both resistors RSET and ROUT program the value of the output current. The question now arises: the ratio of these resistors is known, but what value should each resistor be?

The first resistor to select is RSET. The value selected should generate enough voltage to minimize the error caused by the offset between the SET and OUT pins. A reasonable starting level is ~200mV of voltage across RSET (RSET equal to 4.02k). Resultant errors due to offset voltage are a few percent. The lower the voltage across RSET becomes, the higher the error term due to the offset.

From this point, selecting ROUT is easy, as it is a straightforward calculation from RSET. Take note, however, resistor errors must be accounted for as well. While larger voltage drops across RSET minimize the error due to offset, they also increase the required operating headroom.

Obtaining the best temperature coefficient does not require the use of expensive resistors with low ppm temperature coefficients. Instead, since the output current of the LT3088 is determined by the ratio of RSET to ROUT, those resistors should have matching temperature characteristics. Less expensive resistors made from the same material provide matching temperature coefficients. See resistor manufacturers’ data sheets for more details.

Higher output currents necessitate the use of higher wattage resistors for ROUT. There may be a difference between the resistors used for ROUT and RSET. A better method to maintain consistency in resistors is to use multiple resistors in parallel to create ROUT, allowing the same wattage and type of resistor as RSET.

Stability and Input Capacitance

The LT3088 does not require an input capacitor to maintain stability. Input capacitors are recommended in linear regulator configurations to provide a low impedance input source to the LT3088. If using an input capacitor, low ESR, ceramic input bypass capacitors are acceptable for applications without long input leads. However, applications connecting a power supply to an LT3088 circuit’s IN and GND pins with long input wires combined with low ESR, ceramic input capacitors are prone to voltage spikes, reliability concerns and application-specific board oscillations. The input wire inductance found in many
battery-powered applications, combined with the low ESR ceramic input capacitor, forms a high Q LC resonant tank circuit. In some instances this resonant frequency beats against the output current dependent LDO bandwidth and interferes with proper operation. Simple circuit modifications/solutions are then required. This behavior is not indicative of LT3088 instability, but is a common ceramic input bypass capacitor application issue.

The self-inductance, or isolated inductance, of a wire is directly proportional to its length. Wire diameter is not a major factor on its self-inductance. For example, the self-inductance of a 2-AWG isolated wire (diameter = 0.26") is about half the self-inductance of a 30-AWG wire (diameter = 0.01"). One foot of 30-AWG wire has about 465nH of self inductance.

One of two ways reduces a wire’s self-inductance. One method divides the current flowing towards the LT3088 between two parallel conductors. In this case, the farther apart the wires are from each other, the more the self-inductance is reduced; up to a 50% reduction when placed a few inches apart. Splitting the wires basically connects two equal inductors in parallel, but placing them in close proximity gives the wires mutual inductance adding to the self-inductance. The second and most effective way to reduce overall inductance is to place both forward and return current conductors (the input and GND wires) in very close proximity. Two 30-AWG wires separated by only 0.02", used as forward and return current conductors, reduce the overall self-inductance to approximately one-fifth that of a single isolated wire.

If wiring modifications are not permissible for the applications, including series resistance between the power supply and the input of the LT3088 also stabilizes the application. As little as 0.1Ω to 0.5Ω, often less, is effective in damping the LC resonance. If the added impedance between the power supply and the input is unacceptable, adding ESR to the input capacitor also provides the necessary damping of the LC resonance. However, the required ESR is generally higher than the series impedance required.

### Stability and Frequency Compensation for Linear Regulator Configurations

The LT3088 does not require an output capacitor for stability. LTC recommends an output capacitor of 10µF with an ESR of 0.5Ω or less to provide good transient performance in linear regulator configurations. Larger values of output capacitance decrease peak deviations and provide improved transient response for larger load current changes. Bypass capacitors, used to decouple individual components powered by the LT3088, increase the effective output capacitor value. For improvement in transient performance, place a capacitor across the voltage setting resistor. Capacitors up to 1µF can be used. This bypass capacitor reduces system noise as well, but start-up time is proportional to the time constant of the voltage setting resistor (RSET in Figure 1) and SET pin bypass capacitor.

### Stability and Frequency Compensation for Current Source Configurations

The LT3088 does not require input or output capacitors for stability in many current-source applications. Clean, tight PCB layouts provide a low reactance, well controlled operating environment for the LT3088 without requiring capacitors to frequency compensate the circuit. Figure 6 highlights the simplicity of using the LT3088 as a current source.

Some current source applications use a capacitor connected in parallel with the SET pin resistor to lower the current source’s noise. This capacitor also provides a soft-start function for the current source. See Quieting the Noise section for further details. When operating without output capacitors, the high impedance nature of the SET pin as the input of the error amplifier allows signal from the output to couple in, showing as high frequency ringing during transients. Bypassing the SET resistor with a capacitor in the range of 20pF to 30pF damps the ringing.

Depending on the pole introduced by a capacitor or other complex impedances presented to the LT3088, external
APPLICATIONS INFORMATION

compensation may be required for stability. Techniques are discussed to achieve this in the following paragraphs. Linear Technology strongly recommends testing stability in situ with final components before beginning production.

Although the LT3088’s design strives to be stable without capacitors over a wide variety of operating conditions, it is not possible to test for all possible combinations of input and output impedances that the LT3088 will encounter. These impedances may include resistive, capacitive, and inductive components and may be complex distributed networks. In addition, the current source’s value will differ between applications and its connection may be GND referenced, power supply referenced, or floating in a signal line path. Linear Technology strongly recommends that stability be tested in situ for any LT3088 application.

In LT3088 applications with long wires or PCB traces, the inductive reactance may cause instability. In some cases, adding series resistance to the input and output lines (as shown in Figure 7) may sufficiently dampen these possible high-Q lines and provide stability. The user must evaluate the required resistor values against the design’s headroom constraints. In general, operation at low output current levels (<20mA) automatically requires higher values of programming resistors and may provide the necessary damping without additional series impedance.

If the line impedances in series with the LT3088 are complex enough such that series damping resistors are not sufficient, a frequency compensation network may be necessary. Several options may be considered.

Figure 8 depicts the simplest frequency compensation networks as a single capacitor across the two terminals of the current source. Some applications may use the capacitance to stand off DC voltage but allow the transfer of data down a signal line.

For some applications, pure capacitance may be unacceptable or present a design constraint. One circuit example typifying this is an “intrinsically-safe” circuit in which an overload or fault condition potentially allows the capacitor's stored energy to create a spark or arc. For applications where a single capacitor is unacceptable, Figure 8 alternately shows a series RC network connected across the two terminals of the current source. This network has the added benefit of limiting the discharge current of the

Figure 7. Adding Series Resistance Decouples and Dampens Long Line Reactances

Figure 8. Compensation from Input to Output of Current Source Provides Stability
capacitor under a fault condition, preventing sparks or arcs. In many instances, a series RC network is the best solution for stabilizing the application circuit. Typical resistor values will range from 100Ω to 5k. Once again, Linear Technology strongly recommends testing stability in situ for any LT3088 application across all operating conditions, especially ones that present complex impedance networks at the input and output of the current source.

If an application refers the bottom of the LT3088 current source to GND, it may be necessary to bypass the top of the current source with a capacitor to GND. In some cases, this capacitor may already exist and no additional capacitance is required. For example, if the LT3088 is used as a variable current source on the output of a power supply, the output bypass capacitance would suffice to provide LT3088 stability. Other applications may require the addition of a bypass capacitor. A series RC network may also be used as necessary, and depends on the application requirements.

In some extreme cases, capacitors or series RC networks may be required on both the LT3088’s input and output to stabilize the circuit. Figure 9 depicts a general application using input and output capacitor networks rather than an input-to-output capacitor. As the input of the current source tends to be high impedance, placing a capacitor on the input does not have the same effect as placing a capacitor on the lower impedance output. Capacitors in the range of 0.1µF to 1µF usually provide sufficient bypassing on the input, and the value of input capacitance may be increased without limit. Pay careful attention to using low ESR input capacitors with long input lines (see the Stability and Input Capacitance section for more information).

**Using Ceramic Capacitors**

Give extra consideration to the use of ceramic capacitors. Ceramic capacitors are manufactured with a variety of dielectrics, each with different behavior across temperature and applied voltage. The most common dielectrics used are specified with EIA temperature characteristic codes of Z5U, Y5V, X5R and X7R. The Z5U and Y5V dielectrics are good for providing high capacitances in a small package, but they tend to have strong voltage and temperature coefficients as shown in Figures 10 and 11. When used with a 5V regulator, a 16V 10µF Y5V capacitor can exhibit an effective value as low as 1µF to 2µF for the DC bias voltage applied and over the operating temperature range. The X5R and X7R dielectrics result in more stable characteristics and are more suitable for use as the output capacitor. The X7R type has better stability across temperature, while the X5R is less expensive and is available in higher values. Care still must be exercised when using X5R and X7R capacitors. The X5R and X7R codes only specify operating temperature range and maximum capacitance change over temperature. Capacitance change due to DC bias with X5R and X7R capacitors is better than Y5V and Z5U capacitors, but can still be significant enough to drop capacitor values below appropriate levels. Capacitor DC bias characteristics tend to improve as component case size increases, but expected capacitance at operating voltage should be verified.
Voltage and temperature coefficients are not the only sources of problems. Some ceramic capacitors have a piezoelectric response. A piezoelectric device generates voltage across its terminals due to mechanical stress. In a ceramic capacitor, the stress can be induced by vibrations in the system or thermal transients.

Paralleling Devices

Higher output current is obtained by paralleling multiple LT3088s together. Tie the individual SET pins together and tie the individual IN pins together. Connect the outputs in common using small pieces of PC trace as ballast resistors to promote equal current sharing. PC trace resistance in milliohms/inch is shown in Table 2. Ballasting requires only a tiny area on the PCB.

<table>
<thead>
<tr>
<th>WEIGHT (oz)</th>
<th>10mil WIDTH</th>
<th>20mil WIDTH</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>54.3</td>
<td>27.1</td>
</tr>
<tr>
<td>2</td>
<td>27.1</td>
<td>13.6</td>
</tr>
</tbody>
</table>

Trace resistance is measured in mΩ/in.

The worst-case room temperature offset, only ±1.5mV between the SET pin and the OUT pin, allows the use of very small ballast resistors.

As shown in Figure 12, each LT3088 has a small 10mΩ ballast resistor, which at full output current gives better than 80% equalized sharing of the current. The external resistance of 10mΩ (5mΩ for the two devices in parallel) only adds about 8mV of output regulation drop at an output of 1.6A. Even with an output voltage as low as 1V, this only adds 0.8% to the regulation. Of course, paralleling more than two LT3088s yields even higher output current. Spreading the devices on the PC board also spreads the heat. Series input resistors can further spread the heat if the input-to-output difference is high.
APPLICATIONS INFORMATION

Quieting the Noise

The LT3088 offers numerous noise performance advantages. Every linear regulator has its sources of noise. In general, a linear regulator's critical noise source is the reference. In addition, consider the error amplifier’s noise contribution along with the resistor divider’s noise gain.

Many traditional low noise regulators bond out the voltage reference to an external pin (usually through a large value resistor) to allow for bypassing and noise reduction. The LT3088 does not use a traditional voltage reference like other linear regulators. Instead, it uses a 50µA reference current. The 50µA current source generates noise current levels of 18pA/√Hz (5.7nARMS over a 10Hz to 100kHz bandwidth). The equivalent voltage noise equals the RMS noise current multiplied by the resistor value.

The SET pin resistor generates spot noise equal to √(4kTR) (k = Boltzmann’s constant, 1.38 • 10^-23 J/°K, and T is absolute temperature) which is RMS summed with the voltage noise. If the application requires lower noise performance, bypass the voltage setting resistor with a capacitor to GND. Note that this noise-reduction capacitor increases start-up time as a factor of the RC time constant.

The LT3088 uses a unity-gain follower from the SET pin to the OUT pin. Therefore, multiple possibilities exist (besides a SET pin resistor) to set output voltage. For example, using a high accuracy voltage reference from SET to GND removes the errors in output voltage due to reference current tolerance and resistor tolerance. Active driving of the SET pin is acceptable.

The typical noise scenario for a linear regulator is that the output voltage setting resistor divider gains up the reference noise, especially if V_OUT is much greater than V_REF. The LT3088’s noise advantage is that the unity-gain follower presents no noise gain whatsoever from the SET pin to the output. Thus, noise figures do not increase accordingly. Error amplifier noise is typical 85nV/√Hz (27µVRMS over a 10Hz to 100kHz bandwidth). The error amplifier’s noise is RMS summed with the other noise terms to give a final noise figure for the regulator.

Paralleling of regulators adds the benefit that output noise is reduced. For n regulators in parallel, the output noise drops by a factor of √n.

Curves in the Typical Performance Characteristics section show noise spectral density and peak-to-peak noise characteristics for both the reference current and error amplifier over a 10Hz to 100kHz bandwidth.

Load Voltage Regulation

The LT3088 is a floating device. No ground pin exists on the packages. Thus, the IC delivers all quiescent current and drive current to the load. Therefore, it is not possible to provide true remote load sensing. The connection resistance between the regulator and the load determines load regulation performance. The data sheet’s load regulation specification is Kelvin sensed at the package’s pins. Negative-side sensing is a true Kelvin connection by returning the bottom of the voltage setting resistor to the negative side of the load (see Figure 13).

Connected as shown, system load regulation is the sum of the LT3088’s load regulation and the parasitic line resistance multiplied by the output current. To minimize load regulation, keep the positive connection between the regulator and load as short as possible. If possible, use large diameter wire or wide PC board traces.

Figure 13. Connections for Best Load Regulation
APPLICATIONS INFORMATION

Thermal Considerations

The LT3088’s internal power and thermal limiting circuitry protects itself under overload conditions. For continuous normal load conditions, do not exceed the 125°C (E- and I-grades) or 150°C (H- and MP-grades) maximum junction temperature. Carefully consider all sources of thermal resistance from junction-to-ambient. This includes (but is not limited to) junction-to-case, case-to-heat sink interface, heat sink resistance or circuit board-to-ambient as the application dictates. Consider all additional, adjacent heat generating sources in proximity on the PCB.

Surface mount packages provide the necessary heat sinking by using the heat spreading capabilities of the PC board, copper traces and planes. Surface mount heat sinks, plated through-holes and solder-filled vias can also spread the heat generated by power devices.

Junction-to-case thermal resistance is specified from the IC junction to the bottom of the case directly, or the bottom of the pin most directly in the heat path. This is the lowest thermal resistance path for heat flow. Only proper device mounting ensures the best possible thermal flow from this area of the packages to the heat sinking material.

Note that the exposed pad of the DFN package and the tab of the DD-Pak and SOT-223 packages are electrically connected to the output (V_{OUT}).

Tables 3 through 5 list thermal resistance as a function of copper areas on a fixed board size. All measurements were taken in still air on a 4-layer FR-4 board with 1oz solid internal planes and 2oz external trace planes with a total finished board thickness of 1.6mm.

Table 3. DD Package, 8-Lead DFN

<table>
<thead>
<tr>
<th>COFFER AREA</th>
<th>TOPSIDE*</th>
<th>BACKSIDE</th>
<th>BOARD AREA</th>
<th>THERMAL RESISTANCE (JUNCTION-TO-AMBIENT)</th>
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<tbody>
<tr>
<td>2500mm²</td>
<td>2500mm²</td>
<td>2500mm²</td>
<td>2500mm²</td>
<td>26°C/W</td>
</tr>
<tr>
<td>1000mm²</td>
<td>2500mm²</td>
<td>2500mm²</td>
<td>2500mm²</td>
<td>26°C/W</td>
</tr>
<tr>
<td>225mm²</td>
<td>2500mm²</td>
<td>2500mm²</td>
<td>2500mm²</td>
<td>28°C/W</td>
</tr>
<tr>
<td>100mm²</td>
<td>2500mm²</td>
<td>2500mm²</td>
<td>2500mm²</td>
<td>31°C/W</td>
</tr>
</tbody>
</table>

*Device is mounted on topside

Table 4. ST Package, 3-Lead SOT-223

<table>
<thead>
<tr>
<th>COFFER AREA</th>
<th>TOPSIDE*</th>
<th>BACKSIDE</th>
<th>BOARD AREA</th>
<th>THERMAL RESISTANCE (JUNCTION-TO-AMBIENT)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2500mm²</td>
<td>2500mm²</td>
<td>2500mm²</td>
<td>2500mm²</td>
<td>23°C/W</td>
</tr>
<tr>
<td>1000mm²</td>
<td>2500mm²</td>
<td>2500mm²</td>
<td>2500mm²</td>
<td>23°C/W</td>
</tr>
<tr>
<td>225mm²</td>
<td>2500mm²</td>
<td>2500mm²</td>
<td>2500mm²</td>
<td>25°C/W</td>
</tr>
<tr>
<td>100mm²</td>
<td>2500mm²</td>
<td>2500mm²</td>
<td>2500mm²</td>
<td>27°C/W</td>
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</table>

*Device is mounted on topside

Table 5. M Package, 3-Lead DD-Pak

<table>
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<tr>
<th>COFFER AREA</th>
<th>TOPSIDE*</th>
<th>BACKSIDE</th>
<th>BOARD AREA</th>
<th>THERMAL RESISTANCE (JUNCTION-TO-AMBIENT)</th>
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<tbody>
<tr>
<td>2500mm²</td>
<td>2500mm²</td>
<td>2500mm²</td>
<td>2500mm²</td>
<td>13°C/W</td>
</tr>
<tr>
<td>1000mm²</td>
<td>2500mm²</td>
<td>2500mm²</td>
<td>2500mm²</td>
<td>14°C/W</td>
</tr>
<tr>
<td>225mm²</td>
<td>2500mm²</td>
<td>2500mm²</td>
<td>2500mm²</td>
<td>16°C/W</td>
</tr>
</tbody>
</table>

*Device is mounted on topside

For further information on thermal resistance and using thermal information, refer to JEDEC standard JESD51, notably JESD51-12.

PCB layers, copper weight, board layout and thermal vias affect the resultant thermal resistance. Tables 3 through 5 provide thermal resistance numbers for best-case 4-layer boards with 1oz internal and 2oz external copper. Modern, multilayer PCBs may not be able to achieve quite the same
level performance as found in these tables. Demo circuit DC2279A’s board layout using multiple inner VOUT planes and multiple thermal vias achieves 18°C/W performance for the DD package.

**Calculating Junction Temperature**

Example: Given an output voltage of 0.9V, an IN voltage of 2.5V ±5%, output current range from 10mA to 0.5A and a maximum ambient temperature of 50°C, what is the maximum junction temperature for the DD-Pak on a 2500mm2 board with topside copper of 1000mm2?

The power in the circuit equals:

\[ P_{\text{TOTAL}} = (V_{\text{IN}} - V_{\text{OUT}})I_{\text{OUT}} \]

The current delivered to the SET pin is negligible and can be ignored.

\[ V_{\text{IN(MAX CONTINUOUS)}} = 2.625V \ (2.5V + 5\%) \]

\[ V_{\text{OUT}} = 0.9V, \ I_{\text{OUT}} = 0.5A, \ T_A = 50°C \]

Power dissipation under these conditions equals:

\[ P_{\text{TOTAL}} = (2.625V - 0.9V)(0.5A) = 0.87W \]

Junction Temperature equals:

\[ T_J = T_A + P_{\text{TOTAL}} \cdot \theta_{JA} \ (\text{using tables}) \]

\[ T_J = 50°C + 0.87W \cdot 14°C/W = 62°C \]

In this case, the junction temperature is below the maximum rating, ensuring reliable operation.

Reducing Power Dissipation

In some applications it may be necessary to reduce the power dissipation in the LT3088 package without sacrificing output current capability. Two techniques are available. The first technique, illustrated in Figure 14, employs a resistor in series with the regulator’s input. The voltage drop across RS decreases the LT3088’s IN-to-OUT differential voltage and correspondingly decreases the LT3088’s power dissipation.

As an example, assume: \( V_{\text{IN}} = 7V, \ V_{\text{OUT}} = 3.3V \) and \( I_{\text{OUT(MAX)}} = 0.8A \). Use the formulas from the Calculating Junction Temperature section previously discussed.

Without series resistor \( R_S \), power dissipation in the LT3088 equals:

\[ P_{\text{TOTAL}} = (7V - 3.3V) \cdot 0.8A = 2.96W \]

If the voltage differential \( (V_{\text{DIFF}}) \) across the LT3088 is chosen as 1.5V, then \( R_S \) equals:

\[ R_S = \frac{7V - 3.3V - 1.5V}{0.8A} = 2.75Ω \]

Power dissipation in the LT3088 now equals:

\[ P_{\text{TOTAL}} = 1.5V \cdot 0.8A = 1.2W \]

The LT3088’s power dissipation is now only 40% compared to no series resistor. \( R_S \) dissipates 1.75W of power. Choose appropriate wattage resistors or use multiple resistors in parallel to handle and dissipate the power properly.

**Figure 14. Reducing Power Dissipation Using a Series Resistor**
The second technique for reducing power dissipation, shown in Figure 15, uses a resistor in parallel with the LT3088. This resistor provides a parallel path for current flow, reducing the current flowing through the LT3088. This technique works well if input voltage is reasonably constant and output load current changes are small. This technique also increases the maximum available output current at the expense of minimum load requirements.

As an example, assume: \(V_{IN} = 5\text{V}\), \(V_{IN(\text{MAX})} = 5.5\text{V}\), \(V_{OUT} = 3.3\text{V}\), \(V_{OUT(\text{MIN})} = 3.2\text{V}\), \(I_{OUT(\text{MAX})} = 0.8\text{A}\) and \(I_{OUT(\text{MIN})} = 0.3\text{A}\). Also, assuming that \(R_P\) carries no more than 90% of \(I_{OUT(\text{MIN})} = 270\text{mA}\).

Calculating \(R_P\) yields:

\[
R_P \approx \frac{5.5\text{V} - 3.2\text{V}}{0.27\text{A}} = 8.52\Omega
\]

(5% Standard value = 9.1\(\Omega\))

The maximum total power dissipation is:

\[
(5.5\text{V} - 3.2\text{V}) \times 0.8\text{A} = 1.84\text{W}
\]

However, the LT3088 supplies only:

\[
0.8\text{A} - \frac{5.5\text{V} - 3.2\text{V}}{9.1\Omega} = 0.55\text{A}
\]

Therefore, the LT3088’s power dissipation is only:

\[
P_{\text{DISS}} = (5.5\text{V} - 3.2\text{V}) \times 0.55\text{A} = 1.26\text{W}
\]

\(R_P\) dissipates 0.58W of power. As with the first technique, choose appropriate wattage resistors to handle and dissipate the power properly. With this configuration, the LT3088 supplies only 0.55A. Therefore, load current can increase by 0.25A to a total output current of 1.05A while keeping the LT3088 in its normal operating range.

High Temperature Operation

Care must be taken when designing the LT3088H/LT3088MP applications to operate at high ambient temperatures. The LT3088H/LT3088MP operates at high temperatures, but erratic operation can occur due to unforeseen variations in external components. Some tantalum capacitors are available for high temperature operation, but ESR is often several ohms; capacitor ESR above 0.5\(\Omega\) is unsuitable for use with the LT3088H/LT3088MP. Multiple ceramic capacitor manufacturers now offer ceramic capacitors that are rated to 150°C using an X8R dielectric. Check each passive component for absolute value and voltage ratings over the operating temperature range.

Leakages in capacitors or from solder flux left after insufficient board cleaning adversely affects low current nodes, such as the SET pins. Consider junction temperature increase due to power dissipation in both the junction and nearby components to ensure maximum specifications are not violated for the LT3088H/LT3088MP or external components.

![Figure 15. Reducing Power Dissipation Using a Parallel Resistor](image)
APPLICATIONS INFORMATION

Protection Features

The LT3088 incorporates several protection features ideal for harsh industrial and automotive environments, among other applications. In addition to normal monolithic regulator protection features such as current limiting and thermal limiting, the LT3088 protects itself against reverse-input voltages, reverse-output voltages, and large OUT-to-SET pin voltages.

Current limit protection and thermal overload protection protect the IC against output current overload conditions. For normal operation, do not exceed the rated absolute maximum junction temperature. The thermal shutdown circuit’s temperature threshold is typically 165°C and incorporates about 5°C of hysteresis.

The LT3088’s IN pin withstands ±40V voltages with respect to the OUT and SET pins. Reverse current flow, if OUT is greater than IN, is less than 1mA (typically under 100µA), protecting the LT3088 and sensitive loads.

Clamping diodes and 400Ω limiting resistors protect the LT3088’s SET pin relative to the OUT pin voltage. These protection components typically only carry current under transient overload conditions. These devices are sized to handle ±10V differential voltages and ±25mA crosspin current flow without damage. Relative to these application concerns, note the following two scenarios. The first scenario employs a noise-reducing SET pin bypass capacitor while OUT is instantaneously shorted to GND. The second scenario follows improper shutdown techniques in which the SET pin is reset to GND quickly while OUT is held up by a large output capacitance with light load. During normal operation, keep OUT-to-SET differential voltages below 2V.

TYPICAL APPLICATIONS

Paralleling Regulators

Boosting Fixed Output Regulators

*4mV DROP ENSURES LT3088 IS OFF WITH NO LOAD MULTIPLE LT3088s CAN BE USED
TYPICAL APPLICATIONS

Reference Buffer

![Reference Buffer Diagram]

Adding Soft-Start

![Adding Soft-Start Diagram]

Using a Lower Value Set Resistor

![Using a Lower Value Set Resistor Diagram]

Using an External Reference Current

![Using an External Reference Current Diagram]
PACKAGE DESCRIPTION

Please refer to http://www.linear.com/product/LT3088#packaging for the most recent package drawings.

DD Package
8-Lead Plastic DFN (3mm × 3mm)
(Reference LTC DWG # 05-08-1698 Rev C)

NOTE:
1. DRAWING TO BE MADE A JEDEC PACKAGE OUTLINE M0-229 VARIATION OF (WEED-1)
2. DRAWING NOT TO SCALE
3. ALL DIMENSIONS ARE IN MILLIMETERS
4. DIMENSIONS OF EXPOSED PAD ON BOTTOM OF PACKAGE DO NOT INCLUDE MOLD FLASH. MOLD FLASH, IF PRESENT, SHALL NOT EXCEED 0.15mm ON ANY SIDE
5. EXPOSED PAD SHALL BE SOLDER PLATED
6. SHADED AREA IS ONLY A REFERENCE FOR PIN 1 LOCATION ON TOP AND BOTTOM OF PACKAGE

Recommended Solder Pad Pitch and Dimensions
Apply solder mask to areas that are not soldered.

For more information www.linear.com/LT3088
PACKAGE DESCRIPTION

Please refer to http://www.linear.com/product/LT3088#packaging for the most recent package drawings.

ST Package
3-Lead Plastic SOT-223
(Reference LTC DWG # 05-08-1630)
PACKAGE DESCRIPTION

Please refer to [http://www.linear.com/product/LT3088#packaging](http://www.linear.com/product/LT3088#packaging) for the most recent package drawings.

**M Package**
3-Lead Plastic DD Pak
(Reference LTC DWG # 05-08-1460 Rev F)

BOTTOM VIEW OF DD PAK
HATCHED AREA IS SOLDER PLATED COPPER HEAT SINK

RECOMMENDED SOLDER PAD LAYOUT

NOTE:
1. DIMENSIONS IN INCH/(MILLIMETER)
2. DRAWING NOT TO SCALE
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<td>LT1965</td>
<td>1.1A, Low Noise, Low Dropout Linear Regulator</td>
<td>290mV Dropout Voltage, Low Noise: $40\mu V_{RMS}$, $V_{IN} = 1.8V$ to 19.5V, Stable with Ceramic Capacitors, TO-220, DD-Pak, MSOP and 3mm x 3mm DFN Packages</td>
</tr>
<tr>
<td>LT3022</td>
<td>1A, Low Voltage, VLD0 Linear Regulator</td>
<td>$V_{IN} = 0.9V$ to 10V, Dropout Voltage: 145mV Typical, Adjustable Output ($V_{REF} = V_{OUT(MIN)} = 200mV$), Stable with Low ESR, Ceramic Output Capacitors, 16-Pin DFN (5mm x 3mm) and 16-Lead MSOP Packages</td>
</tr>
<tr>
<td>LT3070</td>
<td>5A, Low Noise, Programmable $V_{OUT}$, 85mV Dropout Linear Regulator with Digital Margining</td>
<td>Dropout Voltage: 85mV, Digitally Programmable $V_{OUT}$, 0.8V to 1.8V, Digital Output Margining: ±1%, ±3% or ±5%, Low Output Noise: 25µV RMS (10Hz to 1kHz), Parallelable: Use Two for a 10A Output, Stable with Low ESR Ceramic Output Capacitors (15µF Minimum), 28-Lead 4mm x 5mm QFN Package</td>
</tr>
<tr>
<td>LT3071</td>
<td>5A, Low Noise, Programmable $V_{OUT}$, 85mV Dropout Linear Regulator with Analog Margining</td>
<td>Dropout Voltage: 85mV, Digitally Programmable $V_{OUT}$, 0.8V to 1.8V, Analog Margining: ±10%, Low Output Noise: 25µV RMS (10Hz to 1kHz), Parallelable: Use Two for a 10A Output, $I_{MON}$ Output Current Monitor, Stable with Low ESR Ceramic Output Capacitors (15µF Minimum) 28-Lead 4mm x 5mm QFN Package</td>
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<tr>
<td>LT3080/</td>
<td>1.1A, Parallelable, Low Noise, Low Dropout Linear Regulator</td>
<td>300mV Dropout Voltage (2-Supply Operation), Low Noise: $40\mu V_{RMS}$, $V_{IN} = 1.2V$ to 36V, $V_{OUT}$: 0V to 35.7V, Current-Based Reference with 1-Resistor $V_{OUT}$ Set; Directly Parallelable (No Op Amp Required), Stable with Ceramic Capacitors, TO-220, DD-Pak, SOT-223, MS8E and 3mm x 3mm DFN-8 Packages; LT3080-1 Version Has Integrated Internal Ballast Resistor</td>
</tr>
<tr>
<td>LT3080A/</td>
<td>200mA, Parallelable, Single Resistor, Low Dropout Linear Regulator</td>
<td>Outputs May Be Paralleled for Higher Output, Current or Heat Spreading, Wide Input Voltage Range: 1.2V to 40V Low Value Input/Output Capacitors Required: 2.2µF, Single Resistor Sets Output Voltage 8-Lead SOT-23, 3-Lead SOT-223 and 8-Lead 3mm x 3mm DFN-8 Packages</td>
</tr>
<tr>
<td>LT3083</td>
<td>Adjustable 3A Single Resistor Low Dropout Regulator</td>
<td>Low Noise: $40\mu V_{RMS}$, 50µA Set Pin Current, Output Adjustable to 0V, Wide Input Voltage Range: 1.2V to 23V (DD-Pak and TO-220), Low Dropout Operation: 310mV (2 Supplies)</td>
</tr>
</tbody>
</table>