

1.5A Low Dropout Positive Regulators Adjustable and Fixed 2.85V, 3.3V, 3.6V, 5V, 12V

**FEATURES**

- ▶ 3-Terminal Adjustable or Fixed 2.85V, 3.3V, 3.6V, 5V, 12V
- ▶ Output Current of 1.5A
- ▶ Operates Down to 1V Dropout
- ▶ Guaranteed Dropout Voltage at Multiple Current Levels
- ▶ Line Regulation: 0.015%
- ▶ Load Regulation: 0.1%
- ▶ 100% Thermal Limit Functional Test
- ▶ Ripple Rejection >75dB
- ▶ Available in 3-Pin TO-220 and 3-Pin DD Packages

**APPLICATIONS**

- ▶ SCSI-2 Active Terminator
- ▶ High Efficiency Linear Regulators
- ▶ Post Regulators for Switching Supplies
- ▶ Constant Current Regulators
- ▶ Battery Chargers
- ▶ Microprocessor Supply

**GENERAL DESCRIPTION**

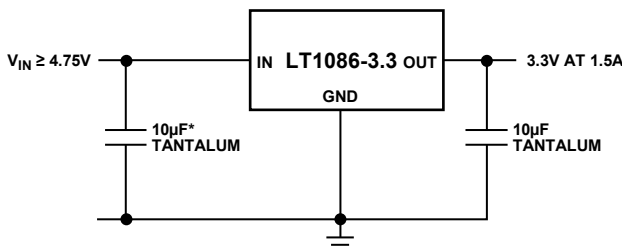
The **LT<sup>®</sup>1086** is designed to provide up to 1.5A output current. All internal circuitry is designed to operate down to 1V input-to-output differential and the dropout voltage is fully specified as a function of load current. Dropout is guaranteed at several operating points up to a maximum of 1.5V at maximum output current. Dropout decreases at lower load currents. On-chip trimming adjusts the reference/output voltage to 1%. The current limit is also trimmed, minimizing the stress on both the regulator and power source circuitry under overload conditions.

The LT1086 is pin-compatible with older 3-terminal adjustable regulators. A minimum 10μF output capacitor is required on these devices.

The LT1086 offers excellent line and load regulation specifications, and ripple rejection exceeds 75dB even at the maximum load current of 1.5A. The LT1086 is a floating architecture with a composite NPN output stage. All of the quiescent current and the drive current for the output stage flow to the load, increasing efficiency.

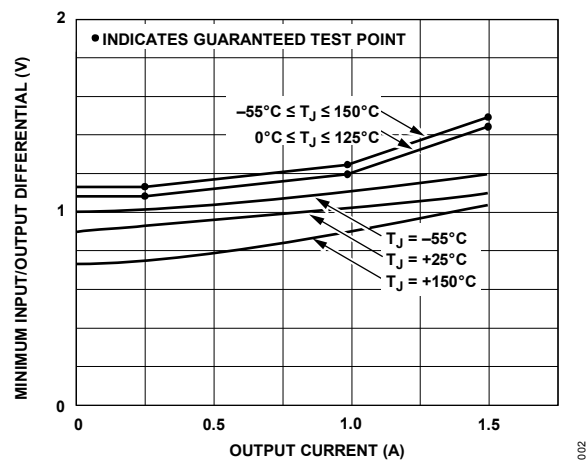
The LT1086 is available in a 3-pin TO-220 package and a space-saving surface mountable 3-pin DD package.

**TYPICAL APPLICATION**



\*MAY BE OMITTED IF INPUT SUPPLY IS WELL BYPASSED WITHIN 2" OF THE LT1086

**Figure 1. 5V to 3.3V Regulator**



**Figure 2. LT1086 Dropout Voltage**

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**REVISION HISTORY**

| <b>REVISION NUMBER</b> | <b>REVISION DATE</b> | <b>DESCRIPTION</b>  | <b>PAGES CHANGED</b> |
|------------------------|----------------------|---|----------------------|
| G                      | 10/24                | Updated to Analog Template, Removed LT1086H from the entire datasheet. Updated Features, General Description, Electrical Characteristics, Absolute Maximum Ratings, Applications Information, Typical Performance Characteristics, Package Information, and Related Parts sections. Added Ordering Information section. | 1-26                 |

## SPECIFICATIONS

**Table 1. Electrical Characteristics**

(All typical specifications are at  $T_J$  (Junction Temperature) = 25°C, and all min and max specifications are across the entire operating temperature range unless otherwise noted.)

| PARAMETER                          | CONDITIONS   | MIN    | TYP    | MAX    | UNITS |
|------------------------------------|--|--------|--------|--------|-------|
| Reference Voltage ( <sup>1</sup> ) | LT1086<br>$I_{OUT} = 10\text{mA}$ , $T_J = 25^\circ\text{C}$ ,<br>$(V_{IN} - V_{OUT}) = 3\text{V}$                         | 1.238  | 1.250  | 1.262  | V     |
|                                    | LT1086<br>$10\text{mA} \leq I_{OUT} \leq 1.5\text{A}$ ,<br>$1.5\text{V} \leq (V_{IN} - V_{OUT}) \leq 15\text{V}$           | 1.225  | 1.250  | 1.270  | V     |
| Output Voltage ( <sup>1</sup> )    | LT1086-2.85<br>$V_{IN} = 5\text{V}$ , $I_{OUT} = 0\text{mA}$ , $T_J = 25^\circ\text{C}$                                    | 2.82   | 2.85   | 2.88   | V     |
|                                    | LT1086-2.85<br>$4.35\text{V} \leq V_{IN} \leq 18\text{V}$ ,<br>$0 \leq I_{OUT} \leq 1.5\text{A}$                           | 2.79   | 2.85   | 2.91   | V     |
|                                    | LT1086-3.3<br>$V_{IN} = 5\text{V}$ , $I_{OUT} = 0\text{mA}$ , $T_J = 25^\circ\text{C}$                                     | 3.267  | 3.300  | 3.333  | V     |
|                                    | LT1086-3.3<br>$4.75\text{V} \leq V_{IN} \leq 18\text{V}$ ,<br>$0 \leq I_{OUT} \leq 1.5\text{A}$                            | 3.235  | 3.300  | 3.365  | V     |
|                                    | LT1086-3.6<br>$V_{IN} = 5\text{V}$ , $I_{OUT} = 0\text{mA}$ , $T_J = 25^\circ\text{C}$                                     | 3.564  | 3.600  | 3.636  | V     |
|                                    | LT1086-3.6<br>$5\text{V} \leq V_{IN} \leq 18\text{V}$ , $0 \leq I_{OUT} \leq 1.5\text{A}$                                  | 3.500  |        | 3.672  | V     |
|                                    | LT1086-3.6<br>$4.75\text{V} \leq V_{IN} \leq 18\text{V}$ , $0 \leq I_{OUT} \leq 1\text{A}$ ,<br>$T_J \geq 0^\circ\text{C}$ | 3.500  |        | 3.672  | V     |
|                                    | LT1086-3.6<br>$V_{IN} = 4.75\text{V}$ , $I_{OUT} = 1.5\text{A}$ , $T_J \geq 0^\circ\text{C}$                               | 3.300  |        | 3.672  | V     |
|                                    | LT1086-5<br>$V_{IN} = 8\text{V}$ , $I_{OUT} = 0\text{mA}$ , $T_J = 25^\circ\text{C}$                                       | 4.950  | 5.000  | 5.050  | V     |
|                                    | LT1086-5<br>$6.5\text{V} \leq V_{IN} \leq 20\text{V}$ , $0 \leq I_{OUT} \leq 1.5\text{A}$                                  | 4.900  | 5.000  | 5.100  | V     |
|                                    | LT1086-12<br>$V_{IN} = 15\text{V}$ , $I_{OUT} = 0\text{mA}$ , $T_J = 25^\circ\text{C}$                                     | 11.880 | 12.000 | 12.120 | V     |
|                                    | LT1086-12<br>$13.5\text{V} \leq V_{IN} \leq 25\text{V}$ ,<br>$0 \leq I_{OUT} \leq 1.5\text{A}$                             | 11.760 | 12.000 | 12.240 | V     |

( All typical specifications are at  $T_J$  (Junction Temperature) = 25°C, and all min and max specifications are across the entire operating temperature range unless otherwise noted.)

| PARAMETER   | CONDITIONS   | MIN   | TYP   | MAX | UNITS |
|---|--|---|-------|-----|-------|
| Line Regulation   | LT1086<br>$I_{OUT} = 10\text{mA}$ , $1.5\text{V} \leq (V_{IN} - V_{OUT}) \leq 15\text{V}$ , $T_J = 25^\circ\text{C}$ |   | 0.015 | 0.2 | %     |
|   | LT1086<br>$I_{OUT} = 10\text{mA}$ ,<br>$1.5\text{V} \leq (V_{IN} - V_{OUT}) \leq 15\text{V}$                         |   | 0.035 | 0.2 | %     |
|   | LT1086-2.85<br>$I_{OUT} = 0\text{mA}$ , $4.35\text{V} \leq V_{IN} \leq 18\text{V}$ ,<br>$T_J = 25^\circ\text{C}$     |   | 0.3   | 6   | mV    |
|   | LT1086-2.85<br>$I_{OUT} = 0\text{mA}$ , $4.35\text{V} \leq V_{IN} \leq 18\text{V}$                                   |   | 0.6   | 6   | mV    |
|   | LT1086-3.3<br>$I_{OUT} = 0\text{mA}$ , $4.5\text{V} \leq V_{IN} \leq 18\text{V}$ ,<br>$T_J = 25^\circ\text{C}$       |   | 0.5   | 10  | mV    |
|   | LT1086-3.3<br>$I_{OUT} = 0\text{mA}$ , $4.5\text{V} \leq V_{IN} \leq 18\text{V}$                                     |   | 1.0   | 10  | mV    |
|   | LT1086-3.6<br>$I_{OUT} = 0\text{mA}$ , $4.75\text{V} \leq V_{IN} \leq 18\text{V}$ ,<br>$T_J = 25^\circ\text{C}$      |   | 0.5   | 10  | mV    |
|   | LT1086-3.6<br>$I_{OUT} = 0\text{mA}$ , $4.75\text{V} \leq V_{IN} \leq 18\text{V}$                                    |   | 1.0   | 10  | mV    |
|   | LT1086-5<br>$I_{OUT} = 0\text{mA}$ , $6.5\text{V} \leq V_{IN} \leq 18\text{V}$ ,<br>$T_J = 25^\circ\text{C}$         |   | 0.5   | 10  | mV    |
|   | LT1086-5<br>$I_{OUT} = 0\text{mA}$ , $6.5\text{V} \leq V_{IN} \leq 18\text{V}$                                       |   | 1.0   | 10  | mV    |
|   | LT1086-12<br>$I_{OUT} = 0\text{mA}$ , $13.5\text{V} \leq V_{IN} \leq 18\text{V}$ ,<br>$T_J = 25^\circ\text{C}$       |   | 1.0   | 25  | mV    |
|   | LT1086-12<br>$I_{OUT} = 0\text{mA}$ , $13.5\text{V} \leq V_{IN} \leq 18\text{V}$                                     |   | 2.0   | 25  | mV    |
|   | Load Regulation  | LT1086<br>$(V_{IN} - V_{OUT}) = 3\text{V}$ , $10\text{mA} \leq I_{OUT} \leq 1.5\text{A}$ , $T_J = 25^\circ\text{C}$ ( <a href="#">1.2</a> ) |       | 0.1 | 0.3   |
| LT1086<br>$(V_{IN} - V_{OUT}) = 3\text{V}$ ,<br>$10\text{mA} \leq I_{OUT} \leq 1.5\text{A}$ ( <a href="#">1.2</a> ) |  |   | 0.2   | 0.4 | %     |

( All typical specifications are at  $T_J$  (Junction Temperature) = 25°C, and all min and max specifications are across the entire operating temperature range unless otherwise noted.)

| PARAMETER                              | CONDITIONS   | MIN  | TYP  | MAX | UNITS |
|--|--|------|------|-----|-------|
|  | LT1086-2.85<br>$V_{IN} = 5V, 0 \leq I_{OUT} \leq 1.5A,$<br>$T_J = 25^\circ C$ (1,2)              |      | 3    | 12  | mV    |
|  | LT1086-2.85<br>$V_{IN} = 5V, 0 \leq I_{OUT} \leq 1.5A$ (1,2)                                     |      | 6    | 20  | mV    |
|  | LT1086-3.3<br>$V_{IN} = 5V, 0 \leq I_{OUT} \leq 1.5A,$<br>$T_J = 25^\circ C$ (1,2)               |      | 3    | 15  | mV    |
|  | LT1086-3.3<br>$V_{IN} = 5V, 0 \leq I_{OUT} \leq 1.5A$ (1,2)                                      |      | 7    | 25  | mV    |
|  | LT1086-3.6<br>$V_{IN} = 5.25V, 0 \leq I_{OUT} \leq 1.5A,$<br>$T_J = 25^\circ C$ (1,2)            |      | 3    | 15  | mV    |
|  | LT1086-3.6<br>$V_{IN} = 5.25V, 0 \leq I_{OUT} \leq 1.5A$ (1,2)                                   |      | 6    | 25  | mV    |
|  | LT1086-3.6<br>$V_{IN} = 5V, 0 \leq I_{OUT} \leq 1A,$<br>$T_J = 25^\circ C$ (1,2)                 |      | 2    | 15  | mV    |
|  | LT1086-3.6<br>$V_{IN} = 5V, 0 \leq I_{OUT} \leq 1A$ (1,2)  |      | 4    | 25  | mV    |
|  | LT1086-5<br>$V_{IN} = 8V, 0 \leq I_{OUT} \leq 1.5A,$<br>$T_J = 25^\circ C$ (1,2)                 |      | 5    | 20  | mV    |
|  | LT1086-5<br>$V_{IN} = 8V, 0 \leq I_{OUT} \leq 1.5A$ (1,2)  |      | 10   | 35  | mV    |
|  | LT1086-12<br>$V_{IN} = 15V, 0 \leq I_{OUT} \leq 1.5A,$<br>$T_J = 25^\circ C$ (1,2)               |      | 12   | 36  | mV    |
|  | LT1086-12<br>$V_{IN} = 15V, 0 \leq I_{OUT} \leq 1.5A$ (1,2)                                      |      | 24   | 72  | mV    |
| Dropout Voltage ( $V_{IN} - V_{OUT}$ ) | LT1086/-2.85/-3.3/-3.6/-5/-12<br>$\Delta V_{OUT}, \Delta V_{REF} = 1\%,$<br>$I_{OUT} = 1.5A$ (3) |      | 1.3  | 1.5 | V     |
| Current Limit                          | LT1086/-2.85/-3.3/-3.6/-5/-12<br>$(V_{IN} - V_{OUT}) = 5V$                                       | 1.50 | 2.00 |     | A     |

( All typical specifications are at  $T_J$  (Junction Temperature) = 25°C, and all min and max specifications are across the entire operating temperature range unless otherwise noted.)

| PARAMETER                       | CONDITIONS   | MIN  | TYP   | MAX  | UNITS |
|---------------------------------|--|------|-------|------|-------|
|                                 | LT1086/-2.85/-3.3/-3.6/-5/-12<br>( $V_{IN} - V_{OUT}$ ) = 25V  | 0.05 | 0.15  |      | A     |
| Minimum Load Current            | LT1086<br>( $V_{IN} - V_{OUT}$ ) = 25V (4)   |      | 5     | 10   | mA    |
| Quiescent Current               | LT1086-2.85<br>$V_{IN} \leq 18V$   |      | 5     | 10   | mA    |
|                                 | LT1086-3.3<br>$V_{IN} \leq 18V$  |      | 5     | 10   | mA    |
|                                 | LT1086-3.6<br>$V_{IN} \leq 18V$  |      | 5     | 10   | mA    |
|                                 | LT1086-5<br>$V_{IN} \leq 20V$  |      | 5     | 10   | mA    |
|                                 | LT1086-12<br>$V_{IN} \leq 25V$   |      | 5     | 10   | mA    |
| Thermal Regulation              | $T_A = 25^\circ C$ , 30ms pulse  |      | 0.008 | 0.04 | %/W   |
| Ripple Rejection<br>(f = 120Hz) | LT1086<br>$C_{OUT} = 25\mu F$ Tantalum,<br>$I_{OUT} = 1.5A$ , $C_{ADJ} = 25\mu F$ ,<br>( $V_{IN} - V_{OUT}$ ) = 3V | 60   | 75    |      | dB    |
| Ripple Rejection<br>(f = 120Hz) | LT1086-2.85<br>$C_{OUT} = 25\mu F$ Tantalum,<br>$I_{OUT} = 1.5A$ , $V_{IN} = 6V$                                   | 60   | 72    |      | dB    |
|                                 | LT1086-3.3<br>$C_{OUT} = 25\mu F$ Tantalum,<br>$I_{OUT} = 1.5A$ , $V_{IN} = 6.3V$                                  | 60   | 72    |      | dB    |
|                                 | LT1086-3.6<br>$C_{OUT} = 25\mu F$ Tantalum,<br>$I_{OUT} = 1.5A$ , $V_{IN} = 6.6V$                                  | 60   | 72    |      | dB    |
|                                 | LT1086-5<br>$C_{OUT} = 25\mu F$ Tantalum,<br>$I_{OUT} = 1.5A$ , $V_{IN} = 8V$                                      | 60   | 68    |      | dB    |
|                                 | LT1086-12<br>$C_{OUT} = 25\mu F$ Tantalum,<br>$I_{OUT} = 1.5A$ , $V_{IN} = 15V$                                    | 54   | 60    |      | dB    |

( All typical specifications are at  $T_J$  (Junction Temperature) = 25°C, and all min and max specifications are across the entire operating temperature range unless otherwise noted.)

| PARAMETER                                    | CONDITIONS  | MIN | TYP   | MAX     | UNITS                     |
|--|---|-----|-------|---------|---------------------------|
| Adjust Pin Current                           | LT1086  |     | 55    |         | $\mu\text{A}$             |
|  |   |     |       | 120     | $\mu\text{A}$             |
| Adjust Pin Current Change                    | LT1086<br>$10\text{mA} \leq I_{\text{OUT}} \leq 1.5\text{A}$ ,<br>$1.5\text{V} \leq (V_{\text{IN}} - V_{\text{OUT}}) \leq 15\text{V}$ |     | 0.2   | 5       | $\mu\text{A}$             |
| Temperature Stability                        | $-40^\circ\text{C} \leq T_J \leq 150^\circ\text{C}$   |     | 0.5   |         | %                         |
| Long-Term Stability                          | $T_A = 125^\circ\text{C}$ , 1000 Hrs.,<br>$T_J = 25^\circ\text{C}$  |     | 0.3   | 1       | %                         |
| RMS Output Noise<br>(% of $V_{\text{OUT}}$ ) | $10\text{Hz} \leq f \leq 10\text{kHz}$  |     | 0.003 |         | %                         |
| Thermal Resistance Junction-to-Case          | M Package: Control<br>Circuitry/Power Transistor  |     |       | 1.5/4.0 | $^\circ\text{C}/\text{W}$ |
|  | T Package: Control<br>Circuitry/Power Transistor  |     |       | 1.5/4.0 | $^\circ\text{C}/\text{W}$ |

1 Line and load regulations are guaranteed up to the maximum power dissipation of 15W. Power dissipation is determined by the input/output differential and the output current. Guaranteed maximum power dissipation will not be available over the full input/output range. See the Short-Circuit Current curve for available output current.

2 See Thermal Regulation specifications for changes in output voltage due to heating effects. Line and load regulation are measured at a constant junction temperature by low-duty cycle pulse testing. Load regulation is measured at the output lead  $\approx 1/8$ " from the package.

3 Dropout voltage is specified over the full output current range of the device. Test points and limits are shown on the Dropout Voltage curve.

4 Minimum load current is defined as the minimum output current required to maintain regulation. At 25V input/output differential, the device is guaranteed to regulate if the output current is greater than 10mA.



## ABSOLUTE MAXIMUM RATINGS

$T_A = 25^\circ\text{C}$  unless otherwise specified.

**Table 2. Absolute Maximum Ratings**

| PARAMETER                            | RATING             |
|--------------------------------------|--------------------|
| Power Dissipation                    | Internally Limited |
| Input Voltage <sup>1</sup>           | 30V                |
| Operating Input Voltage              |                    |
| Adjustable Devices                   | 25V                |
| 2.85V Devices                        | 18V                |
| 3.3V, 3.6V, and 5V Devices           | 20V                |
| 12V Devices                          | 25V                |
| Operating Junction Temperature Range |                    |
| "C" Grades                           |                    |
| Control Section                      | 0°C to 125°C       |
| Power Transistor                     | 0°C to 150°C       |
| "I" Grades                           |                    |
| Control Section                      | -40°C to 125°C     |
| Power Transistor                     | -40°C to 150°C     |
| Storage Temperature Range            | -65°C to 150°C     |
| Lead Temperature (Soldering, 10 sec) | 300°C              |

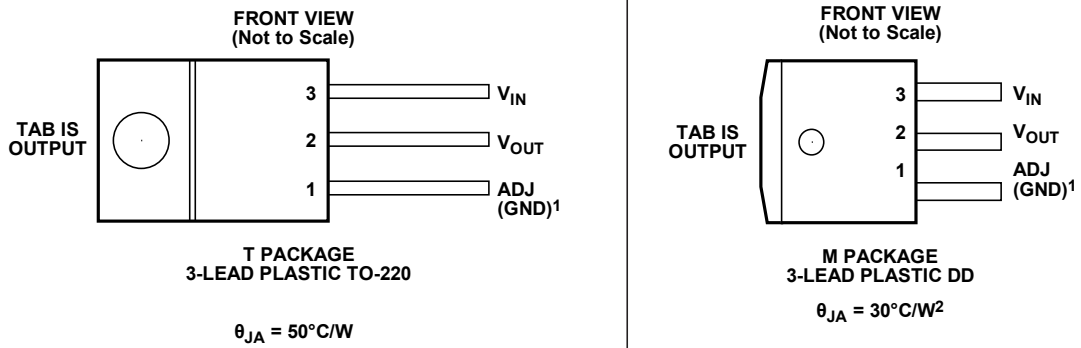
<sup>1</sup> Although the device's maximum operating voltage is limited, (18V for a 2.85V device, 20V for a 5V device, and 25V for adjustable and 12V devices), the devices are guaranteed to withstand transient input voltages up to 30V. For input voltages greater than the maximum operating input voltage some degradation of specifications will occur. For fixed voltage devices operating at input/output voltage differentials greater than 15V, a minimum external load of 5mA is required to maintain regulation.

Stresses beyond those listed under Absolute Maximum Ratings may cause permanent damage to the device. These are stress ratings only, functional operation of the product at these or any other conditions above those indicated in the operational section of this specification is not implied. Operation beyond the maximum operating conditions for extended periods may affect product reliability.

## PRECONDITIONING

100% Thermal Shutdown Functional Test.

PIN CONFIGURATIONS



<sup>1</sup> FOR FIXED VERSIONS.

<sup>2</sup> WITH PACKAGE SOLDERED TO 0.5IN<sup>2</sup> COPPER AREA OVER BACKSIDE GROUND PLANE OR INTERNAL POWER PLANE.  $\theta_{JA}$  CAN VARY FROM 20°C/W TO >40°C/W DEPENDING ON MOUNTING TECHNIQUE.

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Figure 3. Pin Configurations

TYPICAL PERFORMANCE CHARACTERISTICS

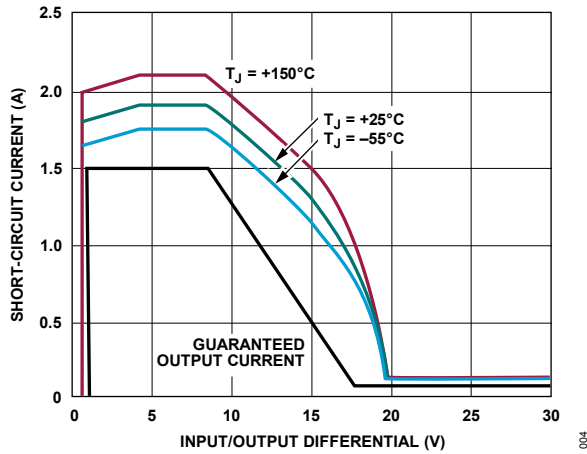


Figure 4. LT1086 Short-Circuit Current

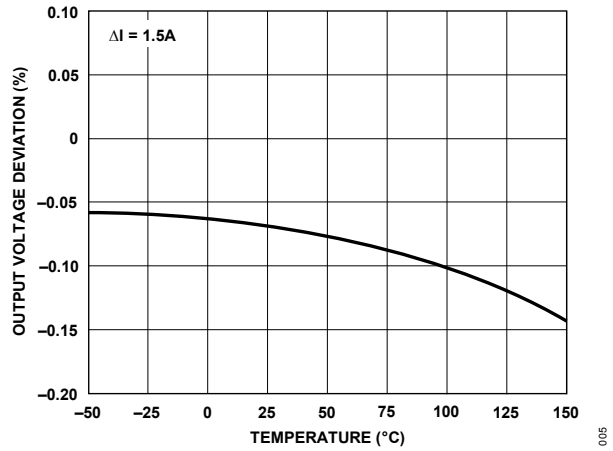


Figure 5. LT1086 Load Regulation

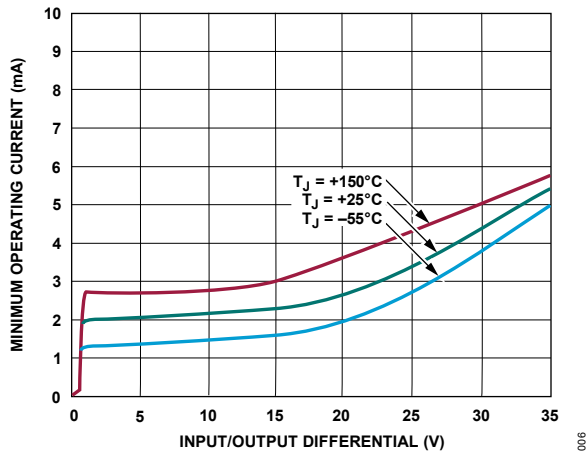


Figure 6. Minimum Operating Current (Adjustable Device)

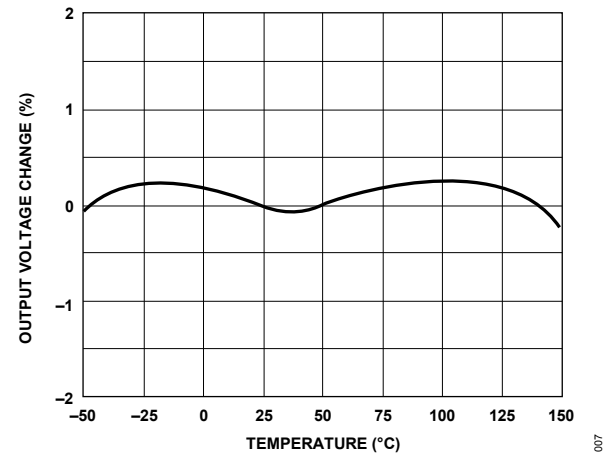


Figure 7. Temperature Stability

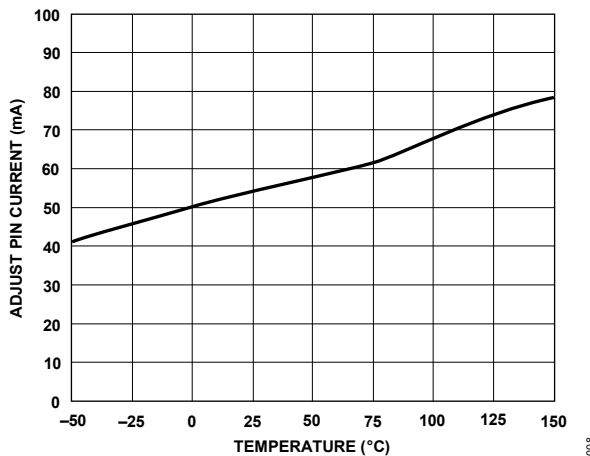


Figure 8. Adjust Pin Current

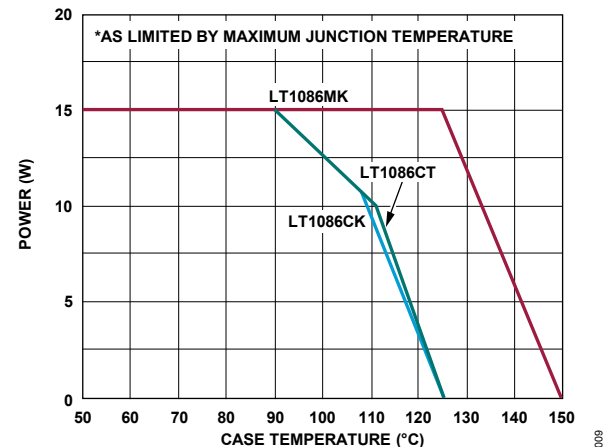


Figure 9. LT1086 Maximum Power Dissipation\*

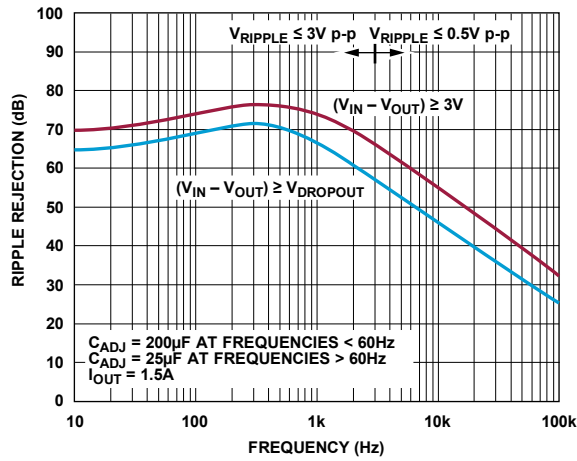


Figure 10. LT1086 Ripple Rejection

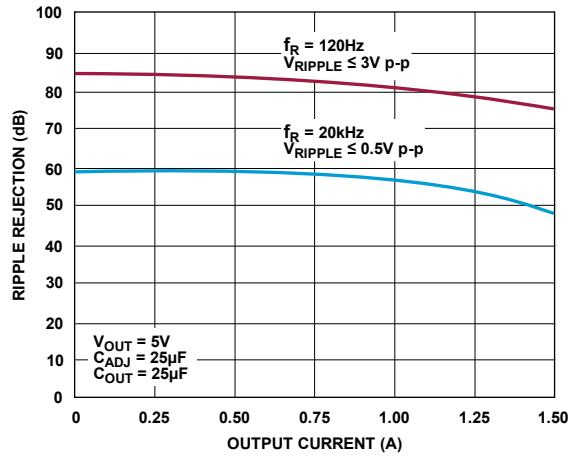


Figure 11. LT1086 Ripple Rejection vs Current

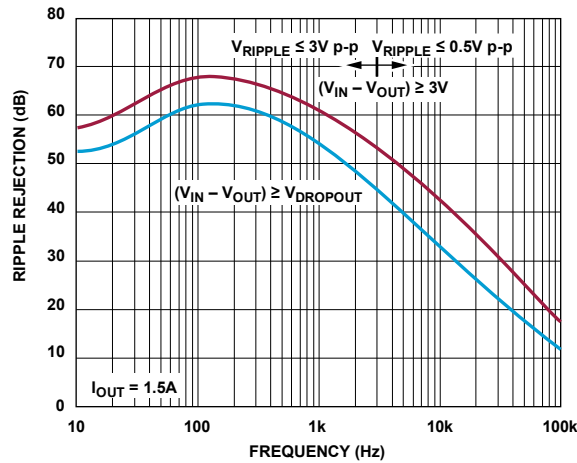


Figure 12. LT1086-5 Ripple Rejection

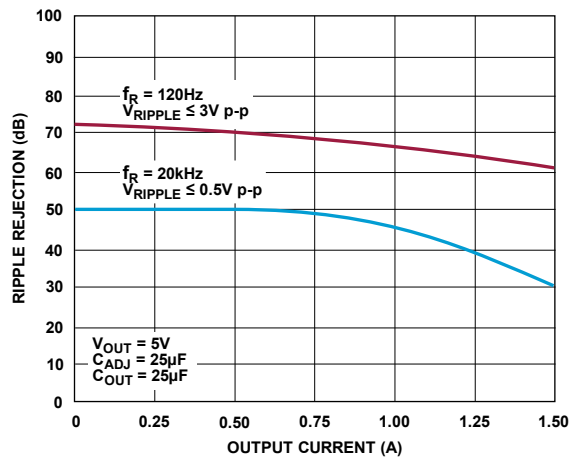


Figure 13. LT1086-5 Ripple Rejection vs Current

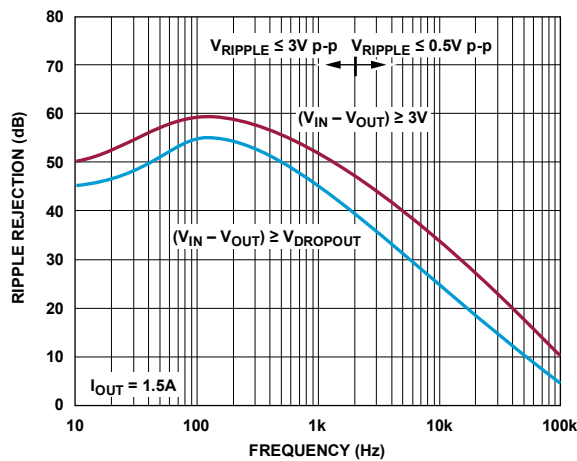


Figure 14. LT1086-12 Ripple Rejection

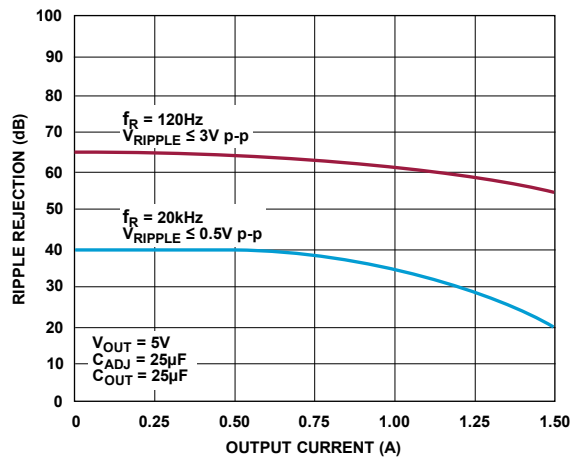


Figure 15. LT1086-12 Ripple Rejection vs Current

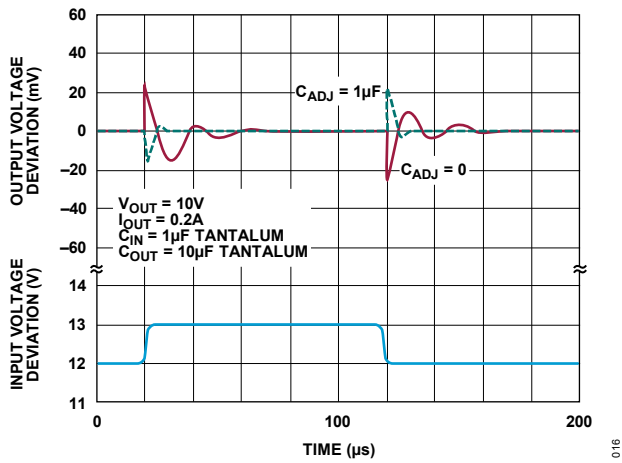


Figure 16. LT1086 Line Transient Response

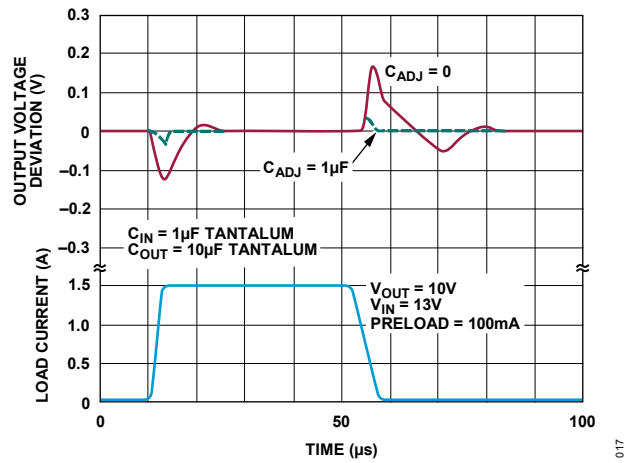
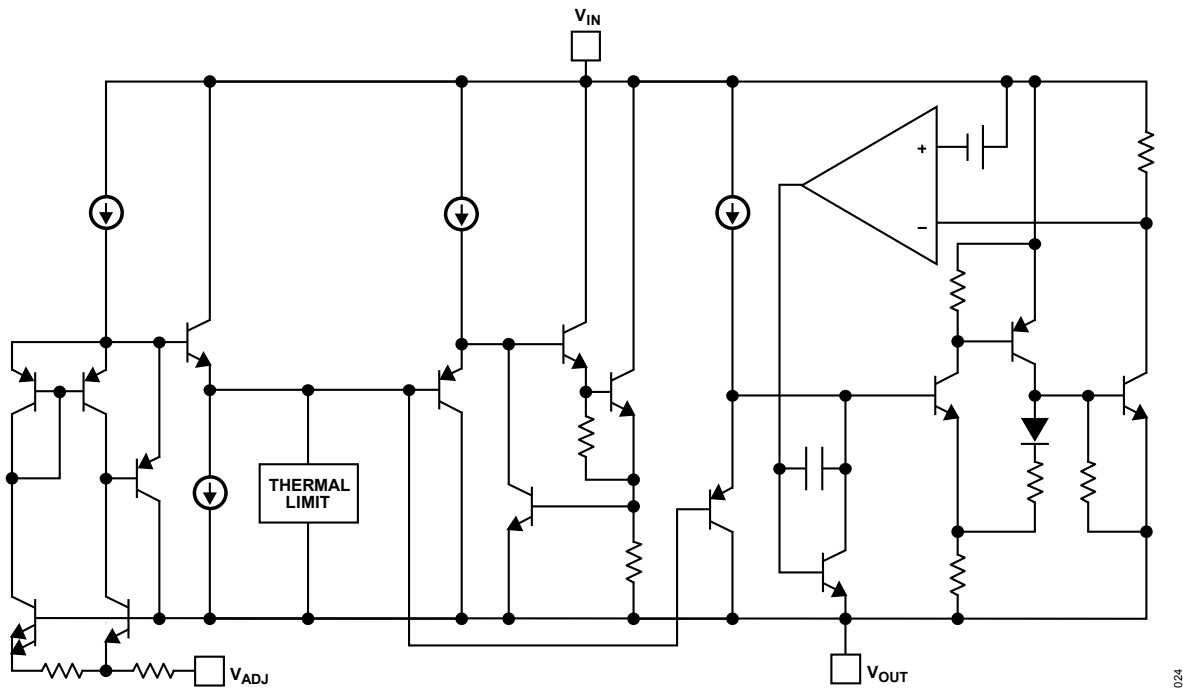


Figure 17. LT1086 Load Transient Response

## BLOCK DIAGRAM



## APPLICATIONS INFORMATION

The LT1086 family of 3-terminal regulators is easy to use and has all the protection features that are expected in high-performance voltage regulators. They are short-circuit protected and have safe area protection as well as a thermal shutdown to turn off the regulator should the temperature exceed about 165°C at the sense point.

These regulators are pin compatible with older 3-terminal adjustable devices, offer lower dropout voltage and more precise reference tolerance. Further, the reference stability with temperature is improved over older types of regulators. The only circuit difference between using the LT1086 family and older regulators is that they require an output capacitor for stability.

### Stability

The circuit design used in the LT1086 family requires the use of an output capacitor as part of the device frequency compensation. For all operating conditions, the addition of 150 $\mu$ F aluminum electrolytic or a 22 $\mu$ F solid tantalum on the output will ensure stability. Normally, capacitors much smaller than this can be used with the LT1086. Many different types of capacitors with widely varying characteristics are available. These capacitors differ in capacitor tolerance (sometimes ranging up to  $\pm 100\%$ ), equivalent series resistance, and capacitance temperature coefficient. The 150 $\mu$ F or 22 $\mu$ F values given will ensure stability.

When using the LT1086, the adjustment terminal can be bypassed to improve ripple rejection. When the adjustment terminal is bypassed, the requirement for an output capacitor increases. The values of 22 $\mu$ F tantalum or 150 $\mu$ F aluminum cover all cases of bypassing the adjustment terminal. For fixed voltage devices or adjustable devices without an adjust pin bypass capacitor, smaller output capacitors can be used with equally good results. The table below shows approximately what size capacitors are needed to ensure stability.

**Table 3. Recommended Capacitor Values**

| INPUT      | OUTPUT                                    | ADJUSTMENT |
|------------|---|------------|
| 10 $\mu$ F | 10 $\mu$ F Tantalum, 50 $\mu$ F Aluminum  | None       |
| 10 $\mu$ F | 22 $\mu$ F Tantalum, 150 $\mu$ F Aluminum | 20 $\mu$ F |

Normally, capacitor values on the order of 100 $\mu$ F are used in the output of many regulators to ensure good transient response with heavy load current changes. Output capacitance can be increased without limit, and larger values of output capacitors further improve the stability and transient response of the LT1086 regulators.

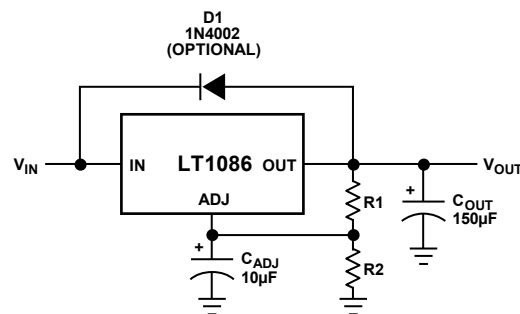
Another possible stability problem that can occur in monolithic IC regulators is current limit oscillations. These can occur because in current limit, the safe area protection exhibits a negative impedance. The safe area protection decreases the current limit as the input-to-output voltage increases. That is the equivalent of having a negative resistance since increasing voltage causes current to decrease. Negative resistance during current limit is not unique to the LT1086 series and has been present on all power IC regulators. The value of negative resistance is a function of how fast the current limit is folded back as input-to-output voltage increases. This negative resistance can react with capacitors or inductors on the input to cause oscillation during current limiting. Depending on the value of series resistance, the overall circuitry may end up unstable. Since this is a system problem, it is not necessarily easy to solve; however, it does not cause any problems with the IC regulator and can usually be ignored.

## Protection Diodes

In normal operation, the LT1086 family does not need any protection diodes. Older adjustable regulators required protection diodes between the adjustment pin and the output and from the output to the input to prevent overstressing the die. The internal current paths on the LT1086 adjustment pin are limited by internal resistors. Therefore, even with capacitors on the adjustment pin, no protection diode is needed to ensure device safety under short-circuit conditions.

Diodes between input and output are usually not needed. The internal diode between the input and the output pins of the LT1086 family can handle microsecond surge currents of 10A to 20A. Even with large output capacitances, it is very difficult to get those values of surge currents in normal operation. Only with high value output capacitors such as 1000 $\mu$ F to 5000 $\mu$ F, and with the input pin instantaneously shorted to ground, can damage occur. A crowbar circuit at the input of the LT1086 can generate those kinds of currents and a diode from output to input is then recommended. Normal power supply cycling or even plugging and unplugging in the system will not generate a current large enough to do any damage.

The adjustment pin can be driven on a transient basis  $\pm 25$ V, with respect to the output without any device degradation. Of course, as with any IC regulator, exceeding the maximum input-to-output voltage differential causes the internal transistors to break down, and none of the protection circuitry is functional.



## Overload Recovery

Like any of the IC power regulators, the LT1086 has safe area protection. The safe area protection decreases the current limit as input-to-output voltage increases and keeps the power transistor inside a safe operating region for all values of input-to-output voltage. The LT1086 protection is designed to provide some output current at all values of input-to-output voltage up to the device breakdown.

When power is first turned on, as the input voltage rises, the output follows the input, allowing the regulator to start up into very heavy loads. During the start-up, as the input voltage is rising, the input-to-output voltage differential remains small, allowing the regulator to supply large output currents. With high input voltage, a problem can occur wherein removal of an output short will not allow the output voltage to recover. Older regulators such as the 7800 series also exhibited this phenomenon, so it is not unique to the LT1086.

The problem occurs with a heavy output load when the input voltage is high and the output voltage is low, such as immediately after a removal of a short. The load line for such a load may intersect the output current curve at two points. If this happens there are two stable output operating points for the regulator. With this double intersection the power supply may need to be cycled down to zero and brought up again to make the output recover.

## Ripple Rejection

For the LT1086 the typical curves for ripple rejection reflect values for a bypassed adjust pin. This curve will be true for all values of output voltage. For proper bypassing and ripple rejection approaching the values shown, the impedance of the adjust pin capacitor at the ripple frequency should equal the value of R1, (normally 100Ω to 120Ω). The size of the required adjust pin capacitor is a function of the input ripple frequency. At 120Hz the adjust pin capacitor should be 13μF if R1 = 100Ω; at 10kHz only 0.16μF is needed.

For circuits without an adjust pin bypass capacitor the ripple rejection will be a function of output voltage. The output ripple will increase directly as a ratio of the output voltage to the reference voltage ( $V_{OUT}/V_{REF}$ ). For example, with the output voltage equal to 5V and no adjust pin capacitor, the output ripple will be higher by the ratio of 5V/1.25V or four times larger. Ripple rejection will be degraded by 12dB from the value shown on the LT1086 curve. Typical curves are provided for the 5V and 12V devices since the adjust pin is not available.

## Output Voltage

The LT1086 develops a 1.25V reference voltage between the output and the adjust terminal (see [Figure 18](#)). By placing resistor R1 between these two terminals, a constant current is caused to flow through R1 and down through R2 to set the overall output voltage. Normally this current is chosen to be the specified minimum load current of 10mA. Because  $I_{ADJ}$  is very small and constant when compared with the current through R1, it represents a small error and can usually be ignored. For fixed voltage devices R1 and R2 are included in the device.

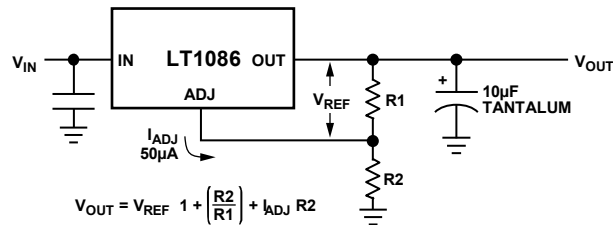


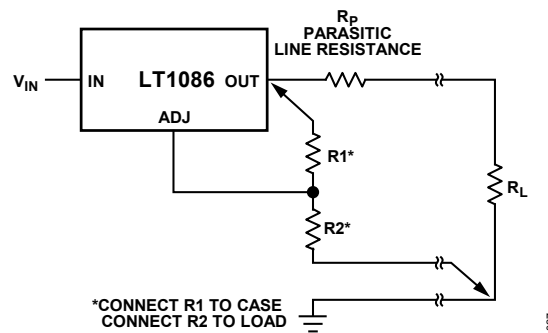
Figure 18. Basic Adjustable Regulator

## Load Regulation

Because the LT1086 is a 3-terminal device, it is not possible to provide true remote load sensing. Load regulation will be limited by the resistance of the wire connecting the regulator to the load. The data sheet specification for load regulation is measured at the bottom of the package. Negative side sensing is a true Kelvin connection, with the bottom of the output divider returned to the negative side of the load. Although it may not be immediately obvious, the best load regulation is obtained when the top of the resistor divider R1 is connected directly to the case, not to the load, as illustrated in [Figure 19](#). If R1 were connected to the load, the effective resistance between the regulator and the load would be:

$$R_P \left( \frac{R_2 + R_1}{R_1} \right), R_P = \text{Parasitic Line Resistance}$$





**Figure 19. Connections for Best Load Regulation**

Connected as shown,  $R_p$  is not multiplied by the divider ratio.  $R_p$  is about  $0.004\Omega$  per foot using a 16-gauge wire. This translates to  $4\text{mV/ft}$  at  $1\text{A}$  load current, so it is important to keep the positive lead between regulator and load as short as possible and use large wire or PC board traces.

Note that the resistance of the package leads for the H package  $\approx 0.06\Omega/\text{inch}$ . While it is usually not possible to connect the load directly to the package, it is possible to connect larger wire or PC traces close to the case to avoid voltage drops that will degrade load regulation.

For fixed voltage devices, the top of  $R1$  is internally Kelvin connected and the ground pin can be used for negative side sensing.

## Thermal Considerations

The LT1086 series of regulators have internal power and thermal limiting circuitry designed to protect the device under overload conditions. For continuous normal load conditions, however, maximum junction temperature ratings must not be exceeded. It is important to give careful consideration to all sources of thermal resistance from junction to ambient. This includes junction-to-case, case-to-heat sink interface, and heat sink resistance itself. New thermal resistance specifications have been developed to more accurately reflect device temperature and ensure safe operating temperatures. The data section for these new regulators provides a separate thermal resistance and maximum junction temperature for both the *Control Section* and the *Power Transistor*. Previous regulators, with a single junction-to-case thermal resistance specification, used an average of the two values provided here and, therefore, could allow excessive junction temperatures under certain conditions of ambient temperature and heat sink resistance. To avoid this possibility, calculations should be made for both sections to ensure that both thermal limits are met.

For example, using a LT1086CT (TO-220, Commercial) and assuming:

$V_{\text{IN}}$  (max continuous) =  $9\text{V}$ ,  $V_{\text{OUT}} = 5\text{V}$ ,  $I_{\text{OUT}} = 1\text{A}$ ,  $T_A = 75^\circ\text{C}$ ,  $\theta_{\text{HEAT SINK}} = 3^\circ\text{C/W}$ ,  $\theta_{\text{CASE-TO-HEAT SINK}} = 0.2^\circ\text{C/W}$  for T package with thermal compound.

Power dissipation under these conditions is equal to:

$$P_D = (V_{\text{IN}} - V_{\text{OUT}})(I_{\text{OUT}}) = 4\text{W}$$

The junction temperature will be equal to:

$$T_J = T_A + P_D (\theta_{\text{HEAT SINK}} + \theta_{\text{CASE-TO-HEAT SINK}} + \theta_{\text{JC}})$$

For the Control Section:

$$T_J = 75^\circ\text{C} + 4\text{W}(3^\circ\text{C/W} + 0.2^\circ\text{C/W} + 1.5^\circ\text{C/W}) = 94.6^\circ\text{C}$$

$94.6^{\circ}\text{C} < 125^{\circ}\text{C} = T_{\text{JMAX}}$  (Control Section Commercial Range)

For the Power Transistor:

$$T_j = 75^{\circ}\text{C} + 4\text{W}(3^{\circ}\text{C}/\text{W} + 0.2^{\circ}\text{C}/\text{W} + 4^{\circ}\text{C}/\text{W}) = 103.8^{\circ}\text{C}$$

$103.8^{\circ}\text{C} < 150^{\circ}\text{C} = T_{\text{JMAX}}$  (Power Transistor Commercial Range)

In both cases, the junction temperature is below the maximum rating for the respective sections, ensuring reliable operation.

Junction-to-case thermal resistance for the T package is specified from the IC junction to the bottom of the case directly below the die. This is the lowest resistance path for heat flow.

In all cases, proper mounting is required to ensure the best possible heat flow from the die to the heat sink. Thermal compound at the case-to-heat sink interface is strongly recommended. Note that the case of all devices in this series is electrically connected to the output.

## TYPICAL APPLICATIONS

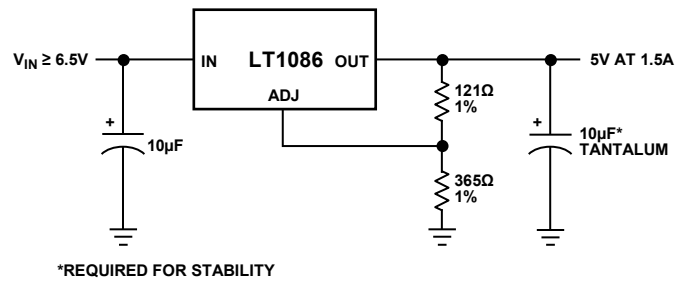


Figure 20. 5V, 1.5A Regulator

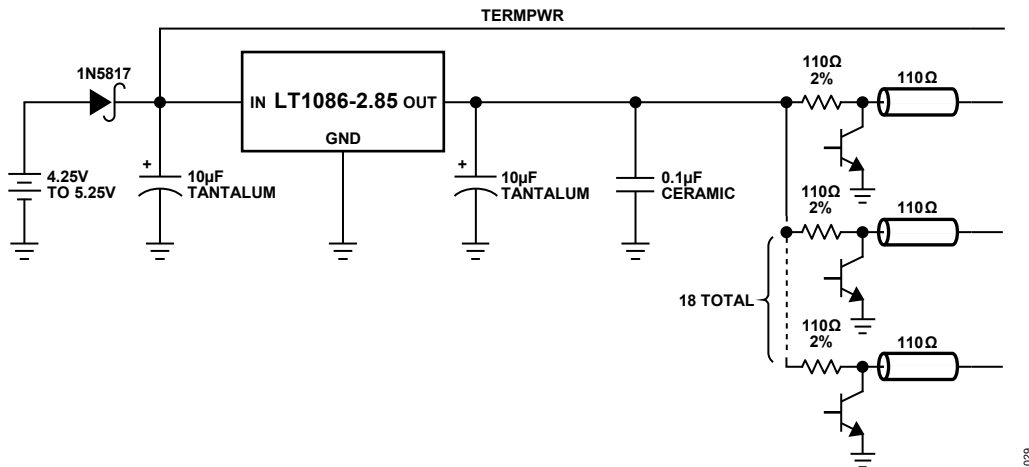
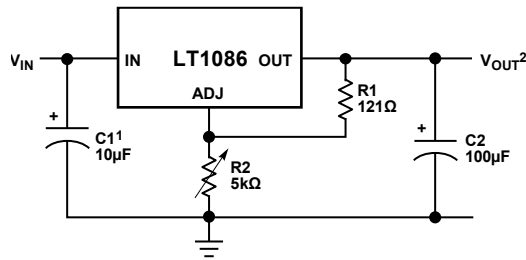


Figure 21. SCSI-2 Active Termination



<sup>1</sup>NEEDED IF DEVICE IS FAR FROM FILTER CAPACITORS

$$V_{OUT} = 1.25V \left( 1 + \frac{R2}{R1} \right)$$

Figure 22. 1.2V to 15V Adjustable Regulator

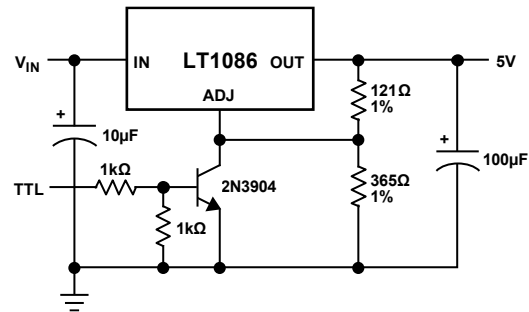
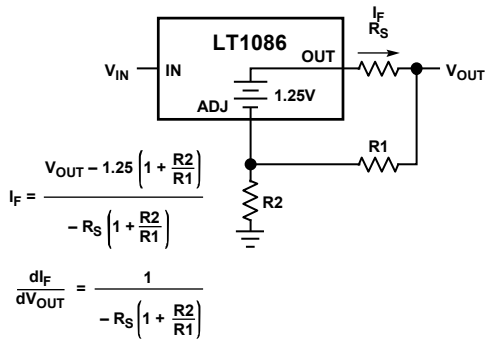


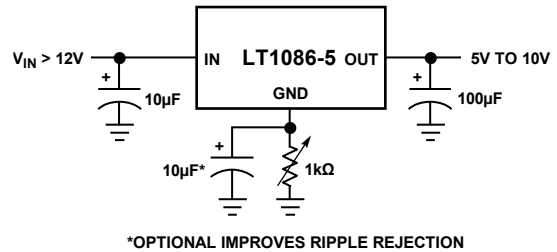
Figure 23. 5V Regulator with Shutdown



$$I_F = \frac{V_{OUT} - 1.25 \left( 1 + \frac{R2}{R1} \right)}{-R_S \left( 1 + \frac{R2}{R1} \right)}$$

$$\frac{dI_F}{dV_{OUT}} = \frac{1}{-R_S \left( 1 + \frac{R2}{R1} \right)}$$

Figure 24. Battery Charger



\*OPTIONAL IMPROVES RIPPLE REJECTION

Figure 25. Adjusting Output Voltage of Fixed Regulators

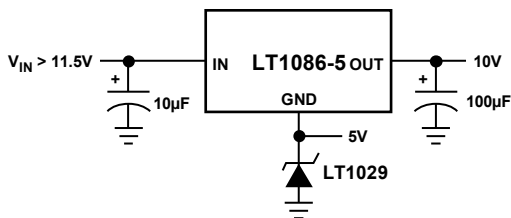


Figure 26. Regulator with Reference

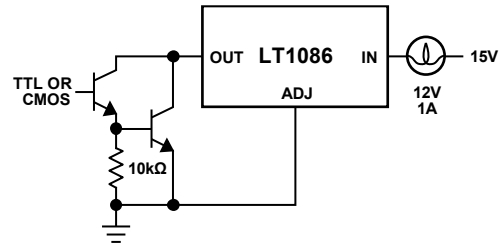


Figure 27. Protected High Current Lamp Driver

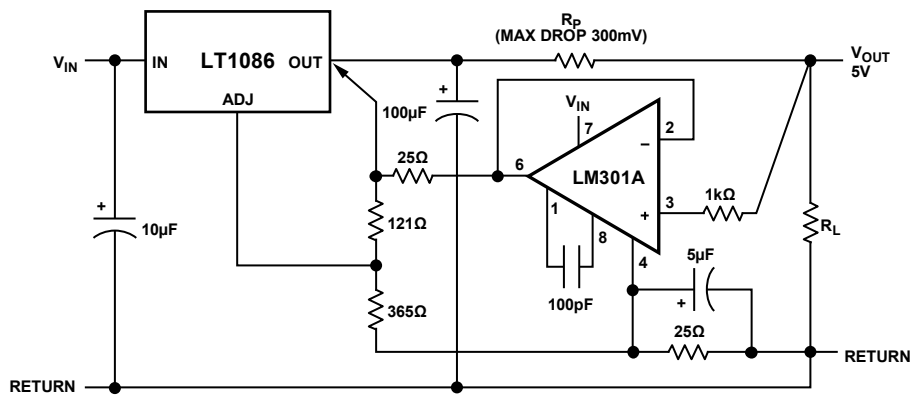


Figure 28. Remote Sensing

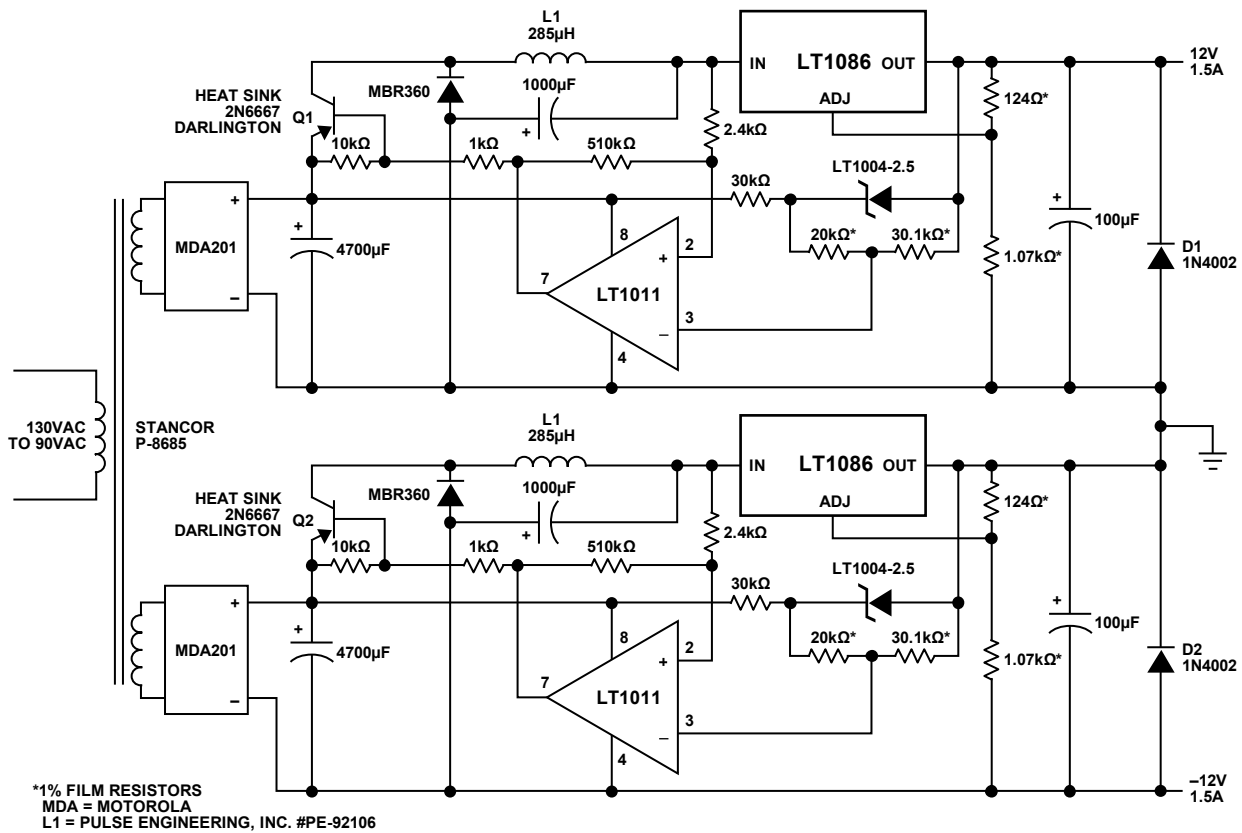


Figure 29. High Efficiency Dual Linear Supply

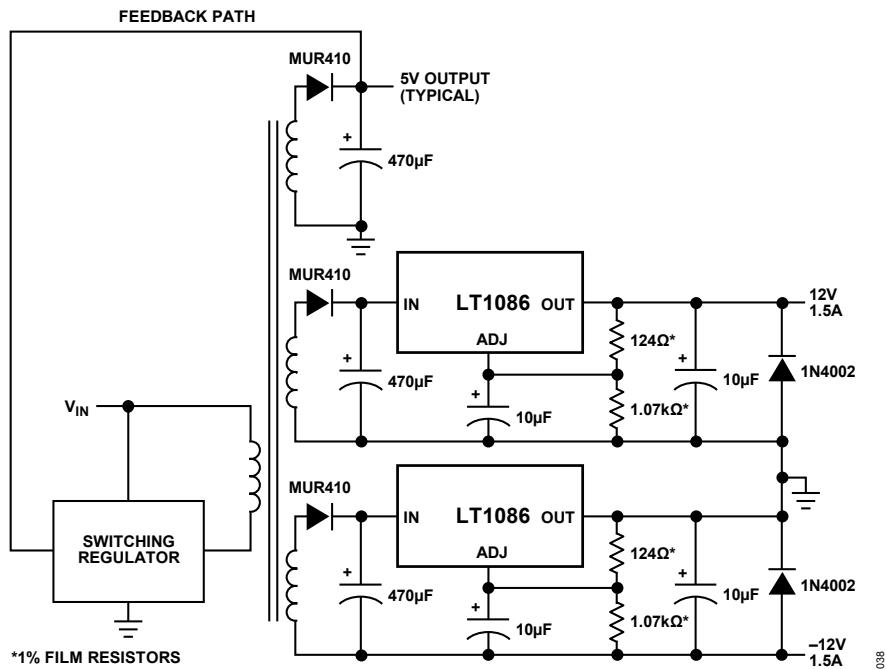


Figure 30. High Efficiency Dual Supply

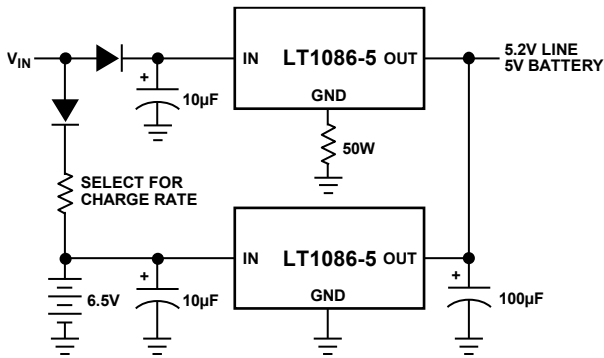
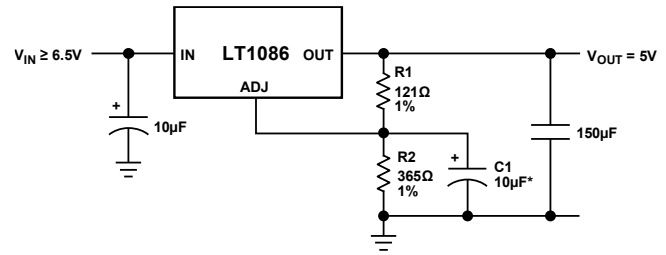


Figure 31. Battery Backed Up Regulated Supply



\*C1 IMPROVES RIPPLE REJECTION.  
X<sub>C</sub> SHOULD BE ≈ R1 AT RIPPLE FREQUENCY

Figure 32. Improving Ripple Rejection

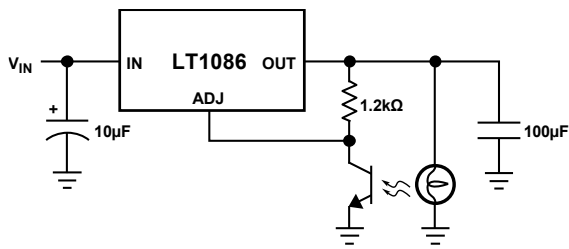


Figure 33. Automatic Light Control

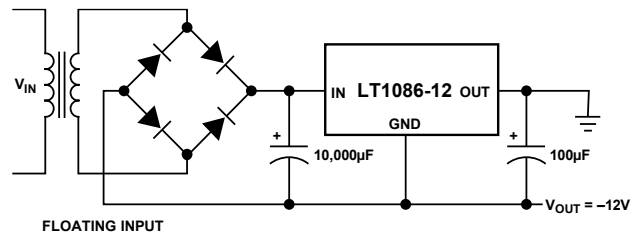
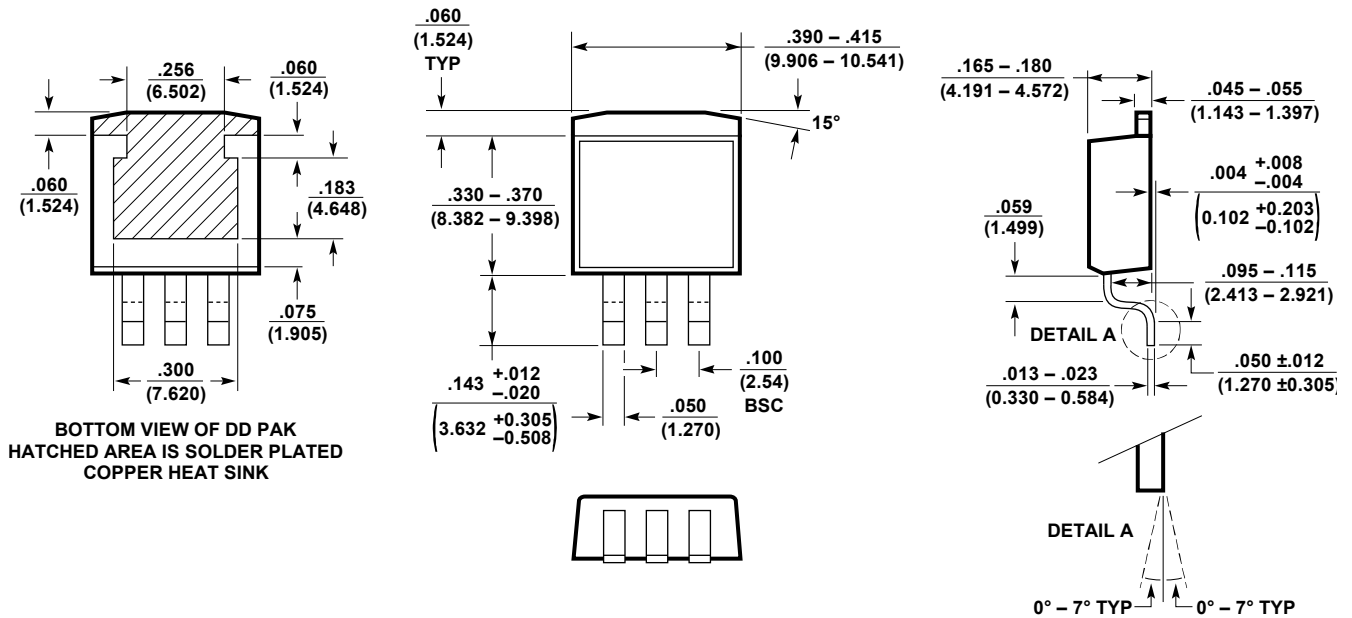


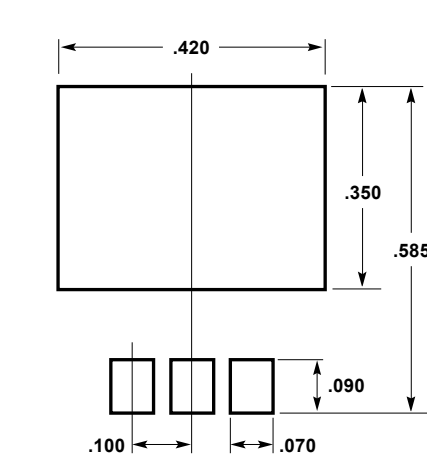
Figure 34. Low Dropout Negative Supply

PACKAGE DESCRIPTION

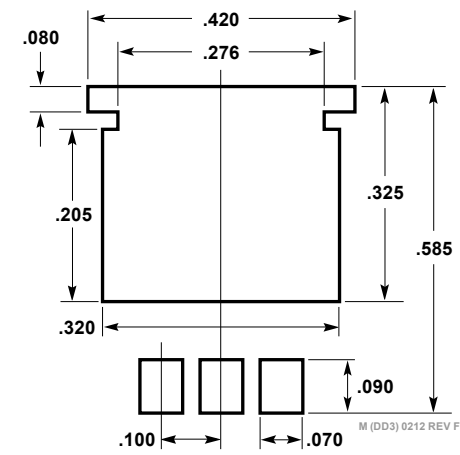
M Package  
3-Lead Plastic DD Pak  
(Reference LTC DWG # 05-08-1460)



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



RECOMMENDED SOLDER PAD LAYOUT

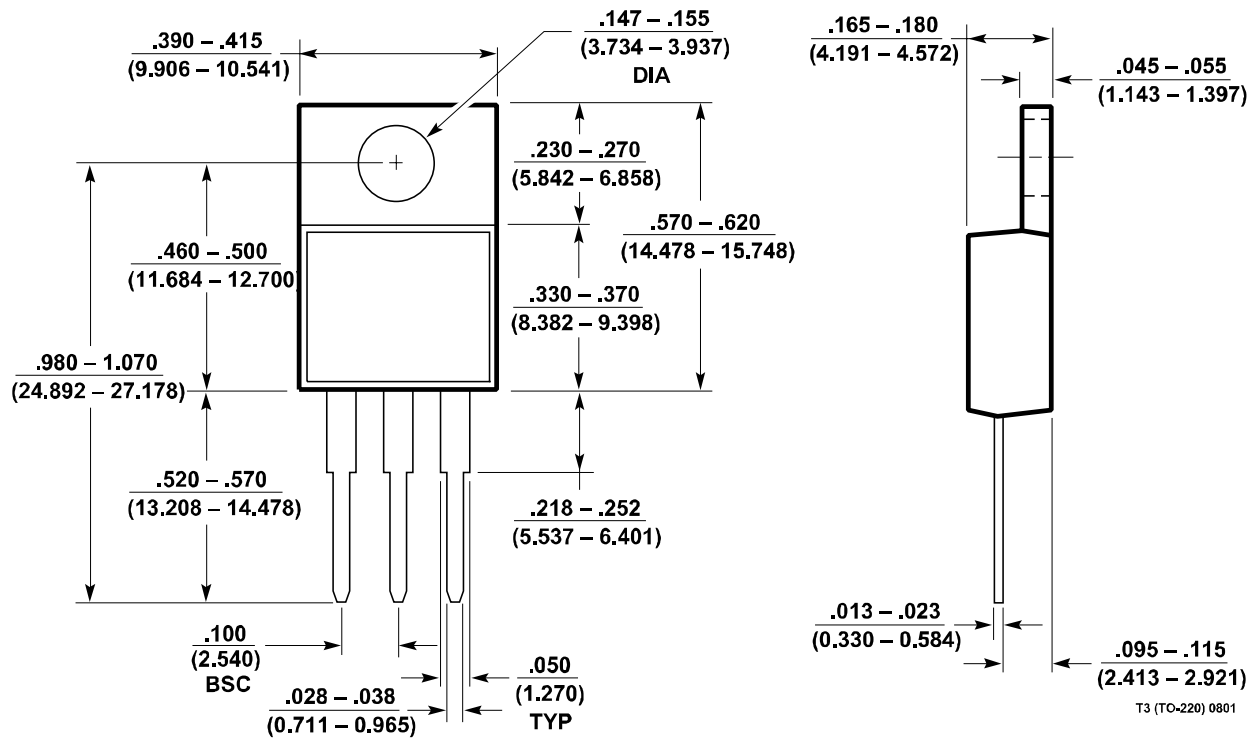


RECOMMENDED SOLDER PAD LAYOUT  
FOR THICKER SOLDER PASTE APPLICATIONS

NOTE:  
1. DIMENSIONS IN INCH/(MILLIMETER)  
2. DRAWING NOT TO SCALE

PACKAGE DESCRIPTION (CONTINUED)

T Package  
 3-Lead Plastic TO-220  
 (Reference LTC DWG # 05-08-1420)



## ORDERING INFORMATION

**Table 4. Ordering Information**

| PART NUMBER              | TAPE AND REEL      | PACKAGE DESCRIPTION                | TEMPERATURE RANGE   |
|--------------------------|--------------------|------------------------------------|---|
| <b>LEAD-FREE FINISH</b>  |                    |                                    |   |
| LT1086CM#PBF             | LT1086CM#TRPBF     | 3-LEAD PLASTIC DD                  | Control Section: 0°C to 125°C<br>Power Transistor: 0°C to 150°C     |
| LT1086CM-3.3#PBF         | LT1086CM-3.3#TRPBF | 3-LEAD PLASTIC DD                  |   |
| LT1086CM-3.6#PBF         | LT1086CM-3.6#TRPBF | 3-LEAD PLASTIC DD                  |   |
| LT1086IM#PBF             | LT1086IM#TRPBF     | 3-LEAD PLASTIC DD                  | Control Section: -40°C to 125°C<br>Power Transistor: -40°C to 150°C |
| LT1086IM-3.3#PBF         | LT1086IM-3.3#TRPBF | 3-LEAD PLASTIC DD                  |   |
| LT1086CT#PBF             |                    | 3-LEAD PLASTIC TO-220              | Control Section: 0°C to 125°C<br>Power Transistor: 0°C to 150°C     |
| LT1086CT-2.85#PBF        |                    | 3-LEAD PLASTIC TO-220              |   |
| LT1086CT-3.3#PBF         |                    | 3-LEAD PLASTIC TO-220              |   |
| LT1086CT-3.6#PBF         |                    | 3-LEAD PLASTIC TO-220              |   |
| LT1086CT-5#PBF           |                    | 3-LEAD PLASTIC TO-220              |   |
| LT1086CT-12#PBF          |                    | 3-LEAD PLASTIC TO-220              |   |
| LT1086IT#36PBF           |                    | 3-LEAD PLASTIC TO-220<br>(Flow 36) | Control Section: -40°C to 125°C<br>Power Transistor: -40°C to 150°C |
| LT1086IT#PBF             |                    | 3-LEAD PLASTIC TO-220              |   |
| LT1086IT-3.3#PBF         |                    | 3-LEAD PLASTIC TO-220              |   |
| LT1086IT-5#PBF           |                    | 3-LEAD PLASTIC TO-220              |   |
| LT1086IT-12#PBF          |                    | 3-LEAD PLASTIC TO-220              |   |
| <b>LEAD-BASED FINISH</b> |                    |                                    |   |
|                          | LT1086CM#TR        | 3-LEAD PLASTIC DD                  | Control Section: 0°C to 125°C<br>Power Transistor: 0°C to 150°C     |
| LT1086CM-3.3             | LT1086CM-3.3#TR    | 3-LEAD PLASTIC DD                  |   |
| LT1086IM                 | LT1086IM#TR        | 3-LEAD PLASTIC DD                  | Control Section: -40°C to 125°C<br>Power Transistor: -40°C to 150°C |
| LT1086IM-3.3             |                    | 3-LEAD PLASTIC DD                  |   |
| LT1086CT                 |                    | 3-LEAD PLASTIC TO-220              | Control Section: 0°C to 125°C<br>Power Transistor: 0°C to 150°C     |
| LT1086CT-3.3             |                    | 3-LEAD PLASTIC TO-220              |   |
| LT1086CT-5               |                    | 3-LEAD PLASTIC TO-220              |   |
| LT1086CT-12              |                    | 3-LEAD PLASTIC TO-220              |   |
| LT1086IT                 |                    | 3-LEAD PLASTIC TO-220              | Control Section: -40°C to 125°C<br>Power Transistor: -40°C to 150°C |
| LT1086IT-5               |                    | 3-LEAD PLASTIC TO-220              |   |
| LT1086IT-12              |                    | 3-LEAD PLASTIC TO-220              |   |

- ▶ For more information on tape and reel specifications, visit [Tape and Reel](#) or contact [Technical Support](#).
- ▶ Lead-based parts are identified by the label on the shipping container.



## RELATED PARTS

| PART NUMBER                    | DESCRIPTION                                    | COMMENTS   |
|--------------------------------|--|--|
| <a href="#">LT1129</a>         | 700mA, Micropower, LDO                         | $V_{IN} = 4.2V$ to $30V$ , $V_{OUT(MIN)} = 3.75V$ , $I_Q = 50\mu A$ , $I_{SD} = 16\mu A$ , DD, SOT-223, S8, TO-220, TSSOP-20 Packages  |
| <a href="#">LT1528</a>         | 3A LDO for Microprocessor Applications         | $V_{IN} = 4V$ to $15V$ , $V_{OUT(MIN)} = 3.30V$ , $I_Q = 400\mu A$ , $I_{SD} = 125\mu A$ , Fast Transient Response, DD, TO-220 Packages  |
| <a href="#">LT1585</a>         | 4.6A LDO, with Fast Transient Response         | $V_{IN} = 2.5V$ to $7V$ , $V_{OUT(MIN)} = 1.25V$ , $I_Q = 8mA$ , Fast Transient Response, DD, TO-220 Packages  |
| <a href="#">LT1761</a>         | 100mA, Low Noise Micropower, LDO               | $V_{IN} = 1.8V$ to $20V$ , $V_{OUT(MIN)} = 1.22V$ , $I_Q = 20\mu A$ , $I_{SD} = <1\mu A$ , Low Noise $< 20\mu V_{RMS P-P}$ , Stable with $1\mu F$ Ceramic Capacitors, ThinSOT™ Package               |
| <a href="#">LT1762</a>         | 150mA, Low Noise Micropower, LDO               | $V_{IN} = 1.8V$ to $20V$ , $V_{OUT(MIN)} = 1.22V$ , $I_Q = 25\mu A$ , $I_{SD} = <1\mu A$ , Low Noise $< 20\mu V_{RMS P-P}$ , MSOP Package  |
| <a href="#">LT1763</a>         | 500mA, Low Noise Micropower, LDO               | $V_{IN} = 1.8V$ to $20V$ , $V_{OUT(MIN)} = 1.22V$ , $I_Q = 30\mu A$ , $I_{SD} = <1\mu A$ , Low Noise $< 20\mu V_{RMS P-P}$ , S8 Package  |
| <a href="#">LT1764/LT1764A</a> | 3A, Low Noise, Fast Transient Response, LDOs   | $V_{IN} = 2.7V$ to $20V$ , $V_{OUT(MIN)} = 1.21V$ , $I_Q = 1mA$ , $I_{SD} = <1\mu A$ , Low Noise $< 40\mu V_{RMS P-P}$ , “A” Version Stable with Ceramic Capacitor, DD, TO-220 Packages              |
| <a href="#">LT1962</a>         | 300mA, Low Noise Micropower, LDO               | $V_{IN} = 1.8V$ to $20V$ , $V_{OUT(MIN)} = 1.22V$ , $I_Q = 30\mu A$ , $I_{SD} = <1\mu A$ , Low Noise $< 20\mu V_{RMS P-P}$ , MS8 Package   |
| <a href="#">LT1963/LT1963A</a> | 1.5A, Low Noise, Fast Transient Response, LDOs | $V_{IN} = 2.1V$ to $20V$ , $V_{OUT(MIN)} = 1.21V$ , $I_Q = 1mA$ , $I_{SD} = <1\mu A$ , Low Noise $< 40\mu V_{RMS P-P}$ , “A” Version Stable with Ceramic Capacitor, DD, TO-220, SOT-223, S8 Packages |
| <a href="#">LT1964</a>         | 200mA, Low Noise Micropower, Negative LDO      | $V_{IN} = -0.9V$ to $-20V$ , $V_{OUT(MIN)} = -1.21V$ , $I_Q = 30\mu A$ , $I_{SD} = 3\mu A$ , Low Noise $< 30\mu V_{RMS P-P}$ , Stable with Ceramic Capacitors, ThinSOT Package                       |

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