

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

## FEATURES

- Three-Terminal Adjustable or Fixed 2.85V, 3.3V, 3.6V, 5V, 12V
- Output Current of 1.5A, (0.5A for LT1086H)
- 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

## APPLICATIONS

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

## DESCRIPTION

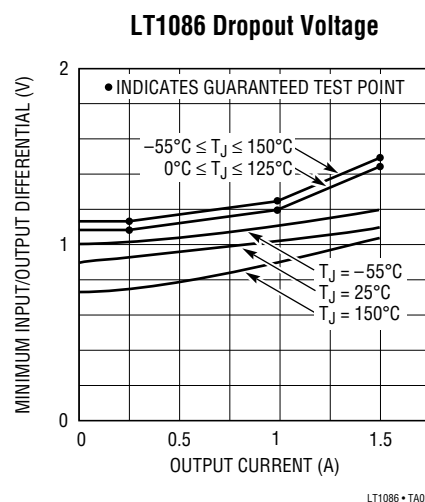
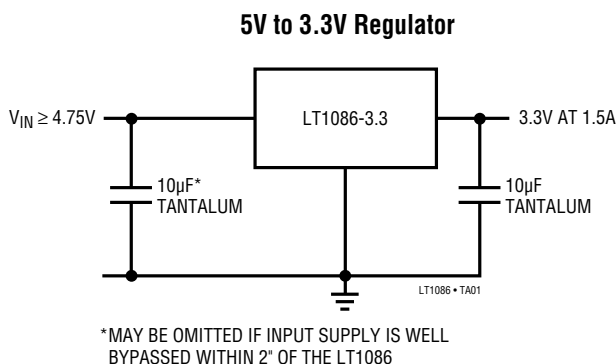
The LT1086 is designed to provide 1.5A with higher efficiency than currently available devices. All internal circuitry is designed to operate down to 1V input-to-output differential and the dropout voltage is fully specified as a function of load current. Dropout is guaranteed at a maximum of 1.5V at maximum output current, decreasing at lower load currents. On-chip trimming adjusts the reference/output voltage to 1%. 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 three-terminal adjustable regulators. A 10 $\mu$ F output capacitor is required on these new devices; however, this is usually included in most regulator designs.

A 2.85V output version is offered for SCSI-2 active termination. For surface mount applications see the LT1117-2.85 data sheet. For high current or lower dropout requirements see the LT1123-2.85 data sheet.

Unlike PNP regulators, where up to 10% of the output current is wasted as quiescent current, the LT1086 quiescent current flows into the load, increasing efficiency.

## TYPICAL APPLICATION



# LT1086 Series

## ABSOLUTE MAXIMUM RATINGS

|                                      |                    |
|--------------------------------------|--------------------|
| Power Dissipation .....              | Internally Limited |
| Input Voltage (Note 1) .....         | 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       |
| "M" Grades                           |                    |
| Control Section .....                | -55°C to 150°C     |
| Power Transistor .....               | -55°C to 200°C     |

|                                            |                |
|--------------------------------------------|----------------|
| Storage Temperature Range .....            | -65°C to 150°C |
| Lead Temperature (Soldering, 10 sec) ..... | 300°C          |

**Note 1:** 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 5V and 12V devices operating at input/output voltage differentials greater than 15V, a minimum external load of 5mA is required to maintain regulation.

## PRECONDITIONING

100% Thermal Shutdown Functional Test.

## PACKAGE/ORDER INFORMATION

|                                                                                                                     |                                                                                |                                                                                                                                                                                                                                                                                                                                            |                                                                                        |
|---------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------|
| <p>BOTTOM VIEW</p> <p>H PACKAGE<br/>3-LEAD TO-39 METAL CAN<br/><math>\theta_{JA} = 150^{\circ}\text{C/W}</math></p> | ORDER<br>PART NUMBER                                                           | <p>FRONT VIEW</p> <p>M PACKAGE<br/>3-LEAD PLASTIC DD<br/><math>\theta_{JA} = 30^{\circ}\text{C/W}^{**}</math></p> <p><b>** WITH PACKAGE SOLDERED TO 0.5IN<sup>2</sup> COPPER AREA OVER BACKSIDE GROUND PLANE OR INTERNAL POWER PLANE. <math>\theta_{JA}</math> CAN VARY FROM 20°C/W TO &gt;40°C/W DEPENDING ON MOUNTING TECHNIQUE.</b></p> | ORDER<br>PART NUMBER                                                                   |
|                                                                                                                     | LT1086MH                                                                       |                                                                                                                                                                                                                                                                                                                                            | LT1086CM<br>LT1086CM-3.3<br>LT1086CM-3.6                                               |
| <p>BOTTOM VIEW</p> <p>K PACKAGE<br/>2-LEAD TO-3 METAL CAN<br/><math>\theta_{JA} = 35^{\circ}\text{C/W}</math></p>   | ORDER<br>PART NUMBER                                                           | <p>FRONT VIEW</p> <p>T PACKAGE<br/>3-LEAD PLASTIC TO-220<br/><math>\theta_{JA} = 50^{\circ}\text{C/W}</math></p>                                                                                                                                                                                                                           | ORDER<br>PART NUMBER                                                                   |
|                                                                                                                     | LT1086CK<br>LT1086CK-5<br>LT1086CK-12<br>LT1086MK<br>LT1086MK-5<br>LT1086MK-12 |                                                                                                                                                                                                                                                                                                                                            | LT1086CT<br>LT1086CT-2.85<br>LT1086CT-3.3<br>LT1086CT-3.6<br>LT1086CT-5<br>LT1086CT-12 |

\*For fixed versions.

Consult factory for Industrial grade parts.

# ELECTRICAL CHARACTERISTICS

| PARAMETER                                 | CONDITIONS                                                                                                                                                                                                                                                                                                                                                        |   | MIN    | TYP    | MAX    | UNITS |
|-------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---|--------|--------|--------|-------|
| Reference Voltage<br>(Note 2)             | LT1086, LT1086H $I_{OUT} = 10\text{mA}$ , $T_J = 25^\circ\text{C}$ , $(V_{IN} - V_{OUT}) = 3\text{V}$ (K Package Only)<br>$10\text{mA} \leq I_{OUT} \leq 1.5\text{A}$ , $(0.5\text{A for LT1086H})$ , $1.5\text{V} \leq (V_{IN} - V_{OUT}) \leq 15\text{V}$                                                                                                       |   | 1.238  | 1.250  | 1.262  | V     |
|                                           |                                                                                                                                                                                                                                                                                                                                                                   | ● | 1.225  | 1.250  | 1.270  | V     |
| Output Voltage<br>(Note 2)                | LT1086-2.85 $I_{OUT} = 0\text{mA}$ , $T_J = 25^\circ\text{C}$ , $V_{IN} = 5\text{V}$ (K Package Only)<br>$0\text{V} \leq I_{OUT} \leq 1.5\text{A}$ , $4.35\text{V} \leq V_{IN} \leq 18\text{V}$                                                                                                                                                                   |   | 2.82   | 2.85   | 2.88   | V     |
|                                           |                                                                                                                                                                                                                                                                                                                                                                   | ● | 2.79   | 2.85   | 2.91   | V     |
|                                           | LT1086-3.3 $V_{IN} = 5\text{V}$ , $I_{OUT} = 0\text{mA}$ , $T_J = 25^\circ\text{C}$ (K Package Only)<br>$4.75\text{V} \leq V_{IN} \leq 15\text{V}$ , $0\text{V} \leq I_{OUT} \leq 1.5\text{A}$                                                                                                                                                                    |   | 3.267  | 3.300  | 3.333  | V     |
|                                           |                                                                                                                                                                                                                                                                                                                                                                   | ● | 3.235  | 3.300  | 3.365  | V     |
|                                           | LT1086-3.6 $V_{IN} = 5\text{V}$ , $I_{OUT} = 0\text{mA}$ , $T_J = 25^\circ\text{C}$<br>$5\text{V} \leq V_{IN} \leq 18\text{V}$ , $0 \leq I_{OUT} \leq 1.5\text{A}$<br>$4.75\text{V} \leq V_{IN} \leq 18\text{V}$ , $0 \leq I_{OUT} \leq 1\text{A}$ , $T_J \geq 0^\circ\text{C}$<br>$V_{IN} = 4.75\text{V}$ , $I_{OUT} = 1.5\text{A}$ , $T_J \geq 0^\circ\text{C}$ |   | 3.564  | 3.600  | 3.636  | V     |
|                                           |                                                                                                                                                                                                                                                                                                                                                                   | ● | 3.500  |        | 3.672  | V     |
|                                           |                                                                                                                                                                                                                                                                                                                                                                   |   | 3.500  |        | 3.672  | V     |
|                                           |                                                                                                                                                                                                                                                                                                                                                                   |   | 3.300  |        | 3.672  | V     |
|                                           | LT1086-5 $I_{OUT} = 0\text{mA}$ , $T_J = 25^\circ\text{C}$ , $V_{IN} = 8\text{V}$ (K Package Only)<br>$0 \leq I_{OUT} \leq 1.5\text{A}$ , $6.5\text{V} \leq V_{IN} \leq 20\text{V}$                                                                                                                                                                               |   | 4.950  | 5.000  | 5.050  | V     |
|                                           |                                                                                                                                                                                                                                                                                                                                                                   | ● | 4.900  | 5.000  | 5.100  | V     |
|                                           | LT1086-12 $I_{OUT} = 0\text{mA}$ , $T_J = 25^\circ\text{C}$ , $V_{IN} = 15\text{V}$ (K Package Only)<br>$0 \leq I_{OUT} \leq 1.5\text{A}$ , $13.5\text{V} \leq V_{IN} \leq 25\text{V}$                                                                                                                                                                            |   | 11.880 | 12.000 | 12.120 | V     |
|                                           |                                                                                                                                                                                                                                                                                                                                                                   | ● | 11.760 | 12.000 | 12.240 | V     |
| Line Regulation                           | LT1086, LT1086H $I_{LOAD} = 10\text{mA}$ , $1.5\text{V} \leq (V_{IN} - V_{OUT}) \leq 15\text{V}$ , $T_J = 25^\circ\text{C}$                                                                                                                                                                                                                                       |   |        | 0.015  | 0.2    | %     |
|                                           |                                                                                                                                                                                                                                                                                                                                                                   | ● |        | 0.035  | 0.2    | %     |
|                                           | LT1086-2.85 $I_{OUT} = 0\text{mA}$ , $T_J = 25^\circ\text{C}$ , $4.35\text{V} \leq V_{IN} \leq 18\text{V}$                                                                                                                                                                                                                                                        |   |        | 0.3    | 6      | mV    |
|                                           |                                                                                                                                                                                                                                                                                                                                                                   | ● |        | 0.6    | 6      | mV    |
|                                           | LT1086-3.3 $4.5\text{V} \leq V_{IN} \leq 18\text{V}$ , $I_{OUT} = 0\text{mA}$ , $T_J = 25^\circ\text{C}$                                                                                                                                                                                                                                                          |   |        | 0.5    | 10     | mV    |
|                                           |                                                                                                                                                                                                                                                                                                                                                                   | ● |        | 1.0    | 10     | mV    |
|                                           | LT1086-3.6 $4.75\text{V} \leq V_{IN} \leq 18\text{V}$ , $I_{OUT} = 0\text{mA}$ , $T_J = 25^\circ\text{C}$                                                                                                                                                                                                                                                         |   |        | 0.5    | 10     | mV    |
|                                           |                                                                                                                                                                                                                                                                                                                                                                   | ● |        | 1.0    | 10     | mV    |
| Load Regulation                           | LT1086, LT1086H $(V_{IN} - V_{OUT}) = 3\text{V}$ , $10\text{mA} \leq I_{OUT} \leq 1.5\text{A}$ , $(0.5\text{A for LT1086H})$<br>$T_J = 25^\circ\text{C}$ (Notes 1, 2)                                                                                                                                                                                             |   |        | 0.1    | 0.3    | %     |
|                                           |                                                                                                                                                                                                                                                                                                                                                                   | ● |        | 0.2    | 0.4    | %     |
|                                           | LT1086-2.85 $V_{IN} = 5\text{V}$ , $0 \leq I_{OUT} \leq 1.5\text{A}$ , $T_J = 25^\circ\text{C}$ (Notes 1, 2)                                                                                                                                                                                                                                                      |   |        | 3      | 12     | mV    |
|                                           |                                                                                                                                                                                                                                                                                                                                                                   | ● |        | 6      | 20     | mV    |
|                                           | LT1086-3.3 $V_{IN} = 5\text{V}$ , $0 \leq I_{OUT} \leq 1.5\text{A}$ , $T_J = 25^\circ\text{C}$ (Notes 1, 2)                                                                                                                                                                                                                                                       |   |        | 3      | 15     | mV    |
|                                           |                                                                                                                                                                                                                                                                                                                                                                   | ● |        | 7      | 25     | mV    |
|                                           | LT1086-3.6 $V_{IN} = 5.25\text{V}$ , $0 \leq I_{OUT} \leq 1.5\text{A}$ , $T_J = 25^\circ\text{C}$ (Notes 1, 2)<br><br>$V_{IN} = 5\text{V}$ , $0 \leq I_{OUT} \leq 1\text{A}$ , $T_J = 25^\circ\text{C}$                                                                                                                                                           |   |        | 3      | 15     | mV    |
|                                           |                                                                                                                                                                                                                                                                                                                                                                   | ● |        | 6      | 25     | mV    |
|                                           |                                                                                                                                                                                                                                                                                                                                                                   |   |        | 2      | 15     | mV    |
|                                           |                                                                                                                                                                                                                                                                                                                                                                   | ● |        | 4      | 25     | mV    |
|                                           | LT1086-5 $V_{IN} = 8\text{V}$ , $0 \leq I_{OUT} \leq 1.5\text{A}$ , $T_J = 25^\circ\text{C}$ (Notes 1, 2)                                                                                                                                                                                                                                                         |   |        | 5      | 20     | mV    |
|                                           |                                                                                                                                                                                                                                                                                                                                                                   | ● |        | 10     | 35     | mV    |
| Dropout Voltage<br>( $V_{IN} - V_{OUT}$ ) | LT1086/-2.85/-3.3/-3.6/-5/-12 $\Delta V_{OUT}$ , $\Delta V_{REF} = 1\%$ , $I_{OUT} = 1.5\text{A}$ (Note 3)                                                                                                                                                                                                                                                        | ● |        | 1.3    | 1.5    | V     |
|                                           | LT1086H $\Delta V_{REF} = 1\%$ , $I_{OUT} = 0.5\text{A}$ (Note 3)                                                                                                                                                                                                                                                                                                 | ● |        | 0.95   | 1.25   | V     |

## ELECTRICAL CHARACTERISTICS

| PARAMETER                              | CONDITIONS                                                                                                                                                        |        | MIN          | TYP            | MAX     | UNITS        |
|----------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------|--------------|----------------|---------|--------------|
| Current Limit                          | LT1086/-2.85/-3.3/-3.6/-5/-12 $(V_{IN} - V_{OUT}) = 5V$<br>$(V_{IN} - V_{OUT}) = 25V$                                                                             | ●<br>● | 1.50<br>0.05 | 2.00<br>0.15   | 2.8     | A<br>A       |
|                                        | LT1086H $(V_{IN} - V_{OUT}) = 5V$<br>$(V_{IN} - V_{OUT}) = 25V$                                                                                                   | ●<br>● | 0.50<br>0.02 | 0.700<br>0.075 | 1.2     | A<br>A       |
| Minimum Load Current                   | LT1086/LT1086H $(V_{IN} - V_{OUT}) = 25V$ (Note 4)                                                                                                                | ●      |              | 5              | 10      | mA           |
| Quiescent Current                      | LT1086-2.85 $V_{IN} \leq 18V$                                                                                                                                     | ●      |              | 5              | 10      | mA           |
|                                        | LT1086-3.3 $V_{IN} \leq 18V$                                                                                                                                      | ●      |              | 5              | 10      | mA           |
|                                        | LT1086-3.6 $V_{IN} \leq 18V$                                                                                                                                      | ●      |              | 5              | 10      | mA           |
|                                        | LT1086-5 $V_{IN} \leq 20V$                                                                                                                                        | ●      |              | 5              | 10      | mA           |
|                                        | LT1086-12 $V_{IN} \leq 25V$                                                                                                                                       | ●      |              | 5              | 10      | mA           |
| Thermal Regulation                     | $T_A = 25^\circ C$ , 30ms pulse                                                                                                                                   |        |              | 0.008          | 0.04    | %/W          |
| Ripple Rejection                       | $f = 120Hz$ , $C_{OUT} = 25\mu F$ Tantalum, $I_{OUT} = 1.5A$ , ( $I_{OUT} = 0.5A$ for LT1086H)<br>LT1086, LT1086H $C_{ADJ} = 25\mu F$ , $(V_{IN} - V_{OUT}) = 3V$ | ●      | 60           | 75             |         | dB           |
|                                        | LT1086-2.85 $V_{IN} = 6V$                                                                                                                                         | ●      | 60           | 72             |         | dB           |
|                                        | LT1086-3.3 $V_{IN} = 6.3V$                                                                                                                                        | ●      | 60           | 72             |         | dB           |
|                                        | LT1086-3.6 $V_{IN} = 6.6V$                                                                                                                                        | ●      | 60           | 72             |         | dB           |
|                                        | LT1086-5 $V_{IN} = 8V$                                                                                                                                            | ●      | 60           | 68             |         | dB           |
|                                        | LT1083-12 $V_{IN} = 15V$                                                                                                                                          | ●      | 54           | 60             |         | dB           |
|                                        |                                                                                                                                                                   |        |              |                |         |              |
| Adjust Pin Current                     | LT1086, LT1086H $T_J = 25^\circ C$                                                                                                                                | ●      |              | 55             |         | $\mu A$      |
|                                        |                                                                                                                                                                   |        |              |                | 120     | $\mu A$      |
| Adjust Pin Current Change              | LT1086, LT1086H $10mA \leq I_{OUT} \leq 1.5A$ , (0.5A for LT1086H)<br>$1.5V \leq (V_{IN} - V_{OUT}) \leq 15V$                                                     | ●      |              | 0.2            | 5       | $\mu A$      |
|                                        |                                                                                                                                                                   |        |              |                |         |              |
| Temperature Stability                  |                                                                                                                                                                   | ●      |              | 0.5            |         | %            |
| Long Term Stability                    | $T_A = 125^\circ C$ , 1000 Hrs.                                                                                                                                   |        |              | 0.3            | 1       | %            |
| RMS Output Noise<br>(% of $V_{OUT}$ )  | $T_A = 25^\circ C$ , $10Hz \leq f \leq 10kHz$                                                                                                                     |        |              | 0.003          |         | %            |
| Thermal Resistance<br>Junction-to-Case | H Package: Control Circuitry/Power Transistor                                                                                                                     |        |              |                | 15/20   | $^\circ C/W$ |
|                                        | K Package: Control Circuitry/Power Transistor                                                                                                                     |        |              |                | 1.7/4.0 | $^\circ C/W$ |
|                                        | M Package: Control Circuitry/Power Transistor                                                                                                                     |        |              |                | 1.5/4.0 | $^\circ C/W$ |
|                                        | T Package: Control Circuitry/Power Transistor                                                                                                                     |        |              |                | 1.5/4.0 | $^\circ C/W$ |

The ● denotes the specifications which apply over the full operating temperature range.

**Note 1:** 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.

**Note 2:** Line and load regulation are guaranteed up to the maximum power dissipation of 15W (3W for the LT1086H). Power dissipation is determined

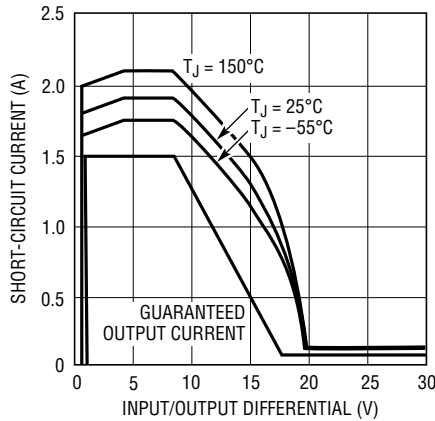
by the input/output differential and the output current. Guaranteed maximum power dissipation will not be available over the full input/output range. See Short-Circuit Current curve for available output current.

**Note 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.

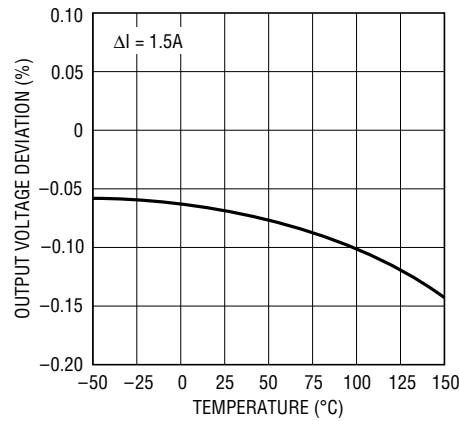
**Note 4:** Minimum load current is defined as the minimum output current required to maintain regulation. At 25V input/output differential the device is guaranteed to regulate if the output current is greater than 10mA.

# TYPICAL PERFORMANCE CHARACTERISTICS

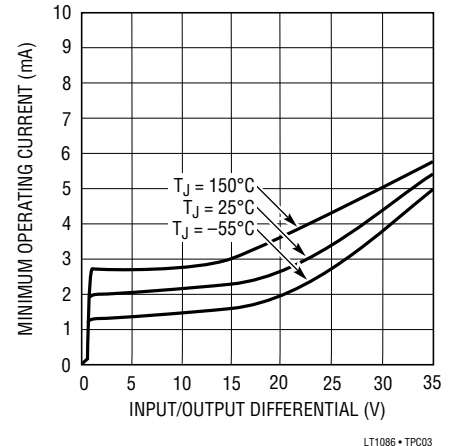
LT1086 Short-Circuit Current



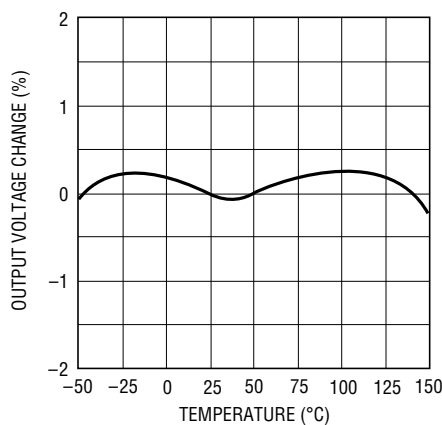
LT1086 Load Regulation



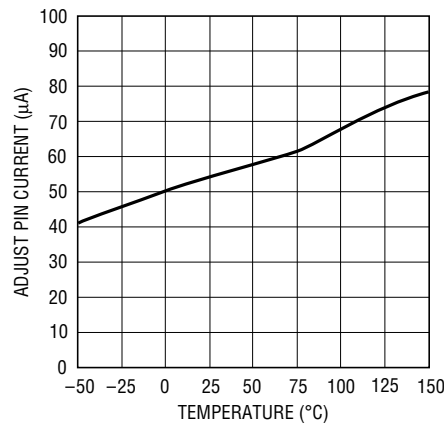
Minimum Operating Current (Adjustable Device)



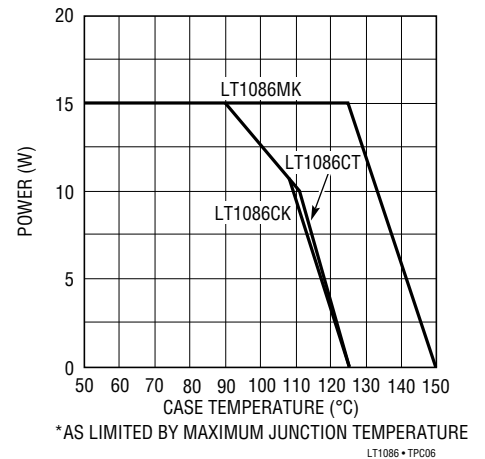
Temperature Stability



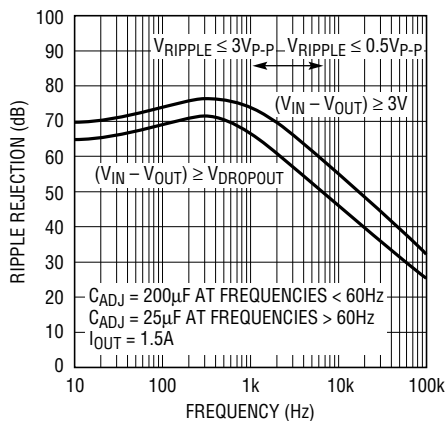
Adjust Pin Current



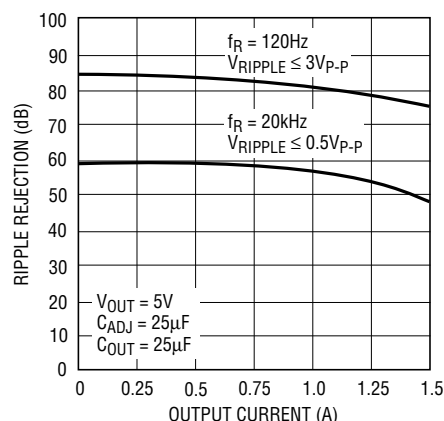
LT1086 Maximum Power Dissipation\*



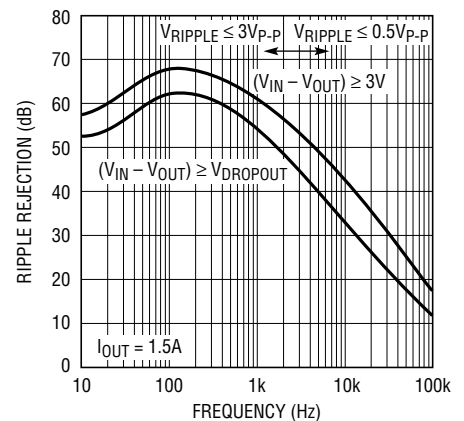
LT1086 Ripple Rejection



LT1086 Ripple Rejection vs Current

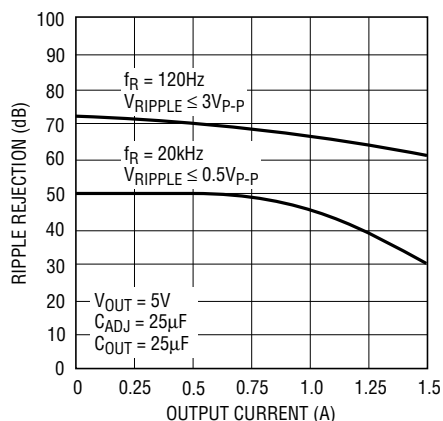


LT1086-5 Ripple Rejection



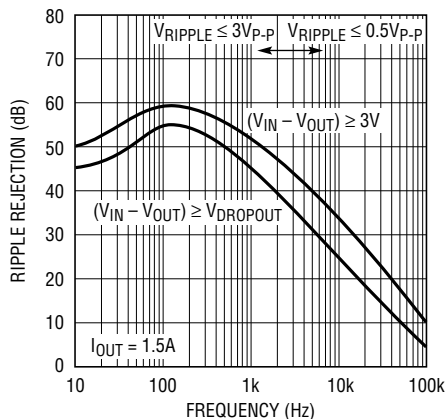
## TYPICAL PERFORMANCE CHARACTERISTICS

### LT1086-5 Ripple Rejection vs Current



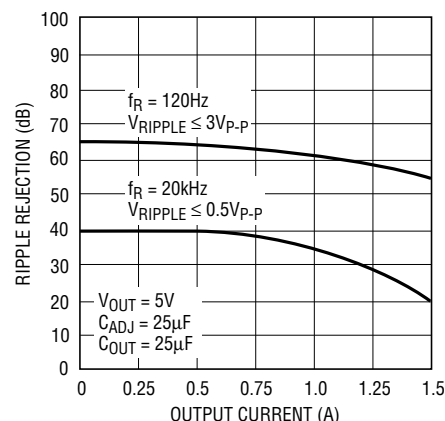
LT1086 • TPC10

### LT1086-12 Ripple Rejection



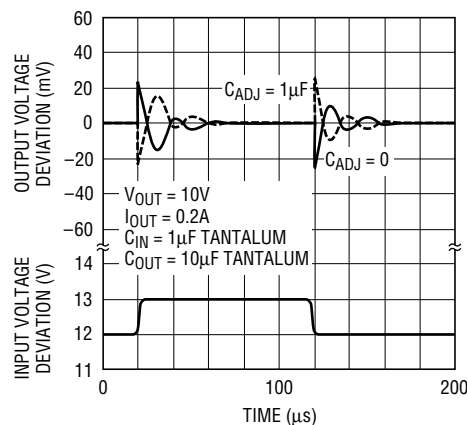
LT1086 • TPC11

### LT1086-12 Ripple Rejection vs Current



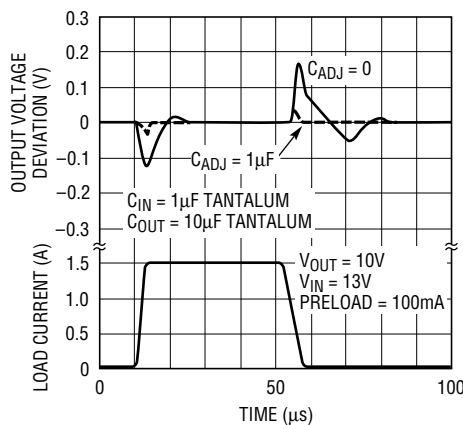
LT1086 • TPC12

### LT1086 Line Transient Response



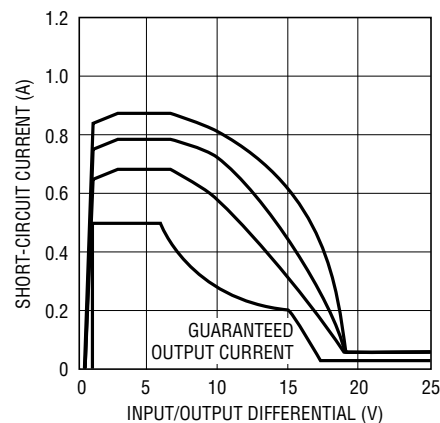
LT1086 • TPC13

### LT1086 Load Transient Response



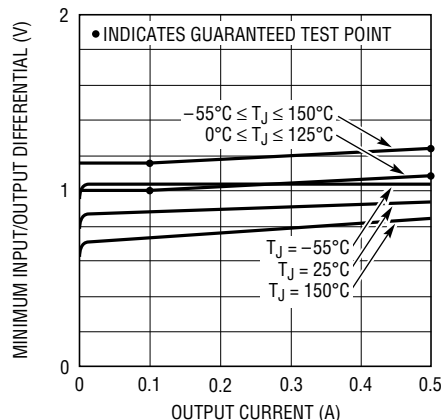
LT1086 • TPC14

### LT1086H Short-Circuit Current



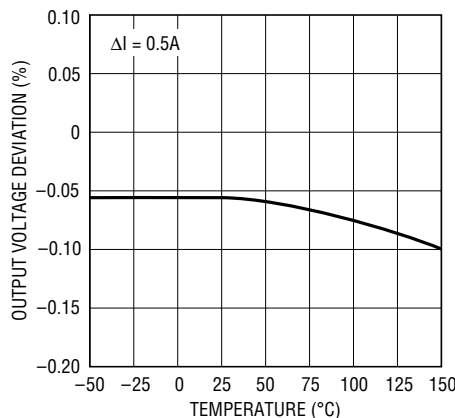
LT1086 • TPC15

### LT1086H Dropout Voltage



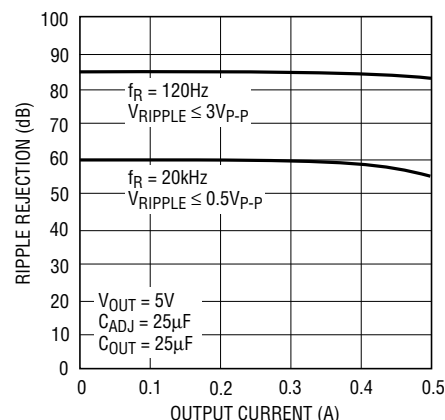
LT1086 • TPC16

### LT1086H Load Regulation



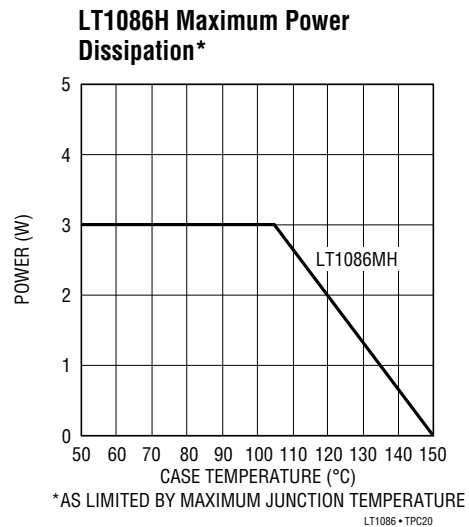
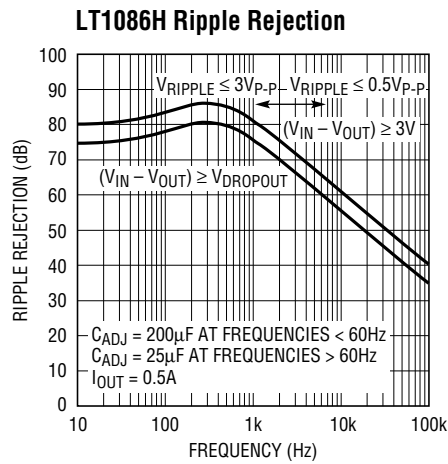
LT1086 • TPC17

### LT1086H Ripple Rejection vs Current

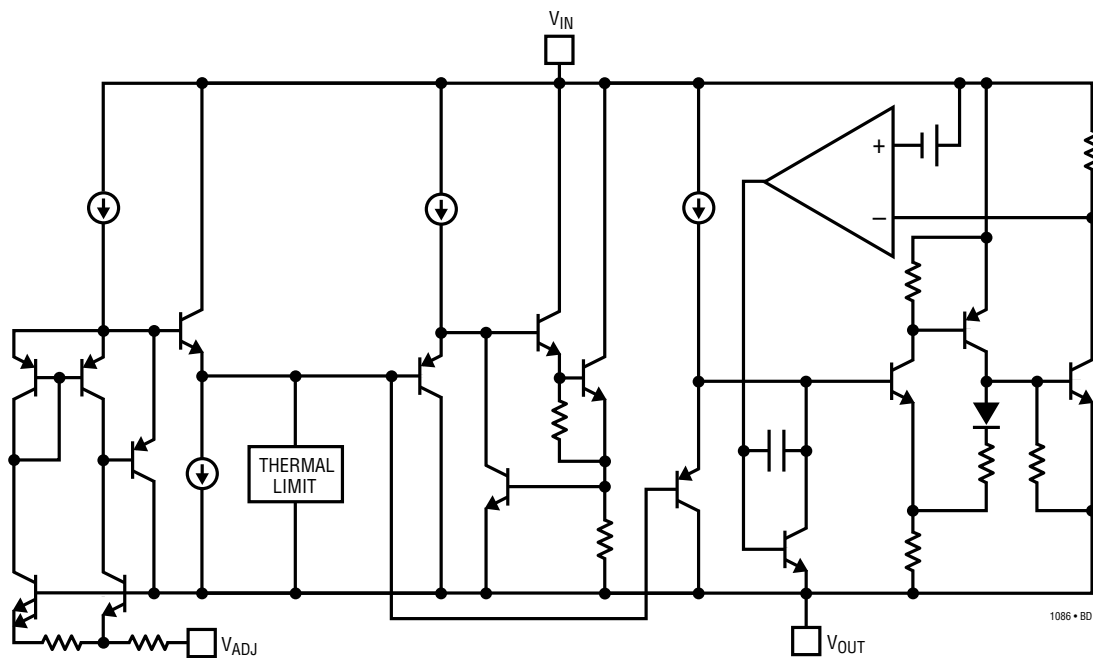


LT1086 • TPC18

## TYPICAL PERFORMANCE CHARACTERISTICS



## BLOCK DIAGRAM



## APPLICATIONS INFORMATION

The LT1086 family of three-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, have safe area protection as well as 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 three-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 150μF aluminum electrolytic or a 22μF 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 ±100%), equivalent series resistance, and capacitance temperature coefficient. The 150μF or 22μF 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 22μF tantalum or 150μF 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 and the table below shows approximately what size capacitors are needed to ensure stability.

#### Recommended Capacitor Values

| INPUT | OUTPUT                        | ADJUSTMENT |
|-------|-------------------------------|------------|
| 10μF  | 10μF Tantalum, 50μF Aluminum  | None       |
| 10μF  | 22μF Tantalum, 150μF Aluminum | 20μF       |

Normally, capacitor values on the order of 100μF 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 capacitor further improve 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.

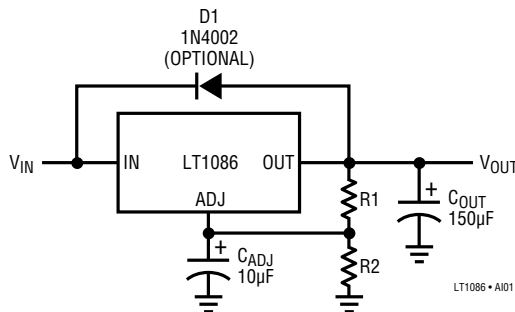
Diodes between input and output are usually not needed. The internal diode between the input and the output pins of the LT1086 family can handle microsecond surge currents of 10A to 20A. Even with large output capacitances, it is very difficult to get those values of surge currents in normal operations. Only with high value output capacitors such as 1000μF to 5000μF, 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



## APPLICATIONS INFORMATION

plugging and unplugging in the system will not generate current large enough to do any damage.

The adjustment pin can be driven on a transient basis  $\pm 25V$ , 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 adjustment 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 1). By placing a 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.

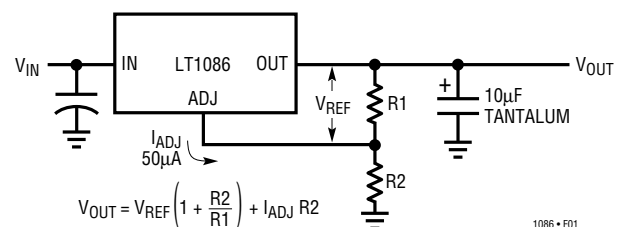


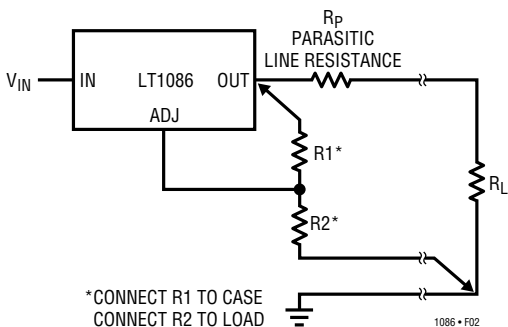
Figure 1. Basic Adjustable Regulator

## APPLICATIONS INFORMATION

### Load Regulation

Because the LT1086 is a three-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, best load regulation is obtained when the top of the resistor divider R1 is connected *directly* to the case *not to the load*. This is illustrated in Figure 2. If R1 were connected to the load, the effective resistance between the regulator and the load would be:

$$R_P \times \frac{R_2 + R_1}{R_1}, R_P = \text{Parasitic Line Resistance}$$



**Figure 2. 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 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  $\approx 0.06\Omega/\text{in}$ . 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 LT1086CK (TO-3, Commercial) and assuming:

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

Power dissipation under these conditions is equal to:

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

Junction temperature will be equal to:

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

For the Control Section:

$$\begin{aligned} T_J &= 75^\circ\text{C} + 4\text{W} (3^\circ\text{C/W} + 0.2^\circ\text{C/W} + 0.7^\circ\text{C/W}) = 95^\circ\text{C} \\ 95^\circ\text{C} &< 125^\circ\text{C} = T_{J\text{MAX}} (\text{Control Section Commercial Range}) \end{aligned}$$

For the Power Transistor:

$$\begin{aligned} T_J &= 75^\circ\text{C} + 4\text{W} (3^\circ\text{C/W} + 0.2^\circ\text{C/W} + 4^\circ\text{C/W}) = 103.8^\circ\text{C} \\ 103.8^\circ\text{C} &< 150^\circ\text{C} = T_{J\text{MAX}} (\text{Power Transistor Commercial Range}) \end{aligned}$$

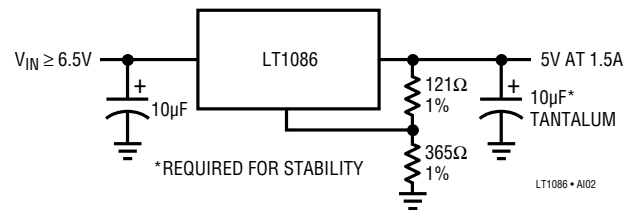
## APPLICATIONS INFORMATION

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 K and T packages 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. While this is also the lowest resistance path for the H package, most available heat sinks for this package are of the clip-on type that attach to the cap of the package. The data sheet specification for thermal resistance for the H package is therefore written to reflect this. 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. In the case of the H package, mounting the

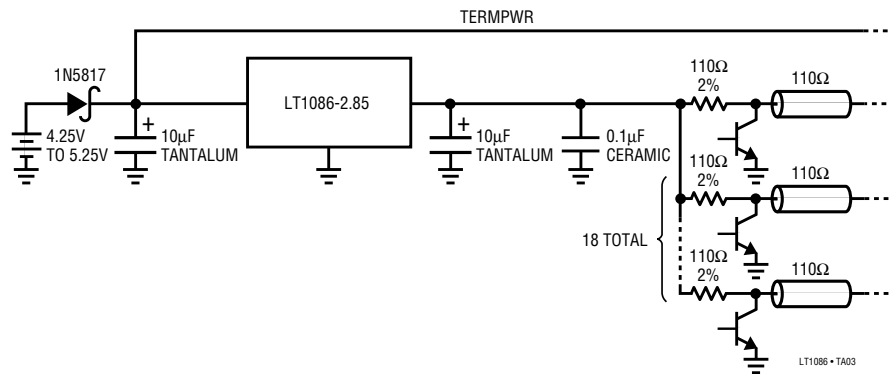
device so that heat can flow out the bottom of the case will significantly lower thermal resistance ( $\approx$  a factor of 2). If the case of the device must be electrically isolated, a thermally conductive spacer can be used as long as its added contribution to thermal resistance is considered. Note that the case of all devices in this series is electrically connected to the output.

### 5V, 1.5A Regulator

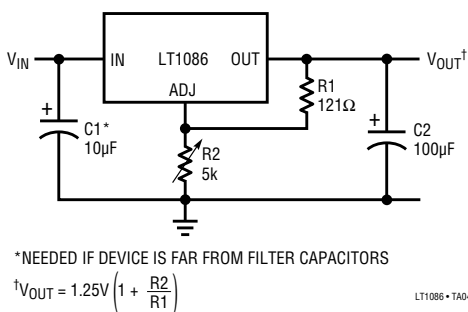


## TYPICAL APPLICATIONS

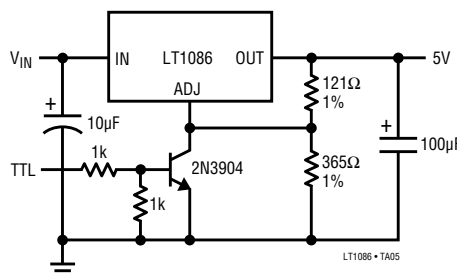
### SCSI-2 Active Termination



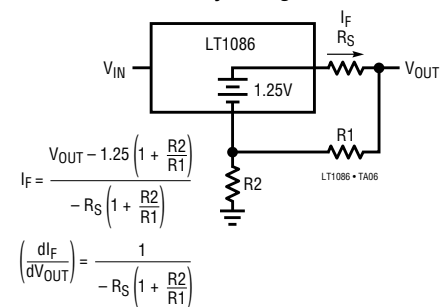
### 1.2V to 15V Adjustable Regulator



### 5V Regulator with Shutdown

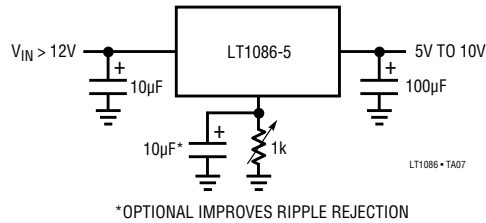


### Battery Charger

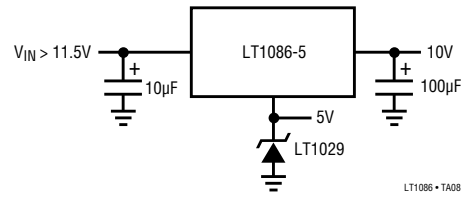


## TYPICAL APPLICATIONS

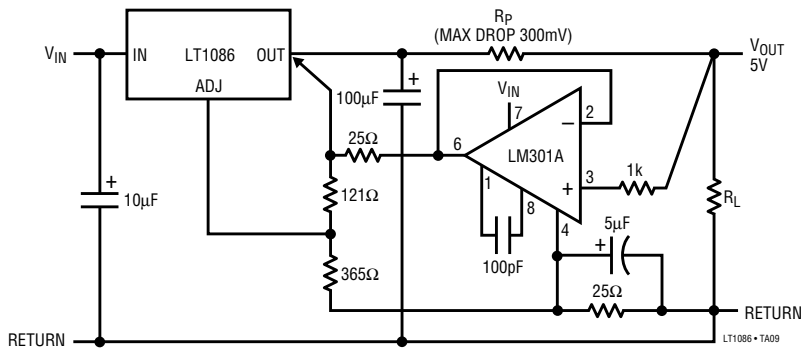
### Adjusting Output Voltage of Fixed Regulators



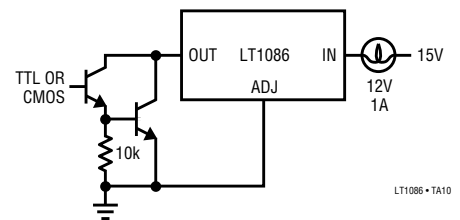
### Regulator with Reference



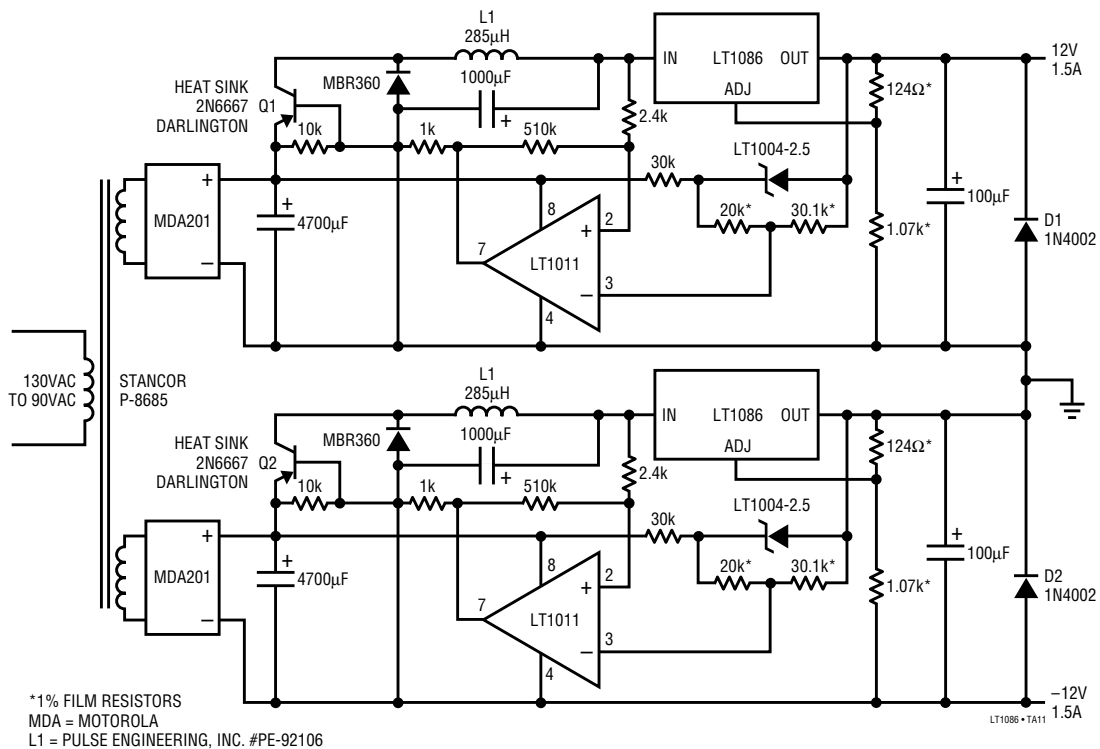
### Remote Sensing



### Protected High Current Lamp Driver

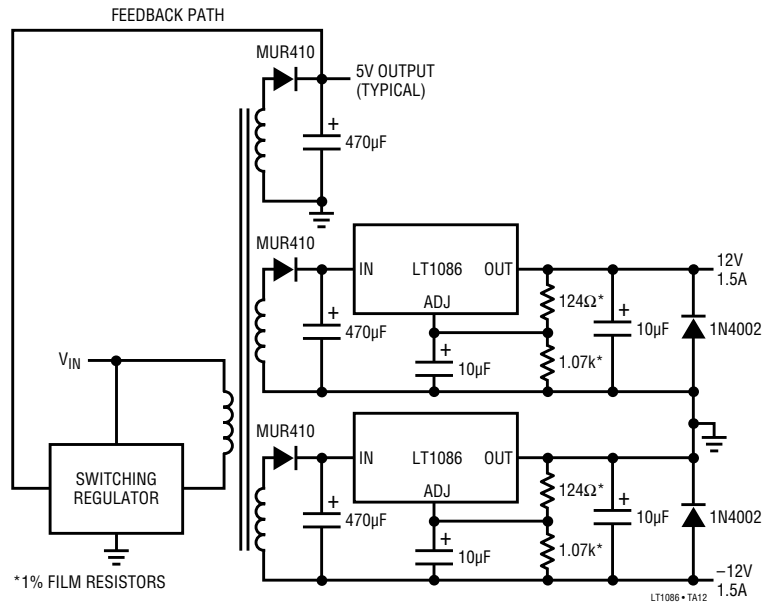


### High Efficiency Dual Linear Supply

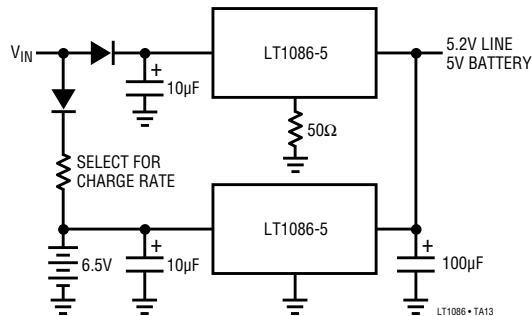


# TYPICAL APPLICATIONS

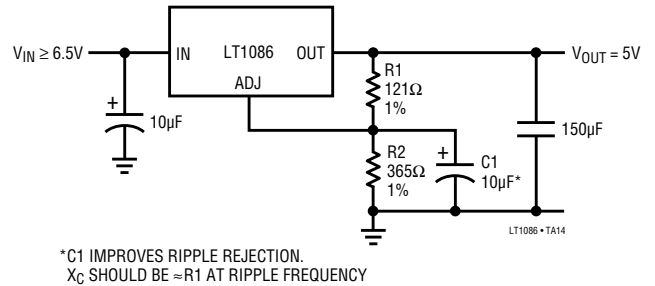
## High Efficiency Dual Supply



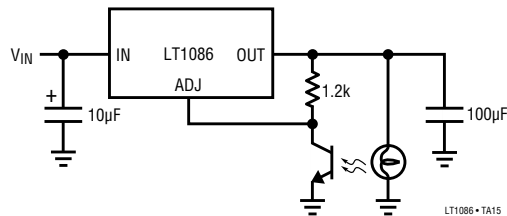
## Battery Backed Up Regulated Supply



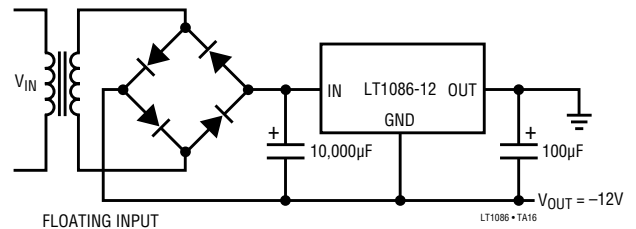
## Improving Ripple Rejection



## Automatic Light Control



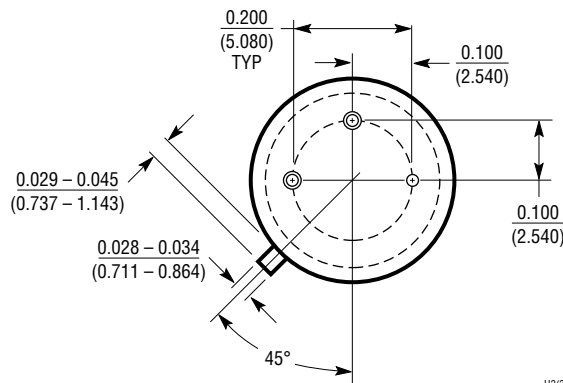
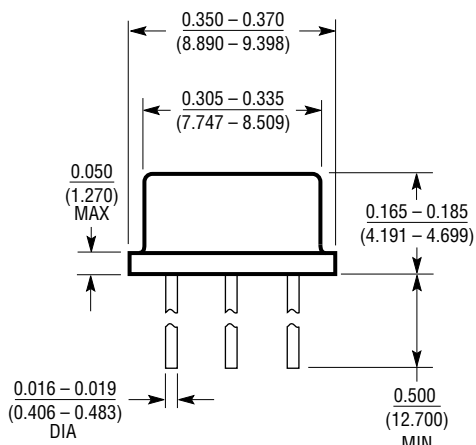
## Improving Ripple Rejection



## PACKAGE DESCRIPTION

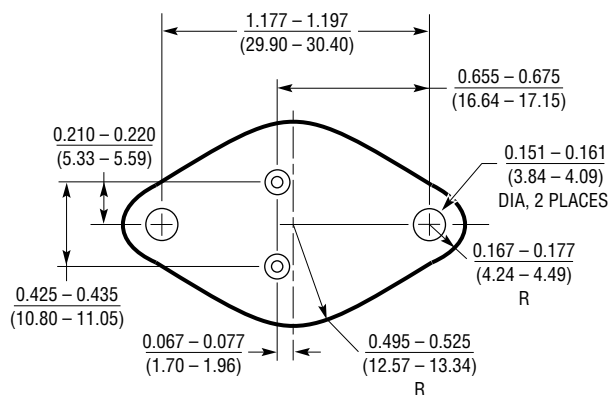
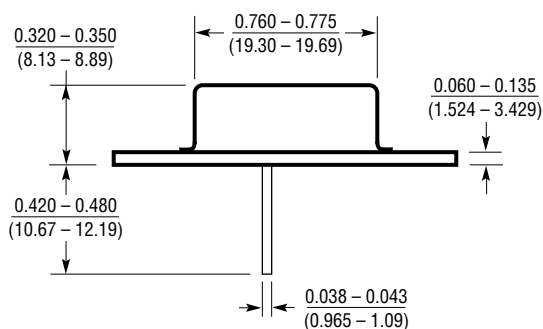
Dimension in inches (millimeters) unless otherwise noted.

### H Package 3-Lead TO-39 Metal Can



H3(39) 0592

### K Package 2-Lead TO-3 Metal Can

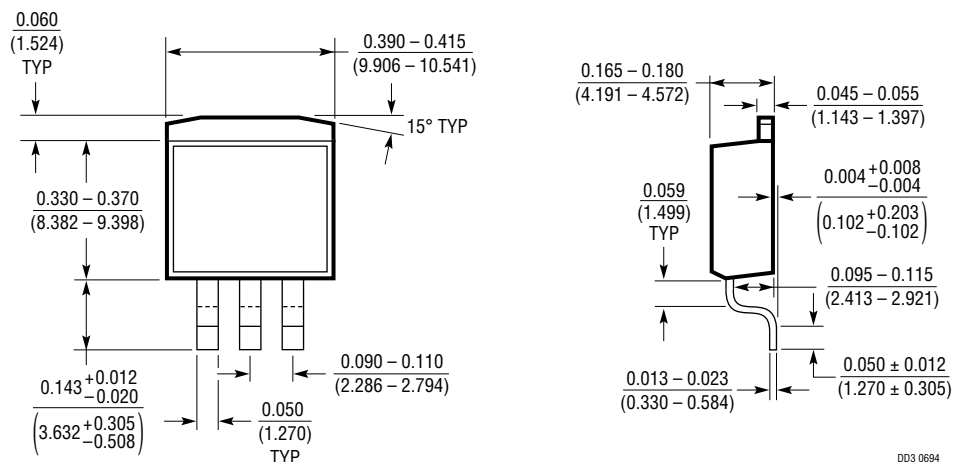


K2 0594

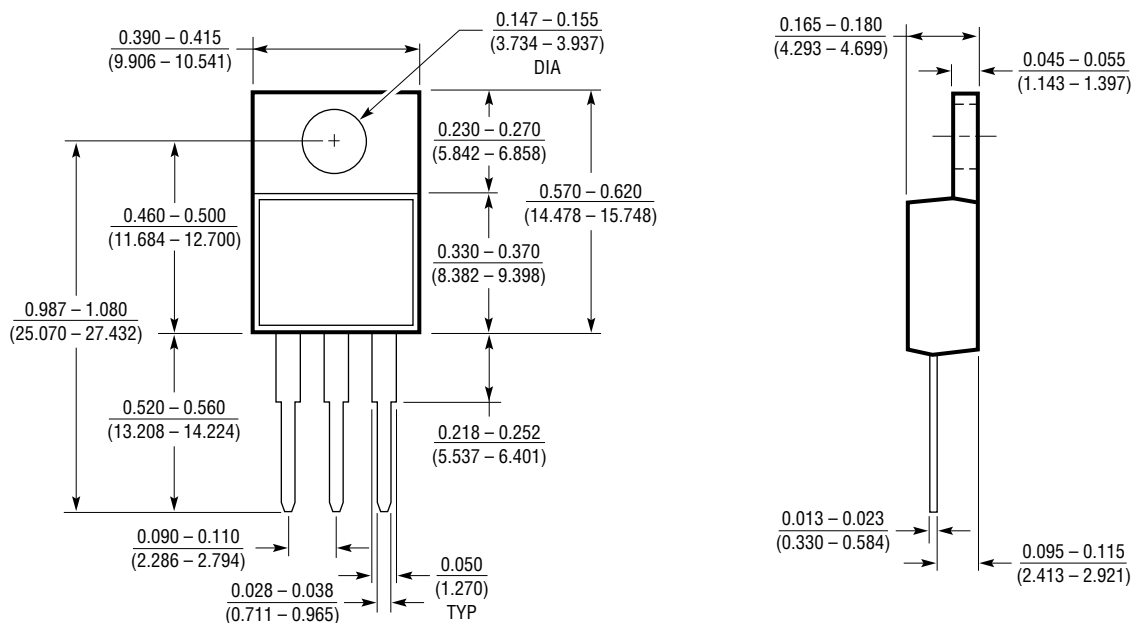
# PACKAGE DESCRIPTION

Dimension in inches (millimeters) unless otherwise noted.

## M Package 3-Lead Plastic DD



## T Package 3-Lead TO-220 Plastic



## U.S. Area Sales Offices

### NORTHEAST REGION

**Linear Technology Corporation**  
One Oxford Valley  
2300 E. Lincoln Hwy., Suite 306  
Langhorne, PA 19047  
Phone: (215) 757-8578  
FAX: (215) 757-5631

### Linear Technology Corporation

266 Lowell St., Suite B-8  
Wilmington, MA 01887  
Phone: (508) 658-3881  
FAX: (508) 658-2701

### SOUTHEAST REGION

**Linear Technology Corporation**  
17060 Dallas Parkway  
Suite 208  
Dallas, TX 75248  
Phone: (214) 733-3071  
FAX: (214) 380-5138

### CENTRAL REGION

**Linear Technology Corporation**  
Chesapeake Square  
229 Mitchell Court, Suite A-25  
Addison, IL 60101  
Phone: (708) 620-6910  
FAX: (708) 620-6977

### SOUTHWEST REGION

**Linear Technology Corporation**  
22141 Ventura Blvd.  
Suite 206  
Woodland Hills, CA 91364  
Phone: (818) 703-0835  
FAX: (818) 703-0517

### NORTHWEST REGION

**Linear Technology Corporation**  
782 Sycamore Dr.  
Milpitas, CA 95035  
Phone: (408) 428-2050  
FAX: (408) 432-6331

## International Sales Offices

### FRANCE

**Linear Technology S.A.R.L.**  
Immeuble "Le Quartz"  
58 Chemin de la Justice  
92290 Chatenay Malabry  
France  
Phone: 33-1-41079555  
FAX: 33-1-46314613

### GERMANY

**Linear Technonlogy GmbH**  
Untere Hauptstr. 9  
D-85386 Eching  
Germany  
Phone: 49-89-3197410  
FAX: 49-89-3194821

### JAPAN

**Linear Technology KK**  
5F YZ Bldg.  
4-4-12 Iidabashi, Chiyoda-Ku  
Tokyo, 102 Japan  
Phone: 81-3-3237-7891  
FAX: 81-3-3237-8010

### KOREA

**Linear Technology Korea Branch**  
Namsong Building, #505  
Itaewon-Dong 260-199  
Yongsan-Ku, Seoul  
Korea  
Phone: 82-2-792-1617  
FAX: 82-2-792-1619

### SINGAPORE

**Linear Technology Pte. Ltd.**  
101 Boon Keng Road  
#02-15 Kallang Ind. Estates  
Singapore 1233  
Phone: 65-293-5322  
FAX: 65-292-0398

### TAIWAN

**Linear Technology Corporation**  
Rm. 801, No. 46, Sec. 2  
Chung Shan N. Rd.  
Taipei, Taiwan, R.O.C.  
Phone: 886-2-521-7575  
FAX: 886-2-562-2285

### UNITED KINGDOM

**Linear Technology (UK) Ltd.**  
The Coliseum, Riverside Way  
Camberley, Surrey GU15 3YL  
United Kingdom  
Phone: 44-276-677676  
FAX: 44-276-64851

## World Headquarters

**Linear Technology Corporation**  
1630 McCarthy Blvd.  
Milpitas, CA 95035-7487  
Phone: (408) 432-1900  
FAX: (408) 434-0507

0294