LINEAR TECHNOLOGY

# LT138A/LT338A
# LM138/LM338

## 5 Amp Positive Adjustable Voltage Regulator

## FEATURES

- *Guaranteed* 1% Initial Tolerance
- *Guaranteed* 0.3% Load Regulation
- *Guaranteed* 5 Amp Output Current
- 100% Thermal Limit Burn-in
- 12 Amp Transient Output Current

## APPLICATIONS

- High Power Linear Regulator
- Battery Chargers
- Power Driver
- Constant Current Regulator

## DESCRIPTION

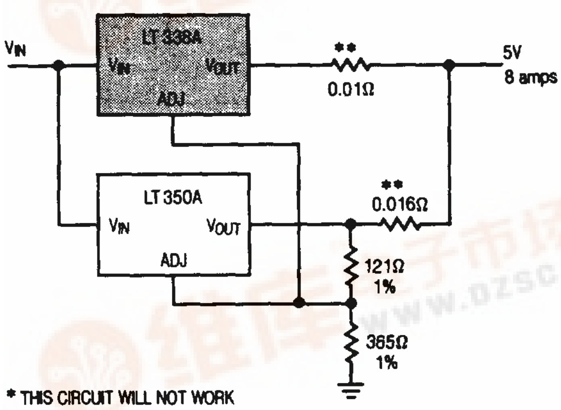
The LT138A series of adjustable regulators provide 5 amps output current over an output voltage range of 1.2 volts to 32 volts. The internal voltage reference is trimmed to less than 1%, enabling a very tight output voltage. In addition to excellent line and load regulation, with full overload protection, the LT138A incorporates new current limiting circuitry allowing large transient load currents to be handled for short periods. Transient load currents of up to 12 amps can be supplied without limiting, eliminating the need for a large output capacitor.

The LT138A is an improved version of the popular LM138 with improved circuit design and advanced process techniques to provide superior performance and reliability.

The graph below shows the significant improvement in output voltage tolerance achieved by using the LT138A or LT338A.

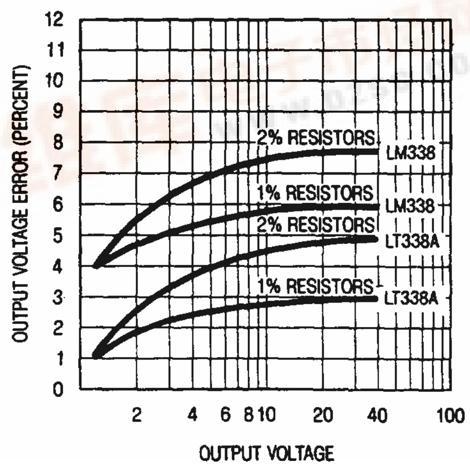


*** Parallel Regulators for Higher Current**




* THIS CIRCUIT WILL NOT WORK WITH LM VERSION DEVICES
** CURRENT SHARING RESISTORS DEGRADE REGULATION TO 1%

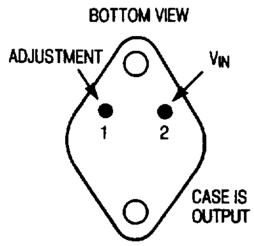
**Output Voltage Error**



## ABSOLUTE MAXIMUM RATINGS

Power Dissipation .............. Internally Limited
Input to Output Voltage Differential ........... 35V
Operating Junction Temperature Range
  LT138A/LM138 .............. −55°C to 150°C
  LT338A/LM338 ................. 0°C to 125°C
Storage Temperature Range
  LT138A/LM138 .............. −65°C to 150°C
  LT338A/LM338 .............. −65°C to 150°C
Lead Temperature (Soldering, 10 sec.)....... 300°C

## PACKAGE/ORDER INFORMATION




K PACKAGE
TO-3 METAL CAN
(STEEL)

| ORDER PART NUMBER |
|---|
| LT138AK |
| LT338AK |
| LM138K |
| LM338K |

## PRECONDITIONING

100% THERMAL LIMIT BURN-IN

## ELECTRICAL CHARACTERISTICS (See Note 1)

| SYMBOL | PARAMETER | CONDITIONS | | LT138A MIN | LT138A TYP | LT138A MAX | LM138 MIN | LM138 TYP | LM138 MAX | UNITS |
|---|---|---|---|---|---|---|---|---|---|---|
| $V_{REF}$ | Reference Voltage | $I_{OUT}$ = 10mA $T_j$ = 25°C | | 1.238 | 1.250 | 1.262 | | | | V |
| | | 3V ≤ ($V_{IN}$ − $V_{OUT}$) ≤ 35V<br>10mA ≤ $I_{OUT}$ ≤ 5A, P ≤ 50W | ● | 1.225 | 1.250 | 1.270 | 1.19 | 1.24 | 1.29 | V |
| $\frac{\Delta V_{OUT}}{\Delta V_{IN}}$ | Line Regulation | 3V ≤ ($V_{IN}$ − $V_{OUT}$) ≤ 35V, (See Note 2)<br>$T_A$ = 25°C | | | 0.005 | 0.01 | | 0.005 | 0.01 | %/V |
| | | | ● | | 0.02 | 0.04 | | 0.02 | 0.04 | %/V |
| $\frac{\Delta V_{OUT}}{\Delta I_{OUT}}$ | Load Regulation | 10mA ≤ $I_{OUT}$ ≤ 5A, (See Note 2)<br>$T_A$ = 25°C<br>$V_{OUT}$ ≤ 5V | | | 5 | 15 | | 5 | 15 | mV |
| | | $V_{OUT}$ ≥ 5V | | | 0.1 | 0.3 | | 0.1 | 0.3 | % |
| | | $V_{OUT}$ ≤ 5V | ● | | 20 | 30 | | 20 | 30 | mV |
| | | $V_{OUT}$ ≥ 5V | ● | | 0.3 | 0.6 | | 0.3 | 0.6 | % |
| | Thermal Regulation | $T_A$ = 25°C, 20msec pulse | | | 0.002 | 0.01 | | 0.002 | 0.01 | %/W |
| | Ripple Rejection | $V_{OUT}$ = 10V, f = 120Hz<br>$C_{ADJ}$ = 0 | ● | | 60 | | | 60 | | dB |
| | | $C_{ADJ}$ = 10μF | ● | 60 | 75 | | 60 | 75 | | dB |
| $I_{ADJ}$ | Adjust Pin Current | | ● | | 45 | 100 | | 45 | 100 | μA |
| $\Delta I_{ADJ}$ | Adjust Pin Current Change | 10mA ≤ $I_{OUT}$ ≤ 5A,<br>3V ≤ ($V_{IN}$−$V_{OUT}$) ≤ 35V | ● | | 0.2 | 5 | | 0.2 | 5 | μA |
| | Minimum Load Current | ($V_{IN}$ − $V_{OUT}$) = 35V | ● | | 3.5 | 5 | | 3.5 | 5 | mA |
| $I_{SC}$ | Current Limit | ($V_{IN}$ − $V_{OUT}$) ≤ 10V<br>DC | ● | 5 | 8 | | 5 | 8 | | A |
| | | 0.5ms peak | ● | 7 | 12 | | 7 | 12 | | A |
| | | ($V_{IN}$ − $V_{OUT}$) = 30V, $T_j$ = 25°C | | | 1 | | | 1 | | A |
| $\frac{\Delta V_{OUT}}{\Delta Temp}$ | Temperature Stability | | ● | | 1 | 2 | | 1 | | % |
| $\frac{\Delta V_{OUT}}{\Delta Time}$ | Long Term Stability | $T_A$ = 125°C, 1000 Hours | | | 0.3 | 1 | | 0.3 | 1 | % |
| $e_n$ | RMS Output Noise (% of $V_{OUT}$) | $T_A$ = 25°C, 10Hz ≤ f ≤ 10kHz | | | 0.001 | | | 0.003 | | % |
| $\theta_{JC}$ | Thermal Resistance Junction to Case | K Package | | | | 1 | | | 1 | °C/W |

# ELECTRICAL CHARACTERISTICS (See Note 1)

| SYMBOL | PARAMETER | CONDITIONS | | LT338A MIN | LT338A TYP | LT338A MAX | LM338 MIN | LM338 TYP | LM338 MAX | UNITS |
|---|---|---|---|---|---|---|---|---|---|---|
| $V_{REF}$ | Reference Voltage | $I_{OUT}$ = 10mA $T_A$ = 25°C | | 1.238 | 1.250 | 1.262 | | | | V |
| | | 3V ≤ ($V_{IN}$ − $V_{OUT}$) ≤ 35V<br>10mA ≤ $I_{OUT}$ ≤ 5A, P ≤ 50W | ● | 1.225 | 1.250 | 1.270 | 1.19 | 1.24 | 1.29 | V |
| $\frac{\Delta V_{OUT}}{\Delta V_{IN}}$ | Line Regulation | 3V ≤ ($V_{IN}$ − $V_{OUT}$) ≤ 35V, (See Note 2)<br>$T_A$ = 25°C | | | 0.005 | 0.01 | | 0.005 | 0.03 | %/V |
| | | | ● | | 0.02 | 0.04 | | 0.02 | 0.06 | %/V |
| $\frac{\Delta V_{OUT}}{\Delta I_{OUT}}$ | Load Regulation | 10mA ≤ $I_{OUT}$ ≤ 5A, (See Note 2)<br>$T_A$ = 25°C<br>$V_{OUT}$ ≤ 5V<br>$V_{OUT}$ ≥ 5V | | | 5<br>0.1 | 15<br>0.3 | | 5<br>0.1 | 25<br>0.5 | mV<br>% |
| | | $V_{OUT}$ ≤ 5V<br>$V_{OUT}$ ≥ 5V | ●<br>● | | 20<br>0.3 | 30<br>0.6 | | 20<br>0.3 | 50<br>1 | mV<br>% |
| | Thermal Regulation | $T_A$ = 25°C, 20msec Pulse | | | 0.002 | 0.02 | | 0.002 | 0.02 | %/W |
| | Ripple Rejection | $V_{OUT}$ = 10V, f = 120Hz<br>$C_{ADJ}$ = 0<br>$C_{ADJ}$ = 10μF | ●<br>● | 60 | 60<br>75 | | 60 | 60<br>75 | | dB<br>dB |
| $I_{ADJ}$ | Adjust Pin Current | | ● | | 45 | 100 | | 45 | 100 | μA |
| $\Delta I_{ADJ}$ | Adjust Pin Current Change | 10mA ≤ $I_{OUT}$ ≤ 5A,<br>3V ≤ ($V_{IN}$−$V_{OUT}$) ≤ 35V | ● | | 0.2 | 5 | | 0.2 | 5 | μA |
| | Minimum Load Current | ($V_{IN}$ − $V_{OUT}$) = 35V | ● | | 3.5 | 10 | | 3.5 | 10 | mA |
| $I_{SC}$ | Current Limit | ($V_{IN}$ − $V_{OUT}$) ≤ 10V<br>DC<br>0.5ms peak | ●<br>● | 5<br>7 | 8<br>12 | | 5<br>7 | 8<br>12 | | A<br>A |
| | | ($V_{IN}$ − $V_{OUT}$) = 30V, $T_J$ = 25°C | | | 1 | 2 | | 1 | | A |
| $\frac{\Delta V_{OUT}}{\Delta Temp}$ | Temperature Stability | | ● | | 1 | 2 | | 1 | | % |
| $\frac{\Delta V_{OUT}}{\Delta Time}$ | Long Term Stability | $T_A$ = 125°C, 1000 Hours | | | 0.3 | 1 | | 0.3 | 1 | % |
| $e_n$ | RMS Output Noise (% of $V_{OUT}$) | $T_A$ = 25°C, 10Hz ≤ f ≤ 10kHz | | | 0.001 | | | 0.003 | | % |
| $\theta_{JC}$ | Thermal Resistance Junction to Case | K Package | | | | 1 | | | 1 | °C/W |

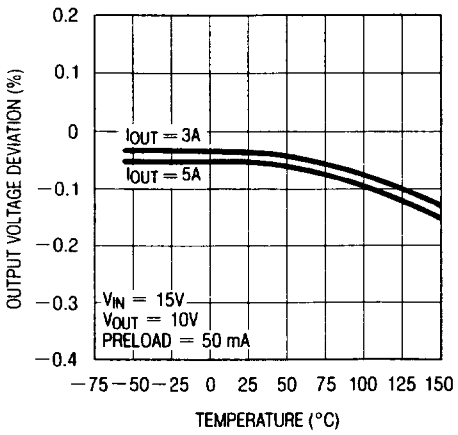
The ● denotes the specifications which apply over the full operating temperature range.

**Note 1:** Unless otherwise specified, these specifications apply: $V_{IN}$ − $V_{OUT}$ = 5V and $I_{OUT}$ = 2.5A. These specifications are applicable for power dissipations up to 50W.

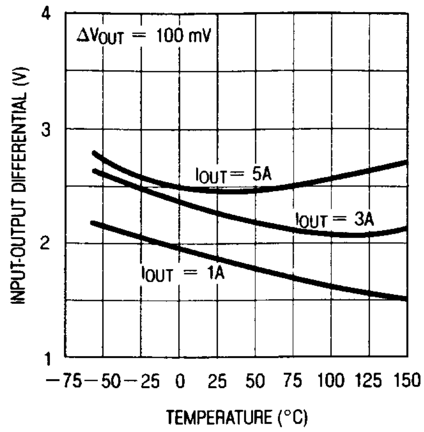
**Note 2:** See thermal regulation specifications for changes in output voltage due to heating effects. Load and line regulation are measured at a constant junction temperature by low duty cycle pulse testing.

# TYPICAL PERFORMANCE CHARACTERISTICS

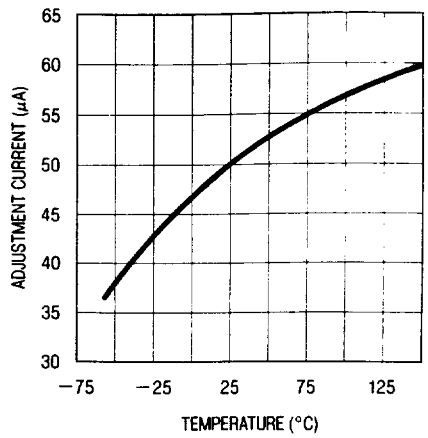
**Load Regulation**



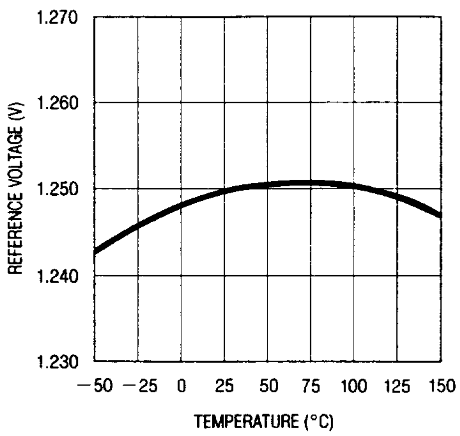

**Dropout Voltage**



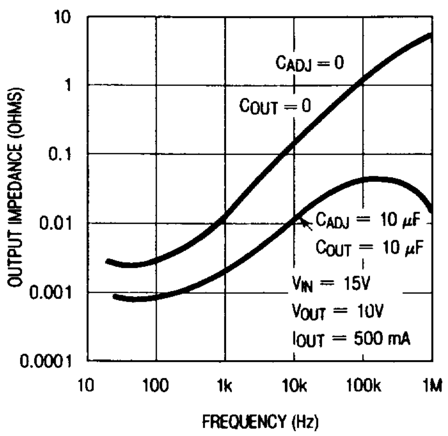

**Adjustment Current**



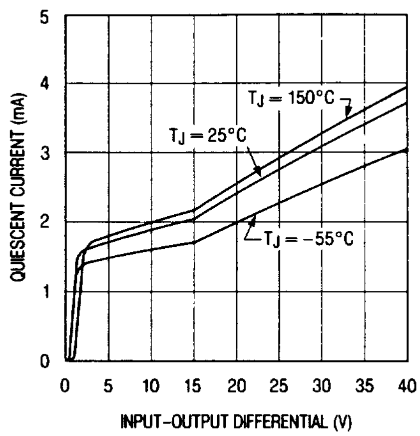

**Temperature Stability**



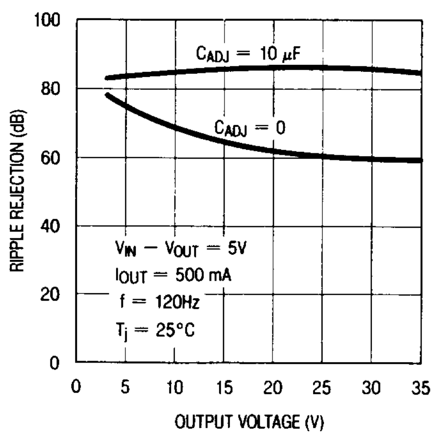

**Output Impedance**



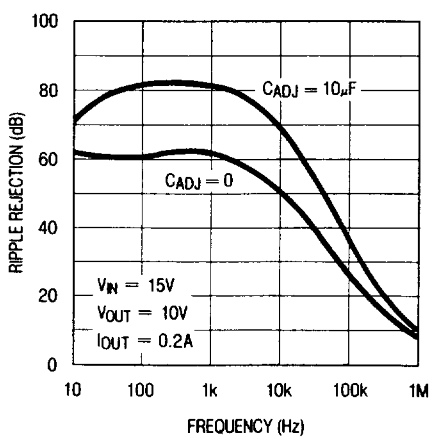

**Minimum Operating Current**



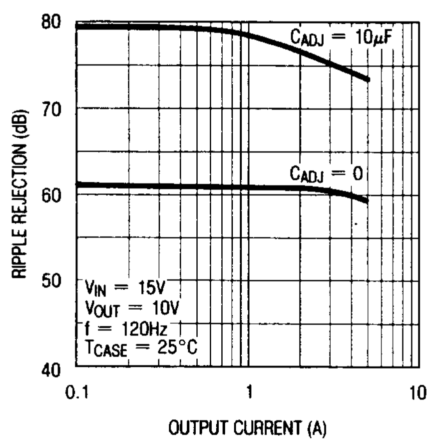

**Ripple Rejection**




**Ripple Rejection**

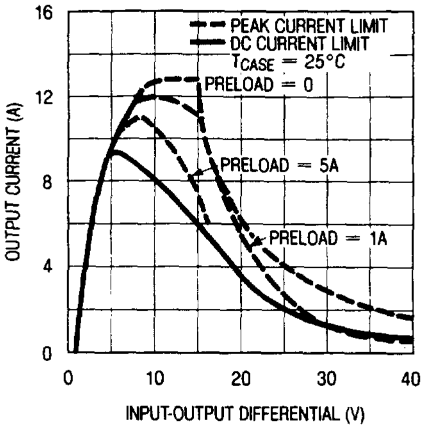



**Ripple Rejection**

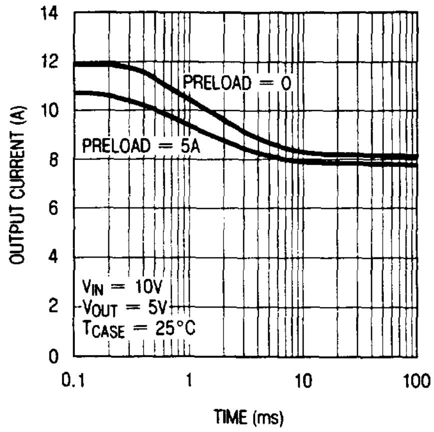


# TYPICAL PERFORMANCE CHARACTERISTICS

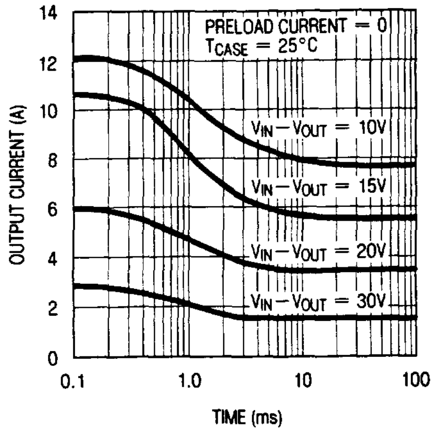
**Current Limit**



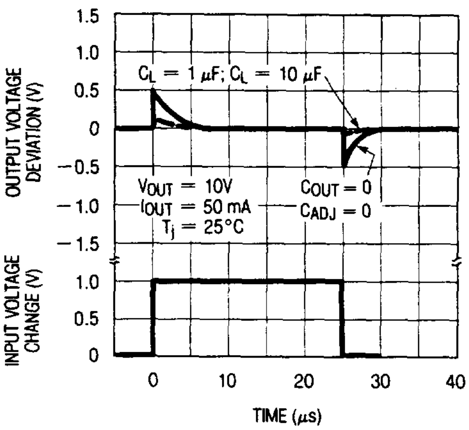

**Current Limit**



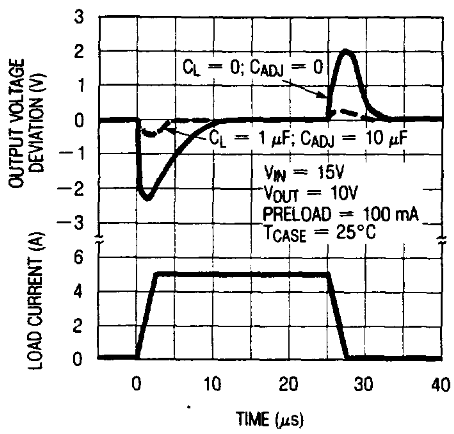

**Current Limit**




**Line Transient Response**




**Load Transient Response**

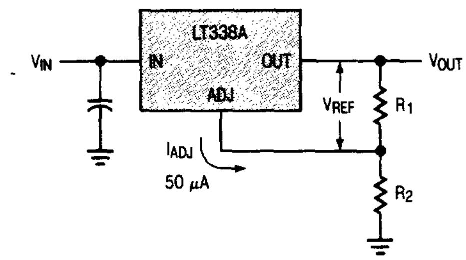





# APPLICATIONS INFORMATION

## General

The LT138A develops a 1.25V reference voltage between the output and the adjustable 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 the specified minimum load current of 5mA or 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. It is easily seen from the output voltage equation, that even if the resistors were of exact value, the accuracy of the output is limited by the accuracy of $V_{REF}$. Earlier adjustable regulators had a reference tolerance of ±4% which is dangerously close to the ±5% supply tolerance required in many logic and analog systems. Further, even 1% resistors can drift 0.01%/°C, adding additional error to the output voltage tolerance.




$$V_{OUT} = V_{REF}\left(1 + \frac{R_2}{R_1}\right) + I_{ADJ} R_2$$

**Basic Adjustable Regulator**
**Figure 1**

For example, using 2% resistors and ±4% tolerance for $V_{REF}$, calculations will show that the expected range of a 5V regulator design would be $4.66V \leqslant V_{OUT} \leqslant 5.36V$ or approximately ±7%. If the same example were used for a 15V regulator, the expected tolerance would be ±8%. With these results most applications required some method of trimming, usually a trim pot. This solution is both expensive and not conducive to volume production.

One of the enhancements of Linear Technology's adjustable regulators over existing devices is the tightened initial tolerance of $V_{REF}$. This allows relatively inexpensive 1% or 2% film resistors to be used for R1 and R2 to set the output voltage within an acceptable tolerance.

With a guaranteed 1% reference, a 5V power supply design, using ±2% resistors, would have a worst case manufacturing tolerance of ±4%. If 1% resistors are used, the tolerance will drop to ±2.5%. A plot of the worst case output voltage tolerance as a function of resistor tolerance is shown on the front page.

For convenience, a table of standard 1% resistor values is shown below.

Table of ½% and 1% Standard Resistance Values

| | | | | | |
|---|---|---|---|---|---|
| 1.00 | 1.47 | 2.15 | 3.16 | 4.64 | 6.81 |
| 1.02 | 1.50 | 2.21 | 3.24 | 4.75 | 6.98 |
| 1.05 | 1.54 | 2.26 | 3.32 | 4.87 | 7.15 |
| 1.07 | 1.58 | 2.32 | 3.40 | 4.99 | 7.32 |
| 1.10 | 1.62 | 2.37 | 3.48 | 5.11 | 7.50 |
| 1.13 | 1.65 | 2.43 | 3.57 | 5.23 | 7.68 |
| 1.15 | 1.69 | 2.49 | 3.65 | 5.36 | 7.87 |
| 1.18 | 1.74 | 2.55 | 3.74 | 5.49 | 8.06 |
| 1.21 | 1.78 | 2.61 | 3.83 | 5.62 | 8.25 |
| 1.24 | 1.82 | 2.67 | 3.92 | 5.76 | 8.45 |
| 1.27 | 1.87 | 2.74 | 4.02 | 5.90 | 8.66 |
| 1.30 | 1.91 | 2.80 | 4.12 | 6.04 | 8.87 |
| 1.33 | 1.96 | 2.87 | 4.22 | 6.19 | 9.09 |
| 1.37 | 2.00 | 2.94 | 4.32 | 6.34 | 9.31 |
| 1.40 | 2.05 | 3.01 | 4.42 | 6.49 | 9.53 |
| 1.43 | 2.10 | 3.09 | 4.53 | 6.65 | 9.76 |

Standard Resistance Values are obtained from the Decade Table by multiplying by multiples of 10. As an example, 1.21 can represent 1.21Ω, 12.1Ω, 121Ω, 1.21KΩ etc.

### Bypass Capacitors

Input bypassing using a 1μF tantalum or 25μF electrolytic is recommended when the input filter capacitors are more than 5 inches from the device. Improved ripple rejection (80 dB) can be accomplished by adding a 10μF capacitor from the adjust pin to ground. Increasing the size of the capacitor to 20μF will help ripple rejection at low output voltage since the reactance of this capacitor should be small compared to the voltage setting resistor, R2. For improved AC transient response and to prevent the possibility of oscillation due to unknown reactive load, a 1μF capacitor is also recommended at the output. Because of their low impedance at high frequencies, the best type of capacitor to use is solid tantalum.

### Protection Diodes

The LT138A/338A do not require a protection diode from the adjustment terminal to the output (see figure 2). Improved internal circuitry eliminates the need for this diode when the adjustment pin is bypassed with a capacitor to improve ripple rejection.

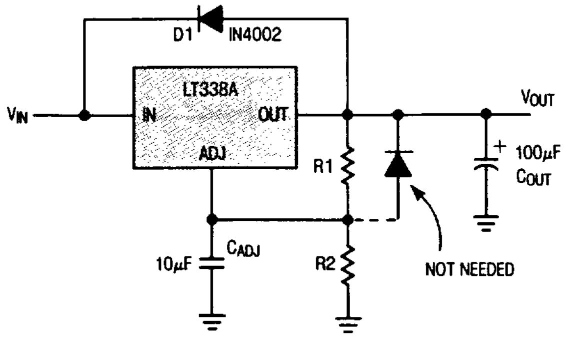



Figure 2

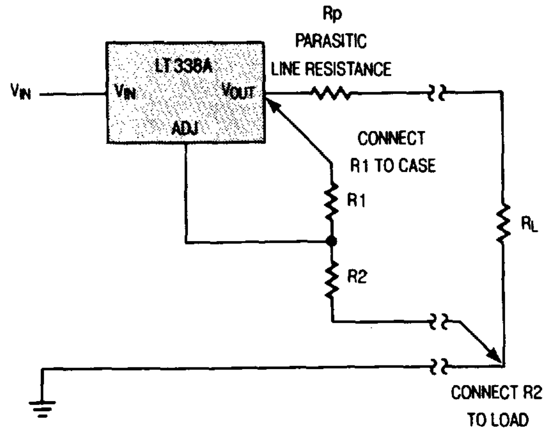
If a very large output capacitor is used, such as a 100μF shown in figure 2, the regulator could be damaged or destroyed if the input is accidentally shorted to ground or crowbarred, due to the output capacitor discharging into the output terminal of the regulator. To prevent this, a diode D1 as shown, is recommended to safely discharge the capacitor.

### Load Regulation

Because the LT138A 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 3.* If R1 were connected to the load, the effective resistance between the regulator and the load would be

$$R_p \times \left(\frac{R2 + R1}{R1}\right), R_p = \text{Parasitic Line Resistance.}$$

Connected as shown, $R_p$ is not multiplied by the divider ratio. $R_p$ is about 0.004Ω per foot using 16 gauge wire. This translates to 4mV/ft at 1A 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.

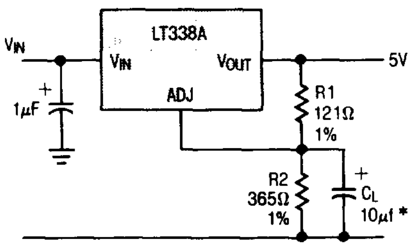



**Connections For Best Load Regulation**
**Figure 3.**



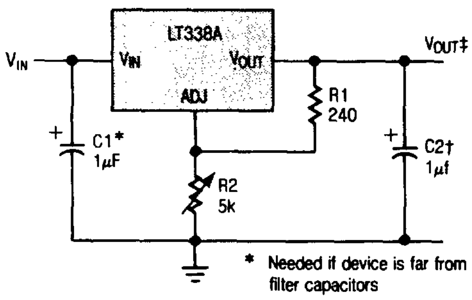
## TYPICAL APPLICATIONS

### Improving Ripple Rejection




* $C_1$ IMPROVES RIPPLE REJECTION $X_C$ SHOULD BE SMALL COMPARED TO $R_2$

### 1.2V–25V Adjustable Regulator

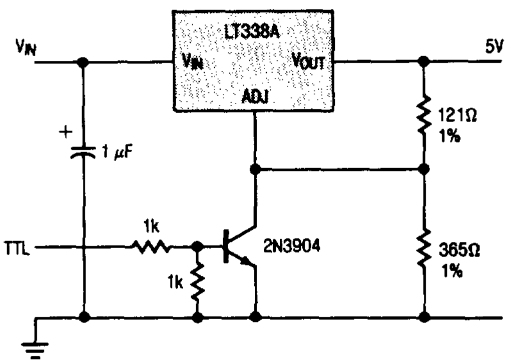



* Needed if device is far from filter capacitors

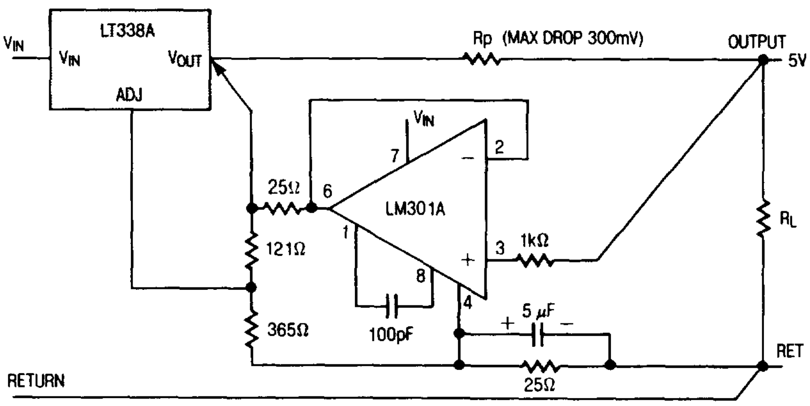
† Optional—improves transient response

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

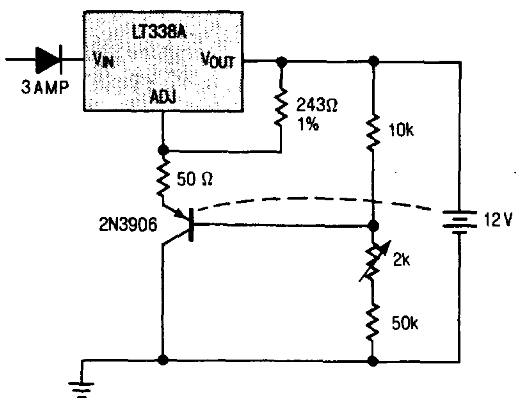
### 5V Regulator With Shut Down



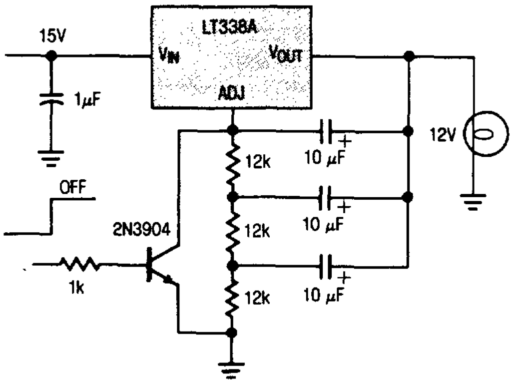

### Remote Sensing



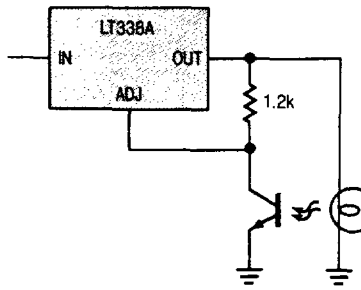

### Temperature Compensated Lead Acid Battery Charger



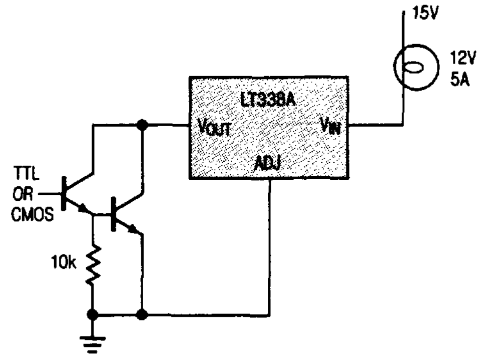
**Lamp Flasher**




**Automatic Light Control**

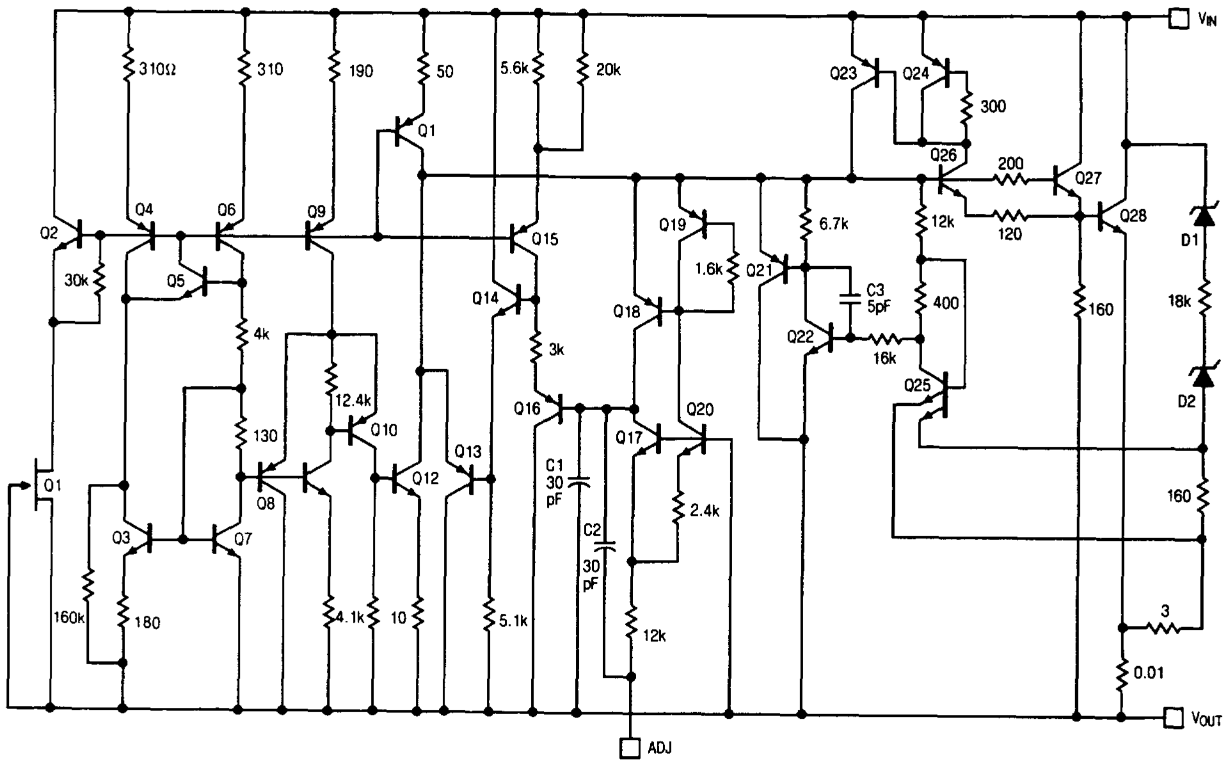



**Protected High Current Lamp Driver**




# SCHEMATIC DIAGRAM

**LT138A/LT338A**




# PACKAGE DESCRIPTION

**K Package To-3**
**Steel Metal Can**

| | $T_j$ max. | $\theta_{ja}$ | $\theta_{jc}$ |
|---|---|---|---|
| 138A<br>138 | 150°C | 35°C/W | 1°C/W |
| 338A<br>338 | 125°C | 35°C/W | 1°C/W |