

5A Positive Adjustable Voltage Regulator

FEATURES

- Guaranteed 1% Initial Tolerance
- Guaranteed 0.3% Load Regulation
- Guaranteed 5A Output Current
- 100% Thermal Limit Burn-In
- 12A Transient Output Current

APPLICATIONS

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

DESCRIPTION

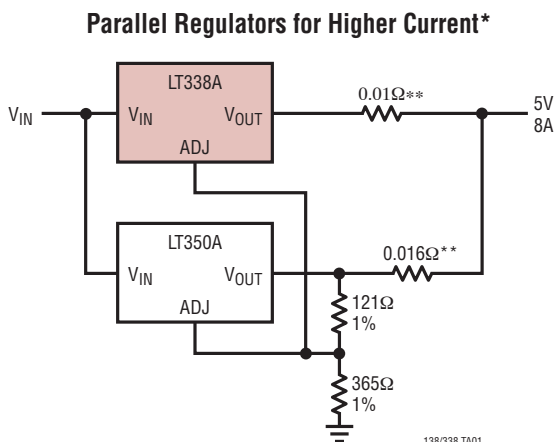
The LT[®]138A series of adjustable regulators provide 5A output current over an output voltage range of 1.2V to 32V. The internal voltage reference is trimmed to less than 1%, enabling a very tight output voltage. In addition to excellent line and load regulation, with full overload protection, the LT138A incorporates new current limiting circuitry allowing large transient load currents to be handled for short periods. Transient load currents of up to 12A 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.

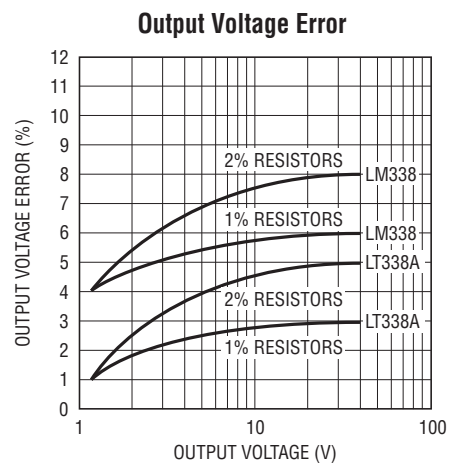
The graph below shows the significant improvement in output voltage tolerance achieved by using the LT138A or LT338A.

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TYPICAL APPLICATION



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



LT138A/LT339A LM138/LM338

ABSOLUTE MAXIMUM RATINGS (Note 1)

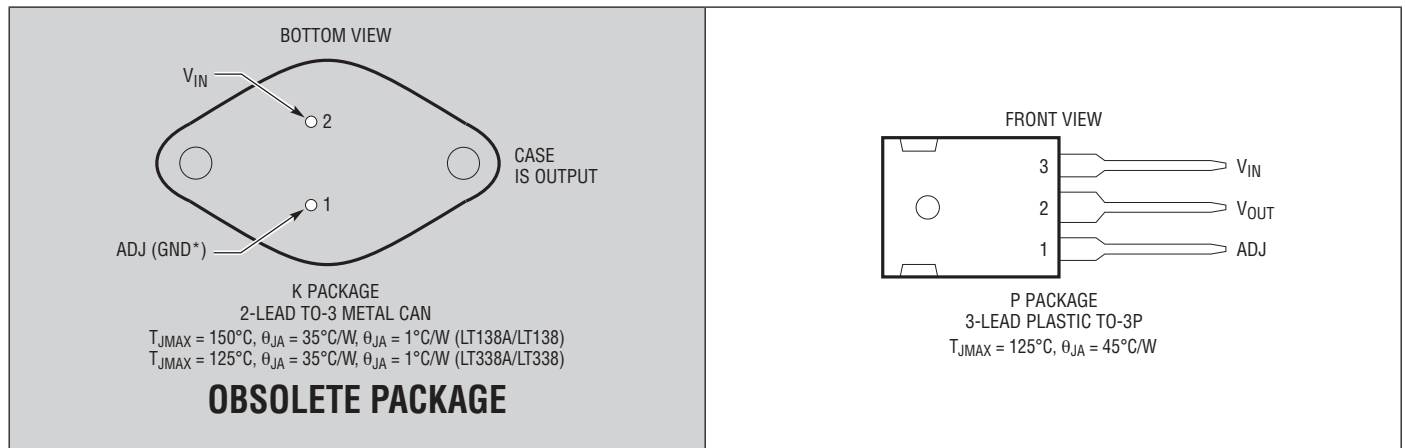
Power Dissipation Internally Limited
 Input-to-Output Voltage Differential 35V
 Operating Junction Temperature Range
 LT138A/LM138 -55°C to 150°C
 LT338A/LM338 0°C to 125°C

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

PRECONDITIONING

100% Thermal Limit Burn-In

PIN CONFIGURATION



ORDER INFORMATION

LEAD FREE FINISH	TAPE AND REEL	PART MARKING	PACKAGE DESCRIPTION	TEMPERATURE RANGE
LM338P#PBF	LM338P#TRPBF	LM338P	3-Lead Plastic TO-3P	0°C to 125°C
LEAD BASED FINISH	TAPE AND REEL	PART MARKING	PACKAGE DESCRIPTION	TEMPERATURE RANGE
LM338P	LM338P#TR	LM338P	3-Lead Plastic TO-3P	0°C to 125°C

Consult LTC Marketing for parts specified with wider operating temperature ranges.

For more information on lead free part marking, go to: <http://www.linear.com/leadfree/>

For more information on tape and reel specifications, go to: <http://www.linear.com/tapeandreeel/>

ELECTRICAL CHARACTERISTICS The ● denotes the specifications which apply over the full operating temperature range, otherwise specifications are at $T_A = 25^\circ\text{C}$. (Note 2)

SYMBOL	PARAMETER	CONDITIONS	LT138A			LM138			UNITS
			MIN	TYP	MAX	MIN	TYP	MAX	
V_{REF}	Reference Voltage	$I_{OUT} = 10\text{mA}$, $T_J = 25^\circ\text{C}$	1.238	1.250	1.262				V
		$3\text{V} \leq (V_{IN} - V_{OUT}) \leq 35\text{V}$, $10\text{mA} \leq I_{OUT} \leq 5\text{A}$, $P \leq 50\text{W}$	● 1.225	1.250	1.270	1.119	1.24	1.29	V
$\frac{\Delta V_{OUT}}{\Delta V_{IN}}$	Line Regulation	$3\text{V} \leq (V_{IN} - V_{OUT}) \leq 35\text{V}$, (Note 3)		0.005 0.02	0.01 0.04		0.005 0.02	0.01 0.04	%/V %/V
$\frac{\Delta V_{OUT}}{\Delta V_{OUT}}$	Load Regulation	$10\text{mA} \leq I_{OUT} \leq 5\text{A}$, (Note 3) $V_{OUT} \leq 5\text{V}$ $V_{OUT} \geq 5\text{V}$		5 0.1	15 0.3		5 0.1	15 0.3	mV %
		$V_{OUT} \leq 5\text{V}$ $V_{OUT} \geq 5\text{V}$	● 20 ● 0.3	30 0.6		20 0.3	30 0.6	mV %	
	Thermal Regulation	20ms Pulse		0.002	0.01		0.002	0.01	%/W
	Ripple Rejection	$V_{OUT} = 10\text{V}$, $f = 120\text{Hz}$ $C_{ADJ} = 0\mu\text{F}$ $C_{ADJ} = 10\mu\text{F}$		60	60 75		60	60 75	dB dB
I_{ADJ}	Adjust Pin Current			45	100		45	100	μA
ΔI_{ADJ}	Adjust Pin Current Change	$10\text{mA} \leq I_{OUT} \leq 5\text{A}$, $3\text{V} \leq (V_{IN} - V_{OUT}) \leq 35\text{V}$		0.2	5		0.2	5	μA
	Minimum Load Current	$(V_{IN} - V_{OUT}) = 35\text{V}$		3.5	5		3.5	5	mA
I_{SC}	Current Limit	$(V_{IN} - V_{OUT}) \leq 10\text{V}$ DC 0.5ms Peak	● 5 ● 6	8 12		5 6	8 12		A A
		$(V_{IN} - V_{OUT}) = 30\text{V}$, $T_J = 25^\circ\text{C}$		1	2		1		A
$\frac{\Delta V_{OUT}}{\Delta \text{Temp}}$	Temperature Stability			1	2		1		%
$\frac{\Delta V_{OUT}}{\Delta \text{Time}}$	Long-Term Stability	$T_A = 125^\circ\text{C}$, 1000 Hours		0.3	1		0.3	1	%
e_n	RMS Output Noise (% of V_{OUT})	$10\text{Hz} \leq f \leq 10\text{kHz}$		0.001			0.003		%
θ_{JC}	Thermal Resistance Junction-to-Case	K Package			1			1	$^\circ\text{C}/\text{W}$

The ● denotes the specifications which apply over the full operating temperature range, otherwise specifications are at $T_A = 25^\circ\text{C}$.

SYMBOL	PARAMETER	CONDITIONS	LT138A			LM138			UNITS
			MIN	TYP	MAX	MIN	TYP	MAX	
V_{REF}	Reference Voltage	$I_{OUT} = 10\text{mA}$	1.238	1.250	1.262				V
		$3\text{V} \leq (V_{IN} - V_{OUT}) \leq 35\text{V}$, $10\text{mA} \leq I_{OUT} \leq 5\text{A}$, $P \leq 50\text{W}$	● 1.225	1.250	1.270	1.19	1.24	1.29	V
$\frac{\Delta V_{OUT}}{\Delta V_{IN}}$	Line Regulation	$3\text{V} \leq (V_{IN} - V_{OUT}) \leq 35\text{V}$, (Note 3)		0.005 0.02	0.01 0.04		0.005 0.02	0.03 0.06	%/V %/V
$\frac{\Delta V_{OUT}}{\Delta V_{OUT}}$	Load Regulation	$10\text{mA} \leq I_{OUT} \leq 5\text{A}$, (Note 3) $V_{OUT} \leq 5\text{V}$ $V_{OUT} \geq 5\text{V}$		5 0.1	15 0.3		5 0.1	25 0.5	mV %
		$V_{OUT} \leq 5\text{V}$ $V_{OUT} \geq 5\text{V}$	● 20 ● 0.3	30 0.6		20 0.3	50 1	mV %	
	Thermal Regulation	20ms Pulse		0.002	0.02		0.002	0.02	%/W
	Ripple Rejection	$V_{OUT} = 10\text{V}$, $f = 120\text{Hz}$ $C_{ADJ} = 0\mu\text{F}$ $C_{ADJ} = 10\mu\text{F}$		60	60 75		60	60 75	dB dB

ELECTRICAL CHARACTERISTICS

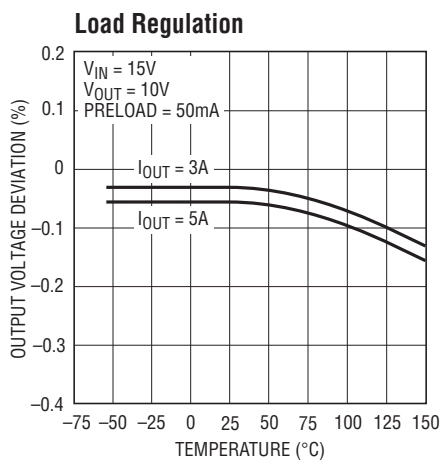
SYMBOL	PARAMETER	CONDITIONS	LT138A			LM138			UNITS
			MIN	TYP	MAX	MIN	TYP	MAX	
I_{ADJ}	Adjust Pin Current		●	45	100		45	100	μA
ΔI_{ADJ}	Adjust Pin Current Change	$10\text{mA} \leq I_{OUT} \leq 5\text{A}$, $3\text{V} \leq (V_{IN} - V_{OUT}) \leq 35\text{V}$	●	0.2	5		0.2	5	μA
	Minimum Load Current	$(V_{IN} - V_{OUT}) = 35\text{V}$	●	3.5	10		3.5	10	mA
I_{SC}	Current Limit	$(V_{IN} - V_{OUT}) \leq 10\text{V}$ DC 0.5ms Peak	●	5	8		5	8	A
			●	6	12		6	12	A
		$(V_{IN} - V_{OUT}) = 30\text{V}$, $T_J = 25^\circ\text{C}$		1	2		1		A
ΔV_{OUT} ΔTemp	Temperature Stability		●	1	2		1		%
ΔV_{OUT} ΔTime	Long-Term Stability	$T_A = 125^\circ\text{C}$, 1000 Hours		0.3	1		0.3	1	%
e_n	RMS Output Noise (% of V_{OUT})	$10\text{HZ} \leq f \leq 10\text{kHz}$		0.001			0.003		%
θ_{JC}	Thermal Resistance Junction-to-Case	K Package			1			1	$^\circ\text{C}/\text{W}$

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

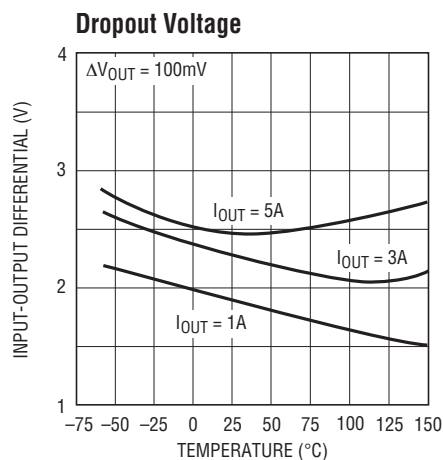
Note 2: Unless otherwise specified, these specifications apply: $V_{IN} - V_{OUT} = 5\text{V}$ and $I_{OUT} = 2.5\text{A}$. These specifications are applicable for power dissipations up to 50W.

Note 3: 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.

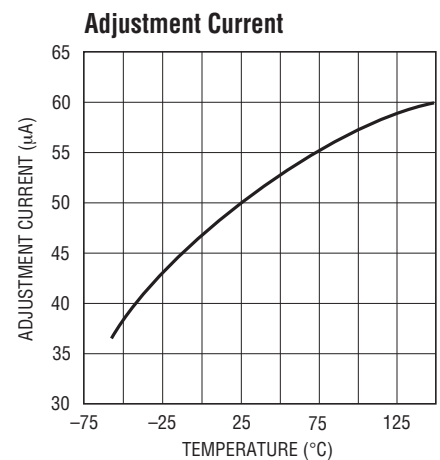
TYPICAL PERFORMANCE CHARACTERISTICS



138/338 G01



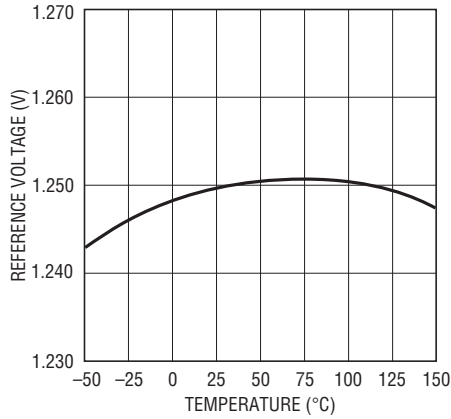
138/338 G02



138A/338A G03

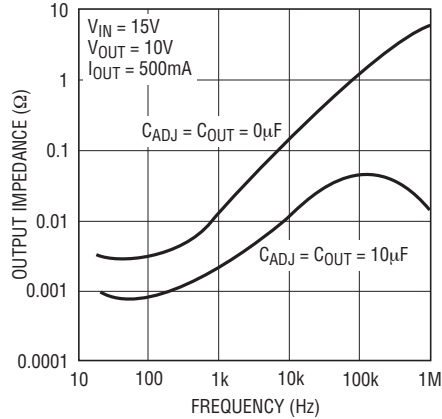
TYPICAL PERFORMANCE CHARACTERISTICS

Temperature Stability



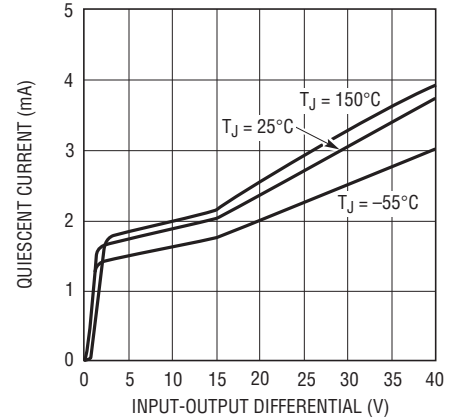
138A/338A G04

Output Impedance



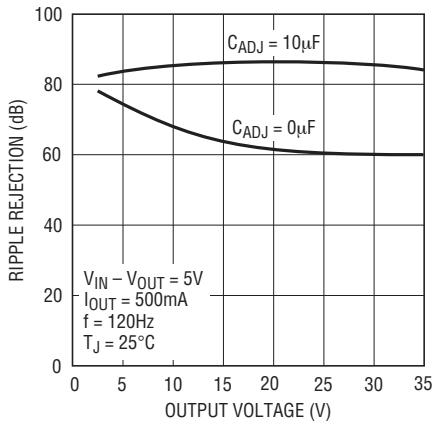
138/338 G05

Minimum Operating Current



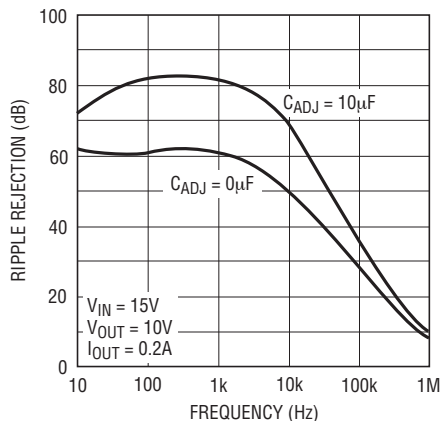
138A/338A G06

Ripple Rejection



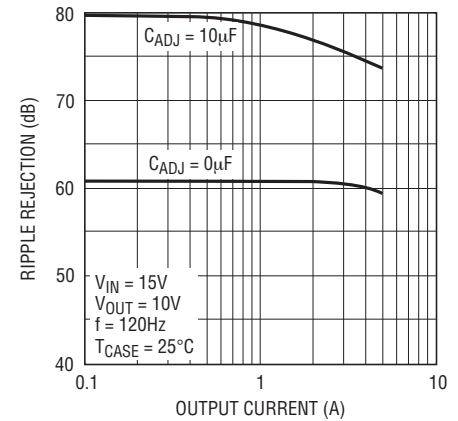
138A/338A G07

Ripple Rejection



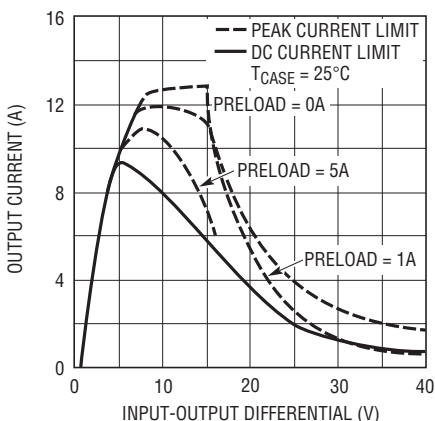
138A/338A G08

Ripple Rejection



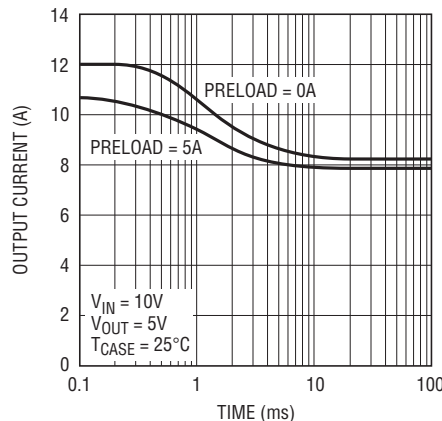
138/338 G09

Current Limit



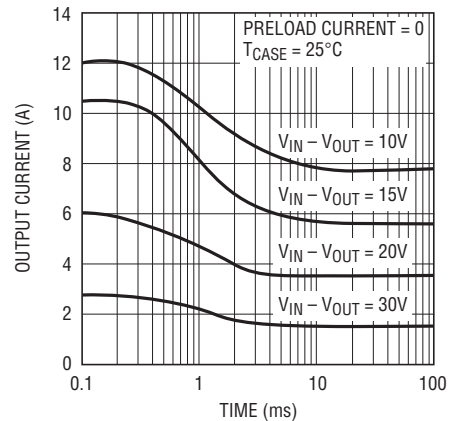
138A/338A G10

Current Limit



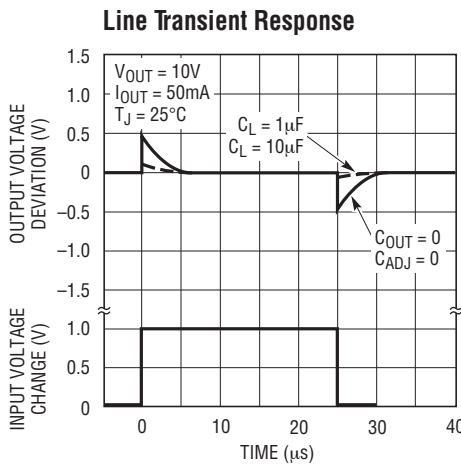
138A/338A G11

Current Limit

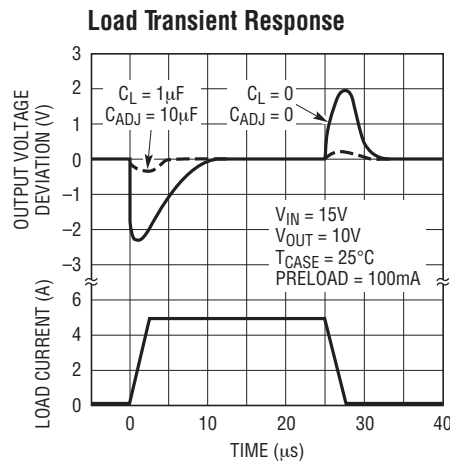


138A/338A G12

TYPICAL PERFORMANCE CHARACTERISTICS



138A/338A G13



138A/338A G14

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 $\pm 4\%$ which is dangerously close to the $\pm 5\%$ supply tolerance required in many logic and analog systems. Further, even 1% resistors can drift $0.01\%/^{\circ}\text{C}$, adding additional error to the output voltage tolerance.

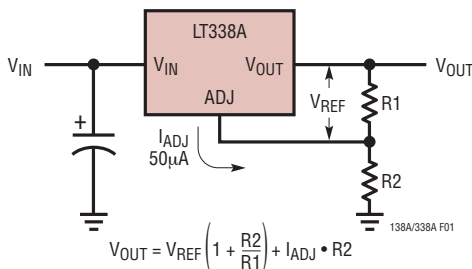


Figure 1. Basic Adjustable Regulator

For example, using 2% resistors and $\pm 4\%$ tolerance for V_{REF} calculations will show that the expected range of a 5V regulator design would be $4.66\text{V} \leq V_{OUT} \leq 5.36\text{V}$ or approximately $\pm 7\%$. If the same example were used for a 15V regulator, the expected tolerance would be $\pm 8\%$. 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 $\pm 2\%$ resistors, would have a worst-case manufacturing tolerance of $\pm 4\%$. If 1% resistors are used, the tolerance will drop to $\pm 2.5\%$. A plot of the worst-case output voltage tolerance as a function of resistor tolerance is shown on the front page of this data sheet.

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

APPLICATIONS INFORMATION

Table 1. 0.5% 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, 1.21k 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 (80dB) can be accomplished by adding a 10μF capacitor from the ADJ 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/LT338A 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.

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.

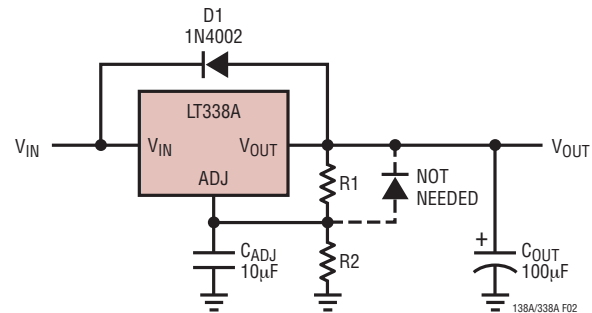


Figure 2

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:

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

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.

APPLICATIONS INFORMATION

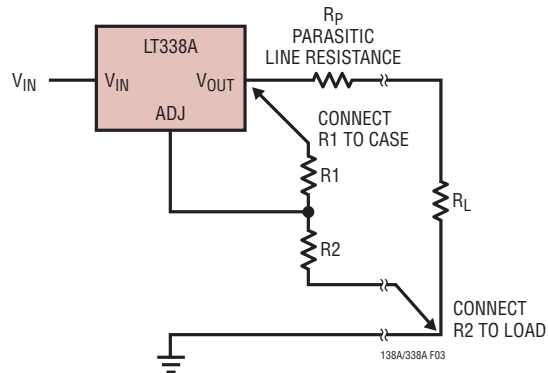
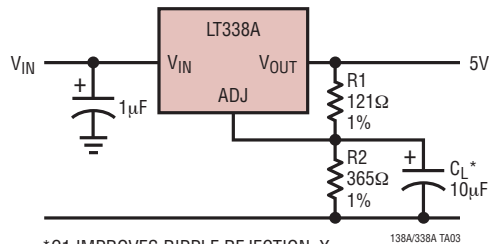


Figure 3. Connections for Best Load Regulation

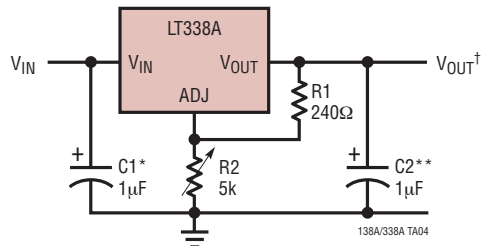
TYPICAL APPLICATIONS

Improving Ripple Rejection



*C1 IMPROVES RIPPLE REJECTION, X_C SHOULD BE SMALL COMPARED TO R2

1.2V to 25V Adjustable Regulator

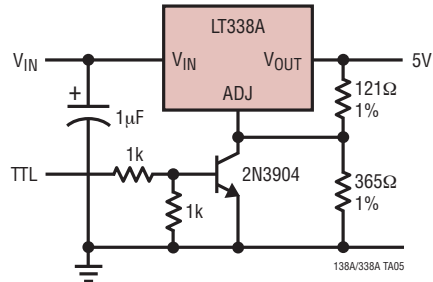


*NEEDED IF DEVICE IS FAR FROM FILTER CAPACITORS
**OPTIONAL, IMPROVES TRANSIENT RESPONSE

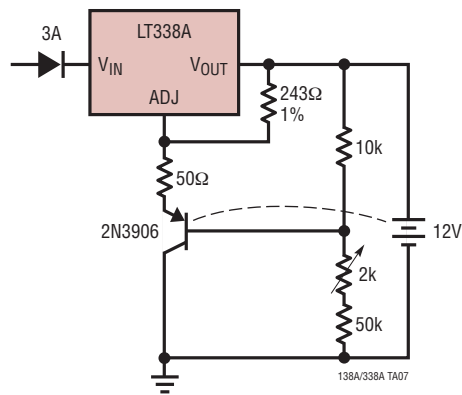
$${}^{\dagger}V_{OUT} = 1.25V \left(1 + \frac{R2}{R1} \right)$$

TYPICAL APPLICATIONS

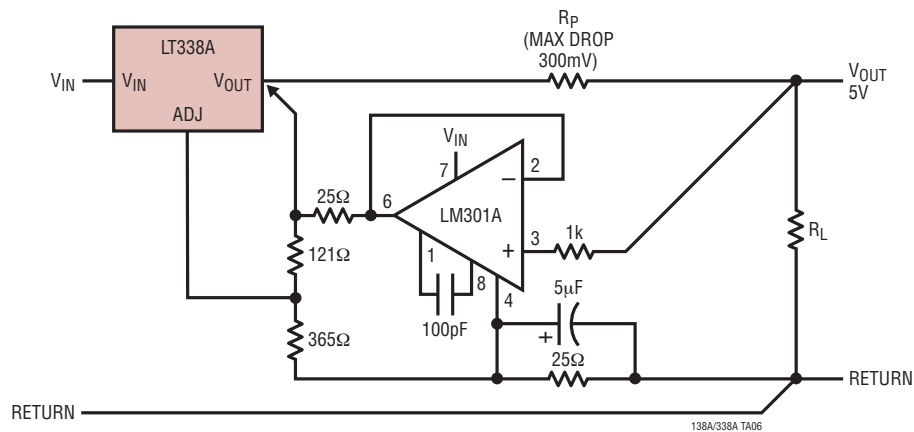
5V Regulator with Shutdown



Temperature Compensated Lead Acid Battery Charger

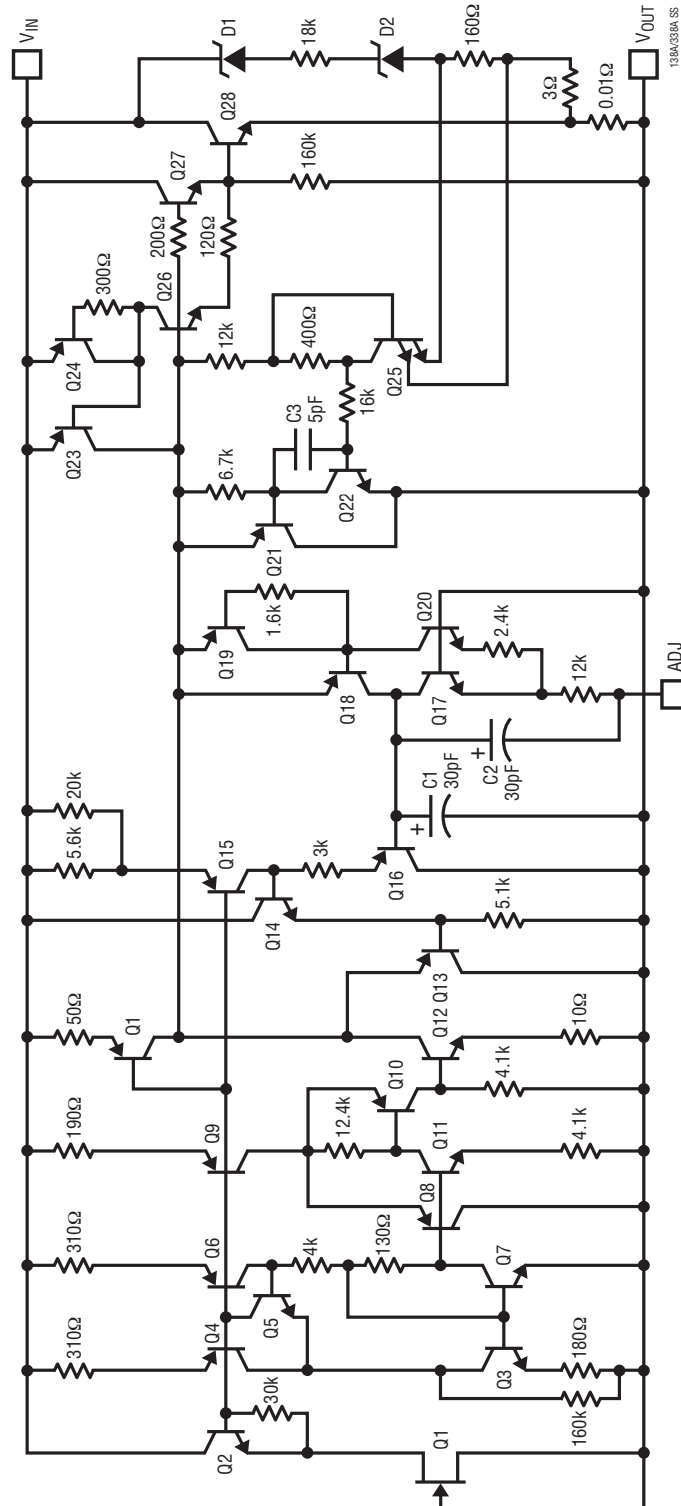


Remote Sensing



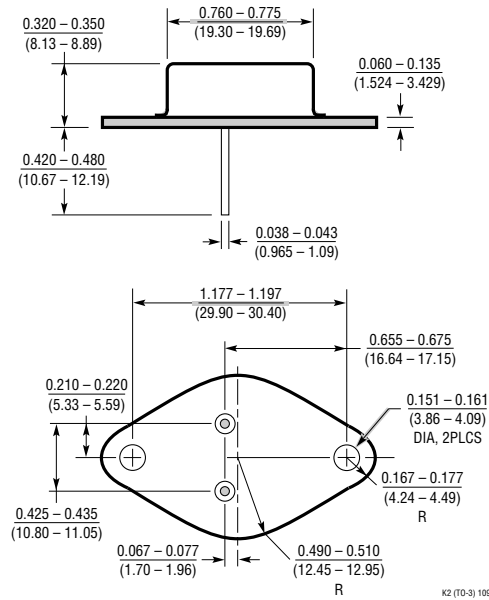
LT138A/LT339A LM138/LM338

SCHEMATIC DIAGRAM LT138A/LT338A



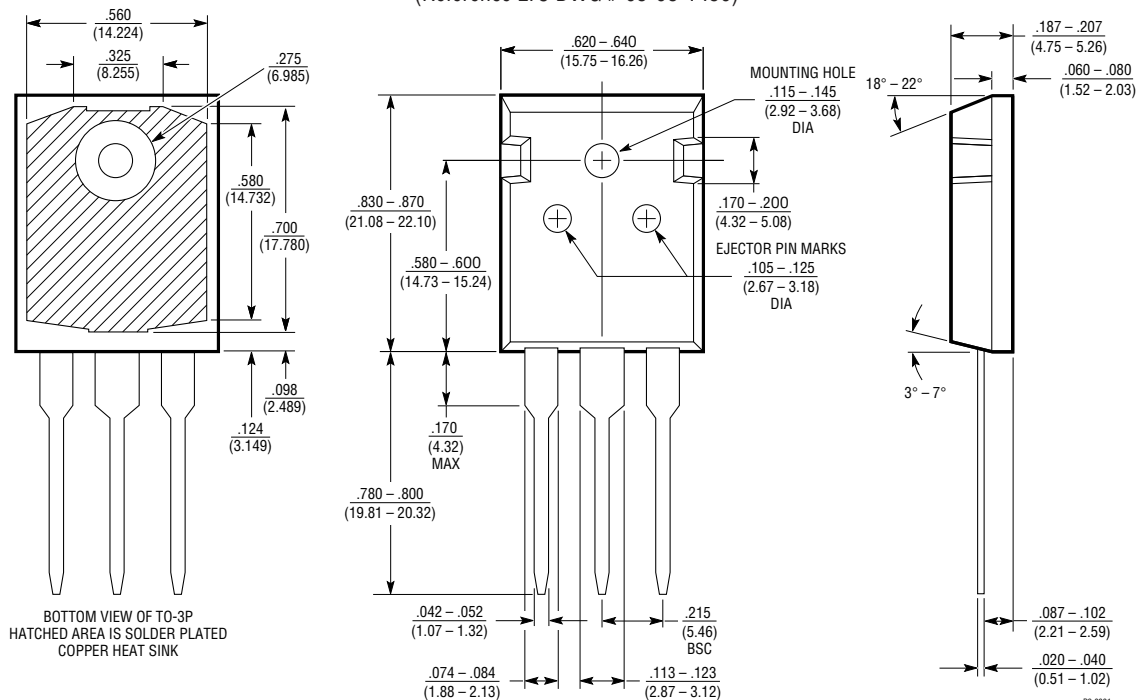
PACKAGE DESCRIPTION

K Package 2-Lead TO-3 Metal Can (Reference LTC DWG # 05-08-1310)

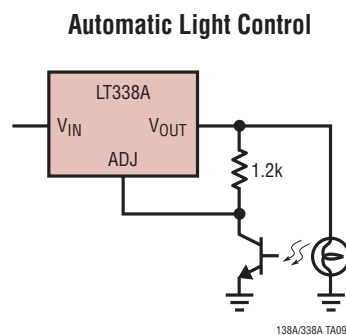
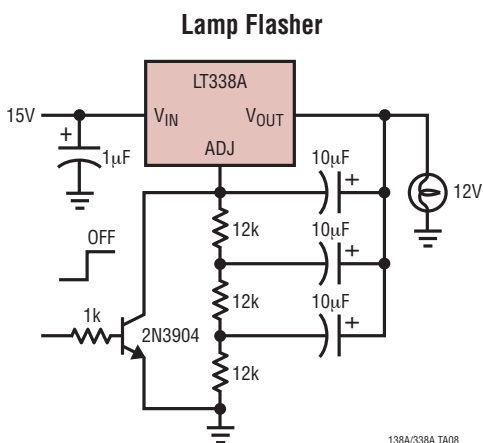


OBsolete PACKAGE

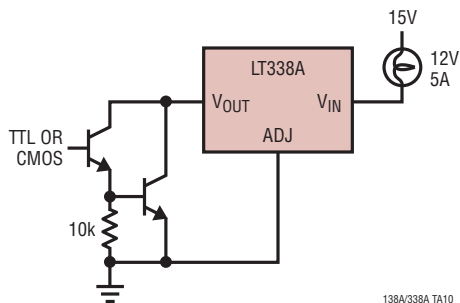
P Package 3-Lead Plastic TO-3P (Similar to TO-247) (Reference LTC DWG # 05-08-1450)



TYPICAL APPLICATION



Protected High Current Lamp Driver



RELATED PARTS

PART NUMBER	DESCRIPTION	COMMENTS
LT1083/LT1084/LT1085	3A/5A/7.5A Low Dropout Regulators	Fixed Outputs, V_{IN} Up to 30V
LT1580	7A Fast Transient Response Regulator with 0.7V Dropout	For 3.3V to 2.xxV Applications
LT1581	10A Fast Transient Response Regulator	For 3.3V to 2.xxV Applications
LT1584/LT1585/LT1587	7A/4.6A/3A Low Dropout Fast Transient Response Regulator	For 1.2V to 3.3V Outputs from 5V
LT1764	3A Fast Transient Response Regulator	Dropout Voltage 340mV, Low Noise: $40\mu V_{RMS}$