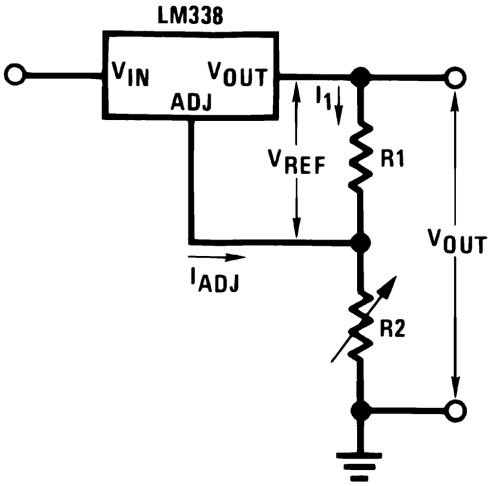
LMx38 5A 可调节稳压器

1 特性

- 额定 7A 峰值输出电流
- 额定 5A 输出电流
- 低至 1.2V 的可调节输出
- 额定热调节
- 电流限制在各种温度下保持恒定
- 测试了 P + 产品增强性能
- 输出受到短路保护

2 应用

- 可调电源
- 恒流调节
- 电池充电器



典型应用电路

3 说明

LM138 系列可调 3 引脚正电压稳压器能够在 1.2V 至 32V 输出范围内提供超过 5A 的电流。这些器件极易使用，并且仅需要两个电阻器即可设置输出电压。电路经过精心设计，可实现出色的负载和线路调节，可与许多商用电源媲美。LM138 系列采用标准的 3 引线晶体管封装。

LM138 系列的一个独特的特性是可提供基于时间的电流限制。电流限制电路允许在短时间内从稳压器提取高达 12A 的峰值电流。该特性使 LM138 能够在高瞬态负载下使用，并加快满载条件下的启动速度。在持续负载条件下，电流限制会降至安全的值，以保护稳压器。此外，芯片中还包含针对功率晶体管的热过载保护和安全区域保护功能。即使调节 (ADJ) 引脚意外断开连接，过载保护功能仍然能起作用。

通常不需要使用电容器，除非器件的位置距离输入滤波电容器达 6 英寸以上，此时需要使用输入旁路。可以添加输出电容器以改善瞬态响应，而绕过调节引脚可提高稳压器的纹波抑制能力。

封装信息

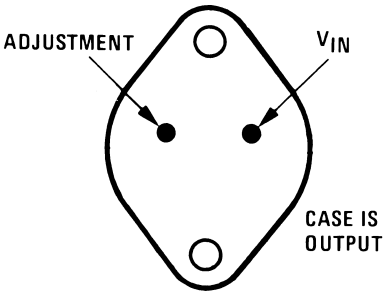
器件型号	封装(1)	封装尺寸(2)
LM138	NDS（TO-CAN，2）	38.94mm × 24.89mm
LM338	NDE（TO-220，3）	10.16mm × 4.58mm
	NDS（TO-CAN，2）	38.94mm × 24.89mm

(1) 如需更多信息，请参阅*机械、封装和可订购信息*。
(2) 封装尺寸（长 × 宽）为标称值，并包括引脚（如适用）。

除了替代固定稳压器或分立式设计之外，LM138 还可用于各种其他应用。由于该稳压器是浮动的并且仅获得输入到输出差分电压，因此，只要不超过最大输入到输出差分电压，就可以调节几百伏特的电源电压，不用将输出短接至地面。LM138 系列中具有 *K* 后缀的器件型号采用标准钢 TO-CAN 封装，而具有 *T* 后缀的器件型号则采用 TO-220 塑料封装。LM138 的额定温度为 T_J = –55°C 至 150°C，而 LM338 的额定温度为 T_J = 0°C 至 125°C。

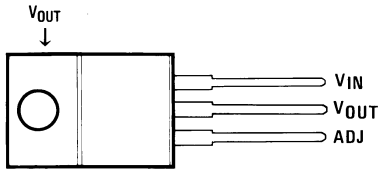
Table of Contents

4 Pin Configuration and Functions



Package Number NDS0002A

图 4-1. NDS Package, 2-Pin TO-CAN (Bottom View)



Package Number NDE0003B

图 4-2. NDE Package, 3-Pin TO-220 (Front View)

表 4-1. Pin Functions

PIN			TYPE	DESCRIPTION
NAME	TO-220	TO-CAN		
ADJ	1	1	I	Output voltage adjustment pin. Connect to a resistor divider to set V_O.
V_{IN}	3	2	I	Supply input pin.
V_{OUT}	2	Case	O	Voltage output pin.

5 Specifications

5.1 Absolute Maximum Ratings

over operating free-air temperature range (unless otherwise noted) (1)

		MIN	MAX	UNIT
Input and output voltage differential		– 0.3	40	V
Power dissipation		Internally limited		
Lead temperature	TO-3 package (soldering, 10 s)		300	°C
	TO-220 package (soldering, 4 s)		260	
Operating temperature, T_J	LM138	– 55	150	°C
	LM338	0	125	
Storage temperature, T_{stg}		– 65	150	°C

(1) Stresses beyond those listed under *Absolute Maximum Ratings* may cause permanent damage to the device. These are stress ratings only, which do not imply functional operation of the device at these or any other conditions beyond those indicated under *Recommended Operating Conditions*. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

5.2 Recommended Operating Conditions

over operating free-air temperature range (unless otherwise noted)

	MIN	MAX	UNIT
Input-to-output voltage differential	3	40	V
Output current		5	A

5.3 Thermal Information

THERMAL METRIC(1)		LM338	LM338		UNIT
		NDS (TO-CAN)	NDE (TO-220)	NDS (TO-CAN)	
		2 PINS	3 PINS	2 PINS	
$R_{\theta JA}$	Junction-to-ambient thermal resistance	35	22.9	35	°C/W
$R_{\theta JC(top)}$	Junction-to-case (top) thermal resistance	1	15.7	1	°C/W
$R_{\theta JB}$	Junction-to-board thermal resistance	—	4.1	—	°C/W
ψ_{JT}	Junction-to-top characterization parameter	—	2.1	—	°C/W
ψ_{JB}	Junction-to-board characterization parameter	—	4.1	—	°C/W
$R_{\theta JC(bot)}$	Junction-to-case (bottom) thermal resistance	—	0.7	—	°C/W

(1) For more information about traditional and new thermal metrics, see the Semiconductor and IC Package Thermal Metrics application note.

5.4 Electrical Characteristics: LM138

Values apply for T_J = 25°C; V_{IN} – V_{OUT} = 5 V; and I_{OUT} = 10 mA (unless otherwise noted).(1)

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
V_{REF}	Reference voltage	3 V ≤ (V_{IN} – V_{OUT}) ≤ 35 V, 10 mA ≤ I_{OUT} ≤ 5 A, P ≤ 50 W, T_J = –55°C to 150°C		1.19	1.24	1.29	V
V_{RLINE}	Line regulation	3 V ≤ (V_{IN} – V_{OUT}) ≤ 35 V(2)	T_J = 25°C		0.005%	0.01%	V
			T_J = –55°C to 150°C		0.02%	0.04%	V
V_{RLOAD}	Load regulation	10 mA ≤ I_{OUT} ≤ 5 A(2)	T_J = 25°C		0.1%	0.3%	
			T_J = –55°C to 150°C		0.3%	0.6%	
	Thermal regulation	20 ms pulse			0.002%	0.01%	W
I_{ADJ}	Adjustment pin current	T_J = –55°C to 150°C			45	100	µA
ΔI_{ADJ}	Adjustment pin current change	10 mA ≤ I_{OUT} ≤ 5 A, 3 V ≤ (V_{IN} – V_{OUT}) ≤ 35 V, T_J = –55°C to 150°C			0.2	5	µA
$\Delta V_{R/T}$	Temperature stability	T_J = –55°C to 150°C			1%		
$I_{LOAD(MIN)}$	Minimum load current	V_{IN} – V_{OUT} = 35 V, T_J = –55°C to 150°C			3.5	5	mA
I_{CL}	Current limit	V_{IN} – V_{OUT} ≤ 10 V					
		DC, T_J = –55°C to 150°C		5	8		A
		0.5-ms peak, T_J = –55°C to 150°C		7	12		A
		V_{IN} – V_{OUT} = 30 V			1	1	A
V_N	RMS output noise (percent of V_{OUT})	10 Hz ≤ f ≤ 10 kHz			0.003%		
$\Delta V_R/\Delta V_{IN}$	Ripple rejection ratio	V_{OUT} = 10 V, f = 120 Hz, C_{ADJ} = 0 µF, T_J = –55°C to 150°C			60		dB
		V_{OUT} = 10 V, f = 120 Hz, C_{ADJ} = 10 µF, T_J = –55°C to 150°C		60	75		dB
	Long-term stability	T_J = 125°C, 1000 Hrs			0.3%	1%	

(1) These specifications are applicable for power dissipation up to 50 W for the TO-3 (NDS) package and 25 W for the TO-220 (NDE) package. Power dissipation is specified at these values up to 15-V input-output differential. Above 15-V differential, power dissipation is limited by internal protection circuitry. All limits (that is, the numbers in the minimum and maximum columns) are specified to TI's AOQL (Average Outgoing Quality Level).

(2) Regulation is measured at a constant junction temperature, using pulse testing with a low duty cycle. Changes in output voltage due to heating effects are covered under the specifications for thermal regulation.

5.5 Electrical Characteristics: LM338

Values apply for T_J = 25°C; V_{IN} – V_{OUT} = 5 V; and I_{OUT} = 10 mA (unless otherwise noted).(1)

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
V_{REF}	Reference voltage	3 V ≤ (V_{IN} – V_{OUT}) ≤ 35 V, 10 mA ≤ I_{OUT} ≤ 5 A, P ≤ 50 W, T_J = 0°C to 125°C		1.19	1.24	1.29	V
V_{RLINE}	Line regulation	3 V ≤ (V_{IN} – V_{OUT}) ≤ 35 V(2)	T_J = 25°C		0.005%	0.03%	V
			T_J = 0°C to 125°C		0.02%	0.06%	V
V_{RLOAD}	Load regulation	10 mA ≤ I_{OUT} ≤ 5 A(2)	T_J = 25°C		0.1	0.5	
			T_J = 0°C to 125°C		0.3	1	
	Thermal regulation	20-ms pulse			0.002%	0.02%	W
I_{ADJ}	Adjustment pin current	T_J = 0°C to 125°C			45	100	µA
ΔI_{ADJ}	Adjustment pin current change	10 mA ≤ I_{OUT} ≤ 5 A, 3 V ≤ (V_{IN} – V_{OUT}) ≤ 35 V, T_J = 0°C to 125°C			0.2	5	µA
$\Delta V_{R/T}$	Temperature stability	T_J = 0°C to 125°C			1		
$I_{LOAD(MIN)}$	Minimum load current	V_{IN} – V_{OUT} = 35 V, T_J = 0°C to 125°C			3.5	10	mA
I_{CL}	Current limit	V_{IN} – V_{OUT} ≤ 10 V					
		DC, T_J = 0°C to 125°C		5	8		A
		0.5-ms peak, T_J = 0°C to 125°C		7	12		A
		V_{IN} – V_{OUT} = 30 V				1	A
V_N	RMS output noise (percent of V_{OUT})	10 Hz ≤ f ≤ 10 kHz			0.003%		
$\Delta V_R / \Delta V_{IN}$	Ripple rejection ratio	V_{OUT} = 10 V, f = 120 Hz, C_{ADJ} = 0 µF, T_J = 0°C to 125°C			60		dB
		V_{OUT} = 10 V, f = 120 Hz, C_{ADJ} = 10 µF, T_J = 0°C to 125°C		60	75		dB
	Long-term stability	T_J = 125°C, 1000 Hrs			0.3%	1%	

(1) These specifications are applicable for power dissipation up to 50 W for the TO-3 (NDS) package and 25 W for the TO-220 (NDE) package. Power dissipation is specified at these values up to 15-V input-output differential. Above 15-V differential, power dissipation is limited by internal protection circuitry. All limits (that is, the numbers in the minimum and maximum columns) are specified to TI's AOQL (Average Outgoing Quality Level).

(2) Regulation is measured at a constant junction temperature, using pulse testing with a low duty cycle. Changes in output voltage due to heating effects are covered under the specifications for thermal regulation.

5.6 Typical Characteristics

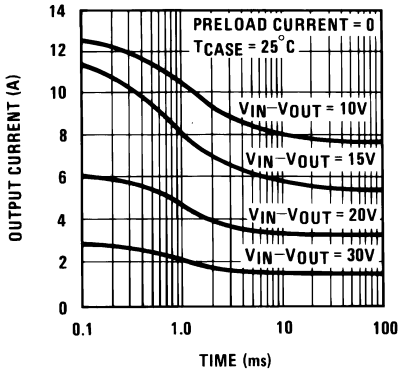


图 5-1. Current Limit

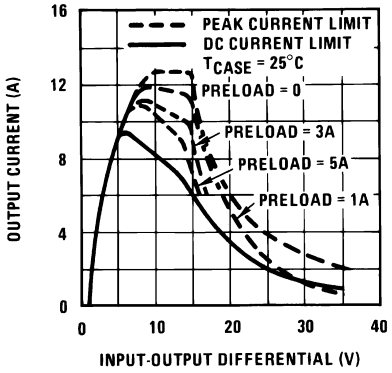


图 5-2. Current Limit

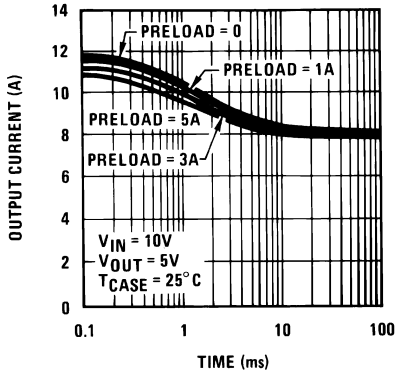


图 5-3. Current Limit

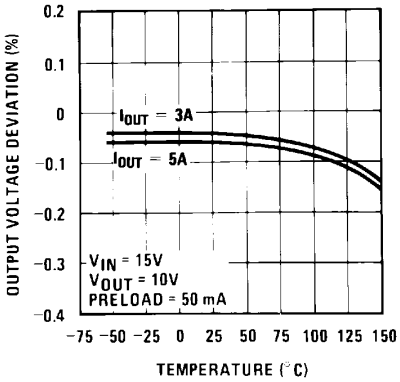


图 5-4. Load Regulation

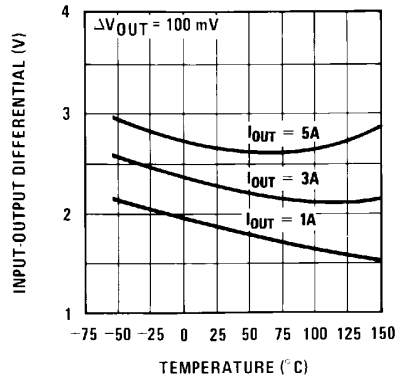


图 5-5. Dropout Voltage

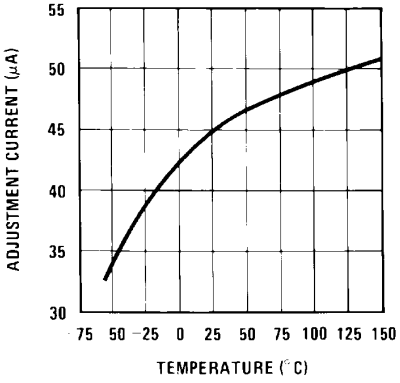


图 5-6. Adjustment Current

5.6 Typical Characteristics (continued)

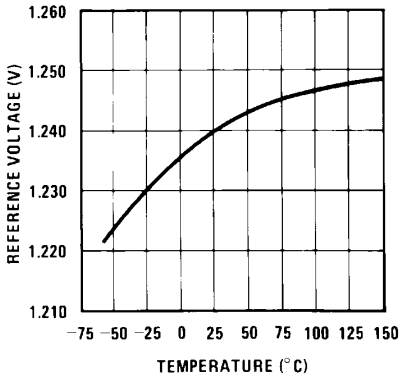


图 5-7. Temperature Stability

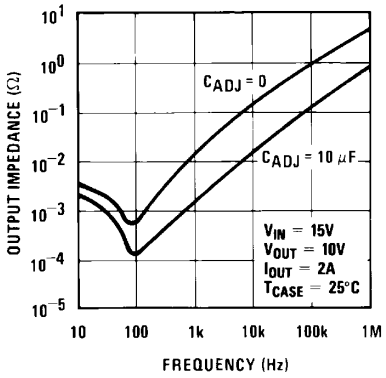


图 5-8. Output Impedance

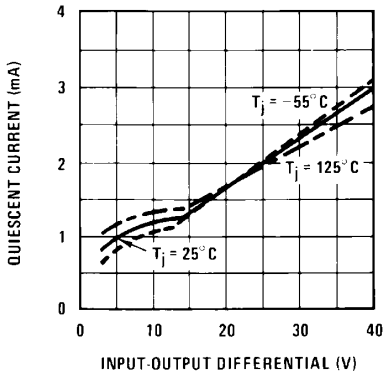


图 5-9. Minimum Operating Current

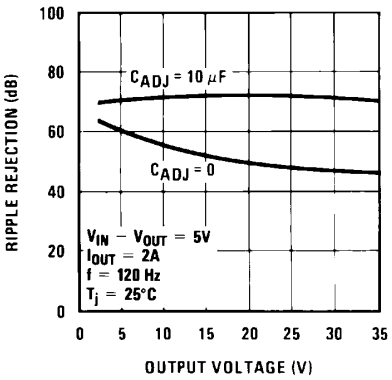


图 5-10. Ripple Rejection

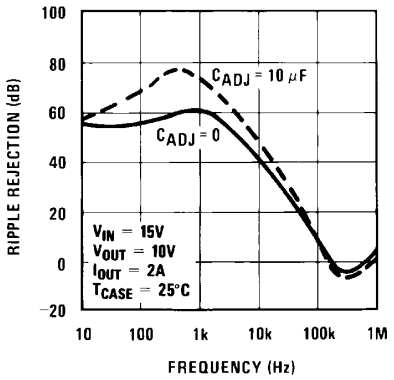


图 5-11. Ripple Rejection

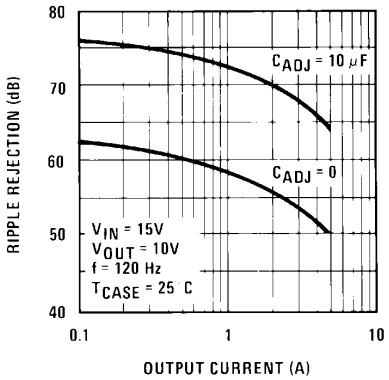


图 5-12. Ripple Rejection

5.6 Typical Characteristics (continued)

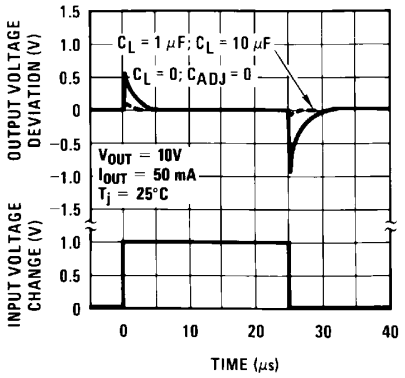


图 5-13. Line Transient Response

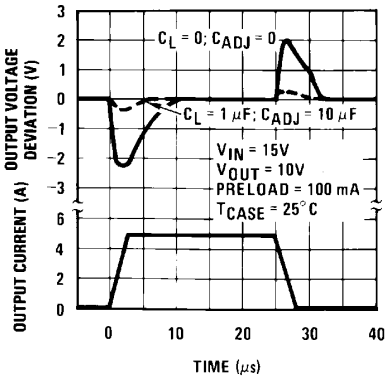


图 5-14. Load Transient Response

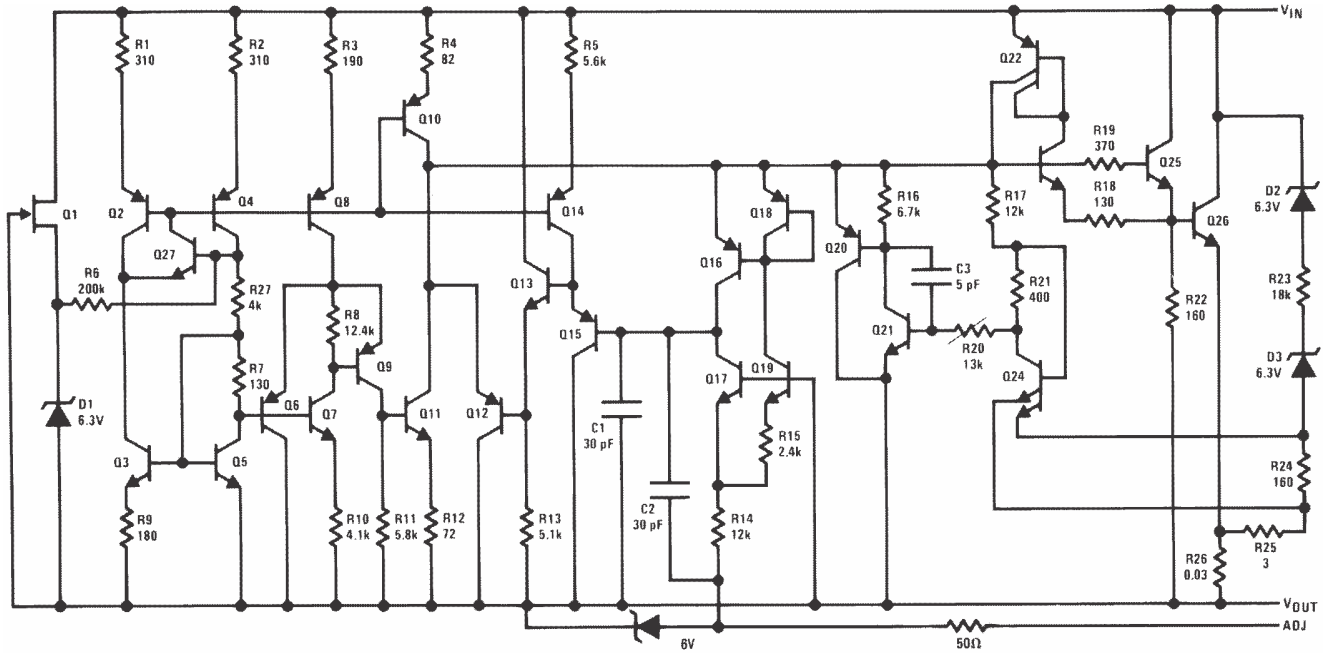
6 Detailed Description

6.1 Overview

The LM138 and LM338 devices are adjustable, three-terminal, positive-voltage regulators capable of supplying more than 5 A over an output-voltage range of 1.2 V to 32 V. It requires only two external resistors to set the output voltage. These devices feature a typical line regulation of 0.005% and typical load regulation of 0.1%. It includes time-dependent current limiting, thermal overload protection, and safe operating area protection. Overload protection remains functional even if the ADJUST terminal is disconnected.

The LM138 and LM338 devices are versatile in their applications, including uses in programmable output regulation and local on-card regulation. Or, by connecting a fixed resistor between the ADJUST and OUTPUT terminals, the LM138 and LM338 devices can function as a precision current regulators. An optional output capacitor can be added to improve transient response. The ADJUST terminal can be bypassed to achieve very high ripple-rejection ratios, which are difficult to achieve with standard three-terminal regulators.

6.2 Functional Block Diagram



6.3 Feature Description

6.3.1 NPN Darlington Output Drive

NPN Darlington output topology provides naturally low output impedance and an output capacitor is optional. To support maximum current and lowest temperature, 3-V headroom is recommended (V_I – V_O).

6.3.2 Overload Block

Overcurrent and overtemperature shutdown protects the device against overload or damage from operating in excessive heat.

6.3.3 Programmable Feedback

Op amp with 1.25-V offset input at the ADJUST terminal provides easy output voltage or current (not both) programming. For current regulation applications, a single resistor whose resistance value is 1.25 V/IO and power rating is greater than 1.25 V^2/R must be used. For voltage regulation applications, two resistors set the output voltage.

6.4 Device Functional Modes

6.4.1 Normal Operation

The device OUTPUT pin sources current necessary to make OUTPUT pin 1.25 V greater than ADJUST terminal to provide output regulation.

6.4.2 Operation With Low Input Voltage

The device requires up to 3-V headroom (V_I – V_O) to operate in regulation. With less headroom, the device may drop out and OUTPUT voltage is INPUT voltage minus drop out voltage.

6.4.3 Operation at Light Loads

The device passes its bias current to the OUTPUT pin. The load or feedback must consume this minimum current for regulation or the output may be too high. A 250-Ω feedback resistor between OUTPUT and ADJUST consumes the worst case minimum load current of 5 mA.

6.4.4 Operation in Self Protection

When an overload occurs, the device shuts down Darlington NPN output stage or reduces the output current to prevent device damage. The device automatically resets from the overload. The output may be reduced or alternate between on and off until the overload is removed.

7 Application and Implementation

备注

以下应用部分中的信息不属于 TI 器件规格的范围，TI 不担保其准确性和完整性。TI 的客 户应负责确定器件是否适用于其应用。客户应验证并测试其设计，以确保系统功能。

7.1 Application Information

In operation, the LM138 develops a nominal 1.25-V reference voltage (V_{REF}) between the output and adjustment terminal. The reference voltage is impressed across program resistor R_1 and, since the voltage is constant, a constant current I_1 then flows through the output set resistor R_2, giving an output voltage calculated with 方程式 1.

$$V_{OUT} = V_{REF}\left(1 + \frac{R2}{R1}\right) + I_{ADJ}R2 \quad (1)$$

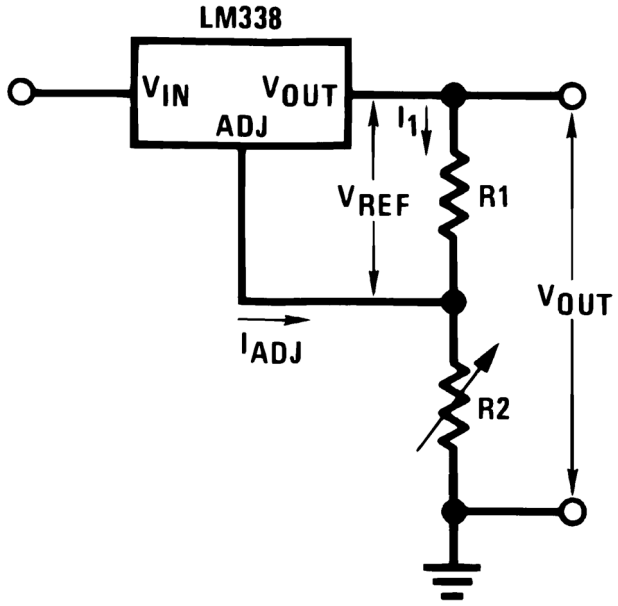
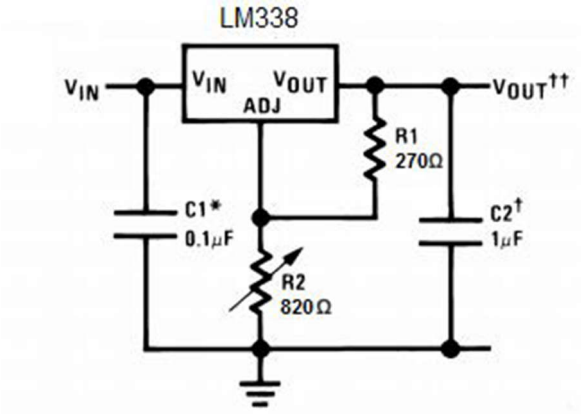


图 7-1. Typical Application Circuit

Because the 50-µA current from the adjustment terminal represents an error term, the LM138 was designed to minimize I_{ADJ} and make it very constant with line and load changes. To do this, all quiescent operating current is returned to the output establishing a minimum load current requirement. If there is insufficient load on the output, the output rises.

7.2 Typical Applications

7.2.1 Constant 5-V Regulator



*Needed if device is more than 6 inches from filter capacitors.

†Optional—improves transient response

†† $V_{OUT} = 1.25\ V\left(1+\frac{R2}{R1}\right)+I_{ADJ}(R_2)$

图 7-2. Constant 5-V Regulator

7.2.1.1 Design Requirements

R1: Because the LM138 produces a typical 1.24 V potential between the OUTPUT and ADJUST pins, placing a 270-Ω resistor between them causes 4.6 mA to flow through R1 and R2.

R2: To achieve a 5-V output, the sum of the voltages across R1 and R2 must equal 5 V. Therefore, Vr2 must equal 3.76 V when 4.6 mA is flowing through it. R2 = Vr2 / I = 3.76 V / 4.6 mA = ~820 Ω.

C_{IN}: 0.1 μF of input capacitance helps filter out unwanted noise, especially if the regulator is located far from the power supply filter capacitors.

C_{OUT}: The regulator is stable without any output capacitance, but adding a 1-μF capacitor improves the transient response.

C_{ADJ}: A 10-μF capacitor bypassing the ADJUST pin to ground improves the regulators ripple rejection.

D1: Protection diode D1 is recommended if C_{OUT} is used. The diode provides a low-impedance discharge path to prevent the capacitor from discharging into the output of the regulator (see the *Protection Diodes* section).

D2: Protection diode D2 is recommended if C_{ADJ} is used. The diode provides a low-impedance discharge path to prevent the capacitor from discharging into the output of the regulator (see the *Protection Diodes* section).

表 7-1 lists the design parameters for this typical application.

表 7-1. Design Parameters

PARAMETER	VALUE
Feedback resistor 1 (R1)	270 Ω
Feedback resistor 2 (R2)	820 Ω
Input capacitor (C_{IN})	0.1 µF
Output capacitor (C_{OUT})	1 µF
Adjust capacitor(C_{ADJ})	10 µF

7.2.1.2 Detailed Design Procedure

7.2.1.2.1 External Capacitors

An input bypass capacitor is recommended. A 0.1-µF disc or 1-µF solid tantalum on the input is suitable input bypassing for almost all applications. The device is more sensitive to the absence of input bypassing when adjustment or output capacitors are used but the above values eliminate the possibility of problems.

The adjustment terminal can be bypassed to ground on the LM138 to improve ripple rejection. This bypass capacitor prevents ripple from being amplified as the output voltage is increased. With a 10-µF bypass capacitor, 75-dB ripple rejection is obtainable at any output level. Increases over 20 µF do not appreciably improve the ripple rejection at frequencies above 120 Hz. If the bypass capacitor is used, it is sometimes necessary to include protection diodes to prevent the capacitor from discharging through internal low current paths and damaging the device.

In general, the best type of capacitors to use are solid tantalum. Solid tantalum capacitors have low impedance even at high frequencies. Depending upon capacitor construction, it takes about 25 µF in aluminum electrolytic to equal 1-µF solid tantalum at high frequencies. Ceramic capacitors are also good at high frequencies; but some types have a large decrease in capacitance at frequencies around 0.5 MHz. For this reason, 0.01-µF disc may seem to work better than a 0.1-µF disc as a bypass.

Although the LM138 is stable with no output capacitors, like any feedback circuit, certain values of external capacitance can cause excessive ringing. This occurs with values between 500 pF and 5000 pF. A 1-µF solid tantalum (or 25-µF aluminum electrolytic) on the output swamps this effect and insures stability.

7.2.1.2.2 Load Regulation

The LM138 is capable of providing extremely good load regulation but a few precautions are needed to obtain maximum performance. The current set resistor connected between the adjustment terminal and the output terminal (usually 240 Ω) must be tied directly to the output of the regulator (case) rather than near the load. This eliminates line drops from appearing effectively in series with the reference and degrading regulation. For example, a 15-V regulator with 0.05-Ω resistance between the regulator and load has a load regulation due to line resistance of 0.05 Ω × I_L. If the set resistor is connected near the load, the effective line resistance is 0.05 Ω (1 + R2/R1) or in this case, 11.5 times worse.

图 7-3 shows the effect of resistance between the regulator and 240-Ω set resistor.

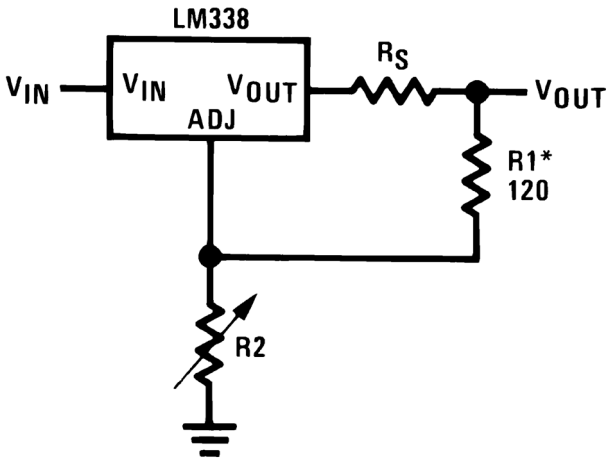


图 7-3. Regulator With Line Resistance in Output Lead

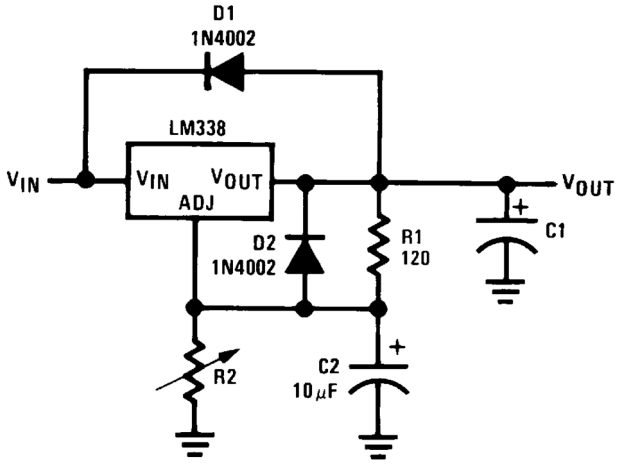
With the TO-3 package, it is easy to minimize the resistance from the case to the set resistor, by using 2 separate leads to the case. The ground of R2 can be returned near the ground of the load to provide remote ground sensing and improve load regulation.

7.2.1.2.3 Protection Diodes

When external capacitors are used with *any* IC regulator it is sometimes necessary to add protection diodes to prevent the capacitors from discharging through low current points into the regulator. Most 20-µF capacitors have low enough internal series resistance to deliver 20-A spikes when shorted. Although the surge is short, there is enough energy to damage parts of the IC.

When an output capacitor is connected to a regulator and the input is shorted, the output capacitor discharges into the output of the regulator. The discharge current depends on the value of the capacitor, the output voltage of the regulator, and the rate of decrease of V_{IN}. In the LM138 this discharge path is through a large junction that is able to sustain 25-A surge with no problem. This is not true of other types of positive regulators. For output capacitors of 100 µF or less at output of 15 V or less, there is no need to use diodes.

The bypass capacitor on the adjustment terminal can discharge through a low current junction. Discharge occurs when *either* the input or output is shorted. Internal to the LM138 is a 50-Ω resistor which limits the peak discharge current. No protection is needed for output voltages of 25-V or less and 10-µF capacitance. 图 7-4 shows an LM138 with protection diodes included for use with outputs greater than 25 V and high values of output capacitance.



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

D1 protects against C1, D2 protects against C2.

图 7-4. Regulator With Protection Diodes

7.2.1.3 Application Curves

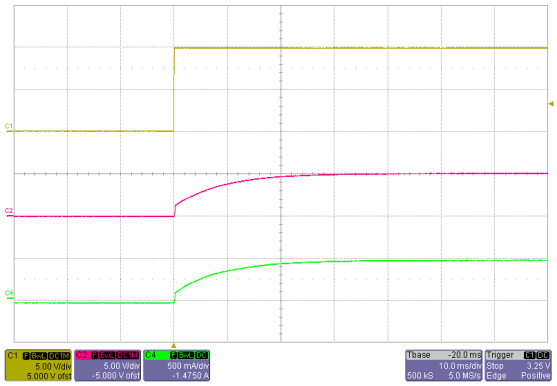


图 7-5. Regulator Start-Up

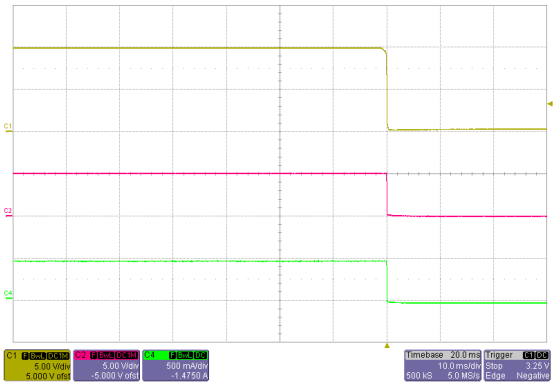


图 7-6. Regulator Shutdown

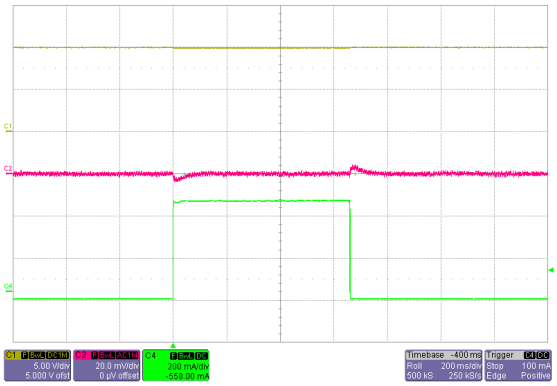


图 7-7. Regulator Response to Load Step

7.3 System Examples

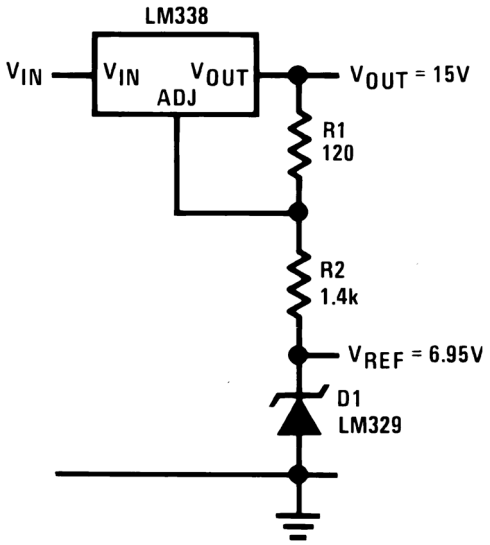


图 7-8. Regulator and Voltage Reference

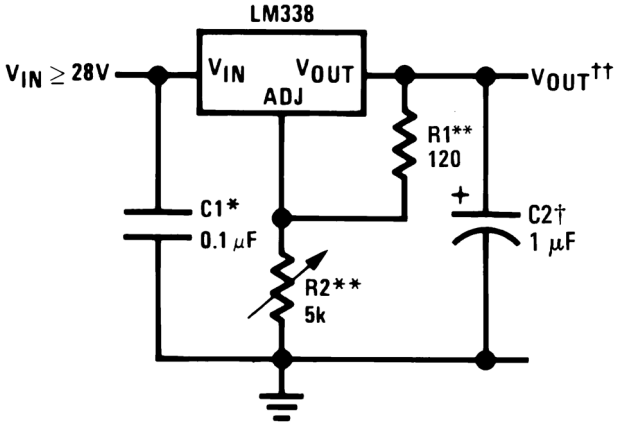
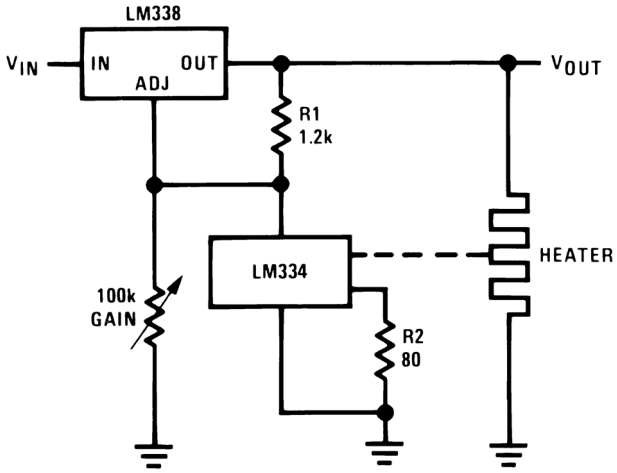


图 7-9. 1.2-V to 25-V Adjustable Regulator



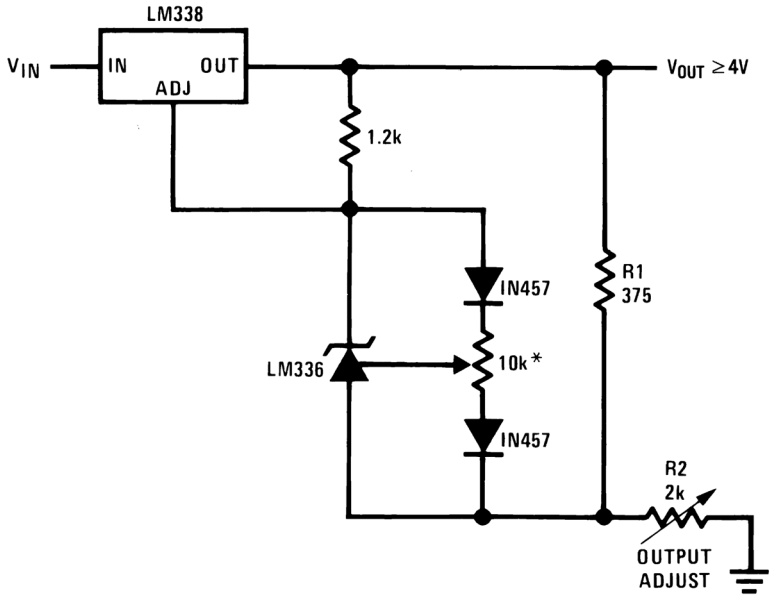
Full output current not available at high input-output voltages †Optional—improves transient response. Output capacitors in the range of 1 µF to 1000 µF of aluminum or tantalum electrolytic are commonly used to provide improved output impedance and rejection of

transients. *Needed if device is more than 6 inches from filter capacitors.

$$\dagger\dagger V_{OUT} = 1.25V \left(1 + \frac{R2}{R1}\right) + I_{ADJ}(R_2)$$

**R1 = 240 Ω for LM138. R1, R2 as an assembly can be ordered from Bourns: MIL part no. 7105A-AT2-502 COMM part no. 7105A-AT7-502

图 7-10. Temperature Controller



* Adjust for 3.75 across R1

图 7-11. Precision Power Regulator With Low Temperature Coefficient

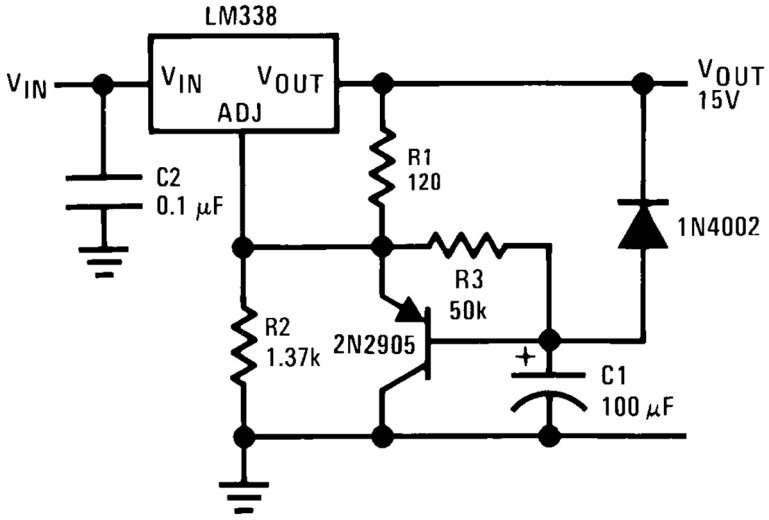
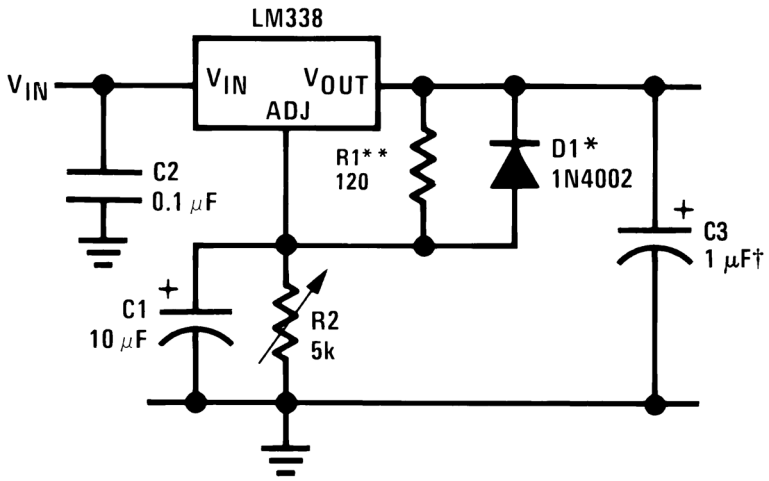


图 7-12. Slow Turnon 15-V Regulator



†Solid tantalum *Discharges C1 if output is shorted to ground **R1 = 240 Ω for LM138

图 7-13. Adjustable Regulator With Improved Ripple Rejection

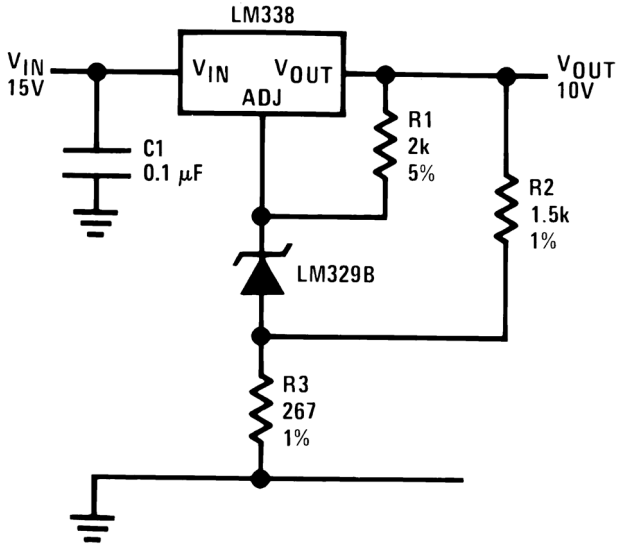
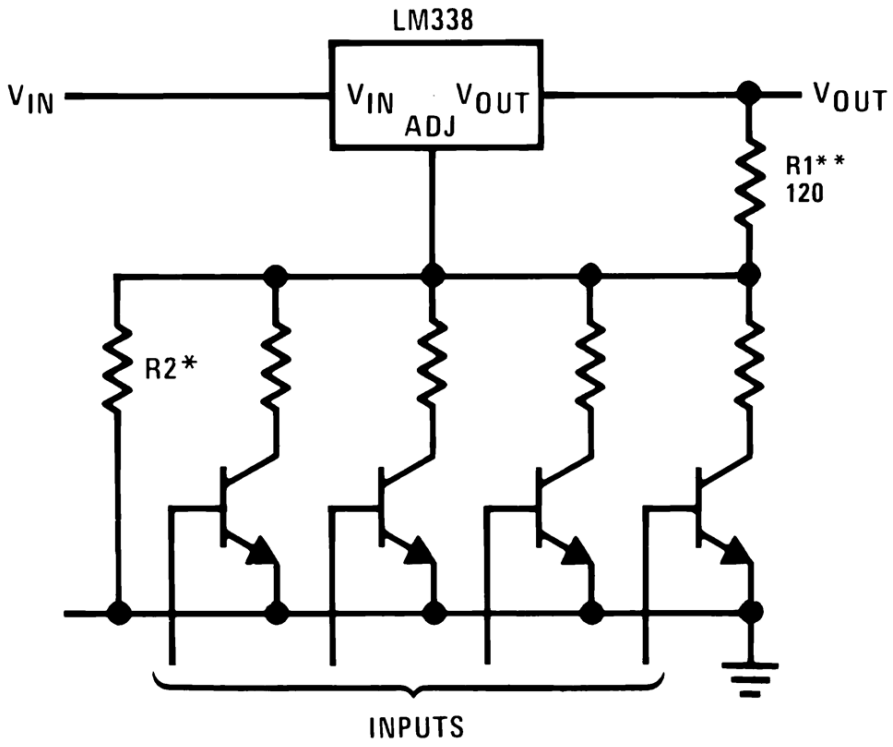
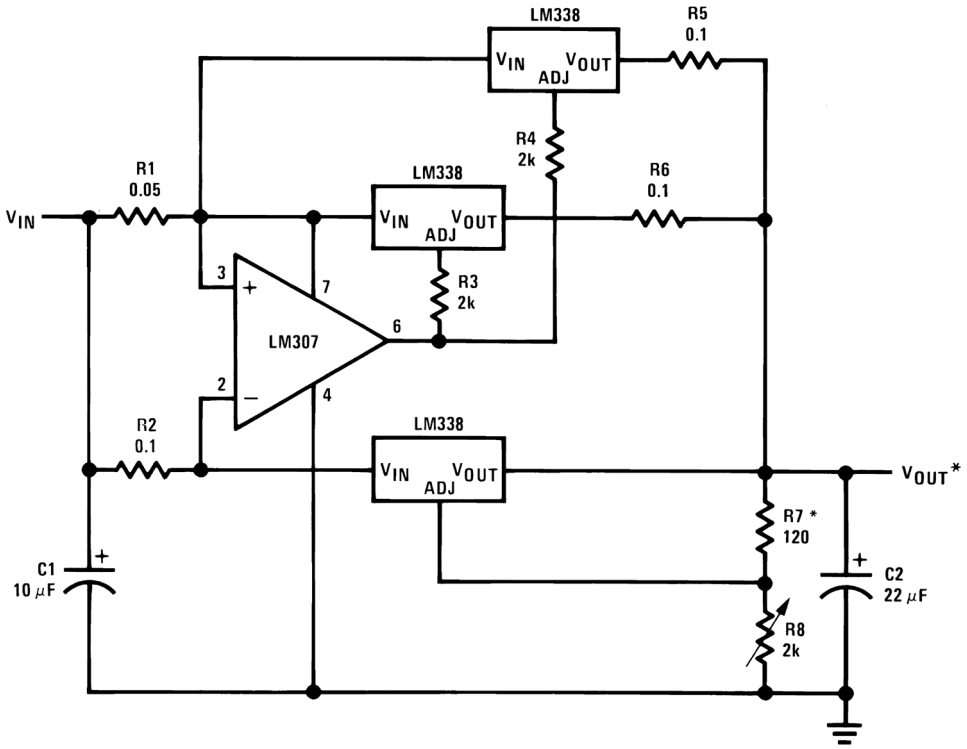


图 7-14. High Stability 10-V Regulator



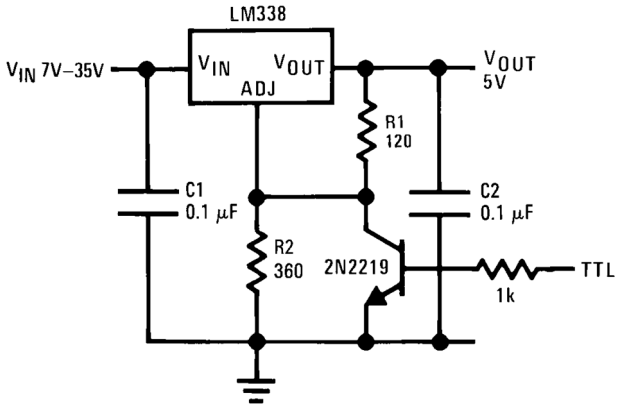
*Sets maximum V_{OUT} **R1 = 240 Ω for LM138

图 7-15. Digitally Selected Outputs



* Minimum load—100 mA

图 7-16. 15-A Regulator



** Minimum output ≈ 1.2 V

图 7-17. 5-V Logic Regulator With Electronic Shutdown**

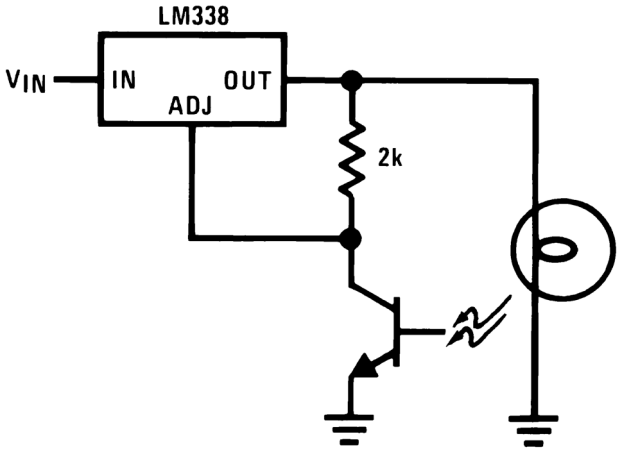
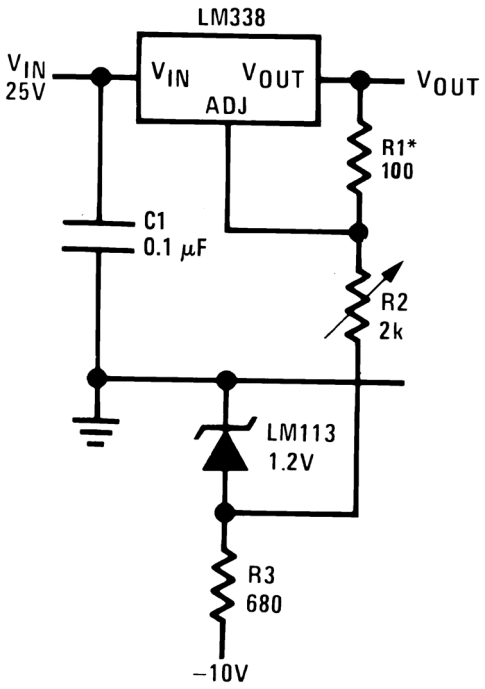


图 7-18. Light Controller



* R1 = 240 Ω, R2 = 5k for LM138 Full output current not available at high input-output voltages

图 7-19. 0 to 22-V Regulator

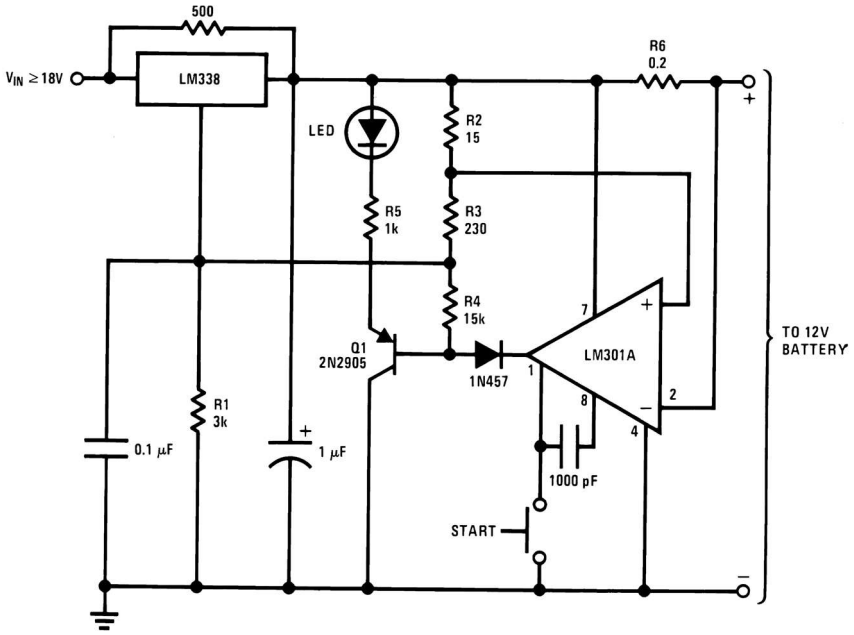


图 7-20. 12-V Battery Charger

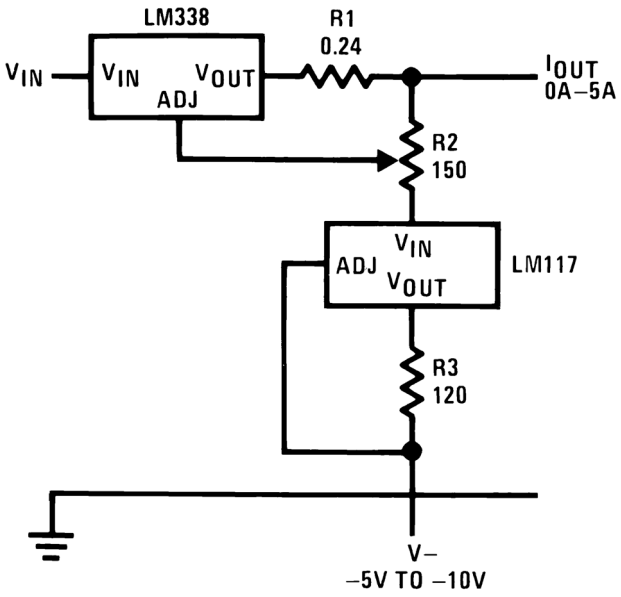


图 7-21. Adjustable Current Regulator

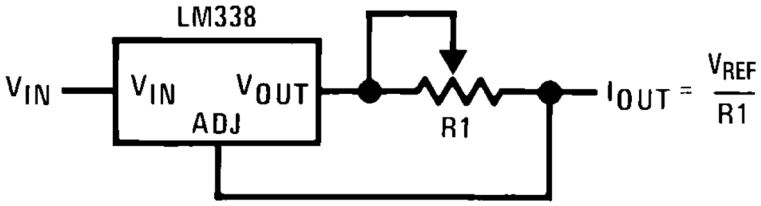


图 7-22. Precision Current Limiter

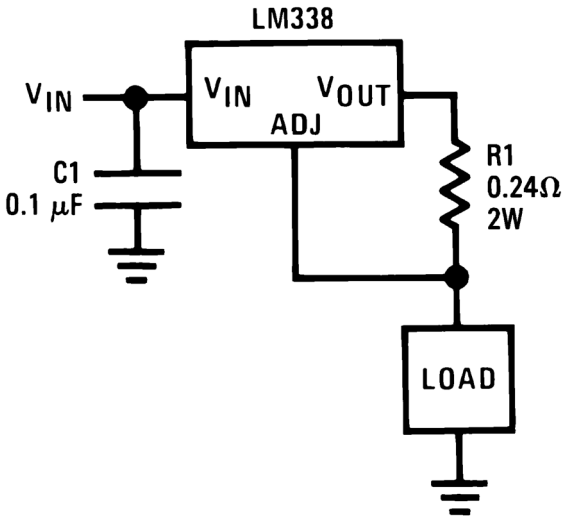


图 7-23. 5-A Current Regulator

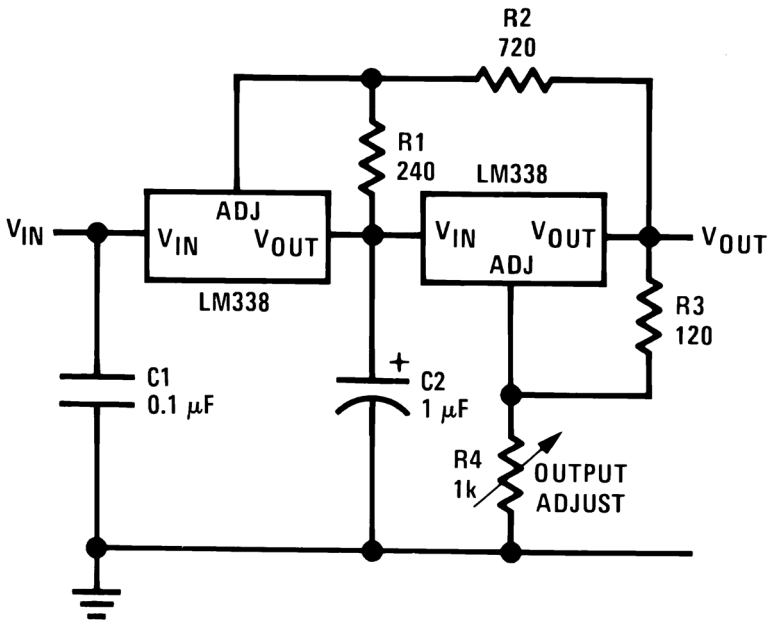
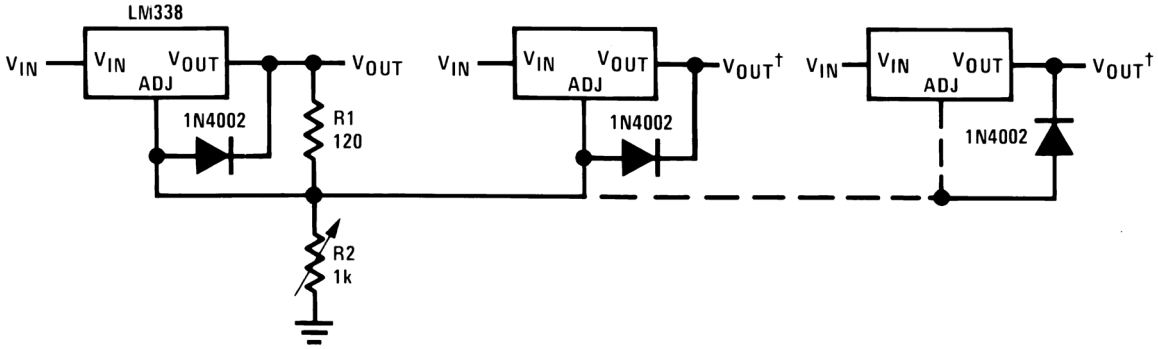
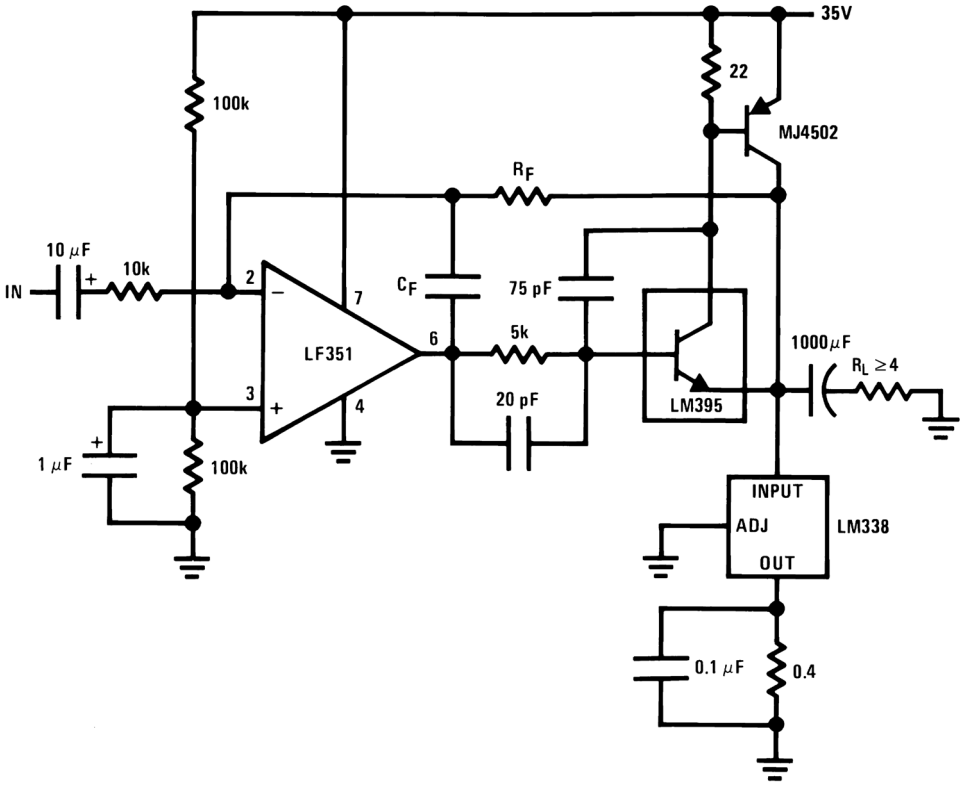


图 7-24. Tracking Preregulator



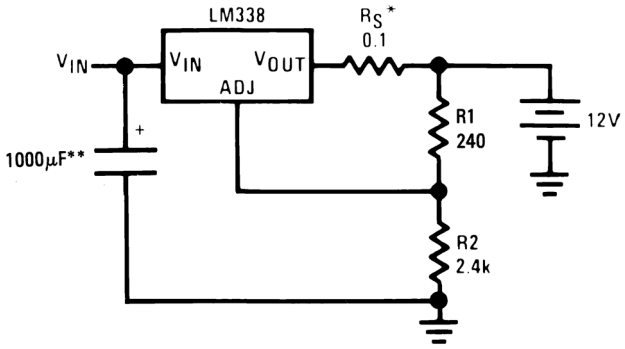
† Minimum load—10 mA * All outputs within ±100 mV

图 7-25. Adjusting Multiple On-Card Regulators With Single Control*



A_V = 1, R_F = 10k, C_F = 100 pF A_V = 10, R_F = 100k, C_F = 10 pF Bandwidth ≥ 100 kHz Distortion ≤ 0.1%

图 7-26. Power Amplifier



*R_S—sets output impedance of charger $Z_{OUT} = R_S \left(1 + \frac{R2}{R1}\right)$

Use of R_S allows low charging rates with fully charged battery. **The 1000 μF is recommended to filter out input transients

$$*R_S\text{—sets output impedance of charger } Z_{OUT} = R_S\left(1 + \frac{R2}{R1}\right)$$

Use of R_S allows low charging rates with fully charged battery. **The 1000 µF is recommended to filter out input transients

图 7-27. Simple 12-V Battery Charger

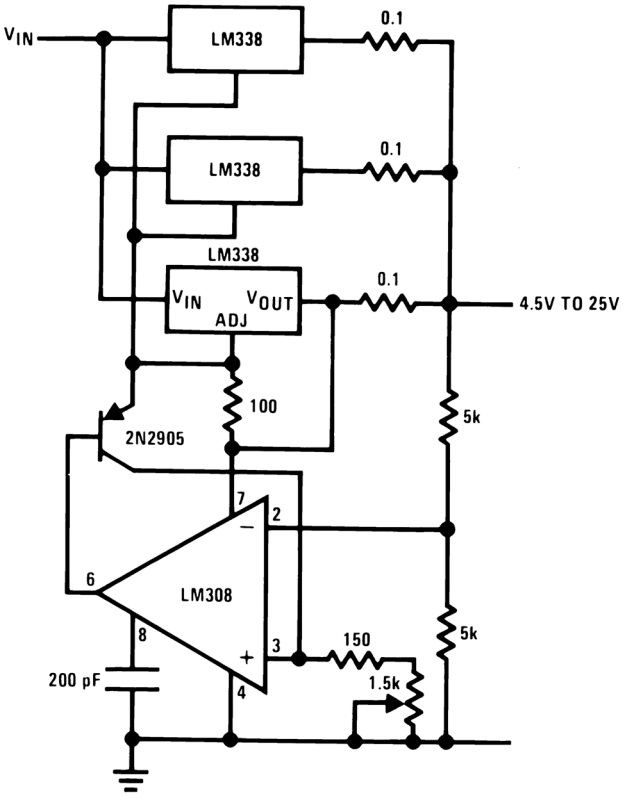
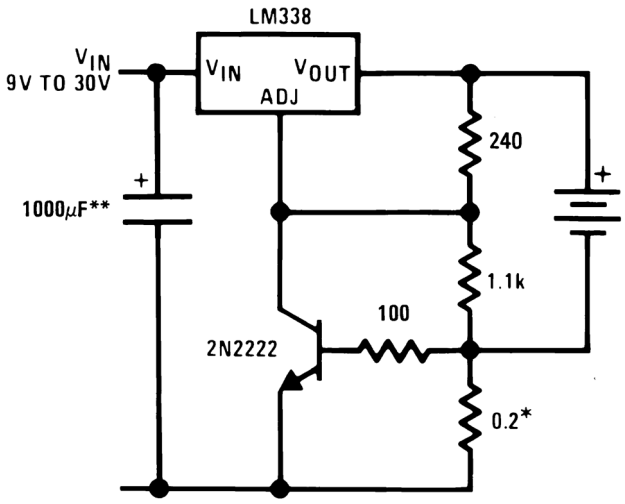
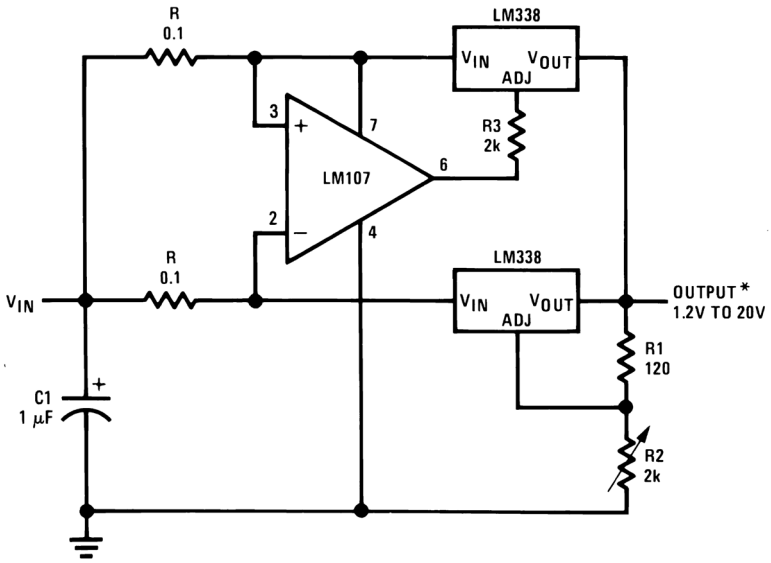


图 7-28. Adjustable 15-A Regulator



* Set max charge current to 3 A ** The 1000 μF is recommended to filter out input transients.

图 7-29. Current Limited 6-V Charger



* Minimum load—100 mA

图 7-30. 10-A Regulator

7.4 Power Supply Recommendations

The input supply to LM138 and LM338 must be kept at a voltage level such that its maximum input to output differential voltage rating is not exceeded. The minimum dropout voltage must also be met with extra headroom when possible to keep the LM138 and LM338 in regulation. TI recommends a capacitor be placed at the input to bypass noise.

7.5 Layout

7.5.1 Layout Guidelines

Some layout guidelines must be followed to ensure proper regulation of the output voltage with minimum noise. Traces carrying the load current must be wide to reduce the amount of parasitic trace inductance and the feedback loop from V_{OUT} to ADJ must be kept as short as possible. To improve PSRR, a bypass capacitor can

be placed at the ADJ pin and must be placed as close as possible to the IC. In cases when V_{IN} shorts to ground, an external diode must be placed from V_{OUT} to V_{IN} to divert the surge current from the output capacitor and protect the IC. Similarly, in cases when a large bypass capacitor is placed at the ADJ pin and VOUT shorts to ground, an external diode must be placed from ADJ to V_{OUT} to provide a path for the bypass capacitor to discharge. These diodes must be placed close to the corresponding IC pins to increase their effectiveness.

7.5.2 Layout Example

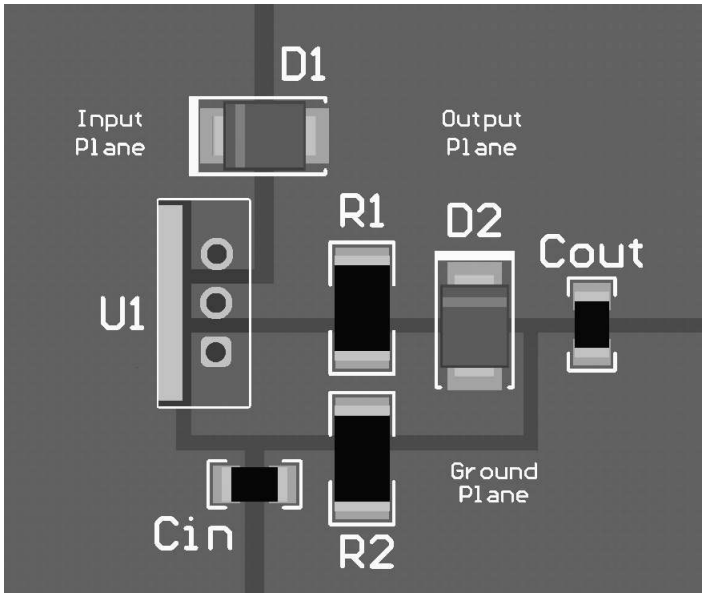


图 7-31. LMx38 Layout

8 Device and Documentation Support

8.1 接收文档更新通知

要接收文档更新通知，请导航至 ti.com 上的器件产品文件夹。点击*通知* 进行注册，即可每周接收产品信息更改摘要。有关更改的详细信息，请查看任何已修订文档中包含的修订历史记录。

8.2 支持资源

TI E2E™ 中文支持论坛是工程师的重要参考资料，可直接从专家处获得快速、经过验证的解答和设计帮助。搜索现有解答或提出自己的问题，获得所需的快速设计帮助。

链接的内容由各个贡献者“按原样”提供。这些内容并不构成 TI 技术规范，并且不一定反映 TI 的观点；请参阅 TI 的使用条款。

8.3 Trademarks

TI E2E™ is a trademark of Texas Instruments.
所有商标均为其各自所有者的财产。

8.4 静电放电警告

静电放电 (ESD) 会损坏这个集成电路。德州仪器 (TI) 建议通过适当的预防措施处理所有集成电路。如果不遵守正确的处理和安装程序，可能会损坏集成电路。

ESD 的损坏小至导致微小的性能降级，大至整个器件故障。精密的集成电路可能更容易受到损坏，这是因为非常细微的参数更改都可能会导致器件与其发布的规格不相符。

8.5 术语表

TI 术语表　　本术语表列出并解释了术语、首字母缩略词和定义。

9 Revision History

注：以前版本的页码可能与当前版本的页码不同

Changes from Revision C (December 2016) to Revision D (May 2025)	Page
• 删除了 *可用封装* 图	1
• Changed denominator to R1 in 方程式 1	13

Changes from Revision B (April 2013) to Revision C (December 2016)	Page
• 添加了 *器件信息* 表、*引脚配置和功能* 部分、*规格* 部分、*建议运行条件* 表、*热信息* 表、*详细说明* 部分、*应用和实施* 部分、*电源相关建议* 部分、*布局* 部分、*器件和文档支持* 部分 以及 *机械、封装和可订购信息* 部分	1
• Deleted RETS138K military specification reference from *Absolute Maximum Ratings* table	5
• Changed Junction to Ambient, $R_{\theta JA}$, value in *Thermal Information* table From: 50°C/W To: 22.9°C/W (NDE)	5
• Changed Junction to Case, $R_{\theta JC(top)}$, value in *Thermal Information* table From: 4°C/W To: 15.7°C/W (NDE)	5

10 Mechanical, Packaging, and Orderable Information

The following pages include mechanical, packaging, and orderable information. This information is the most current data available for the designated devices. This data is subject to change without notice and revision of this document. For browser-based versions of this data sheet, refer to the left-hand navigation.

PACKAGING INFORMATION

Orderable part number	Status (1)	Material type (2)	Package | Pins	Package qty | Carrier	RoHS (3)	Lead finish/ Ball material (4)	MSL rating/ Peak reflow (5)	Op temp (°C)	Part marking (6)
LM138K STEEL	Active	Production	TO-3 (NDS) | 2	50 | TRAY NON-STD	No	Call TI	Call TI	-55 to 125	LM138K STEELP+
LM138K STEEL/NOPB	Active	Production	TO-3 (NDS) | 2	50 | TRAY NON-STD	Yes	Call TI	Level-1-NA-UNLIM	-55 to 125	LM138K STEELP+
LM338T/NOPB	Active	Production	TO-220 (NDE) | 3	45 | TUBE	Yes	SN	Level-1-NA-UNLIM	0 to 125	LM338T P+
LM338T/NOPB.B	Active	Production	TO-220 (NDE) | 3	45 | TUBE	Yes	SN	Level-1-NA-UNLIM	0 to 125	LM338T P+

(1) **Status:** For more details on status, see our product life cycle.

(2) **Material type:** When designated, preproduction parts are prototypes/experimental devices, and are not yet approved or released for full production. Testing and final process, including without limitation quality assurance, reliability performance testing, and/or process qualification, may not yet be complete, and this item is subject to further changes or possible discontinuation. If available for ordering, purchases will be subject to an additional waiver at checkout, and are intended for early internal evaluation purposes only. These items are sold without warranties of any kind.

(3) **RoHS values:** Yes, No, RoHS Exempt. See the TI RoHS Statement for additional information and value definition.

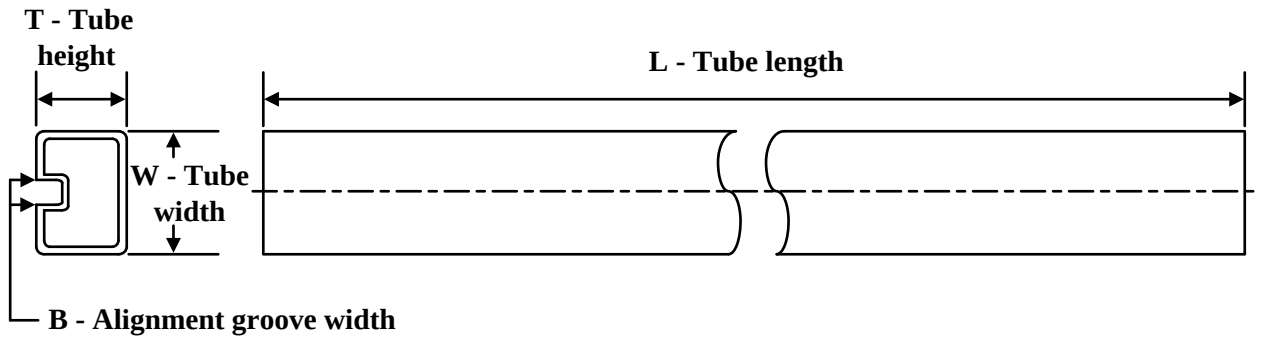
(4) **Lead finish/Ball material:** Parts may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead finish/Ball material values may wrap to two lines if the finish value exceeds the maximum column width.

(5) **MSL rating/Peak reflow:** The moisture sensitivity level ratings and peak solder (reflow) temperatures. In the event that a part has multiple moisture sensitivity ratings, only the lowest level per JEDEC standards is shown. Refer to the shipping label for the actual reflow temperature that will be used to mount the part to the printed circuit board.

(6) **Part marking:** There may be an additional marking, which relates to the logo, the lot trace code information, or the environmental category of the part.

Multiple part markings will be inside parentheses. Only one part marking contained in parentheses and separated by a "~" will appear on a part. If a line is indented then it is a continuation of the previous line and the two combined represent the entire part marking for that device.

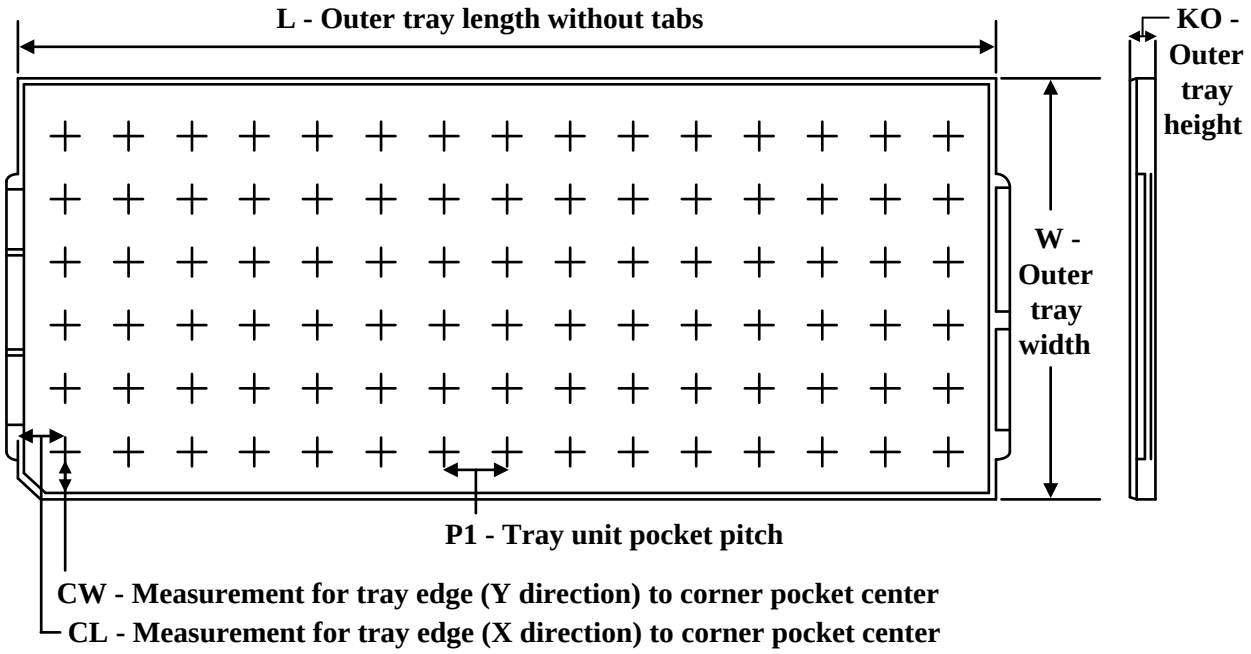
TUBE



*All dimensions are nominal

Device	Package Name	Package Type	Pins	SPQ	L (mm)	W (mm)	T (µm)	B (mm)
LM338T/NOPB	NDE	TO-220	3	45	502	33	6985	4.06
LM338T/NOPB.B	NDE	TO-220	3	45	502	33	6985	4.06

TRAY

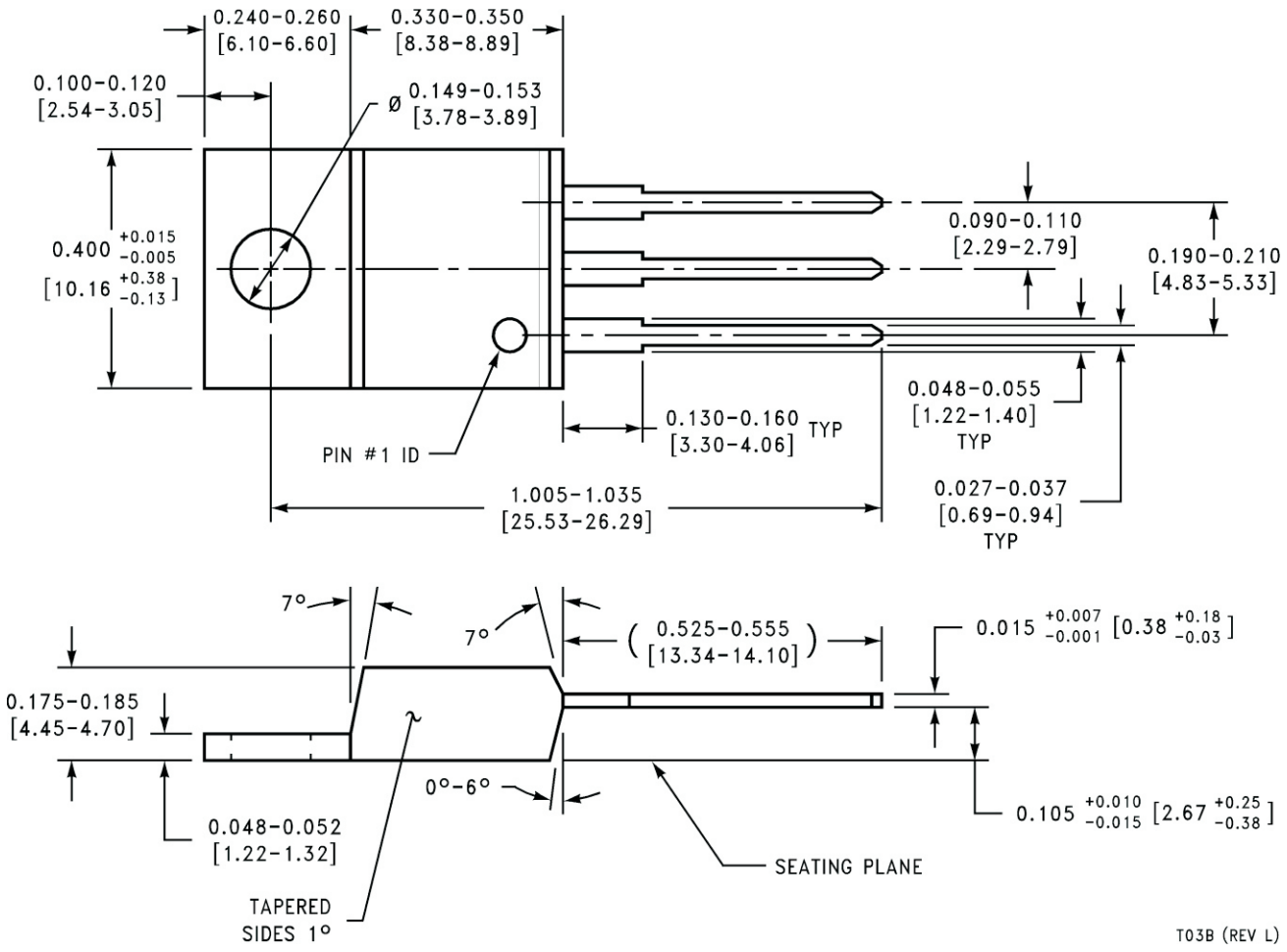


Chamfer on Tray corner indicates Pin 1 orientation of packed units.

*All dimensions are nominal

Device	Package Name	Package Type	Pins	SPQ	Unit array matrix	Max temperature (°C)	L (mm)	W (mm)	K0 (µm)	P1 (mm)	CL (mm)	CW (mm)
LM138K STEEL	NDS	TO-CAN	2	50	9 X 6	NA	292.1	215.9	25654	3.87	22.3	25.4
LM138K STEEL/NOPB	NDS	TO-CAN	2	50	9 X 6	NA	292.1	215.9	25654	3.87	22.3	25.4

NDE0003B

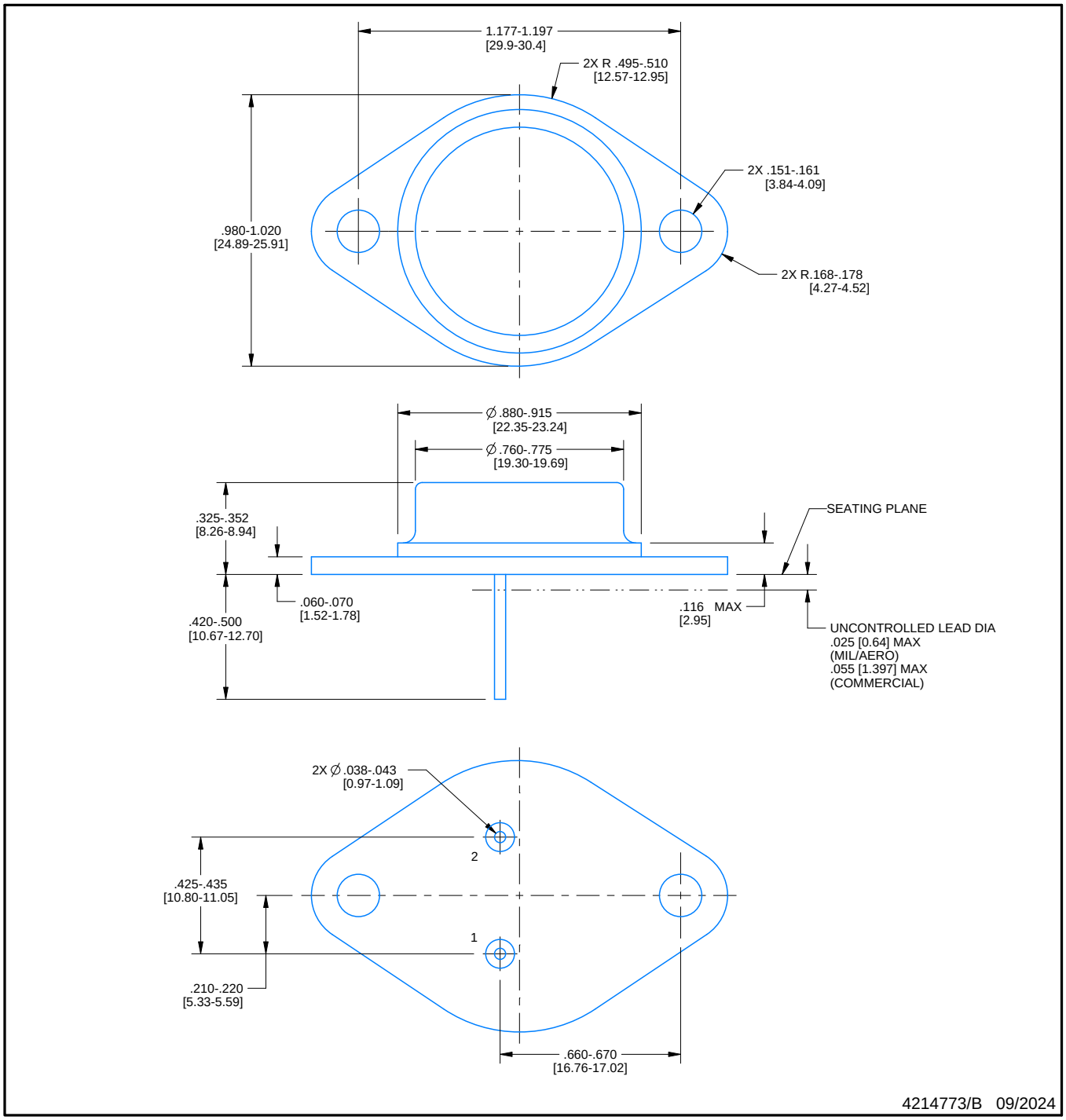

0.240-0.260
[6.10-6.60]
0.330-0.350
[8.38-8.89]
0.100-0.120
[2.54-3.05]
Ø 0.149-0.153
[3.78-3.89]
0.400 +0.015 -0.005
[10.16 +0.38 -0.13]
0.090-0.110
[2.29-2.79]
0.190-0.210
[4.83-5.33]
PIN #1 ID
0.130-0.160 TYP
[3.30-4.06]
0.048-0.055
[1.22-1.40]
TYP
1.005-1.035
[25.53-26.29]
0.027-0.037
[0.69-0.94]
TYP
7°
7°
(0.525-0.555
[13.34-14.10])
0.015 +0.007 -0.001 [0.38 +0.18 -0.03]
0.175-0.185
[4.45-4.70]
0°-6°
0.105 +0.010 -0.015 [2.67 +0.25 -0.38]
0.048-0.052
[1.22-1.32]
SEATING PLANE
TAPERED
SIDES 1°
T03B (REV L)

PACKAGE OUTLINE

NDS0002A

TO-CAN - 8.94 mm max height

TRANSISTOR OUTLINE



4214773/B 09/2024

NOTES:

1. Linear dimensions are in inches [millimeters]. Dimensions in parenthesis are for reference only. Controlling dimensions are in inches. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.

重要通知和免责声明

TI“按原样”提供技术和可靠性数据（包括数据表）、设计资源（包括参考设计）、应用或其他设计建议、网络工具、安全信息和其他资源，不保证没有瑕疵且不做出任何明示或暗示的担保，包括但不限于对适销性、与某特定用途的适用性或不侵犯任何第三方知识产权的暗示担保。

这些资源可供使用 TI 产品进行设计的熟练开发人员使用。您将自行承担以下全部责任：(1) 针对您的应用选择合适的 TI 产品，(2) 设计、验证并测试您的应用，(3) 确保您的应用满足相应标准以及任何其他安全、安保法规或其他要求。

这些资源如有变更，恕不另行通知。TI 授权您仅可将这些资源用于研发本资源所述的 TI 产品的相关应用。严禁以其他方式对这些资源进行复制或展示。您无权使用任何其他 TI 知识产权或任何第三方知识产权。对于因您对这些资源的使用而对 TI 及其代表造成的任何索赔、损害、成本、损失和债务，您将全额赔偿，TI 对此概不负责。

TI 提供的产品受 TI 销售条款)、TI 通用质量指南 或 ti.com 上其他适用条款或 TI 产品随附的其他适用条款的约束。TI 提供这些资源并不会扩展或以其他方式更改 TI 针对 TI 产品发布的适用的担保或担保免责声明。 除非德州仪器 (TI) 明确将某产品指定为定制产品或客户特定产品，否则其产品均为按确定价格收入目录的标准通用器件。

TI 反对并拒绝您可能提出的任何其他或不同的条款。

最后更新日期：2025 年 10 月