

# LM138QML 军用级 5A 可调输出线性稳压器

## 1 特性

- 按照德州仪器 (TI) 军用级流程进行制造和测试
- 额定峰值输出电流为 7A
- 额定输出电流为 5A
- 宽温度范围:  $-55^{\circ}\text{C}$  至  $150^{\circ}\text{C}$
- 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
- 已通过 P+ 产品增强性能测试
- 输出具有短路保护

## 2 应用

- 可调节电源
- 恒定电流稳压器
- 电池充电器

## 3 说明

LM138QML 可调节 3 端子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。该器件极易使用, 并且仅需要 2 个电阻器即可设置输出电压。电路设计精心细致, 可实现出色的负载和线路调节, 并且可与许多商用电源相媲美。

LM138QML 器件的一项独特功能是可提供基于时间的电流限制。电流限制电路支持稳压器在较短的时间内牵引高达 12A 的峰值电流。因此, LM138QML 器件能够在高瞬态负载下使用, 并且可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, 芯片中还包含热过载保护和安全区域保护功能 (针对功率晶体管)。即使调节引脚意外断开, 过载保护功能仍然起作用。

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超过 6 英寸, 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, 而旁路掉调节引脚可提高稳压器的纹波抑制能力。

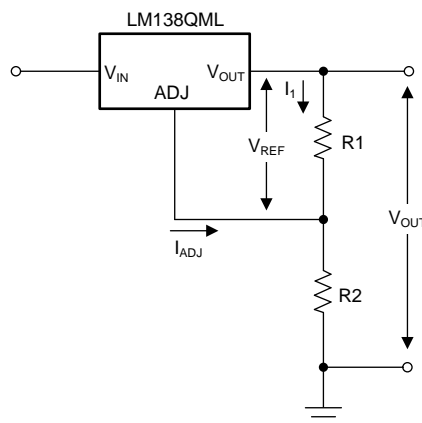
除了替代固定稳压器或分立式设计之外, LM138QML 也可应用于各种其他应用。由于该稳压器属于“浮动型”稳压器, 并且仅接收输入到输出差分电压, 因此, 只要不超过最大输入到输出差分电压, 就可以调节几百伏特的电源电压; 换言之, 不会让输出发生接地短路故障。

器件信息<sup>(1)</sup>

器件型号	等级	封装
LM138K-MIL	军用	TO-3 (2)
LM138KG-MD8	军用	裸片
LM138KG-MW8	军用	晶圆

(1) 如需了解所有可用封装, 请参阅数据表末尾的可订购产品附录。

典型应用电路



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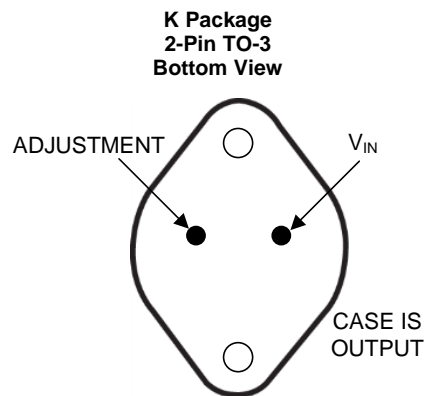
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## 4 修订历史记录

日期	修订版本	说明
2017 年 10 月	*	初始发行版

## 5 Pin Configuration and Functions



Package Number K0002C

### Pin Functions

PIN		I/O	DESCRIPTION
NAME	NO.		
ADJ	1	I	Output voltage adjustment pin. Connect to a resistor divider to set $V_O$ .
$V_{IN}$	2	I	Supply input pin.
$V_{OUT}$	Case	O	Voltage output pin.

## 6 Specifications

### 6.1 Absolute Maximum Ratings

over operating free-air temperature range (unless otherwise noted)<sup>(1)</sup>

	MIN	MAX	UNIT
Power dissipation	Internally limited		
Input and output voltage differential	–0.3	40	V
Storage temperature, T <sub>stg</sub>	–65	150	°C
Lead temperature (soldering, 10 seconds)		300	°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.

### 6.2 Recommended Operating Conditions

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

	MIN	MAX	UNIT
Operating temperature, T <sub>J</sub>	–55	150	°C
Input-to-output voltage differential	3	40	V
Output current		5	A

### 6.3 Thermal Information

THERMAL METRIC <sup>(1)</sup>		LM138QML	UNIT
		K (TO-3)	
		2 PINS	
R <sub>θJA</sub>	Junction-to-ambient thermal resistance	42.8	°C/W
R <sub>θJC(top)</sub>	Junction-to-case (top) thermal resistance	3.3	°C/W
ψ <sub>JT</sub>	Junction-to-top characterization parameter	2.5	°C/W
ψ <sub>JB</sub>	Junction-to-board characterization parameter	37.4	°C/W

(1) For more information about traditional and new thermal metrics, see the *IC Package Thermal Metrics* application report, [SPRA953](#).

### 6.4 Electrical Characteristics

Values apply for V<sub>IN</sub> – V<sub>OUT</sub> = 5 V; and I<sub>OUT</sub> = 10 mA (unless otherwise noted)<sup>(1)</sup>

PARAMETER	TEST CONDITIONS	SUB-GROUPS	MIN	TYP <sup>(2)</sup>	MAX	UNIT
V <sub>REF</sub> Reference voltage	V <sub>IN</sub> – V <sub>OUT</sub> = 3 V <sup>(3)</sup>	[1, 2, 3]	1.19		1.29	V
	V <sub>IN</sub> – V <sub>OUT</sub> = 3 V, I <sub>OUT</sub> = 5 A	[1, 2, 3]	1.19		1.29	
	V <sub>IN</sub> – V <sub>OUT</sub> = 5 V, I <sub>OUT</sub> = 7 A	[1, 2, 3]	1.19		1.29	
	V <sub>IN</sub> – V <sub>OUT</sub> = 35 V	[1, 2, 3]	1.19		1.29	
	V <sub>IN</sub> – V <sub>OUT</sub> = 35 V, I <sub>OUT</sub> = 150 mA	[1, 2, 3]	1.19		1.29	
V <sub>RLINE</sub> Line regulation <sup>(4)</sup>	3 V ≤ (V <sub>IN</sub> – V <sub>OUT</sub> ) ≤ 35 V	[1]	–3.5		3.5	mV
	3.3 V ≤ (V <sub>IN</sub> – V <sub>OUT</sub> ) ≤ 35 V	[2, 3]	–14		14	
V <sub>RLOAD</sub> Load regulation <sup>(4)</sup>	V <sub>IN</sub> – V <sub>OUT</sub> = 3 V, 10 mA ≤ I <sub>OUT</sub> ≤ 5 A, V <sub>OUT</sub> = V <sub>REF</sub>	[1]	–3.8		3.8	mV
	V <sub>IN</sub> – V <sub>OUT</sub> = 3.3 V, 10 mA ≤ I <sub>OUT</sub> ≤ 5 A, V <sub>OUT</sub> = V <sub>REF</sub>	[2, 3]	–8		8	
	V <sub>IN</sub> – V <sub>OUT</sub> = 35 V, 10 mA ≤ I <sub>OUT</sub> ≤ 150 mA, V <sub>OUT</sub> = V <sub>REF</sub>	[1]	–3.8		3.8	
	V <sub>IN</sub> – V <sub>OUT</sub> = 35 V, 10 mA ≤ I <sub>OUT</sub> ≤ 150 mA, V <sub>OUT</sub> = V <sub>REF</sub>	[2, 3]	–8		8	
V <sub>RTH</sub> Thermal regulation	V <sub>IN</sub> – V <sub>OUT</sub> = 10 V, pulse = 20 ms, I <sub>OUT</sub> = 1 A <sup>(5)</sup>	[1]		0.002	0.01	%/W
I <sub>ADJ</sub> Adjustment pin current	V <sub>IN</sub> – V <sub>OUT</sub> = 3 V <sup>(3)</sup>	[1, 2, 3]	2	45	100	μA
	V <sub>IN</sub> – V <sub>OUT</sub> = 35 V	[1, 2, 3]	2		100	
ΔI <sub>ADJ</sub> Adjustment pin current change	3 V ≤ (V <sub>IN</sub> – V <sub>OUT</sub> ) ≤ 35 V <sup>(3)</sup>	[1, 2, 3]	–5	0.2	5	μA
	10 mA ≤ I <sub>OUT</sub> ≤ 5 A	[1, 2, 3]	–5		5	
I <sub>LOAD(MIN)</sub> Minimum load current	V <sub>IN</sub> – V <sub>OUT</sub> = 3 V, V <sub>OUT</sub> = 1.4 V <sup>(3)</sup>	[1, 2, 3]	0.5		5	mA
	V <sub>IN</sub> – V <sub>OUT</sub> = 35 V, V <sub>OUT</sub> = 1.4 V	[1, 2, 3]	0.5	3.5	5	
I <sub>CL</sub> Current limit	V <sub>IN</sub> – V <sub>OUT</sub> = 10 V, T = 0.5 ms, V <sub>OUT</sub> = 0 V	[1, 2, 3]	7		16	A
	T = 5 ms, V <sub>OUT</sub> = 0 V	[1, 2, 3]	5		15	
ΔV <sub>R</sub> /ΔV <sub>IN</sub> Ripple rejection ratio	V <sub>OUT</sub> = V <sub>REF</sub> , e <sub>IN</sub> = 1 V <sub>RMS</sub> , f = 120 Hz, I <sub>OUT</sub> = 500 mA <sup>(6)</sup>	[4]	60			dB

(1) These specifications are applicable for power dissipations up to 50W. Power dissipation is specified at these values up to 15-V input-output differential. Above 15-V differential, power dissipation will be 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) Typical figures are at T<sub>A</sub> = 25°C, and represent most likely parametric norms. Test limits are ensured to Texas Instruments' average outgoing quality level (AOQL).

(3) V<sub>IN</sub> – V<sub>OUT</sub> = 3.3 V at –55°C and 125°C.

(4) 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) Datalog reading in mV, 0.01% = 1.19 mV.

(6) Family board not required for this device.

## 6.5 Quality Conformance Inspection

MIL-STD-883, Method 5005 - Group A

SUBGROUP	DESCRIPTION	TEMPERATURE (°C)
1	Static tests at	25
2	Static tests at	125
3	Static tests at	–55
4	Dynamic tests at	25
5	Dynamic tests at	125
6	Dynamic tests at	–55
7	Functional tests at	25
8A	Functional tests at	125
8B	Functional tests at	–55
9	Switching tests at	25
10	Switching tests at	125
11	Switching tests at	–55
12	Setting time at	25
13	Setting time at	125
14	Setting time at	–55

## 6.6 Typical Performance Characteristics

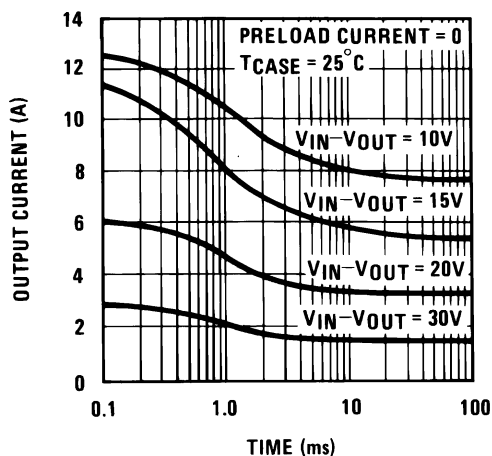


图 1. Current Limit

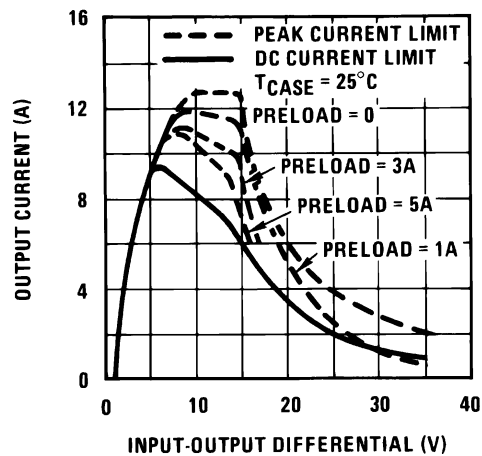


图 2. Current Limit

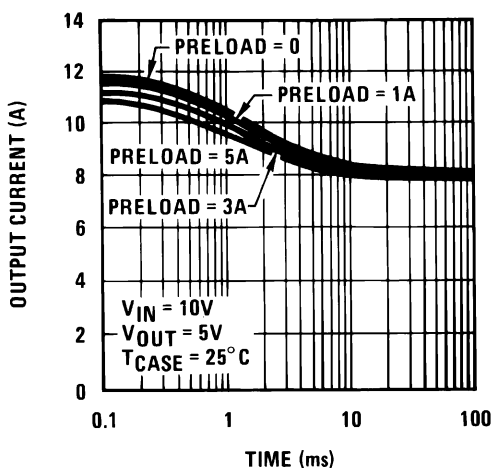


图 3. Current Limit

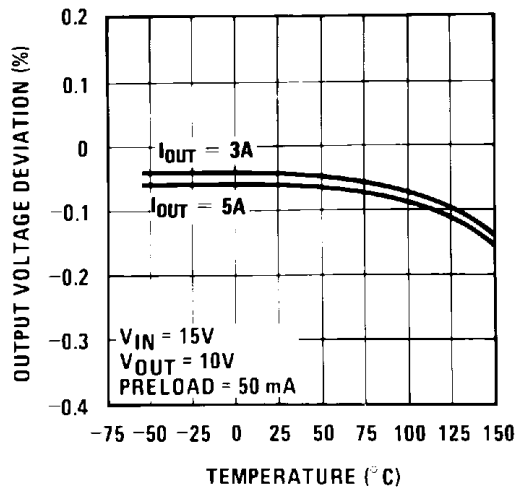


图 4. Load Regulation

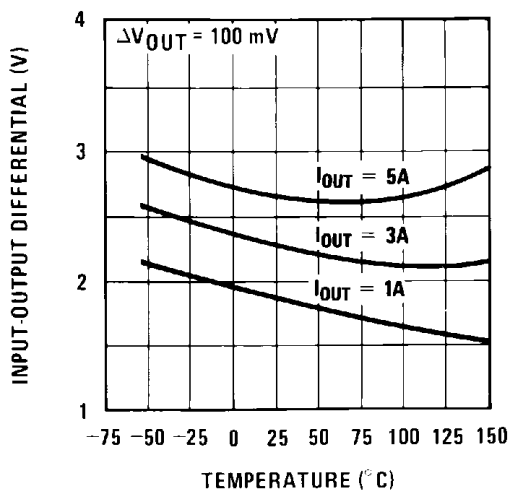


图 5. Dropout Voltage

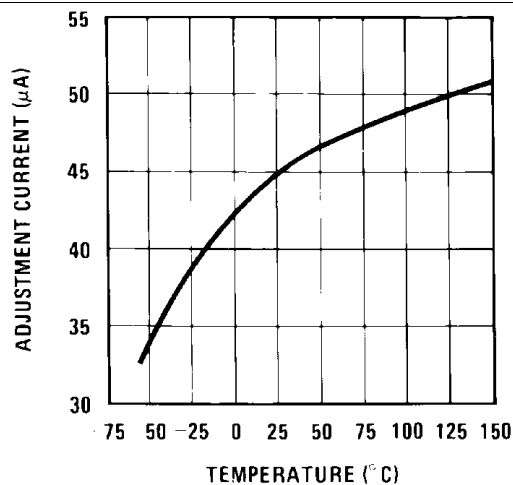


图 6. Adjustment Current

# Typical Performance Characteristics (接下页)

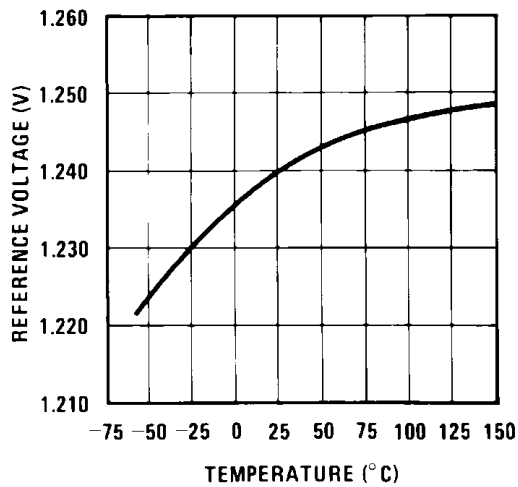


图 7. Temperature Stability

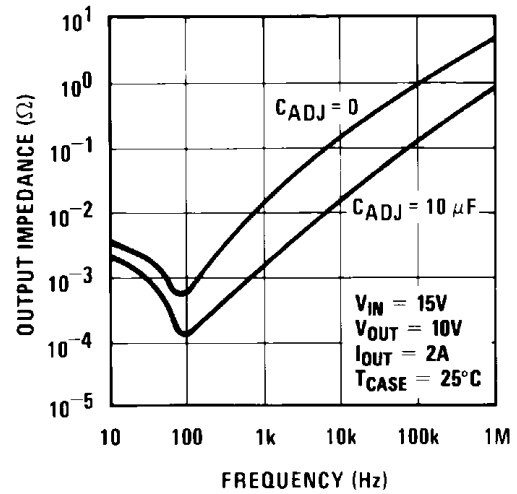


图 8. Output Impedance

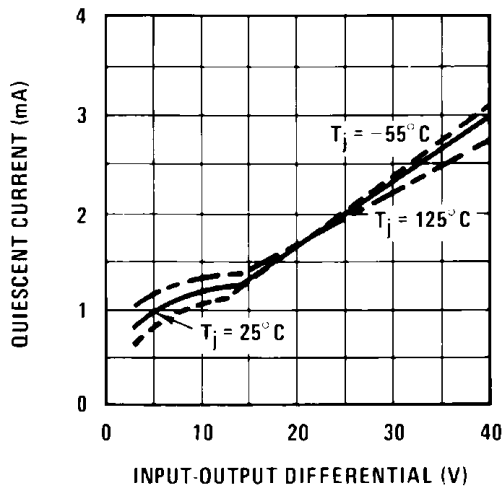


图 9. Minimum Operating Current

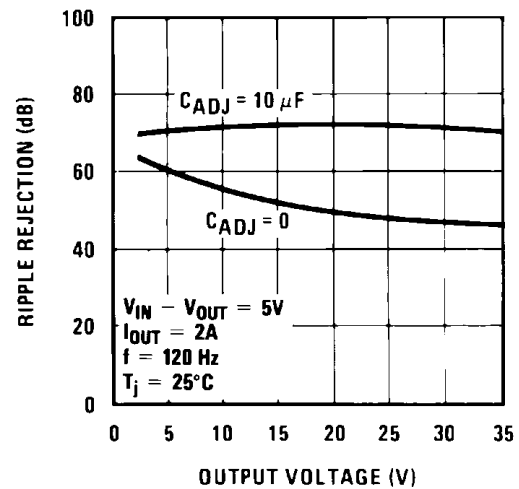


图 10. Ripple Rejection

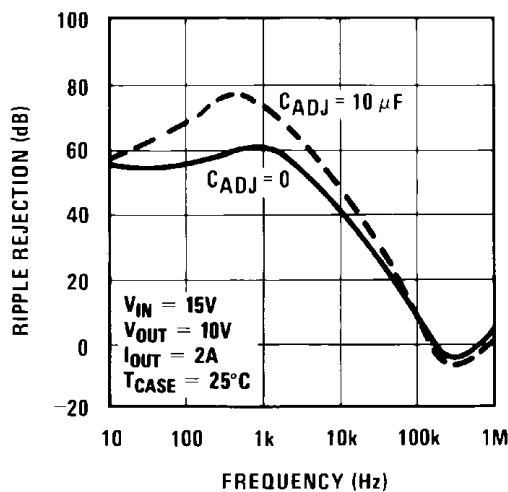


图 11. Ripple Rejection

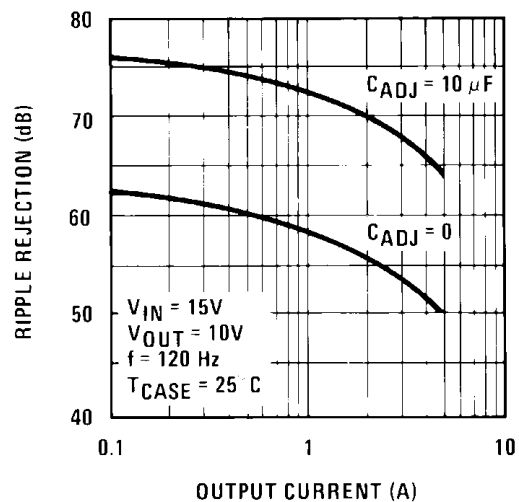


图 12. Ripple Rejection



## Typical Performance Characteristics (接下页)

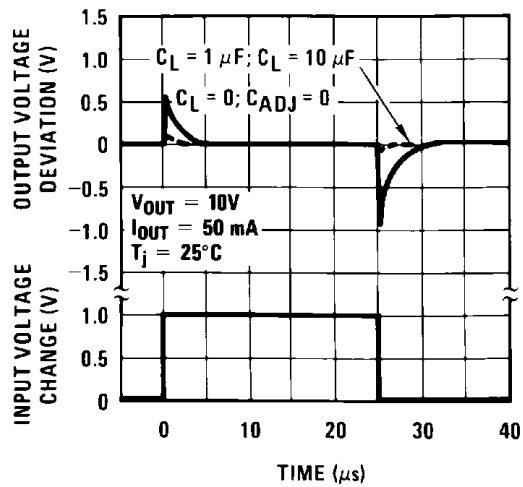


图 13. Line Transient Response

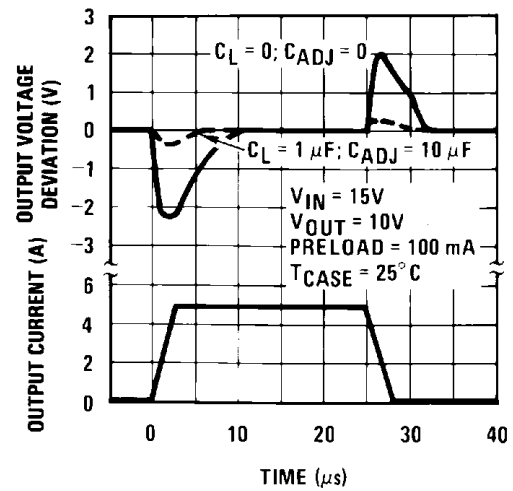


图 14. Load Transient Response

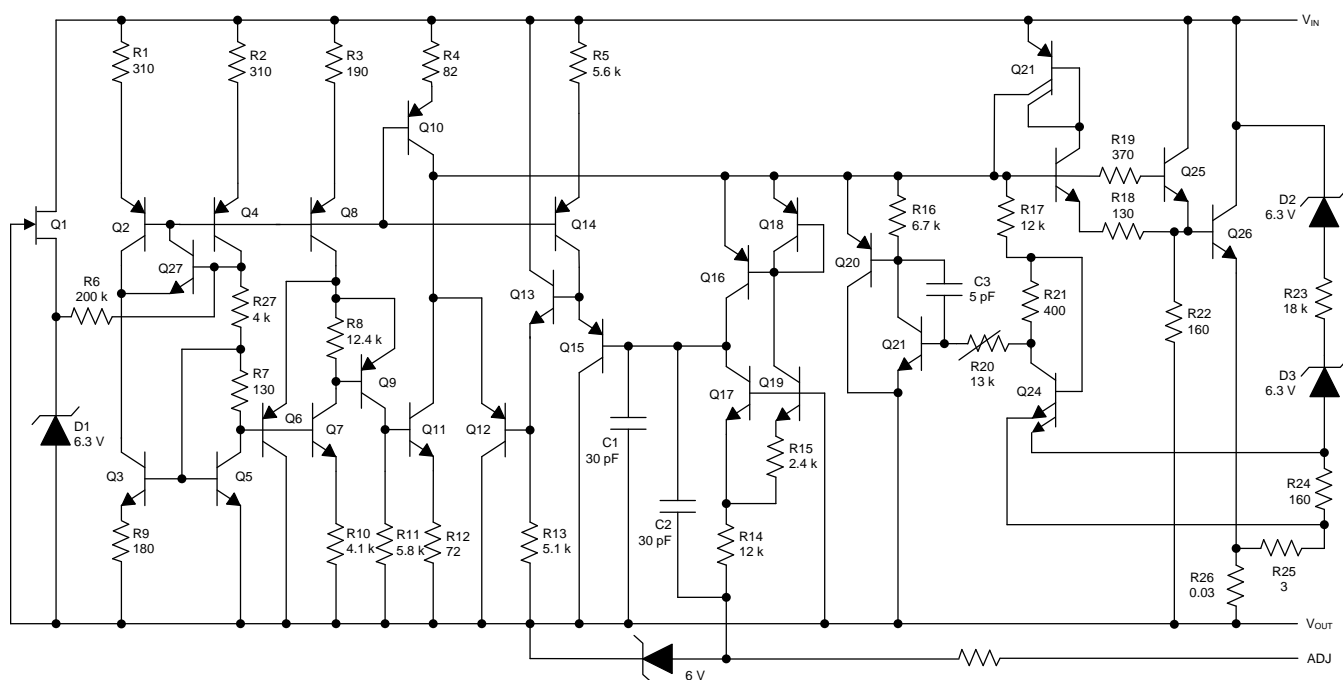
## 7 Detailed Description

### 7.1 Overview

The LM138QML device is an adjustable, three-terminal, positive-voltage regulator 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. The LM138QML device features 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 LM138QML 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 LM138QML device can function as a precision current regulator. 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.

### 7.2 Functional Block Diagram



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### 7.3 Feature Description

#### 7.3.1 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 ( $V_I - V_O$ ).

#### 7.3.2 Overload Block

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

#### 7.3.3 Programmable Feedback

An op amp with 1.25-V offset input at the ADJUST terminal provides easy output voltage or current, but not both, programming. For current regulation applications, a single resistor whose resistance value is  $1.25 \text{ V}/I_O$  and power rating is greater than  $1.25 \text{ V}^2/R$  must be used. For voltage regulation applications, two resistors set the output voltage.

## **7.4 Device Functional Modes**

### **7.4.1 Normal Operation**

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

### **7.4.2 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 the OUTPUT voltage is then the INPUT voltage minus the drop out voltage.

### **7.4.3 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- $\Omega$  feedback resistor between OUTPUT and ADJUST consumes the worst case minimum load current of 5 mA.

### **7.4.4 Operation in Self Protection**

When an overload occurs, the device shuts down the 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.

## 8 Application and Implementation

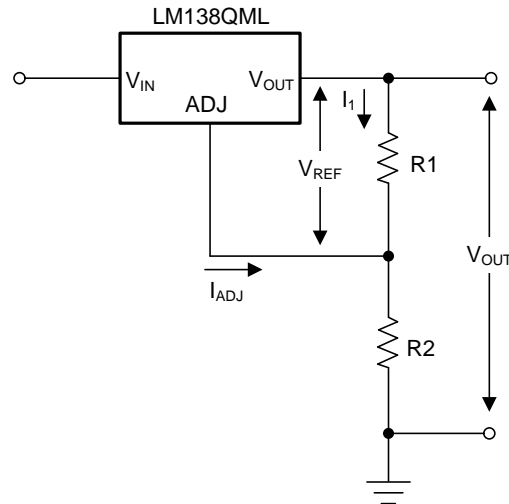
### 注

Information in the following applications sections is not part of the TI component specification, and TI does not warrant its accuracy or completeness. TI's customers are responsible for determining suitability of components for their purposes. Customers should validate and test their design implementation to confirm system functionality.

### 8.1 Application Information

In operation, the LM138QML device 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 of:

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

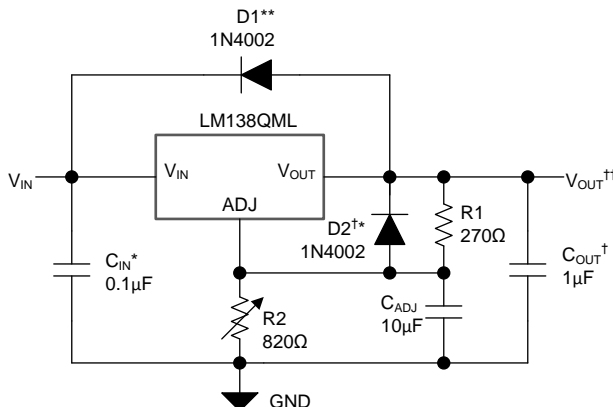


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Because the 50- $\mu$ A current from the adjustment terminal represents an error term, the LM138QML was designed to minimize  $I_{ADJ}$  and make it very constant with line and load changes. To do this, all quiescent operating current is returned to the output establishing a minimum load current requirement. If there is insufficient load on the output, the output rises.

## 8.2 Typical Applications

### 8.2.1 Constant 5-V Regulator



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

†Optional—improves transient response

\*\*Recommended if C<sub>OUT</sub> is used

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

†\*Recommended if C<sub>ADJ</sub> is used

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**图 15. Constant 5-V Regulator**

#### 8.2.1.1 Design Requirements

**表 1. Design Parameters**

PARAMETER	PART NUMBER/VALUE	DESCRIPTION
Feedback resistor 1 (R1)	270 Ω	The LM138QML produces a typical 1.24-V potential between the OUTPUT and ADJUST pins; therefore, placing a 270-Ω resistor between the OUTPUT and ADJUST pins causes 4.6 mA to flow through R1 and R2
Feedback resistor 2 (R2)	820 Ω	To achieve a 5-V output, the sum of the voltages across R1 and R2 must equal 5 V. Therefore, V <sub>R2</sub> must equal 3.76 V when 4.6 mA is flowing through it. R2 = V <sub>R2</sub> / I = 3.76 V / 4.6 mA = ~820 Ω.
Input capacitor (C <sub>IN</sub> )	0.1 μF	0.1 μF of input capacitance helps filter out unwanted noise, especially if the regulator is located far from the power supply filter capacitors.
Output capacitor (C <sub>OUT</sub> )	1 μF	The regulator is stable without any output capacitance, but adding a 1-μF capacitor improves the transient response.
Adjust capacitor (C <sub>ADJ</sub> )	10 μF	A 10-μF capacitor bypassing the ADJUST pin to ground improves the regulators ripple rejection.
Protection diode 1 (D1)	1N4002	Protection diode D1 is recommended if C <sub>OUT</sub> is used. The diode provides a low-impedance discharge path to prevent the capacitor from discharging into the output of the regulator (see <a href="#">Protection Diodes</a> ).
Protection diode 2 (D2)	1N4002	Protection diode D2 is recommended if C <sub>ADJ</sub> is used. The diode provides a low-impedance discharge path to prevent the capacitor from discharging into the output of the regulator (see <a href="#">Protection Diodes</a> ).

## 8.2.1.2 Detailed Design Procedure

### 8.2.1.2.1 External Capacitors

An input bypass capacitor is recommended. A 0.1- $\mu\text{F}$  disc or 1- $\mu\text{F}$  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 will eliminate the possibility of problems.

The adjustment terminal can be bypassed to ground on the LM138QML to improve ripple rejection. This bypass capacitor prevents ripple from being amplified as the output voltage is increased. With a 10- $\mu\text{F}$  bypass capacitor, 75-dB ripple rejection is obtainable at any output level. Increases over 20  $\mu\text{F}$  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.

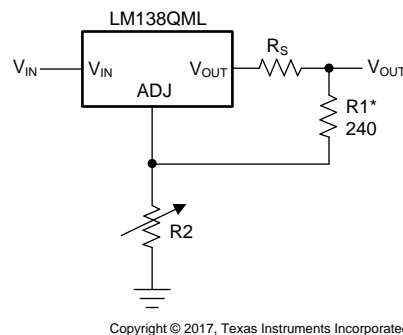
In general, the best type of capacitors to use are solid tantalum. Solid tantalum capacitors have low impedance even at high frequencies. Depending upon capacitor construction, it takes about 25  $\mu\text{F}$  in aluminum electrolytic to equal 1- $\mu\text{F}$  solid tantalum at high frequencies. Ceramic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

Although the LM138QML 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- $\mu\text{F}$  solid tantalum (or 25- $\mu\text{F}$  aluminum electrolytic) on the output swamps this effect and insures stability.

### 8.2.1.2.2 Load Regulation

The LM138QML device 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  $\Omega$ ) should 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- $\Omega$  resistance between the regulator and load will have a load regulation due to line resistance of  $0.05 \Omega \times I_L$ . If the set resistor is connected near the load the effective line resistance will be  $0.05 \Omega (1 + R_2/R_1)$  or in this case, 11.5 times worse.

图 16 shows the effect of resistance between the regulator and 240- $\Omega$  set resistor.



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图 16. Regulator With Line Resistance in Output Lead

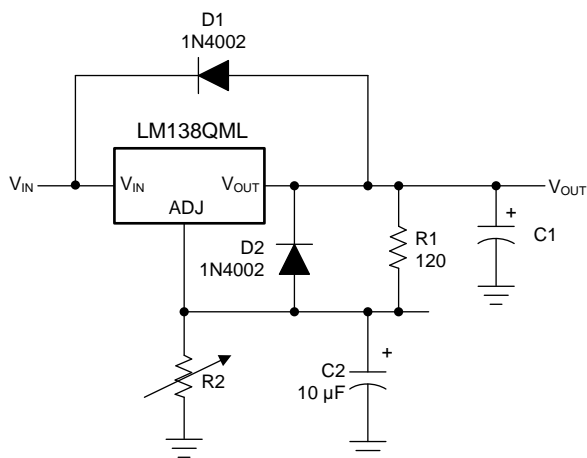
With the TO-3 package, it is easy to minimize the resistance from the case to the set resistor by using two separate leads to the case. The ground of  $R_2$  can be returned near the ground of the load to provide remote ground sensing and improve load regulation.

### 8.2.1.2.3 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- $\mu\text{F}$  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 LM138QML, 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  $\mu\text{F}$  or less at an 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 LM138QML is a 50- $\Omega$  resistor which limits the peak discharge current. No protection is needed for output voltages of 25-V or less and 10- $\mu\text{F}$  capacitance. 图 17 shows an LM138QML with protection diodes included for use with outputs greater than 25 V and high values of output capacitance.



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D1 protects against C1  
D2 protects against C2

$$V_{OUT} = 1.25 \text{ V} \left( 1 + \frac{R_2}{R_1} \right) + I_{ADJ} R_2$$

图 17. Regulator With Protection Diodes

### 8.2.1.3 Application Curves

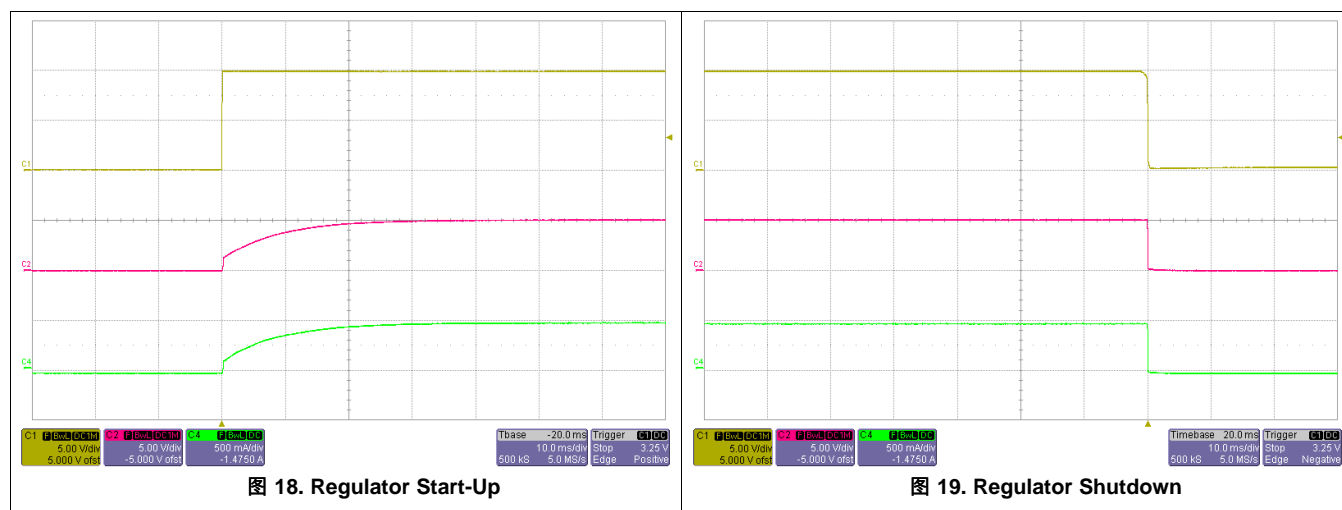


图 18. Regulator Start-Up

图 19. Regulator Shutdown

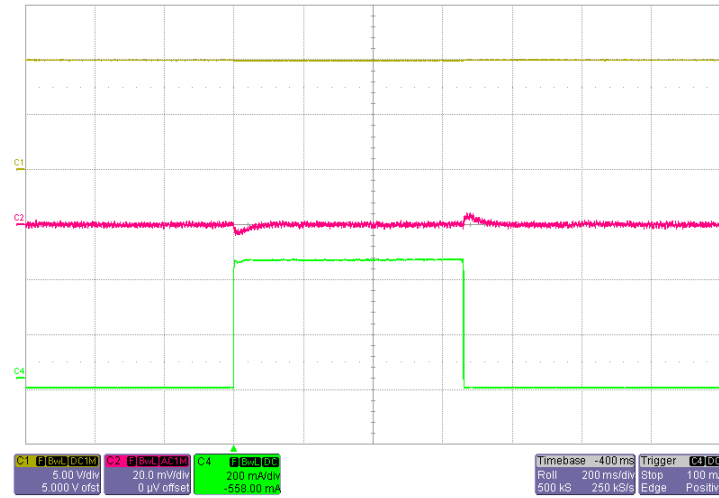
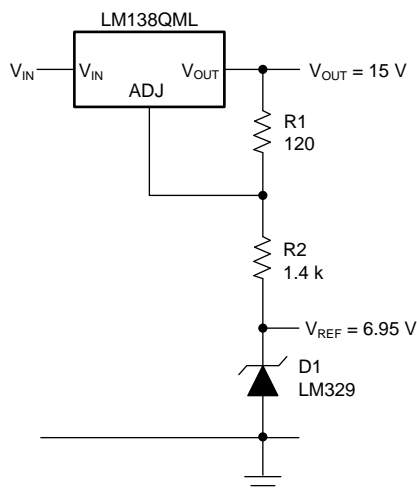


图 20. Regulator Response to Load Stop

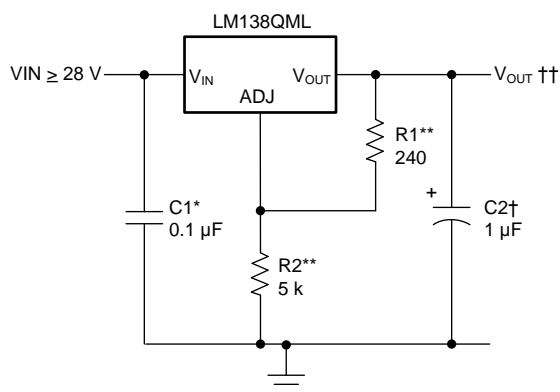


## 8.3 System Examples



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**图 21. Regulator and Voltage Reference**



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Full output current not available at high input-output voltages

$\dagger$  Optional—improves transient response. Output capacitors in the range of 1  $\mu$ F to 1000  $\mu$ F 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.

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

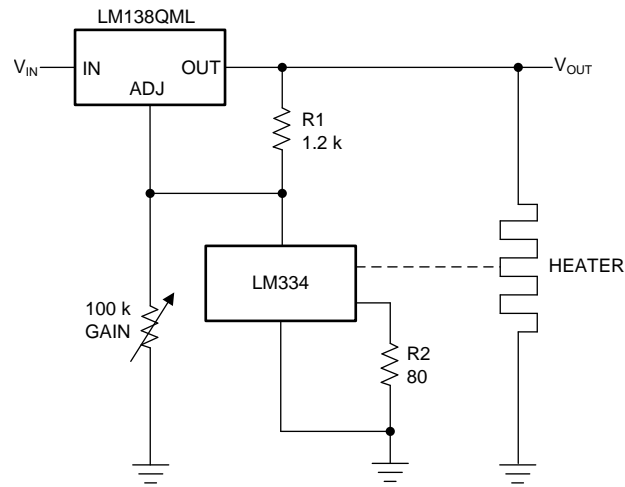
\*\* R1, R2 as an assembly can be ordered from Bourns:

MIL part no. 7105A-AT2-502

COMM part no. 7105A-AT7-502

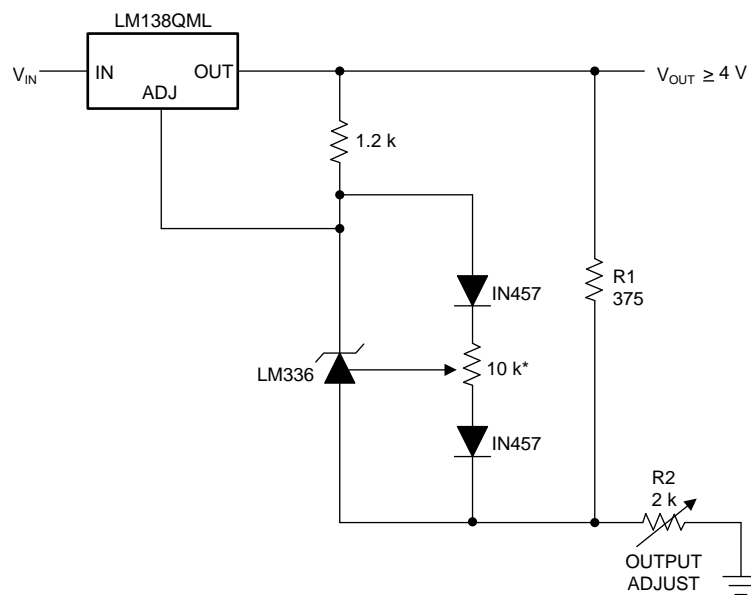
**图 22. 1.2-V to 25-V Adjustable Regulator**

## System Examples (接下页)



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**图 23. Temperature Controller**

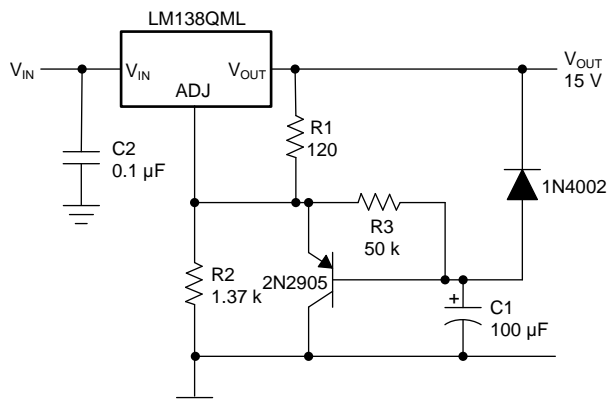


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\* Adjust for 3.75 V across R1

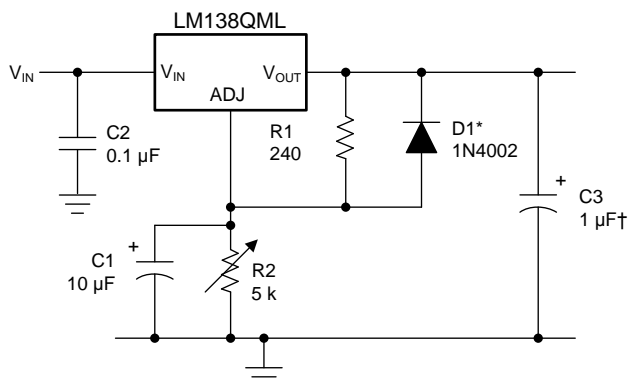
**图 24. Precision Power Regulator With Low Temperature Coefficient**

## System Examples (接下页)



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图 25. Slow Turnon 15-V Regulator

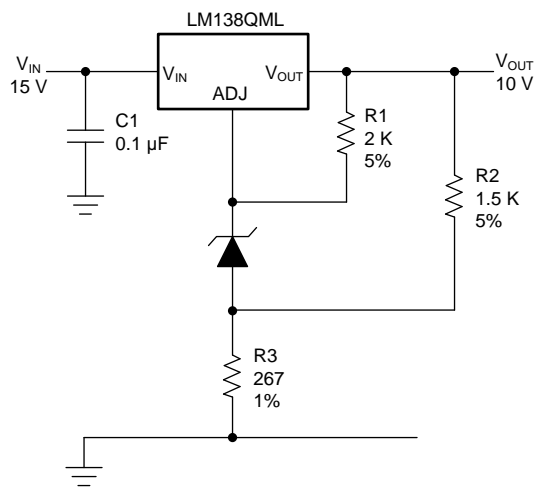


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† Solid tantalum

\* Discharges C1 if output is shorted to ground

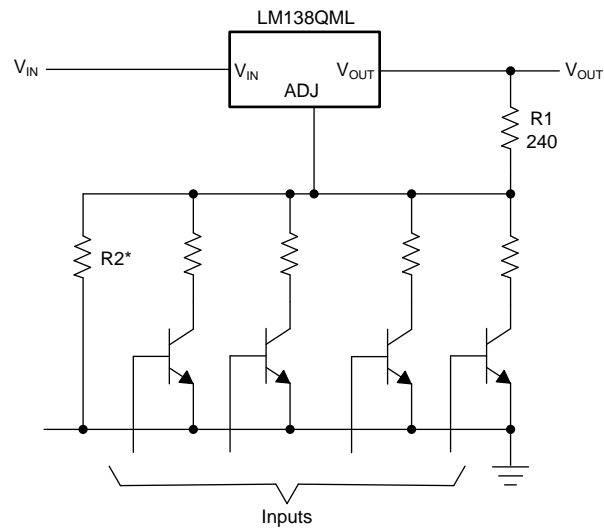
图 26. Adjustable Regulator With Improved Ripple Rejection



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图 27. High Stability 10-V Regulator

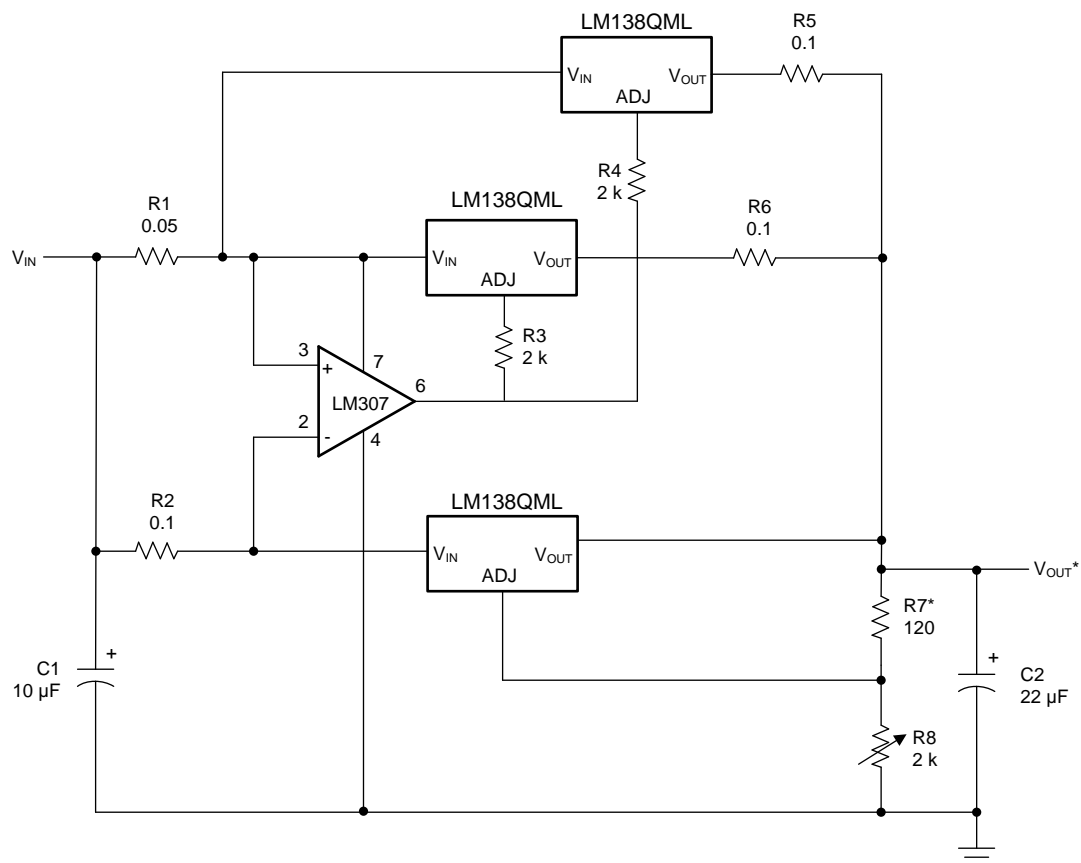
## System Examples (接下页)



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\* Sets maximum  $V_{OUT}$

**图 28. Digitally Selected Outputs**

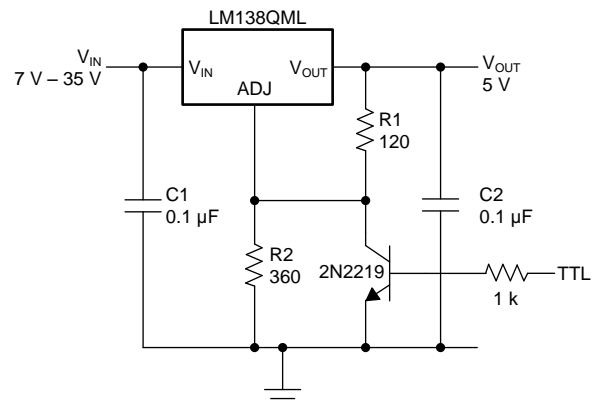


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\* Minimum load—100 mA

**图 29. 15-A Regulator**

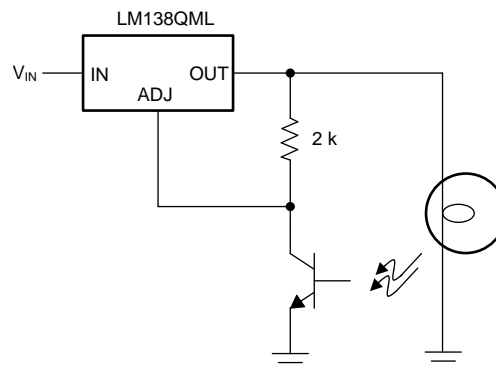
## System Examples (接下页)



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\*\* Minimum output  $\approx 1.2$  V

**图 30. 5-V Logic Regulator With Electronic Shutdown\*\***

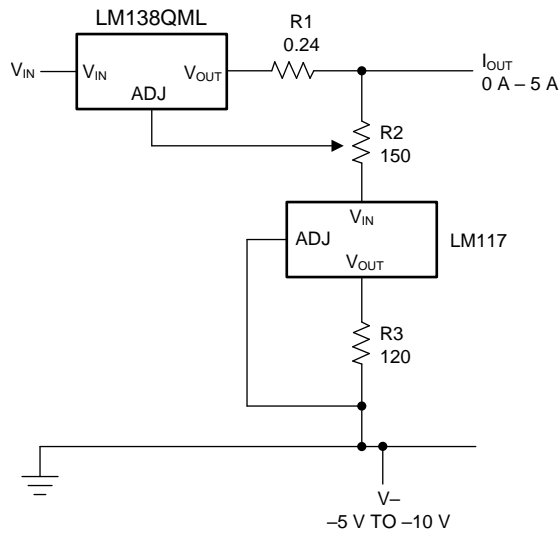


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**图 31. Light Controller**

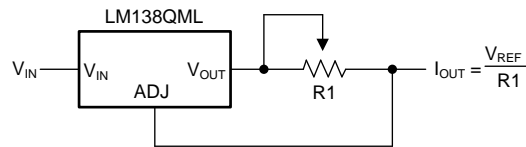


## System Examples (接下页)



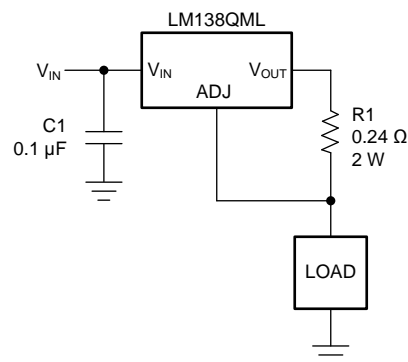
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**图 34. Adjustable Current Regulator**



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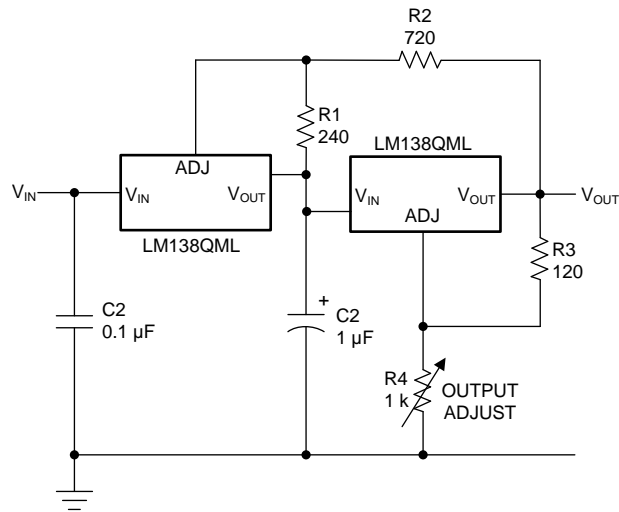
**图 35. Precision Current Limiter**



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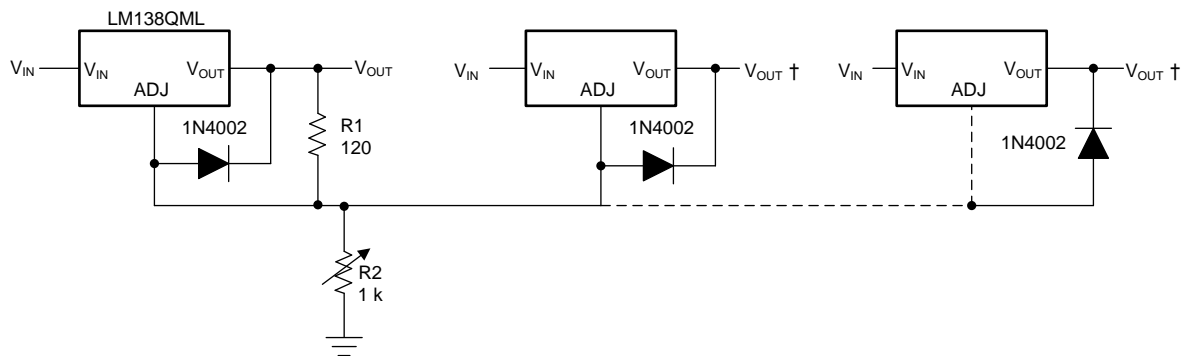
**图 36. 5-A Current Regulator**

## System Examples (接下页)



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**图 37. Tracking Preregulator**



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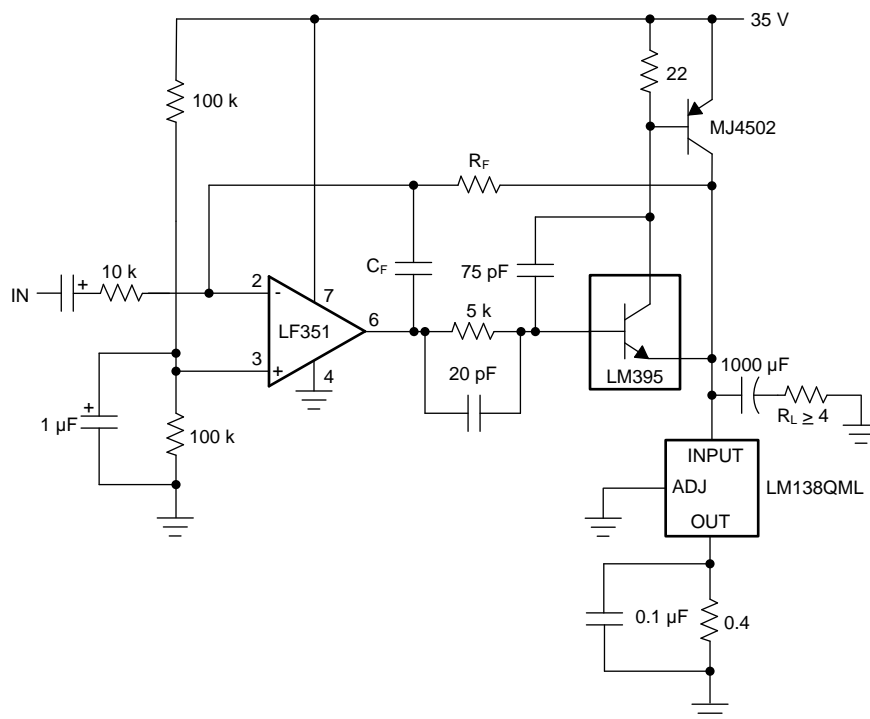
† Minimum load—10 mA

\* All outputs within  $\pm 100$  mV

**图 38. Adjusting Multiple On-Card Regulators With Single Control\***



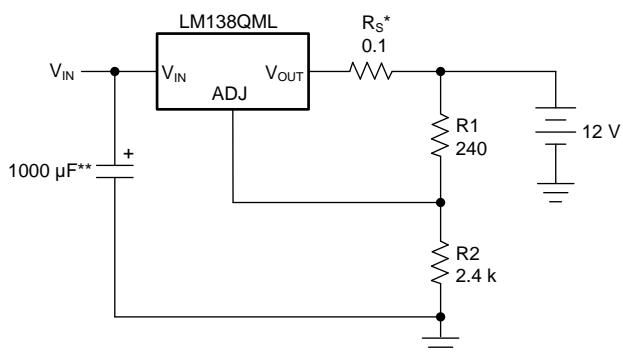
## System Examples (接下页)



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$A_V = 1$ ,  $R_F = 10k$ ,  $C_F = 100$  pF  
 $A_V = 10$ ,  $R_F = 100k$ ,  $C_F = 10$  pF  
 Bandwidth  $\geq 100$  kHz  
 Distortion  $\leq 0.1\%$

图 39. Power Amplifier



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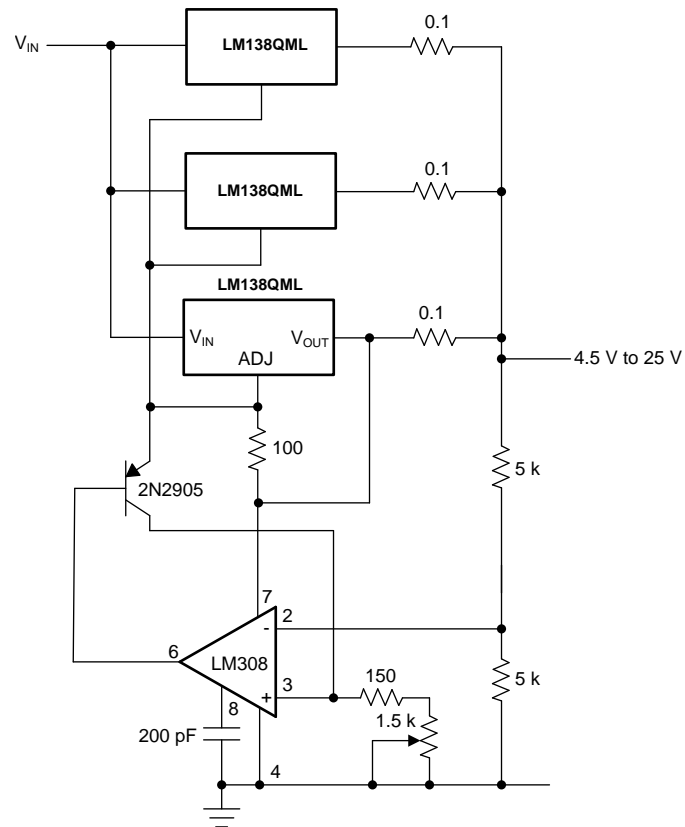
\*  $R_S$  sets output impedance of charger  $Z_{OUT} = R_S \left( 1 + \frac{R_2}{R_1} \right)$

Use of  $R_S$  allows low charging rates with fully charged battery.

\*\* The 1000  $\mu\text{F}$  is recommended to filter out input transients

图 40. Simple 12-V Battery Charger

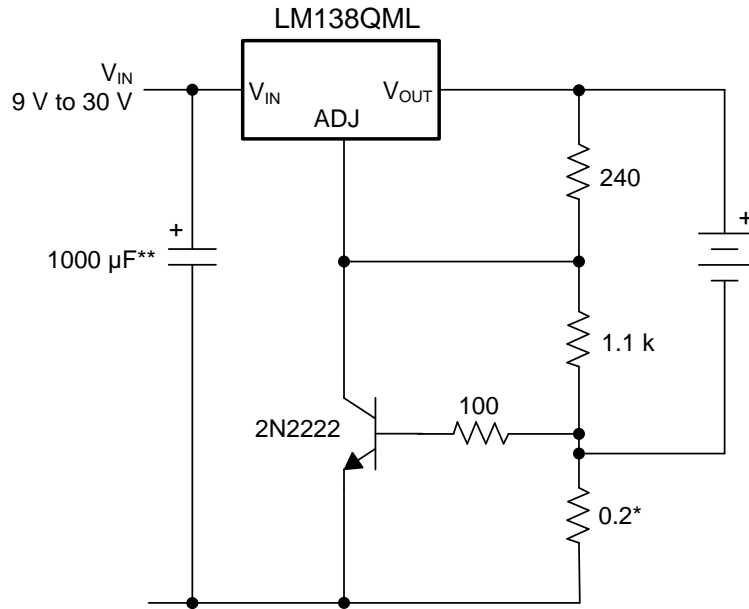
## System Examples (接下页)



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**图 41. Adjustable 15-A Regulator**

## System Examples (接下页)

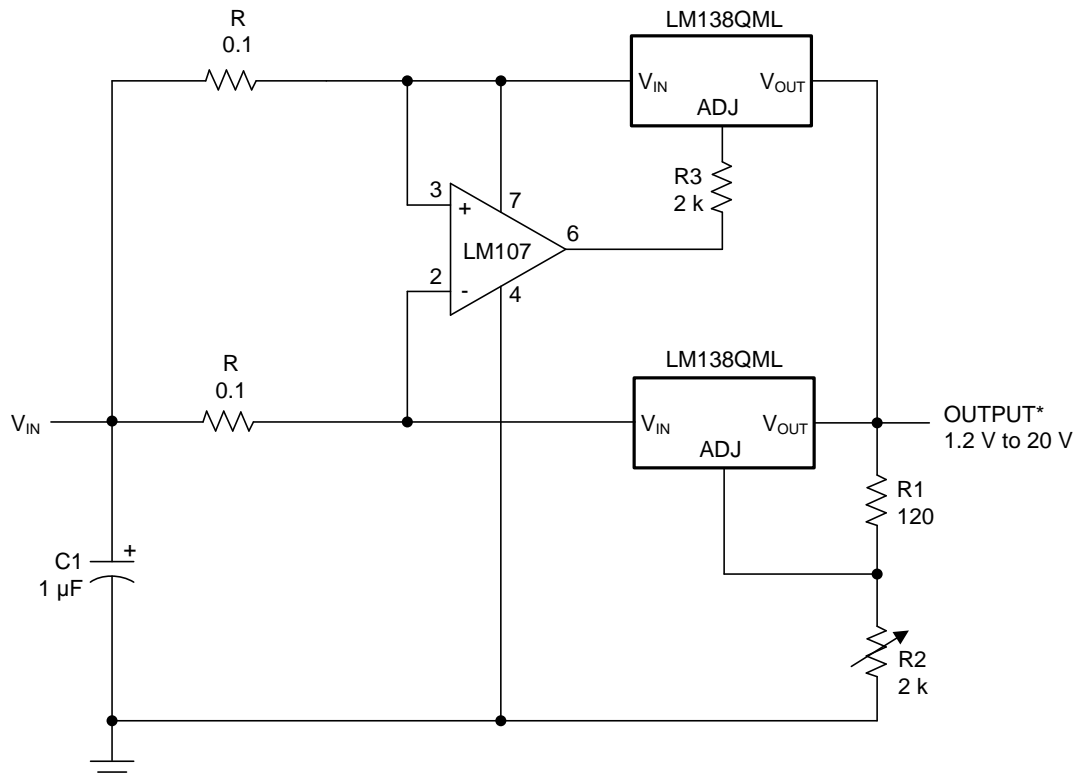


\* Set max charge current to 3 A

\*\* The 1000 µF is recommended to filter out input transients.

**图 42. Current Limited 6-V Charger**

## System Examples (接下页)



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\* Minimum load—100 mA

**图 43. 10-A Regulator**

## 9 Power Supply Recommendations

The input supply to LM138QML 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 LM138QML in regulation. TI recommends a capacitor be placed at the input to bypass noise.

## 10 Layout

### 10.1 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 device. 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 device. Similarly, in cases when a large bypass capacitor is placed at the ADJ pin and  $V_{OUT}$  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 device pins to increase their effectiveness.

### 10.2 Layout Example

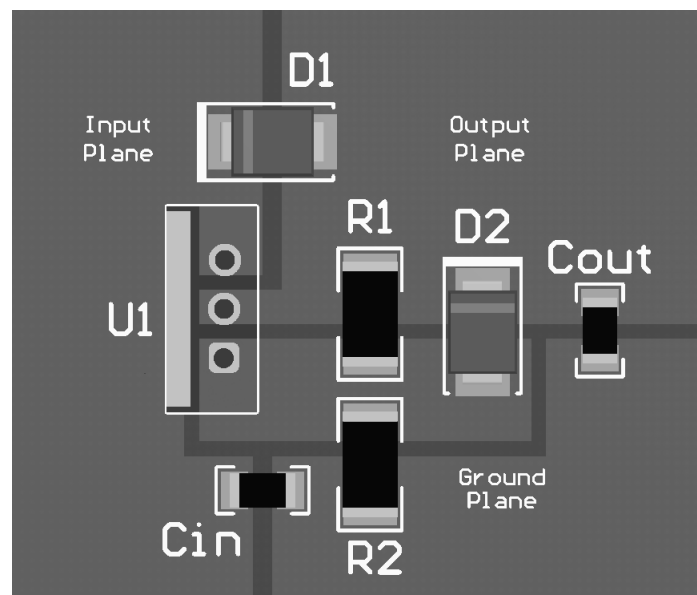


图 44. LM138QML Layout

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### 11.5 Glossary

[SLYZ022](#) — *TI Glossary*.

This glossary lists and explains terms, acronyms, and definitions.

## 12 机械、封装和可订购信息

以下页面包含机械、封装和可订购信息。这些信息是指定器件的最新可用数据。这些数据如有变更，恕不另行通知和修订此文档。如欲获取此数据表的浏览器版本，请参阅左侧的导航。

## 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)
<a href="#">LM138K-MIL</a>	Active	Production	TO (K)   2	50   TRAY NON-STD	Yes	Call TI	Level-1-NA-UNLIM	-	LM138K-MIL ACO >T
LM138KG-MD8	Active	Production	DIESALE (Y)   0	100   JEDEC TRAY (5+1)	Yes	Call TI	Level-1-NA-UNLIM	-55 to 125	

<sup>(1)</sup> **Status:** For more details on status, see our [product life cycle](#).

<sup>(2)</sup> **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.

<sup>(3)</sup> **RoHS values:** Yes, No, RoHS Exempt. See the [TI RoHS Statement](#) for additional information and value definition.

<sup>(4)</sup> **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.

<sup>(5)</sup> **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.

<sup>(6)</sup> **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.

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## 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-MIL	K	TO-CAN	2	50	9 X 6	NA	292.1	215.9	25654	3.87	22.3	25.4

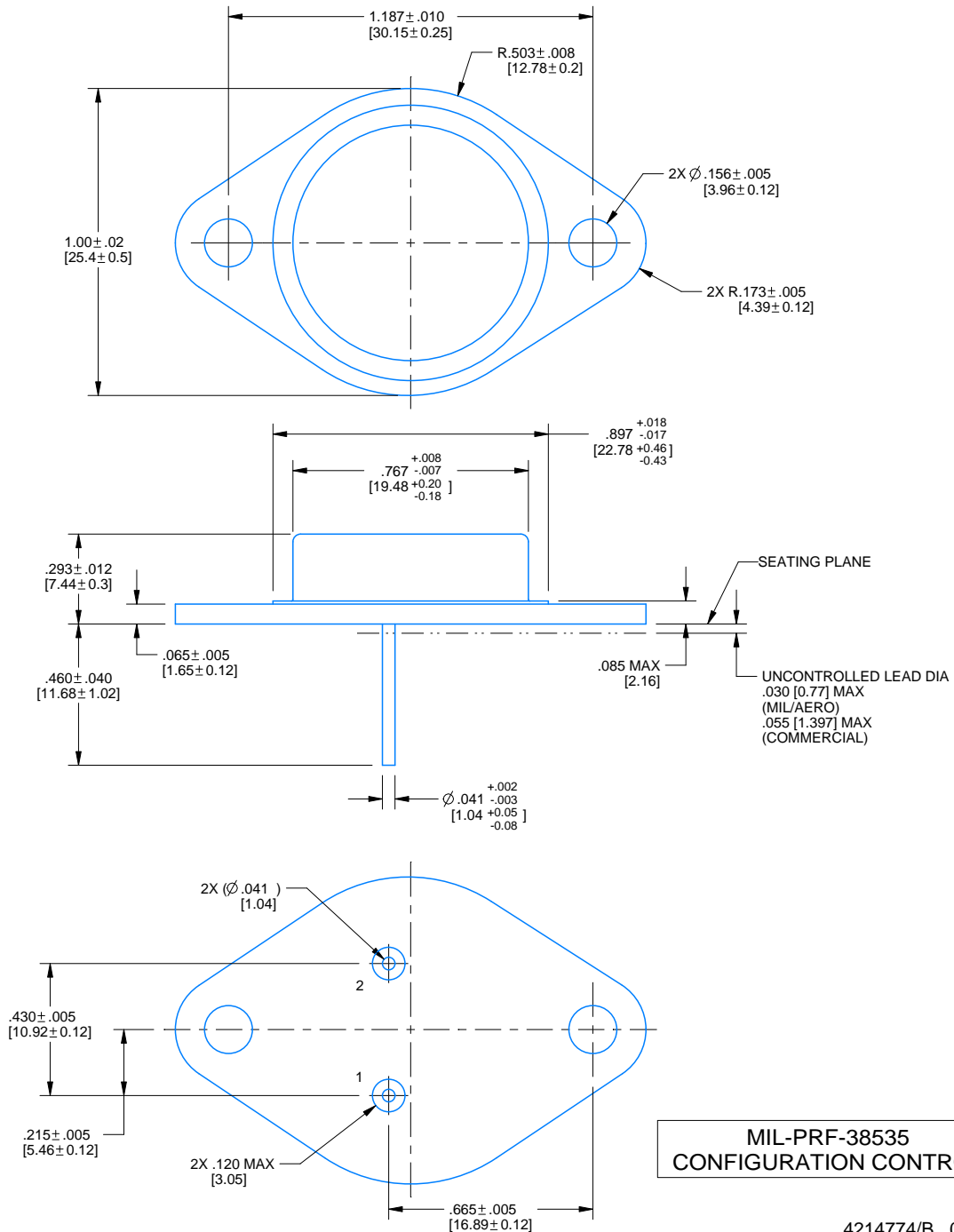


**K0002A**

# PACKAGE OUTLINE

## TO-CAN - 7.747 mm max height

TRANSISTOR OUTLINE



4214774/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.
3. Leads not to be bent greater than  $15^\circ$ .

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