THREE-TERMINAL 5-A ADJUSTABLE VOLTAGE REGULATORS

- GUARANTEED 7A PEAK OUTPUT CURRENT
- GUARANTEED 5A OUTPUT CURRENT
- ADJUSTABLE OUTPUT DOWN TO 1.2V
- LINE REGULATION TYPICALLY 0.005%/V
- LOAD REGULATION TYPICALLY 0.1%
- GUARANTEED THERMAL REGULATION
- CURRENT LIMIT CONSTANT WITH TEMPERATURE
- STANDARD 3-LEAD TRANSISTOR PACKAGE

DESCRIPTION
The LM138/LM238/LM338 are adjustable 3-terminal positive voltage regulators capable of supplying in excess of 5A over a 1.2V to 32V output range. They are exceptionally easy to use and require only 2 resistors to set the output voltage. Careful circuit design has resulted in outstanding load and line regulation comparable to many commercial power supplies. The LM138 family is supplied in a standard 3-lead transistor package.

A unique feature of the LM138 family is time-dependent current limiting. The current limit circuitry allows peak currents of up to 12A to be drawn from the regulator for short periods of time. This allows the LM138 to be used with heavy transient loads and speeds start-up under full-load conditions. Under sustained loading conditions, the current limit decreases to a safe value protecting the regulator. Also included on the chip are thermal overload protection and safe area protection for the power transistor. Overload protection remains functional even if the adjustment pin is accidentally disconnected.

Normally, no capacitors are needed unless the device is situated far from the input filter capacitors in which case an input bypass is needed. An optional output capacitor can be added to improve transient response. The adjustment terminal can be bypassed to achieve very high ripple rejection ratios which are difficult to achieve with standard 3-terminal regulators.

Besides replacing fixed regulators or discrete designs, the LM238 is useful in a wide variety of other applications. Since the regulator is "floating" and sees only the input-to-output differential voltage, supplies of several hundred volts can be regulated as long as the maximum input to input differential is not exceeded.

The LM138/LM238/LM338 are packaged in standard steel TO-3 transistor packages. The LM138 is rated for operation from -55°C to 150°C, the LM238 from -25°C to +150°C and the LM338 from 0°C to +125°C.

ORDER CODE

<table>
<thead>
<tr>
<th>PART NUMBER</th>
<th>TEMPERATURE RANGE</th>
<th>PACKAGE</th>
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<tbody>
<tr>
<td>LM138</td>
<td>-55°C to +150°C</td>
<td>K</td>
</tr>
<tr>
<td>LM238</td>
<td>-25°C to +150°C</td>
<td></td>
</tr>
<tr>
<td>LM338</td>
<td>0°C to +125°C</td>
<td></td>
</tr>
</tbody>
</table>

EXAMPLE: LM138K

PIN CONNECTION

Case is output
LM138-LM238-LM338

ABSOLUTE MAXIMUM RATING

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Parameter</th>
<th>Value</th>
<th>Unit</th>
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<tbody>
<tr>
<td>P_D</td>
<td>Power Dissipation</td>
<td>Internally Limited</td>
<td>W</td>
</tr>
<tr>
<td>V_IN  - V_OUT</td>
<td>Input-Output Voltage Differential</td>
<td>35</td>
<td>V</td>
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<tr>
<td>T_OPER</td>
<td>Operating Junction Temperature Range</td>
<td>LM138 -55 to 150</td>
<td>°C</td>
</tr>
<tr>
<td></td>
<td>LM238 -25 to 150</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>LM338 0 to 125</td>
<td></td>
<td></td>
</tr>
<tr>
<td>T_STG</td>
<td>Storage Temperature Range</td>
<td>-65 to 150</td>
<td>°C</td>
</tr>
<tr>
<td>T_MAX</td>
<td>Lead Temperature (Soldering, 10 seconds)</td>
<td>300</td>
<td>°C</td>
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THERMAL CHARACTERISTICS

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Parameter</th>
<th>Value</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>R_THJC</td>
<td>Typical Junction-Case Thermal Resistance</td>
<td>1.4</td>
<td>°C/W</td>
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<tr>
<td>R_THJA</td>
<td>Max Junction-Ambient Thermal Resistance</td>
<td>35</td>
<td>°C/W</td>
</tr>
</tbody>
</table>

SCHEMATIC DIAGRAM
## ELECTRICAL CHARACTERISTICS

LM138: $-55 \leq T_J \leq 150 \, ^\circ C$, $V_i - V_o = 5V$, $I_O = 2.5\, A$

LM238: $-25 \leq T_J \leq 150 \, ^\circ C$, $V_i - V_o = 5V$, $I_O = 2.5\, A$

LM338: $0 \leq T_J \leq 150 \, ^\circ C$, $V_i - V_o = 5V$, $I_O = 2.5\, A$

Although power dissipation is internally limited, these specifications apply to power dissipation up to 50W (unless otherwise specified).

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Parameter</th>
<th>LM138-LM238</th>
<th>LM338</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>$K_V$</td>
<td>Line Regulation - (note 1)</td>
<td>0.005</td>
<td>0.01</td>
<td>0.005</td>
</tr>
</tbody>
</table>

| $K_{V0}$ | Load Regulation $T_{Amb} = 25 \, ^\circ C$, 10 mA $\leq I_O \leq 5$ A $V_O \leq 5V$ - (note 1) | 5 | 15 | 5 | 25 | mV |
|          | $V_O \geq 5V$ - (note 1) | 0.1 | 0.3 | 0.1 | 0.5 | % |

| $I_{(th)}$ | Adjustment Pin Current | 45 | 100 | 45 | 100 | mA |

| $\Delta I_{(th)}$ | Adjustment Pin Current Change | 10 mA $\leq I_O \leq 5$ A, $3 \, V \leq (V_i - V_o) \leq 35$ V | 0.2 | 5 | 0.2 | 5 | mA |

| $V_{(th)}$ | Reference Voltage | 3V $\leq (V_i - V_o) \leq 35$ V, 10 mA $\leq I_O \leq 5$ A, P $\leq 50$ W | 1.19 | 1.24 | 1.29 | 1.19 | 1.24 | 1.29 | V |

| $K_V$  | Line Regulation - (note 1) | 0.02 | 0.04 | 0.02 | 0.06 | %/V |

| $K_{V0}$ | Load Regulation 10 mA $\leq I_O \leq 5$ A $V_O \leq 5V$ - (note 1) | 20 | 30 | 20 | 50 | mV |
|          | $V_O \geq 5V$ - (note 1) | 0.3 | 0.6 | 0.3 | 1 | % |

| $K_{VT}$ | Temperature Stability ($T_{Amb} \leq T_J \leq T_{Max}$) | 1 | 1 | % |

| $I_{(gen)}$ | Minimum Load Current ($V_i - V_o \leq 35$ V) | 3.5 | 5 | 3.5 | 10 | mA |

| $I_{(max)}$ | Current Limit ($V_i - V_o \leq 10$ V) | 5 | 8 | 5 | 8 | A |
| DC | 0.5 ms Peak $V_i - V_o = 30$ V | 7 | 12 | 7 | 12 | |

| $R_{out}$ | RMS Output Noise, % of $V_O$ ($T_{Amb} = 25 \, ^\circ C$, 10 Hz $\leq f \leq 10$ kHz) | 0.003 | % |

| $R_{ip}$ | Ripple Rejection Ratio $V_O = 10$ V, f = 120 Hz $C_{(in)} = 10 \, \mu F$ | 60 | 60 | 60 | 75 | 75 | dB |

| $K_{th}$ | Long Term Stability ($T_{Amb} = 125 \, ^\circ C$) | 0.3 | 1 | % |

**Note 1:** Regulation is measured at constant junction temperature. Changes in output voltage due to heating effects are taken into account separately by thermal rejection.

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### CURRENT LIMIT

**OUTPUT CURRENT (A)**

**TIME (ms)**

**OUTPUT CURRENT (A)**

**INPUT-OUTPUT DIFFERENTIAL (V)**

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**CURRENT LIMIT**

**PEAK CURRENT LIMIT**

**DC CURRENT LIMIT**

**PRELOAD = 0**

**PRELOAD = 3A**

**PRELOAD = 5A**

**PRELOAD = 1A**

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**7929237 0051508 850**

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**505**
TYPICAL APPLICATIONS

+ 1.2V to + 25V ADJUSTABLE REGULATOR

Since the 50μA current from the adjustment terminal represents an error term, the LM338 was designed to minimize Iq 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 will rise.

EXTERNAL CAPACITORS

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

The adjustment terminal can be bypassed to ground on the LM338 to improve ripple rejection. This bypass capacitor prevents ripple form being amplified as the output voltage is increased. With a 10μF bypass capacitor, 75dB ripple rejection is obtainable at any output level. Increases over 20μF do not appreciably improve the ripple rejection at frequencies above 120Hz. 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 25μF in aluminum electrolytic to equal 1μF 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 0.5MHz. For this reason, 0.01μF disc may seem to work better than a 0.1μF disc as a bypass.

Although the LM338 is stable with no output capacitors, like any feedback circuit, certain values of external capacitance can cause excessive ringing. This occurs with values between 500pF and 5000pF. A 1μF solid tantalum (or 25μF aluminum electrolytic) on the output swamps this effect and insures stability.

LOAD REGULATION

The LM338 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 240Ω) should be tied directly to the output of the regulator rather than near the load. This eliminates line drops from appearing effectively in series with the reference and degrading regulation. For example, a 15V regulator with 0.05Ω resistance between the regulator and load will have a load regulation due to line resistance of 0.05Ω x I. If the set resistor is connected near the load, the effective line resis-
Resistance will be $0.05\Omega (1 + R_2/R_1)$ or in this case, 11.5 times worse.

Figure 2 shows the effect of resistance between the regulator and 140Ω set resistor.

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.

**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.

**Figure 2** : Regulator with Line Resistance in Output Lead.

Most 20μF capacitors have low enough internal series resistance to deliver 20A 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 will discharge 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 $V_i$. In the LM338 this discharge path is through a large junction that is able to sustain 25A surge with no problem. This is not true of other types of positive regulators. For output capacitors of 100μF or less at output of 15V 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 LM338 is a 50Ω resistor which limits the peak discharge current. No protection is needed for output voltages of 25V or less and 10μF capacitance. Figure 3 shows an LM338 with protection diodes included for use with outputs greater than 25V and high values of output capacitance.

**Figure 3** : Regulator with Protection Diodes.
10A REGULATOR

* Minimum load = 100mA
V_i ≥ 10V
V_o ≥ 3V
V_i - V_o ≥ 3.5V

5A CURRENT REGULATOR

* Minimum load = 100mA
V_i ≥ 10V
V_o ≥ 3V
V_i - V_o ≥ 3.5V
15A REGULATOR

Minimum load = 100mA
V1 ≥ +10V
V0 ≥ +3V
V1 = V0 ≥ +4V

5V LOGIC REGULATOR WITH ELECTRONIC SHUTDOWN**

R1 = 240Ω for LM138 or LM238
R2 = 720Ω for LM138 or LM238
Minimum output = +1.2V
LM138-LM238-LM338

TRACKING PREREGULATOR

![Tracking Preregulator Diagram]

- R1 = 240Ω for LM138 or LM238
- R2 = 720Ω for LM138 or LM238
- Minimum output = +1.2V

SLOW TURN-ON 15V REGULATOR

![Slow Turn-On 15V Regulator Diagram]

- R1 = 240Ω
- R2 = 2.7kΩ for LM138 and LM238