

## Micropower Voltage Regulator

Check for Samples: [SM72238](#)

### FEATURES

- Renewable Energy Grade
- High-Accuracy Output Voltage
- Ensured 100mA Output Current
- Extremely Low Quiescent Current
- Low Dropout Voltage
- Extremely Tight Load and Line Regulation
- Very Low Temperature Coefficient
- Use as Regulator or Reference
- Needs Minimum Capacitance for Stability
- Current and Thermal Limiting
- Stable With Low-ESR Output Capacitors (10mΩ to 6Ω)

### DESCRIPTION

The SM72238 is a micropower voltage regulator with very low quiescent current (75μA typ.) and very low dropout voltage (typ. 40mV at light loads and 380mV at 100mA). It is ideally suited for use in battery-powered systems. Furthermore, the quiescent current of the SM72238 increases only slightly in dropout, prolonging battery life.

The SM72238 is available in the surface-mount D-Pak package.

Careful design of the SM72238 has minimized all contributions to the error budget. This includes a tight initial tolerance (.5% typ.), extremely good load and line regulation (.05% typ.) and a very low output voltage temperature coefficient, making the part useful as a low-power voltage reference.

### Block Diagram and Typical Applications

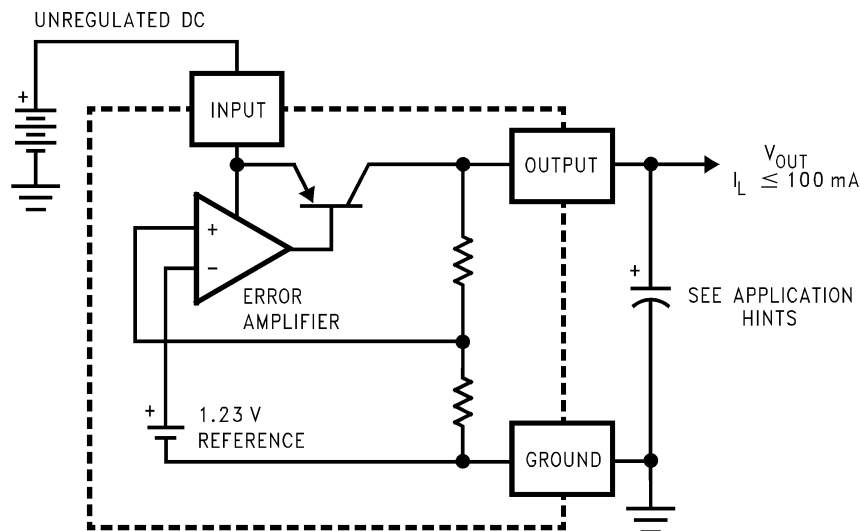


Figure 1. SM72238



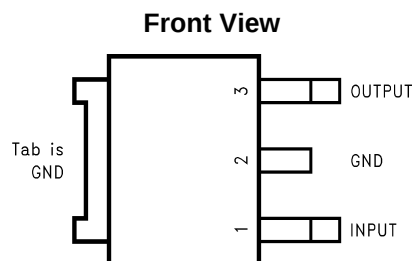
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PRODUCTION DATA information is current as of publication date. Products conform to specifications per the terms of the Texas Instruments standard warranty. Production processing does not necessarily include testing of all parameters.

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## Connection Diagrams



**Figure 2. PFM Package**  
**See Package Number NDP0003B**



These devices have limited built-in ESD protection. The leads should be shorted together or the device placed in conductive foam during storage or handling to prevent electrostatic damage to the MOS gates.

### Absolute Maximum Ratings<sup>(1)(2)</sup>

|                                        |                                 |                    |
|----------------------------------------|---------------------------------|--------------------|
| Input Supply Voltage                   |                                 | -0.3 to +30V       |
| Power Dissipation                      |                                 | Internally Limited |
| Junction Temperature (T <sub>J</sub> ) |                                 | +150°C             |
| Ambient Storage Temperature            |                                 | -65° to +150°C     |
| Soldering Dwell Time, Temperature      | Wave                            | 4 seconds, 260°C   |
|                                        | Infrared                        | 10 seconds, 240°C  |
|                                        | Vapor Phase                     | 75 seconds, 219°C  |
| ESD Rating                             | Human Body Model <sup>(3)</sup> | 2500V              |

- (1) Absolute Maximum Ratings are limits beyond which damage to the device may occur. Operating Ratings are conditions under which operation of the device is ensured. Operating Ratings do not imply ensured performance limits. For ensured performance limits and associated test conditions, see the Electrical Characteristics tables.
- (2) If Military/Aerospace specified devices are required, please contact the TI Sales Office/ Distributors for availability and specifications.
- (3) Human Body Model 1.5kΩ in series with 100pF.

### Operating Ratings<sup>(1)</sup>

|                                                              |                |
|--------------------------------------------------------------|----------------|
| Maximum Input Supply Voltage                                 | 30V            |
| Junction Temperature Range, (T <sub>J</sub> ) <sup>(2)</sup> | -40° to +125°C |

- (1) Absolute Maximum Ratings are limits beyond which damage to the device may occur. Operating Ratings are conditions under which operation of the device is ensured. Operating Ratings do not imply ensured performance limits. For ensured performance limits and associated test conditions, see the Electrical Characteristics tables.
- (2) Junction-to-case thermal resistance for the PFM package is 5.4°C/W.

**Electrical Characteristics<sup>(1)</sup>**

| Parameter                              | Conditions <sup>(1)</sup>                                             | Typ       | Tested Limit <sup>(2)</sup> | Design Limit <sup>(3)</sup> | Units  |
|----------------------------------------|-----------------------------------------------------------------------|-----------|-----------------------------|-----------------------------|--------|
| 3V Versions                            |                                                                       |           |                             |                             |        |
| Output Voltage                         | T <sub>J</sub> = 25°C                                                 | 3.0       | 3.030                       |                             | V max  |
|                                        |                                                                       |           | 2.970                       |                             | V min  |
|                                        | −25°C ≤ T <sub>J</sub> ≤ 85°C                                         | 3.0       |                             | 3.045                       | V max  |
|                                        |                                                                       |           |                             | 2.955                       | V min  |
|                                        | Full Operating Temperature Range                                      | 3.0       |                             | <b>3.060</b>                | V max  |
|                                        |                                                                       |           | <b>2.940</b>                | V min                       |        |
| Output Voltage                         | 100μA ≤ I <sub>L</sub> ≤ 100mA,<br>T <sub>J</sub> ≤ T <sub>JMAX</sub> | 3.0       |                             | <b>3.072</b>                | V max  |
|                                        |                                                                       |           |                             | <b>2.928</b>                | V min  |
| 3.3V Versions                          |                                                                       |           |                             |                             |        |
| Output Voltage                         | T <sub>J</sub> = 25°C                                                 | 3.3       | 3.333                       |                             | V max  |
|                                        |                                                                       |           | 3.267                       |                             | V min  |
|                                        | −25°C ≤ T <sub>J</sub> ≤ 85°C                                         | 3.3       |                             | 3.350                       | V max  |
|                                        |                                                                       |           |                             | 3.251                       | V min  |
|                                        | Full Operating Temperature Range                                      | 3.3       |                             | <b>3.366</b>                | V max  |
|                                        |                                                                       |           | <b>3.234</b>                | V min                       |        |
| Output Voltage                         | 100μA ≤ I <sub>L</sub> ≤ 100mA<br>T <sub>J</sub> ≤ T <sub>JMAX</sub>  | 3.3       |                             | <b>3.379</b>                | V max  |
|                                        |                                                                       |           |                             | <b>3.221</b>                | V min  |
| 5.0V Versions                          |                                                                       |           |                             |                             |        |
| Output Voltage                         | T <sub>J</sub> = 25°C                                                 | 5.0       | 5.05                        |                             | V max  |
|                                        |                                                                       |           | 4.95                        |                             | V min  |
|                                        | −25°C ≤ T <sub>J</sub> ≤ 85°C                                         | 5.0       |                             | 5.075                       | V max  |
|                                        |                                                                       |           |                             | 4.925                       | V min  |
|                                        | Full Operating Temperature Range                                      | 5.0       |                             | <b>5.1</b>                  | V max  |
|                                        |                                                                       |           | <b>4.9</b>                  | V min                       |        |
| Output Voltage                         | 100μA ≤ I <sub>L</sub> ≤ 100mA<br>T <sub>J</sub> ≤ T <sub>JMAX</sub>  | 5.0       |                             | <b>5.12</b>                 | V max  |
|                                        |                                                                       |           |                             | <b>4.88</b>                 | V min  |
| All Voltage Options                    |                                                                       |           |                             |                             |        |
| Output Voltage Temperature Coefficient | See <sup>(4)</sup>                                                    | <b>50</b> |                             | <b>150</b>                  | ppm/°C |
| Line Regulation <sup>(5)</sup>         | (V <sub>ONOM</sub> + 1)V ≤ V <sub>in</sub> ≤ 30V <sup>(6)</sup>       | 0.04      | 0.2                         |                             | % max  |
|                                        |                                                                       |           |                             | <b>0.4</b>                  | % max  |
| Load Regulation <sup>(5)</sup>         | 100μA ≤ I <sub>L</sub> ≤ 100mA                                        | 0.1       | 0.2                         |                             | % max  |
|                                        |                                                                       |           |                             | <b>0.3</b>                  | % max  |
| Dropout Voltage <sup>(7)</sup>         | I <sub>L</sub> = 100μA                                                | 50        | 80                          |                             | mV max |
|                                        |                                                                       |           |                             | <b>150</b>                  | mV max |
|                                        | I <sub>L</sub> = 100mA                                                | 380       | 450                         |                             | mV max |
|                                        |                                                                       |           |                             | <b>600</b>                  | mV max |

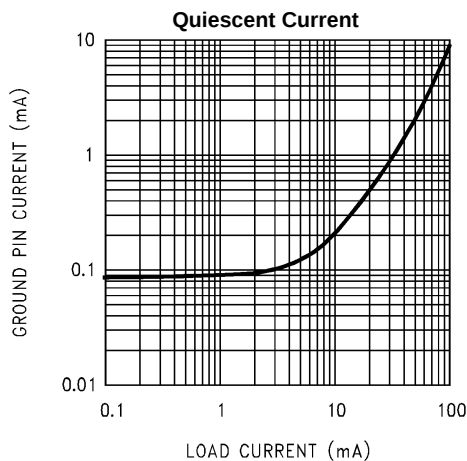
- (1) Unless otherwise specified all limits ensured for  $V_{\text{IN}} = (V_{\text{ONOM}} + 1)\text{V}$ ,  $I_L = 100\mu\text{A}$  and  $C_L = 1\mu\text{F}$ . Limits appearing in **boldface** type apply over the entire junction temperature range for operation. Limits appearing in normal type apply for  $T_A = T_J = 25^\circ\text{C}$ .
- (2) Ensured and 100% production tested.
- (3) Ensured but not 100% production tested. These limits are not used to calculate outgoing AQL levels.
- (4) Output or reference voltage temperature coefficient is defined as the worst case voltage change divided by the total temperature range.
- (5) Regulation is measured at constant junction temperature, using pulse testing with a low duty cycle. Changes in output voltage due to heating effects are covered under the specification for thermal regulation.
- (6) For  $I_L = 100\mu\text{A}$  and  $T_J = 125^\circ\text{C}$ , line regulation is ensured by design to 0.2%. See Typical Performance Characteristics for line regulation versus temperature and load current.
- (7) Dropout Voltage is defined as the input to output differential at which the output voltage drops 100 mV below its nominal value measured at 1V differential. At very low values of programmed output voltage, the minimum input supply voltage of 2V (2.3V over temperature) must be taken into account.

**Electrical Characteristics<sup>(1)</sup> (continued)**

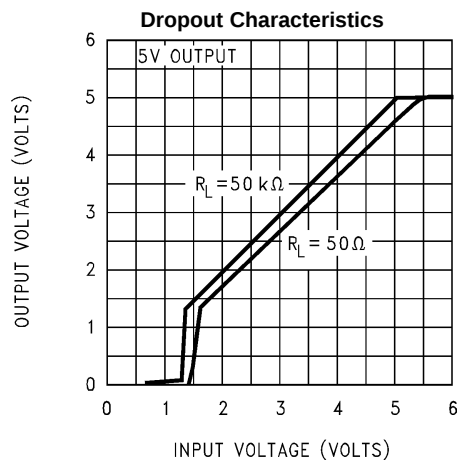
| Parameter                         | Conditions <sup>(1)</sup>                                       | Typ  | Tested Limit <sup>(2)</sup> | Design Limit <sup>(3)</sup> | Units             |
|-----------------------------------|-----------------------------------------------------------------|------|-----------------------------|-----------------------------|-------------------|
| Ground Current                    | $I_L = 100\mu\text{A}$                                          | 75   | 120                         |                             | $\mu\text{A max}$ |
|                                   |                                                                 |      |                             | <b>140</b>                  | $\mu\text{A max}$ |
|                                   | $I_L = 100\text{mA}$                                            | 8    | 12                          |                             | $\text{mA max}$   |
|                                   |                                                                 |      |                             | <b>14</b>                   | $\text{mA max}$   |
| Dropout Ground Current            | $V_{in} = (V_{ONOM} - 0.5)\text{V}$ ,<br>$I_L = 100\mu\text{A}$ | 110  | 170                         |                             | $\mu\text{A max}$ |
|                                   |                                                                 |      |                             | <b>200</b>                  | $\mu\text{A max}$ |
| Current Limit                     | $V_{out} = 0$                                                   | 160  | 200                         |                             | $\text{mA max}$   |
|                                   |                                                                 |      |                             | <b>220</b>                  | $\text{mA max}$   |
| Thermal Regulation                | See <sup>(8)</sup>                                              | 0.05 | 0.2                         |                             | $\%/W$<br>max     |
| Output Noise,<br>10 Hz to 100 kHz | $C_L = 1\mu\text{F}$ (5V Only)                                  | 430  |                             |                             | $\mu\text{V rms}$ |
|                                   | $C_L = 200\mu\text{F}$                                          | 160  |                             |                             | $\mu\text{V rms}$ |
|                                   | $C_L = 3.3\mu\text{F}$<br>(Bypass = $0.01\mu\text{F}$ )         | 100  |                             |                             | $\mu\text{V rms}$ |

(8) Thermal regulation is defined as the change in output voltage at a time T after a change in power dissipation is applied, excluding load or line regulation effects. Specifications are for a 50mA load pulse at  $V_{IN} = 30\text{V}$  (1.25W pulse) for  $T = 10\text{ms}$ .

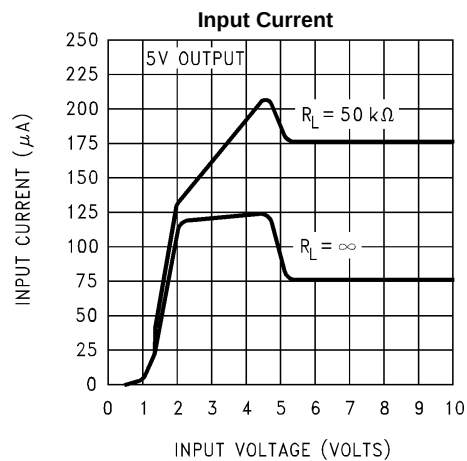
## Typical Performance Characteristics



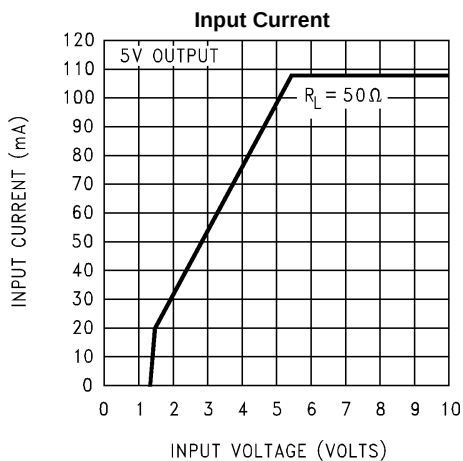
**Figure 3.**



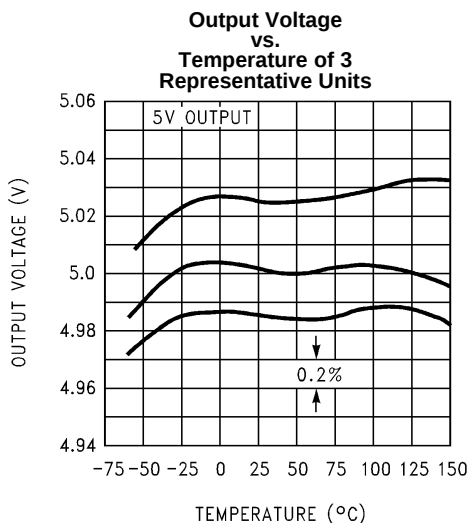
**Figure 4.**



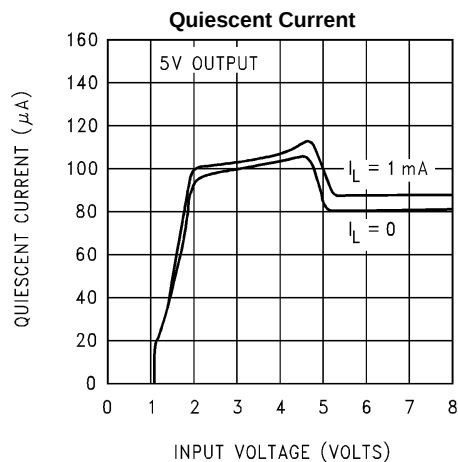
**Figure 5.**



**Figure 6.**



**Figure 7.**



**Figure 8.**

## Typical Performance Characteristics (continued)

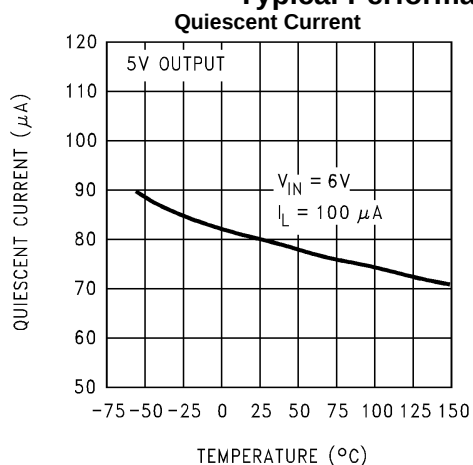


Figure 9.

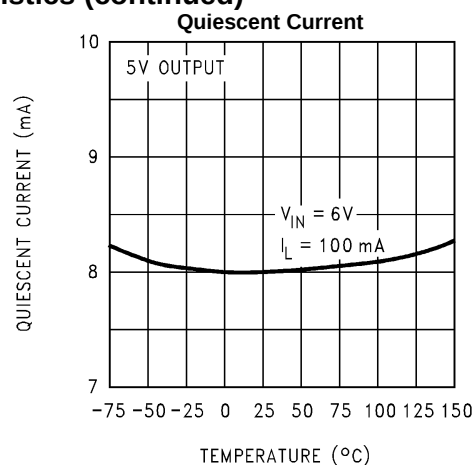


Figure 10.

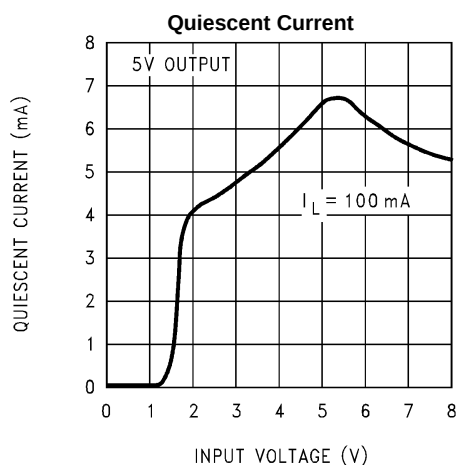


Figure 11.

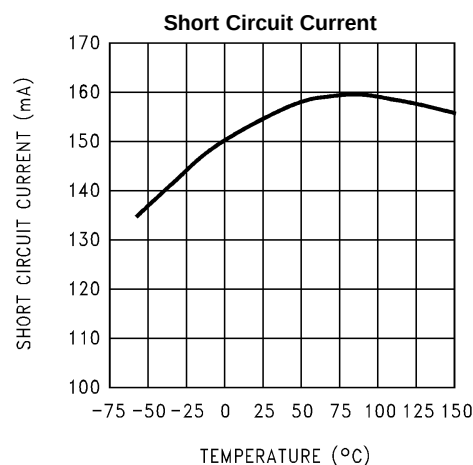


Figure 12.

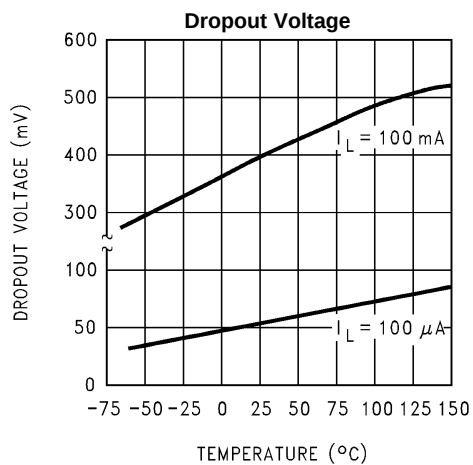


Figure 13.

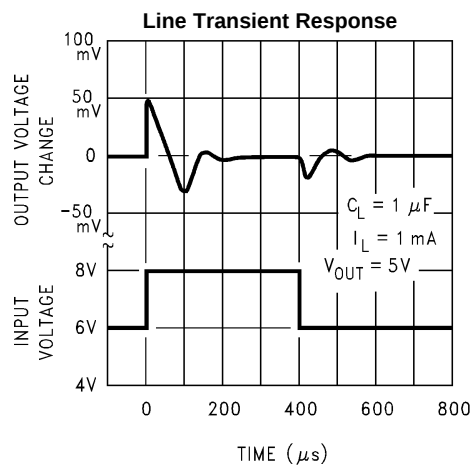
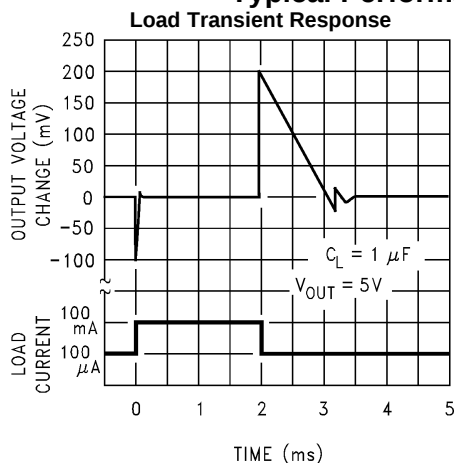
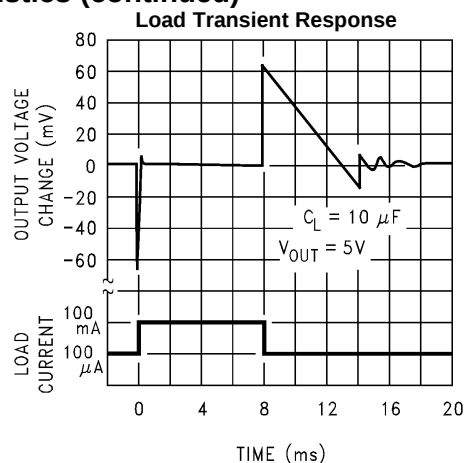


Figure 14.

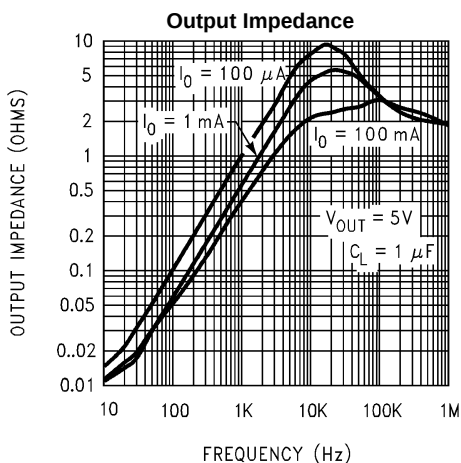
## Typical Performance Characteristics (continued)



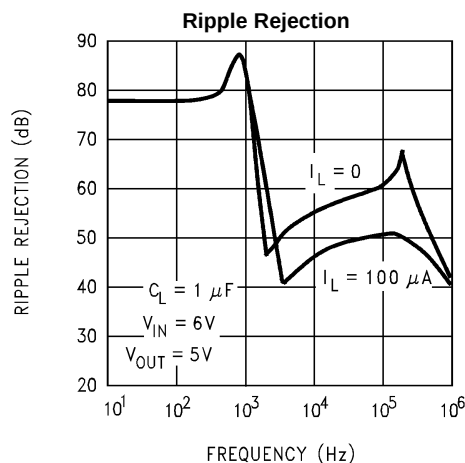
**Figure 15.**



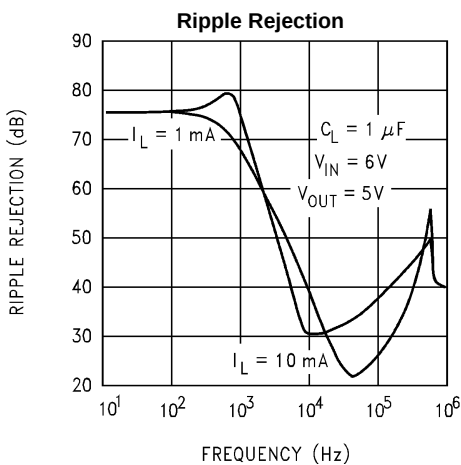
**Figure 16.**



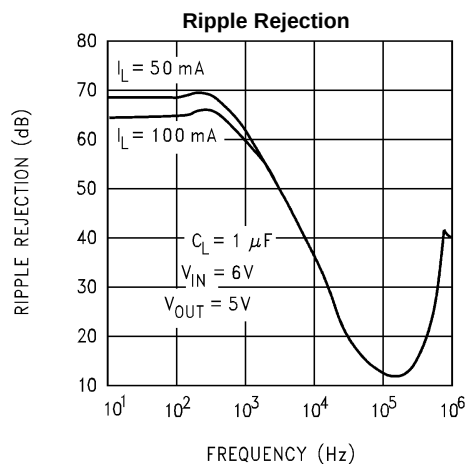
**Figure 17.**



**Figure 18.**



**Figure 19.**



**Figure 20.**

## Typical Performance Characteristics (continued)

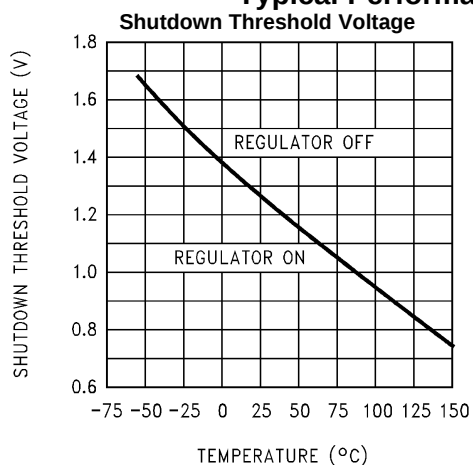


Figure 21.

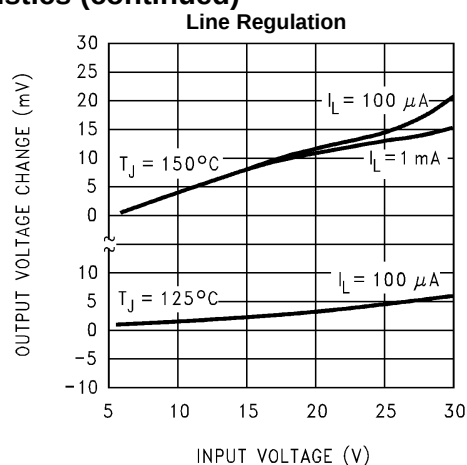


Figure 22.

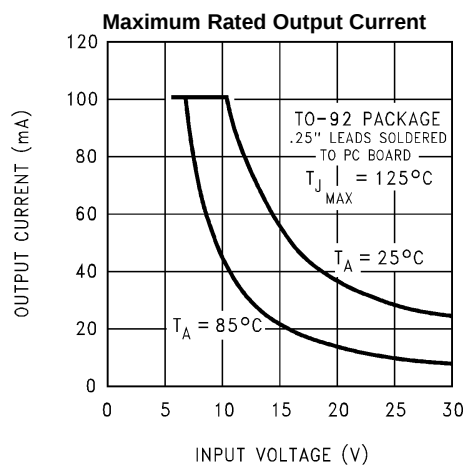


Figure 23.

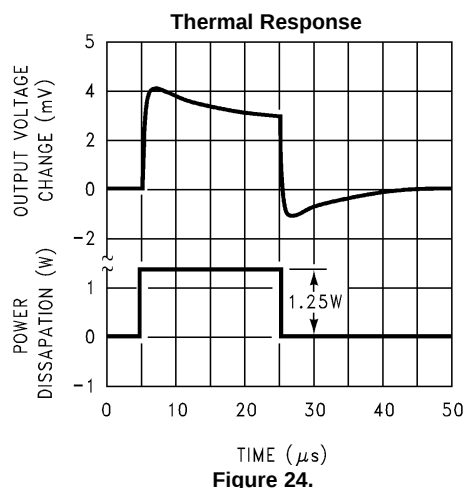


Figure 24.

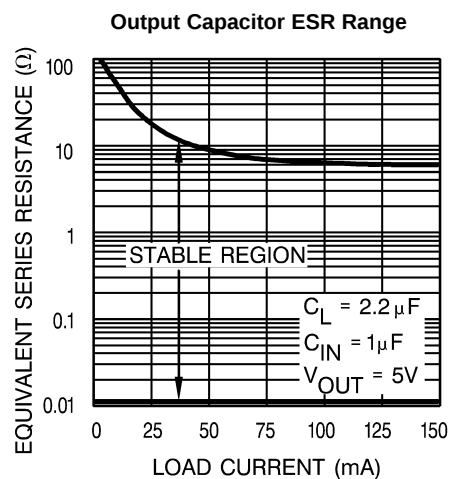


Figure 25.

## APPLICATION HINTS

### EXTERNAL CAPACITORS

A 1.0 $\mu$ F (or greater) capacitor is required between the output and ground for stability. Without this capacitor the part will oscillate. Most types of tantalum or aluminum electrolytics work fine here; even film types work but are not recommended for reasons of cost. Many aluminum electrolytics have electrolytes that freeze at about  $-30^{\circ}\text{C}$ , so solid tantalums are recommended for operation below  $-25^{\circ}\text{C}$ . The important parameters of the capacitor are an ESR of about  $5\Omega$  or less and a resonant frequency above 500kHz. The value of this capacitor may be increased without limit.

Ceramic capacitors whose value is greater than 1000pF should not be connected directly from the SM72238 output to ground. Ceramic capacitors typically have ESR values in the range of 5 to 10m $\Omega$ , a value below the lower limit for stable operation (see Figure 25).

The reason for the lower ESR limit is that the loop compensation of the part relies on the ESR of the output capacitor to provide the zero that gives added phase lead. The ESR of ceramic capacitors is so low that this phase lead does not occur, significantly reducing phase margin. A ceramic output capacitor can be used if a series resistance is added (recommended value of resistance about 0.1 $\Omega$  to 2 $\Omega$ ).

At lower values of output current, less output capacitance is required for stability. The capacitor can be reduced to 0.33 $\mu$ F for currents below 10mA or 0.1 $\mu$ F for currents below 1mA.

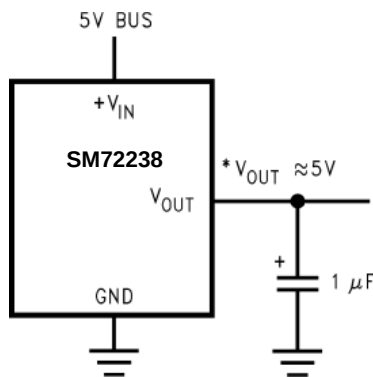
Unlike many other regulators, the SM72238 will remain stable and in regulation with no load in addition to the internal voltage divider. This is especially important in CMOS RAM keep-alive applications.

A 1 $\mu$ F tantalum, ceramic or aluminum electrolytic capacitor should be placed from the SM72238 input to ground if there is more than 10 inches of wire between the input and the AC filter capacitor or if a battery is used as the input.

### REDUCING OUTPUT NOISE

In reference applications it may be advantageous to reduce the AC noise present at the output. One method is to reduce the regulator bandwidth by increasing the size of the output capacitor. This is the only way noise can be reduced but is relatively inefficient, as increasing the capacitor from 1 $\mu$ F to 220 $\mu$ F only decreases the noise from 430 $\mu$ V to 160 $\mu$ V rms for a 100kHz bandwidth at 5V output.

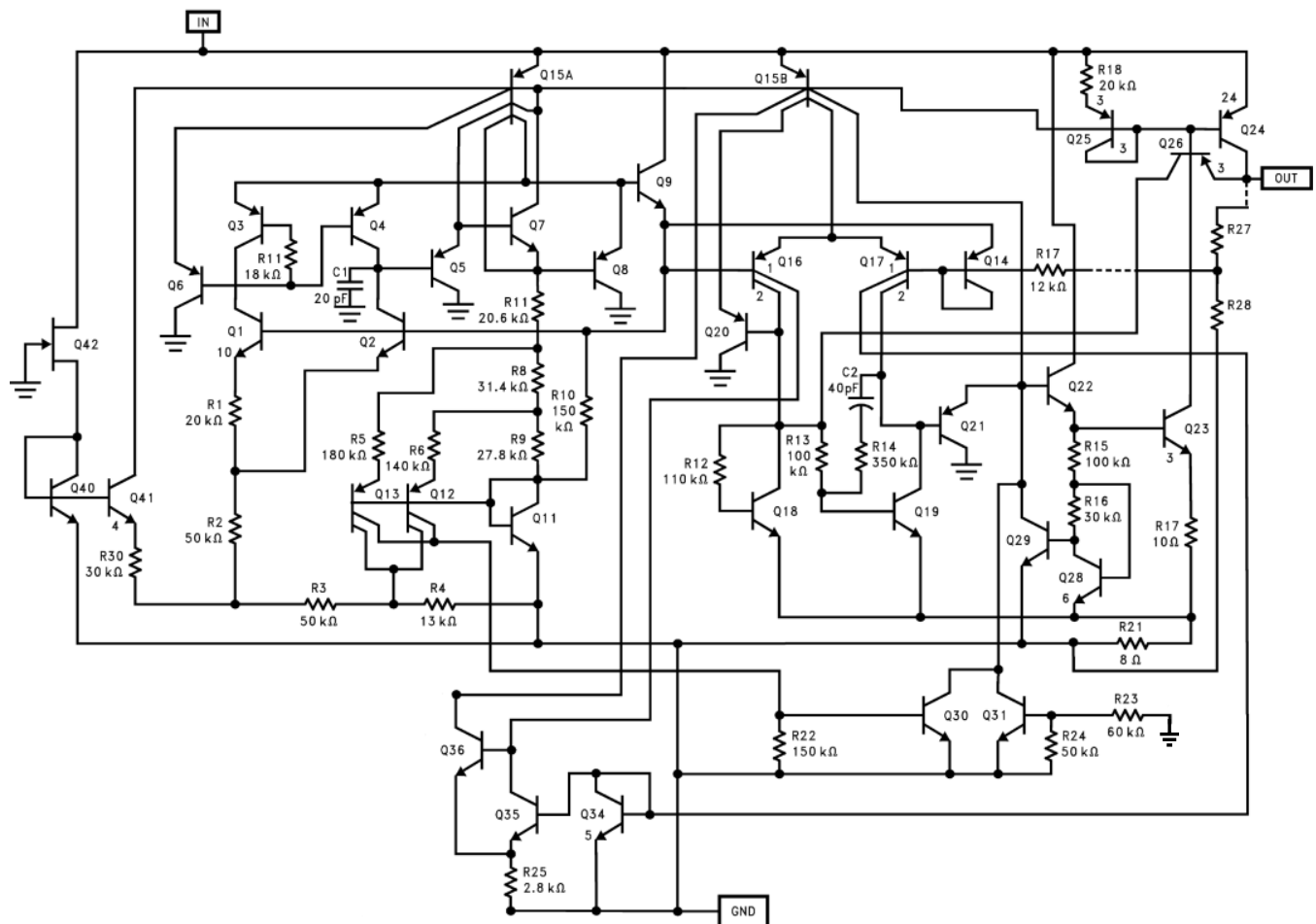
### Typical Applications



\*Minimum input-output voltage ranges from 40mV to 400mV, depending on load current. Current limit is typically 160mA.

Figure 26. 5 Volt Current Limiter

## Schematic Diagram



## REVISION HISTORY

| Changes from Revision B (April 2013) to Revision C         | Page               |
|------------------------------------------------------------|--------------------|
| • Changed layout of National Data Sheet to TI format ..... | <a href="#">10</a> |

## PACKAGING INFORMATION

| Orderable Device    | Status<br>(1) | Package Type | Package<br>Drawing | Pins | Package<br>Qty | Eco Plan<br>(2)            | Lead/Ball Finish | MSL Peak Temp<br>(3) | Op Temp (°C) | Device Marking<br>(4/5) | Samples                 |
|---------------------|---------------|--------------|--------------------|------|----------------|----------------------------|------------------|----------------------|--------------|-------------------------|-------------------------|
| SM72238TD-3.0/NOPB  | ACTIVE        | TO-252       | NDP                | 3    | 75             | Green (RoHS<br>& no Sb/Br) | CU SN            | Level-2-260C-1 YEAR  | -40 to 125   | S72238<br>-3.0          | <a href="#">Samples</a> |
| SM72238TD-3.3/NOPB  | ACTIVE        | TO-252       | NDP                | 3    | 75             | Green (RoHS<br>& no Sb/Br) | CU SN            | Level-2-260C-1 YEAR  | -40 to 125   | S72238<br>-3.3          | <a href="#">Samples</a> |
| SM72238TD-5.0/NOPB  | ACTIVE        | TO-252       | NDP                | 3    | 75             | Green (RoHS<br>& no Sb/Br) | CU SN            | Level-2-260C-1 YEAR  | -40 to 125   | S72238                  | <a href="#">Samples</a> |
| SM72238TDE-3.0/NOPB | ACTIVE        | TO-252       | NDP                | 3    | 250            | Green (RoHS<br>& no Sb/Br) | CU SN            | Level-2-260C-1 YEAR  | -40 to 125   | S72238<br>-3.0          | <a href="#">Samples</a> |
| SM72238TDE-3.3/NOPB | ACTIVE        | TO-252       | NDP                | 3    | 250            | Green (RoHS<br>& no Sb/Br) | CU SN            | Level-2-260C-1 YEAR  | -40 to 125   | S72238<br>-3.3          | <a href="#">Samples</a> |
| SM72238TDE-5.0/NOPB | ACTIVE        | TO-252       | NDP                | 3    | 250            | Green (RoHS<br>& no Sb/Br) | CU SN            | Level-2-260C-1 YEAR  | -40 to 125   | S72238                  | <a href="#">Samples</a> |
| SM72238TDX-3.0/NOPB | ACTIVE        | TO-252       | NDP                | 3    | 2500           | Green (RoHS<br>& no Sb/Br) | CU SN            | Level-2-260C-1 YEAR  | -40 to 125   | S72238<br>-3.0          | <a href="#">Samples</a> |
| SM72238TDX-3.3/NOPB | ACTIVE        | TO-252       | NDP                | 3    | 2500           | Green (RoHS<br>& no Sb/Br) | CU SN            | Level-2-260C-1 YEAR  | -40 to 125   | S72238<br>-3.3          | <a href="#">Samples</a> |
| SM72238TDX-5.0/NOPB | ACTIVE        | TO-252       | NDP                | 3    | 2500           | Green (RoHS<br>& no Sb/Br) | CU SN            | Level-2-260C-1 YEAR  | -40 to 125   | S72238                  | <a href="#">Samples</a> |

(1) The marketing status values are defined as follows:

**ACTIVE:** Product device recommended for new designs.

**LIFEBUY:** TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.

**NRND:** Not recommended for new designs. Device is in production to support existing customers, but TI does not recommend using this part in a new design.

**PREVIEW:** Device has been announced but is not in production. Samples may or may not be available.

**OBsolete:** TI has discontinued the production of the device.

(2) Eco Plan - The planned eco-friendly classification: Pb-Free (RoHS), Pb-Free (RoHS Exempt), or Green (RoHS & no Sb/Br) - please check <http://www.ti.com/productcontent> for the latest availability information and additional product content details.

**TBD:** The Pb-Free/Green conversion plan has not been defined.

**Pb-Free (RoHS):** TI's terms "Lead-Free" or "Pb-Free" mean semiconductor products that are compatible with the current RoHS requirements for all 6 substances, including the requirement that lead not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, TI Pb-Free products are suitable for use in specified lead-free processes.

**Pb-Free (RoHS Exempt):** This component has a RoHS exemption for either 1) lead-based flip-chip solder bumps used between the die and package, or 2) lead-based die adhesive used between the die and leadframe. The component is otherwise considered Pb-Free (RoHS compatible) as defined above.

**Green (RoHS & no Sb/Br):** TI defines "Green" to mean Pb-Free (RoHS compatible), and free of Bromine (Br) and Antimony (Sb) based flame retardants (Br or Sb do not exceed 0.1% by weight in homogeneous material)

<sup>(3)</sup> MSL, Peak Temp. -- The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications, and peak solder temperature.

<sup>(4)</sup> There may be additional marking, which relates to the logo, the lot trace code information, or the environmental category on the device.

<sup>(5)</sup> Multiple Device Markings will be inside parentheses. Only one Device Marking contained in parentheses and separated by a "--" will appear on a device. If a line is indented then it is a continuation of the previous line and the two combined represent the entire Device Marking for that device.

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**TAPE AND REEL INFORMATION**


\*All dimensions are nominal

| Device              | Package Type | Package Drawing | Pins | SPQ  | Reel Diameter (mm) | Reel Width W1 (mm) | A0 (mm) | B0 (mm) | K0 (mm) | P1 (mm) | W (mm) | Pin1 Quadrant |
|---------------------|--------------|-----------------|------|------|--------------------|--------------------|---------|---------|---------|---------|--------|---------------|
| SM72238TDE-3.0/NOPB | TO-252       | NDP             | 3    | 250  | 178.0              | 16.4               | 6.9     | 10.5    | 2.7     | 8.0     | 16.0   | Q2            |
| SM72238TDE-3.3/NOPB | TO-252       | NDP             | 3    | 250  | 178.0              | 16.4               | 6.9     | 10.5    | 2.7     | 8.0     | 16.0   | Q2            |
| SM72238TDE-5.0/NOPB | TO-252       | NDP             | 3    | 250  | 178.0              | 16.4               | 6.9     | 10.5    | 2.7     | 8.0     | 16.0   | Q2            |
| SM72238TDX-3.0/NOPB | TO-252       | NDP             | 3    | 2500 | 330.0              | 16.4               | 6.9     | 10.5    | 2.7     | 8.0     | 16.0   | Q2            |
| SM72238TDX-3.3/NOPB | TO-252       | NDP             | 3    | 2500 | 330.0              | 16.4               | 6.9     | 10.5    | 2.7     | 8.0     | 16.0   | Q2            |
| SM72238TDX-5.0/NOPB | TO-252       | NDP             | 3    | 2500 | 330.0              | 16.4               | 6.9     | 10.5    | 2.7     | 8.0     | 16.0   | Q2            |

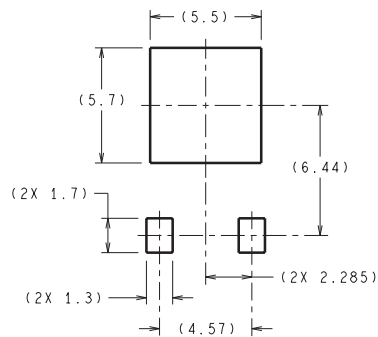
## TAPE AND REEL BOX DIMENSIONS



\*All dimensions are nominal

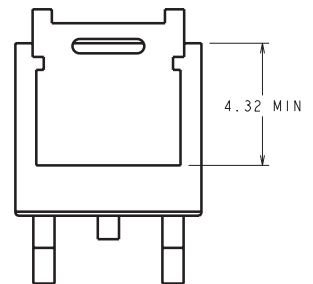
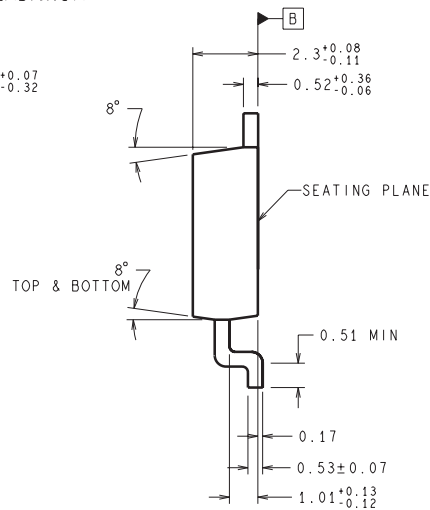
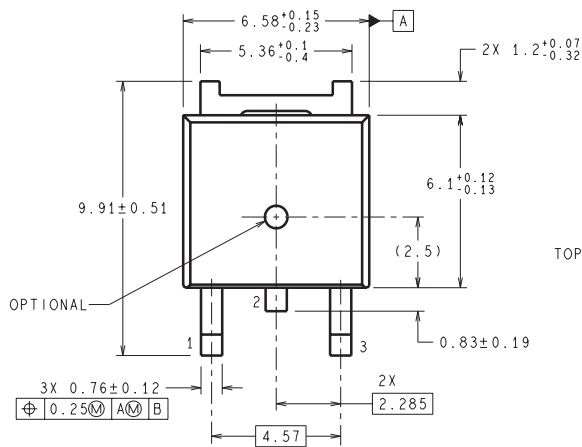
| Device              | Package Type | Package Drawing | Pins | SPQ  | Length (mm) | Width (mm) | Height (mm) |
|---------------------|--------------|-----------------|------|------|-------------|------------|-------------|
| SM72238TDE-3.0/NOPB | TO-252       | NDP             | 3    | 250  | 213.0       | 191.0      | 55.0        |
| SM72238TDE-3.3/NOPB | TO-252       | NDP             | 3    | 250  | 213.0       | 191.0      | 55.0        |
| SM72238TDE-5.0/NOPB | TO-252       | NDP             | 3    | 250  | 213.0       | 191.0      | 55.0        |
| SM72238TDX-3.0/NOPB | TO-252       | NDP             | 3    | 2500 | 367.0       | 367.0      | 38.0        |
| SM72238TDX-3.3/NOPB | TO-252       | NDP             | 3    | 2500 | 367.0       | 367.0      | 38.0        |
| SM72238TDX-5.0/NOPB | TO-252       | NDP             | 3    | 2500 | 367.0       | 367.0      | 38.0        |

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