LM723/LM723C Voltage Regulator

Check for Samples: LM723, LM723C

FEATURES

• 150 mA Output Current Without External Pass Transistor
• Output Currents in Excess of 10A Possible by Adding External Transistors
• Input Voltage 40V Max
• Output Voltage Adjustable from 2V to 37V
• Can be Used as Either a Linear or a Switching Regulator

DESCRIPTION

The LM723/LM723C is a voltage regulator designed primarily for series regulator applications. By itself, it will supply output currents up to 150 mA; but external transistors can be added to provide any desired load current. The circuit features extremely low standby current drain, and provision is made for either linear or foldback current limiting.

The LM723/LM723C is also useful in a wide range of other applications such as a shunt regulator, a current regulator or a temperature controller.

The LM723C is identical to the LM723 except that the LM723C has its performance ensured over a 0 °C to +70 °C temperature range, instead of −55 °C to +125 °C.

Connection Diagram

Note: Pin 5 connected to case.
Equivalent Circuit*

*Pin numbers refer to metal can package.

Typical Application

Typical Performance

Regulated Output Voltage 5V
Line Regulation ($\Delta V_{IN} = 3V$) 0.5mV
Load Regulation ($\Delta I_L = 50 \text{ mA}$) 1.5mV

Figure 4. Basic Low Voltage Regulator ($V_{OUT} = 2$ to $7 \text{ Volts}$)
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**

1. Pulse Voltage from V+ to V− (50 ms) 50V
2. Continuous Voltage from V+ to V− 40V
3. Input-Output Voltage Differential 40V
4. Maximum Amplifier Input Voltage (Either Input) 8.5V
5. Maximum Amplifier Input Voltage (Differential) 5V
6. Current from VZ 25 mA
7. Current from VREF 15 mA
8. Internal Power Dissipation
   - Metal Can (3) 800 mW
   - CDIP (3) 900 mW
   - PDIP (3) 660 mW
9. Operating Temperature Range
   - LM723 −55°C to +150°C
   - LM723C 0°C to +70°C
10. Storage Temperature Range
    - Metal Can −65°C to +150°C
    - PDIP −55°C to +150°C
11. Lead Temperature (Soldering, 4 sec. max.)
    - Hermetic Package 300°C
    - Plastic Package 260°C
12. ESD Tolerance 1200V (Human body model, 1.5 kΩ in series with 100 pF)

(1) “Absolute Maximum Ratings” indicate limits beyond which damage to the device may occur. Operating Ratings indicate conditions for which the device is functional, but do not ensure specific performance limits.

(2) A military RETS specification is available on request. At the time of printing, the LM723 RETS specification complied with the Min and Max limits in this table. The LM723E, H, and J may also be procured as a Standard Military Drawing.

(3) See derating curves for maximum power rating above 25°C.

**ELECTRICAL CHARACTERISTICS**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Conditions</th>
<th>LM723 Min</th>
<th>LM723 Typ</th>
<th>LM723 Max</th>
<th>LM723C Min</th>
<th>LM723C Typ</th>
<th>LM723C Max</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Line Regulation</td>
<td>VIN = 12V to VIN = 15V</td>
<td>0.01</td>
<td>0.1</td>
<td>0.01</td>
<td>0.1</td>
<td></td>
<td></td>
<td>% VOUT</td>
</tr>
<tr>
<td></td>
<td>−55°C ≤ TA ≤ +125°C</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>0°C ≤ TA ≤ +70°C</td>
<td>0.02</td>
<td>0.2</td>
<td>0.02</td>
<td>0.1</td>
<td>0.1</td>
<td>0.5</td>
<td>% VOUT</td>
</tr>
<tr>
<td></td>
<td>VIN = 12V to VIN = 40V</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Load Regulation</td>
<td>IL = 1 mA to IL = 50 mA</td>
<td>0.03</td>
<td>0.15</td>
<td>0.03</td>
<td>0.2</td>
<td></td>
<td></td>
<td>% VOUT</td>
</tr>
<tr>
<td></td>
<td>−55°C ≤ TA ≤ +125°C</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>0°C ≤ TA ≤ +70°C</td>
<td>0.06</td>
<td>0.6</td>
<td>0.06</td>
<td>0.6</td>
<td></td>
<td></td>
<td>% VOUT</td>
</tr>
<tr>
<td>Ripple Rejection</td>
<td>f = 50 Hz to 10 kHz, CREF = 0</td>
<td>74</td>
<td></td>
<td>74</td>
<td></td>
<td></td>
<td></td>
<td>dB</td>
</tr>
<tr>
<td></td>
<td>f = 50 Hz to 10 kHz, CREF = 5 μF</td>
<td>86</td>
<td>86</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(1) Unless otherwise specified, TA = 25°C, VIN = V+ = VIN = 12V, V− = 0, VOUT = 5V, IL = 1 mA, RSC = 100 pF, CREF = 0 and divider impedance as seen by error amplifier ≤ 10 kΩ connected as shown in Figure 4. Line and load regulation specifications are given for the condition of constant chip temperature. Temperature drifts must be taken into account separately for high dissipation conditions.

(2) A military RETS specification is available on request. At the time of printing, the LM723 RETS specification complied with the Min and Max limits in this table. The LM723E, H, and J may also be procured as a Standard Military Drawing.

(3) Specified by correlation to other tests.

(4) Ll is 40 turns of No. 20 enameled copper wire wound on Ferroxcube P36/22-3B7 pot core or equivalent with 0.009 in. air gap.
## ELECTRICAL CHARACTERISTICS (continued)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Conditions</th>
<th>Parameter</th>
<th>Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Temperature Coefficient of Output Voltage (°C)</td>
<td>Min 0.002 Typ 0.015 Max</td>
<td>Reference Voltage</td>
<td>Min 6.95 Typ 7.15 Max 7.35</td>
</tr>
<tr>
<td></td>
<td>0°C ≤ T_A ≤ +70°C Typ 0.003 Max 0.015</td>
<td>Output Noise Voltage</td>
<td>86 μVrms</td>
</tr>
<tr>
<td></td>
<td>-55°C ≤ T_A ≤ +125°C</td>
<td></td>
<td>BW = 100 Hz to 10 kHz, C_REF = 0</td>
</tr>
<tr>
<td></td>
<td>0°C ≤ T_A ≤ +70°C</td>
<td></td>
<td>BW = 100 Hz to 10 kHz, C_REF = 5 μF</td>
</tr>
<tr>
<td>Short Circuit Current Limit</td>
<td>R_SC = 100Ω, V_OUT = 0</td>
<td>Output Noise Voltage</td>
<td>65 mA</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Long Term Stability</td>
<td>0.05 %/1000 hrs</td>
</tr>
<tr>
<td>Reference Voltage</td>
<td>65 mA</td>
<td>Input Voltage Range</td>
<td>1.7 mAh</td>
</tr>
<tr>
<td>Short Circuit Current Limit</td>
<td></td>
<td>Footprint</td>
<td>9.5 1.7</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Standby Current Drain</td>
<td>40 4.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
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<td></td>
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<td></td>
<td></td>
</tr>
</tbody>
</table>

(5) For metal can applications where V_Z is required, an external 6.2V zener diode should be connected in series with V_OUT.
TYPICAL PERFORMANCE CHARACTERISTICS

Load Regulation Characteristics with Current Limiting

![Load Regulation Characteristics](image1)

Figure 5.

Load & Line Regulation vs Input-Output Voltage Differential

![Load & Line Regulation](image2)

Figure 7.

Current Limiting Characteristics vs Junction Temperature

![Current Limiting Characteristics](image3)

Figure 9.

Standby Current Drain vs Input Voltage

![Standby Current Drain](image4)

Figure 10.
TYPICAL PERFORMANCE CHARACTERISTICS (continued)

Line Transient Response

![Line Transient Response Diagram](image1)

**Figure 11.**

Load Transient Response

![Load Transient Response Diagram](image2)

**Figure 12.**

Output Impedence vs Frequency

![Output Impedence vs Frequency Diagram](image3)

**Figure 13.**
MAXIMUM POWER RATINGS

Noise vs Filter Capacitor
(CREF in Circuit of Figure 4)
(Bandwidth 100 Hz to 10 kHz)

Figure 14.

Power Dissipation vs Ambient Temperature

Figure 15.

Power Dissipation vs Ambient Temperature

Figure 16.
### Table 1. Resistor Values (kΩ) for Standard Output Voltage

<table>
<thead>
<tr>
<th>Positive Output Voltage</th>
<th>Applicable Figures</th>
<th>Fixed Output ±5%</th>
<th>Output Adjustable ±10%</th>
<th>Negative Output Voltage</th>
<th>Applicable Figures</th>
<th>Fixed Output ±5%</th>
<th>5% Output Adjustable ±10%</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>R1</td>
<td>R2</td>
<td>R1</td>
<td>P1</td>
<td>R2</td>
<td>R1</td>
</tr>
<tr>
<td>+3.0</td>
<td>Figure 4, Figure 19, Figure 24, Figure 27 (Figure 19)</td>
<td>4.12</td>
<td>3.01</td>
<td>1.8</td>
<td>0.5</td>
<td>1.2</td>
<td>+100</td>
</tr>
<tr>
<td>+3.6</td>
<td>Figure 4, Figure 19, Figure 24, Figure 27 (Figure 19)</td>
<td>3.57</td>
<td>3.65</td>
<td>1.5</td>
<td>0.5</td>
<td>1.5</td>
<td>+250</td>
</tr>
<tr>
<td>+5.0</td>
<td>Figure 4, Figure 19, Figure 24, Figure 27 (Figure 19)</td>
<td>2.15</td>
<td>4.99</td>
<td>0.75</td>
<td>0.5</td>
<td>2.2</td>
<td>−6(3)</td>
</tr>
<tr>
<td>+6.0</td>
<td>Figure 4, Figure 19, Figure 24, Figure 27 (Figure 19)</td>
<td>1.15</td>
<td>6.04</td>
<td>0.5</td>
<td>0.5</td>
<td>2.7</td>
<td>−9</td>
</tr>
<tr>
<td>+9.0</td>
<td>Figure 17, Figure 19, Figure 24, Figure 27 (Figure 19)</td>
<td>1.87</td>
<td>7.15</td>
<td>0.75</td>
<td>1.0</td>
<td>2.7</td>
<td>−12</td>
</tr>
<tr>
<td>+12</td>
<td>Figure 17, Figure 19, Figure 24, Figure 27 (Figure 19)</td>
<td>4.87</td>
<td>7.15</td>
<td>2.0</td>
<td>1.0</td>
<td>3.0</td>
<td>−15</td>
</tr>
<tr>
<td>+15</td>
<td>Figure 17, Figure 19, Figure 24, Figure 27 (Figure 19)</td>
<td>7.87</td>
<td>7.15</td>
<td>3.3</td>
<td>1.0</td>
<td>3.0</td>
<td>−28</td>
</tr>
<tr>
<td>+28</td>
<td>Figure 17, Figure 19, Figure 24, Figure 27 (Figure 19)</td>
<td>21.0</td>
<td>7.15</td>
<td>5.6</td>
<td>1.0</td>
<td>2.0</td>
<td>−45</td>
</tr>
<tr>
<td>+45</td>
<td>Figure 22</td>
<td>3.57</td>
<td>48.7</td>
<td>2.2</td>
<td>10</td>
<td>39</td>
<td>−100</td>
</tr>
<tr>
<td>+75</td>
<td>Figure 22</td>
<td>3.57</td>
<td>78.7</td>
<td>2.2</td>
<td>10</td>
<td>68</td>
<td>−250</td>
</tr>
</tbody>
</table>

(1) Replace R1/R2 in figures with divider shown in Figure 28.
(2) Figures in parentheses may be used if R1/R2 divider is placed on opposite input of error amp.
(3) V+ and VCC must be connected to a +3V or greater supply.

### Table 2. Formulae for Intermediate Output Voltages

<table>
<thead>
<tr>
<th>Outputs from +2 to +7 volts</th>
<th>Outputs from +4 to +250 volts</th>
<th>Current Limiting</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Figure 4 Figure 19 Figure 20 Figure 21 Figure 24 Figure 27)</td>
<td>(Figure 22)</td>
<td>I_{LIMIT} = V_{SENSE} R_{SC}</td>
</tr>
<tr>
<td>V_{OUT} = \left( V_{REF} \times \frac{R_2}{R_1 + R_2} \right)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Outputs from +7 to +37 volts</th>
<th>Outputs from –6 to –250 volts</th>
<th>Foldback Current Limiting</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Figure 17 Figure 19 Figure 20 Figure 21 Figure 24 Figure 27)</td>
<td>(Figure 18 Figure 23 Figure 25)</td>
<td>I_{SHORT, CKT} = \left( V_{SENSE} \times \frac{R_3 + R_4}{R_{SC}} \right)</td>
</tr>
<tr>
<td>V_{OUT} = \left( V_{REF} \times \frac{R_1 + R_2}{R_2} \right)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| V_{OUT} = \left( \frac{V_{REF}}{2} \times \frac{R_2 - R_1}{R_1} \right) | | I_{KNEE} = \left( \frac{V_{OUT} R_3}{R_{SC} R_4} + \frac{V_{SENSE} (R_3 + R_4)}{R_{SC} R_4} \right) |

| V_{OUT} = \left( \frac{V_{REF}}{2} \times \frac{R_1 + R_2}{R_1} \right) | | I_{SHORT, CKT} = \left( V_{SENSE} \times \frac{R_3 + R_4}{R_{SC}} \right) |
TYPICAL APPLICATIONS

![Typical Applications Diagram](image)

Note: $R_3 = \frac{R_1 \cdot R_2}{R_1 + R_2}$
for minimum temperature drift.
$R_3$ may be eliminated for minimum component count.

**Typical Performance**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regulated Output Voltage</td>
<td>15V</td>
</tr>
<tr>
<td>Line Regulation ($\Delta V_{IN} = 3V$)</td>
<td>1.5 mV</td>
</tr>
<tr>
<td>Load Regulation ($\Delta I_L = 50 mA$)</td>
<td>4.5 mV</td>
</tr>
</tbody>
</table>

**Figure 17. Basic High Voltage Regulator ($V_{OUT} = 7$ to 37 Volts)**

![Negative Voltage Regulator Diagram](image)

**Typical Performance**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regulated Output Voltage</td>
<td>−15V</td>
</tr>
<tr>
<td>Line Regulation ($\Delta V_{IN} = 3V$)</td>
<td>1 mV</td>
</tr>
<tr>
<td>Load Regulation ($\Delta I_L = 100 mA$)</td>
<td>2 mV</td>
</tr>
</tbody>
</table>

**Figure 18. Negative Voltage Regulator**
Typical Performance

Regulated Output Voltage  
+15V

Line Regulation ($\Delta V_{IN} = 3V$)  
1.5 mV

Load Regulation ($\Delta I_L = 1A$)  
15 mV

**Figure 19. Positive Voltage Regulator (External NPN Pass Transistor)**

Typical Performance

Regulated Output Voltage  
+5V

Line Regulation ($\Delta V_{IN} = 3V$)  
0.5 mV

Load Regulation ($\Delta I_L = 1A$)  
5 mV

**Figure 20. Positive Voltage Regulator (External PNP Pass Transistor)**
**Typical Performance**

**Regulated Output Voltage**

+5V

Line Regulation ($\Delta V_{IN} = 3V$) 0.5 mV

Load Regulation ($\Delta I_L = 10 \text{ mA}$) 1 mV

Short Circuit Current 20 mA

**Figure 21. Foldback Current Limiting**

**Regulated Output Voltage**

+50V

Line Regulation ($\Delta V_{IN} = 20V$) 15 mV

Load Regulation ($\Delta I_L = 50 \text{ mA}$) 20 mV

**Figure 22. Positive Floating Regulator**
Typical Performance

Regulated Output Voltage
-100V
Line Regulation ($\Delta V_{IN} = 20V$) 30 mV
Load Regulation ($\Delta I_L = 100 mA$) 20 mV

Figure 23. Negative Floating Regulator

Regulated Output Voltage +5V
Line Regulation ($\Delta V_{IN} = 30V$) 10 mV
Load Regulation ($\Delta I_L = 2A$) 80 mV

Figure 24. Positive Switching Regulator
Typical Performance

Regulated Output Voltage  
-15V

Line Regulation ($\Delta V_{IN} = 20V$)  
8 mV

Load Regulation ($\Delta I_L = 2A$)  
6 mV

Figure 25. Negative Switching Regulator

Note: Current limit transistor may be used for shutdown if current limiting is not required.

Typical Performance

Regulated Output Voltage  
+5V

Line Regulation ($\Delta V_{IN} = 3V$)  
0.5 mV

Load Regulation ($\Delta I_L = 50 mA$)  
1.5 mV

Figure 26. Remote Shutdown Regulator with Current Limiting
Regulated Output Voltage

+5V

Line Regulation ($\Delta V_{IN} = 10V$)

0.5 mV

Load Regulation ($\Delta I_L = 100 mA$)

1.5 mV

Figure 27. Shunt Regulator

Figure 28. Output Voltage Adjust (1)

(1) Replace $R1/R2$ in figures with divider shown in Figure 28.
## REVISION HISTORY

### Changes from Revision B (April 2013) to Revision C

<table>
<thead>
<tr>
<th>Change Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Changed layout of National Data Sheet to TI format</td>
<td>15</td>
</tr>
</tbody>
</table>

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## PACKAGING INFORMATION

<table>
<thead>
<tr>
<th>Orderable Device</th>
<th>Status (1)</th>
<th>Package Type</th>
<th>Package Drawing</th>
<th>Pins</th>
<th>Package Qty</th>
<th>Eco Plan (2)</th>
<th>Lead finish/Ball material (6)</th>
<th>MSL Peak Temp (3)</th>
<th>Op Temp (°C)</th>
<th>Device Marking (4/5)</th>
<th>Samples</th>
</tr>
</thead>
<tbody>
<tr>
<td>LM723CH</td>
<td>ACTIVE</td>
<td>TO-100</td>
<td>LME</td>
<td>10</td>
<td>500</td>
<td>Non-RoHS &amp; Green</td>
<td>Call TI</td>
<td>Level-1-NA-UNLIM</td>
<td>0 to 70</td>
<td>(LM723CH, LM723CH)</td>
<td>Samples</td>
</tr>
<tr>
<td>LM723CH/NOPB</td>
<td>ACTIVE</td>
<td>TO-100</td>
<td>LME</td>
<td>10</td>
<td>500</td>
<td>RoHS &amp; Green</td>
<td>Call TI</td>
<td>Level-1-NA-UNLIM</td>
<td>0 to 70</td>
<td>(LM723CH, LM723CH)</td>
<td>Samples</td>
</tr>
<tr>
<td>LM723H</td>
<td>ACTIVE</td>
<td>TO-100</td>
<td>LME</td>
<td>10</td>
<td>500</td>
<td>Non-RoHS &amp; Green</td>
<td>Call TI</td>
<td>Level-1-NA-UNLIM</td>
<td>-55 to 150</td>
<td>(LM723H, LM723H)</td>
<td>Samples</td>
</tr>
<tr>
<td>LM723H/NOPB</td>
<td>ACTIVE</td>
<td>TO-100</td>
<td>LME</td>
<td>10</td>
<td>500</td>
<td>RoHS &amp; Green</td>
<td>Call TI</td>
<td>Level-1-NA-UNLIM</td>
<td>-55 to 150</td>
<td>(LM723H, LM723H)</td>
<td>Samples</td>
</tr>
</tbody>
</table>

(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) **RoHS**: TI defines "RoHS" to mean semiconductor products that are compliant with the current EU RoHS requirements for all 10 RoHS substances, including the requirement that RoHS substance do not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, "RoHS" products are suitable for use in specified lead-free processes. TI may reference these types of products as "Pb-Free".

**RoHS Exempt**: TI defines "RoHS Exempt" to mean products that contain lead but are compliant with EU RoHS pursuant to a specific EU RoHS exemption.

**Green**: TI defines "Green" to mean the content of Chlorine (Cl) and Bromine (Br) based flame retardants meet JS709B low halogen requirements of <=1000ppm threshold. Antimony trioxide based flame retardants must also meet the <=1000ppm threshold requirement.

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

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

(5) 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.

(6) Lead finish/Ball material - Orderable Devices 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.

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NOTES:

1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. Reference JEDEC registration MO-006/TO-100.
EXAMPLE BOARD LAYOUT
TO-CAN - 5.72 mm max height
METAL CYLINDRICAL PACKAGE

LAND PATTERN EXAMPLE
NON-SOLDER MASK DEFINED
SCALE: 12X
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