**LM723/LM723C Voltage Regulator**

**General 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 guaranteed over a 0°C to +70°C temperature range, instead of −55°C to +125°C.

**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

**Connection Diagrams**

Dual-in-Line Package

![Dual-in-Line Package Diagram]

- Order Number LM723J/883 or LM723CN
- See NS Package J14A or N14A

Metal Can Package

![Metal Can Package Diagram]

- Order Number LM723H, LM723H/883 or LM723CH
- See NS Package H10C

Note: Pin 5 connected to case.

© 1999 National Semiconductor Corporation  DS008563 www.national.com
**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** ($\Delta I_L = 50 mA$): 1.5mV

**FIGURE 1. Basic Low Voltage Regulator**

(V$_{OUT} = 2$ to 7 Volts)
**Absolute Maximum Ratings** (Note 1)

*If Military/Aerospace specified devices are required, please contact the National Semiconductor Sales Office/Distributors for availability and specifications. (Note 10)*

- **Pulse Voltage from V+ to V− (50 ms)**: 50V
- **Continuous Voltage from V+ to V−**: 40V
- **Input-Output Voltage Differential**: 40V
- **Maximum Amplifier Input Voltage (Either Input)**: 8.5V
- **Maximum Amplifier Input Voltage (Differential)**: 5V
- **Current from V+**: 25 mA
- **Current from VREF**: 15 mA
- **Internal Power Dissipation (Metal Can)** (Note 2): 800 mW
- **Internal Power Dissipation (Cavity DIP)** (Note 2): 900 mW
- **Internal Power Dissipation (Molded DIP)** (Note 2): 660 mW
- **Operating Temperature Range**: LM723: −55˚C to +150˚C
- **Operating Temperature Range**: LM723C: 0˚C to +70˚C
- **Storage Temperature Range**: Metal Can: −65˚C to +150˚C
- **Lead Temperature (Soldering, 4 sec. max.)**: 300˚C
- **ESD Tolerance**: 1200V (Human body model, 1.5 kΩ in series with 100 pF)

**Electrical Characteristics** (Note 3) (Note 10)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Conditions</th>
<th>LM723</th>
<th>LM723C</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Line Regulation</td>
<td>V IN = 12V to V IN = 15V</td>
<td>0.01</td>
<td>0.01</td>
<td>% V OUT</td>
</tr>
<tr>
<td></td>
<td>−55˚C ≤ T A ≤ +125˚C</td>
<td>0.3</td>
<td>0.3</td>
<td>% V OUT</td>
</tr>
<tr>
<td></td>
<td>0˚C ≤ T A ≤ +70˚C</td>
<td>0.1</td>
<td>0.1</td>
<td>% V OUT</td>
</tr>
<tr>
<td>Load Regulation</td>
<td>I L = 1 mA to I L = 50 mA</td>
<td>0.03</td>
<td>0.03</td>
<td>% V OUT</td>
</tr>
<tr>
<td></td>
<td>−55˚C ≤ T A ≤ +125˚C</td>
<td>0.2</td>
<td>0.2</td>
<td>% V OUT</td>
</tr>
<tr>
<td></td>
<td>0˚C ≤ T A ≤ +70˚C</td>
<td>0.6</td>
<td>0.6</td>
<td>% V OUT</td>
</tr>
<tr>
<td>Ripple Rejection</td>
<td>f = 50 Hz to 10 kHz, C REF = 0</td>
<td>74</td>
<td>74</td>
<td>dB</td>
</tr>
<tr>
<td></td>
<td>f = 50 Hz to 10 kHz, C REF = 5 µF</td>
<td>86</td>
<td>86</td>
<td>dB</td>
</tr>
<tr>
<td>Average Temperature Coefficient of Output Voltage (Note 8)</td>
<td>−55˚C ≤ T A ≤ +125˚C</td>
<td>0.002</td>
<td>0.002</td>
<td>%/˚C</td>
</tr>
<tr>
<td></td>
<td>0˚C ≤ T A ≤ +70˚C</td>
<td>0.015</td>
<td>0.015</td>
<td>%/˚C</td>
</tr>
<tr>
<td>Short Circuit Current Limit</td>
<td>R SC = 10Ω, V OUT = 0</td>
<td>65</td>
<td>65</td>
<td>mA</td>
</tr>
<tr>
<td>Reference Voltage</td>
<td></td>
<td>6.95</td>
<td>7.15</td>
<td>7.35</td>
</tr>
<tr>
<td>Output Noise Voltage</td>
<td>BW = 100 Hz to 10 kHz, C REF = 0</td>
<td>86</td>
<td>86</td>
<td>µVrms</td>
</tr>
<tr>
<td></td>
<td>BW = 100 Hz to 10 kHz, C REF = 5 µF</td>
<td>2.5</td>
<td>2.5</td>
<td>µVrms</td>
</tr>
<tr>
<td>Long Term Stability</td>
<td></td>
<td>0.05</td>
<td>0.05</td>
<td>%/1000 hrs</td>
</tr>
<tr>
<td>Standby Current Drain</td>
<td>I L = 0, V IN = 30V</td>
<td>1.7</td>
<td>1.7</td>
<td>4.0</td>
</tr>
<tr>
<td>Input Voltage Range</td>
<td></td>
<td>9.5</td>
<td>9.5</td>
<td>40</td>
</tr>
<tr>
<td>Output Voltage Range</td>
<td></td>
<td>2.0</td>
<td>2.0</td>
<td>37</td>
</tr>
<tr>
<td>Input-Output Voltage Differential</td>
<td></td>
<td>3.0</td>
<td>3.0</td>
<td>38</td>
</tr>
<tr>
<td>θ JA</td>
<td>Molded DIP</td>
<td>105</td>
<td>V/W</td>
<td></td>
</tr>
<tr>
<td>θ JA</td>
<td>Cavity DIP</td>
<td>150</td>
<td>V/W</td>
<td></td>
</tr>
<tr>
<td>θ JA</td>
<td>H10C Board Mount in Still Air</td>
<td>165</td>
<td>V/W</td>
<td></td>
</tr>
<tr>
<td>θ JA</td>
<td>H10C Board Mount in 400 LF/Min Air Flow</td>
<td>66</td>
<td>66</td>
<td>V/W</td>
</tr>
<tr>
<td>θ JC</td>
<td></td>
<td>22</td>
<td>22</td>
<td>V/W</td>
</tr>
</tbody>
</table>

**Notes:**

- **Note 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 guarantee specific performance limits.
- **Note 2:** See derating curves for maximum power rating above 25˚C.
- **Note 3:** Unless otherwise specified, T A = 25˚C, V IN = V+ = V C = 12V, V− = 0, V OUT = 5V, I L = 1 mA, R SC = 0, C 1 = 100 pF, C REF = 0 and divider impedance as seen by error amplifier ≤ 10 kΩ connected as shown in Figure 1. 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.
- **Note 4:** L 1 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.
- **Note 5:** Figures in parentheses may be used if R1/R2 divider is placed on opposite input of error amp.
- **Note 6:** Replace R1/R2 in figures with divider shown in Figure 13.
- **Note 7:** V+ and VCC must be connected to a +3V or greater supply.
- **Note 8:** For metal can applications where V Z is required, an external 6.2V zener diode should be connected in series with V OUT.
Electrical Characteristics (Note 3) (Note 10) (Continued)

Note 9: Guaranteed by correlation to other tests.

Note 10: 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.

Typical Performance Characteristics

Load Regulation Characteristics with Current Limiting

Load & Line Regulation vs Input-Output Voltage Differential

Current Limiting Characteristics

Current Limiting Characteristics vs Junction Temperature

Standby Current Drain vs Input Voltage

Line Transient Response

Load Transient Response

Output Impedence vs Frequency

www.national.com
### Maximum Power Ratings

**Noise vs Filter Capacitor**  
(C<sub>REF</sub> in Circuit of Figure 1)  
(Bandwidth 100 Hz to 10 kHz)

**LM723**  
Power Dissipation vs Ambient Temperature

**LM723C**  
Power Dissipation vs Ambient Temperature

---

#### 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% (Note 6)</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>R&lt;sub&gt;1&lt;/sub&gt; R&lt;sub&gt;2&lt;/sub&gt;</td>
<td></td>
<td>R&lt;sub&gt;1&lt;/sub&gt; P&lt;sub&gt;1&lt;/sub&gt; R&lt;sub&gt;2&lt;/sub&gt;</td>
<td></td>
<td>R&lt;sub&gt;1&lt;/sub&gt; R&lt;sub&gt;2&lt;/sub&gt;</td>
<td></td>
<td>R&lt;sub&gt;1&lt;/sub&gt; P&lt;sub&gt;1&lt;/sub&gt; R&lt;sub&gt;2&lt;/sub&gt;</td>
</tr>
<tr>
<td>+3.0</td>
<td>1, 5, 6, 9, 12 (4)</td>
<td>4.12</td>
<td>3.01</td>
<td>+100</td>
<td>7</td>
<td>3.57</td>
<td>102</td>
</tr>
<tr>
<td>+3.6</td>
<td>1, 5, 6, 9, 12 (4)</td>
<td>3.57</td>
<td>3.65</td>
<td>+250</td>
<td>7</td>
<td>3.57</td>
<td>255</td>
</tr>
<tr>
<td>+5.0</td>
<td>1, 5, 6, 9, 12 (4)</td>
<td>2.15</td>
<td>4.99</td>
<td>−6 (Note 7)</td>
<td>3, (10)</td>
<td>3.57</td>
<td>243</td>
</tr>
<tr>
<td>+6.0</td>
<td>1, 5, 6, 9, 12 (4)</td>
<td>1.15</td>
<td>6.04</td>
<td>−9</td>
<td>3, 10</td>
<td>3.48</td>
<td>536</td>
</tr>
<tr>
<td>+9.0</td>
<td>2, 4, (5, 6, 9, 12)</td>
<td>1.87</td>
<td>7.15</td>
<td>−12</td>
<td>3, 10</td>
<td>3.57</td>
<td>845</td>
</tr>
<tr>
<td>+12</td>
<td>2, 4, (5, 6, 9, 12)</td>
<td>4.87</td>
<td>7.15</td>
<td>−15</td>
<td>3, 10</td>
<td>3.65</td>
<td>115</td>
</tr>
<tr>
<td>+15</td>
<td>2, 4, (5, 6, 9, 12)</td>
<td>7.87</td>
<td>7.15</td>
<td>−28</td>
<td>3, 10</td>
<td>3.57</td>
<td>243</td>
</tr>
<tr>
<td>+25</td>
<td>2, 4, (5, 6, 9, 12)</td>
<td>21.0</td>
<td>7.15</td>
<td>−45</td>
<td>8</td>
<td>3.57</td>
<td>412</td>
</tr>
<tr>
<td>+45</td>
<td>7</td>
<td>3.57</td>
<td>48.7</td>
<td>−100</td>
<td>8</td>
<td>3.57</td>
<td>976</td>
</tr>
<tr>
<td>+75</td>
<td>7</td>
<td>3.57</td>
<td>78.7</td>
<td>−250</td>
<td>8</td>
<td>3.57</td>
<td>249</td>
</tr>
</tbody>
</table>

---

#### TABLE 2. Formulae for Intermediate Output Voltages

- Outputs from +2 to +7 volts  
  (Figures 1, 4, 5, 6, 9, 12)

- Outputs from +4 to +250 volts  
  (Figure 7)

- Current Limiting

- Foldback Current Limiting

---

### Formulae

**Outputs from +2 to +7 volts**  
(Figures 1, 4, 5, 6, 9, 12)

\[
V_{\text{OUT}} = \left( \frac{V_{\text{REF}} \times R_2}{R_1 + R_2} \right)
\]

**Outputs from +4 to +250 volts**  
(Figure 7)

\[
V_{\text{OUT}} = \left( \frac{V_{\text{REF}} \times R_2}{2} \right) \times \left( \frac{R_2 - R_1}{R_1} \right) ; R_3 = R_4
\]

**Current Limiting**

\[
I_{\text{LIMIT}} = \frac{V_{\text{SENSE}}}{R_S}
\]

**Foldback Current Limiting**

\[
I_{\text{KNEE}} = \left( \frac{I_{\text{OUT}} R_3}{R_4} \right) + \left( \frac{V_{\text{SENSE}} (R_3 + R_4)}{R_4} \right)
\]

\[
I_{\text{SHORT CTK}} = \left( \frac{V_{\text{SENSE}}}{R_S} \right) \times \left( \frac{R_3 + R_4}{R_4} \right)
\]
Typical Applications

![Diagram of a voltage regulator](image1)

**DS008563-9**

R3 may be eliminated for minimum component count.

**Typical Performance**

- Regulated Output Voltage: 15V
- Line Regulation ($\Delta V_{IN}$ = 3V): 1.5 mV
- Load Regulation ($\Delta I_L$ = 50 mA): 4.5 mV

**FIGURE 2. Basic High Voltage Regulator**

($V_{OUT} = 7$ to 37 Volts)

![Diagram of a negative voltage regulator](image2)

**DS008563-10**

**Typical Performance**

- Regulated Output Voltage: −15V
- Line Regulation ($\Delta V_{IN}$ = 3V): 1 mV
- Load Regulation ($\Delta I_L$ = 100 mA): 2 mV

**FIGURE 3. Negative Voltage Regulator**

![Diagram of a positive voltage regulator](image3)

**DS008563-11**

**Typical Performance**

- Regulated Output Voltage: +15V
- Line Regulation ($\Delta V_{IN}$ = 3V): 1.5 mV
- Load Regulation ($\Delta I_L$ = 1A): 15 mV

**FIGURE 4. Positive Voltage Regulator**

(External NPN Pass Transistor)
Typical Applications (Continued)

FIGURE 5. Positive Voltage Regulator (External PNP Pass Transistor)

Typical Performance
Regulated Output Voltage +5V
Line Regulation ($\Delta V_{IN} = 3V$) 0.5 mV
Load Regulation ($\Delta I_L = 1A$) 5 mV

FIGURE 6. Foldback Current Limiting

Typical Performance
Regulated Output Voltage +5V
Line Regulation ($\Delta V_{IN} = 3V$) 0.5 mV
Load Regulation ($\Delta I_L = 10 mA$) 1 mV
Short Circuit Current 20 mA
Typical Applications (Continued)

**FIGURE 7. Positive Floating Regulator**

Typical Performance

- Regulated Output Voltage: +50V
- Line Regulation ($\Delta V_{IN} = 20V$): 15 mV
- Load Regulation ($\Delta I_L = 50 mA$): 20 mV

**FIGURE 8. Negative 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
Typical Applications (Continued)

**FIGURE 9. Positive Switching Regulator**

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

**FIGURE 10. Negative Switching Regulator**

Typical Performance
- Regulated Output Voltage: $-15V$
- Line Regulation ($\Delta V_{IN} = 20V$): 8 mV
- Load Regulation ($\Delta I_L = 2A$): 6 mV
Typical Applications  
(Continued)

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 ($\Delta I_L = 50mA$): 1.5 mV

**FIGURE 11. Remote Shutdown Regulator with Current Limiting**

- Regulated Output Voltage: +5V
- Line Regulation ($\Delta V_{IN} = 10V$): 0.5 mV
- Load Regulation ($\Delta I_L = 100mA$): 1.5 mV

**FIGURE 12. Shunt Regulator**
Typical Applications (Continued)

FIGURE 13. Output Voltage Adjust
(Note 6)

Schematic Diagram
Physical Dimensions inches (millimeters) unless otherwise noted

Leadless Chip Carrier Package (E)
Order Number LM723E/883
NS Package E20A

Metal Can Package (H)
Order Number LM723H, LM723H/883 or LM723CH
NS Package H10C
Physical Dimensions inches (millimeters) unless otherwise noted (Continued)

Ceramic Dual-In-Line Package (J)
Order Number LM723J/883
NS Package J14A
LIFE SUPPORT POLICY

NATIONAL'S PRODUCTS ARE NOT AUTHORIZED FOR USE AS CRITICAL COMPONENTS IN LIFE SUPPORT DEVICES OR SYSTEMS WITHOUT THE EXPRESS WRITTEN APPROVAL OF THE PRESIDENT AND GENERAL COUNSEL OF NATIONAL SEMICONDUCTOR CORPORATION. As used herein:

1. Life support devices or systems are devices or systems which, (a) are intended for surgical implant into the body, or (b) support or sustain life, and whose failure to perform when properly used in accordance with instructions for use provided in the labeling, can be reasonably expected to result in a significant injury to the user.

2. A critical component is any component of a life support device or system whose failure to perform can be reasonably expected to cause the failure of the life support device or system, or to affect its safety or effectiveness.

National Semiconductor
Americas
Tel: 1-800-272-9959
Fax: 1-800-737-7018
Email: support@nsc.com

National Semiconductor
Europe
Fax: +49 (0) 1 80-530 85 86
Email: europe.support@nsc.com

National Semiconductor
Asia Pacific Customer Response Group
Tel: 65-2544466
Fax: 65-2504466
Email: sea.support@nsc.com

National Semiconductor
Japan Ltd.
Tel: 81-3-5639-7560
Fax: 81-3-5639-7507

www.national.com

National does not assume any responsibility for use of any circuitry described, no circuit patent licenses are implied and National reserves the right at any time without notice to change said circuitry and specifications.