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

<table>
<thead>
<tr>
<th>Pin</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>NC</td>
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<tr>
<td>2</td>
<td>CURRENT LIMIT</td>
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<tr>
<td>3</td>
<td>CODC</td>
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<td>4</td>
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<td>7</td>
<td>V+</td>
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<td>9</td>
<td>V+</td>
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<td>13</td>
<td>NC</td>
</tr>
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<td>14</td>
<td>NC</td>
</tr>
</tbody>
</table>

Top View

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

Note: Pin 5 connected to case.

Metal Can Package

<table>
<thead>
<tr>
<th>Pin</th>
<th>Description</th>
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<tbody>
<tr>
<td>1</td>
<td>CURRENT LIMIT</td>
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<tr>
<td>2</td>
<td>CODC</td>
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<td>6</td>
<td>V+</td>
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<td>7</td>
<td>V+</td>
</tr>
</tbody>
</table>

Top View

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

Equivalent Circuit*

*Pin numbers refer to metal can package.
### Absolute Maximum Ratings

If Military/Aerospace specified devices are required, please contact the National Semiconductor Sales Office/Distributors for availability and specifications. (Note 9)

- 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 $V_Z$ 25 mA
- Current from $V_{REF}$ 15 mA

- Internal Power Dissipation Metal Can (Note 1) 800 mW
- Cavity DIP (Note 1) 900 mW
- Molded DIP (Note 1) 660 mW

#### Operating Temperature Range
- LM723 $-55^\circ C$ to $+150^\circ C$
- LM723C $0^\circ C$ to $+70^\circ C$

#### Storage Temperature Range
- Metal Can $-65^\circ C$ to $+150^\circ C$
- Molded DIP 55 $^\circ C$ to $150^\circ C$

#### Lead Temperature (Soldering, 4 sec. max.)
- Hermetic Package 300 $^\circ C$
- Plastic Package 260 $^\circ C$

#### ESD Tolerance
- 1200V (Human body model, 1.5 kΩ in series with 100 pF)

### Electrical Characteristics

#### Parameter
- Conditions
- **LM723**
- **LM723C**
- Units

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Conditions</th>
<th>Min</th>
<th>Typ</th>
<th>Max</th>
<th>Min</th>
<th>Typ</th>
<th>Max</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>0.1</td>
<td>0.3</td>
<td>0.01</td>
<td>0.1</td>
<td>0.3</td>
<td>% $V_{OUT}$</td>
</tr>
<tr>
<td></td>
<td>$-55^\circ C$ to $125^\circ C$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>$0^\circ C$ to $70^\circ C$</td>
<td>0.02</td>
<td>0.2</td>
<td>0.1</td>
<td>0.01</td>
<td>0.2</td>
<td>0.5</td>
<td>% $V_{OUT}$</td>
</tr>
<tr>
<td></td>
<td>$V_{IN} - 12V$ to $V_{IN} - 40V$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Load Regulation</td>
<td>$I_L = 1 mA$ to $50 mA$</td>
<td>0.03</td>
<td>0.15</td>
<td>0.6</td>
<td>0.03</td>
<td>0.2</td>
<td>0.6</td>
<td>% $V_{OUT}$</td>
</tr>
<tr>
<td></td>
<td>$-55^\circ C$ to $125^\circ C$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>$0^\circ C$ to $70^\circ C$</td>
<td></td>
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<td></td>
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<tr>
<td>Ripple Rejection</td>
<td>$f = 50$ Hz to 10 kHz, $C_{REF} = 0$</td>
<td>74</td>
<td>86</td>
<td>dB</td>
<td>74</td>
<td>86</td>
<td>dB</td>
<td></td>
</tr>
<tr>
<td></td>
<td>$f = 50$ Hz to 10 kHz, $C_{REF} = 5 \mu F$</td>
<td></td>
<td></td>
<td>dB</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average Temperature Coefficient of Output Voltage</td>
<td>$-55^\circ C$ to $125^\circ C$</td>
<td>0.002</td>
<td>0.015</td>
<td>0.003</td>
<td>0.015</td>
<td>%/$^\circ C$</td>
<td></td>
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</tr>
<tr>
<td></td>
<td>$0^\circ C$ to $70^\circ C$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Short Circuit Current Limit</td>
<td>$R_{SC} = 10\Omega$, $V_{OUT} = 0$</td>
<td>65</td>
<td>65</td>
<td>mA</td>
<td></td>
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<tr>
<td>Reference Voltage</td>
<td>$6.95$ $V$ to $7.15$ $V$, $C_{REF} = 0$</td>
<td>6.95</td>
<td>7.15</td>
<td>V</td>
<td>6.80</td>
<td>7.15</td>
<td>V</td>
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<td></td>
<td>$BW = 100$ Hz to $10$ kHz, $C_{REF} = 0$</td>
<td>86</td>
<td>86</td>
<td>$\mu V_{rms}$</td>
<td>86</td>
<td>86</td>
<td>$\mu V_{rms}$</td>
<td></td>
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<tr>
<td></td>
<td>$BW = 100$ Hz to $10$ kHz, $C_{REF} = 5 \mu F$</td>
<td>2.5</td>
<td>2.5</td>
<td>$\mu V_{rms}$</td>
<td>2.5</td>
<td>2.5</td>
<td>$\mu V_{rms}$</td>
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<td>Long Term Stability</td>
<td>$I_L = 0$, $V_{IN} = 30V$</td>
<td>0.05</td>
<td>0.05</td>
<td>%/$1000$ hrs</td>
<td>1.7</td>
<td>3.5</td>
<td>mA</td>
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<td>Standby Current Drain</td>
<td>$9.5$ $V$ to $40$ $V$</td>
<td>9.5</td>
<td>40</td>
<td>9.5</td>
<td>40</td>
<td>V</td>
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<td></td>
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<tr>
<td>Output Voltage Range</td>
<td>$2.0$ $V$ to $37$ $V$</td>
<td>2.0</td>
<td>37</td>
<td>37</td>
<td>V</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Input-Output Voltage Differential</td>
<td>$3.0$ $V$ to $38$ $V$</td>
<td>3.0</td>
<td>38</td>
<td>38</td>
<td>V</td>
<td></td>
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<td>$\theta_{JA}$</td>
<td>Molded DIP</td>
<td>105</td>
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<td></td>
<td></td>
<td></td>
<td>%/$^\circ C/W$</td>
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<tr>
<td>$\theta_{JA}$</td>
<td>Cavity DIP</td>
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<td></td>
<td></td>
<td></td>
<td>%/$^\circ C/W$</td>
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<td>$\theta_{JA}$</td>
<td>H10C Board Mount in Still Air</td>
<td>165</td>
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<td></td>
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<td></td>
<td>%/$^\circ C/W$</td>
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<td>$\theta_{JA}$</td>
<td>H10C Board Mount in 400 LF/Min Air Flow</td>
<td>66</td>
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<td></td>
<td></td>
<td></td>
<td>%/$^\circ C/W$</td>
<td></td>
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<tr>
<td>$\theta_{JC}$</td>
<td>22</td>
<td>22</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>%/$^\circ C/W$</td>
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</tr>
</tbody>
</table>

**Note 1:** See derating curves for maximum power rating above 25$^\circ C$.

**Note 2:** Unless otherwise specified, $T_A = 25^\circ C$, $V_{IN} = V^+ = V^-$ = $12V$, $V_{OUT} = 5V$, $I_L = 1 mA$, $R_{SC} = 0$, $C_1 = 100 \mu F$, $C_{REF} = 0$ 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 3:** $L_1$ 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 4:** Figures in parentheses may be used if $R_1/R_2$ divider is placed on opposite input of error amp.

**Note 5:** Replace $R_1/R_2$ in figures with divider shown in Figure 13.

**Note 6:** $V^+$ and $V_{CC}$ must be connected to a ±3V or greater supply.

**Note 7:** For metal can applications where $V_Z$ is required, an external 6.2V zener diode should be connected in series with $V_{OUT}$.

**Note 8:** Guaranteed by correlation to other tests.

**Note 9:** 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 Regulation Characteristics with Input-Output Voltage Differential

Current Limiting Characteristics vs Input Voltage

Standby Current Drain vs Input Voltage

Line Transient Response

Load Transient Response

Output Impedence vs Frequency

Noise vs Filter Capacitor (C\text{REF} in Circuit of Figure 1) (Bandwidth 100 Hz to 10 kHz)

LM723 Power Dissipation vs Ambient Temperature

LM723C Power Dissipation vs Ambient Temperature

Maximum Power Ratings
### TABLE I. 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 5)</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>R1 R2</td>
<td>R1 P1 R2</td>
<td></td>
<td>R1 R2</td>
<td>R1 P1 R2</td>
<td>R1 P1 R2</td>
<td></td>
</tr>
<tr>
<td>+3.0</td>
<td>1, 5, 6, 9, 12 (4)</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>1, 5, 6, 9, 12 (4)</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>1, 5, 6, 9, 12 (4)</td>
<td>2.15</td>
<td>4.99</td>
<td>0.75</td>
<td>0.5</td>
<td>2.2</td>
<td>−6 (Note 6)</td>
</tr>
<tr>
<td>+6.0</td>
<td>1, 5, 6, 9, 12 (4)</td>
<td>1.15</td>
<td>6.04</td>
<td>0.5</td>
<td>0.5</td>
<td>2.7</td>
<td>−9</td>
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<tr>
<td>+9.0</td>
<td>2, 4, (5, 6, 9, 12)</td>
<td>1.87</td>
<td>7.15</td>
<td>0.75</td>
<td>1.0</td>
<td>2.7</td>
<td>−12</td>
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<tr>
<td>+12</td>
<td>2, 4, (5, 6, 9, 12)</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>2, 4, (5, 6, 9, 12)</td>
<td>7.87</td>
<td>7.15</td>
<td>3.3</td>
<td>1.0</td>
<td>3.0</td>
<td>−28</td>
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<tr>
<td>+28</td>
<td>2, 4, (5, 6, 9, 12)</td>
<td>21.0</td>
<td>7.15</td>
<td>5.6</td>
<td>1.0</td>
<td>2.0</td>
<td>−45</td>
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<tr>
<td>+45</td>
<td>7</td>
<td>3.57</td>
<td>48.7</td>
<td>2.2</td>
<td>10</td>
<td>39</td>
<td>−100</td>
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<tr>
<td>+75</td>
<td>7</td>
<td>3.57</td>
<td>78.7</td>
<td>2.2</td>
<td>10</td>
<td>68</td>
<td>−250</td>
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</table>

### TABLE II. Formulae for Intermediate Output Voltages

**Outputs from ±2 to ±7 volts**  
(Figures 1, 5, 6, 9, 12, [4])  
\[ V_{OUT} = \frac{V_{REF} \times R_2}{R_1 + R_2} \]

**Outputs from ±4 to ±250 volts**  
(Figure 7)  
\[ V_{OUT} = \frac{V_{REF} \times R_2 - R_1}{2 \times R_1}; R_3 = R_4 \]

**Current Limiting**  
\[ I_{LIMIT} = \frac{V_{SENSE}}{R_{SC}} \]

**Foldback Current Limiting**  
\[ I_{KNEE} = \frac{V_{OUT} R_3 + V_{SENSE} (R_3 + R_4)}{R_{SC} R_4}; R_{SHORT CTK} = \frac{V_{SENSE} \times (R_3 + R_4)}{R_{SC} R_4} \]

### Typical Applications

**FIGURE 1. Basic Low Voltage Regulator**  
(V$_{OUT}$ ≈ 2 to 7 Volts)

**FIGURE 2. Basic High Voltage Regulator**  
(V$_{OUT}$ ≈ 7 to 37 Volts)
Typical Applications (Continued)

FIGURE 3. Negative Voltage Regulator

Typical Performance
Regulated Output Voltage -15V
Line Regulation (ΔVIN = 3V) 1 mV
Load Regulation (ΔI = 100 mA) 2 mV

FIGURE 4. Positive Voltage Regulator
(External NPN Pass Transistor)

Typical Performance
Regulated Output Voltage +15V
Line Regulation (ΔVIN = 3V) 1.5 mV
Load Regulation (ΔI = 1A) 15 mV

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

Typical Performance
Regulated Output Voltage +5V
Line Regulation (ΔVIN = 3V) 0.5 mV
Load Regulation (ΔI = 1A) 5 mV

FIGURE 6. Foldback Current Limiting

Typical Performance
Regulated Output Voltage +5V
Line Regulation (ΔVIN = 3V) 0.5 mV
Load Regulation (ΔI = 10 mA) 1 mV
Short Circuit Current 20 mA
Typical Applications (Continued)

**FIGURE 7. Positive Floating Regulator**

**FIGURE 8. Negative Floating Regulator**
Typical Applications (Continued)

FIGURE 9. Positive Switching Regulator

**Typical Performance**

- Regulated Output Voltage: +5V
- Line Regulation ($\Delta V_{IN} = \pm 30V$): 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)

![Diagram of Remote Shutdown Regulator with Current Limiting](image1)

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

- **Regulated Output Voltage**: +5V
- **Line Regulation** ($\Delta V_{IN} = 10V$): 0.5 mV
- **Load Regulation** ($\Delta I_L = 50 mA$): 1.5 mV

**Typical Performance**

**FIGURE 12. Shunt Regulator**

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

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**Note:** Current limit transistor may be used for shutdown if current limiting is not required.
Typical Applications (Continued)

FIGURE 13. Output Voltage Adjust
(See Note 5)

Schematic Diagram
Physical Dimensions inches (millimeters)

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) (Continued)

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