MCP1700

Low Quiescent Current LDO

Features

• AEC-Q100 Qualified and PPAP Capable
• 1.6 µA Typical Quiescent Current
• Input Operating Voltage Range: 2.3V to 6.0V
• Output Voltage Range: 1.2V to 5.0V
• 250 mA Output Current for Output Voltages ≥ 2.5V
• 200 mA Output Current for Output Voltages < 2.5V
• Low Dropout (LDO) Voltage
  - 178 mV Typical @ 250 mA for VOUT = 2.8V
• 0.4% Typical Output Voltage Tolerance
• Standard Output Voltage Options:
  - 1.2V, 1.8V, 2.5V, 2.8V, 3.0V, 3.3V, 5.0V
• Stable with 1.0 µF Ceramic Output Capacitor
• Short Circuit Protection
• Overtemperature Protection

Applications

• Battery-Powered Devices
• Battery-Powered Alarm Circuits
• Smoke Detectors
• CO₂ Detectors
• Pagers and Cellular Phones
• Smart Battery Packs
• Low Quiescent Current Voltage Reference
• PDAs
• Digital Cameras
• Microcontroller Power

Related Literature

• AN765, “Using Microchip’s Micropower LDOs” (DS00765), Microchip Technology Inc., 2002
• AN766, “Pin-Compatible CMOS Upgrades to BiPolar LDOs” (DS00766), Microchip Technology Inc., 2002
• AN792, “A Method to Determine How Much Power a SOT23 Can Dissipate in an Application” (DS00792), Microchip Technology Inc., 2001

General Description

The MCP1700 is a family of CMOS low dropout (LDO) voltage regulators that can deliver up to 250 mA of current while consuming only 1.6 µA of quiescent current (typical). The input operating range is specified from 2.3V to 6.0V, making it an ideal choice for two and three primary cell battery-powered applications, as well as single cell Li-Ion-powered applications.

The MCP1700 is capable of delivering 250 mA with only 178 mV of input to output voltage differential (VOUT = 2.8V). The output voltage tolerance of the MCP1700 is typically ±0.4% at +25°C and ±3% maximum over the operating junction temperature range of -40°C to +125°C.

Output voltages available for the MCP1700 range from 1.2V to 5.0V. The LDO output is stable when using only 1 µF output capacitance. Ceramic, tantalum or aluminum electrolytic capacitors can all be used for input and output. Overcurrent limit and overtemperature shutdown provide a robust solution for any application.

Package options include SOT-23, SOT-89, TO-92 and 2x2 DFN-6.

Package Types

3-Pin SOT-23

3-Pin SOT-89

3-Pin TO-92

2x2 DFN-6

* Includes Exposed Thermal Pad (EP); see Table 3-1.
MCP1700

Functional Block Diagrams

Typical Application Circuits

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1.0 ELECTRICAL CHARACTERISTICS

Absolute Maximum Ratings †

VDD .................................................. +6.5V
All inputs and outputs w.r.t. (VSS - 0.3V) to (VIN + 0.3V)
Peak Output Current ............................................................... Internally Limited
Storage Temperature ................................................................. -65°C to +150°C
Maximum Junction Temperature ............................................ 150°C
Operating Junction Temperature ............................................. -40°C to +125°C
ESD protection on all pins (HBM, MM) ........................................ 4kV, ≥ 400V

† Notice: Stresses above those listed under “Maximum Ratings” may cause permanent damage to the device. This is a stress rating only, and functional operation of the device at those or any other conditions above those indicated in the operational listings of this specification is not implied. Exposure to maximum rating conditions for extended periods may affect device reliability.

DC CHARACTERISTICS

Electrical Characteristics: Unless otherwise specified, all limits are established for VIN = VR +1V, IL = 100 µA, COUT = 1 µF (X7R), CIN = 1 µF (X7R), TA = +25°C.

Boldface type applies for junction temperatures, TJ (Note 6) of -40°C to +125°C.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Sym.</th>
<th>Min.</th>
<th>Typ.</th>
<th>Max.</th>
<th>Units</th>
<th>Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Input/Output Voltage</td>
<td>VIN</td>
<td>2.3</td>
<td>—</td>
<td>6.0</td>
<td>V</td>
<td>Note 1</td>
</tr>
<tr>
<td>Input Quiescent Current</td>
<td>IQ</td>
<td>—</td>
<td>1.6</td>
<td>4</td>
<td>µA</td>
<td>I0 = 0 mA, VIN = VR +1V</td>
</tr>
<tr>
<td>Maximum Output Current</td>
<td>IOUT_mA</td>
<td>250</td>
<td>—</td>
<td>—</td>
<td>mA</td>
<td>For VR ≥ 2.5V</td>
</tr>
<tr>
<td>Output Short Circuit Current</td>
<td>IOUT_SC</td>
<td>—</td>
<td>408</td>
<td>—</td>
<td>mA</td>
<td>VIN = VR +1V, VOUT = GND</td>
</tr>
<tr>
<td>Output Voltage Regulation</td>
<td>VOUT</td>
<td>VR - 2.0%</td>
<td>VR ± 0.4%</td>
<td>VR + 2.0%</td>
<td>RR + 3.0%</td>
<td>V</td>
</tr>
<tr>
<td>VOUT Temperature Coefficient</td>
<td>TCVOUT</td>
<td>—</td>
<td>50</td>
<td>—</td>
<td>ppm/°C</td>
<td>Note 3</td>
</tr>
<tr>
<td>Line Regulation</td>
<td>ΔVOUT/(VOUT×ΔVIN)</td>
<td>-1.0</td>
<td>±0.75</td>
<td>+1.0</td>
<td>%/V</td>
<td>VR +1V ≤ VIN ≤ 6V</td>
</tr>
<tr>
<td>Load Regulation</td>
<td>ΔVOUT/VOUT</td>
<td>-1.5</td>
<td>±1.0</td>
<td>+1.5</td>
<td>%</td>
<td>I0 = 0.1 mA to 250 mA for VR ≥ 2.5V</td>
</tr>
<tr>
<td>Dropout Voltage</td>
<td>VIN - VOUT</td>
<td>—</td>
<td>178</td>
<td>350</td>
<td>mV</td>
<td>I0 = 250 mA, (Note 1, Note 5)</td>
</tr>
<tr>
<td>Dropout Voltage</td>
<td>VOUT</td>
<td>—</td>
<td>150</td>
<td>350</td>
<td>mV</td>
<td>I0 = 200 mA, (Note 1, Note 5)</td>
</tr>
<tr>
<td>Output Rise Time</td>
<td>TR</td>
<td>—</td>
<td>500</td>
<td>—</td>
<td>µs</td>
<td>10% VR to 90% VR, VIN = 0V to 6V, RL = 50Ω resistive</td>
</tr>
</tbody>
</table>

Note 1: The minimum VIN must meet two conditions: VIN ≥ 2.3V and VIN ≥ (VR + 3.0%) + VDROP.
2: VR is the nominal regulator output voltage. For example: VR = 1.2V, 1.5V, 1.8V, 2.5V, 2.8V, 2.9V, 3.0V, 3.3V, 4.0V, 5.0V. The input voltage VIN = VIN + 1.0V, IOUT = 100 µA.
3: TCVOUT = (VOUT-HIGH - VOUT-LOW) *10² / (VR * ΔTemperature). VOUT-HIGH = highest voltage measured over the temperature range. VOUT-LOW = lowest voltage measured over the temperature range.
4: Load regulation is measured at a constant junction temperature using low duty cycle pulse testing. Changes in output voltage due to heating effects are determined using thermal regulation specification TCVOUT.
5: Dropout voltage is defined as the input to output differential at which the output voltage drops 2% below its measured value with a VR + 1V differential applied.
6: The maximum allowable power dissipation is a function of ambient temperature, the maximum allowable junction temperature and the thermal resistance from junction to air (i.e. TJA, θJA). Exceeding the maximum allowable power dissipation will cause the device operating junction temperature to exceed the maximum 150°C rating. Sustained junction temperatures above 150°C can impact the device reliability.
7: The junction temperature is approximated by soaking the device under test at an ambient temperature equal to the desired Junction temperature. The test time is small enough such that the rise in the Junction temperature over the ambient temperature is not significant.
**DC CHARACTERISTICS (CONTINUED)**

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Sym.</th>
<th>Min.</th>
<th>Typ.</th>
<th>Max.</th>
<th>Units</th>
<th>Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Output Noise</td>
<td>$e_N$</td>
<td>—</td>
<td>3</td>
<td>—</td>
<td>µV/Hz$^{1/2}$</td>
<td>$I_L = 100$ mA, $f = 1$ kHz, $C_{OUT} = 1$ µF</td>
</tr>
<tr>
<td>Power Supply Ripple Rejection</td>
<td>PSRR</td>
<td>—</td>
<td>44</td>
<td>—</td>
<td>dB</td>
<td>$f = 100$ Hz, $C_{OUT} = 1$ µF, $I_L = 50$ mA, $V_{INAC} = 100$ mV pk-pk, $C_{IN} = 0$ µF, $V_R = 1.2$ V</td>
</tr>
<tr>
<td>Thermal Shutdown Protection</td>
<td>$T_{SD}$</td>
<td>—</td>
<td>140</td>
<td>—</td>
<td>°C</td>
<td>$V_{IN} = V_R + 1$ V, $I_L = 100$ µA</td>
</tr>
</tbody>
</table>

**Note 1:**
- The maximum power dissipation is a function of ambient temperature, the maximum allowable junction temperature and the thermal resistance from junction to air (i.e. $T_A$, $T_J$, $\theta_{JA}$). Exceeding the maximum allowable power dissipation will cause the device operating junction temperature to exceed the maximum 150°C rating. Sustained junction temperatures above 150°C can impact the device reliability.

**TEMPERATURE SPECIFICATIONS**

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Sym.</th>
<th>Min.</th>
<th>Typ.</th>
<th>Max.</th>
<th>Units</th>
<th>Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature Ranges</td>
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<tr>
<td>Specified Temperature Range</td>
<td>$T_A$</td>
<td>-40</td>
<td></td>
<td>+125</td>
<td>°C</td>
<td>EIA/JEDEC JESD51-7 FR-4 4-Layer Board</td>
</tr>
<tr>
<td>Operating Temperature Range</td>
<td>$T_J$</td>
<td>-40</td>
<td></td>
<td>+125</td>
<td>°C</td>
<td></td>
</tr>
<tr>
<td>Storage Temperature Range</td>
<td>$T_A$</td>
<td>-65</td>
<td></td>
<td>+150</td>
<td>°C</td>
<td></td>
</tr>
<tr>
<td>Thermal Package Resistance</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thermal Resistance, 2x2 DFN</td>
<td>$\theta_{JA}$</td>
<td>—</td>
<td>91</td>
<td>—</td>
<td>°C/W</td>
<td></td>
</tr>
<tr>
<td></td>
<td>$\theta_{JC(top)}$</td>
<td>—</td>
<td>286</td>
<td>—</td>
<td>°C/W</td>
<td></td>
</tr>
<tr>
<td></td>
<td>$\theta_{JC(bottom)}$</td>
<td>—</td>
<td>28.57</td>
<td>—</td>
<td>°C/W</td>
<td></td>
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<tr>
<td></td>
<td>$\Psi_{JT}$</td>
<td>—</td>
<td>8.95</td>
<td>—</td>
<td>°C/W</td>
<td></td>
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<tr>
<td>Thermal Resistance, SOT-23</td>
<td>$\theta_{JA}$</td>
<td>—</td>
<td>212</td>
<td>—</td>
<td>°C/W</td>
<td></td>
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<tr>
<td></td>
<td>$\theta_{JC(top)}$</td>
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<td>139</td>
<td>—</td>
<td>°C/W</td>
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<tr>
<td></td>
<td>$\theta_{JC(bottom)}$</td>
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<td>11.95</td>
<td>—</td>
<td>°C/W</td>
<td></td>
</tr>
<tr>
<td></td>
<td>$\Psi_{JT}$</td>
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<td>6.15</td>
<td>—</td>
<td>°C/W</td>
<td></td>
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<tr>
<td>Thermal Resistance, SOT-89</td>
<td>$\theta_{JA}$</td>
<td>—</td>
<td>104</td>
<td>—</td>
<td>°C/W</td>
<td></td>
</tr>
<tr>
<td></td>
<td>$\theta_{JC(top)}$</td>
<td>—</td>
<td>74</td>
<td>—</td>
<td>°C/W</td>
<td></td>
</tr>
<tr>
<td></td>
<td>$\Psi_{JT}$</td>
<td>—</td>
<td>30</td>
<td>—</td>
<td>°C/W</td>
<td></td>
</tr>
</tbody>
</table>

**Note 1:**
- The maximum power dissipation is a function of ambient temperature, the maximum allowable junction temperature and the thermal resistance from junction to air (i.e. $T_A$, $T_J$, $\theta_{JA}$). Exceeding the maximum allowable power dissipation will cause the device operating junction temperature to exceed the maximum 150°C rating. Sustained junction temperatures above 150°C can impact the device reliability.
TEMPERATURE SPECIFICATIONS (CONTINUED)

**Electrical Characteristics:** Unless otherwise specified, all limits are established for $V_{IN} = V_R + 1V$, $I_{LOAD} = 100 \mu A$, $C_{OUT} = 1 \mu F$ (X7R), $C_{IN} = 1 \mu F$ (X7R), $T_A = +25^\circ C$.

**Boldface** type applies for junction temperatures, $T_J$ [Note 1] of -40°C to +125°C.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Sym.</th>
<th>Min.</th>
<th>Typ.</th>
<th>Max.</th>
<th>Units</th>
<th>Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thermal Resistance, TO-92</td>
<td></td>
<td></td>
<td>92</td>
<td></td>
<td>°C/W</td>
<td>EIA/JEDEC JESD51-7 FR-4 4-Layer Board</td>
</tr>
<tr>
<td>$\theta_J$ (Top)</td>
<td></td>
<td>74</td>
<td></td>
<td></td>
<td>°C/W</td>
<td></td>
</tr>
</tbody>
</table>

**Note 1:** The maximum allowable power dissipation is a function of ambient temperature, the maximum allowable junction temperature and the thermal resistance from junction to air (i.e. $T_A$, $T_J$, $\theta_J$). Exceeding the maximum allowable power dissipation will cause the device operating junction temperature to exceed the maximum 150°C rating. Sustained junction temperatures above 150°C can impact the device reliability.
2.0 TYPICAL PERFORMANCE CURVES

Note: The graphs and tables provided following this note are a statistical summary based on a limited number of samples and are provided for informational purposes only. The performance characteristics listed herein are not tested or guaranteed. In some graphs or tables, the data presented may be outside the specified operating range (e.g., outside specified power supply range) and therefore outside the warranted range.

Note: Unless otherwise indicated: \( V_R = 1.8V \), \( C_{OUT} = 1 \mu F \) Ceramic (X7R), \( C_{IN} = 1 \mu F \) Ceramic (X7R), \( I_L = 100 \mu A \), \( T_A = +25°C \), \( V_{IN} = V_R + 1V \).

Note: Junction Temperature (\( T_J \)) is approximated by soaking the device under test to an ambient temperature equal to the desired junction temperature. The test time is small enough such that the rise in Junction temperature over the Ambient temperature is not significant.

**FIGURE 2-1:** Input Quiescent Current vs. Input Voltage.

**FIGURE 2-2:** Ground Current vs. Load Current.

**FIGURE 2-3:** Quiescent Current vs. Junction Temperature.

**FIGURE 2-4:** Output Voltage vs. Input Voltage (\( V_R = 1.2V \)).

**FIGURE 2-5:** Output Voltage vs. Input Voltage (\( V_R = 1.8V \)).

**FIGURE 2-6:** Output Voltage vs. Input Voltage (\( V_R = 2.8V \)).
**Note:** Unless otherwise indicated: $V_R = 1.8V$, $C_{OUT} = 1$ µF Ceramic (X7R), $C_{IN} = 1$ µF Ceramic (X7R), $I_L = 100$ µA, $T_A = +25^\circ C$, $V_{IN} = V_R + 1V$.

**FIGURE 2-7:** Output Voltage vs. Input Voltage ($V_R = 5.0V$).

**FIGURE 2-8:** Output Voltage vs. Load Current ($V_R = 1.2V$).

**FIGURE 2-9:** Output Voltage vs. Load Current ($V_R = 1.8V$).

**FIGURE 2-10:** Output Voltage vs. Load Current ($V_R = 2.8V$).

**FIGURE 2-11:** Output Voltage vs. Load Current ($V_R = 5.0V$).

**FIGURE 2-12:** Dropout Voltage vs. Load Current ($V_R = 2.8V$).
Note: Unless otherwise indicated: \( V_R = 1.8\,\text{V}, C_{\text{OUT}} = 1\,\mu\text{F}\) Ceramic (X7R), \( C_{\text{IN}} = 1\,\mu\text{F}\) Ceramic (X7R), \( I_L = 100\,\mu\text{A}, T_A = +25^\circ\text{C}, V_{\text{IN}} = V_R + 1\,\text{V}. \)

**FIGURE 2-13:** Dropout Voltage vs. Load Current \( (V_R = 5.0\,\text{V}). \)

**FIGURE 2-14:** Power Supply Ripple Rejection vs. Frequency \( (V_R = 1.2\,\text{V}). \)

**FIGURE 2-15:** Power Supply Ripple Rejection vs. Frequency \( (V_R = 2.8\,\text{V}). \)

**FIGURE 2-16:** Noise vs. Frequency.

**FIGURE 2-17:** Dynamic Load Step \( (V_R = 1.2\,\text{V}). \)

**FIGURE 2-18:** Dynamic Load Step \( (V_R = 1.8\,\text{V}). \)
Note: Unless otherwise indicated: \( V_R = 1.8\, \text{V}, \) \( C_{OUT} = 1\, \mu\text{F} \) Ceramic (X7R), \( C_{IN} = \mu\text{F} \) Ceramic (X7R), \( I_L = 100\, \mu\text{A}, \) \( T_A = +25^\circ\text{C}, \) \( V_{IN} = V_R + 1\, \text{V}. \)

**FIGURE 2-19:** Dynamic Load Step \( (V_R = 2.8\, \text{V}). \)

**FIGURE 2-20:** Dynamic Load Step \( (V_R = 1.8\, \text{V}). \)

**FIGURE 2-21:** Dynamic Load Step \( (V_R = 2.8\, \text{V}). \)

**FIGURE 2-22:** Dynamic Load Step \( (V_R = 5.0\, \text{V}). \)

**FIGURE 2-23:** Dynamic Line Step \( (V_R = 2.8\, \text{V}). \)

**FIGURE 2-24:** Start-up from \( V_{IN} \) \( (V_R = 1.2\, \text{V}). \)
Note: Unless otherwise indicated: $V_R = 1.8V$, $C_{OUT} = 1 \mu F$ Ceramic (X7R), $C_{IN} = 1 \mu F$ Ceramic (X7R), $I_L = 100 \mu A$, $T_A = +25^\circ C$, $V_{IN} = V_R + 1V$.

**FIGURE 2-25:** Start-up from $V_{IN}$
($V_R = 1.8V$).

**FIGURE 2-26:** Start-up from $V_{IN}$
($V_R = 2.8V$).

**FIGURE 2-27:** Load Regulation vs.
Junction Temperature ($V_R = 1.8V$).

**FIGURE 2-28:** Load Regulation vs.
Junction Temperature ($V_R = 2.8V$).

**FIGURE 2-29:** Load Regulation vs.
Junction Temperature ($V_R = 5.0V$).

**FIGURE 2-30:** Line Regulation vs.
Temperature ($V_R = 1.2V, 1.8V, 2.8V$).
3.0 PIN DESCRIPTIONS

The descriptions of the pins are listed in Table 3-1.

**TABLE 3-1: PIN FUNCTION TABLE**

<table>
<thead>
<tr>
<th>Pin No.</th>
<th>Pin No.</th>
<th>Pin No.</th>
<th>Pin No.</th>
<th>Name</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>SOT-23</td>
<td>SOT-89</td>
<td>TO-92</td>
<td>2x2 DFN-6</td>
<td>GND</td>
<td>Ground Terminal</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>V_{OUT}</td>
<td>Regulated Voltage Output</td>
</tr>
<tr>
<td>2</td>
<td>3</td>
<td>3</td>
<td>6</td>
<td>V_{IN}</td>
<td>Unregulated Supply Voltage</td>
</tr>
<tr>
<td>3</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>NC</td>
<td>No Connect</td>
</tr>
<tr>
<td>—</td>
<td>—</td>
<td>—</td>
<td>2, 4, 5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>EP</td>
<td></td>
<td></td>
<td>Exposed Thermal Pad</td>
<td></td>
</tr>
</tbody>
</table>

3.1 Ground Terminal (GND)

Regulator ground. Tie GND to the negative side of the output and the negative side of the input capacitor. Only the LDO bias current (1.6 µA typical) flows out of this pin; there is no high current. The LDO output regulation is referenced to this pin. Minimize voltage drops between this pin and the negative side of the load.

3.2 Regulated Output Voltage (V_{OUT})

Connect V_{OUT} to the positive side of the load and the positive terminal of the output capacitor. The positive side of the output capacitor should be physically located as close to the LDO V_{OUT} pin as is practical. The current flowing out of this pin is equal to the DC load current.

3.3 Unregulated Input Voltage Pin (V_{IN})

Connect V_{IN} to the input unregulated source voltage. As with all low dropout linear regulators, low source impedance is necessary for the stable operation of the LDO. The amount of capacitance required to ensure low source impedance will depend on the proximity of the input source capacitors or battery type. For most applications, 1 µF of capacitance will ensure stable operation of the LDO circuit. For applications that have load currents below 100 mA, the input capacitance requirement can be lowered. The type of capacitor used can be ceramic, tantalum or aluminum electrolytic. The low ESR characteristics of the ceramic will yield better noise and PSRR performance at high frequency.

3.4 No Connect (NC)

No internal connection. The pins marked NC are true "No Connect" pins.

3.5 Exposed Thermal Pad (EP)

There is an internal electrical connection between the Exposed Thermal Pad (EP) and the GND pin; they must be connected to the same potential on the Printed Circuit Board (PCB).
4.0  DETAILED DESCRIPTION

4.1  Output Regulation

A portion of the LDO output voltage is fed back to the internal error amplifier and compared with the precision internal bandgap reference. The error amplifier output will adjust the amount of current that flows through the P-Channel pass transistor, thus regulating the output voltage to the desired value. Any changes in input voltage or output current will cause the error amplifier to respond and adjust the output voltage to the target voltage (refer to Figure 4-1).

4.2  Overcurrent

The MCP1700 internal circuitry monitors the amount of current flowing through the P-Channel pass transistor. In the event of a short circuit or excessive output current, the MCP1700 will turn off the P-Channel device for a short period, after which the LDO will attempt to restart. If the excessive current remains, the cycle will repeat itself.

4.3  Overtemperature

The internal power dissipation within the LDO is a function of input-to-output voltage differential and load current. If the power dissipation within the LDO is excessive, the internal junction temperature will rise above the typical shutdown threshold of 140°C. At that point, the LDO will shut down and begin to cool to the typical turn-on junction temperature of 130°C. If the power dissipation is low enough, the device will continue to cool and operate normally. If the power dissipation remains high, the thermal shutdown protection circuitry will again turn off the LDO, protecting it from catastrophic failure.

FIGURE 4-1:  Block Diagram.
5.0 FUNCTIONAL DESCRIPTION

The MCP1700 CMOS low dropout linear regulator is intended for applications that need the lowest current consumption while maintaining output voltage regulation. The operating continuous load of the MCP1700 ranges from 0 mA to 250 mA ($V_R \geq 2.5\text{V}$). The input operating voltage ranges from 2.3V to 6.0V, making it capable of operating from two, three or four alkaline cells or a single Li-Ion cell battery input.

5.1 Input

The input of the MCP1700 is connected to the source of the P-Channel PMOS pass transistor. As with all LDO circuits, a relatively low source impedance (10Ω) is needed to prevent the input impedance from causing the LDO to become unstable. The size and type of the required capacitor depend heavily on the input source type (battery, power supply) and the output current range of the application. For most applications (up to 100 mA), a 1 µF ceramic capacitor will be sufficient to ensure circuit stability. Larger values can be used to improve circuit AC performance.

5.2 Output

The maximum rated continuous output current for the MCP1700 is 250 mA ($V_R \geq 2.5\text{V}$). For applications where $V_R < 2.5\text{V}$, the maximum output current is 200 mA.

A minimum output capacitance of 1.0 µF is required for small signal stability in applications that have up to 250 mA output current capability. The capacitor type can be ceramic, tantalum or aluminum electrolytic. The ESR range on the output capacitor can range from 0Ω to 2.0Ω.

5.3 Output Rise time

When powering up the internal reference output, the typical output rise time of 500 µs is controlled to prevent overshoot of the output voltage.
6.0 APPLICATION CIRCUITS AND ISSUES

6.1 Typical Application

The MCP1700 is most commonly used as a voltage regulator. Its low quiescent current and low dropout voltage make it ideal for many battery-powered applications.

**FIGURE 6-1: Typical Application Circuit.**

6.1.1 APPLICATION INPUT CONDITIONS

- Package Type = SOT-23
- Input Voltage Range = 2.3V to 3.2V
- $V_{IN}$ maximum = 3.2V
- $V_{OUT}$ typical = 1.8V
- $I_{OUT}$ maximum = 150 mA

6.2 Power Calculations

6.2.1 POWER DISSIPATION

The internal power dissipation of the MCP1700 is a function of input voltage, output voltage and output current. The power dissipation resulting from the quiescent current draw is so low it is insignificant (1.6 µA x $V_{IN}$). The following equation can be used to calculate the internal power dissipation of the LDO.

**EQUATION 6-1:**

$$P_{LDO} = (V_{IN(MAX)} - V_{OUT(MIN)}) \times I_{OUT(MAX)}$$

- $P_{LDO}$ = Internal power dissipation of the LDO Pass device
- $V_{IN(MAX)}$ = Maximum input voltage
- $V_{OUT(MIN)}$ = Minimum output voltage of the LDO

The maximum continuous operating junction temperature specified for the MCP1700 is +125°C. To estimate the internal junction temperature of the MCP1700, the total internal power dissipation is multiplied by the thermal resistance from junction to ambient ($R_{θJA}$). The thermal resistance from junction to ambient for the SOT-23 pin package is estimated at 230°C/W.

**EQUATION 6-2:**

$$T_{J(MAX)} = P_{TOTAL} \times R_{θJA} + T_{A(MAX)}$$

- $T_{J(MAX)}$ = Maximum continuous junction temperature
- $P_{TOTAL}$ = Total power dissipation of the device
- $R_{θJA}$ = Thermal resistance from junction to ambient
- $T_{A(MAX)}$ = Maximum ambient temperature

The maximum power dissipation capability for a package can be calculated given the junction-to-ambient thermal resistance and the maximum ambient temperature for the application. The following equation can be used to determine the maximum internal power dissipation of the package.

**EQUATION 6-3:**

$$P_{D(MAX)} = \frac{(T_{J(MAX)} - T_{A(MAX)})}{R_{θJA}}$$

- $P_{D(MAX)}$ = Maximum power dissipation of the device
- $T_{J(MAX)}$ = Maximum continuous junction temperature
- $T_{A(MAX)}$ = Maximum ambient temperature
- $R_{θJA}$ = Thermal resistance from junction to ambient

**EQUATION 6-4:**

$$T_{J(RISE)} = P_{D(MAX)} \times R_{θJA}$$

- $T_{J(RISE)}$ = Rise in the device’s junction temperature over the ambient temperature
- $P_{TOTAL}$ = Maximum power dissipation of the device
- $R_{θJA}$ = Thermal resistance from junction to ambient
6.3 Voltage Regulator

Internal power dissipation, junction temperature rise, junction temperature and maximum power dissipation are calculated in the following example. The power dissipation resulting from ground current is small enough to be neglected.

6.3.1 POWER DISSIPATION EXAMPLE

**Package**

Package Type = SOT-23

Input Voltage

\[ V_{IN} = 2.3V \text{ to } 3.2V \]

**LDO Output Voltages and Currents**

\[ V_{OUT} = 1.8V \]

\[ I_{OUT} = 150 \text{ mA} \]

**Maximum Ambient Temperature**

\[ T_{A(MAX)} = +40°C \]

**Internal Power Dissipation**

Internal Power dissipation is the product of the LDO output current times the voltage across the LDO (\(V_{IN}\) to \(V_{OUT}\)).

\[ P_{LDO(MAX)} = (V_{IN(MAX)} - V_{OUT(MIN)}) \times I_{OUT(MAX)} \]

\[ P_{LDO} = (3.2V - (0.97 \times 1.8V)) \times 150 \text{ mA} \]

\[ P_{LDO} = 218.1 \text{ milliwatts} \]

**Device Junction Temperature Rise**

The internal junction temperature rise is a function of internal power dissipation and the thermal resistance from junction to ambient for the application. The thermal resistance from junction to ambient (\(R_{JA}\)) is derived from an EIA/JEDEC® standard for measuring thermal resistance for small surface mount packages. The EIA/JEDEC specification is JESD51-7, "High Effective Thermal Conductivity Test Board for Leaded Surface Mount Packages". The standard describes the test method and board specifications for measuring the thermal resistance from junction to ambient. The actual thermal resistance for a particular application can vary depending on many factors, such as copper area and thickness. Refer to AN792, "A Method to Determine How Much Power a SOT-23 Can Dissipate in an Application" (DS00792), for more information regarding this subject.

**Junction Temperature Estimate**

To estimate the internal junction temperature, the calculated temperature rise is added to the ambient or offset temperature. For this example, the worst-case junction temperature is estimated below.

\[ T_J = T_J(RISE) + T_A(MAX) \]

\[ T_J = 218.1 \text{ milliwatts} \times 212.0°C/Watt \]

\[ T_J = 46.2°C \]

**Maximum Package Power Dissipation at +40°C Ambient Temperature**

2x2 DFN-6 (91°C/Watt = \(\theta_{JA}\))

\[ P_D(MAX) = (125°C - 40°C) / 91°C/W \]

\[ P_D(MAX) = 934 \text{ milliwatts} \]

SOT-23 (212.0°C/Watt = \(\theta_{JA}\))

\[ P_D(MAX) = (125°C - 40°C) / 212°C/W \]

\[ P_D(MAX) = 401 \text{ milliwatts} \]

SOT-89 (104°C/Watt = \(\theta_{JA}\))

\[ P_D(MAX) = (125°C - 40°C) / 104°C/W \]

\[ P_D(MAX) = 817 \text{ milliwatts} \]

TO-92 (92°C/Watt = \(\theta_{JA}\))

\[ P_D(MAX) = (125°C - 40°C) / 92°C/W \]

\[ P_D(MAX) = 924 \text{ milliwatts} \]
6.4 Voltage Reference

The MCP1700 can be used not only as a regulator, but also as a low quiescent current voltage reference. In many microcontroller applications, the initial accuracy of the reference can be calibrated using production test equipment or by using a ratio measurement. When the initial accuracy is calibrated, the thermal stability and line regulation tolerance are the only errors introduced by the MCP1700 LDO. The low cost, low quiescent current and small ceramic output capacitor are all advantages when using the MCP1700 as a voltage reference.

![Ratio Metric Reference Diagram]

**FIGURE 6-2:** Using the MCP1700 as a voltage reference.

6.5 Pulsed Load Applications

For some applications, there are pulsed load current events that may exceed the specified 250 mA maximum specification of the MCP1700. The internal current limit of the MCP1700 will prevent high peak load demands from causing non-recoverable damage. The 250 mA rating is a maximum average continuous rating. As long as the average current does not exceed 250 mA, pulsed higher load currents can be applied to the MCP1700. The typical current limit for the MCP1700 is 550 mA (TA + 25°C).
7.0 PACKAGING INFORMATION

7.1 Package Marking Information

<table>
<thead>
<tr>
<th>3-Pin SOT-23</th>
<th>3-Pin SOT-89</th>
<th>3-Pin TO-92</th>
</tr>
</thead>
<tbody>
<tr>
<td>CKNN</td>
<td>CUYYWW</td>
<td>XXXXXXXX</td>
</tr>
<tr>
<td></td>
<td></td>
<td>YWWNNNN</td>
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### Standard

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<th>Symbol</th>
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</thead>
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<td>CK</td>
<td>1.2</td>
</tr>
<tr>
<td>CM</td>
<td>1.8</td>
</tr>
<tr>
<td>CP</td>
<td>2.5</td>
</tr>
<tr>
<td>CQ</td>
<td>2.8</td>
</tr>
<tr>
<td>GC</td>
<td>2.9</td>
</tr>
<tr>
<td>CR</td>
<td>3.0</td>
</tr>
<tr>
<td>CS</td>
<td>3.3</td>
</tr>
<tr>
<td>CU</td>
<td>5.0</td>
</tr>
</tbody>
</table>

* Custom output voltages available upon request. Contact your local Microchip sales office for more information.

#### Example

- **1700 1202E TO**(53) 322256

---

### Legend:

- XX...X  Customer-specific information
- Y  Year code (last digit of calendar year)
- YY  Year code (last 2 digits of calendar year)
- WW  Week code (week of January 1 is week ‘01’)
- NNN  Alphanumeric traceability code
- **(53)** Pb-free JEDEC® designator for Matte Tin (Sn)
- *  This package is Pb-free. The Pb-free JEDEC designator (53) can be found on the outer packaging for this package.

**Note:** In the event the full Microchip part number cannot be marked on one line, it will be carried over to the next line, thus limiting the number of available characters for customer-specific information.
3-Lead Plastic Small Outline Transistor (TT) [SOT-23]

**Note:** For the most current package drawings, please see the Microchip Packaging Specification located at http://www.microchip.com/packaging

<table>
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<tr>
<th>Units</th>
<th>Dimension Limits</th>
<th>MIN</th>
<th>NOM</th>
<th>MAX</th>
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</thead>
<tbody>
<tr>
<td>Number of Pins</td>
<td>N</td>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lead Pitch</td>
<td>e</td>
<td>0.79</td>
<td>0.95</td>
<td>1.02</td>
</tr>
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<td>Outside Lead Pitch</td>
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<td>0.01</td>
<td>1.90</td>
<td>2.64</td>
</tr>
<tr>
<td>Overall Height</td>
<td>A</td>
<td>0.89</td>
<td>–</td>
<td>1.12</td>
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<td>A2</td>
<td>1.16</td>
<td>1.30</td>
<td>1.40</td>
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<td>Standoff</td>
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<td>0.10</td>
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<td>Overall Width</td>
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<td>2.10</td>
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<td>0.50</td>
<td>0.60</td>
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<tr>
<td>Foot Length</td>
<td>L</td>
<td>0.08</td>
<td>–</td>
<td>0.20</td>
</tr>
<tr>
<td>Foot Angle</td>
<td>φ</td>
<td>0°</td>
<td>–</td>
<td>10°</td>
</tr>
<tr>
<td>Lead Thickness</td>
<td>c</td>
<td>0.30</td>
<td>–</td>
<td>0.54</td>
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<tr>
<td>Lead Width</td>
<td>b</td>
<td></td>
<td></td>
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**Notes:**
1. Dimensions D and E1 do not include mold flash or protrusions. Mold flash or protrusions shall not exceed 0.25 mm per side.
2. Dimensioning and tolerancing per ASME Y14.5M.
   BSC: Basic Dimension. Theoretically exact value shown without tolerances.
3-Lead Plastic Small Outline Transistor (TT) [SOT-23]

**Note:** For the most current package drawings, please see the Microchip Packaging Specification located at http://www.microchip.com/packaging

---

**RECOMMENDED LAND PATTERN**

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<tr>
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<tr>
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<tr>
<td>Contact Pitch</td>
<td>E</td>
</tr>
<tr>
<td>Contact Pad Spacing</td>
<td>C</td>
</tr>
<tr>
<td>Contact Pad Width (X3)</td>
<td>X</td>
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<tr>
<td>Contact Pad Length (X3)</td>
<td>Y</td>
</tr>
<tr>
<td>Distance Between Pads</td>
<td>G</td>
</tr>
<tr>
<td>Overall Width</td>
<td>Z</td>
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**Notes:**

1. Dimensioning and tolerancing per ASME Y14.5M
   BSC: Basic Dimension. Theoretically exact value shown without tolerances.

Microchip Technology Drawing No. C04-2104A
3-Lead Plastic Small Outline Transistor (MB) - [SOT-89]

Note: For the most current package drawings, please see the Microchip Packaging Specification located at http://www.microchip.com/packaging

Optional backside patterns — parts may be supplied with any pattern shown.
3-Lead Plastic Small Outline Transistor (MB) - [SOT-89]

**Note:** For the most current package drawings, please see the Microchip Packaging Specification located at http://www.microchip.com-packaging

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<td>Pitch</td>
<td>e</td>
</tr>
<tr>
<td>Outside Lead Pitch</td>
<td>e1</td>
</tr>
<tr>
<td>Overall Height</td>
<td>A</td>
</tr>
<tr>
<td>Overall Width</td>
<td>H</td>
</tr>
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<td>Molded Package Width at Base</td>
<td>E</td>
</tr>
<tr>
<td>Molded Package Width at Top</td>
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</tr>
<tr>
<td>Tab Length (Option B)</td>
<td>D1B</td>
</tr>
<tr>
<td>Tab Length (Option C)</td>
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<td>Lead Thickness</td>
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</tr>
<tr>
<td>Lead 2 Width</td>
<td>b</td>
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<tr>
<td>Leads 1 &amp; 3 Width</td>
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**Notes:**

1. Dimensions D and E do not include mold flash or protrusions. Mold flash or protrusions shall not exceed 0.127mm per side.
2. Dimensioning and tolerancing per ASME Y14.5M
   BSC: Basic Dimension. Theoretically exact value shown without tolerances.
3-Lead Plastic Small Outline Transistor (MB) - [SOT-89]

**Note:** For the most current package drawings, please see the Microchip Packaging Specification located at http://www.microchip.com/packaging

RECOMMENDED LAND PATTERN

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<td>C</td>
<td>1.50 (BSC)</td>
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<td></td>
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<tr>
<td>X (3 PLACES)</td>
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<td>X1</td>
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<td>G (2 PLACES)</td>
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<td>Y (2 PLACES)</td>
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**Notes:**

1. Dimensioning and tolerancing per ASME Y14.5M
   BSC: Basic Dimension. Theoretically exact value shown without tolerances.
3-Lead Plastic Transistor Outline (TO) [TO-92]

**Note:** For the most current package drawings, please see the Microchip Packaging Specification located at [http://www.microchip.com/packaging](http://www.microchip.com/packaging)
3-Lead Plastic Transistor Outline (TO) [TO-92]

Note: For the most current package drawings, please see the Microchip Packaging Specification located at http://www.microchip.com/packaging

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<td>Pitch</td>
<td>e</td>
</tr>
<tr>
<td>Bottom to Package Flat</td>
<td>D</td>
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<tr>
<td>Overall Width</td>
<td>E</td>
</tr>
<tr>
<td>Overall Length</td>
<td>A</td>
</tr>
<tr>
<td>Molded Package Radius</td>
<td>R</td>
</tr>
<tr>
<td>Tip to Seating Plane</td>
<td>L</td>
</tr>
<tr>
<td>Lead Thickness</td>
<td>c</td>
</tr>
<tr>
<td>Lead Width</td>
<td>b</td>
</tr>
</tbody>
</table>

Notes:
1. Dimensions D and E do not include mold flash or protrusions. Mold flash or protrusions shall not exceed .005" per side.
2. Dimensioning and tolerancing per ASME Y14.5M
   BSC: Basic Dimension. Theoretically exact value shown without tolerances.
6-Lead Plastic Dual Flat, No Lead Package (MA[Y]) - 2x2x0.9mm Body [DFN]

Note: For the most current package drawings, please see the Microchip Packaging Specification located at http://www.microchip.com/packaging
6-Lead Plastic Dual Flat, No Lead Package (MA[Y]) - 2x2x0.9mm Body [DFN]

**Note:** For the most current package drawings, please see the Microchip Packaging Specification located at http://www.microchip.com/packaging

<table>
<thead>
<tr>
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<tbody>
<tr>
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<tr>
<td>Number of Pins</td>
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</tr>
<tr>
<td>Pitch</td>
<td>e</td>
</tr>
<tr>
<td>Overall Height</td>
<td>A</td>
</tr>
<tr>
<td>Standoff</td>
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<tr>
<td>Contact Thickness</td>
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<tr>
<td>Overall Length</td>
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<td>Exposed Pad Length</td>
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<td>Exposed Pad Width</td>
<td>E2</td>
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<tr>
<td>Contact Width</td>
<td>b</td>
</tr>
<tr>
<td>Contact Length</td>
<td>L</td>
</tr>
<tr>
<td>Contact-to-Exposed Pad</td>
<td>K</td>
</tr>
</tbody>
</table>

**Notes:**
1. Pin 1 visual index feature may vary, but must be located within the hatched area.
2. Package may have one or more exposed tie bars at ends.
3. Package is saw singulated.
4. Dimensioning and tolerancing per ASME Y14.5M.
   - BSC: Basic Dimension. Theoretically exact value shown without tolerances.
   - REF: Reference Dimension, usually without tolerance, for information purposes only.

Microchip Technology Drawing C04-120C Sheet 2 of 2
APPENDIX A:  REVISION HISTORY

Revision E (November 2018)
The following is the list of modifications:
• Added information related to the 2.9V option throughout the document
• Updated Features.
• Updated DC Characteristics.
• Updated Temperature Specifications.
• Updated Power Dissipation example in Section 6.3 “Voltage Regulator”.
• Updated Package Marking Information in Section 7.0 “Packaging Information”.
• Updated Product Identification System.

Revision D (September 2016)
The following is the list of modifications:
• Updated DC Characteristics.
• Updated Product Identification System.
• Minor typographical changes.

Revision C (October 2013)
The following is the list of modifications:
• Added new package to the family (2x2 DFN-6) and related information throughout the document.
• Updated thermal package resistance information in Temperature Specifications.
• Updated Section 3.0 “Pin Descriptions”.
• Added package markings and drawings for the 2x2 DFN-6 package.
• Added information related to the 2.8V option throughout the document.
• Updated Product Identification System.
• Minor typographical changes.

Revision B (February 2007)
• Updated Packaging Information.
• Corrected Product Identification System.
• Changed X5R to X7R in Notes to DC Characteristics, Temperature Specifications, and Section 2.0 “Typical Performance Curves”.

Revision A (November 2005)
• Original release of this document.
MCP1700

PRODUCT IDENTIFICATION SYSTEM

To order or obtain information, e.g., on pricing or delivery, refer to the factory or the listed sales office.

<table>
<thead>
<tr>
<th>PART NO.</th>
<th>X-</th>
<th>Voltage</th>
<th>Tolerance</th>
<th>Temp. Range</th>
<th>Package</th>
</tr>
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<tbody>
<tr>
<td>MCP1700</td>
<td></td>
<td>XXX</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Tape &amp; Reel</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Device: MCP1700: Low Quiescent Current LDO

Tape and Reel: T: Tape and Reel only applies to SOT-23 and SOT-89 devices

Standard Output Voltage: *

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<th>Voltage</th>
<th>Tolerance</th>
<th>Temp. Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>120</td>
<td>2</td>
<td>-40°C to +125°C (Standard)</td>
</tr>
<tr>
<td>180</td>
<td>2</td>
<td>-40°C to +125°C (Standard)</td>
</tr>
<tr>
<td>250</td>
<td>2</td>
<td>-40°C to +125°C (Standard)</td>
</tr>
<tr>
<td>280</td>
<td>2</td>
<td>-40°C to +125°C (Standard)</td>
</tr>
<tr>
<td>290</td>
<td>2</td>
<td>-40°C to +125°C (Standard)</td>
</tr>
<tr>
<td>300</td>
<td>2</td>
<td>-40°C to +125°C (Standard)</td>
</tr>
<tr>
<td>330</td>
<td>2</td>
<td>-40°C to +125°C (Standard)</td>
</tr>
<tr>
<td>500</td>
<td>2</td>
<td>-40°C to +125°C (Standard)</td>
</tr>
</tbody>
</table>

* Custom output voltages available upon request. Contact your local Microchip sales office for more information

Tolerance: 2 = 2% (Standard)

Temperature Range: E = -40°C to +125°C (Extended)

<table>
<thead>
<tr>
<th>Package</th>
<th>Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>MAY</td>
<td>Plastic Small Outline Transistor (DFN), 6-lead</td>
</tr>
<tr>
<td>MB</td>
<td>Plastic Small Outline Transistor (SOT-89), 3-lead</td>
</tr>
<tr>
<td>TO</td>
<td>Plastic Small Outline Transistor (TO-92), 3-lead</td>
</tr>
<tr>
<td>TT</td>
<td>Plastic Small Outline Transistor (SOT-23), 3-lead</td>
</tr>
</tbody>
</table>

Examples:

- **2x2 DFN-6 Package:**
  a) MCP1700T-1202E/MAY: 1.2V \( V_{\text{OUT}} \)
  b) MCP1700T-1802E/MAY: 1.8V \( V_{\text{OUT}} \)
  c) MCP1700T-2502E/MAY: 2.5V \( V_{\text{OUT}} \)
  d) MCP1700T-2802E/MAY: 2.8V \( V_{\text{OUT}} \)
  e) MCP1700T-3002E/MAY: 3.0V \( V_{\text{OUT}} \)
  f) MCP1700T-3302E/MAY: 3.3V \( V_{\text{OUT}} \)
  g) MCP1700T-5002E/MAY: 5.0V \( V_{\text{OUT}} \)

- **SOT-89 Package:**
  a) MCP1700T-1202E/MB: 1.2V \( V_{\text{OUT}} \)
  b) MCP1700T-1802E/MB: 1.8V \( V_{\text{OUT}} \)
  c) MCP1700T-2502E/MB: 2.5V \( V_{\text{OUT}} \)
  d) MCP1700T-2802E/MB: 2.8V \( V_{\text{OUT}} \)
  e) MCP1700T-3002E/MB: 3.0V \( V_{\text{OUT}} \)
  f) MCP1700T-3302E/MB: 3.3V \( V_{\text{OUT}} \)
  g) MCP1700T-5002E/MB: 5.0V \( V_{\text{OUT}} \)

- **TO-92 Package:**
  a) MCP1700-1202E/TO: 1.2V \( V_{\text{OUT}} \)
  b) MCP1700-1802E/TO: 1.8V \( V_{\text{OUT}} \)
  c) MCP1700-2502E/TO: 2.5V \( V_{\text{OUT}} \)
  d) MCP1700-2802E/TO: 2.8V \( V_{\text{OUT}} \)
  e) MCP1700-3002E/TO: 3.0V \( V_{\text{OUT}} \)
  f) MCP1700-3302E/TO: 3.3V \( V_{\text{OUT}} \)
  g) MCP1700-5002E/TO: 5.0V \( V_{\text{OUT}} \)

- **SOT-23 Package:**
  a) MCP1700T-1202E/TT: 1.2V \( V_{\text{OUT}} \)
  b) MCP1700T-1802E/TT: 1.8V \( V_{\text{OUT}} \)
  c) MCP1700T-2502E/TT: 2.5V \( V_{\text{OUT}} \)
  d) MCP1700T-2802E/TT: 2.8V \( V_{\text{OUT}} \)
  e) MCP1700T-2902E/TT: 2.9V \( V_{\text{OUT}} \)
  f) MCP1700T-3002E/TT: 3.0V \( V_{\text{OUT}} \)
  g) MCP1700T-3302E/TT: 3.3V \( V_{\text{OUT}} \)
  h) MCP1700T-5002E/TT: 5.0V \( V_{\text{OUT}} \)
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