

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

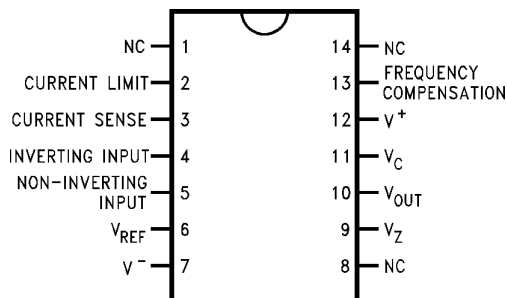
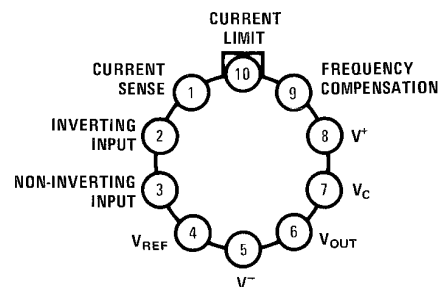
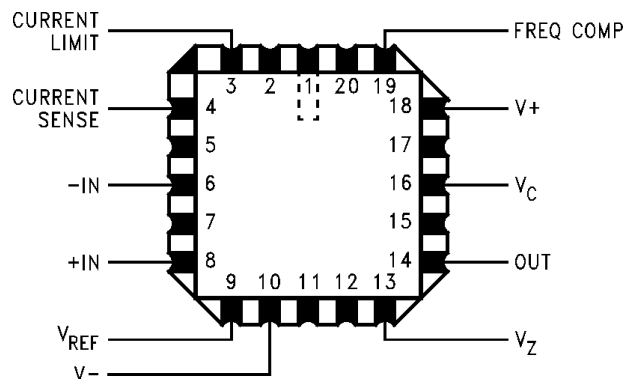


Figure 1. Top View
CDIP Package or PDIP Package
 See Package J or NFF0014A

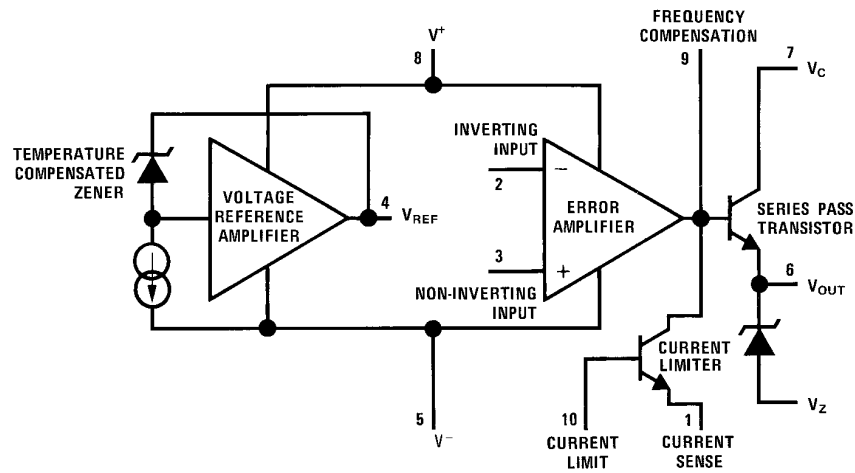


Note: Pin 5 connected to case.

Figure 2. Top View
TO-100
 See Package LME

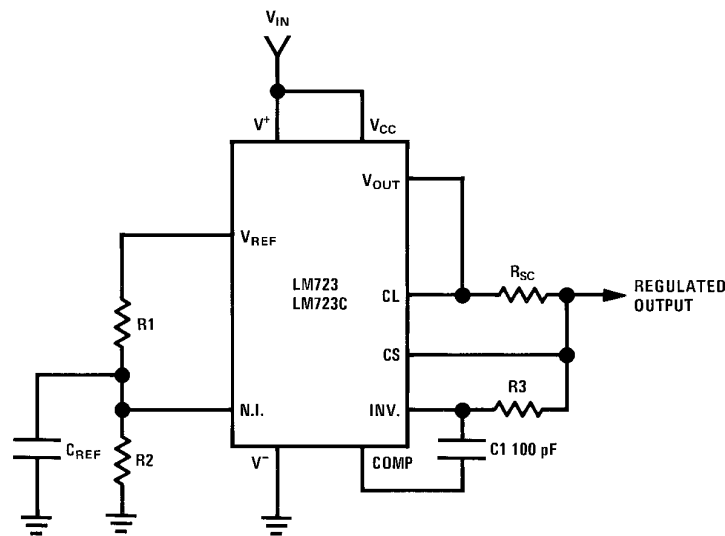


Equivalent Circuit*



*Pin numbers refer to metal can package.

Typical Application



Note: $R3 = \frac{R1 R2}{R1 + R2}$

for minimum temperature drift.

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 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⁾⁽²⁾

| | |
|--|-----------------|
| 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 ⁽³⁾ | 800 mW |
| CDIP ⁽³⁾ | 900 mW |
| PDIP ⁽³⁾ | 660 mW |
| Operating Temperature Range | |
| LM723 | -55°C to +150°C |
| LM723C | 0°C to +70°C |
| Storage Temperature Range Metal Can | |
| PDIP | -65°C to +150°C |
| Lead Temperature (Soldering, 4 sec. max.) | |
| Hermetic Package | 300°C |
| Plastic Package | 260°C |
| ESD Tolerance | |
| | 1200V |
| (Human body model, 1.5 k Ω 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⁽¹⁾⁽²⁾⁽³⁾⁽⁴⁾

| Parameter | Conditions | LM723 | | | LM723C | | | Units |
|------------------|--|-------|------|------|--------|------|-----|-------------|
| | | Min | Typ | Max | Min | Typ | Max | |
| Line Regulation | $V_{IN} = 12V$ to $V_{IN} = 15V$ | | 0.01 | 0.1 | | 0.01 | 0.1 | % V_{OUT} |
| | $-55^\circ C \leq T_A \leq +125^\circ C$ | | | 0.3 | | | | % V_{OUT} |
| | $0^\circ C \leq T_A \leq +70^\circ C$ | | | | | | 0.3 | % V_{OUT} |
| | $V_{IN} = 12V$ to $V_{IN} = 40V$ | | 0.02 | 0.2 | | 0.1 | 0.5 | % V_{OUT} |
| Load Regulation | $I_L = 1$ mA to $I_L = 50$ mA | | 0.03 | 0.15 | | 0.03 | 0.2 | % V_{OUT} |
| | $-55^\circ C \leq T_A \leq +125^\circ C$ | | | 0.6 | | | | % V_{OUT} |
| | $0^\circ C \leq T_A \leq +70^\circ C$ | | | | | | 0.6 | % V_{OUT} |
| Ripple Rejection | $f = 50$ Hz to 10 kHz, $C_{REF} = 0$ | | 74 | | | 74 | | dB |
| | $f = 50$ Hz to 10 kHz, $C_{REF} = 5$ μF | | 86 | | | 86 | | dB |

- (1) Unless otherwise specified, $T_A = 25^\circ C$, $V_{IN} = V^+ = V_C = 12V$, $V^- = 0$, $V_{OUT} = 5V$, $I_L = 1$ mA, $R_{SC} = 0$, $C_1 = 100$ pF, $C_{REF} = 0$ and divider impedance as seen by error amplifier ≤ 10 k Ω 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) 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.

ELECTRICAL CHARACTERISTICS⁽¹⁾⁽²⁾⁽³⁾⁽⁴⁾ (continued)

| Parameter | Conditions | LM723 | | | LM723C | | | Units |
|--|--|-------|-------|-------|--------|-------|-------|------------------|
| | | Min | Typ | Max | Min | Typ | Max | |
| Average Temperature Coefficient of Output Voltage ⁽⁵⁾ | $-55^{\circ}\text{C} \leq T_A \leq +125^{\circ}\text{C}$ | | 0.002 | 0.015 | | | | %/°C |
| | $0^{\circ}\text{C} \leq T_A \leq +70^{\circ}\text{C}$ | | | | | 0.003 | 0.015 | %/°C |
| Short Circuit Current Limit | $R_{SC} = 10\Omega, V_{OUT} = 0$ | | 65 | | | 65 | | mA |
| Reference Voltage | | 6.95 | 7.15 | 7.35 | 6.80 | 7.15 | 7.50 | V |
| Output Noise Voltage | BW = 100 Hz to 10 kHz, $C_{REF} = 0$ | | 86 | | | 86 | | μVrms |
| | BW = 100 Hz to 10 kHz, $C_{REF} = 5 \mu\text{F}$ | | 2.5 | | | 2.5 | | μVrms |
| Long Term Stability | | | 0.05 | | | 0.05 | | %/1000 hrs |
| Standby Current Drain | $I_L = 0, V_{IN} = 30\text{V}$ | | 1.7 | 3.5 | | 1.7 | 4.0 | mA |
| Input Voltage Range | | 9.5 | | 40 | 9.5 | | 40 | V |
| Output Voltage Range | | 2.0 | | 37 | 2.0 | | 37 | V |
| Input-Output Voltage Differential | | 3.0 | | 38 | 3.0 | | 38 | V |
| θ_{JA} | PDIP | | | | | 105 | | °C/W |
| θ_{JA} | CDIP | | 150 | | | | | °C/W |
| θ_{JA} | H10C Board Mount in Still Air | | 165 | | | 165 | | °C/W |
| θ_{JA} | H10C Board Mount in 400 LF/Min Air Flow | | 66 | | | 66 | | °C/W |
| θ_{JC} | | | 22 | | | 22 | | °C/W |

(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

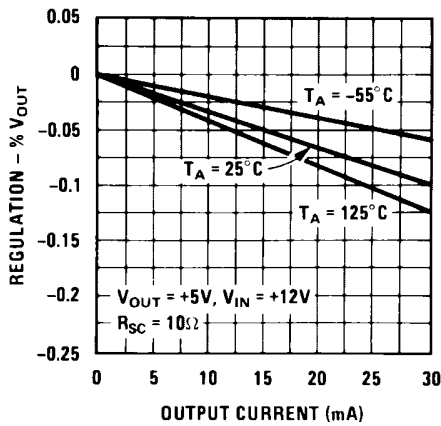


Figure 5.

Load Regulation Characteristics with Current Limiting

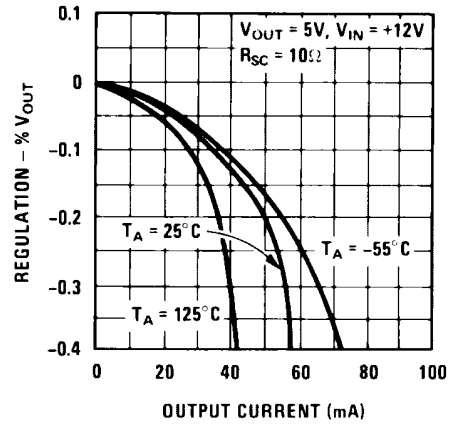


Figure 6.

Load & Line Regulation vs Input-Output Voltage Differential

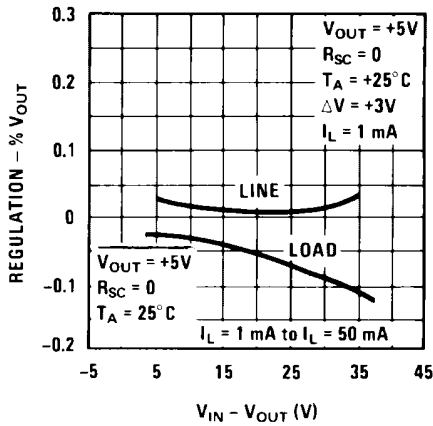


Figure 7.

Current Limiting Characteristics

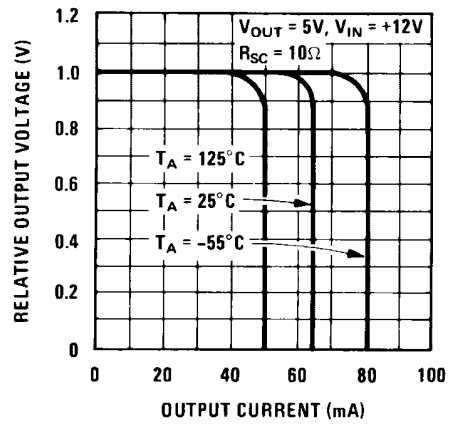


Figure 8.

Current Limiting Characteristics vs Junction Temperature

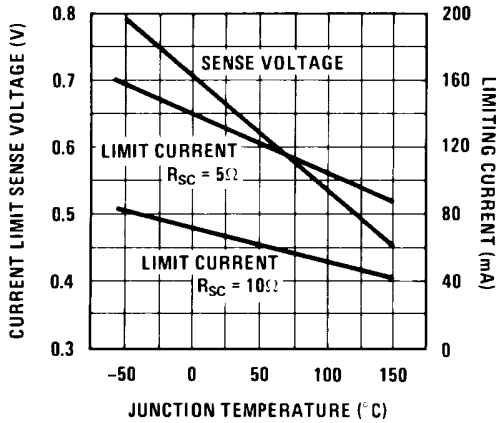


Figure 9.

Standby Current Drain vs Input Voltage

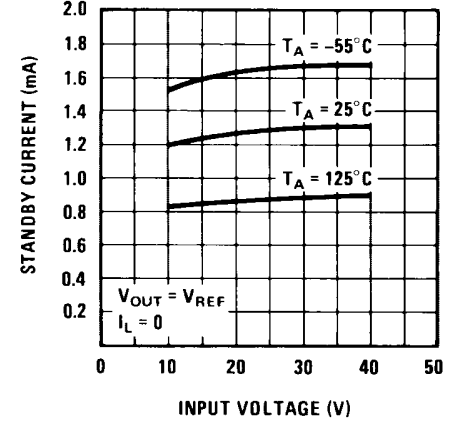


Figure 10.

TYPICAL PERFORMANCE CHARACTERISTICS (continued)

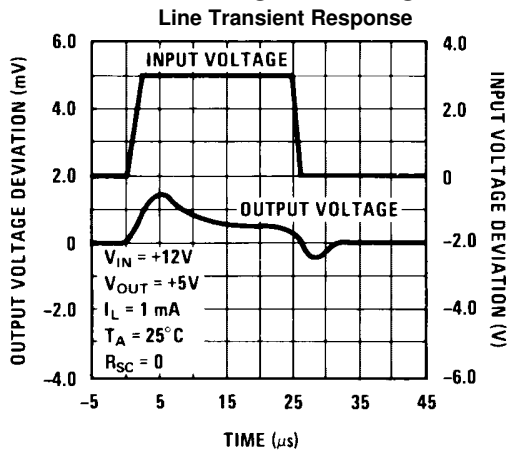


Figure 11.

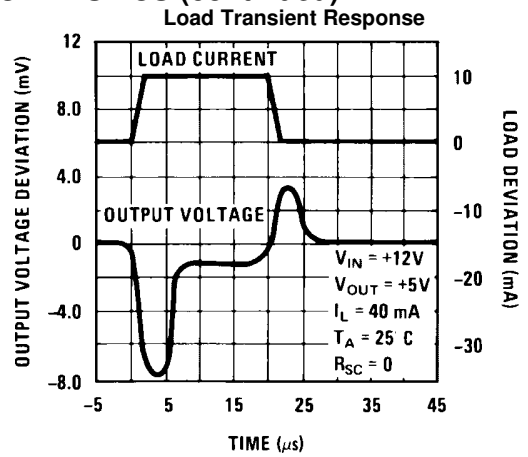


Figure 12.

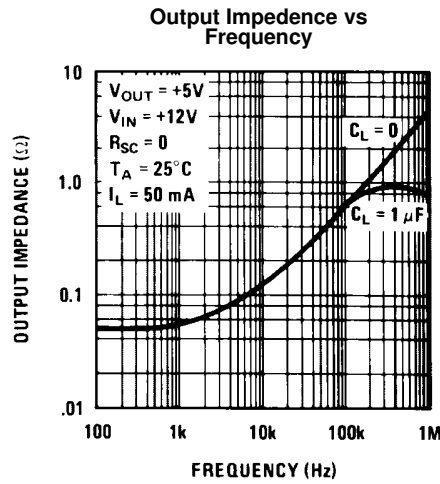


Figure 13.

MAXIMUM POWER RATINGS

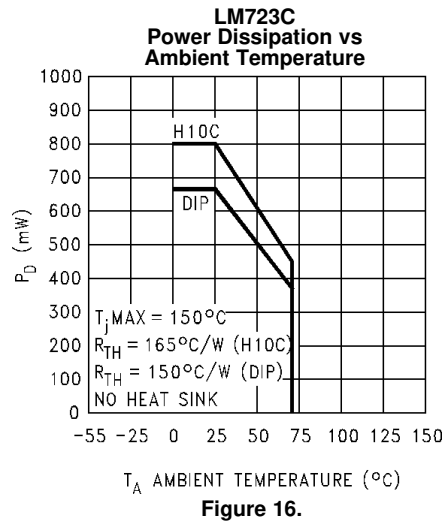
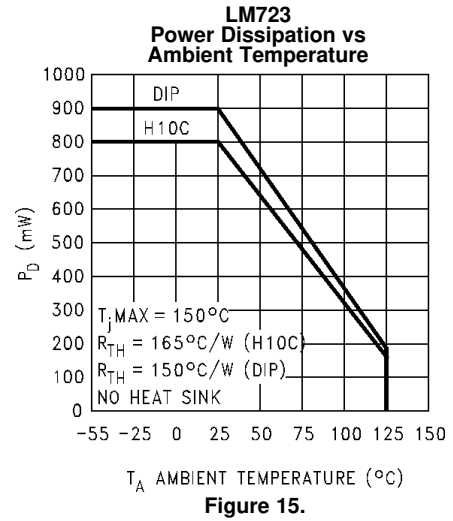
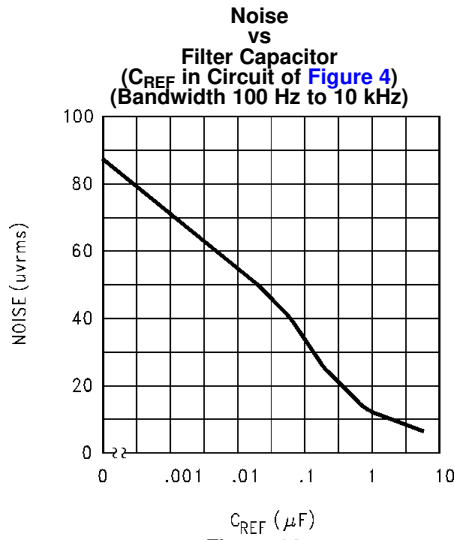


Table 1. Resistor Values (kΩ) for Standard Output Voltage

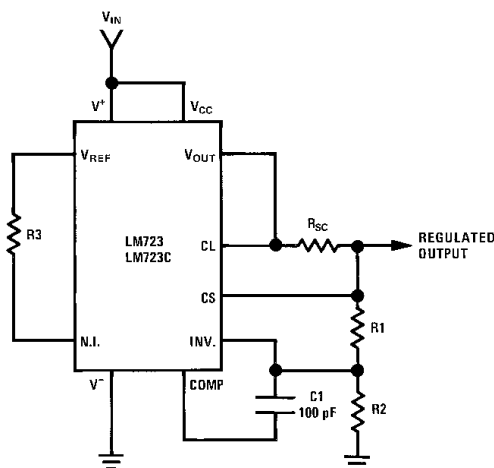
| Positive Output Voltage | Applicable Figures See ⁽²⁾ | Fixed Output ±5% | | Output Adjustable ±10% ⁽¹⁾ | | | Negative Output Voltage | Applicable Figures | Fixed Output ±5% | | 5% Output Adjustable ±10% | | |
|-------------------------|--|------------------|------|---------------------------------------|-----|-----|-------------------------|------------------------|------------------|------|---------------------------|-----|------|
| | | R1 | R2 | R1 | P1 | R2 | | | R1 | R2 | R1 | P1 | R2 |
| +3.0 | Figure 4, Figure 19, Figure 21, Figure 24, Figure 27 (Figure 19) | 4.12 | 3.01 | 1.8 | 0.5 | 1.2 | +100 | Figure 22 | 3.57 | 102 | 2.2 | 10 | 91 |
| +3.6 | Figure 4, Figure 19, Figure 21, Figure 24, Figure 27 (Figure 19) | 3.57 | 3.65 | 1.5 | 0.5 | 1.5 | +250 | Figure 22 | 3.57 | 255 | 2.2 | 10 | 240 |
| +5.0 | Figure 4, Figure 19, Figure 21, Figure 24, Figure 27 (Figure 19) | 2.15 | 4.99 | 0.75 | 0.5 | 2.2 | -6 ⁽³⁾ | Figure 18, (Figure 25) | 3.57 | 2.43 | 1.2 | 0.5 | 0.75 |
| +6.0 | Figure 4, Figure 19, Figure 21, Figure 24, Figure 27 (Figure 19) | 1.15 | 6.04 | 0.5 | 0.5 | 2.7 | -9 | Figure 18, Figure 25 | 3.48 | 5.36 | 1.2 | 0.5 | 2.0 |
| +9.0 | Figure 17, Figure 19, (Figure 19, Figure 21, Figure 24, Figure 27) | 1.87 | 7.15 | 0.75 | 1.0 | 2.7 | -12 | Figure 18, Figure 25 | 3.57 | 8.45 | 1.2 | 0.5 | 3.3 |
| +12 | Figure 17, Figure 19, (Figure 19, Figure 21, Figure 24, Figure 27) | 4.87 | 7.15 | 2.0 | 1.0 | 3.0 | -15 | Figure 18, Figure 25 | 3.65 | 11.5 | 1.2 | 0.5 | 4.3 |
| +15 | Figure 17, Figure 19, (Figure 19, Figure 21, Figure 24, Figure 27) | 7.87 | 7.15 | 3.3 | 1.0 | 3.0 | -28 | Figure 18, Figure 25 | 3.57 | 24.3 | 1.2 | 0.5 | 10 |
| +28 | Figure 17, Figure 19, (Figure 19, Figure 21, Figure 24, Figure 27) | 21.0 | 7.15 | 5.6 | 1.0 | 2.0 | -45 | Figure 23 | 3.57 | 41.2 | 2.2 | 10 | 33 |
| +45 | Figure 22 | 3.57 | 48.7 | 2.2 | 10 | 39 | -100 | Figure 23 | 3.57 | 97.6 | 2.2 | 10 | 91 |
| +75 | Figure 22 | 3.57 | 78.7 | 2.2 | 10 | 68 | -250 | Figure 23 | 3.57 | 249 | 2.2 | 10 | 240 |

- (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 V_{CC} must be connected to a +3V or greater supply.

Table 2. Formulae for Intermediate Output Voltages

| | | |
|--|--|---|
| Outputs from +2 to +7 volts (Figure 4 Figure 19 Figure 20 Figure 21 Figure 24 Figure 27) $V_{OUT} = \left(V_{REF} \times \frac{R2}{R1 + R2} \right)$ | Outputs from +4 to +250 volts (Figure 22) $V_{OUT} = \left(\frac{V_{REF}}{2} \times \frac{R2 - R1}{R1} \right); R3 = R4$ | Current Limiting $I_{LIMIT} = \frac{V_{SENSE}}{R_{SC}}$ |
| Outputs from +7 to +37 volts (Figure 17 Figure 19 Figure 20 Figure 21 Figure 24 Figure 27) $V_{OUT} = \left(V_{REF} \times \frac{R1 + R2}{R2} \right)$ | Outputs from -6 to -250 volts (Figure 18 Figure 23 Figure 25) $V_{OUT} = \left(\frac{V_{REF}}{2} \times \frac{R1 + R2}{R1} \right); R3 = R4$ | Foldback Current Limiting $I_{KNEE} = \left(\frac{V_{OUT} R3}{R_{SC} R4} + \frac{V_{SENSE} (R3 + R4)}{R_{SC} R4} \right)$ $I_{SHORT\ CKT} = \left(\frac{V_{SENSE}}{R_{SC}} \times \frac{R3 + R4}{R4} \right)$ |

TYPICAL APPLICATIONS



Note: $R3 = \frac{R1 R2}{R1 + R2}$

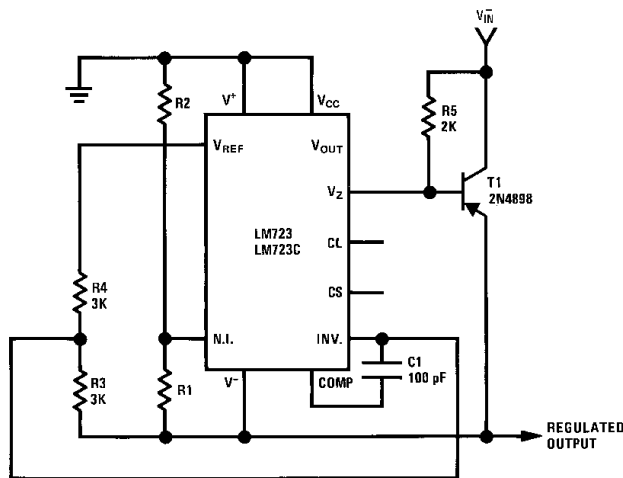
for minimum temperature drift.

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 ($\Delta I_L = 50 \text{ mA}$) | 4.5 mV |

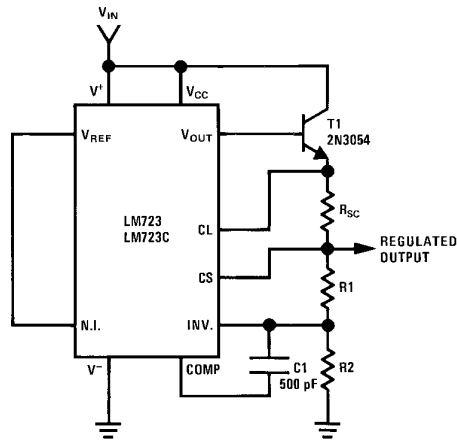
Figure 17. Basic High Voltage Regulator ($V_{OUT} = 7$ to 37 Volts)



Typical Performance

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

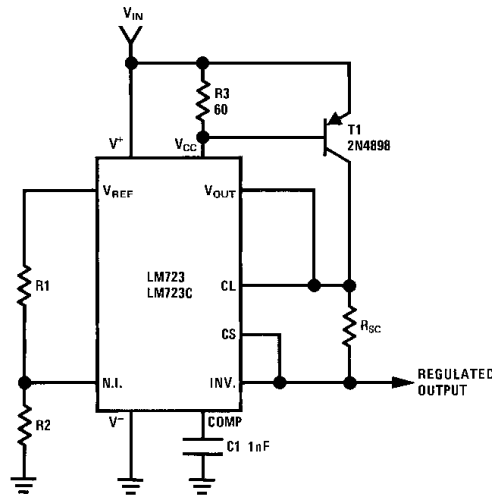
Figure 18. Negative Voltage Regulator



Typical Performance

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

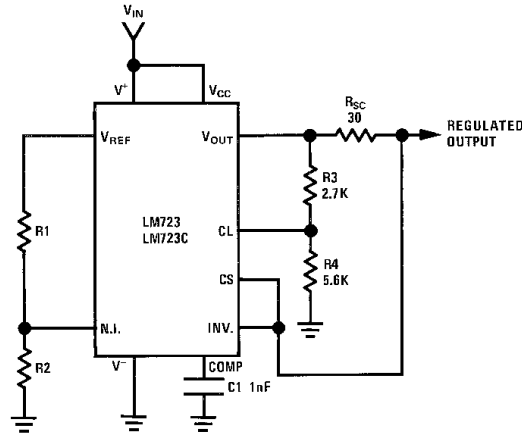
Figure 19. Positive Voltage Regulator (External NPN Pass Transistor)



Typical Performance

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

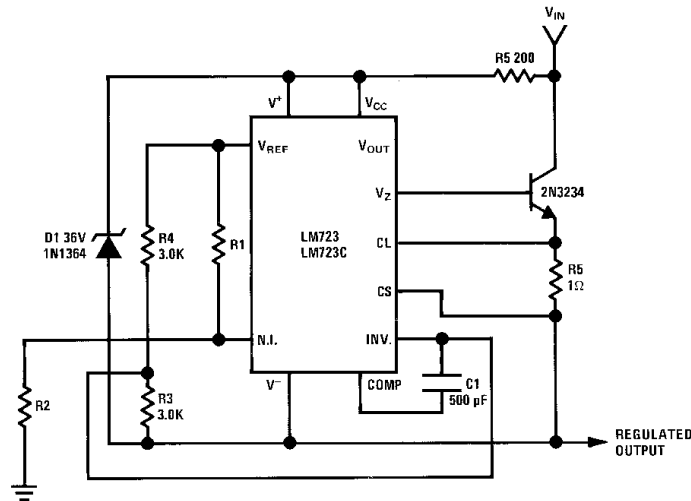
Figure 20. Positive Voltage Regulator (External PNP Pass Transistor)



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 |

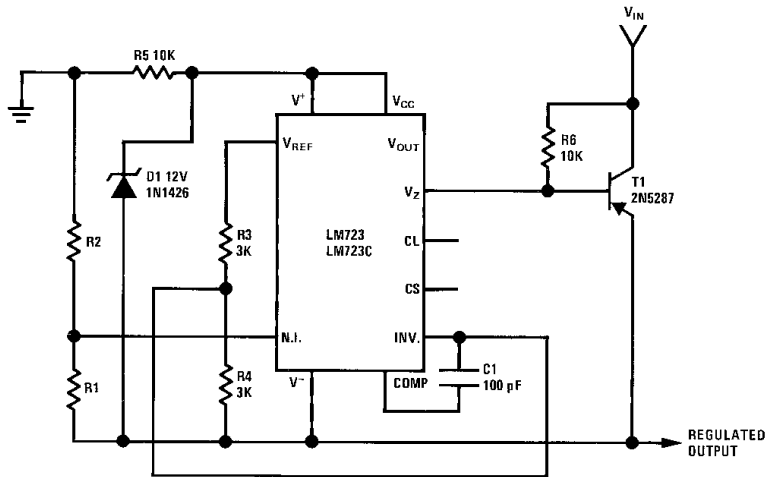
Figure 21. Foldback Current Limiting



Typical Performance

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

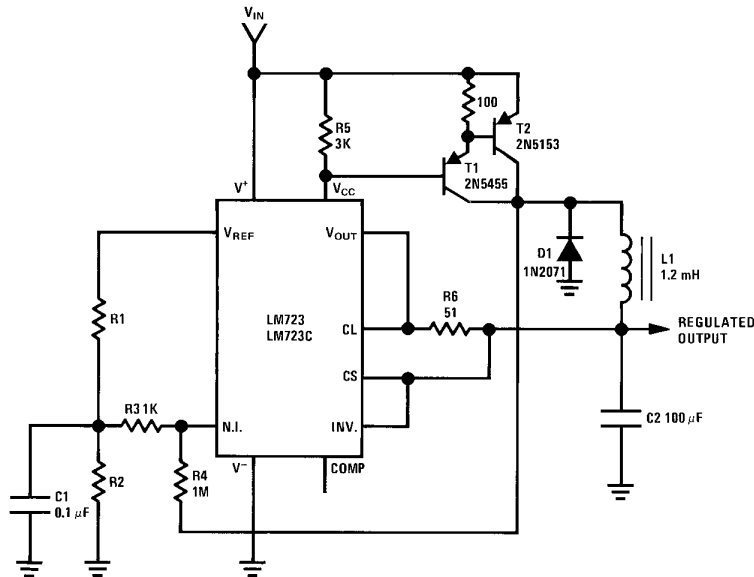
Figure 22. Positive Floating Regulator



Typical Performance

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

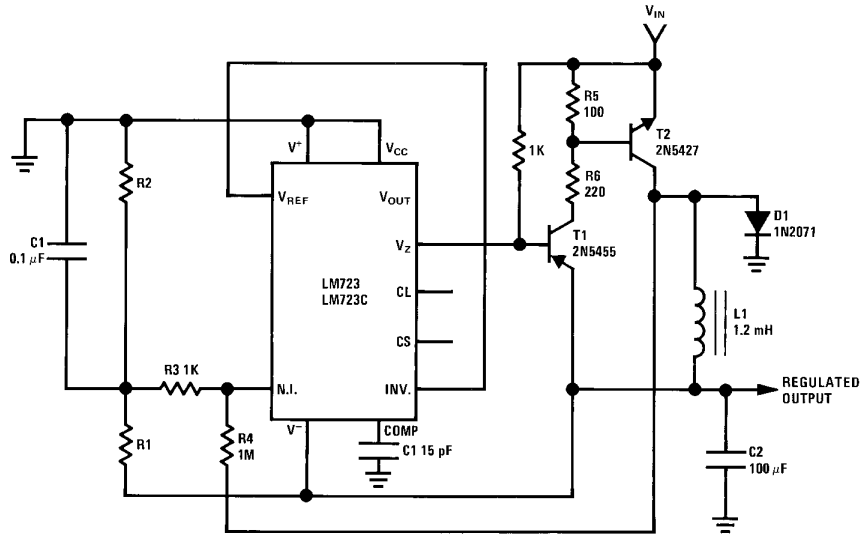
Figure 23. Negative Floating Regulator



Typical Performance

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

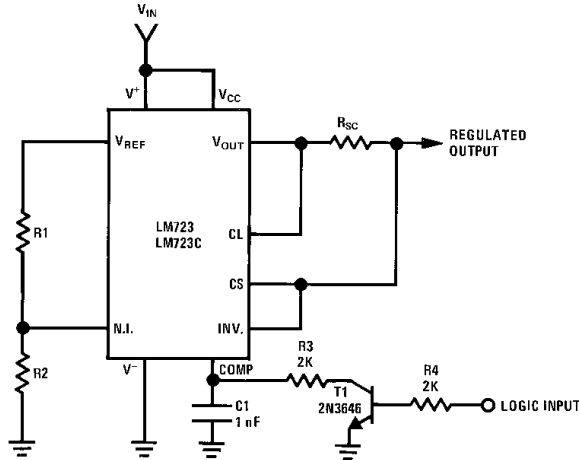
Figure 24. Positive Switching Regulator



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

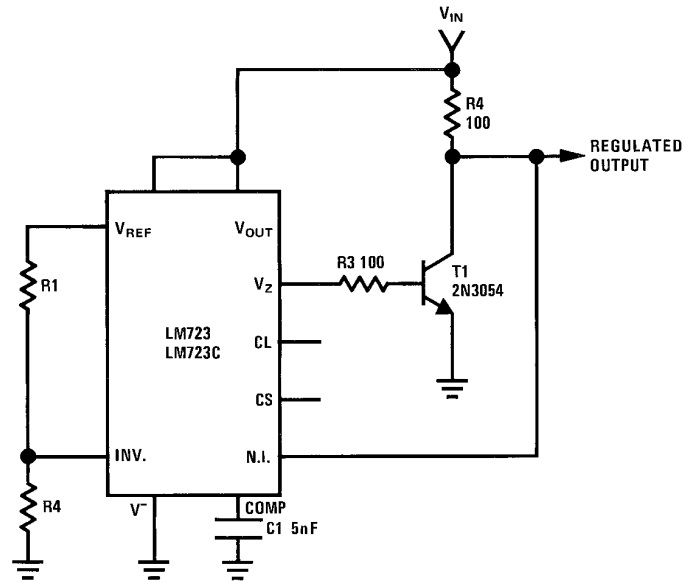


Note: Current limit transistor may be used for shutdown if current limiting is not required.

Typical Performance

| | |
|--|--------|
| Regulated Output Voltage | +5V |
| Line Regulation ($\Delta V_{IN} = 3V$) | 0.5 mV |
| Load Regulation ($\Delta I_L = 50 \text{ mA}$) | 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 ($\Delta I_L = 100 \text{ mA}$) | 1.5 mV |

Figure 27. Shunt Regulator

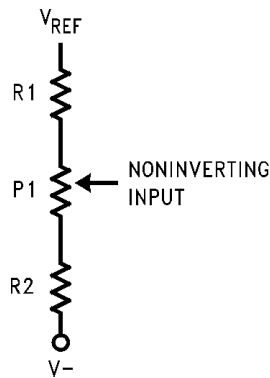
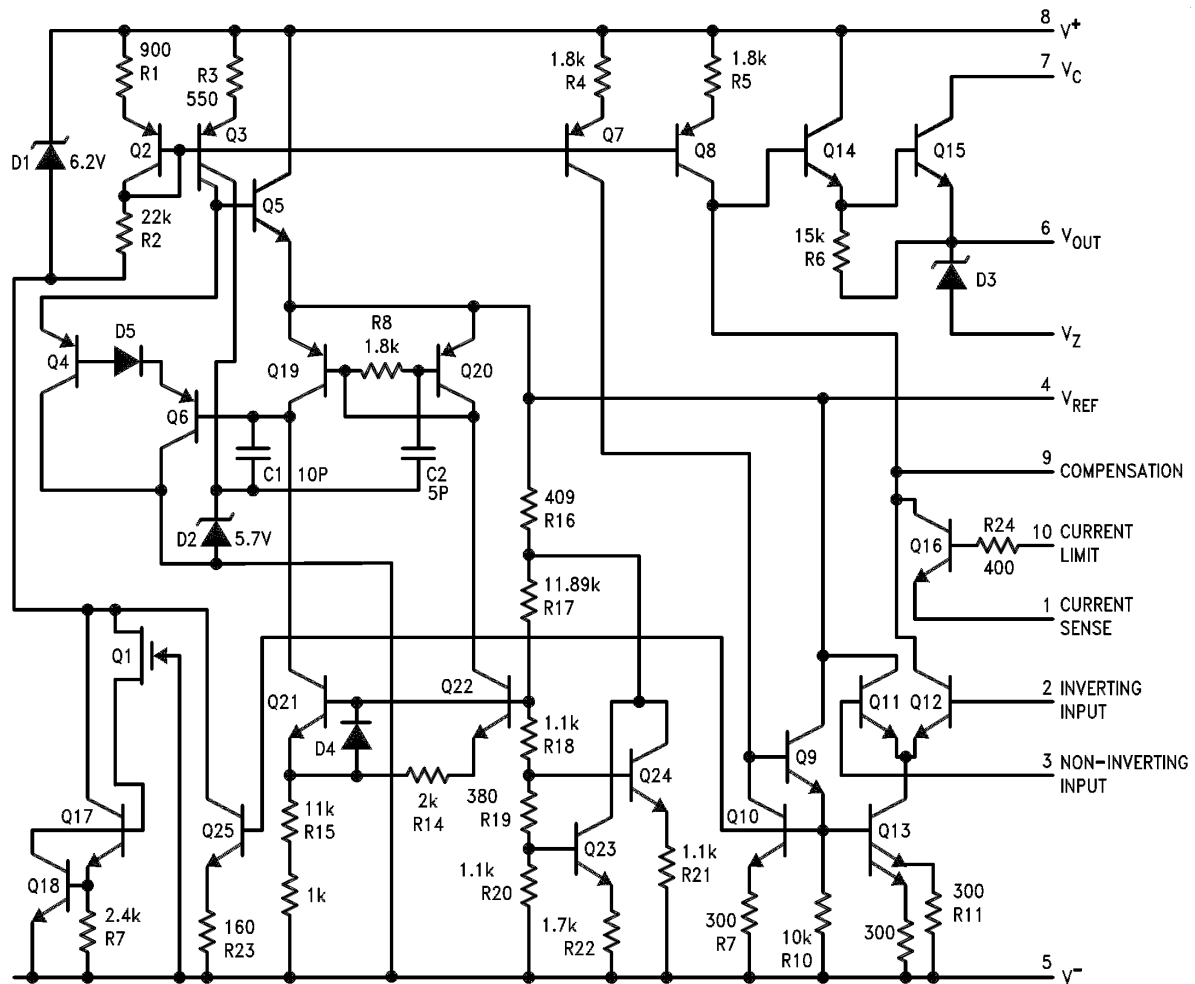


Figure 28. Output Voltage Adjust ⁽¹⁾

(1) Replace R1/R2 in figures with divider shown in [Figure 28](#).

Schematic Diagram



REVISION HISTORY

| Changes from Revision B (April 2013) to Revision C | Page |
|--|--------------------|
| • Changed layout of National Data Sheet to TI format | 15 |

PACKAGING INFORMATION

| Orderable Device | Status (1) | Package Type | Package Drawing | Pins | Package Qty | Eco Plan (2) | Lead/Ball Finish (6) | MSL Peak Temp (3) | Op Temp (°C) | Device Marking (4/5) | Samples |
|------------------|---------------|--------------|-----------------|------|-------------|-------------------------|-------------------------|----------------------|--------------|-------------------------|-------------------------|
| LM723CH | ACTIVE | TO-100 | LME | 10 | 500 | TBD | Call TI | Call TI | 0 to 70 | (LM723CH, LM723CH) | Samples |
| LM723CH/NOPB | ACTIVE | TO-100 | LME | 10 | 500 | Green (RoHS & no Sb/Br) | Call TI | Level-1-NA-UNLIM | 0 to 70 | (LM723CH, LM723CH) | Samples |
| LM723H | ACTIVE | TO-100 | LME | 10 | 500 | TBD | Call TI | Call TI | -55 to 150 | (LM723H, LM723H) | Samples |
| LM723H/NOPB | ACTIVE | TO-100 | LME | 10 | 500 | Green (RoHS & no Sb/Br) | Call TI | Level-1-NA-UNLIM | -55 to 150 | (LM723H, LM723H) | Samples |

(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.

OBSELETE: 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/Ball Finish - Orderable Devices may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead/Ball Finish values may wrap to two lines if the finish value exceeds the maximum column width.

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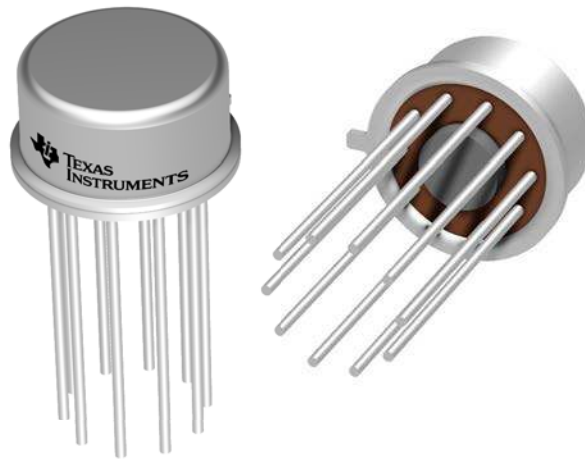
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GENERIC PACKAGE VIEW

LME 10

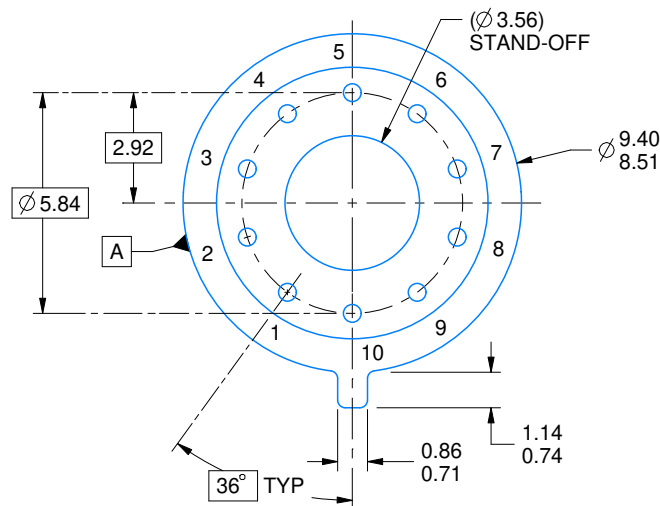
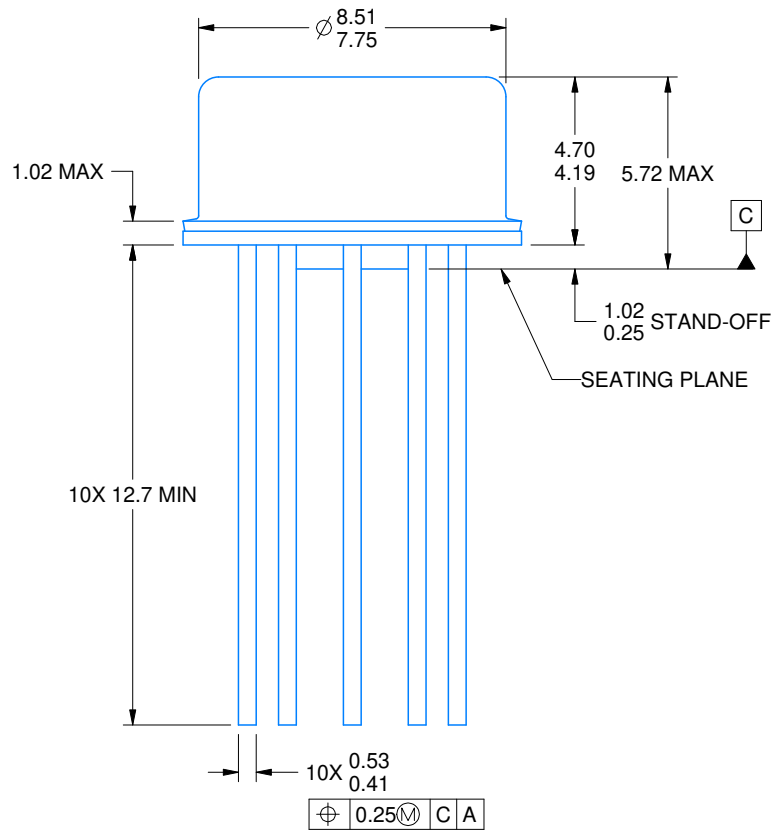
TO-CAN - 5.72 mm max height

METAL CYLINDRICAL PACKAGE



Images above are just a representation of the package family, actual package may vary.
Refer to the product data sheet for package details.

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NOTES:

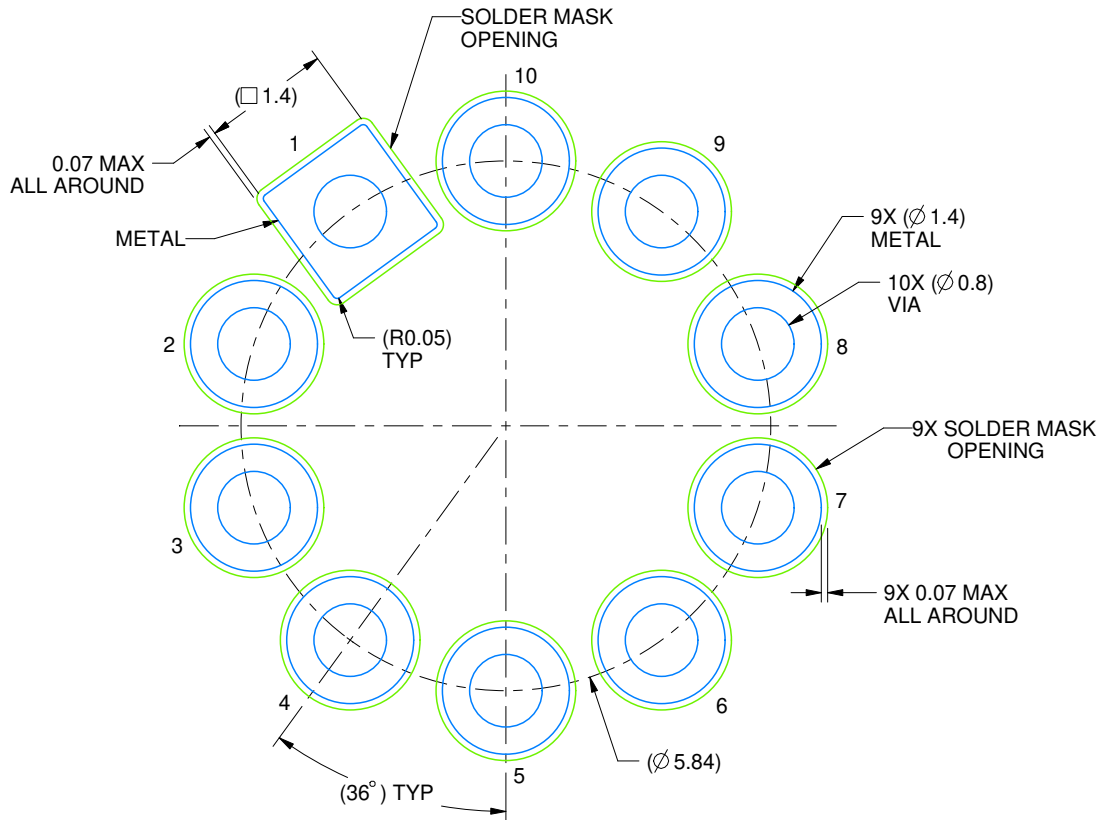
1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. Reference JEDEC registration MO-006/TO-100.

EXAMPLE BOARD LAYOUT

LME0010A

TO-CAN - 5.72 mm max height

METAL CYLINDRICAL PACKAGE



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

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