# Programmable Shunt Regulator

# LM431SA, LM431SB, LM431SC

1

**SOT−89**
**CASE 528AH**

1. Ref
2. Anode
3. Cathode

1 2

**SOT−23FL**
**CASE 318AB**

1. Cathode
2. Ref
3. Anode

1 2

**SOT−23**
**CASE 318BM**

| M32 | M3 |
|---|---|
| 1. Ref | 1. Cathode |
| 2. Cathode | 2. Ref |
| 3. Anode | 3. Anode |

## Description

The LM431SA / LM431SB / LM431SC are three−terminal the output adjustable regulators with thermal stability over operating temperature range. The output voltage can be set any value between $V_{REF}$ (approximately 2.5 V) and 36 V with two external resistors. These devices have a typical dynamic output impedance of 0.2 Ω. Active output circuit provides a sharp turn−on characteristic, making these devices excellent replacement for zener diodes in many applications.

## Features

- Programmable Output Voltage to 36 V
- Low Dynamic Output Impedance: 0.2 Ω (Typical)
- Sink Current Capability: 1.0 to 100 mA
- Equivalent Full−Range Temperature Coefficient of 50 ppm/°C (Typical)
- Temperature Compensated for Operation Over Full Rated Operating Temperature Range
- Low Output Noise Voltage
- Fast Turn−on Response
- These Devices are Pb−Free, Halogen Free/BFR Free and are RoHS Compliant

## ORDERING INFORMATION

| Product Number | Output Voltage Tolerance | Operating Temperature | Top Mark[1] | Package | Shipping† |
|---|---|---|---|---|---|
| LM431SACMFX | 2% | −25 to +85°C | 43A □ | SOT−23FL 3L | Tape and Reel |
| LM431SACM3X | | | 43L ◎ | SOT−23 3L | |
| LM431SACM32X | | | 43G ◎ | SOT−23 3L | |
| LM431SBCMFX | 1% | | 43B □ | SOT−23FL 3L | |
| LM431SBCM3X | | | 43M ◎ | SOT−23 3L | |
| LM431SBCM32X | | | 43H ◎ | SOT−23 3L | |
| LM431SCCMLX | 0.5% | | 43C | SOT−89 3L | |
| LM431SCCMFX | | | 43C □ | SOT−23FL 3L | |
| LM431SCCM3X | | | 43N ◎ | SOT−23 3L | |
| LM431SCCM32X | | | 43J ◎ | SOT−23 3L | |
| LM431SAIMFX | 2% | −40 to +85°C | 43AI | SOT−23FL 3L | |
| LM431SBIMFX | 1% | | 43BI | SOT−23FL 3L | |
| LM431SCIMFX | 0.5% | | 43CI | SOT−23FL 3L | |

†For information on tape and reel specifications, including part orientation and tape sizes, please refer to our Tape and Reel Packaging Specification Brochure, BRD8011/D.

1. SOT−23 and SOT−23FL have basically four−character marking except LM431SAIMFX. (3 letters for device code + 1 letter for date code) SOT−23FL date code is composed of 1 digit numeric or alphabetic week code adding bar−type year code.

## BLOCK DIAGRAM

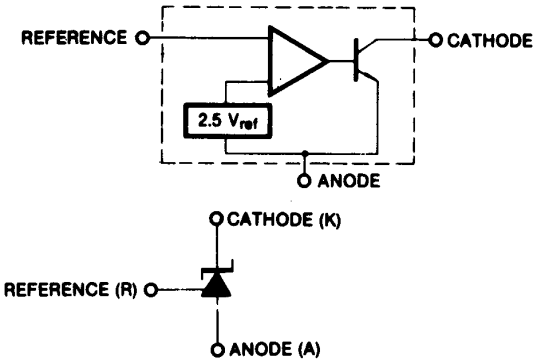



**Figure 1. Block Diagram**

## ABSOLUTE MAXIMUM RATINGS ($T_A$ = 25°C unless otherwise noted)

| Symbol | Parameter | | Value | Unit |
|---|---|---|---|---|
| $V_{KA}$ | Cathode Voltage | | 37 | V |
| $I_{KA}$ | Cathode current Range (Continuous) | | −100 to +150 | mA |
| $I_{REF}$ | Reference Input Current Range | | −0.05 to +10.00 | mA |
| $R_{\theta JA}$ | Thermal Resistance Junction−Air (2, 3) | ML Suffix Package (SOT−89) | 220 | °C/W |
| | | MF Suffix Package (SOT−23FL) | 350 | |
| | | M32, M3 Suffix Package (SOT−23) | 400 | |
| $P_D$ | Power Dissipation (4, 5) | ML Suffix Package (SOT−89) | 560 | mW |
| | | MF Suffix Package (SOT−23FL) | 350 | |
| | | M32, M3 Suffix Package (SOT−23) | 310 | |
| $T_J$ | Junction Temperature | | 150 | °C |
| $T_{OPR}$ | Operating Temperature Range | All products except LM431SAIMFX | −25 to +85 | °C |
| | | LM431SAIMFX, SBIMFX, SCIMFX | −40 to +85 | |
| $T_{STG}$ | Storage Temperature Range | | −65 to +150 | °C |

Stresses exceeding those listed in the Maximum Ratings table may damage the device. If any of these limits are exceeded, device functionality should not be assumed, damage may occur and reliability may be affected.

2. Thermal resistance test board
   Size: 1.6 mm x 76.2 mm x 114.3 mm (1S0P) JEDEC Standard: JESD51−3, JESD51−7.
3. Assume no ambient airflow.
4. $T_{JMAX}$ = 150°C; ratings apply to ambient temperature at 25°C.
5. Power dissipation calculation: $P_D = (T_J - T_A) / R_{\theta JA}$.

## RECOMMENDED OPERATING CONDITIONS

| Symbol | Parameter | Min. | Max. | Unit |
|---|---|---|---|---|
| $V_{KA}$ | Cathode Voltage | $V_{REF}$ | 36 | V |
| $I_{KA}$ | Cathode Current | 1 | 100 | mA |

Functional operation above the stresses listed in the Recommended Operating Ranges is not implied. Extended exposure to stresses beyond the Recommended Operating Ranges limits may affect device reliability.

**ELECTRICAL CHARACTERISTICS** (Note 6, Values are at $T_A$ = 25°C unless otherwise noted)

| Symbol | Parameter | Conditions | | LM431SA | | | LM431SB | | | LM431SC | | | Unit |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Min. | Typ. | Max. | Min. | Typ. | Max. | Min. | Typ. | Max. | |
| $V_{REF}$ | Reference Input Voltage | $V_{KA} = V_{REF}$, $I_{KA}$ = 10 mA | | 2.450 | 2.500 | 2.550 | 2.470 | 2.495 | 2.520 | 2.482 | 2.495 | 2.508 | V |
| $\Delta V_{REF} / \Delta T$ | Deviation of Reference Input Voltage Over− Temperature | $V_{KA} = V_{REF}$, $I_{KA}$ = 10 mA $T_{MIN} \le T_A \le T_{MAX}$ | SOT−89 SOT−23FL | | 4.5 | 17.0 | | 4.5 | 17.0 | | 4.5 | 17.0 | mV |
| | | | SOT−23 | | 6.6 | 24 | | 6.6 | 24 | | 6.6 | 24 | mV |
| $\Delta V_{REF} / \Delta V_{KA}$ | Ratio of Change in Reference Input Voltage to the Change in Cathode Voltage | $I_{KA}$ =10 mA | $\Delta V_{KA}$ = 10 V−$V_{REF}$ | | −1.0 | −2.7 | | −1.0 | −2.7 | | −1.0 | −2.7 | mV/V |
| | | | $\Delta V_{KA}$ = 36 V − 10 V | | −0.5 | −2.0 | | −0.5 | −2.0 | | −0.5 | −2.0 | |
| $I_{REF}$ | Reference Input Current | $I_{KA}$ = 10 mA, $R_1$ = 10 KΩ, $R_2$ = ∞ | | | 1.5 | 4.0 | | 1.5 | 4.0 | | 1.5 | 4.0 | μA |
| $\Delta I_{REF} / \Delta T$ | Deviation of Reference Input Current Over Full Temperature Range | $I_{KA}$ = 10 mA, $R_1$ = 10 KΩ, $R_2$ = ∞, $T_A$ = Full Range | SOT−89 SOT−23FL | | 0.4 | 1.2 | | 0.4 | 1.2 | | 0.4 | 1.2 | μA |
| | | | SOT−23 | | 0.8 | 2.0 | | 0.8 | 2.0 | | 0.8 | 2.0 | μA |
| $I_{KA(MIN)}$ | Minimum Cathode Current for Regulation | $V_{KA} = V_{REF}$ | | | 0.45 | 1.00 | | 0.45 | 1.00 | | 0.45 | 1.00 | mA |
| $I_{KA(OFF)}$ | Off −Stage Cathode Current | $V_{KA}$ = 36 V, $V_{REF}$ = 0 | | | 0.05 | 1.00 | | 0.05 | 1.00 | | 0.05 | 1.00 | μA |
| $Z_{KA}$ | Dynamic Impedance | $V_{KA} = V_{REF}$, $I_{KA}$ = 1 to 100 mA, f ≥ 1.0 kHz | | | 0.15 | 0.50 | | 0.15 | 0.50 | | 0.15 | 0.50 | Ω |

Product parametric performance is indicated in the Electrical Characteristics for the listed test conditions, unless otherwise noted. Product performance may not be indicated by the Electrical Characteristics if operated under different conditions.

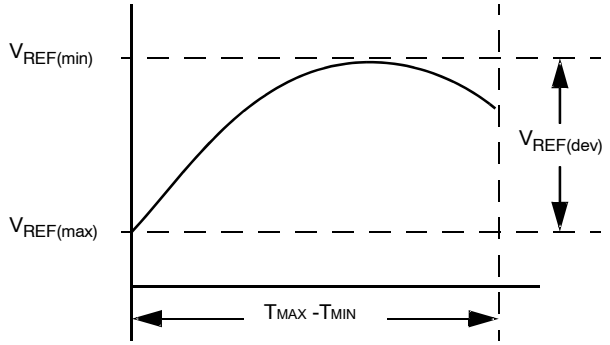
6. LM431SAI, LM431SBI, LM431SCI: − $T_{A(min)}$ = −40°C, $T_{A(max)}$ = +85°C
   All other pins: − $T_{A(min)}$ = −25°C, $T_{A(max)}$ = +85°C

**ELECTRICAL CHARACTERISTICS** (Continued) (Notes 7 and 8, Values are at $T_A$ = 25°C unless otherwise noted)

| Symbol | Parameter | Conditions | | LM431SAI | | | LM431SBI | | | LM431SCI | | | Unit |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Min. | Typ. | Max. | Min. | Typ. | Max. | Min. | Typ. | Max. | |
| $V_{REF}$ | Reference Input Voltage | $V_{KA} = V_{REF}$, $I_{KA}$ = 10 mA | | 2.450 | 2.500 | 2.550 | 2.470 | 2.495 | 2.520 | 2.482 | 2.495 | 2.508 | V |
| $V_{REF(dev)}$ | Deviation of Reference Input Voltage Over−Temperature | $V_{KA} = V_{REF}$, $I_{KA}$ = 10 mA, $T_{MIN} \le T_A \le T_{MAX}$ | | | 5 | 20 | | 5 | 20 | | 5 | 20 | mV |
| $\Delta V_{REF} / \Delta V_{KA}$ | Ratio of Change in Reference Input Voltage to Change in Cathode Voltage | $I_{KA}$ = 10 mA | $\Delta V_{KA}$ = 10 V−$V_{REF}$ | | −1.0 | −2.7 | | −1.0 | −2.7 | | −1.0 | −2.7 | mV/V |
| | | | $\Delta V_{KA}$ = 36 V − 10 V | | −0.5 | −2.0 | | −0.5 | −2.0 | | −0.5 | −2.0 | |
| $I_{REF}$ | Reference Input Current | $I_{KA}$ = 10 mA, $R_1$ =10 KΩ, $R_2 = \infty$ | | | 1.5 | 4.0 | | 1.5 | 4.0 | | 1.5 | 4.0 | μA |
| $I_{REF(dev)}$ | Deviation of Reference Input Current Over Full Temperature Range | $I_{KA}$ = 10 mA, $R_1$ = 10 KΩ, $R_2 = \infty$, $T_{MIN} \le T_A \le T_{MAX}$ | | | 0.8 | 2.0 | | 0.8 | 2.0 | | 0.8 | 2.0 | μA |
| $I_{KA(MIN)}$ | Minimum Cathode Current for Regulation | $V_{KA} = V_{REF}$ | | | 0.45 | 1.00 | | 0.45 | 1.00 | | 0.45 | 1.00 | mA |
| $I_{KA(OFF)}$ | Off −Stage Cathode Current | $V_{KA}$ = 36 V, $V_{REF}$ = 0 | | | 0.05 | 1.00 | | 0.05 | 1.00 | | 0.05 | 1.00 | μA |
| ZKA | Dynamic Impedance | $V_{KA} = V_{REF}$, $I_{KA}$ = 1 to 100 mA, f ≥ 1.0 kHz | | | 0.15 | 0.50 | | 0.15 | 0.50 | | 0.15 | 0.50 | Ω |

7. LM431SAI, LM431SBI, LM431SCI: − $T_{A(min)}$ = −40°C, $T_{A(max)}$ = +85°C
   All other pins: − $T_{A(min)}$ = −25°C, $T_{A(max)}$ = +85°C
8. The deviation parameters $V_{REF(dev)}$ and $I_{REF(dev)}$ are defined as the differences between the maximum and minimum values obtained over the rated temperature range. The average full−range temperature coefficient of the reference input voltage, $\alpha V_{REF}$, is defined as:

$$|\alpha V_{REF}|\left(\frac{ppm}{°C}\right) = \frac{\left(\frac{V_{REF(dev)}}{V_{REF}(at\ 25°C)}\right) \cdot 10^6}{T_{MAX} - T_{MIN}}$$




where $T_{MAX}$ −$T_{MIN}$ is the rated operating free−air temperature range of the device.

$\alpha V_{REF}$ can be positive or negative, depending on whether minimum $V_{REF}$ or maximum $V_{REF}$, respectively, occurs at the lower temperature.

Example:
$V_{REF(dev)}$ = 4.5 mV, $V_{REF}$ = 2500 mV at 25°C,
$T_{MAX}$ −$T_{MIN}$ = 125°C for LM431SAI.

$$|\alpha V_{REF}| = \frac{\left(\frac{4.5\ mV}{2500\ mV}\right) \cdot 10^6}{125°C} = 14.4\ ppm/°C$$

Because minimum $V_{REF}$ occurs at the lower temperature, the coefficient is positive.

## TEST CIRCUITS

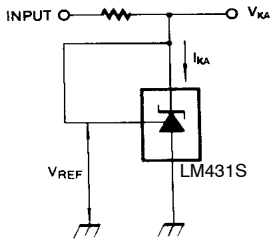



**Figure 2. Test Circuit for $V_{KA} = V_{REF}$**

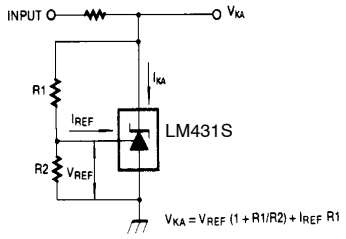



**Figure 3. Test Circuit for $V_{KA} \geq V_{REF}$**

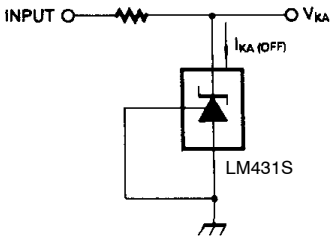



**Figure 4. Test Circuit for $I_{KA(OFF)}$**

## TYPICAL APPLICATIONS

$$V_O = \left(1 + \frac{R_1}{R_2}\right) V_{ref}$$

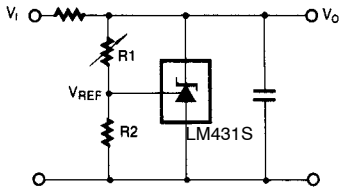



**Figure 5. Shunt Regulator**

$$V_O = \left(1 + \frac{R_1}{R_2}\right) V_{ref}$$

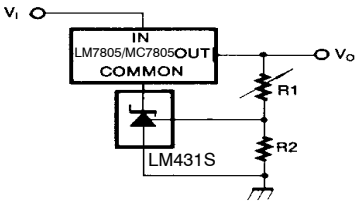



**Figure 6. Output Control for Three−Terminal Fixed Regulator**

$$V_O = \left(1 + \frac{R_1}{R_2}\right) V_{ref}$$

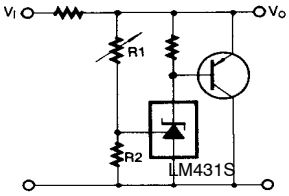



**Figure 7. High Current Shunt Regulator**

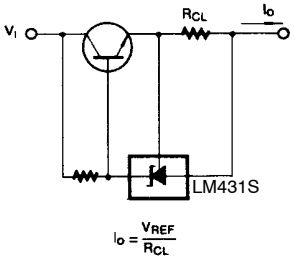



**Figure 8. Current Limit or Current Source**

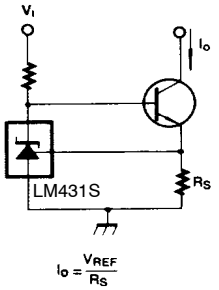



**Figure 9. Constant−Current Sink**

## TYPICAL PERFORMANCE CHARACTERISTICS

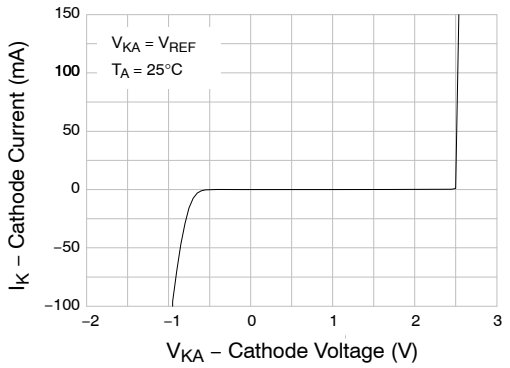



**Figure 10. Cathode Current vs. Cathode Voltage**

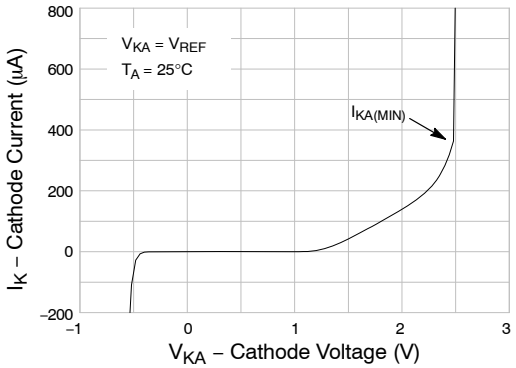



**Figure 11. Cathode Current vs. Cathode Voltage**

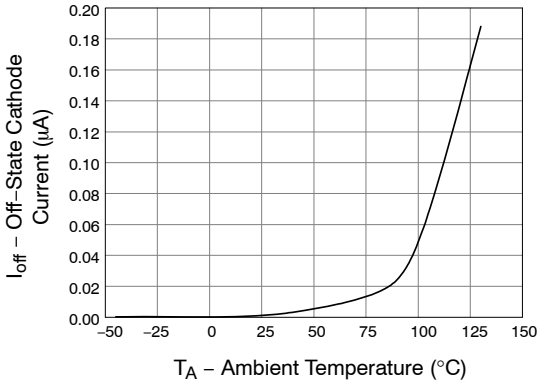



**Figure 12. OFF–State Cathode Current vs. Ambient Temperature**

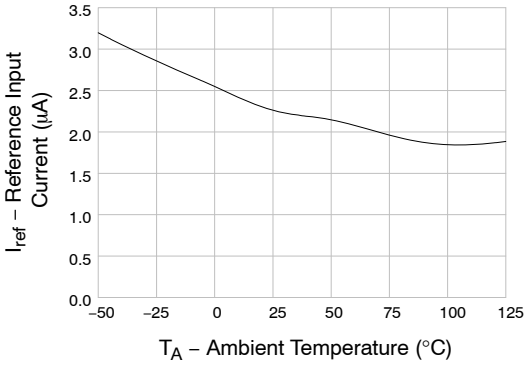



**Figure 13. Reference Input Current vs. Ambient Temperature**

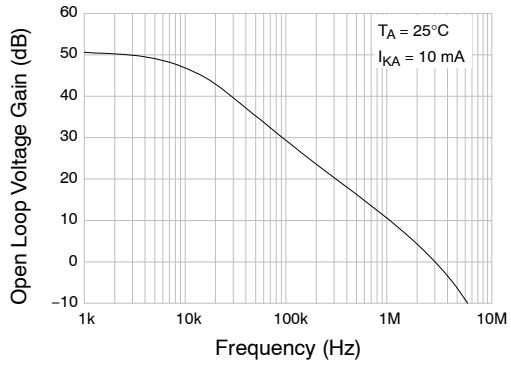



**Figure 14. Frequency vs. Small Signal Voltage Amplification**

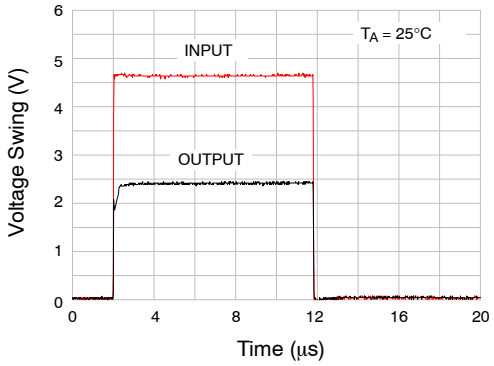



**Figure 15. Pulse Response**

## TYPICAL PERFORMANCE CHARACTERISTICS

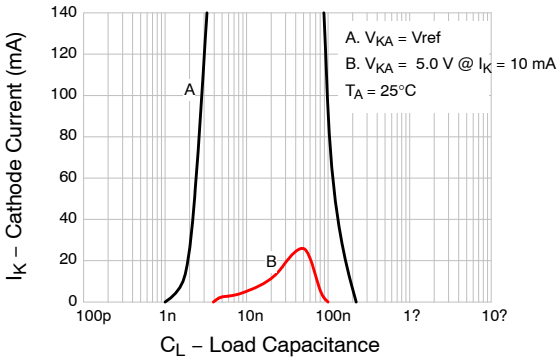



**Figure 16. Stability Boundary Conditions**

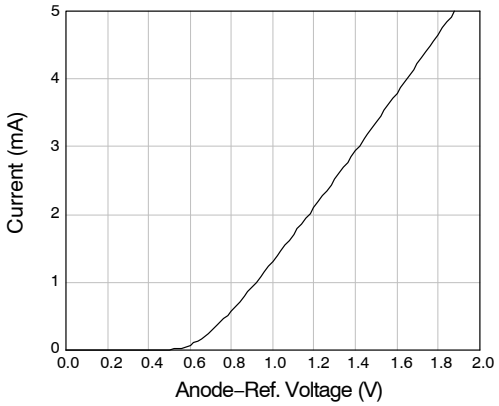



**Figure 17. Anode–Reference Diode Curve**

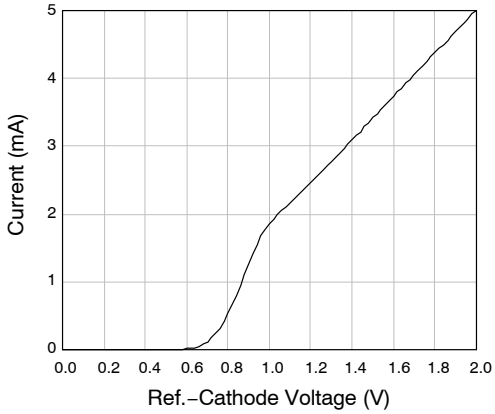



**Figure 18. Reference–Cathode Diode Curve**

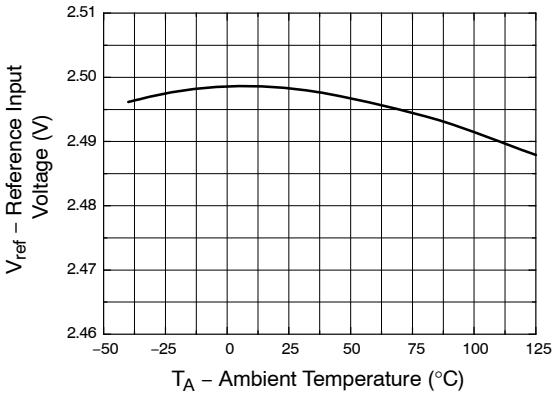
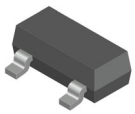
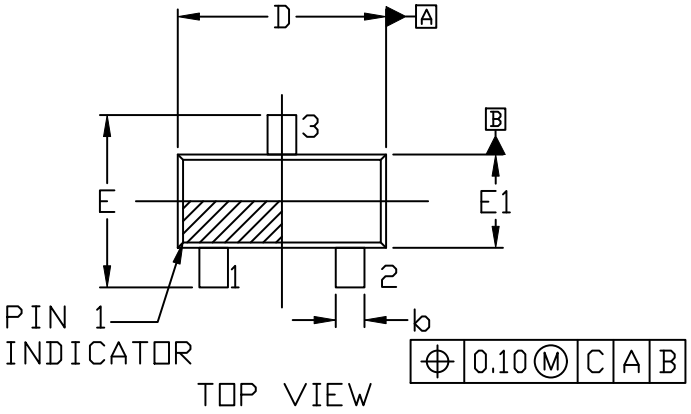


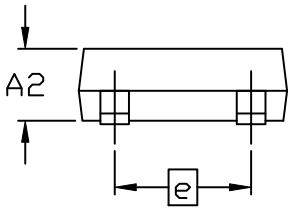

**Figure 19. Reference Input Voltage vs. Ambient Temperature**

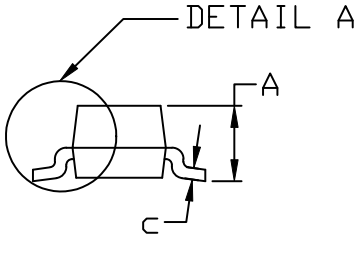


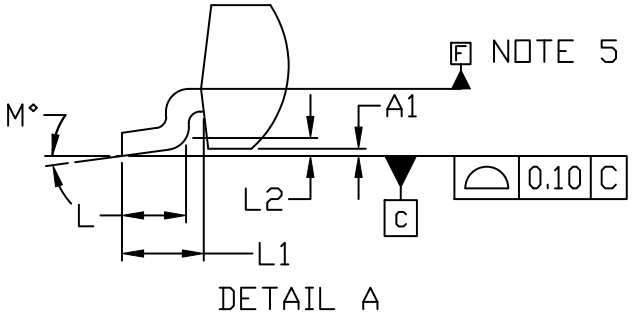
**SOT23−3L**
CASE 318AB
ISSUE A

DATE 14 DEC 2021



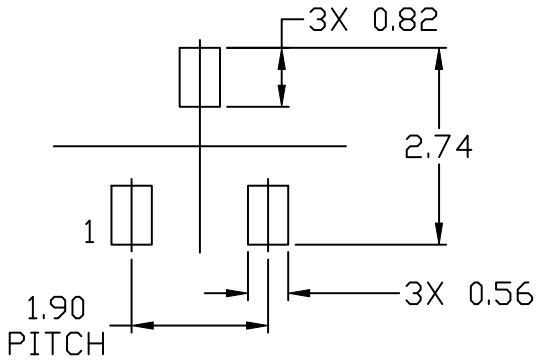



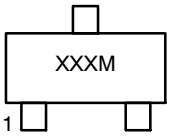

NOTES:
1. DIMENSIONING AND TOLERANCING PER ASME Y14.5M, 2009.
2. CONTROLLING DIMENSION: MILLIMETERS
3. DIMENSION b DOES NOT INCLUDE DAMBAR PROTRUSION. ALLOWABLE PROTRUSION SHALL BE 0.127 mm IN EXCESS OF MAXIMUM MATERIAL CONDITION.
4. DIMENSIONS D AND E1 DO NOT INCLUDE MOLD FLASH, PROTRUSIONS, OR GATE BURRS. MOLD FLASH, PROTRUSIONS, OR GATE BURRS SHALL NOT EXCEED 0.15 mm PER SIDE. DIMENSIONS D AND E1 ARE DETERMINED AT DATUM F.
5. DATUMS A AND B ARE TO BE DETERMINED AT DATUM F.
6. A1 IS DEFINED AS THE VERTICAL DISTANCE FROM THE SEATING PLANE TO THE LOWEST POINT ON THE PACKAGE BODY.
7. LEAD THICKNESS (c) AND LEAD WIDTH (b) INCLUDE PLATING THICKNESS.

| | MILLIMETERS | | |
|---|---|---|---|
| DIM | MIN. | NOM. | MAX. |
| A | --- | --- | 1.15 |
| A1 | 0.00 | --- | 0.10 |
| A2 | 0.90 | 1.00 | 1.10 |
| b | 0.30 | --- | 0.50 |
| c | 0.127 REF | | |
| D | 2.80 | 2.90 | 3.00 |
| E | 2.25 | 2.40 | 2.55 |
| E1 | 1.20 | 1.30 | 1.40 |
| e | 1.90 BSC | | |
| L | 0.30 | --- | --- |
| L1 | 0.55 REF | | |
| L2 | 0.25 REF | | |
| M | 0° | --- | 8° |




* For additional information on our Pb-Free strategy and soldering details, please download the ON Semiconductor Soldering and Mounting Techniques Reference Manual, SOLDERRM/D.

**GENERIC**
**MARKING DIAGRAM***




XXX = Specific Device Code
M = Date Code

*This information is generic. Please refer to device data sheet for actual part marking. Pb−Free indicator, “G” or microdot “▪”, may or may not be present. Some products may not follow the Generic Marking.

| | | | |
|---|---|---|---|
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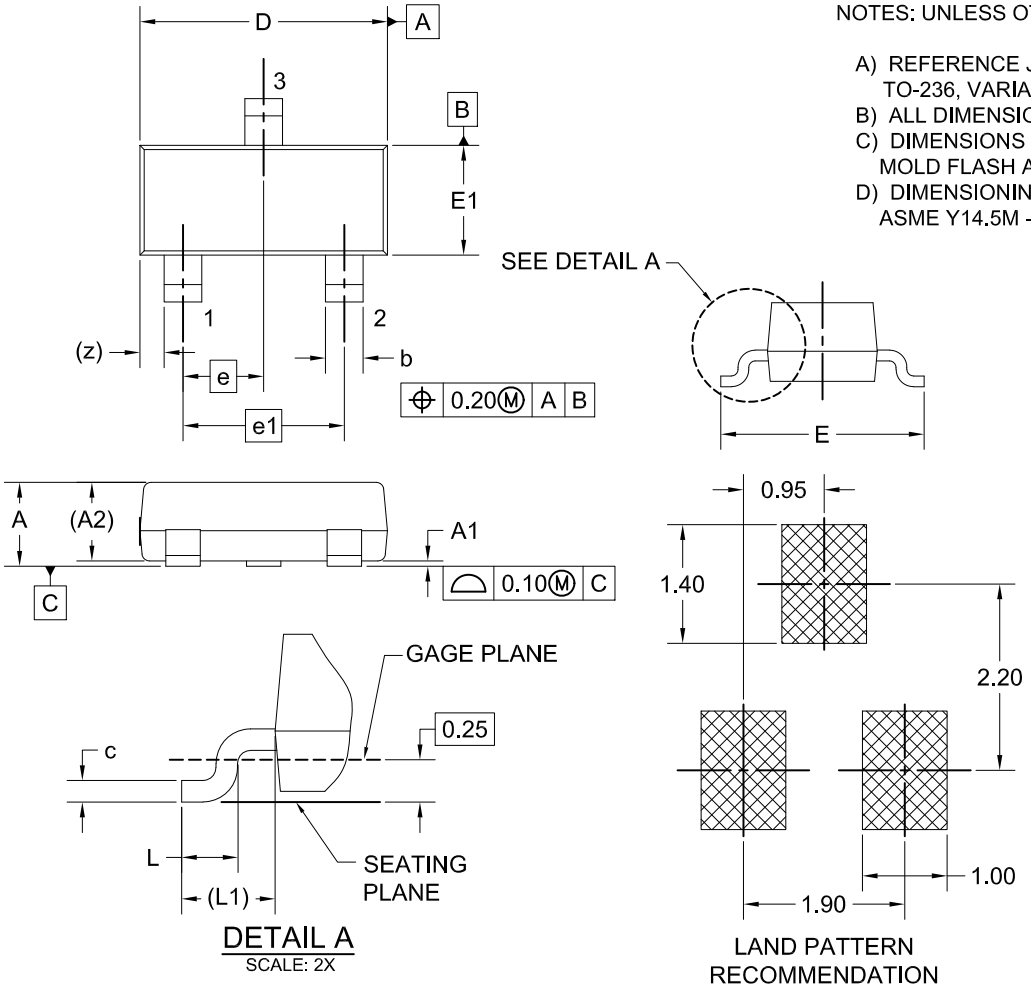
| **DESCRIPTION:** | **SOT23−3L** | | **PAGE 1 OF 1** |

**SOT−23**
CASE 318BM
ISSUE A

DATE 01 SEP 2021



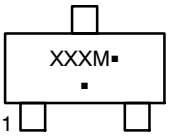

NOTES: UNLESS OTHERWISE SPECIFIED

A) REFERENCE JEDEC REGISTRATION TO-236, VARIATION AB, ISSUE H.
B) ALL DIMENSIONS ARE IN MILLIMETERS.
C) DIMENSIONS ARE INCLUSIVE OF BURRS, MOLD FLASH AND TIE BAR EXTRUSIONS.
D) DIMENSIONING AND TOLERANCING PER ASME Y14.5M - 2009.

| DIM | MILLIMETERS | | |
|---|---|---|---|
| | MIN. | NOM. | MAX. |
| A | --- | --- | 1.20 |
| A1 | 0.00 | 0.05 | 0.10 |
| A2 | | 0.93 REF | |
| b | 0.37 | 0.44 | 0.60 |
| c | 0.08 | 0.15 | 0.23 |
| D | 2.72 | 2.92 | 3.12 |
| E | 2.10 | 2.40 | 2.70 |
| E1 | 1.15 | 1.30 | 1.50 |
| e | | 0.95 BSC | |
| e1 | | 1.90 BSC | |
| L | 0.20 | --- | --- |
| L1 | | 0.55 REF | |
| z | | 0.29 REF | |

*FOR ADDITIONAL INFORMATION ON OUR PB-FREE STRATEGY AND SOLDERING DETAILS, PLEASE DOWNLOAD THE ON SEMICONDUCTOR SOLDERING AND MOUNTING TECHNIQUES REFERENCE MANUAL, SOLDERRM/D.

**GENERIC MARKING DIAGRAM***




XXX = Specific Device Code
M = Date Code
▪ = Pb−Free Package

*This information is generic. Please refer to device data sheet for actual part marking. Pb−Free indicator, “G” or microdot “▪”, may or may not be present. Some products may not follow the Generic Marking.

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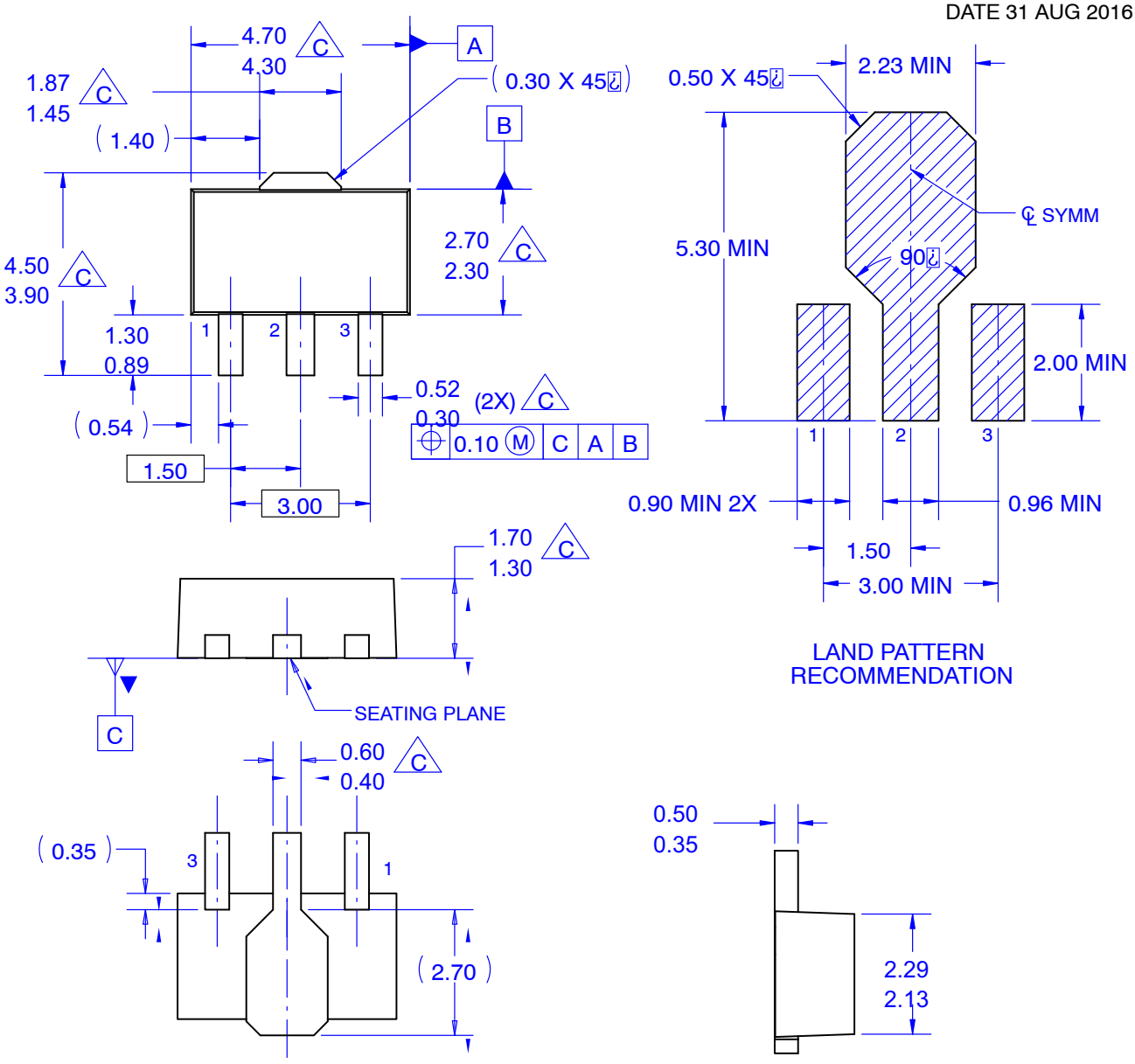
| DESCRIPTION: | SOT−23 | PAGE 1 OF 1 |

**SOT−89 3 LEAD**
CASE 528AH
ISSUE O

DATE 31 AUG 2016




NOTES: UNLESS OTHERWISE SPECIFIED.

A. REFERENCE TO JEDEC TO-243 VARIATION AA.
B. ALL DIMENSIONS ARE IN MILLIMETERS.
C DOES NOT COMPLY JEDEC STANDARD VALUE.
D. DIMENSIONS ARE EXCLUSIVE OF BURRS, MOLD FLASH AND TIE BAR PROTRUSION.
E. DIMENSION AND TOLERANCE AS PER ASME Y14.5−1994.

| | | | |
|---|---|---|---|
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| **DESCRIPTION:** | **SOT−89 3 LEAD** | | **PAGE 1 OF 1** |

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