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June 2015

# LM431SA / LM431SB / LM431SC
# Programmable Shunt Regulator

## 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

## 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.

**SOT-89**


1. Ref 2. Anode 3. Cathode

**SOT-23F**


1. Cathode 2. Ref 3. Anode

**SOT-23**


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

## Ordering Information

| Product Number | Output Voltage Tolerance | Operating Temperature | Top Mark(1) | Package | Packing Method |
|---|---|---|---|---|---|
| LM431SACMFX | 2% | -25 to +85°C | 43A □ | SOT-23F 3L | Tape and Reel |
| LM431SACM3X | | | 43L ◎ | SOT-23 3L | |
| LM431SACM32X | | | 43G ◎ | SOT-23 3L | |
| LM431SBCMLX | 1% | | 43B | SOT-89 3L | |
| LM431SBCMFX | | | 43B □ | SOT-23F 3L | |
| LM431SBCM3X | | | 43M ◎ | SOT-23 3L | |
| LM431SBCM32X | | | 43H ◎ | SOT-23 3L | |
| LM431SCCMLX | 0.5% | | 43C | SOT-89 3L | |
| LM431SCCMFX | | | 43C □ | SOT-23F 3L | |
| LM431SCCM3X | | | 43N ◎ | SOT-23 3L | |
| LM431SCCM32X | | | 43J ◎ | SOT-23 3L | |
| LM431SAIMFX | 2% | -40 to +85°C | 43AI | SOT-23F 3L | |

**Note:**

1. SOT-23 and SOT-23F have basically four-character marking except LM431SAIMFX.
   (3 letters for device code + 1 letter for date code)
   SOT-23F date code is composed of 1 digit numeric or alphabetic week code adding bar-type year code.
   > Week code: Change in every two weeks

| Week | 01~02 | 03~04 | 05~06 | 07~08 | 09~10 | 11~12 | 13~14 | 15~16 | 17~18 | 19~20 | 21~22 | 23~24 | 25~26 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Code | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | A | D | E | F |
| Week | 27~28 | 29~30 | 31~32 | 33~34 | 35~36 | 37~38 | 39~40 | 41~42 | 43~44 | 45~46 | 47~48 | 49~50 | 51~52 |
| Code | H | J | K | L | N | O | P | R | S | T | U | V | X |

   > Year code (additional bar): Rotate in three year cycle

| Year | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Code | □ | □ | □ | □ | □ | □ | □ | □ | □ | □ | □ |

## Block Diagram

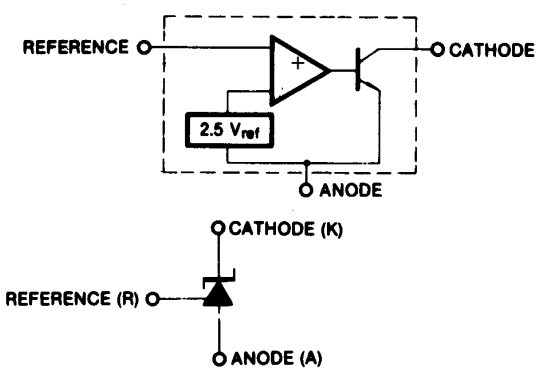



**Figure 1. Block Diagram**

## Absolute Maximum Ratings

Stresses exceeding the absolute maximum ratings may damage the device. The device may not function or be operable above the recommended operating conditions and stressing the parts to these levels is not recommended. In addition, extended exposure to stresses above the recommended operating conditions may affect device reliability. The absolute maximum ratings are stress ratings only. Values are at $T_A$ = 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-23F) | 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-23F) | 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 | -40 to +85 | |
| $T_{STG}$ | Storage Temperature Range | | -65 to +150 | °C |

**Notes:**

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

The Recommended Operating Conditions table defines the conditions for actual device operation. Recommended operating conditions are specified to ensure optimal performance to the datasheet specifications. Fairchild does not recommend exceeding them or designing to Absolute Maximum Ratings.

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

## Electrical Characteristics[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-23F | | 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-23F | | 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 |

**Note:**

6. $T_{MIN}$ = -25°C, $T_{MAX}$ = +85°C.

## Electrical Characteristics[7, 8] (Continued)

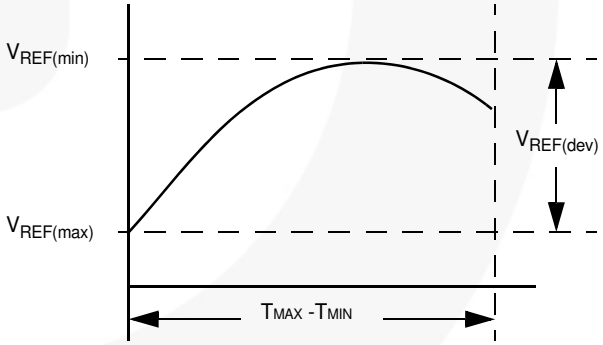
Values are at $T_A$ = 25°C unless otherwise noted.

| Symbol | Parameter | Conditions | | LM431SAI | | | Unit |
|---|---|---|---|---|---|---|---|
| | | | | Min. | Typ. | Max. | |
| $V_{REF}$ | Reference Input Voltage | $V_{KA} = V_{REF}$, $I_{KA}$ = 10 mA | | 2.450 | 2.500 | 2.550 | 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 | 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 | mV/V |
| | | | $\Delta V_{KA}$ = 36 V - 10 V | | -0.5 | -2.0 | |
| $I_{REF}$ | Reference Input Current | $I_{KA}$ = 10 mA, $R_1$ =10 KΩ, $R_2$ = ∞ | | | 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, $R_2$ = ∞, $T_{MIN} \le T_A \le T_{MAX}$ | | | 0.8 | 2.0 | µA |
| $I_{KA(MIN)}$ | Minimum Cathode Current for Regulation | $V_{KA} = V_{REF}$ | | | 0.45 | 1.00 | mA |
| $I_{KA(OFF)}$ | Off -Stage Cathode Current | $V_{KA}$ = 36 V, $V_{REF}$ = 0 | | | 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 | Ω |

**Notes:**

7. $T_{MIN}$ = -40°C, $T_{MAX}$ = +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:

$$\left|\alpha V_{REF}\right|\left(\frac{ppm}{°C}\right) = \frac{\left(\frac{V_{REF(dev)}}{V_{REF(at25°C)}}\right) \cdot 10^6}{T_{MAX} - T_{MIN}}$$




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.

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

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

## Test Circuits

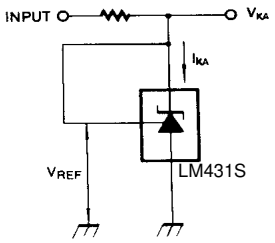



**Figure 2. Test Circuit for $V_{KA} = V_{REF}$**

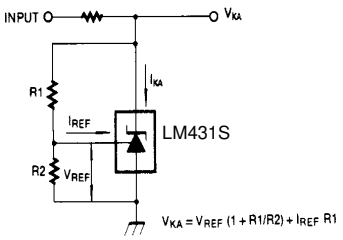



**Figure 3. Test Circuit for $V_{KA} \geq V_{REF}$**

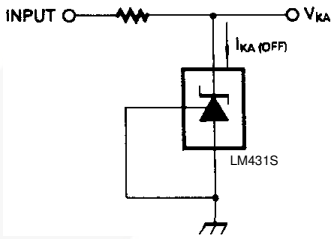



**Figure 4. Test Circuit for $I_{KA(OFF)}$**

## Typical Applications

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

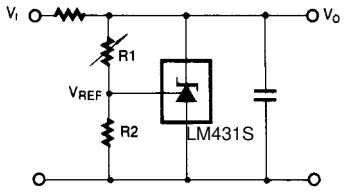



**Figure 5. Shunt Regulator**

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

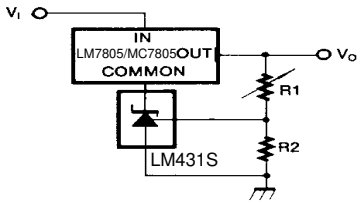



**Figure 6. Output Control for Three- Terminal Fixed Regulator**

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

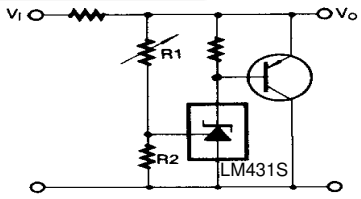



**Figure 7. High Current Shunt Regulator**

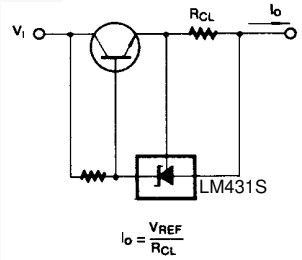



**Figure 8. Current Limit or Current Source**

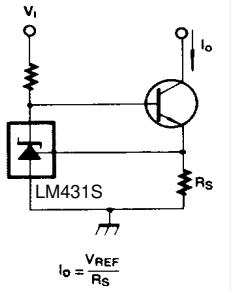



**Figure 9. Constant-Current Sink**

## Typical Performance Characteristics

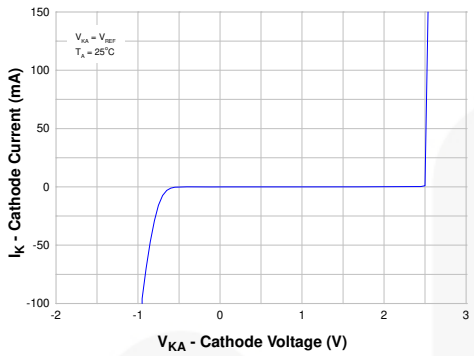



**Figure 10. Cathode Current vs. Cathode Voltage**

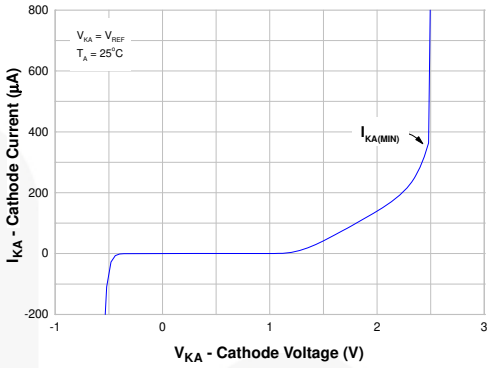



**Figure 11. Cathode Current vs. Cathode Voltage**

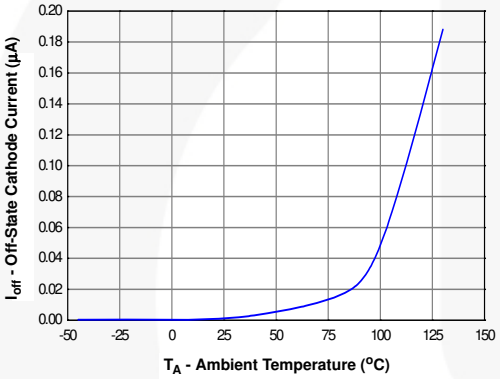



**Figure 12. OFF-State Cathode Current vs. Ambient Temperature**

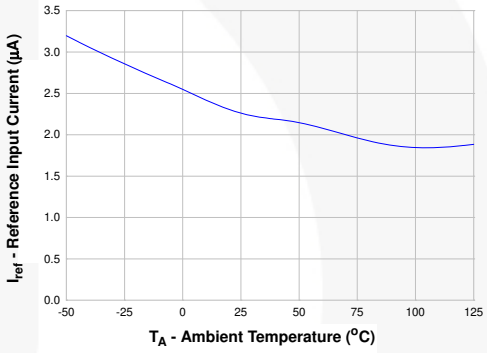



**Figure 13. Reference Input Current vs. Ambient Temperature**

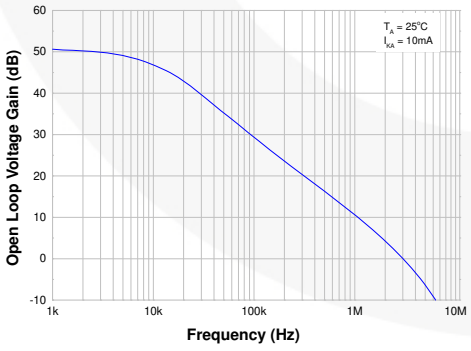



**Figure 14. Frequency vs. Small Signal Voltage Amplification**

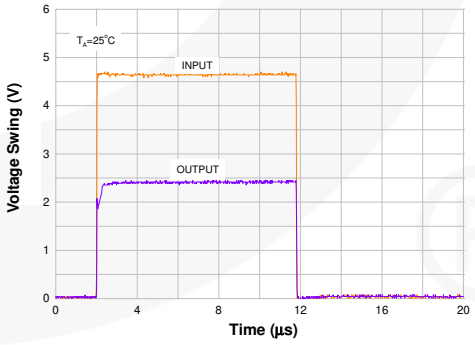



**Figure 15. Pulse Response**

## Typical Performance Characteristics (Continued)

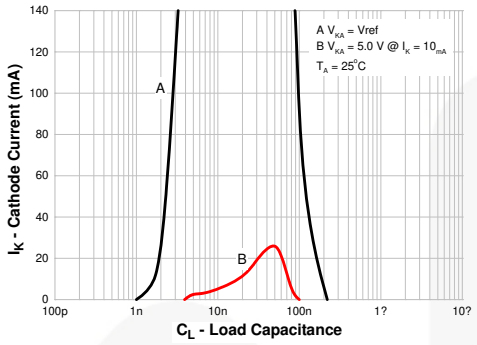



Figure 16. Stability Boundary Conditions

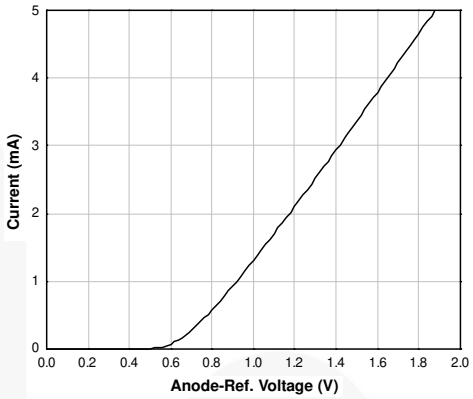



Figure 17. Anode-Reference Diode Curve

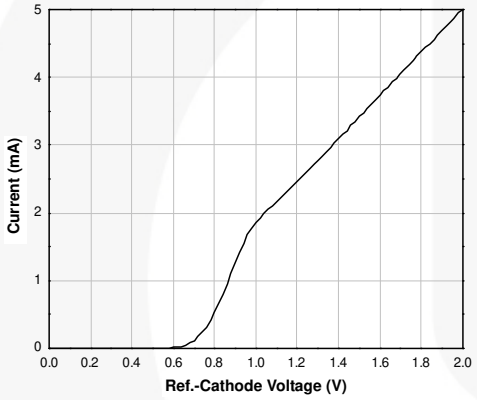



Figure 18. Reference-Cathode Diode Curve

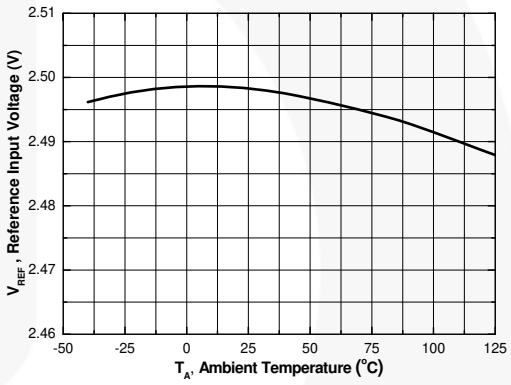
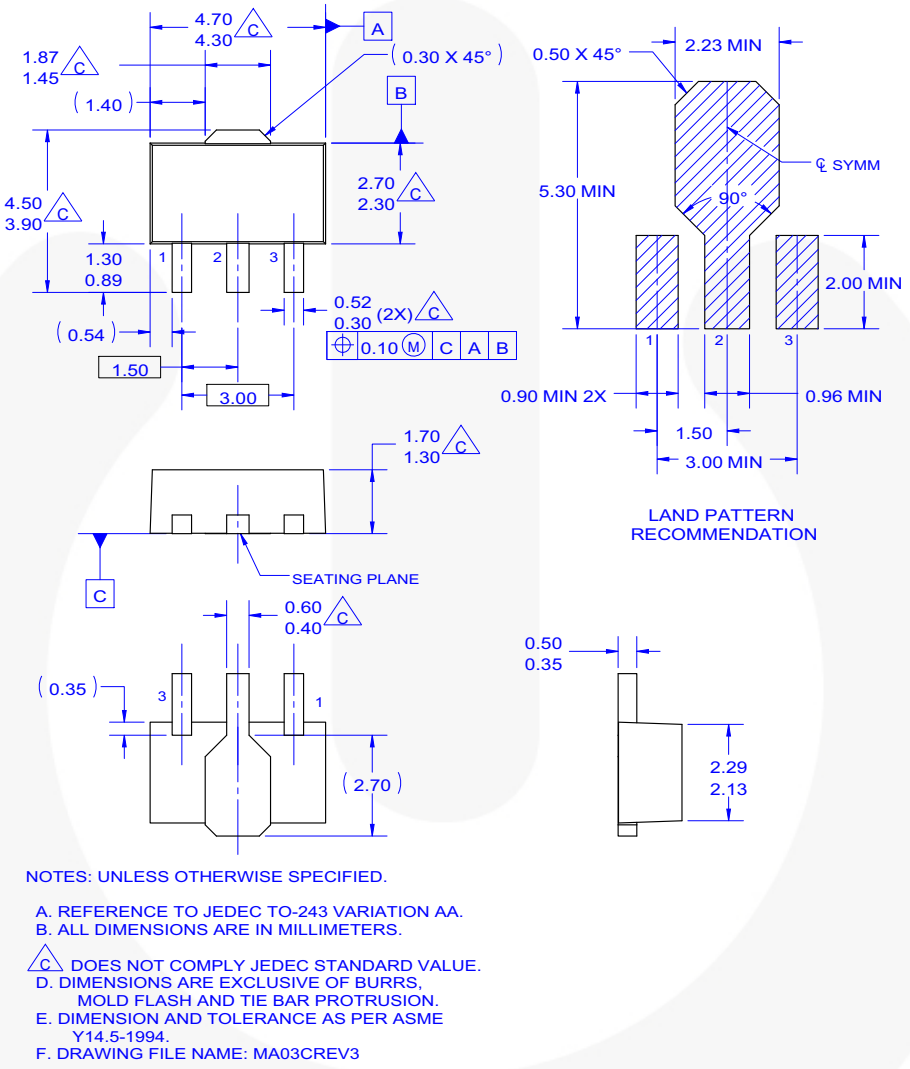



Figure 19. Reference Input Voltage vs. Ambient Temperature

## Physical Dimensions

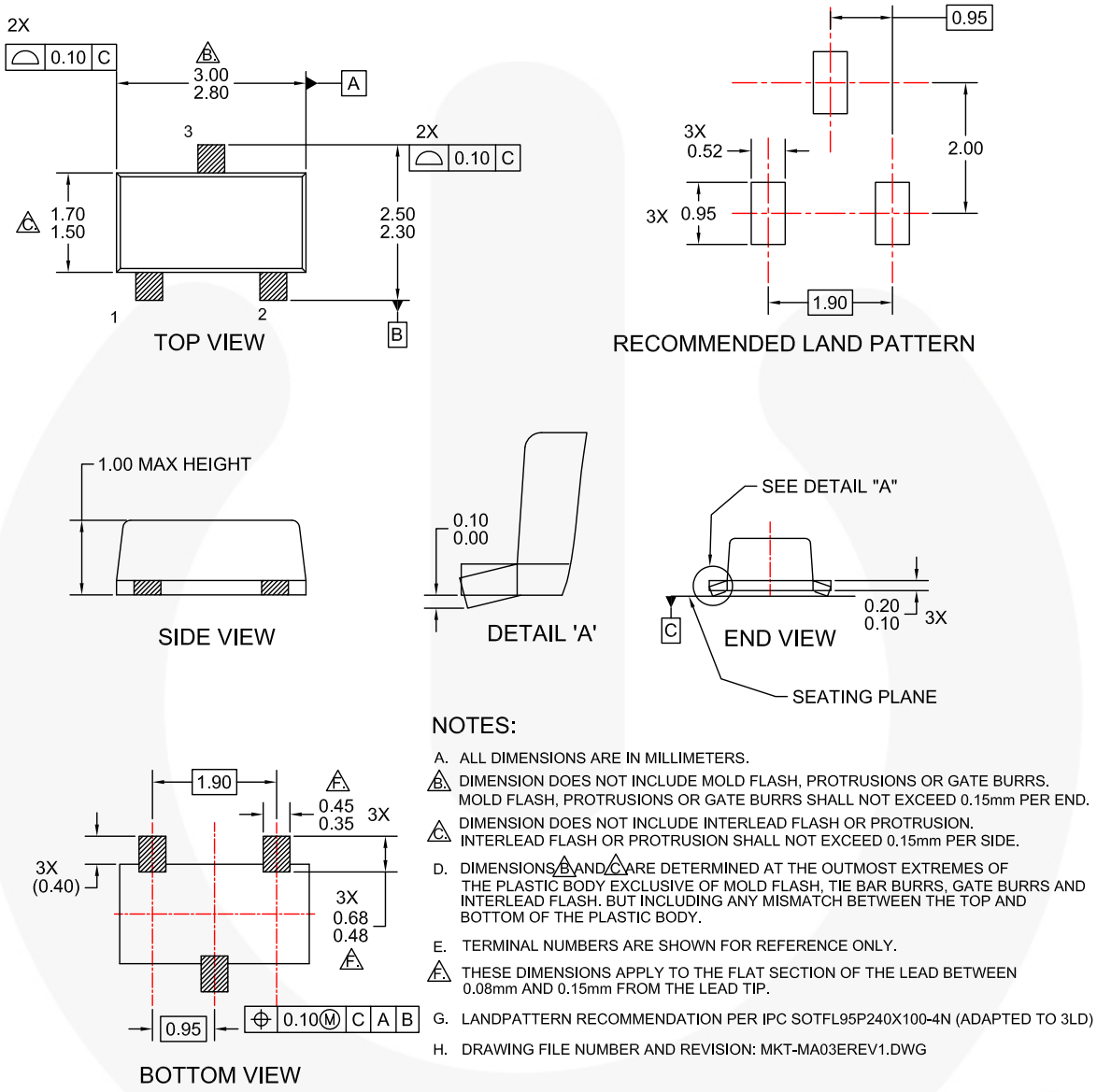



NOTES: UNLESS OTHERWISE SPECIFIED.

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.
F. DRAWING FILE NAME: MA03CREV3

**Figure 20. 3-LEAD, SOT-89, JEDEC TO-243, OPTION AA**

## Physical Dimensions (Continued)




NOTES:

A. ALL DIMENSIONS ARE IN MILLIMETERS.

B. DIMENSION DOES NOT INCLUDE MOLD FLASH, PROTRUSIONS OR GATE BURRS. MOLD FLASH, PROTRUSIONS OR GATE BURRS SHALL NOT EXCEED 0.15mm PER END.

C. DIMENSION DOES NOT INCLUDE INTERLEAD FLASH OR PROTRUSION. INTERLEAD FLASH OR PROTRUSION SHALL NOT EXCEED 0.15mm PER SIDE.

D. DIMENSIONS B AND C ARE DETERMINED AT THE OUTMOST EXTREMES OF THE PLASTIC BODY EXCLUSIVE OF MOLD FLASH, TIE BAR BURRS, GATE BURRS AND INTERLEAD FLASH. BUT INCLUDING ANY MISMATCH BETWEEN THE TOP AND BOTTOM OF THE PLASTIC BODY.

E. TERMINAL NUMBERS ARE SHOWN FOR REFERENCE ONLY.

F. THESE DIMENSIONS APPLY TO THE FLAT SECTION OF THE LEAD BETWEEN 0.08mm AND 0.15mm FROM THE LEAD TIP.

G. LANDPATTERN RECOMMENDATION PER IPC SOTFL95P240X100-4N (ADAPTED TO 3LD)

H. DRAWING FILE NUMBER AND REVISION: MKT-MA03EREV1.DWG

**Figure 21. 3-LEAD, SOT23F, FLAT LEAD, LOW PROFILE**

## Physical Dimensions (Continued)

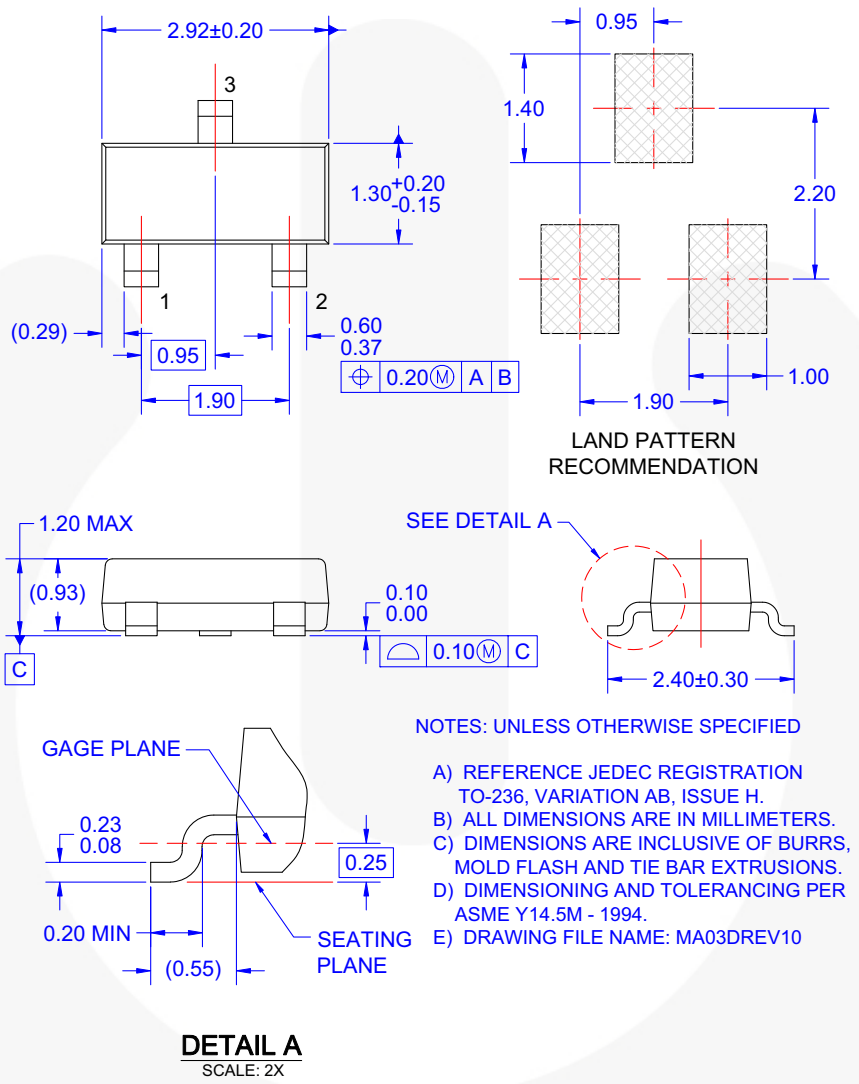



**Figure 22. 3-LEAD, SOT-23, JEDEC TO-236, LOW PROFILE**

## TRADEMARKS

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CorePOWER™
*CROSSVOLT*™
CTL™
Current Transfer Logic™
DEUXPEED®
Dual Cool™
EcoSPARK®
EfficientMax™
ESBC™
Fairchild®
Fairchild Semiconductor®
FACT Quiet Series™
FACT®
FAST®
FastvCore™
FETBench™
FPS™
F-PFS™
FRFET®
Global Power Resource SM
GreenBridge™
Green FPS™
Green FPS™ e-Series™
G*max*™
GTO™
IntelliMAX™
ISOPLANAR™
Making Small Speakers Sound Louder and Better™
MegaBuck™
MICROCOUPLER™
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