FAIRCHILD
SEMICONDUCTOR®

June 2013

# LM431SA / LM431SB / LM431SC
# Programmable Shunt Regulator

## Features

- Programmable Output Voltage to 36 V
- Low Dynamic Output Impedance: 0.2 Ω (Typical)
- Sink Current Capability of 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 | 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-23 3L | |
| LM431SCCM3X | | | 43N | SOT-23F 3L | |
| LM431SCCM32X | | | 43J | SOT-23 3L | |
| LM431SAIMFX | 2% | -40 to +85°C | 43AI | SOT-23F 3L | |

## Block Diagram

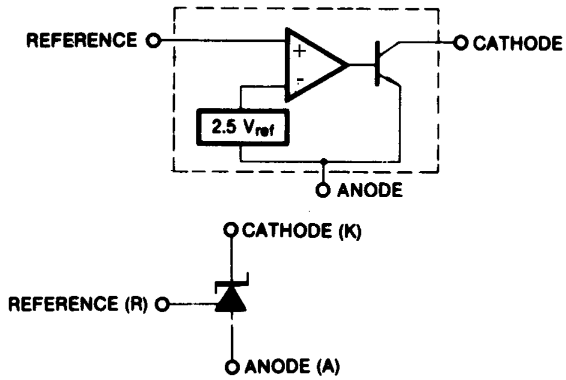



**Figure 1. Block Diagram**

## 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 [1,2] | 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 [3,4] | 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 | | -25 ~ +85 | °C |
| $T_{STG}$ | Storage Temperature Range | | -65 ~ +150 | °C |

**Notes:**

1. Thermal resistance test board
   Size: 1.6 mm x 76.2 mm x 114.3 mm (1S0P)
   JEDEC Standard: JESD51-3, JESD51-7.
2. Assume no ambient airflow.
3. $T_{JMAX}$ = 150°C; ratings apply to ambient temperature at 25°C.
4. 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 |

## Electrical Characteristics

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 $T_{MIN} \leq T_A \leq T_{MAX}$ | 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, $R_2 = \infty$ | | | 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, $R_2 = \infty$, $T_A$ = 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:**
5. $T_{MIN}$ = -25°C, $T_{MAX}$ = +85°C.

## Electrical Characteristics[6, 7] (Continued)

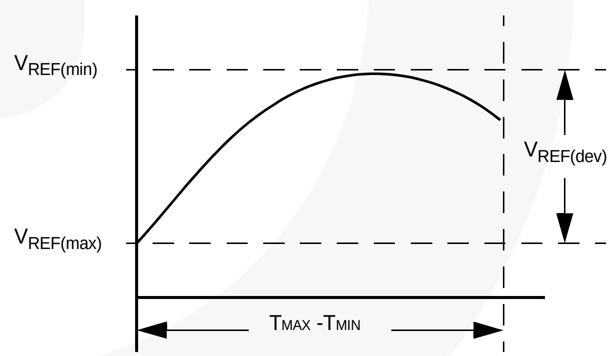
Values are at $T_A$ = 25°C unless otherwise noted.

| Symbol | Parameter | Conditions | | LM431SAI Min. | Typ. | Max. | Unit |
|---|---|---|---|---|---|---|---|
| $V_{REF}$ | 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, $T_{MIN} \leq T_A \leq T_{MAX}$ | | | 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, $R_2 = \infty$ | | | 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, $R_2 = \infty$, $T_{MIN} \leq T_A \leq T_{MAX}$ | | | 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:**

6. $T_{MIN}$ = -40°C, $T_{MAX}$ = +85°C.
7. 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.

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

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

## Test Circuits

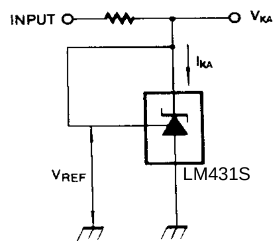



Figure 2. Test Circuit for $V_{KA} = V_{REF}$

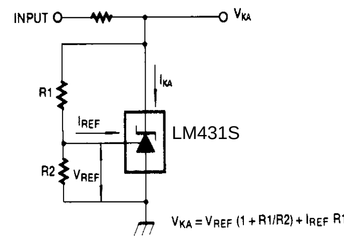



Figure 3. Test Circuit for $V_{KA} \geq V_{REF}$

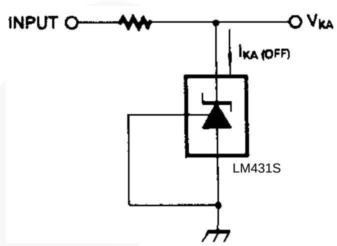



Figure 4. Test Circuit for $I_{KA(OFF)}$

## Typical Performance Characteristics

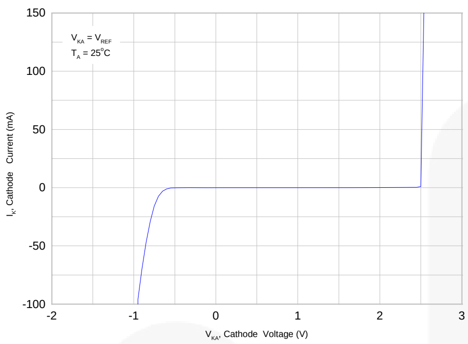



**Figure 5. Cathode Current vs. Cathode Voltage**

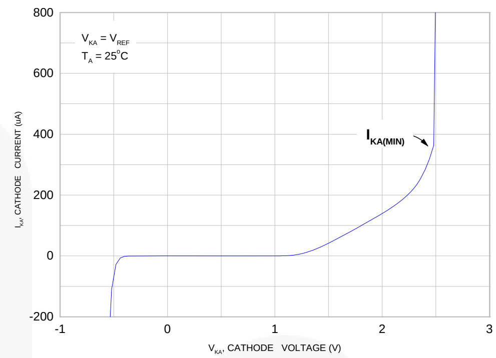



**Figure 6. Cathode Current vs. Cathode Voltage**

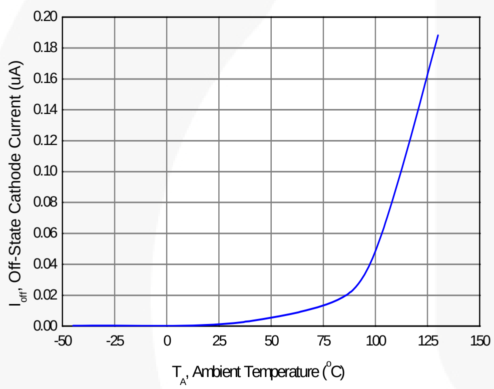



**Figure 7. OFF-State Cathode Current vs. Ambient Temperature**

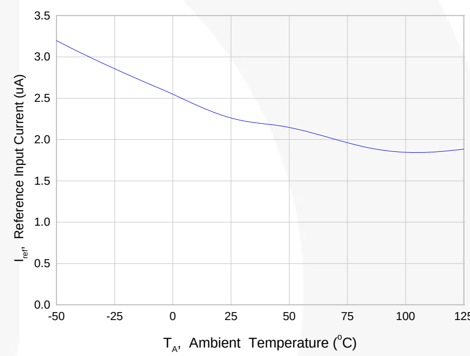



**Figure 8. Reference Input Current vs. Ambient Temperature**

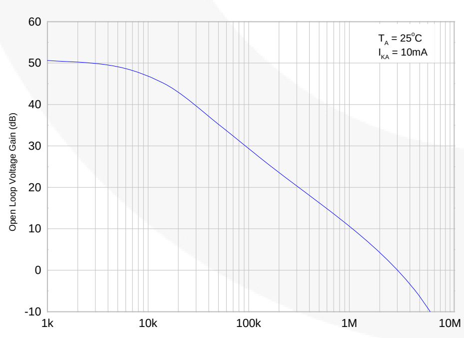



**Figure 9. Frequency vs. Small Signal Voltage Amplification**

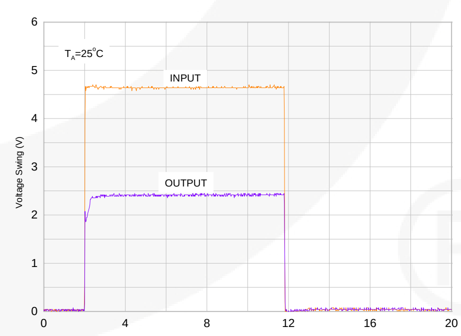



**Figure 10. Pulse Response**

## Typical Performance Characteristics (Continued)

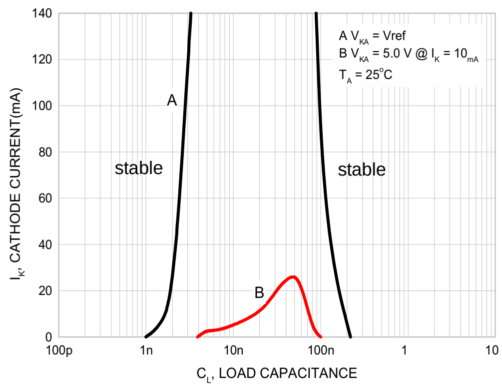



**Figure 11. Stability Boundary Conditions**

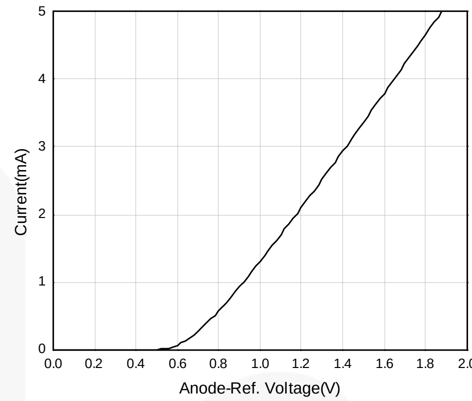



**Figure 12. Anode-Reference Diode Curve**

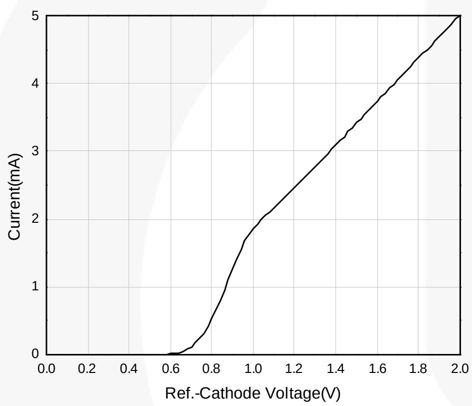



**Figure 13. Reference-Cathode Diode Curve**

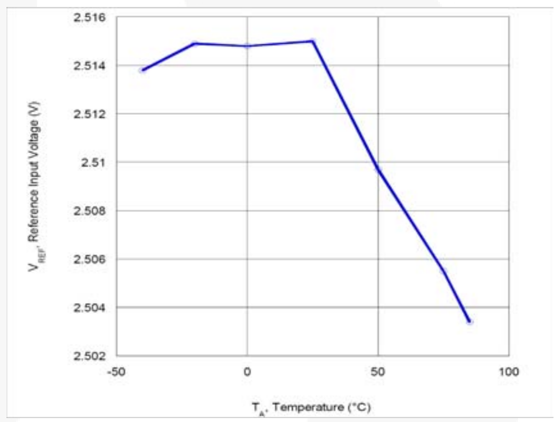



**Figure 14. Reference Input Voltage vs. Ambient Temperature**

## Typical Application

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

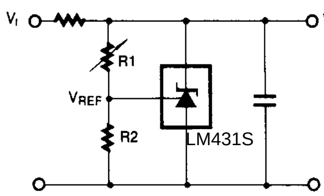



**Figure 15. Shunt Regulator**

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

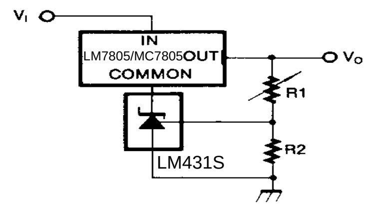



**Figure 16. Output fir Three-Terminal Fixed Regulator**

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

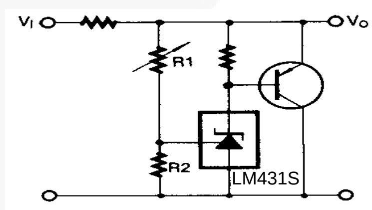



**Figure 17. High Current Shunt Regulator**

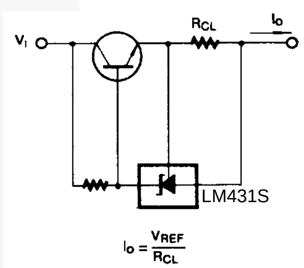



**Figure 18. Current Limit or Current Source**

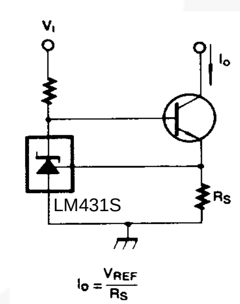
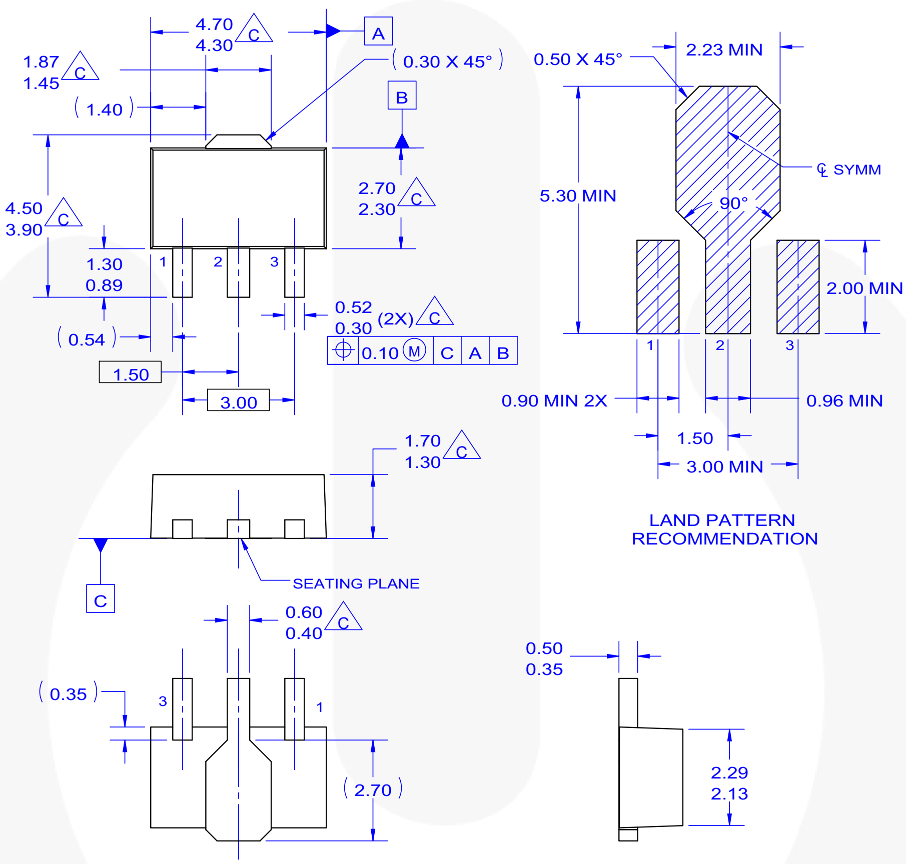



**Figure 19. Constant-Current Sink**

## Physical Dimensions

SOT-89




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 (ACTIVE)**

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## Physical Dimensions

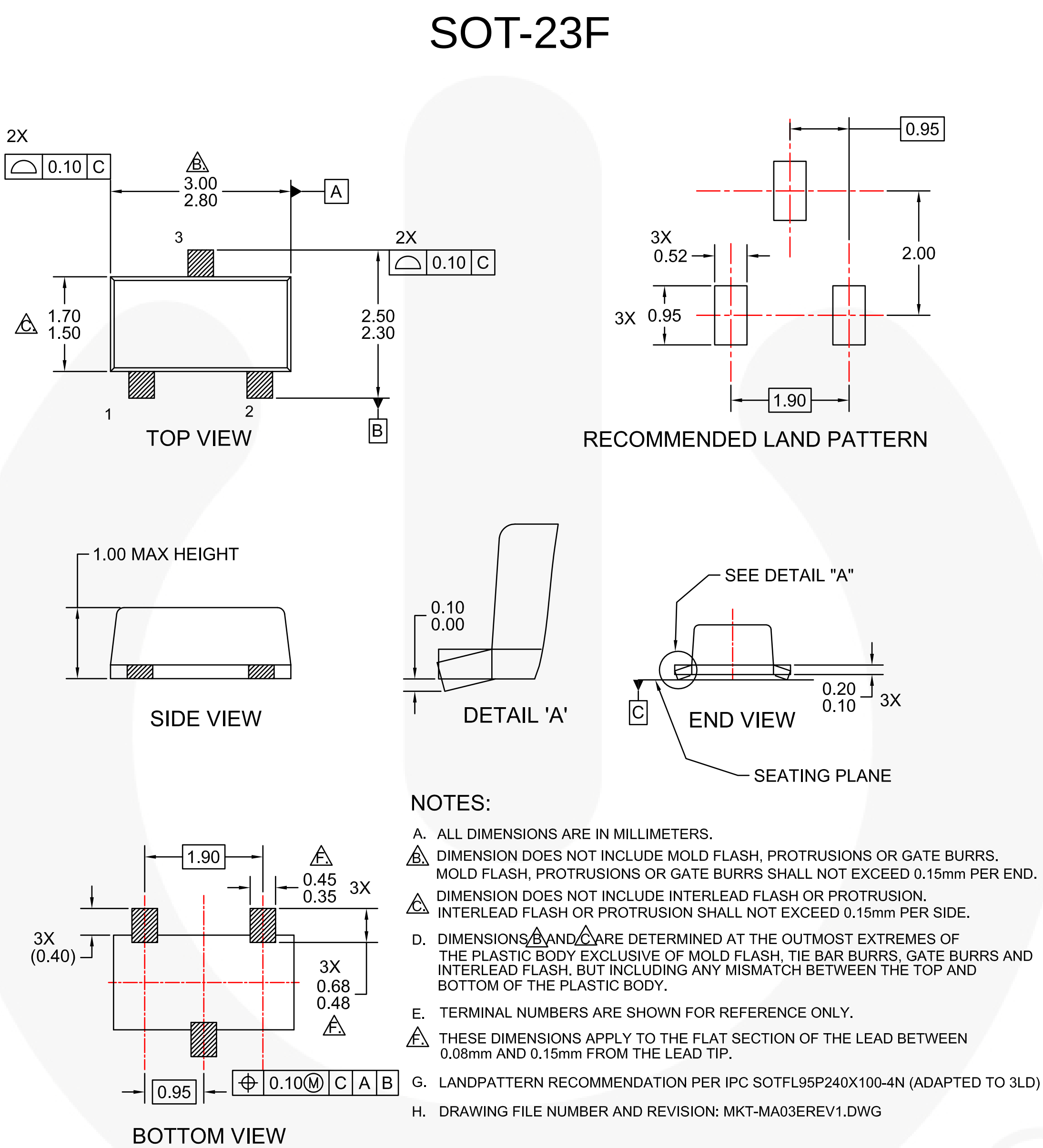


**Figure 21. 3-LEAD, SOT-23, FLAT LEAD, LOW PROFILE (ACTIVE)**

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## Physical Dimensions

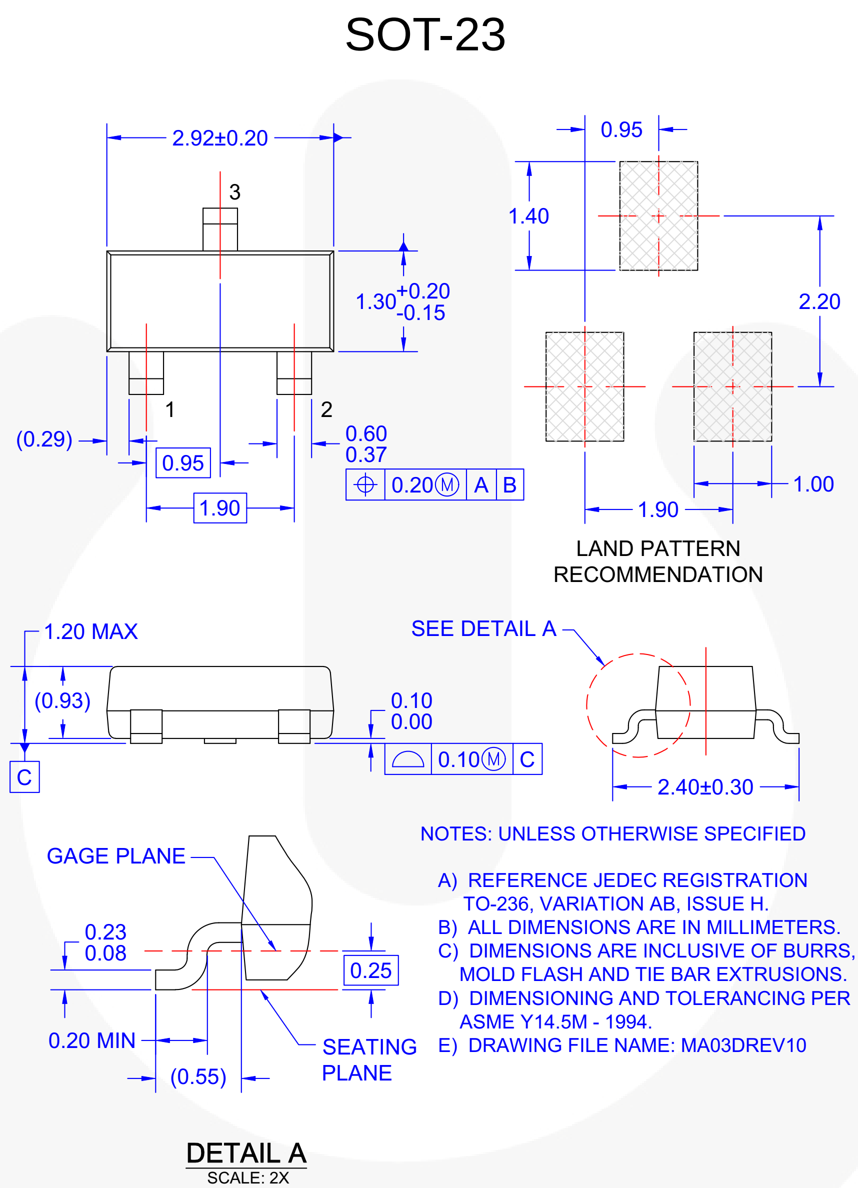


**Figure 22. 3-LEAD, SOT-23, JEDEC TO-236, LOW PROFILE (ACTIVE)**

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MicroPak2™
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MotionMax™
mWSaver™
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| No Identification Needed | Full Production | Datasheet contains final specifications. Fairchild Semiconductor reserves the right to make changes at any time without notice to improve the design. |
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