

Programmable Shunt Regulator

LM431SA, LM431SB, LM431SC

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/ $^{\circ}$ 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

BLOCK DIAGRAM

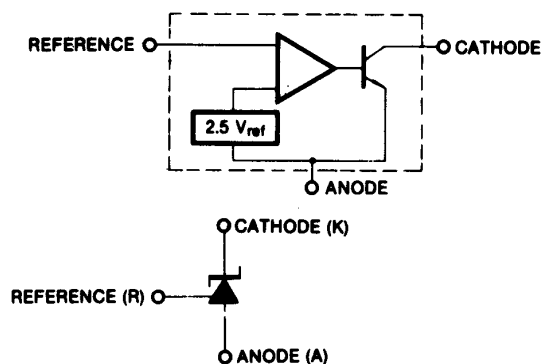
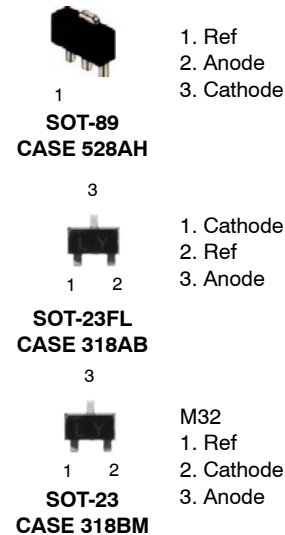


Figure 1. Block Diagram



ORDERING INFORMATION

See detailed ordering and shipping information in the package dimensions section on page 9 of this data sheet.

NOTE: Some of the devices on this data sheet have been **DISCONTINUED**. Please refer to the table on page 9.

LM431SA, LM431SB, LM431SC

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 _{θJA}	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.

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_{θJA}.

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.

LM431SA, LM431SB, LM431SC

ELECTRICAL CHARACTERISTICS (Note 5, Values are at $T_A = 25^\circ\text{C}$ unless otherwise noted)

Symbol	Parameter	Conditions		LM431SA			LM431SB			LM431SC			Unit
				Min.	Typ.	Max.	Min.	Typ.	Max.	Min.	Typ.	Max.	
V_{REF}	Reference Input Voltage	$V_{KA} = V_{REF}$, $I_{KA} = 10\text{ mA}$		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	$V_{KA} = V_{REF}$, $I_{KA} = 10\text{ mA}$, $T_{MIN} \leq T_A \leq T_{MAX}$	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	$I_{KA} = 10\text{ mA}$	$\Delta V_{KA} = 10\text{ V} - V_{REF}$		-1.0	-2.7		-1.0	-2.7		-1.0	-2.7	mV/V
			$\Delta V_{KA} = 36\text{ V} - 10\text{ V}$		-0.5	-2.0		-0.5	-2.0		-0.5	-2.0	
I_{REF}	Reference Input Current	$I_{KA} = 10\text{ mA}$, $R_1 = 10\text{ K}\Omega$, $R_2 = \infty$			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	$I_{KA} = 10\text{ mA}$, $R_1 = 10\text{ K}\Omega$, $R_2 = \infty$, $T_A = \text{Full Range}$	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	$V_{KA} = 36\text{ V}$, $V_{REF} = 0$			0.05	1.00		0.05	1.00		0.05	1.00	μA
Z_{KA}	Dynamic Impedance	$V_{KA} = V_{REF}$, $I_{KA} = 1\text{ to }100\text{ mA}$, $f \geq 1.0\text{ kHz}$			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.

5. LM431SAI, LM431SBI, LM431SCI: $-T_{A(min)} = -40^\circ\text{C}$, $T_{A(max)} = +85^\circ\text{C}$

All other pins: $-T_{A(min)} = -25^\circ\text{C}$, $T_{A(max)} = +85^\circ\text{C}$

LM431SA, LM431SB, LM431SC

ELECTRICAL CHARACTERISTICS (Continued) (Notes 6 and 7, Values are at $T_A = 25^\circ\text{C}$ unless otherwise noted)

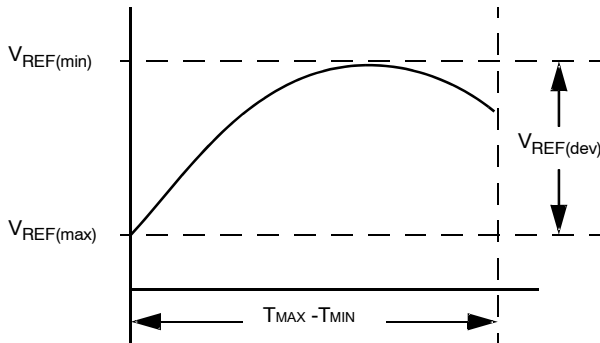
Symbol	Parameter	Conditions	LM431SAI			LM431SBI			LM431SCI			Unit
			Min.	Typ.	Max.	Min.	Typ.	Max.	Min.	Typ.	Max.	
V_{REF}	Reference Input Voltage	$V_{KA} = V_{REF}$ $I_{KA} = 10\text{ mA}$	2.450	2.500	2.550	2.470	2.495	2.520	2.482	2.495	2.508	V
$V_{REF(dev)}$	Deviation of Reference Input Voltage Over-Temperature	$V_{KA} = V_{REF}$ $I_{KA} = 10\text{ mA}$, $T_{MIN} \leq T_A \leq T_{MAX}$		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	$I_{KA} = 10\text{ mA}$ $\Delta V_{KA} = 10\text{ V} - V_{REF}$		-1.0	-2.7		-1.0	-2.7		-1.0	-2.7	mV/V
		$\Delta V_{KA} = 36\text{ V} - 10\text{ V}$		-0.5	-2.0		-0.5	-2.0		-0.5	-2.0	
I_{REF}	Reference Input Current	$I_{KA} = 10\text{ mA}$, $R_1 = 10\text{ K}\Omega$, $R_2 = \infty$		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	$I_{KA} = 10\text{ mA}$, $R_1 = 10\text{ K}\Omega$, $R_2 = \infty$, $T_{MIN} \leq T_A \leq T_{MAX}$		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	$V_{KA} = 36\text{ V}$, $V_{REF} = 0$		0.05	1.00		0.05	1.00		0.05	1.00	μA
Z_{KA}	Dynamic Impedance	$V_{KA} = V_{REF}$ $I_{KA} = 1\text{ to }100\text{ mA}$, $f \geq 1.0\text{ kHz}$		0.15	0.50		0.15	0.50		0.15	0.50	Ω

6. LM431SAI, LM431SBI, LM431SCI: $-T_{A(min)} = -40^\circ\text{C}$, $T_{A(max)} = +85^\circ\text{C}$

All other pins: $-T_{A(min)} = -25^\circ\text{C}$, $T_{A(max)} = +85^\circ\text{C}$

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, αV_{REF} , is defined as:

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



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

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

Example:

$V_{REF(dev)} = 4.5\text{ mV}$, $V_{REF} = 2500\text{ mV}$ at 25°C ,

$T_{MAX} - T_{MIN} = 125^\circ\text{C}$ for LM431SAI.

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

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

LM431SA, LM431SB, LM431SC

TEST CIRCUITS

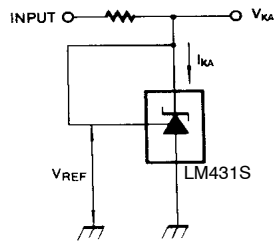


Figure 2. Test Circuit for $V_{KA} = V_{REF}$

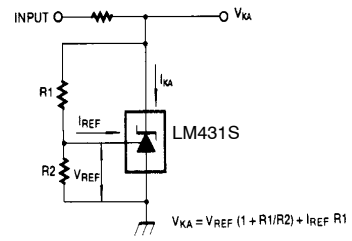


Figure 3. Test Circuit for $V_{KA} \geq V_{REF}$

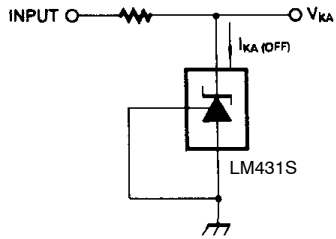


Figure 4. Test Circuit for $I_{KA(OFF)}$

LM431SA, LM431SB, LM431SC

TYPICAL APPLICATIONS

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

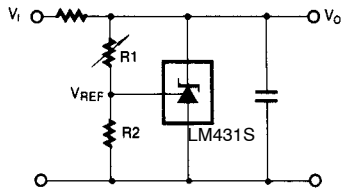


Figure 5. Shunt Regulator

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

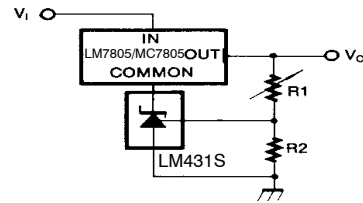


Figure 6. Output Control for Three-Terminal Fixed Regulator

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

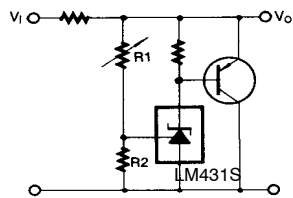


Figure 7. High Current Shunt Regulator

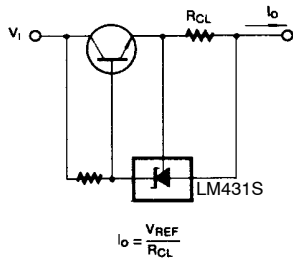


Figure 8. Current Limit or Current Source

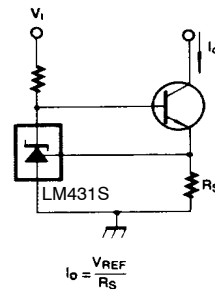


Figure 9. Constant-Current Sink

TYPICAL PERFORMANCE CHARACTERISTICS

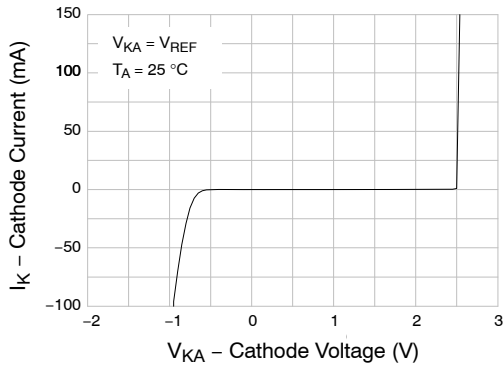


Figure 10. Cathode Current vs. Cathode Voltage

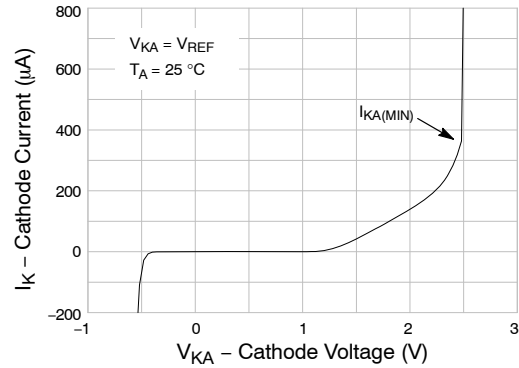


Figure 11. Cathode Current vs. Cathode Voltage

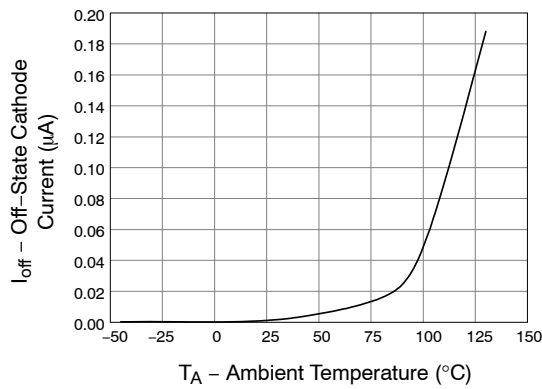


Figure 12. OFF-State Cathode Current vs. Ambient Temperature

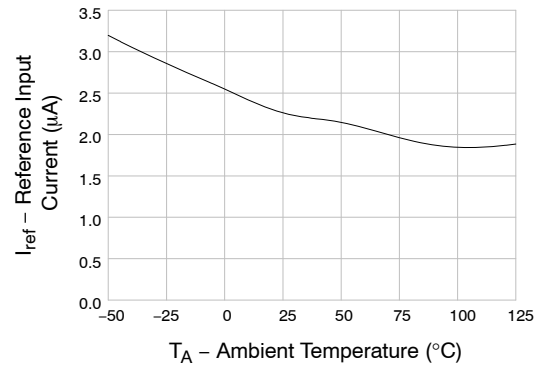


Figure 13. Reference Input Current vs. Ambient Temperature

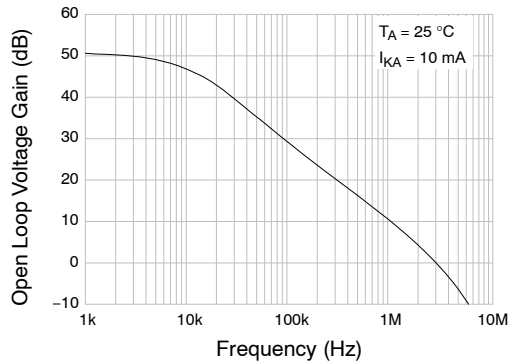


Figure 14. Frequency vs. Small Signal Voltage Amplification

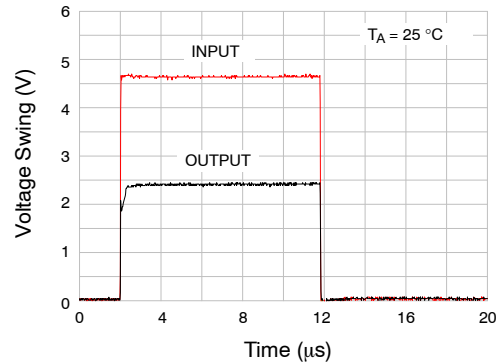


Figure 15. Pulse Response

TYPICAL PERFORMANCE CHARACTERISTICS

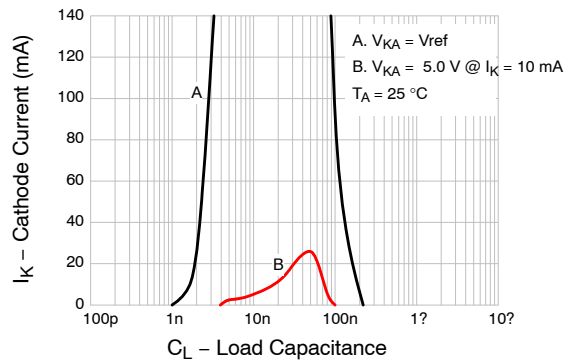


Figure 16. Stability Boundary Conditions

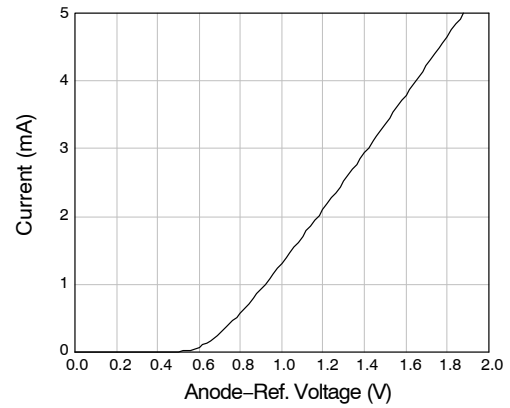


Figure 17. Anode-Reference Diode Curve

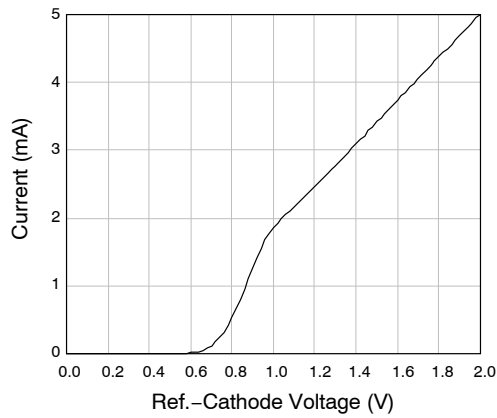


Figure 18. Reference-Cathode Diode Curve

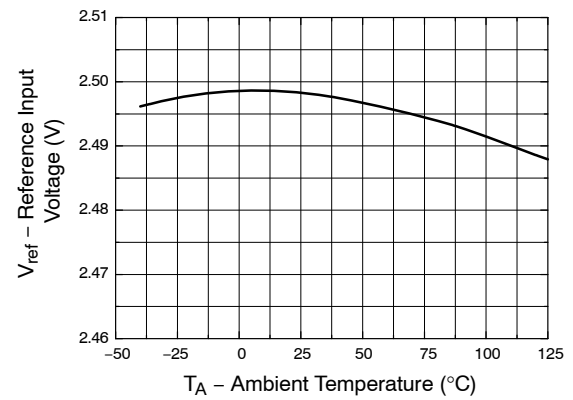


Figure 19. Reference Input Voltage vs. Ambient Temperature

LM431SA, LM431SB, LM431SC

ORDERING INFORMATION

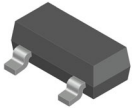
Product Number	Output Voltage Tolerance	Operating Temperature	Top Mark ⁽¹⁾	Package	Shipping [†]
LM431SBCMFX	1%	–25 to +85 °C	43B □	SOT-23FL 3L	Tape and Reel
LM431SCCMFX	0.5%		43C □	SOT-23FL 3L	

DISCONTINUED (Note 9)

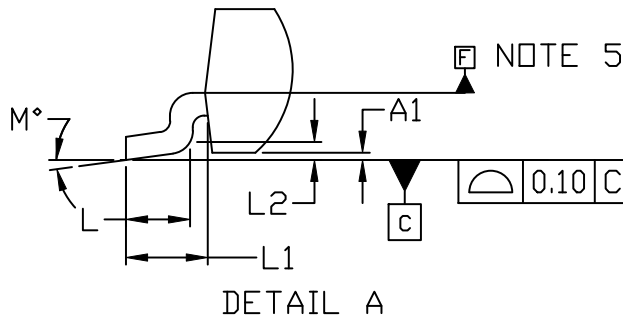
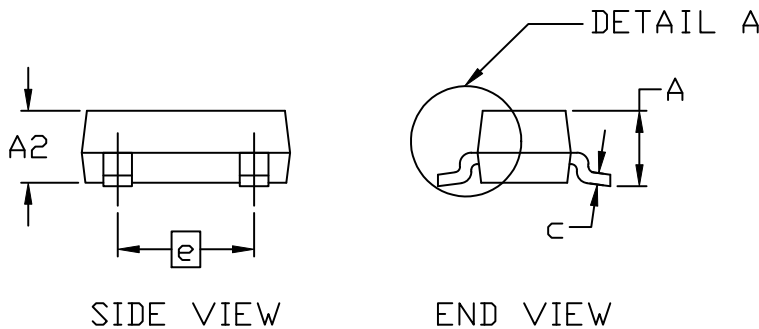
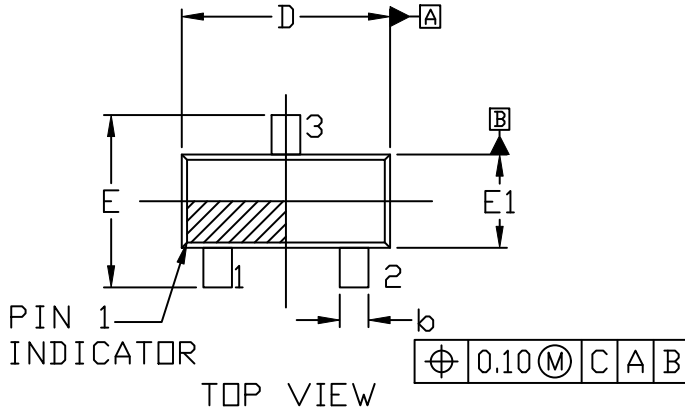
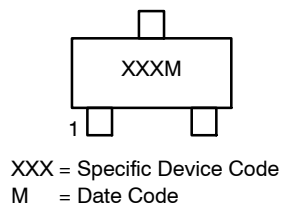
LM431SACMFX	2%	–25 to +85 °C	43A □	SOT-23FL 3L	Tape and Reel	
LM431SACM3X			43L ◎	SOT-23 3L		
LM431SACM32X			43G ◎	SOT-23 3L		
LM431SBCM3X	1%		43M ◎	SOT-23 3L		
LM431SBCM32X			43H ◎	SOT-23 3L		
LM431SCCMLX	0.5%		43C	SOT-89 3L		
LM431SCCM3X	0.5%		43N ◎	SOT-23 3L		
LM431SCCM32X			43J ◎	SOT-23 3L		
LM431SAIMFX	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.

- 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.
- DISCONTINUED:** These devices are not recommended for new design. Please contact your **onsemi** representative for information. The most current information on these devices may be available on www.onsemi.com.


SOT23-3L
CASE 318AB
ISSUE A

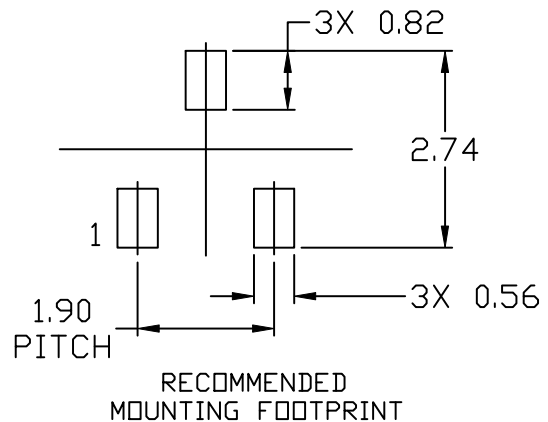
DATE 14 DEC 2021


GENERIC
MARKING DIAGRAM*


*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.

- 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.

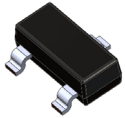
DIM	MILLIMETERS		
	MIN.	NOM.	MAX.
A	---	---	1.15
A1	0.00	---	0.10
A2	0.90	1.00	1.10
b	0.30	---	0.50
c	0.127 REF		
D	2.80	2.90	3.00
E	2.25	2.40	2.55
E1	1.20	1.30	1.40
e	1.90 BSC		
L	0.30	---	---
L1	0.55 REF		
L2	0.25 REF		
M	0°	---	8°



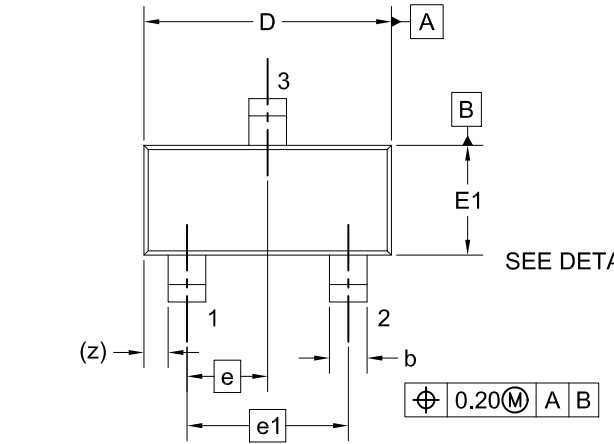
* For additional information on our Pb-Free strategy and soldering details, please download the ON Semiconductor Soldering and Mounting Techniques Reference Manual, SOLDERM/D.

DOCUMENT NUMBER:	98AON27911H	Electronic versions are uncontrolled except when accessed directly from the Document Repository. Printed versions are uncontrolled except when stamped "CONTROLLED COPY" in red.
DESCRIPTION:	SOT23-3L	PAGE 1 OF 1

onsemi and onsemi are trademarks of Semiconductor Components Industries, LLC dba onsemi or its subsidiaries in the United States and/or other countries. onsemi reserves the right to make changes without further notice to any products herein. onsemi makes no warranty, representation or guarantee regarding the suitability of its products for any particular purpose, nor does onsemi assume any liability arising out of the application or use of any product or circuit, and specifically disclaims any and all liability, including without limitation special, consequential or incidental damages. onsemi does not convey any license under its patent rights nor the rights of others.


SOT-23
CASE 318BM
ISSUE A

DATE 01 SEP 2021

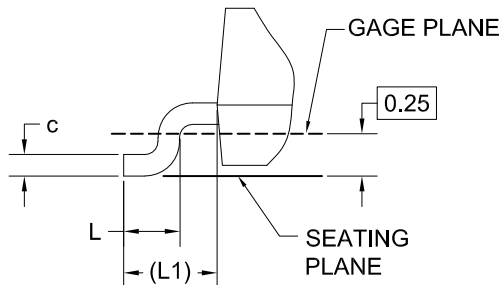
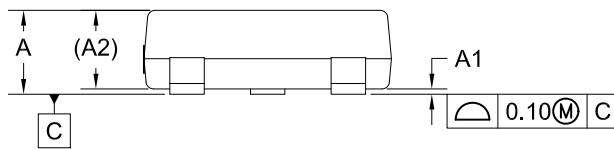
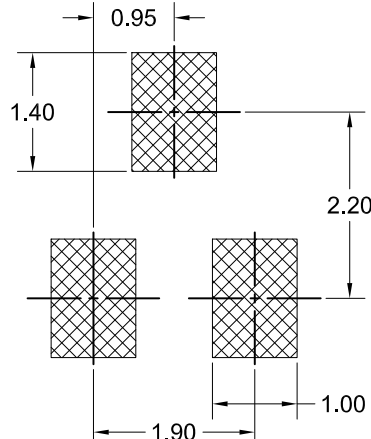
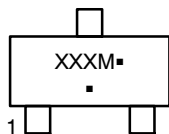


SEE DETAIL A

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		


DETAIL A
SCALE: 2X

LAND PATTERN
RECOMMENDATION
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.

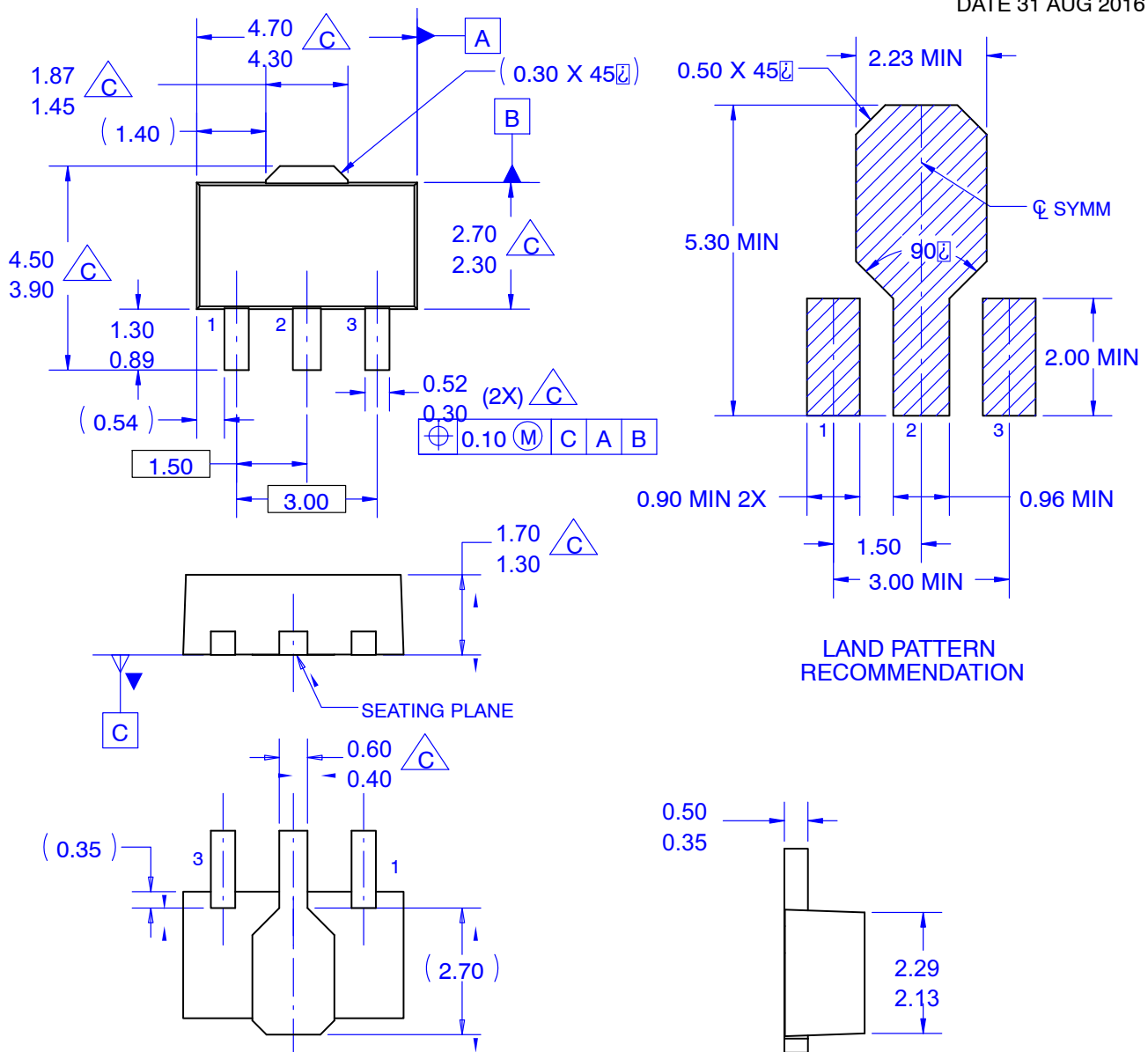
*FOR ADDITIONAL INFORMATION ON OUR PB-FREE STRATEGY AND SOLDERING DETAILS, PLEASE DOWNLOAD THE ON SEMICONDUCTOR SOLDERING AND MOUNTING TECHNIQUES REFERENCE MANUAL, SOLDERRM/D.

DOCUMENT NUMBER:	98AON13784G	Electronic versions are uncontrolled except when accessed directly from the Document Repository. Printed versions are uncontrolled except when stamped "CONTROLLED COPY" in red.
DESCRIPTION:	SOT-23	PAGE 1 OF 1

onsemi and onsemi are trademarks of Semiconductor Components Industries, LLC dba onsemi or its subsidiaries in the United States and/or other countries. onsemi reserves the right to make changes without further notice to any products herein. onsemi makes no warranty, representation or guarantee regarding the suitability of its products for any particular purpose, nor does onsemi assume any liability arising out of the application or use of any product or circuit, and specifically disclaims any and all liability, including without limitation special, consequential or incidental damages. onsemi does not convey any license under its patent rights nor the rights of others.

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.

DOCUMENT NUMBER:	98AON13791G	Electronic versions are uncontrolled except when accessed directly from the Document Repository. Printed versions are uncontrolled except when stamped "CONTROLLED COPY" in red.
DESCRIPTION:	SOT-89 3 LEAD	PAGE 1 OF 1

onsemi and onsemi are trademarks of Semiconductor Components Industries, LLC dba onsemi or its subsidiaries in the United States and/or other countries. onsemi reserves the right to make changes without further notice to any products herein. onsemi makes no warranty, representation or guarantee regarding the suitability of its products for any particular purpose, nor does onsemi assume any liability arising out of the application or use of any product or circuit, and specifically disclaims any and all liability, including without limitation special, consequential or incidental damages. onsemi does not convey any license under its patent rights nor the rights of others.

onsemi, **Onsemi**, and other names, marks, and brands are registered and/or common law trademarks of Semiconductor Components Industries, LLC dba "**onsemi**" or its affiliates and/or subsidiaries in the United States and/or other countries. **onsemi** owns the rights to a number of patents, trademarks, copyrights, trade secrets, and other intellectual property. A listing of **onsemi**'s product/patent coverage may be accessed at www.onsemi.com/site/pdf/Patent-Marking.pdf. **onsemi** reserves the right to make changes at any time to any products or information herein, without notice. The information herein is provided "as-is" and **onsemi** makes no warranty, representation or guarantee regarding the accuracy of the information, product features, availability, functionality, or suitability of its products for any particular purpose, nor does **onsemi** assume any liability arising out of the application or use of any product or circuit, and specifically disclaims any and all liability, including without limitation special, consequential or incidental damages. Buyer is responsible for its products and applications using **onsemi** products, including compliance with all laws, regulations and safety requirements or standards, regardless of any support or applications information provided by **onsemi**. "Typical" parameters which may be provided in **onsemi** data sheets and/or specifications can and do vary in different applications and actual performance may vary over time. All operating parameters, including "Typicals" must be validated for each customer application by customer's technical experts. **onsemi** does not convey any license under any of its intellectual property rights nor the rights of others. **onsemi** products are not designed, intended, or authorized for use as a critical component in life support systems or any FDA Class 3 medical devices or medical devices with a same or similar classification in a foreign jurisdiction or any devices intended for implantation in the human body. Should Buyer purchase or use **onsemi** products for any such unintended or unauthorized application, Buyer shall indemnify and hold **onsemi** and its officers, employees, subsidiaries, affiliates, and distributors harmless against all claims, costs, damages, and expenses, and reasonable attorney fees arising out of, directly or indirectly, any claim of personal injury or death associated with such unintended or unauthorized use, even if such claim alleges that **onsemi** was negligent regarding the design or manufacture of the part. **onsemi** is an Equal Opportunity/Affirmative Action Employer. This literature is subject to all applicable copyright laws and is not for resale in any manner.

ADDITIONAL INFORMATION

TECHNICAL PUBLICATIONS:

Technical Library: www.onsemi.com/design/resources/technical-documentation
onsemi Website: www.onsemi.com

ONLINE SUPPORT: www.onsemi.com/support

For additional information, please contact your local Sales Representative at
www.onsemi.com/support/sales