



# TL431 family

## Adjustable precision shunt regulators

Rev. 6 — 9 January 2019

Product data sheet

## 1. Product profile

### 1.1. General description

Three-terminal shunt regulator family with an output voltage range between  $V_{ref} = 2.495\text{ V}$  and  $36\text{ V}$ , to be set by two external resistors.

Table 1. Product overview

Reference voltage tolerance ( $V_{ref}$ )	Temperature range ( $T_{amb}$ )			Pinning configuration (see Table 5)
	0 °C to 70 °C	-40 °C to 85 °C	-40 °C to 125 °C	
2.0 %	TL431CDBZR	TL431IDBZR	TL431QDBZR	normal pinning
			TL431FDT	normal pinning
			TL431MFDT	mirrored pinning
1.0 %	TL431ACDBZR	TL431AIDBZR	TL431AQDBZR	normal pinning
			TL431AFDT	normal pinning
			TL431AMFDT	mirrored pinning
0.5 %	TL431BCDBZR	TL431BIDBZR	TL431BQDBZR	normal pinning
			TL431BFDT	normal pinning
			TL431BMFDT	mirrored pinning

### 1.2. Features and benefits

- Programmable output voltage up to  $36\text{ V}$
- Three different reference voltage tolerances:
  - Standard grade: 2 %
  - A-Grade: 1 %
  - B-Grade: 0.5 %
- Typical temperature drift:  $9\text{ mV}$  (in a range of  $0\text{ °C}$  up to  $70\text{ °C}$ )
- Low output noise
- Typical output impedance:  $0.2\ \Omega$
- Sink current capability:  $1\text{ mA}$  to  $100\text{ mA}$
- AEC-Q100 qualified (grade 1)

### 1.3. Applications

- Shunt regulator
- Precision current limiter
- Precision constant current sink
- Isolated feedback loop for Switch Mode Power Supply (SMPS)

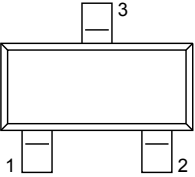
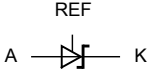
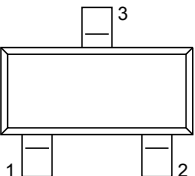
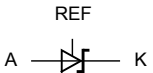
### 1.4. Quick reference data

Table 2. Quick reference data

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
$V_{KA}$	cathode-anode voltage		$V_{ref}$	-	36	V
$I_K$	cathode current		1	-	100	mA
$V_{ref}$	reference voltage	$V_{KA} = V_{ref}; I_K = 10 \text{ mA};$ $T_{amb} = 25 \text{ }^\circ\text{C}$				
	• Standard-Grade (2.0 %)		2440	2495	2550	mV
	• A-Grade (1.0 %)		2470	2495	2520	mV
	• B-Grade (0.5 %)		2483	2495	2507	mV

## 2. Pinning information

Table 3. Pinning

Pin	Symbol	Description	Simplified outline	Graphic symbol
<b>SOT23; normal pinning: All types without MFDT ending</b>				
1	K	cathode		 006aab355
2	REF	reference		
3	A	anode		
<b>SOT23; mirrored pinning: All types with MFDT ending</b>				
1	REF	reference		 006aab355
2	K	cathode		
3	A	anode		

### 3. Ordering information

Table 4. Ordering information

Type number	Package		Version
	Name	Description	
TL431CDBZR	TO-236AB	plastic surface-mounted package; 3 leads	SOT23
TL431IDBZR			
TL431QDBZR			
TL431FDT			
TL431MFDT			
TL431ACDBZR			
TL431AIDBZR			
TL431AQDBZR			
TL431AFDT			
TL431AMFDT			
TL431BCDBZR			
TL431BIDBZR			
TL431BQDBZR			
TL431BFDT			
TL431BMFDT			

### 4. Marking

Table 5. Marking codes

Type number	Marking code [1]	Type number	Marking code [1]
TL431CDBZR	CA%	TL431AFDT	AS%
TL431IDBZR	CB%	TL431AMFDT	AV%
TL431QDBZR	CC%	TL431BCDBZR	CG%
TL431FDT	AR%	TL431BIDBZR	CH%
TL431MFDT	AU%	TL431BQDBZR	CJ%
TL431ACDBZR	CD%	TL431BFDT	AT%
TL431AIDBZR	CE%	TL431BMFDT	AW%
TL431AQDBZR	CF%	-	-

[1] % = placeholder for manufacturing site code.

## 5. Functional diagram

The TL431 family comprises a range of 3-terminal adjustable shunt regulators, with specified thermal stability over applicable automotive and commercial temperature ranges. The output voltage can be set to any value between  $V_{\text{ref}}$  (approximately 2.5 V) and 36 V with two external resistors (see Figure 8). These devices have a typical output impedance of 0.2  $\Omega$ . Active output circuitry provides a very sharp turn-on characteristic, making these devices excellent replacements for Zener diodes in many applications like on-board regulation, adjustable power supplies and switching power supplies.



Fig. 1. Functional diagram

## 6. Limiting values

**Table 6. Limiting values**

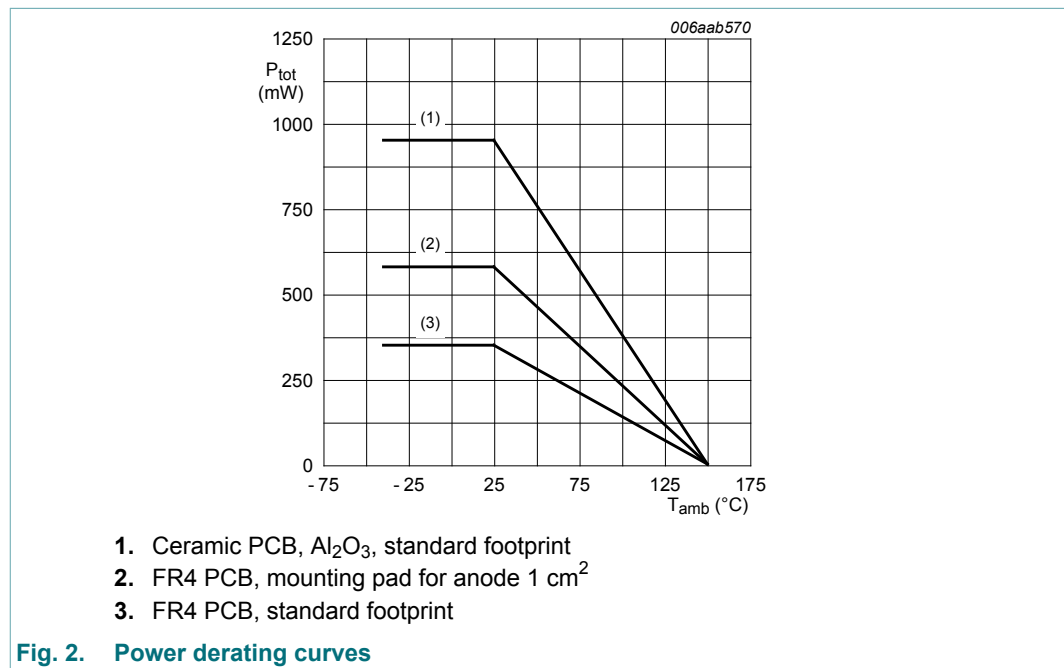
In accordance with the Absolute Maximum Rating System (IEC 60134).

Symbol	Parameter	Conditions	Min	Max	Unit	
$V_{KA}$	cathode-anode voltage		-	37	V	
$I_K$	cathode current		-100	150	mA	
$I_{ref}$	reference current		-0.05	10	mA	
$P_{tot}$	total power dissipation	$T_{amb} \leq 25\text{ °C}$	[1]	-	350	mW
			[2]	-	580	mW
			[3]	-	950	mW
$T_j$	junction temperature		-	150	°C	
$T_{amb}$	ambient temperature					
	TL431XCDBZR		0	+70	°C	
	TL431XIDBZR		-40	+85	°C	
	TL431XQDBZR TL431XFDT		-40	+125	°C	
$T_{stg}$	storage temperature		-65	+150	°C	

[1] Device mounted on an FR4 Printed-Circuit Board (PCB), single-sided copper, tin-plated and standard footprint.

[2] Device mounted on an FR4 PCB, single-sided copper, tin-plated, mounting pad for anode 1 cm<sup>2</sup>.

[3] Device mounted on a ceramic PCB, Al<sub>2</sub>O<sub>3</sub>, standard footprint.



**Table 7. ESD maximum ratings**

$T_{amb} = 25\text{ °C}$  unless otherwise specified.

Symbol	Parameter	Conditions	Min	Max	Unit
$V_{ESD}$	electrostatic discharge voltage	MIL-STD-883 (human body model)	-	4	kV

## 7. Recommended operating conditions

Table 8. Operating conditions

Symbol	Parameter	Conditions	Min	Max	Unit
$V_{KA}$	cathode-anode voltage		$V_{ref}$	36	V
$I_K$	cathode current		1	100	mA

## 8. Thermal characteristics

Table 9. Thermal characteristics

Symbol	Parameter	Conditions	Min	Typ	Max	Unit	
$R_{th(j-a)}$	thermal resistance from junction to ambient	in free air	[1]	-	-	360	K/W
			[2]	-	-	216	K/W
			[3]	-	-	132	K/W
$R_{th(j-sp)}$	thermal resistance from junction to solder point		[4]	-	-	50	K/W

- [1] Device mounted on an FR4 PCB, single-sided copper, tin-plated and standard footprint.  
 [2] Device mounted on an FR4 PCB, single-sided copper, tin-plated, mounting pad for anode 1 cm<sup>2</sup>.  
 [3] Device mounted on a ceramic PCB, Al<sub>2</sub>O<sub>3</sub>, standard footprint.  
 [4] Soldering point of anode.

## 9. Characteristics

**Table 10. Characteristics**
 $T_{amb} = 25\text{ °C}$  unless otherwise specified.

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
Standard-Grade (2.0 %): TL431CDBZR; TL431IDBZR; TL431QDBZR; TL431FDT; TL431MFDT						
$V_{ref}$	reference voltage	$V_{KA} = V_{ref}$ ; $I_K = 10\text{ mA}$	2440	2495	2550	mV
$\Delta V_{ref}$	reference voltage variation	$V_{KA} = V_{ref}$ ; $I_K = 10\text{ mA}$				
	TL431CDBZR	$T_{amb} = 0\text{ °C to }70\text{ °C}$	-	9	16	mV
	TL431IDBZR	$T_{amb} = -40\text{ °C to }85\text{ °C}$	-	17	34	mV
	TL431QDBZR	$T_{amb} = -40\text{ °C to }125\text{ °C}$				
	TL431FDT TL431MFDT					
$\Delta V_{ref}/\Delta V_{KA}$	reference voltage variation to cathode -anode voltage variation ratio	$I_K = 10\text{ mA}$				
		$\Delta V_{KA} = 10\text{ V to }V_{ref}$	-	-1.4	-2.7	mV/V
		$\Delta V_{KA} = 36\text{ V to }10\text{ V}$	-	-1	-2	mV/V
$I_{ref}$	reference current	$I_K = 10\text{ mA}$ ; $R1 = 10\text{ k}\Omega$ ; $R2 = \text{open}$	-	2	4	$\mu\text{A}$
$\Delta I_{ref}$	reference current variation	$I_K = 10\text{ mA}$ ; $R1 = 10\text{ k}\Omega$ ; $R2 = \text{open}$				
	TL431CDBZR	$T_{amb} = 0\text{ °C to }70\text{ °C}$	-	0.4	1.2	$\mu\text{A}$
	TL431IDBZR	$T_{amb} = -40\text{ °C to }85\text{ °C}$	-	0.8	2.5	$\mu\text{A}$
	TL431QDBZR	$T_{amb} = -40\text{ °C to }125\text{ °C}$				
	TL431FDT TL431MFDT					
$I_{K(min)}$	minimum cathode current	$V_{KA} = V_{ref}$	-	0.4	1	mA
$I_{off}$	off-state current	$V_{KA} = 36\text{ V}$ ; $V_{ref} = 0$	-	0.1	1	$\mu\text{A}$
$Z_{KA}$	dynamic cathode-anode impedance	$I_K = 0.1\text{ mA to }100\text{ mA}$ ; $V_{KA} = V_{ref}$ ; $f < 1\text{ kHz}$	-	0.20	0.5	$\Omega$
A-Grade (1 %): TL431ACDBZR; TL431AIDBZR; TL431AQDBZR; TL431AFDT; TL431AMFDT						
$V_{ref}$	reference voltage	$V_{KA} = V_{ref}$ ; $I_K = 10\text{ mA}$	2470	2495	2520	mV
$\Delta V_{ref}$	reference voltage variation	$V_{KA} = V_{ref}$ ; $I_K = 10\text{ mA}$				
	TL431ACDBZR	$T_{amb} = 0\text{ °C to }70\text{ °C}$	-	9	16	mV
	TL431AIDBZR	$T_{amb} = -40\text{ °C to }85\text{ °C}$	-	17	34	mV
	TL431AQDBZR	$T_{amb} = -40\text{ °C to }125\text{ °C}$				
	TL431AFDT TL431AMFDT					
$\Delta V_{ref}/\Delta V_{KA}$	reference voltage variation to cathode-anode voltage variation ratio	$I_K = 10\text{ mA}$				
		$\Delta V_{KA} = 10\text{ V to }V_{ref}$	-	-1.4	-2.7	mV/V
		$\Delta V_{KA} = 36\text{ V to }10\text{ V}$	-	-1.0	-2.0	mV
$I_{ref}$	reference current	$I_K = 10\text{ mA}$ ; $R1 = 10\text{ k}\Omega$ ; $R2 = \text{open}$	-	2.0	4.0	$\mu\text{A}$

## Adjustable precision shunt regulators

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
$\Delta I_{\text{ref}}$	reference current variation	$I_K = 10 \text{ mA}$ ; $R1 = 10 \text{ k}\Omega$ ; $R2 = \text{open}$				
	TL431ACDBZR	$T_{\text{amb}} = 0 \text{ }^\circ\text{C}$ to $70 \text{ }^\circ\text{C}$	-	0.4	1.2	$\mu\text{A}$
	TL431AIDBZR	$T_{\text{amb}} = -40 \text{ }^\circ\text{C}$ to $85 \text{ }^\circ\text{C}$	-	0.8	2.5	$\mu\text{A}$
	TL431AQDBZR	$T_{\text{amb}} = -40 \text{ }^\circ\text{C}$ to $125 \text{ }^\circ\text{C}$				
	TL431AFDT TL431AMFDT					
$I_{K(\text{min})}$	minimum cathode current	$V_{KA} = V_{\text{ref}}$				
	TL431ACDBZR	$T_{\text{amb}} = 0 \text{ }^\circ\text{C}$ to $70 \text{ }^\circ\text{C}$	-	0.4	0.6	$\text{mA}$
	TL431AIDBZR	$T_{\text{amb}} = -40 \text{ }^\circ\text{C}$ to $85 \text{ }^\circ\text{C}$				
	TL431AQDBZR	$T_{\text{amb}} = -40 \text{ }^\circ\text{C}$ to $125 \text{ }^\circ\text{C}$				
	TL431AFDT TL431AMFDT					
$I_{\text{off}}$	off-state current	$V_{KA} = 36 \text{ V}$ ; $V_{\text{ref}} = 0$	-	0.1	0.5	$\mu\text{A}$
$Z_{KA}$	dynamic cathode-anode impedance	$I_K = 0.1 \text{ mA}$ to $100 \text{ mA}$ ; $V_{KA} = V_{\text{ref}}$ ; $f < 1 \text{ kHz}$	-	0.2	0.5	$\Omega$
B-Grade (0.5 %): TL431BCDBZR; TL431BIDBZR; TL431BFDT; TL431BMFDT						
$V_{\text{ref}}$	reference voltage	$V_{KA} = V_{\text{ref}}$ ; $I_K = 10 \text{ mA}$	2483	2495	2507	$\text{mV}$
$\Delta V_{\text{ref}}$	reference voltage variation	$V_{KA} = V_{\text{ref}}$ ; $I_K = 10 \text{ mA}$				
	TL431BCDBZR	$T_{\text{amb}} = 0 \text{ }^\circ\text{C}$ to $70 \text{ }^\circ\text{C}$	-	9	16	$\text{mV}$
	TL431BIDBZR	$T_{\text{amb}} = -40 \text{ }^\circ\text{C}$ to $85 \text{ }^\circ\text{C}$	-	17	34	$\text{mV}$
	TL431BQDBZR	$T_{\text{amb}} = -40 \text{ }^\circ\text{C}$ to $125 \text{ }^\circ\text{C}$				
	TL431BFDT TL431BMFDT					
$\Delta V_{\text{ref}}/\Delta V_{KA}$	reference voltage variation to cathode-anode voltage variation ratio	$I_K = 10 \text{ mA}$				
		$\Delta V_{KA} = 10 \text{ V}$ to $V_{\text{ref}}$	-	-1.4	-2.7	$\text{mV/V}$
		$\Delta V_{KA} = 36 \text{ V}$ to $10 \text{ V}$	-	-1.0	-2.0	$\text{mV/V}$
$I_{\text{ref}}$	reference current	$I_K = 10 \text{ mA}$ ; $R1 = 10 \text{ k}\Omega$ ; $R2 = \text{open}$	-	2.0	4.0	$\mu\text{A}$
$\Delta I_{\text{ref}}$	reference current variation	$I_K = 10 \text{ mA}$ ; $R1 = 10 \text{ k}\Omega$ ; $R2 = \text{open}$				
	TL431BCDBZR	$T_{\text{amb}} = 0 \text{ }^\circ\text{C}$ to $70 \text{ }^\circ\text{C}$	-	0.4	1.2	$\mu\text{A}$
	TL431BIDBZR	$T_{\text{amb}} = -40 \text{ }^\circ\text{C}$ to $85 \text{ }^\circ\text{C}$	-	0.8	2.5	$\mu\text{A}$
	TL431BQDBZR	$T_{\text{amb}} = -40 \text{ }^\circ\text{C}$ to $125 \text{ }^\circ\text{C}$				
	TL431BFDT TL431BMFDT					
$I_{K(\text{min})}$	minimum cathode current	$V_{KA} = V_{\text{ref}}$				
	TL431BCDBZR	$T_{\text{amb}} = 0 \text{ }^\circ\text{C}$ to $70 \text{ }^\circ\text{C}$	-	0.4	0.6	$\text{mA}$
	TL431BIDBZR	$T_{\text{amb}} = -40 \text{ }^\circ\text{C}$ to $85 \text{ }^\circ\text{C}$				
	TL431BQDBZR	$T_{\text{amb}} = -40 \text{ }^\circ\text{C}$ to $125 \text{ }^\circ\text{C}$				
	TL431BFDT TL431BMFDT					
$I_{\text{off}}$	off-state current	$V_{KA} = 36 \text{ V}$ ; $V_{\text{ref}} = 0$	-	0.1	0.5	$\mu\text{A}$
$Z_{KA}$	dynamic cathode-anode impedance	$I_K = 0.1 \text{ mA}$ to $100 \text{ mA}$ ; $V_{KA} = V_{\text{ref}}$ ; $f < 1 \text{ kHz}$	-	0.2	0.5	$\Omega$





$I_K = 10 \text{ mA}; V_{KA} = V_{ref}$

**Fig. 3. Reference voltage as a function of ambient temperature; typical values**



$V_{KA} = V_{ref}; T_{amb} = 25 \text{ °C}$

**Fig. 4. Cathode current as a function of cathode-anode voltage; typical values**



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$I_K = 10 \text{ mA}; V_{KA} = V_{ref}$

**Fig. 5. Test circuit to Figures 3 and 4**



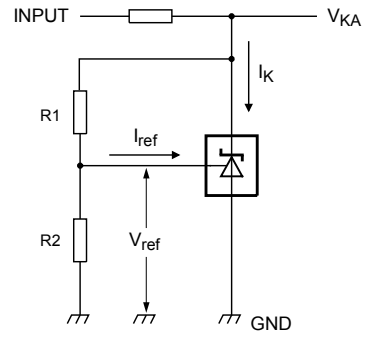
$I_K = 10 \text{ mA}; R1 = 10 \text{ k}\Omega; R2 = \text{open}$

**Fig. 6. Reference current as a function of ambient temperature; typical values**



I<sub>K</sub> = 10 mA; T<sub>amb</sub> = 25 °C

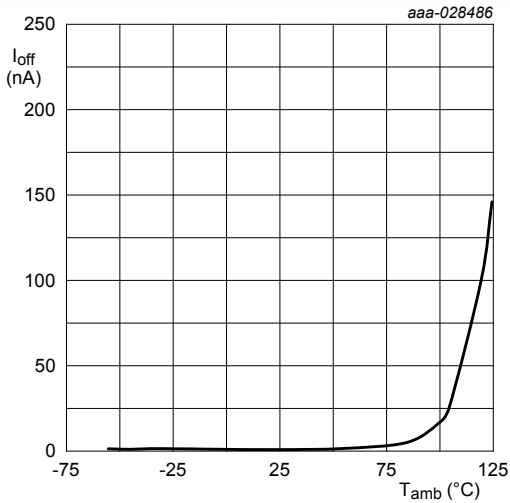
Fig. 7. Reference voltage variation as a function of cathode-anode voltage; typical values



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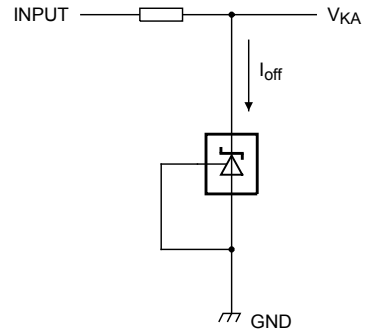
$$V_{KA} = V_{ref} \times \left(1 + \frac{R1}{R2}\right) + I_{ref} \times R1$$

Fig. 8. Test circuit to Figures 6 and 7



V<sub>KA</sub> = 36 V; V<sub>ref</sub> = 0 V

Fig. 9. Off-state current as a function of ambient temperature; typical values



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V<sub>KA</sub> = 36 V; V<sub>ref</sub> = 0 V

Fig. 10. Test circuit to Figure 9



1. input  
2. output  
 $T_{amb} = 25\text{ }^{\circ}\text{C}$

**Fig. 11. Input voltage and output voltage as a function of time; typical values**



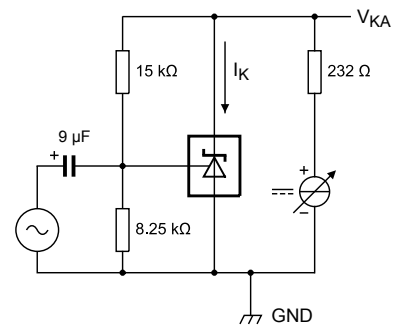
$T_{amb} = 25\text{ }^{\circ}\text{C}$

**Fig. 12. Test circuit to Figure 11**



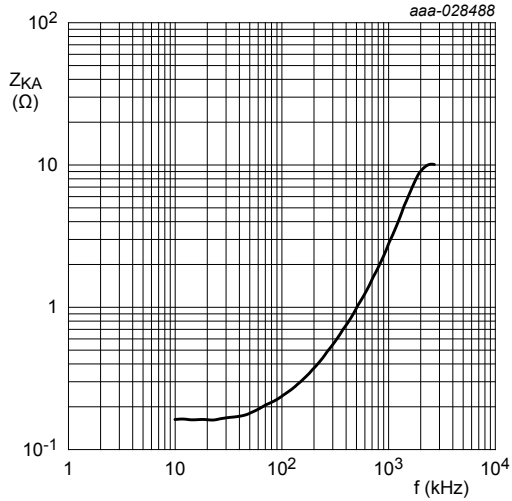
$I_K = 10\text{ mA}; T_{amb} = 25\text{ }^{\circ}\text{C}$

**Fig. 13. Voltage amplification as a function of frequency; typical values**



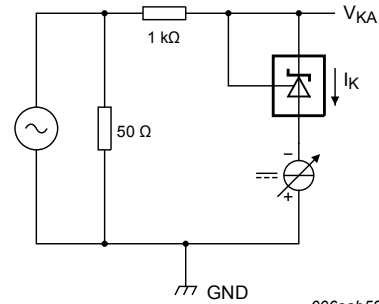
$I_K = 10\text{ mA}; T_{amb} = 25\text{ }^{\circ}\text{C}$

**Fig. 14. Test circuit to Figure 13**



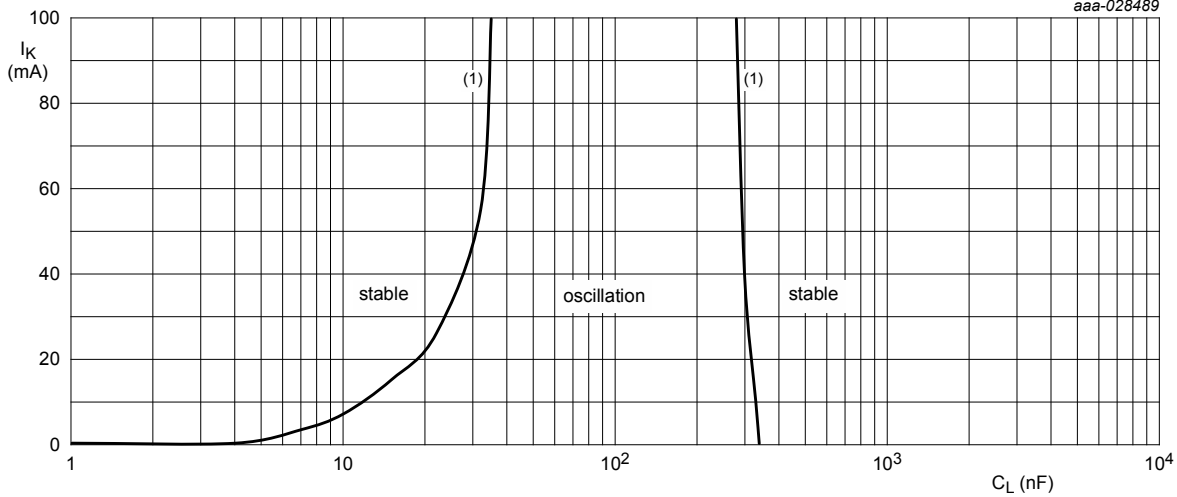
$I_K = 10 \text{ mA}; T_{\text{amb}} = 25 \text{ }^\circ\text{C}$

**Fig. 15. Dynamic cathode-anode impedance as a function of frequency; typical values**



$I_K = 10 \text{ mA}; T_{\text{amb}} = 25 \text{ }^\circ\text{C}$

**Fig. 16. Test circuit to Figure 15**



$T_{\text{amb}} = 25 \text{ }^\circ\text{C}$

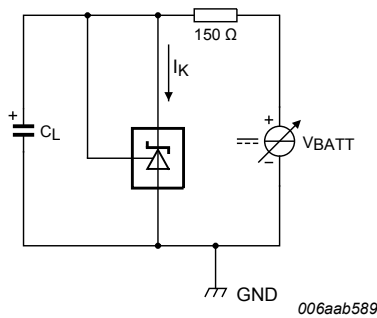
(1)  $V_{KA} = V_{\text{ref}}$

$V_{KA} = 5 \text{ V};$  no oscillation

$V_{KA} = 10 \text{ V};$  no oscillation

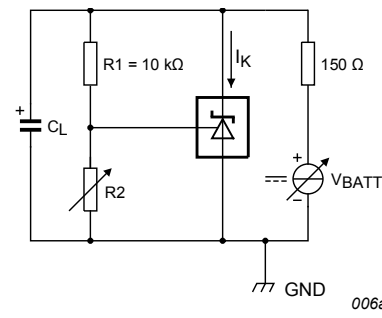
$V_{KA} = 15 \text{ V};$  no oscillation

**Fig. 17. Cathode current as a function of load capacitance, typical values**



$V_{KA} = V_{\text{ref}}; T_{\text{amb}} = 25 \text{ }^\circ\text{C}$

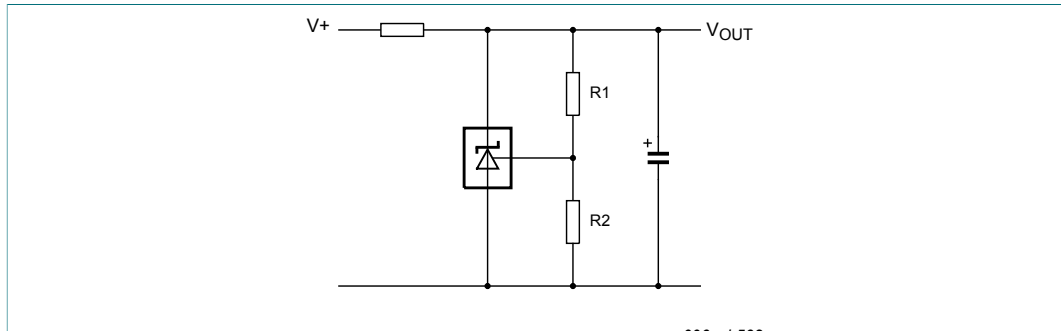
**Fig. 18. Test circuit to Figure 17**



$V_{KA} > 5 \text{ V};$  stable operation;  $T_{\text{amb}} = 25 \text{ }^\circ\text{C}$

**Fig. 19. Test circuit to Figure 17**

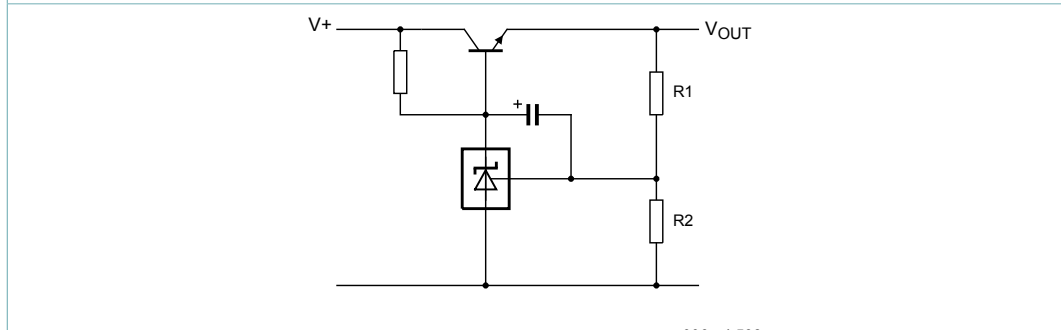
10. Application information



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$$V_{OUT} = \left(1 + \frac{R1}{R2}\right) \times V_{ref}$$

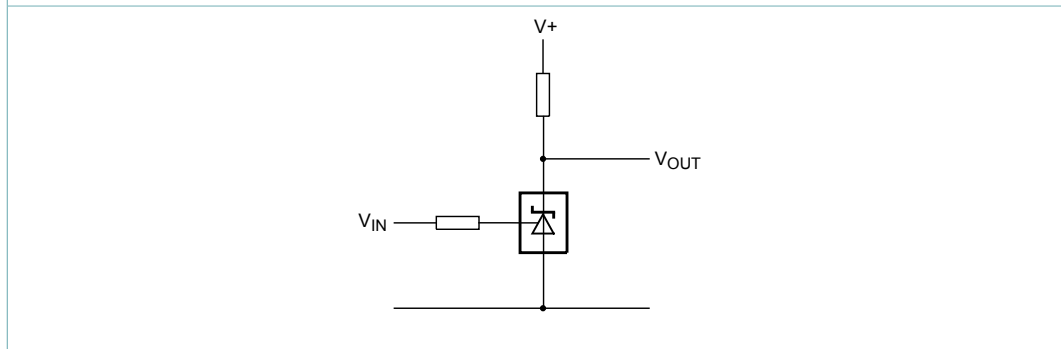
Fig. 20. Shunt regulator



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$$V_{OUT} = \left(1 + \frac{R1}{R2}\right) \times V_{ref} \quad V_{OUT(min)} = V_{ref} + V_{be}$$

Fig. 21. Series pass regulator



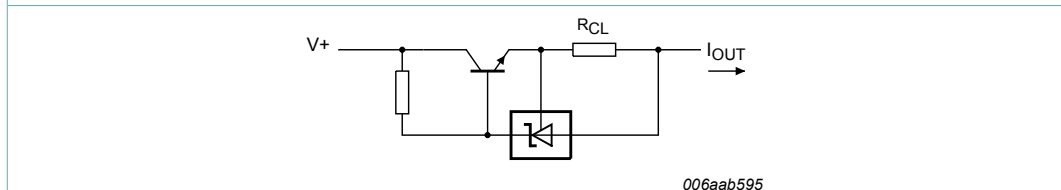
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$$T_{th} = V_{ref}$$

$$T_{IN} < V_{ref} \Rightarrow V_{OUT} > 0$$

$$T_{IN} > V_{ref} \Rightarrow V_{OUT} \cong 2$$

Fig. 22. Single-supply comparator with temperature-compensated threshold



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$$I_{OUT} = \frac{V_{ref}}{R_{CL}}$$

Fig. 23. Constant current source



## 11. Test information

### Quality information

This product has been qualified in accordance with the Automotive Electronics Council (AEC) standard Q100 - Failure mechanism based stress test qualification for integrated circuits, and is suitable for use in automotive applications.

## 12. Package outline



Fig. 27. Package outline SOT23 (TO-236AB)

## 13. Soldering

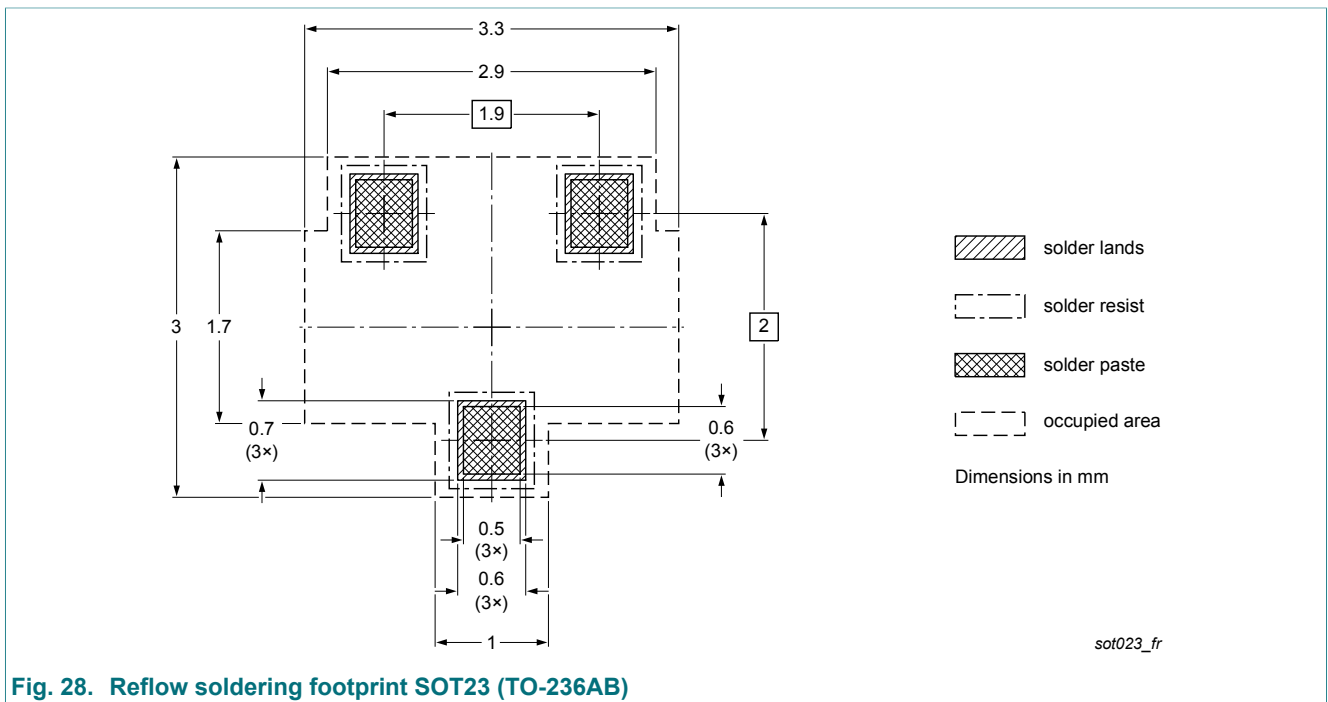


Fig. 28. Reflow soldering footprint SOT23 (TO-236AB)

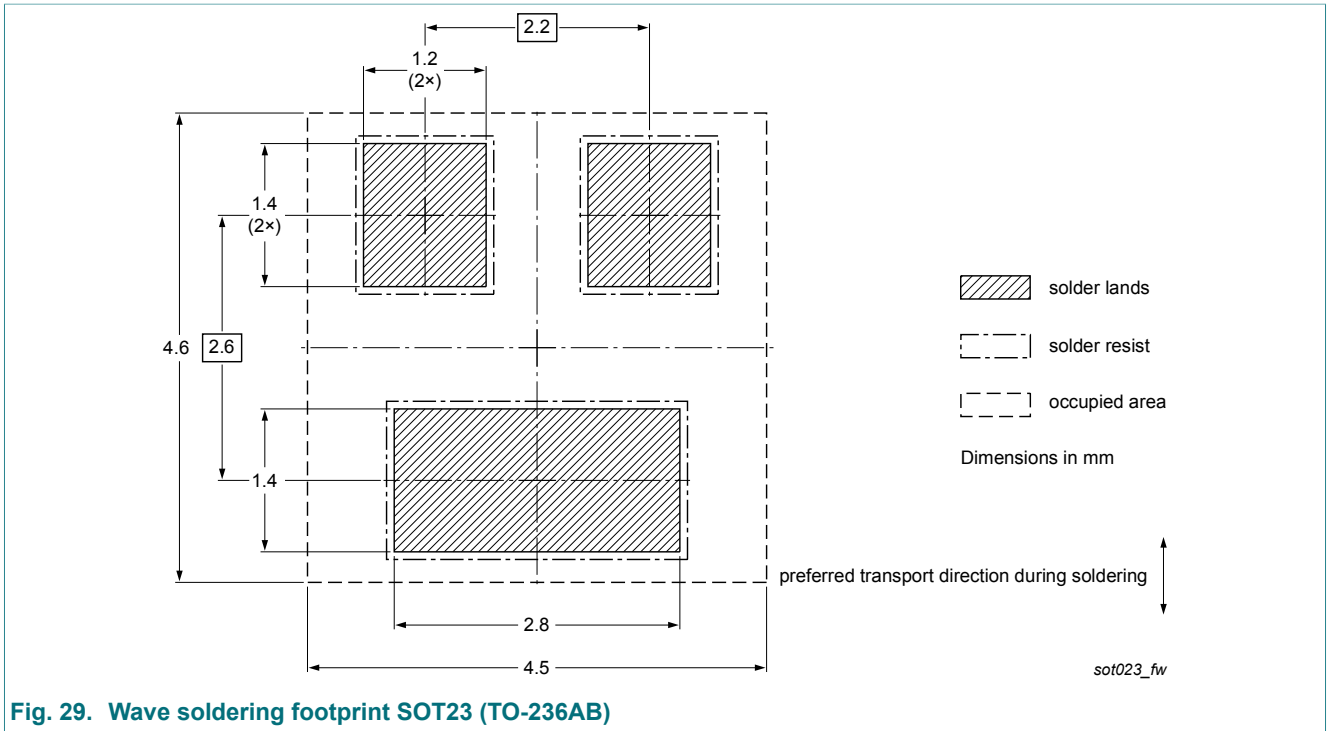


Fig. 29. Wave soldering footprint SOT23 (TO-236AB)



## 14. Revision history

Table 11. Revision history

Document ID	Release date	Data sheet status	Change notice	Supersedes
TL431_8_FAM v.6	20190109	Product data sheet	-	TL431FAM v.5
Modifications	<ul style="list-style-type: none"> <li>• TL431SDT and TL431MSDT removed</li> <li>• Figures of TL431XDBZR and TL431XFDT updated</li> <li>• The format of this data sheet has been redesigned to comply with the identity guidelines of Nexperia.</li> <li>• Legal texts have been adapted to the new company name where appropriate.</li> </ul>			
TL431FAM v.5	20150901	Product data sheet	-	TL431FAM v.4
TL431FAM v.4	20110630	Product data sheet	-	TL431FAM v.3
TL431FAM v.3	20101105	Product data sheet	-	TL431FAM v.2
TL431FAM v.2	20100120	Product data sheet	-	TL431FAM v.1
TL431FAM v.1	20090806	Product data sheet	-	-

## 15. Legal information

### Data sheet status

Document status [1][2]	Product status [3]	Definition
Objective [short] data sheet	Development	This document contains data from the objective specification for product development.
Preliminary [short] data sheet	Qualification	This document contains data from the preliminary specification.
Product [short] data sheet	Production	This document contains the product specification.

- [1] Please consult the most recently issued document before initiating or completing a design.
- [2] The term 'short data sheet' is explained in section "Definitions".
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