



# 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)

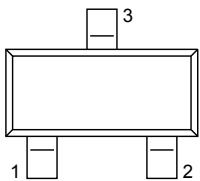
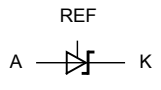
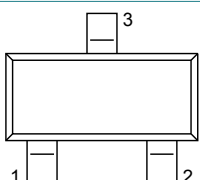
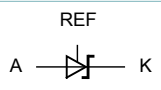
### 1.4. Quick reference data

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.

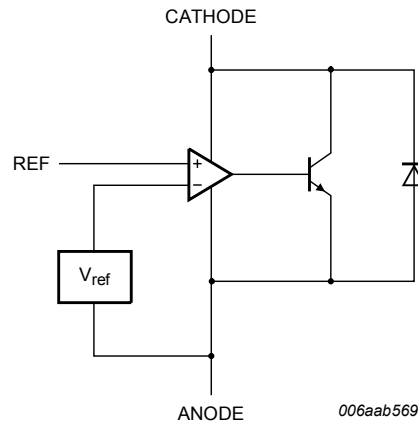


Fig. 1. Functional diagram

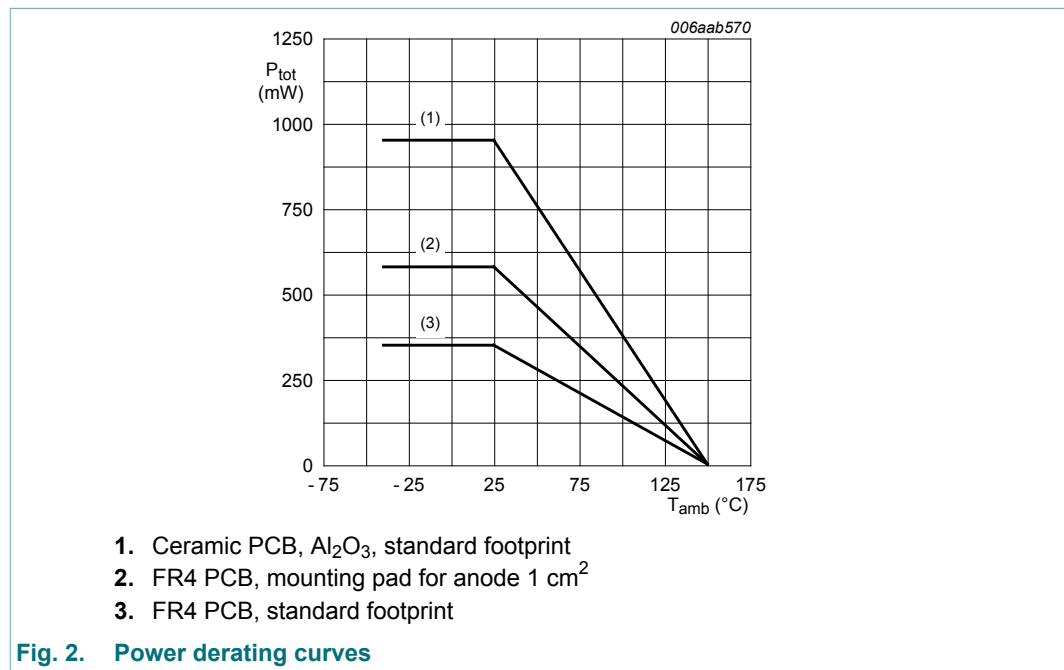
## 6. Limiting values

**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.

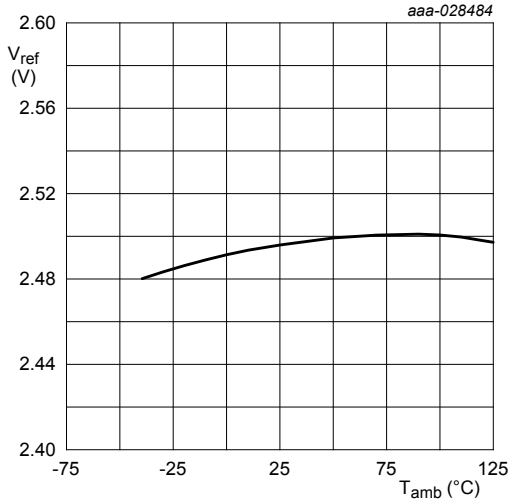
## 9. Characteristics

**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	$\mu\text{A}$

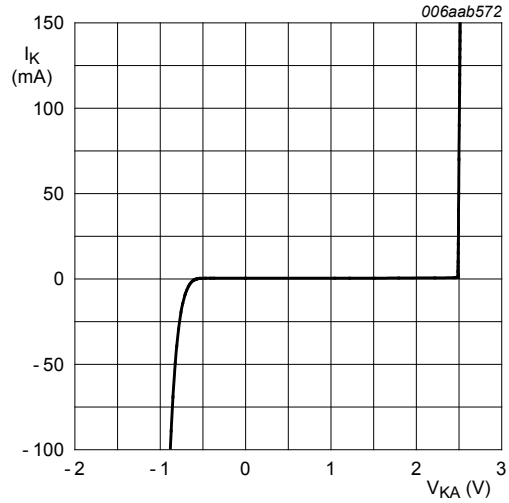
Symbol	Parameter	Conditions	Min	Typ	Max	Unit
$\Delta I_{\text{ref}}$	reference current variation	$I_K = 10 \text{ mA}$ ; $R1 = 10 \text{ k}\Omega$ ; $R2 = \text{open}$				
	TL431ACDBZR	$T_{\text{amb}} = 0 \text{ }^\circ\text{C}$ to $70 \text{ }^\circ\text{C}$	-	0.4	1.2	$\mu\text{A}$
	TL431AIDBZR	$T_{\text{amb}} = -40 \text{ }^\circ\text{C}$ 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	$\Omega$





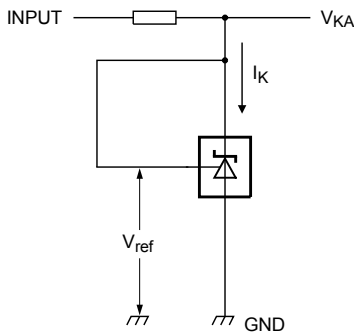
$I_K = 10 \text{ mA}; V_{KA} = V_{ref}$

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



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

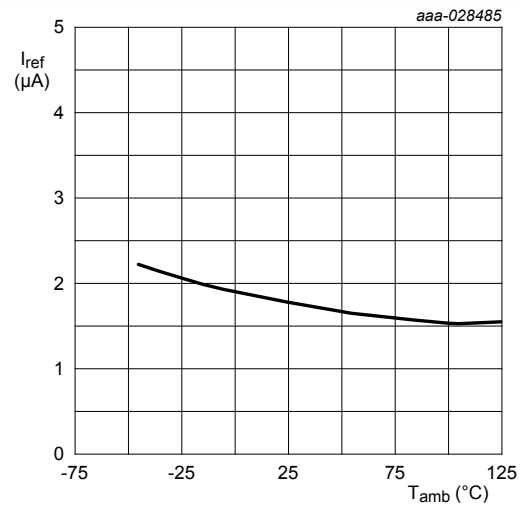
**Fig. 4. Cathode current as a function of cathode-anode voltage; typical values**



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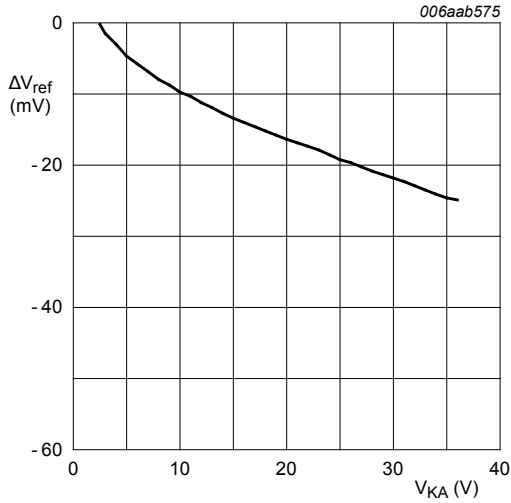
$I_K = 10 \text{ mA}; V_{KA} = V_{ref}$

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



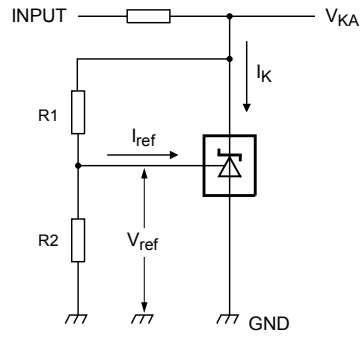
$I_K = 10 \text{ mA}; R1 = 10 \text{ k}\Omega; R2 = \text{open}$

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



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

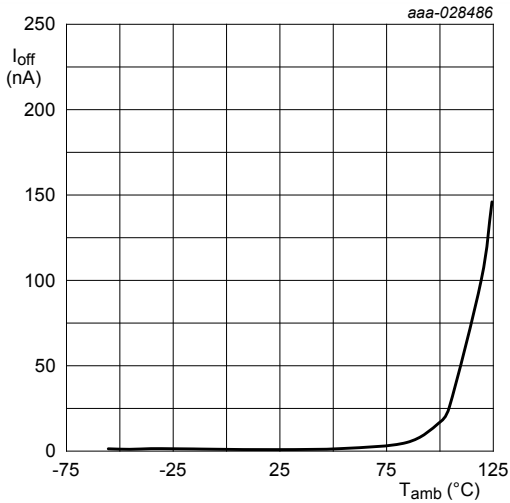
Fig. 7. Reference voltage variation as a function of cathode-anode voltage; typical values



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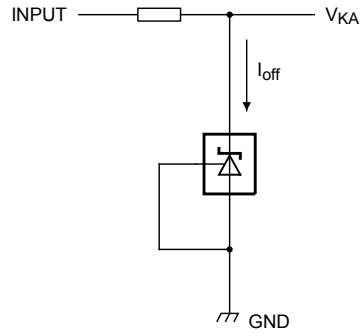
$$V_{KA} = V_{ref} \times \left(1 + \frac{R1}{R2}\right) + I_{ref} \times R1$$

Fig. 8. Test circuit to Figures 6 and 7



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

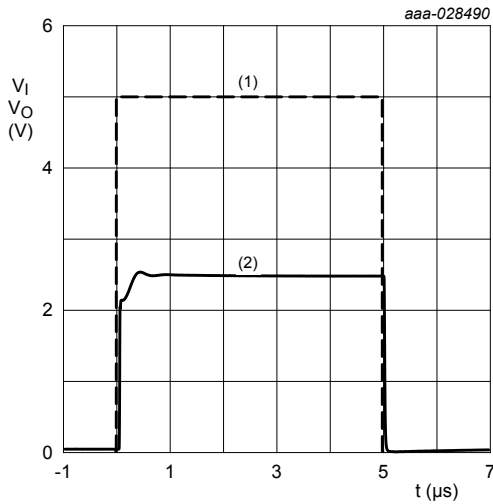
Fig. 9. Off-state current as a function of ambient temperature; typical values



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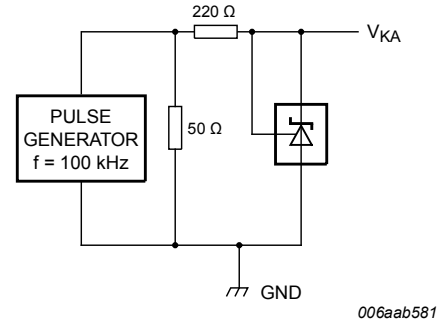
V<sub>KA</sub> = 36 V; V<sub>ref</sub> = 0 V

Fig. 10. Test circuit to Figure 9



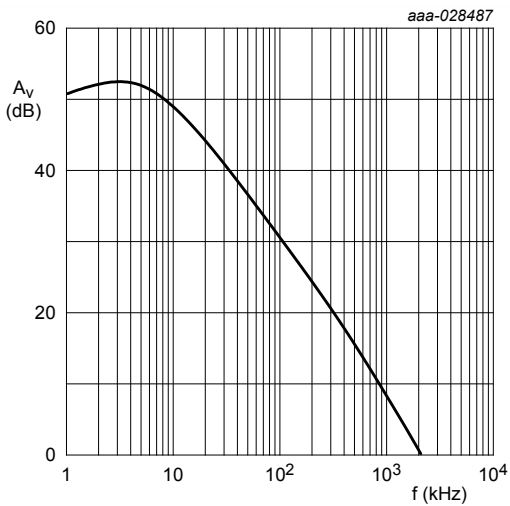
1. input  
2. output  
 $T_{amb} = 25\text{ }^{\circ}\text{C}$

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



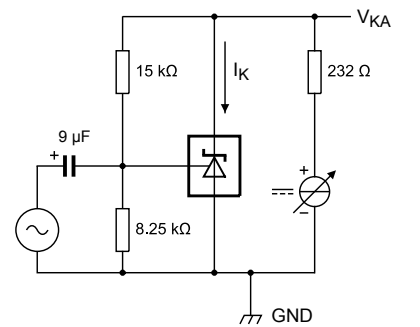
$T_{amb} = 25\text{ }^{\circ}\text{C}$

Fig. 12. Test circuit to Figure 11



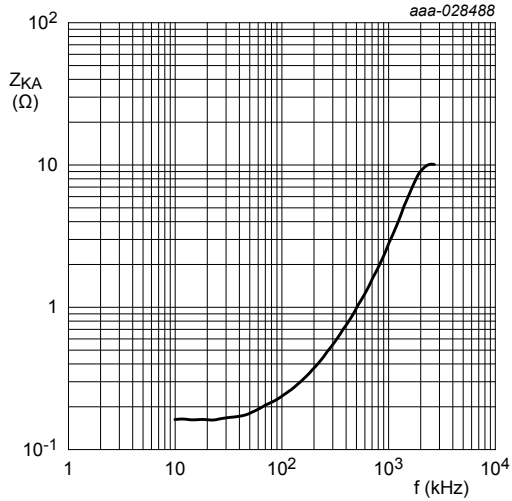
$I_K = 10\text{ mA}$ ;  $T_{amb} = 25\text{ }^{\circ}\text{C}$

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



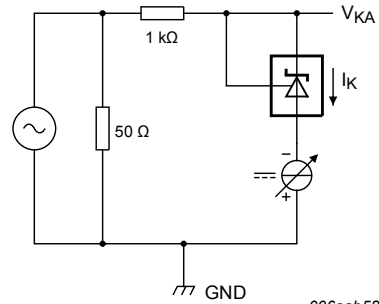
$I_K = 10\text{ mA}$ ;  $T_{amb} = 25\text{ }^{\circ}\text{C}$

Fig. 14. Test circuit to Figure 13



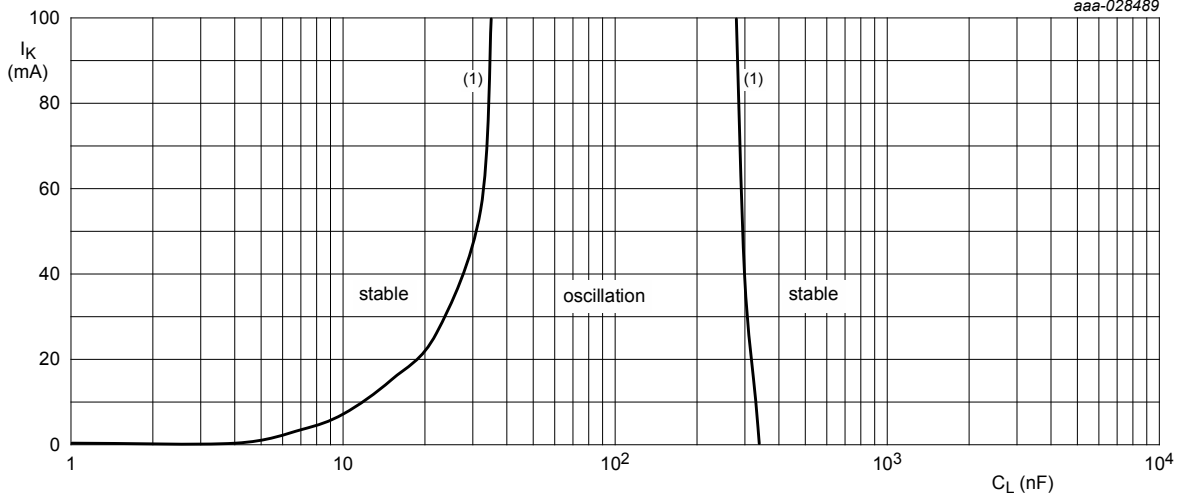
$I_K = 10 \text{ mA}; T_{\text{amb}} = 25 \text{ }^\circ\text{C}$

**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**



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

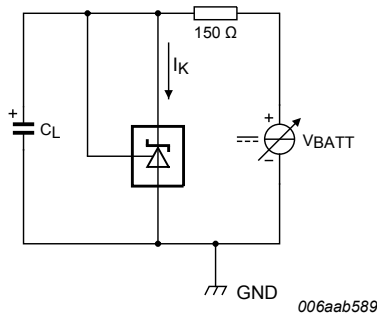
(1)  $V_{KA} = V_{\text{ref}}$

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

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

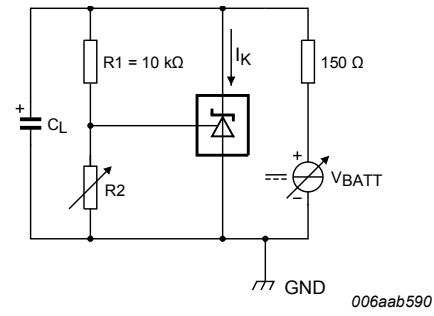
$V_{KA} = 15 \text{ V};$  no oscillation

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



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

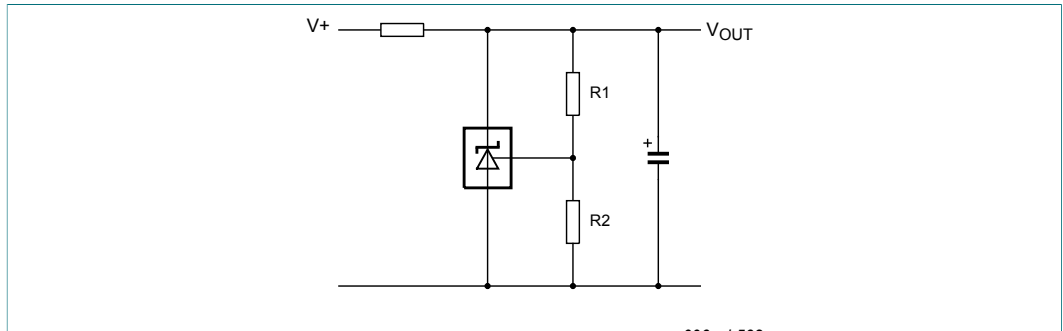
**Fig. 18. Test circuit to Figure 17**



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

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

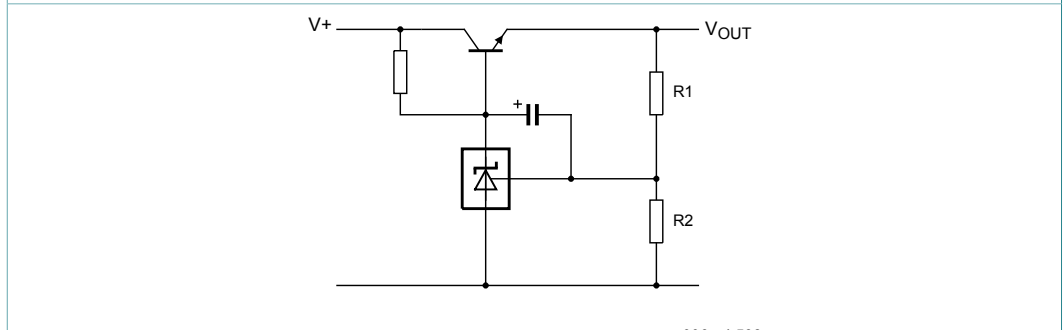
10. Application information



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

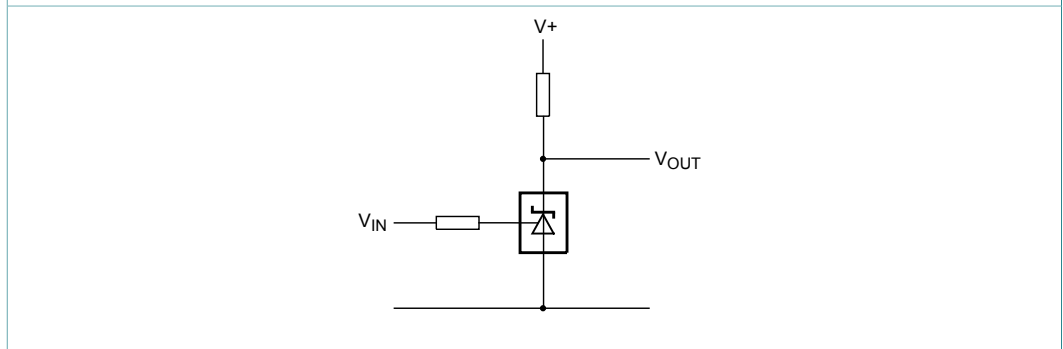
Fig. 20. Shunt regulator



006aab593

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

Fig. 21. Series pass regulator



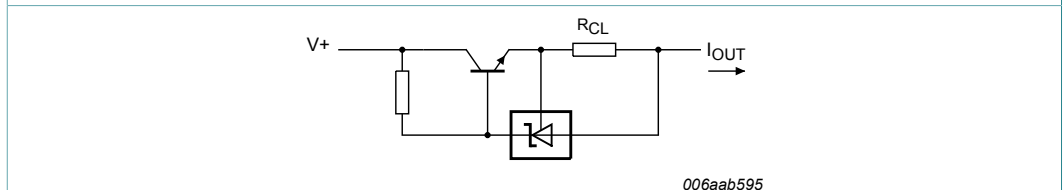
006aab594

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

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

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

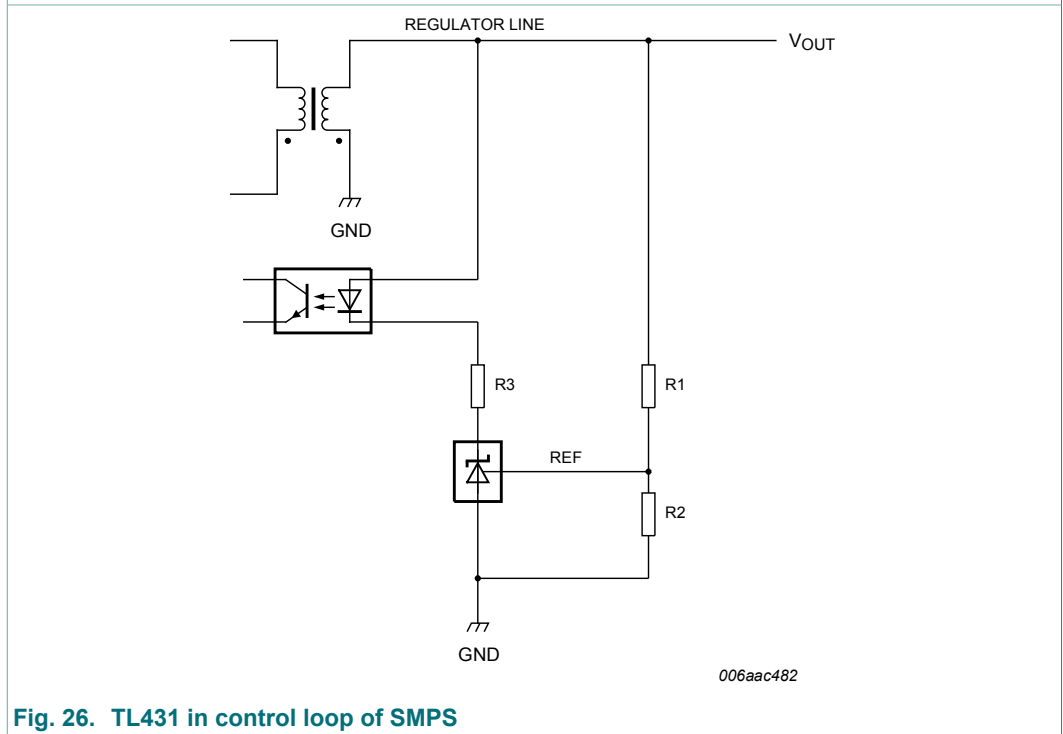
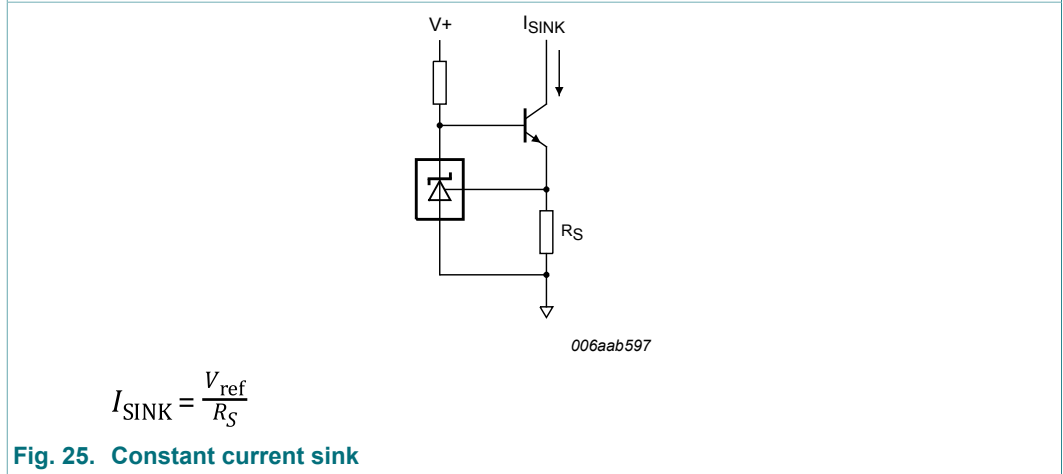
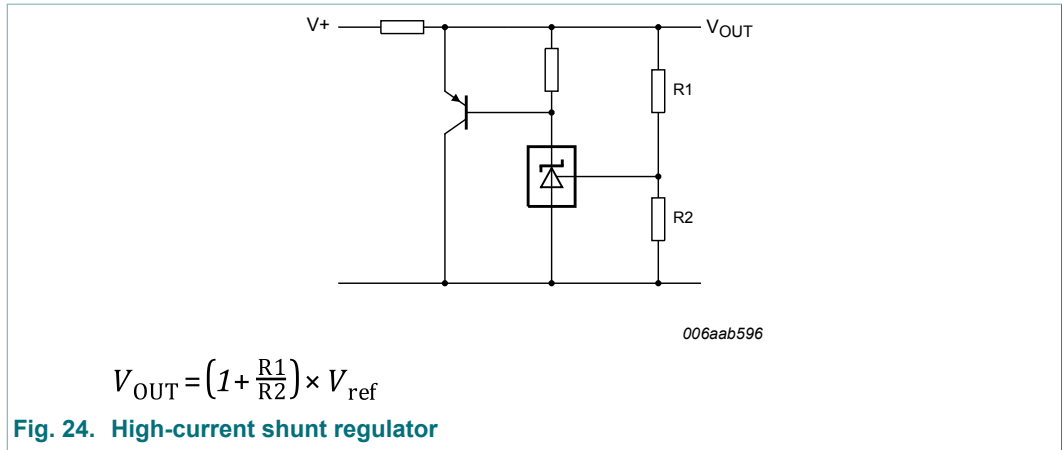
Fig. 22. Single-supply comparator with temperature-compensated threshold



006aab595

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

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

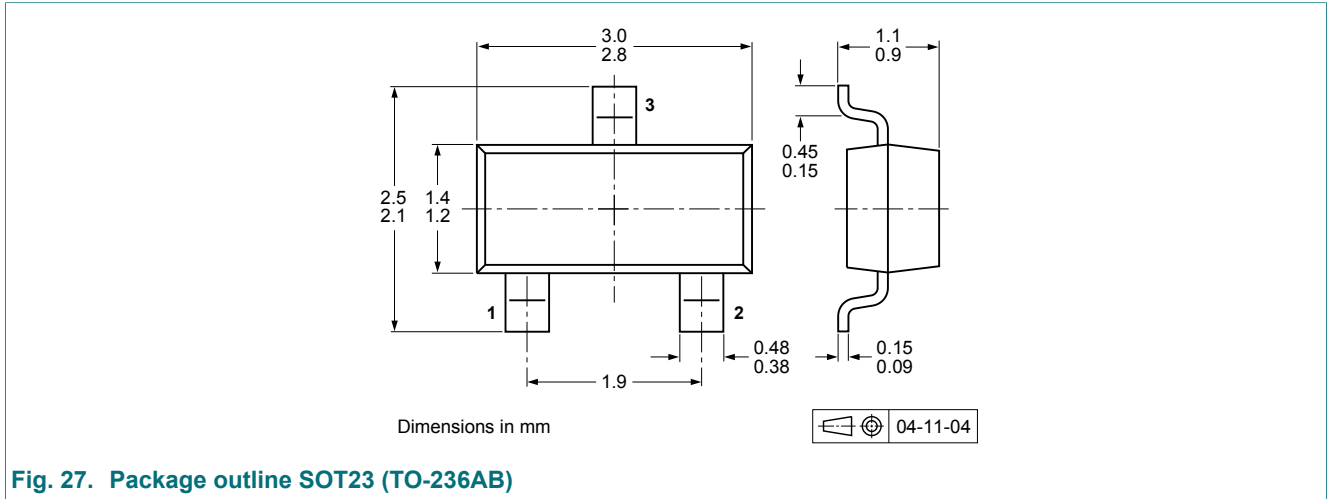


Fig. 27. Package outline SOT23 (TO-236AB)

## 13. Soldering

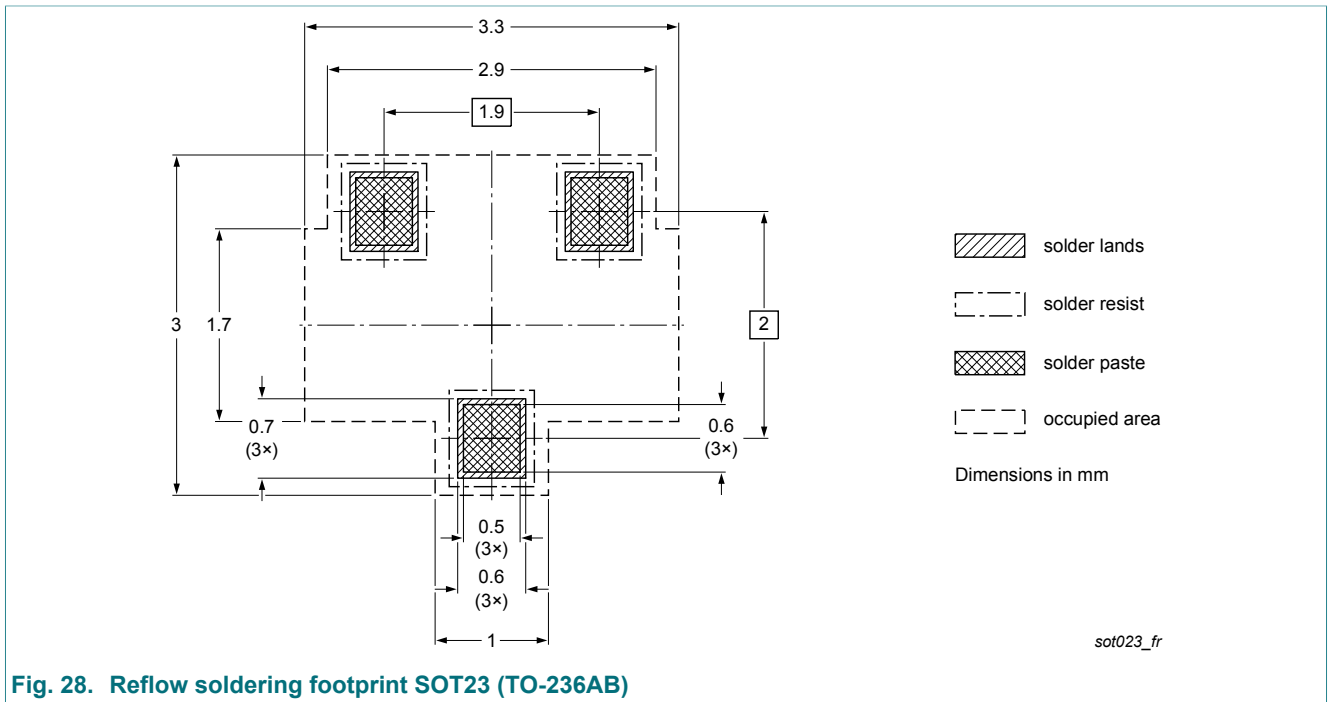


Fig. 28. Reflow soldering footprint SOT23 (TO-236AB)

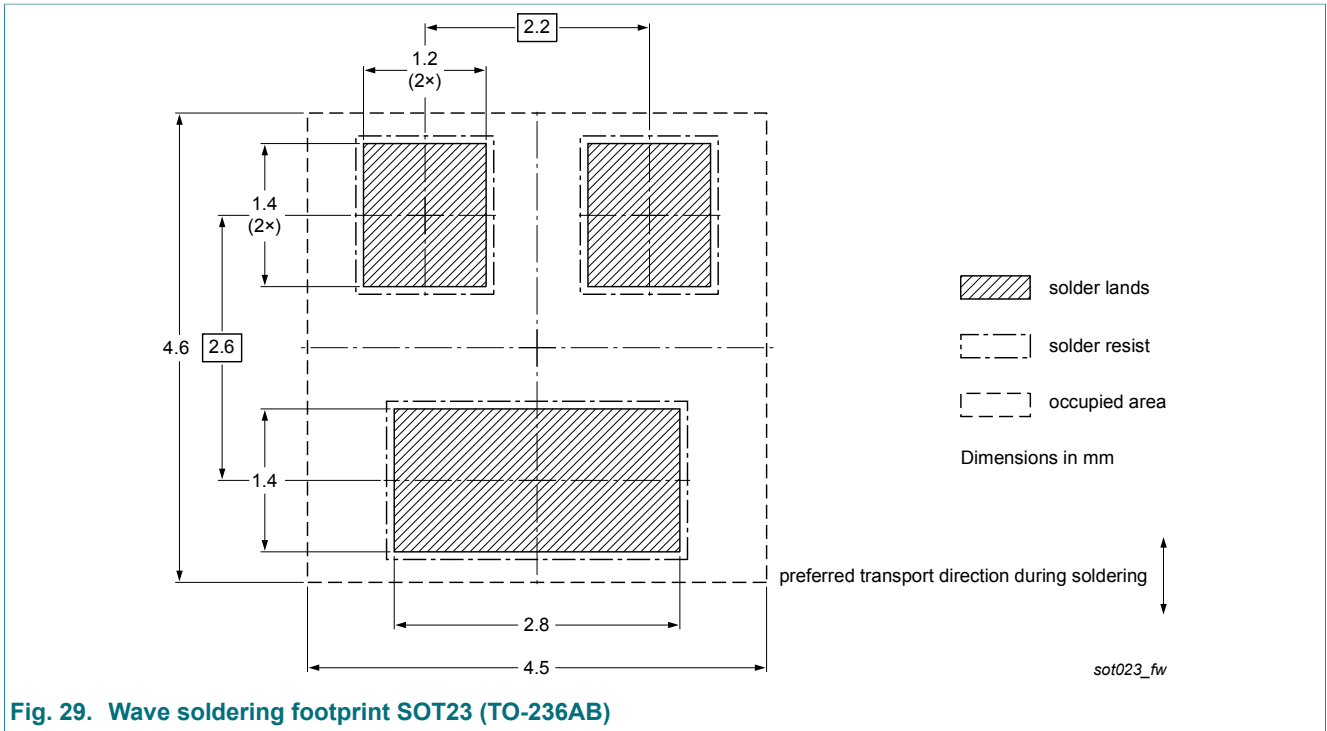


Fig. 29. Wave soldering footprint SOT23 (TO-236AB)



## 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".
- [3] The product status of device(s) described in this document may have changed since this document was published and may differ in case of multiple devices. The latest product status information is available on the internet at <https://www.nexperia.com>.

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#### Как с нами связаться

**Телефон:** 8 (812) 309 58 32 (многоканальный)

**Факс:** 8 (812) 320-02-42

**Электронная почта:** [org@eplast1.ru](mailto:org@eplast1.ru)

**Адрес:** 198099, г. Санкт-Петербург, ул. Калинина, дом 2, корпус 4, литера А.