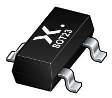


TL431 family

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 V and 36 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 V
- Three different reference voltage tolerances:
-
    - Standard grade: 2 %
    - A-Grade: 1 %
    - B-Grade: 0.5 %
- Typical temperature drift: 9 mV (in a range of 0 °C up to 70 °C)
- Low output noise
- Typical output impedance: 0.2 Ω
- Sink current capability: 1 mA to 100 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)

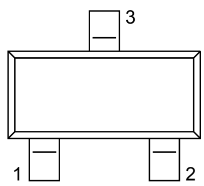
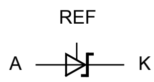
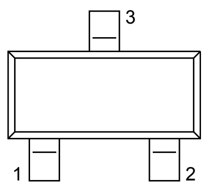
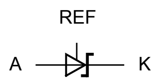
1.4. Quick reference data

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 mA; T_{amb} = 25 °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
SOT23; normal pinning: All types without MFDT ending					
1	K	cathode			 006aab355
2	REF	reference			
3	A	anode			
SOT23; mirrored pinning: All types with MFDT ending					
1	REF	reference			 006aab355
2	K	cathode			
3	A	anode			

3. Ordering information

Table 4. Ordering information

Type number	Package		
	Name	Description	Version
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_{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 Ω. 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.

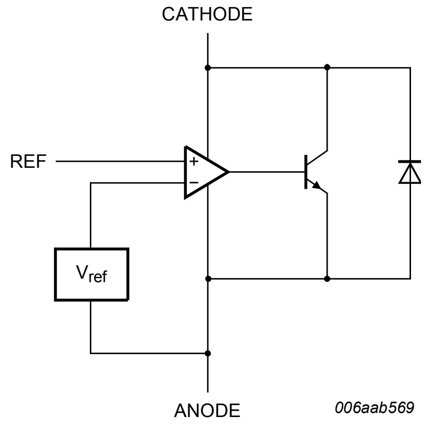


Fig. 1. Functional diagram

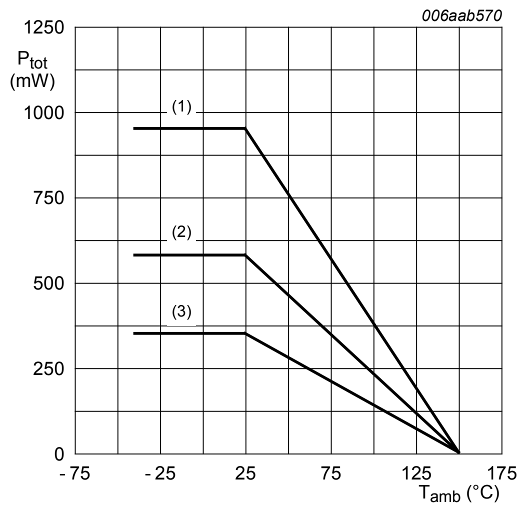
6. Limiting values

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	$T_{amb} \leq 25$ °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^2.
[3] Device mounted on a ceramic PCB, Al_2O_3, standard footprint.



1. Ceramic PCB, Al_2O_3, standard footprint
2. FR4 PCB, mounting pad for anode 1 cm^2
3. FR4 PCB, standard footprint

Fig. 2. Power derating curves

Table 7. ESD maximum ratings

T_{amb} = 25 °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^2.
[3] Device mounted on a ceramic PCB, Al_2O_3, standard footprint.
[4] Soldering point of anode.

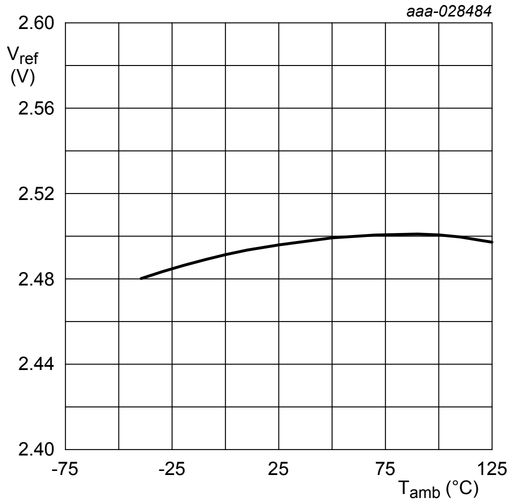
9. Characteristics

Table 10. Characteristics

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

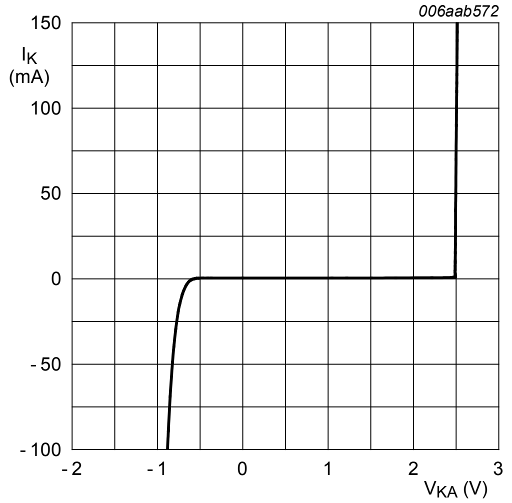
Symbol	Parameter	Conditions	Min	Typ	Max	Unit
Standard-Grade (2.0 %): TL431CDBZR; TL431IDBZR; TL431QDBZR; TL431FDT; TL431MFDT						
V_{ref}	reference voltage	$V_{KA} = V_{ref}$; I_K = 10 mA	2440	2495	2550	mV
ΔV_{ref}	reference voltage variation	$V_{KA} = V_{ref}$; I_K = 10 mA				
	TL431CDBZR	T_{amb} =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

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



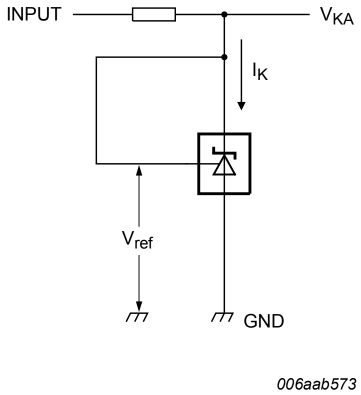
I_K = 10 mA; V_{KA} = V_{ref}

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



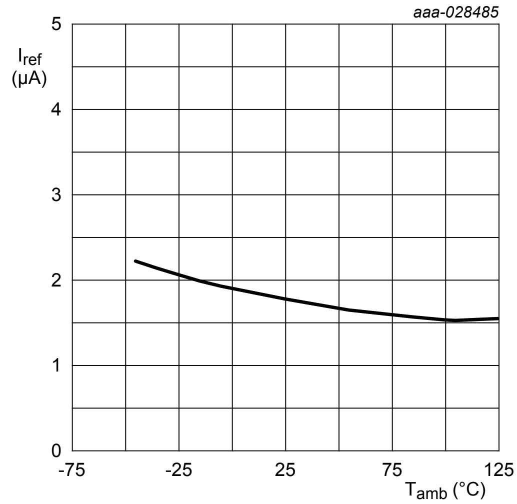
V_{KA} = V_{ref}; T_{amb} = 25 °C

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



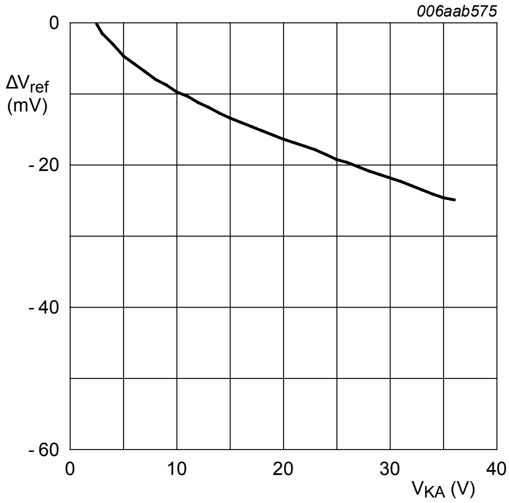
I_K = 10 mA; V_{KA} = V_{ref}

Fig. 5. Test circuit to Figures 3 and 4



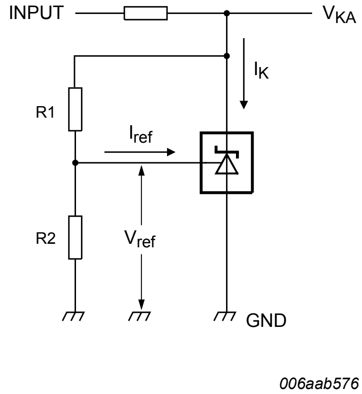
I_K = 10 mA; R1 = 10 kΩ; R2 = open

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



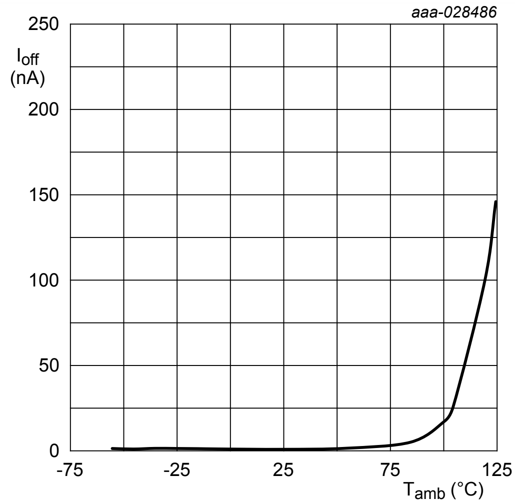
I_K = 10 mA; T_{amb} = 25 °C

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



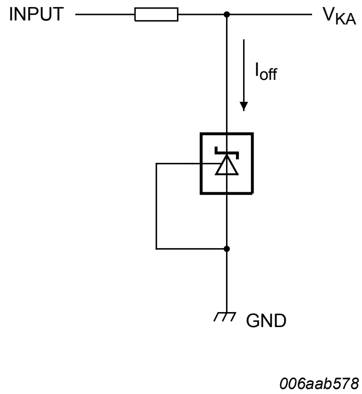
$$V_{KA} = V_{ref} \times \left(1 + \frac{R1}{R2}\right) + I_{ref} \times R1$$

Fig. 8. Test circuit to Figures 6 and 7



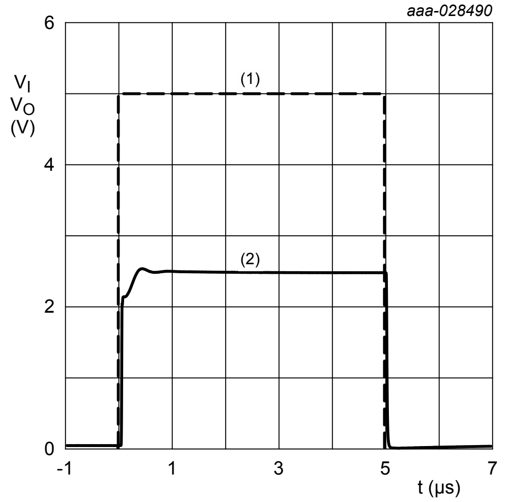
V_{KA} = 36 V; V_{ref} = 0 V

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



V_{KA} = 36 V; V_{ref} = 0 V

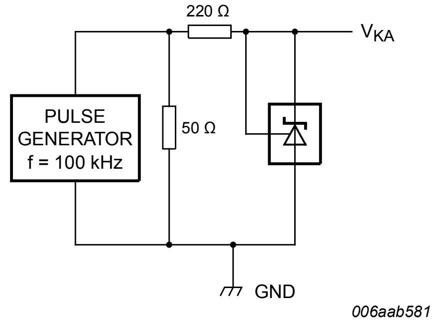
Fig. 10. Test circuit to Figure 9



1. input
2. output

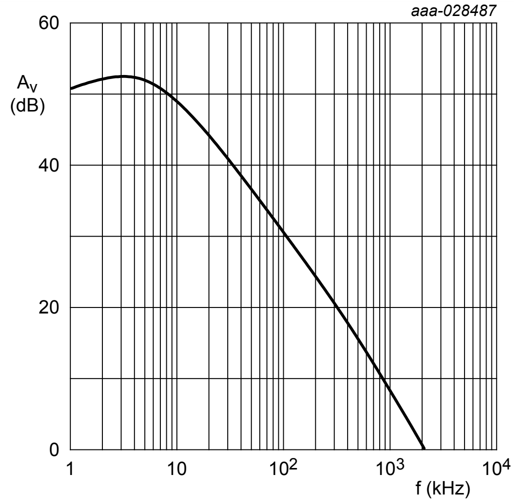
T_{amb} = 25 °C

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



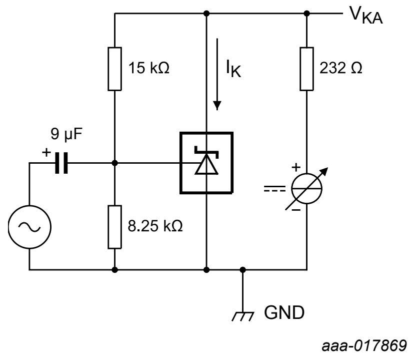
T_{amb} = 25 °C

Fig. 12. Test circuit to Figure 11



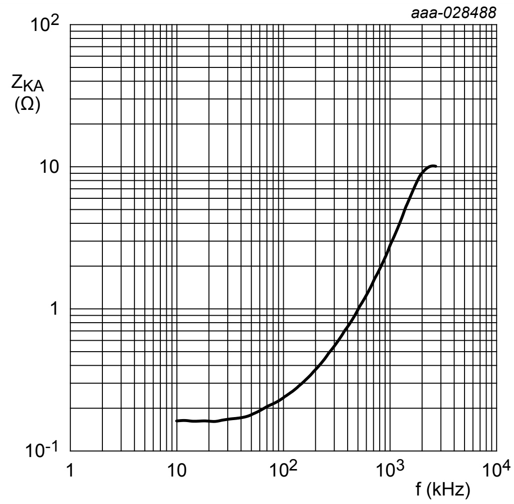
I_K = 10 mA; T_{amb} = 25 °C

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



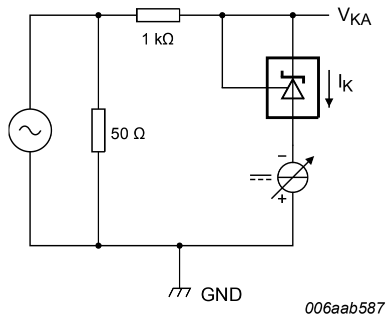
I_K = 10 mA; T_{amb} = 25 °C

Fig. 14. Test circuit to Figure 13



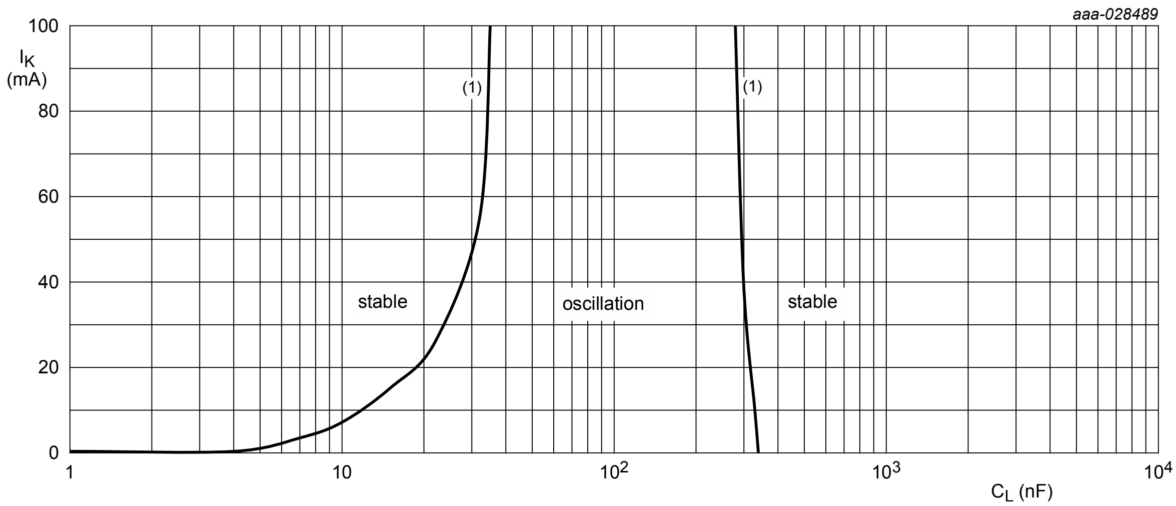
I_K = 10 mA; T_{amb} = 25 °C

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



I_K = 10 mA; T_{amb} = 25 °C

Fig. 16. Test circuit to Figure 15



T_{amb} = 25 °C

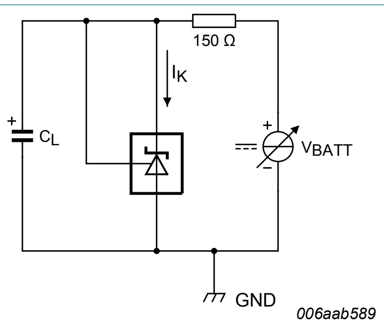
(1) $V_{KA} = V_{ref}$

V_{KA} = 5 V; no oscillation

V_{KA} = 10 V; no oscillation

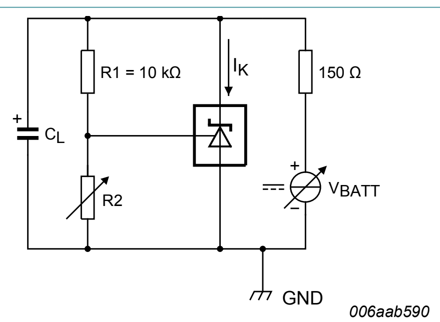
V_{KA} = 15 V; no oscillation

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



$V_{KA} = V_{ref}$; T_{amb} = 25 °C

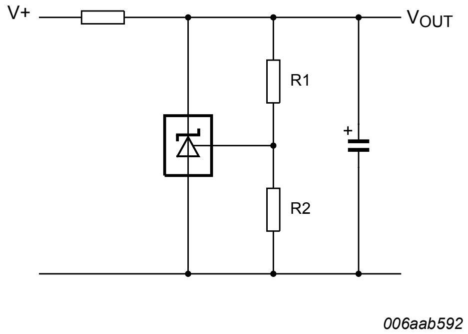
Fig. 18. Test circuit to Figure 17



V_{KA} > 5 V; stable operation; T_{amb} = 25 °C

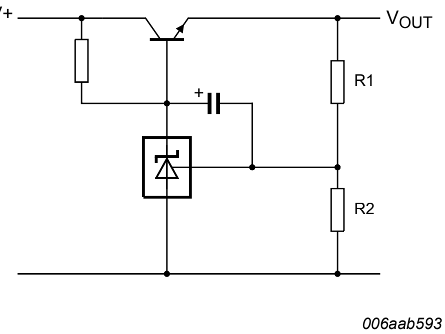
Fig. 19. Test circuit to Figure 17

10. Application information



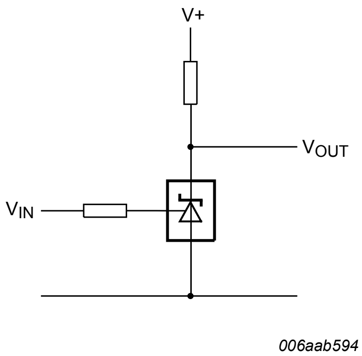
$$V_{OUT} = \left(1 + \frac{R1}{R2}\right) \times V_{ref}$$

Fig. 20. Shunt regulator



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

Fig. 21. Series pass regulator

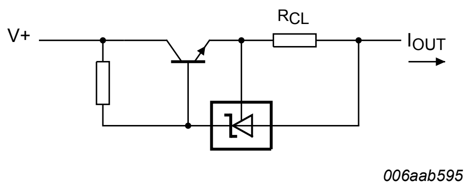


$T_{th} = V_{ref}$

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

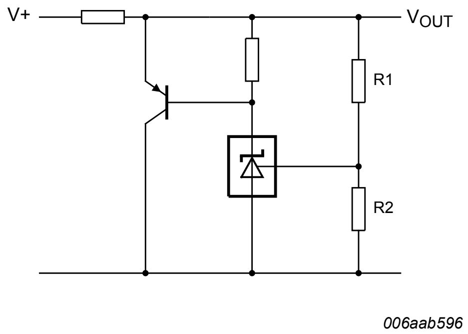
$T_{IN} > V_{ref} \Rightarrow V_{OUT} \cong 2$

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



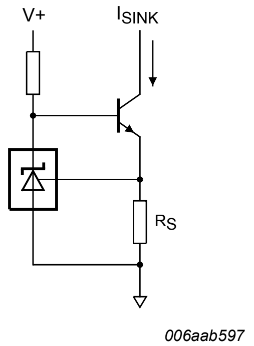
$$I_{OUT} = \frac{V_{ref}}{R_{CL}}$$

Fig. 23. Constant current souce



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

Fig. 24. High-current shunt regulator



$$I_{SINK} = \frac{V_{ref}}{R_S}$$

Fig. 25. Constant current sink

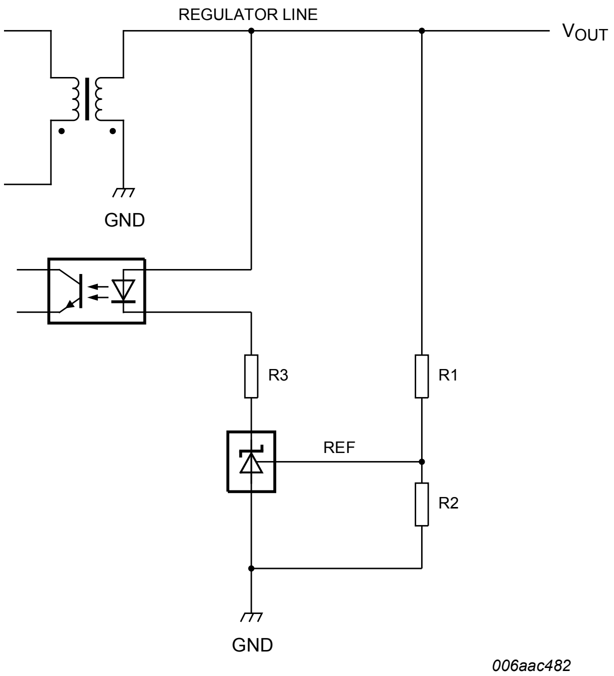


Fig. 26. TL431 in control loop of SMPS

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

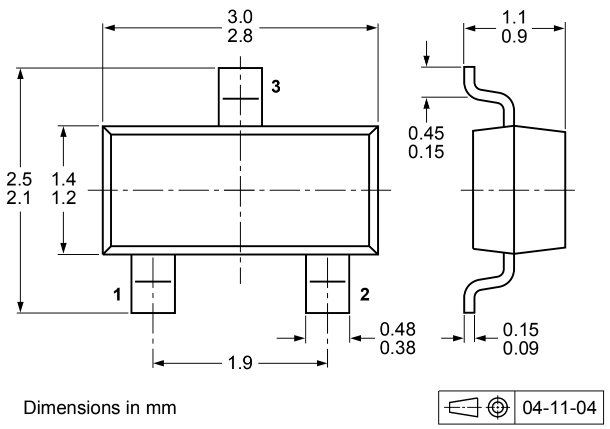


Fig. 27. Package outline SOT23 (TO-236AB)

13. Soldering

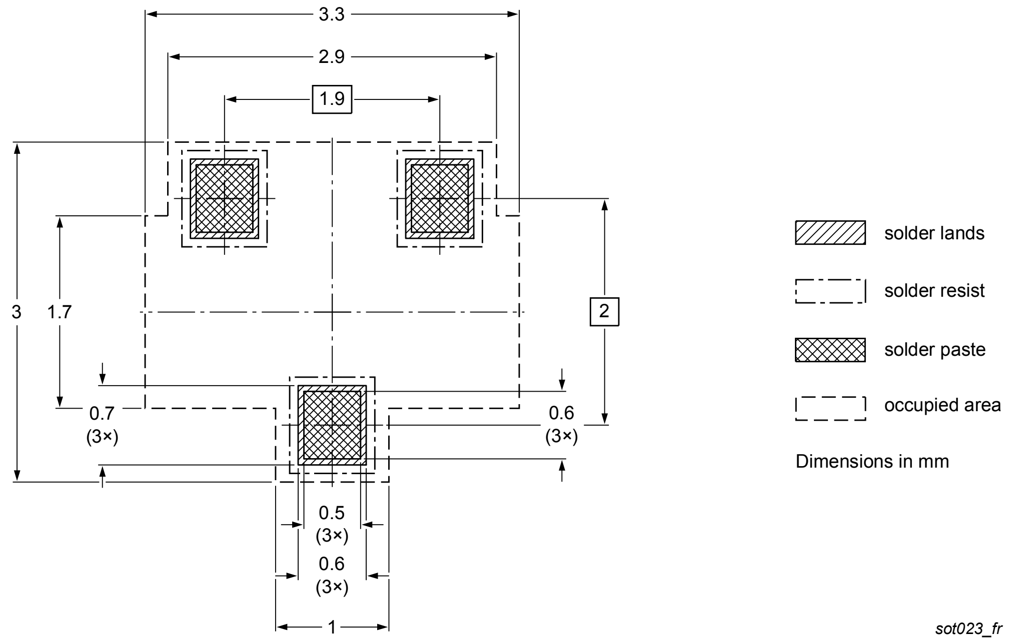


Fig. 28. Reflow soldering footprint SOT23 (TO-236AB)

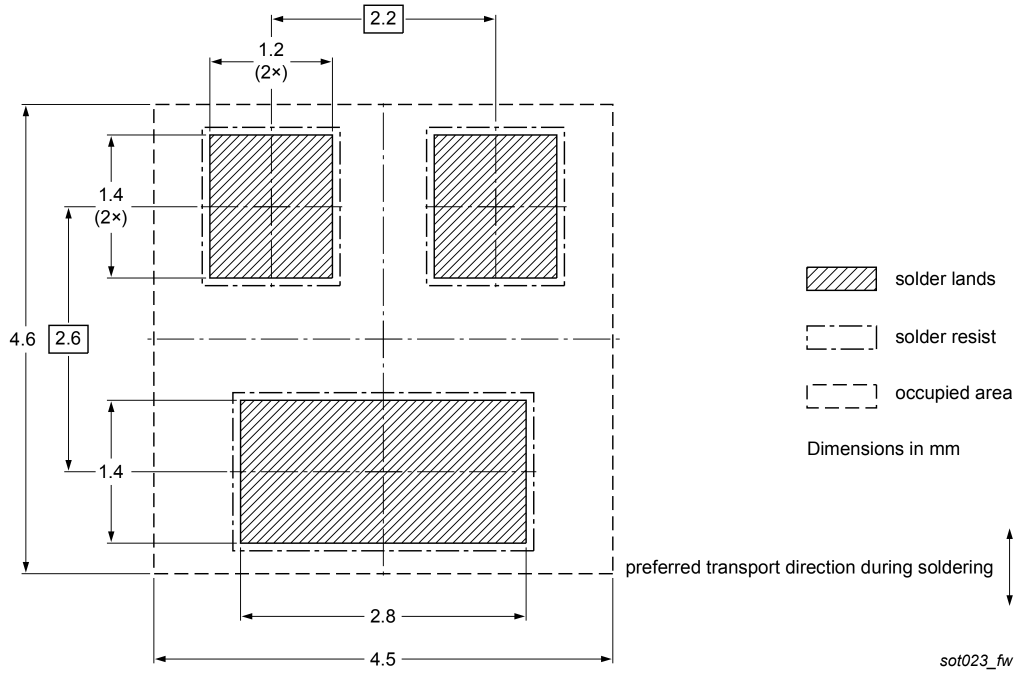


Fig. 29. Wave soldering footprint SOT23 (TO-236AB)

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	• TL431SDT and TL431MSDT removed • Figures of TL431XDBZR and TL431XFDT updated • The format of this data sheet has been redesigned to comply with the identity guidelines of Nexperia. • Legal texts have been adapted to the new company name where appropriate.			
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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