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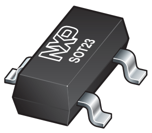


TL431 family

Adjustable precision shunt regulator

Rev. 5 — 01 September 2015 Product data sheet

1. Product profile

1.1 General description

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

- The TL431xDBZR types feature an enhanced stability area with a very low load capacity requirement.
- The TL431xFDT types offer an enhanced stability area and a higher ElectroMagnetic Interference (EMI) ruggedness, for example, for Switch Mode Power Supply (SMPS) applications.
- The TL431xSDT types are designed for standard requirements and linear applications.

Table 1. Product overview

Reference voltage tolerance (V_{ref})	Temperature range (T_{amb})			Pinning configuration (see Table 3)
	0 °C to 70 °C	–40 °C to 85 °C	–40 °C to 125 °C	
2 %	TL431CDBZR	TL431IDBZR	TL431QDBZR	normal pinning
			TL431FDT	normal pinning
			TL431MFDT	mirrored pinning
			TL431SDT	normal pinning
			TL431MSDT	mirrored pinning
1 %	TL431ACDBZR	TL431AIDBZR	TL431AQDBZR	normal pinning
			TL431AFDT	normal pinning
			TL431AMFDT	mirrored pinning
			TL431ASDT	normal pinning
			TL431AMSDT	mirrored pinning
0.5 %	TL431BCDBZR	TL431BIDBZR	TL431BQDBZR	normal pinning
			TL431BFDT	normal pinning
			TL431BMFDT	mirrored pinning
			TL431BSDT	normal pinning
			TL431BMSDT	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: 6 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)

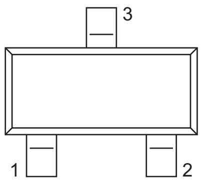
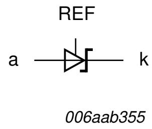
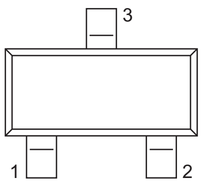
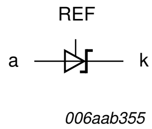
1.4 Quick reference data

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 %)		2440	2495	2550	mV
	A-Grade (1 %)		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
Normal pinning: All types without MFDT and MSDT ending				
1	k	cathode		
2	REF	reference		
3	a	anode		
Mirrored pinning: All types with MFDT and MSDT ending				
1	REF	reference		
2	k	cathode		
3	a	anode		

3. Ordering information

Table 4. Ordering information

Type number	Package		
	Name	Description	Version
TL431CDBZR	-	plastic surface-mounted package; 3 leads	SOT23
TL431IDBZR			
TL431QDBZR			
TL431FDT			
TL431MFDT			
TL431SDT			
TL431MSDT			
TL431ACDBZR			
TL431AIDBZR			
TL431AQDBZR			
TL431AFDT			
TL431AMFDT			
TL431ASDT			
TL431AMSDT			
TL431BCDBZR			
TL431BIDBZR			
TL431BQDBZR			
TL431BFDT			
TL431BMFDT			
TL431BSDT			
TL431BMSDT			

4. Marking

Table 5. Marking codes

Type number	Marking code[1]	Type number	Marking code[1]
TL431CDBZR	CA*	TL431ASDT	RL*
TL431IDBZR	CB*	TL431AMSDT	LQ*
TL431QDBZR	CC*	TL431BCDBZR	CG*
TL431FDT	AR*	TL431BIDBZR	CH*
TL431MFDT	AU*	TL431BQDBZR	CJ*
TL431SDT	RM*	TL431BFDT	AT*
TL431MSDT	LR*	TL431BMFDT	AW*
TL431ACDBZR	CD*	TL431BSDT	MA*
TL431AIDBZR	CE*	TL431BMSDT	MB*
TL431AQDBZR	CF*	-	-
TL431AFDT	AS*	-	-
TL431AMFDT	AV*	-	-

[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 may 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.

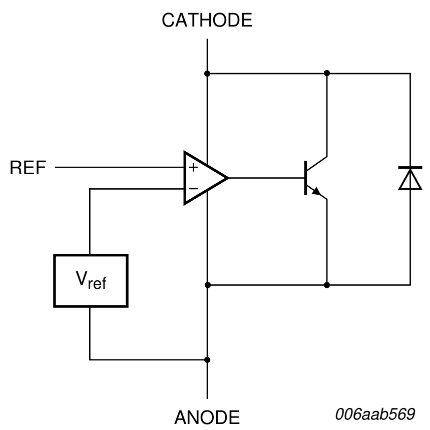


Fig 1. Functional diagram

6. Limiting values

Table 6. Limiting values

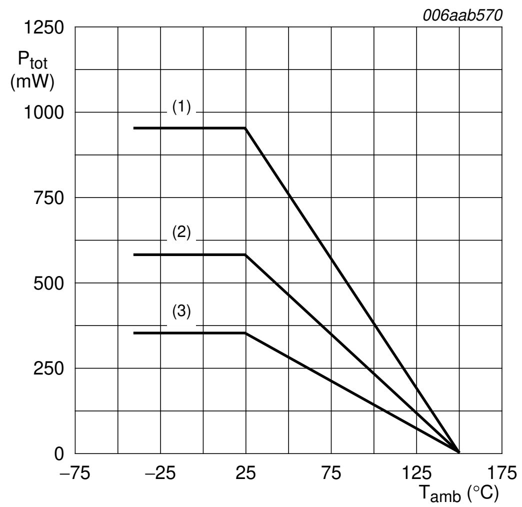
In accordance with the Absolute Maximum Rating System (IEC 60134).

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 TL431XSDT			–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 %): TL431CDBZR; TL431IDBZR; TL431QDBZR; TL431FDT; TL431MFDT; TL431SDT; TL431MSDT						
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	-	6	16	mV
	TL431IDBZR	T_{amb} = –40 °C to 85 °C	-	14	34	mV
	TL431QDBZR TL431FDT TL431MFDT TL431SDT TL431MSDT	T_{amb} = –40 °C to 125 °C				
$\Delta V_{ref}/\Delta V_{KA}$	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 TL431FDT TL431MFDT TL431SDT TL431MSDT	T_{amb} = –40 °C to 125 °C				
$I_{K(min)}$	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 = 1 mA to 100 mA; $V_{KA} = V_{ref}$; f < 1 kHz	-	0.2	0.5	Ω
A-Grade (1 %): TL431ACDBZR; TL431AIDBZR; TL431AQDBZR; TL431AFDT; TL431AMFDT; TL431ASDT; TL431AMSDT						
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	-	6	16	mV
	TL431AIDBZR	T_{amb} = –40 °C to 85 °C	-	14	34	mV
	TL431AQDBZR TL431AFDT TL431AMFDT TL431ASDT TL431AMSDT	T_{amb} = –40 °C to 125 °C				
$\Delta V_{ref}/\Delta V_{KA}$	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

Table 10. Characteristics *...continued*

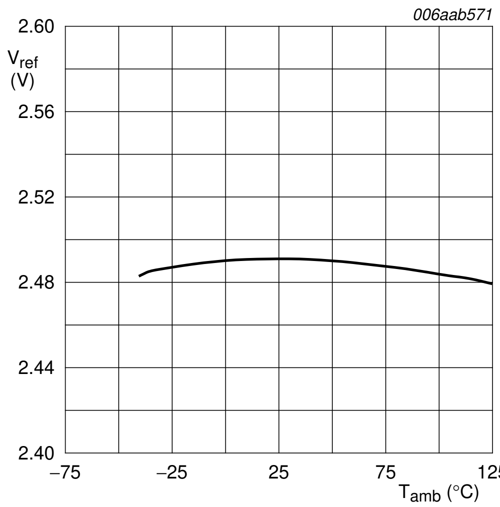
T_{amb} = 25 °C unless otherwise specified.

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
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				
	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 TL431AFDT TL431AMFDT TL431ASDT TL431AMSDT	T_{amb} = −40 °C to 125 °C				
$I_{K(min)}$	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 TL431AFDT TL431AMFDT TL431ASDT TL431AMSDT	T_{amb} = −40 °C to 125 °C				
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 = 1 mA to 100 mA; $V_{KA} = V_{ref}$; f < 1 kHz	-	0.2	0.5	Ω
B-Grade (0.5 %): TL431BCDBZR; TL431BIDBZR; TL431BQDBZR; TL431BFDT; TL431BMFDT; TL431BSDT; TL431BMSDT						
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	-	6	16	mV
	TL431BIDBZR	T_{amb} = −40 °C to 85 °C	-	14	34	mV
	TL431BQDBZR TL431BFDT TL431BMFDT TL431BSDT TL431BMSDT	T_{amb} = −40 °C to 125 °C				
$\Delta V_{ref}/\Delta V_{KA}$	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

Table 10. Characteristics *…continued*

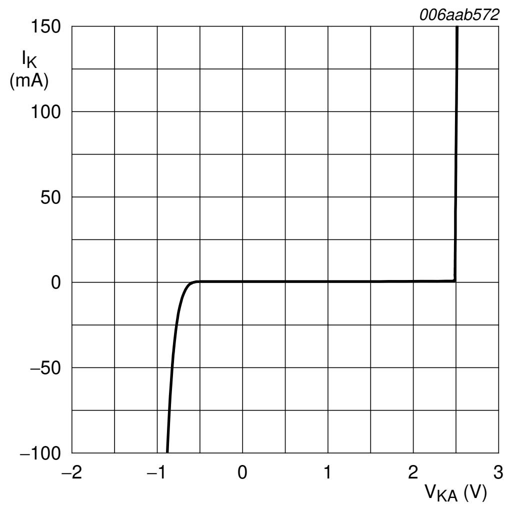
T_{amb} = 25 °C unless otherwise specified.

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
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 TL431BFDT TL431BMFDT TL431BSDT TL431BMSDT	T_{amb} = −40 °C to 125 °C				
$I_{K(min)}$	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 TL431BFDT TL431BMFDT TL431BSDT TL431BMSDT	T_{amb} = −40 °C to 125 °C				
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 = 1 mA to 100 mA; $V_{KA} = V_{ref}$; f < 1 kHz	-	0.2	0.5	Ω



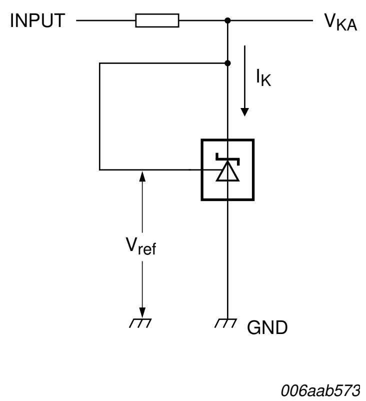
I_K = 10 mA; V_{KA} = V_{ref}

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



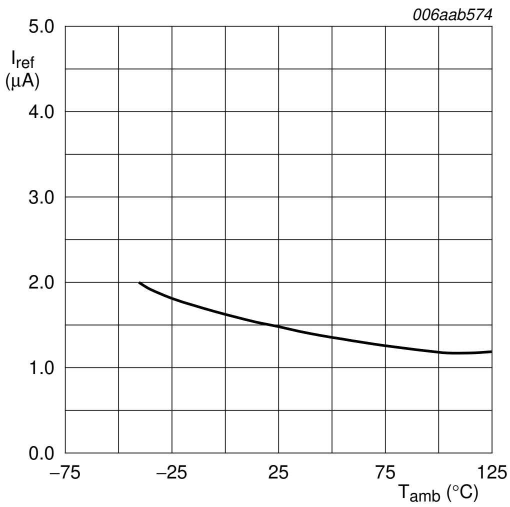
V_{KA} = V_{ref}; T_{amb} = 25 °C

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



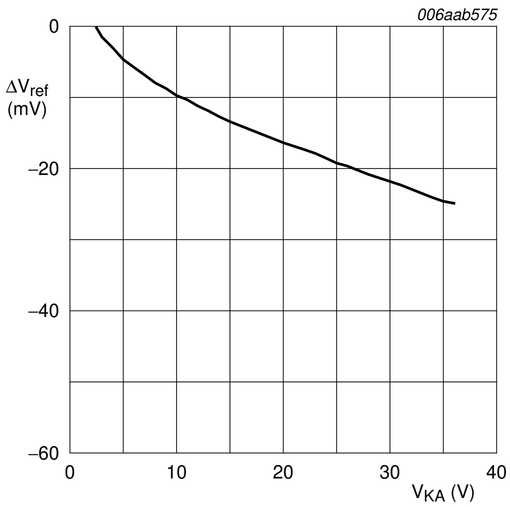
I_K = 10 mA; V_{KA} = V_{ref}

Fig 5. Test circuit to Figure 3 and Figure 4



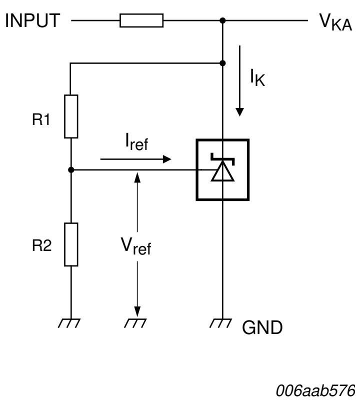
I_K = 10 mA; R1 = 10 kΩ; R2 = open

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



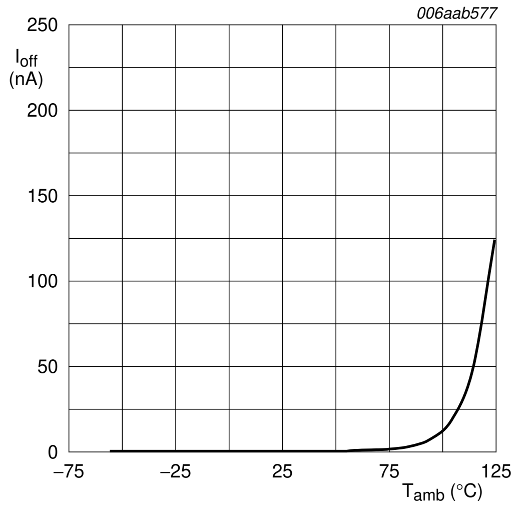
I_K = 10 mA; T_{amb} = 25 °C

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



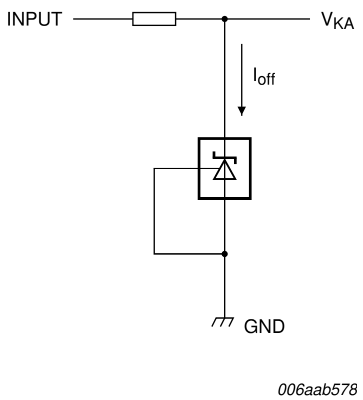
$$V_{KA} = V_{ref} \times \left(1 + \frac{R1}{R2}\right) + I_{ref} \times R1$$

Fig 8. Test circuit to Figure 6 and Figure 7



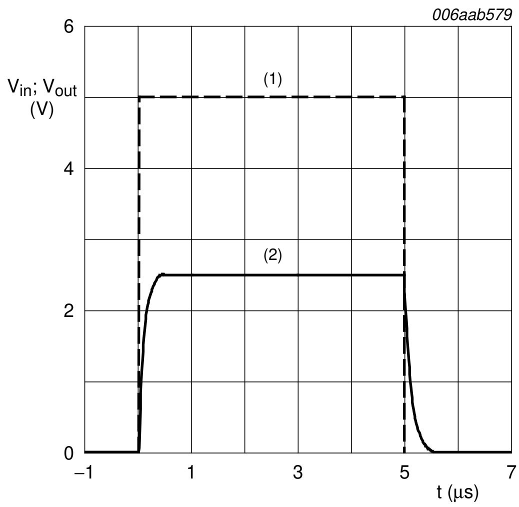
V_{KA} = 36 V; V_{ref} = 0 V

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



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

Fig 10. Off-state current as a function of ambient temperature; test circuit

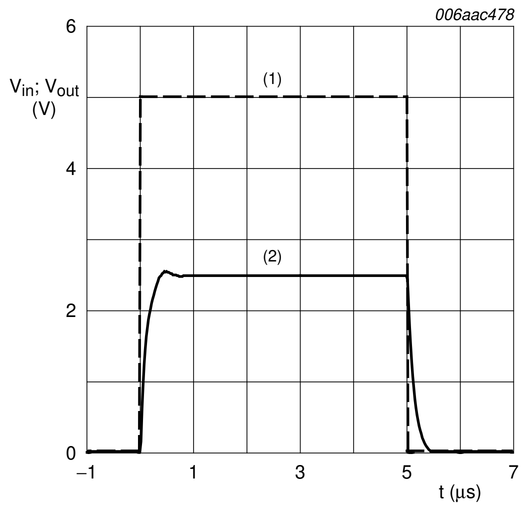


T_{amb} = 25 °C

(1) Input

(2) Output

Fig 11. All types except TL431XFDT and TL431XSDT: Input voltage and output voltage as a function of time; typical values

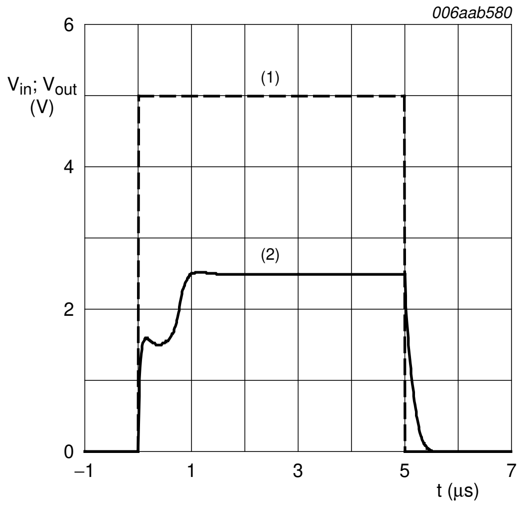


T_{amb} = 25 °C

(1) Input

(2) Output

Fig 12. TL431XFDT: Input voltage and output voltage as a function of time; typical values

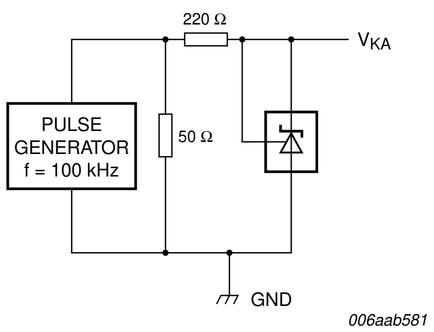


T_{amb} = 25 °C

(1) Input

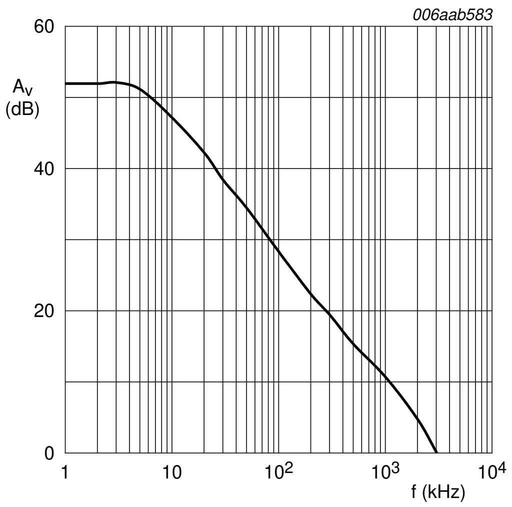
(2) Output

Fig 13. TL431XSDT: Input voltage and output voltage as a function of time; typical values



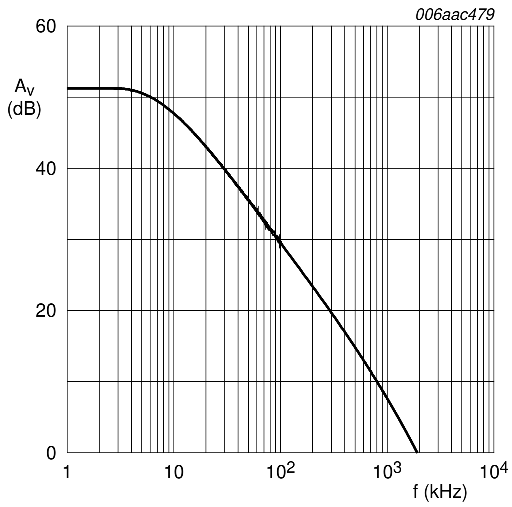
T_{amb} = 25 °C

Fig 14. Test circuit to Figure 11, Figure 12 and Figure 13



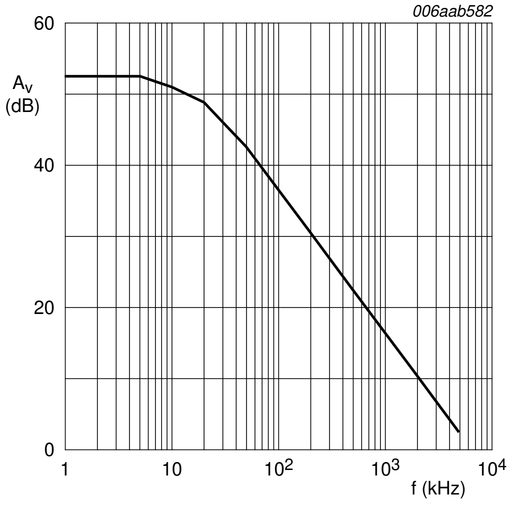
I_K = 10 mA; T_{amb} = 25 °C

Fig 15. All types except TL431XFDT and TL431XSDT: Voltage amplification as a function of frequency; typical values



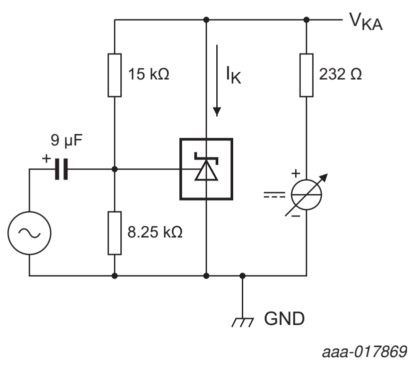
I_K = 10 mA; T_{amb} = 25 °C

Fig 16. TL431XFDT: Voltage amplification as a function of frequency; typical values



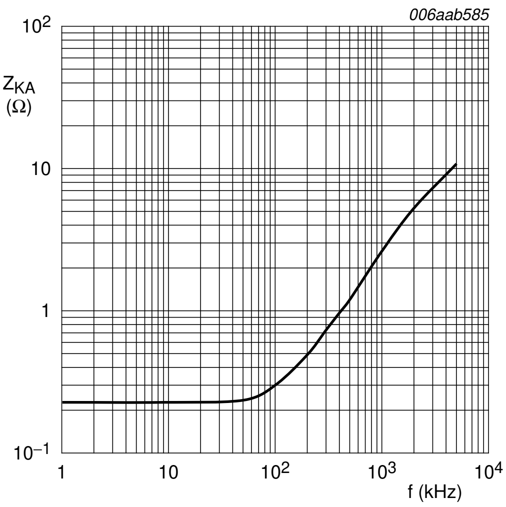
I_K = 10 mA; T_{amb} = 25 °C

Fig 17. TL431XSDT: Voltage amplification as a function of frequency; typical values



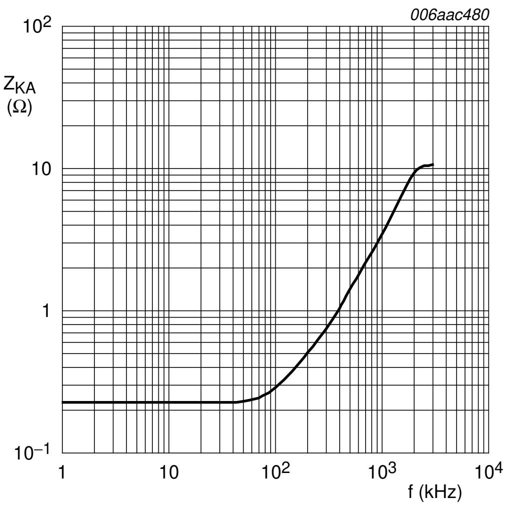
I_K = 10 mA; T_{amb} = 25 °C

Fig 18. Test circuit to Figure 15, Figure 16 and Figure 17



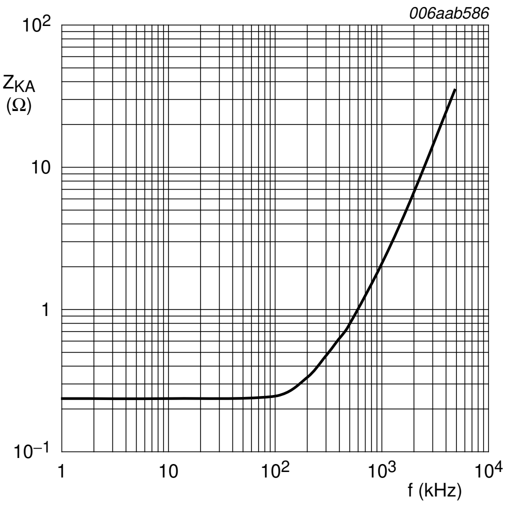
I_K = 10 mA; T_{amb} = 25 °C

Fig 19. All types except TL431XFDT and TL431XSDT: Dynamic cathode-anode impedance as a function of frequency; typical values



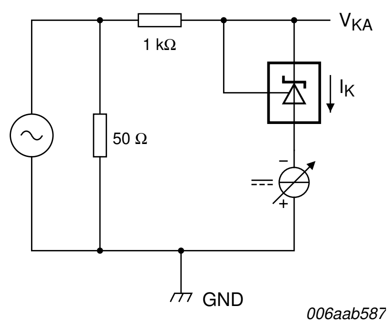
I_K = 10 mA; T_{amb} = 25 °C

Fig 20. TL431XFDT: Dynamic cathode-anode impedance as a function of frequency; typical values



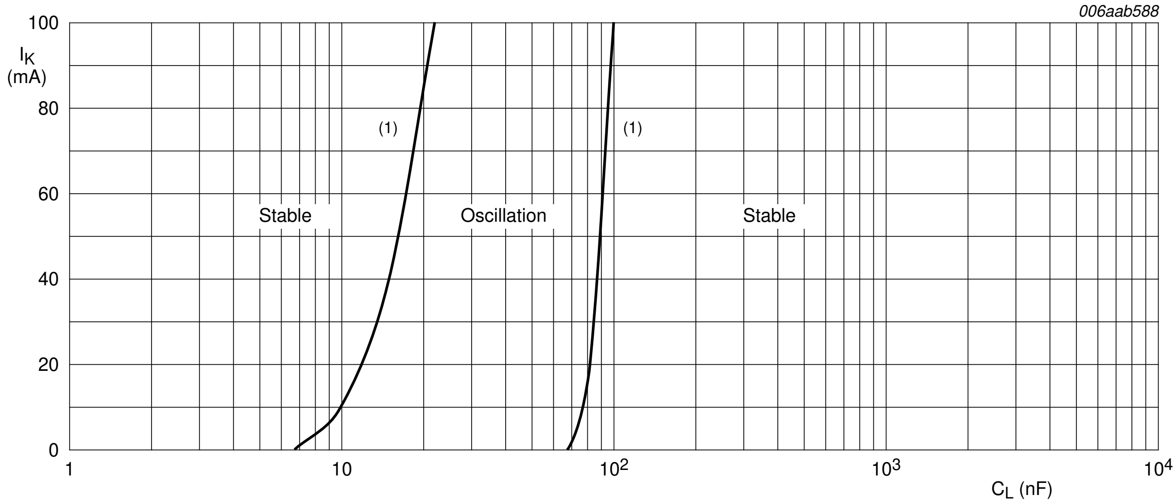
I_K = 10 mA; T_{amb} = 25 °C

Fig 21. TL431XSDT: Dynamic cathode-anode impedance as a function of frequency; typical values



I_K = 10 mA; T_{amb} = 25 °C

Fig 22. Test circuit to Figure 19, Figure 20 and Figure 21



T_{amb} = 25 °C

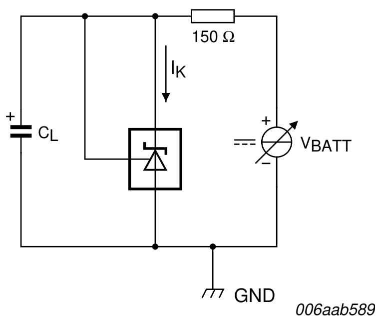
(1) $V_{KA} = V_{ref}$

V_{KA} = 5 V: no oscillation

V_{KA} = 10 V: no oscillation

V_{KA} = 15 V: no oscillation

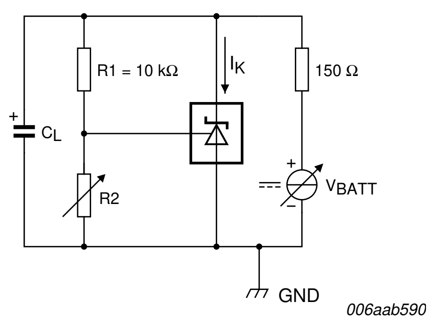
Fig 23. All types except TL431XFDT and TL431XSDT: Cathode current as a function of load capacitance; typical values



$V_{KA} = V_{ref}$

T_{amb} = 25 °C

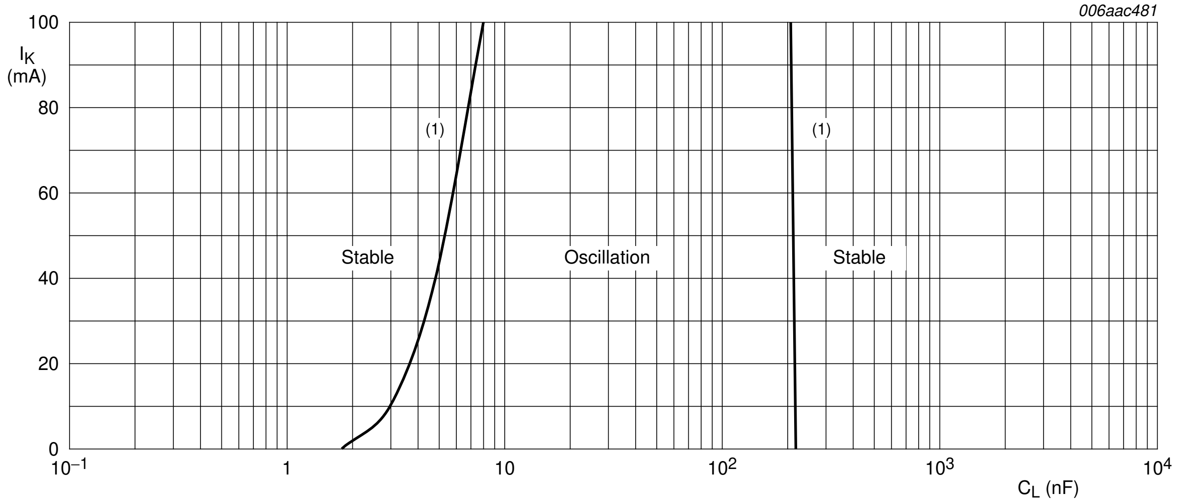
Fig 24. Test circuit (1) to Figure 23



V_{KA} > 5 V: stable operation

T_{amb} = 25 °C

Fig 25. Test circuit (2) to Figure 23



T_{amb} = 25 °C

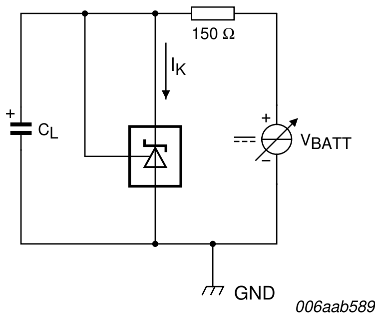
(1) $V_{KA} = V_{ref}$

V_{KA} = 5 V: no oscillation

V_{KA} = 10 V: no oscillation

V_{KA} = 15 V: no oscillation

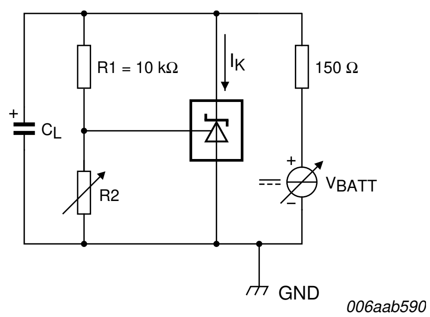
Fig 26. TL431XFDT: Cathode current as a function of load capacitance; typical values



$V_{KA} = V_{ref}$

T_{amb} = 25 °C

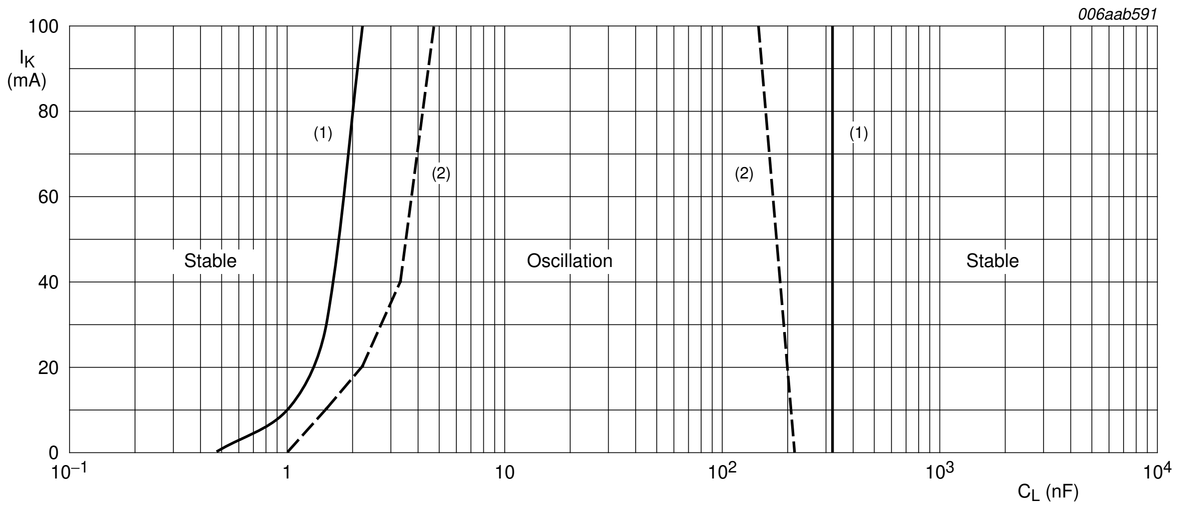
Fig 27. Test circuit (1) to Figure 26



V_{KA} > 5 V: stable operation

T_{amb} = 25 °C

Fig 28. Test circuit (2) to Figure 26



T_{amb} = 25 °C

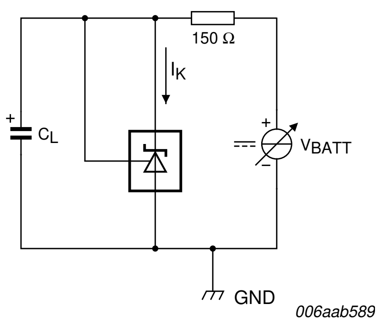
(1) $V_{KA} = V_{ref}$

(2) V_{KA} = 5 V

V_{KA} = 10 V: no oscillation

V_{KA} = 15 V: no oscillation

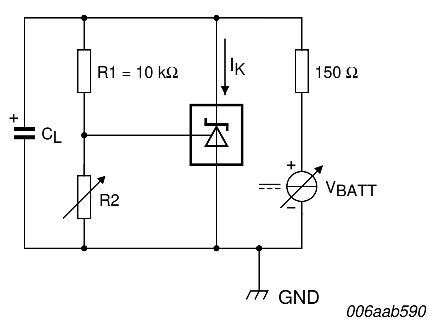
Fig 29. TL431XSDT: Cathode current as a function of load capacitance; typical values



$V_{KA} = V_{ref}$

T_{amb} = 25 °C

Fig 30. Test circuit (1) to Figure 29



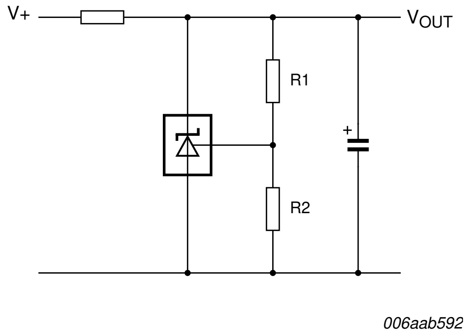
V_{KA} = 5 V

V_{KA} > 10 V: stable operation

T_{amb} = 25 °C

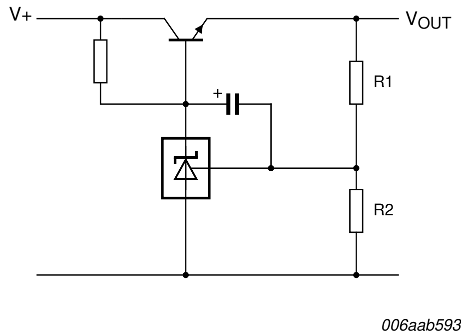
Fig 31. Test circuit (2) to Figure 29

10. Application information



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

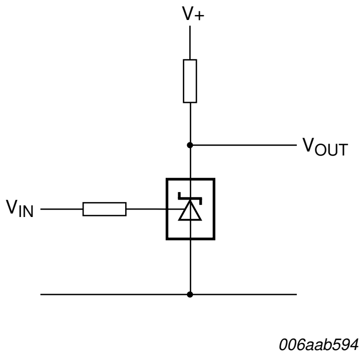
Fig 32. Shunt regulator



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

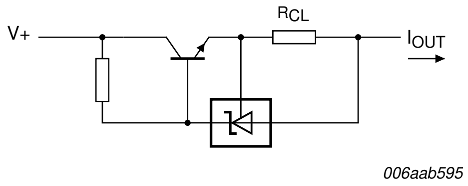
$$V_{OUT(min)} = V_{ref} + V_{be}$$

Fig 33. Series pass regulator



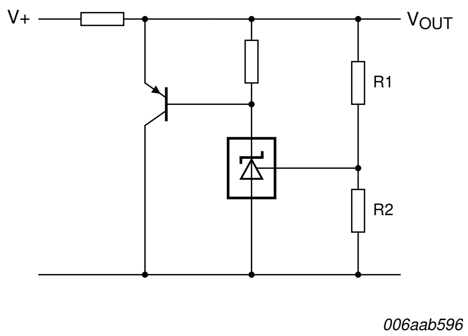
$$V_{th} = V_{ref}$$
$$V_{IN} < V_{ref} \Rightarrow V_{OUT} > 0$$
$$V_{IN} > V_{ref} \Rightarrow V_{OUT} \cong 2V$$

Fig 34. Single-supply comparator with temperature-compensated threshold



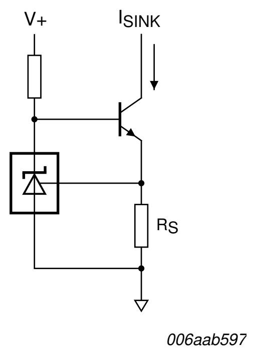
$$I_{OUT} = \frac{V_{ref}}{R_{CL}}$$

Fig 35. Constant current source



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

Fig 36. High-current shunt regulator



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

Fig 37. Constant current sink

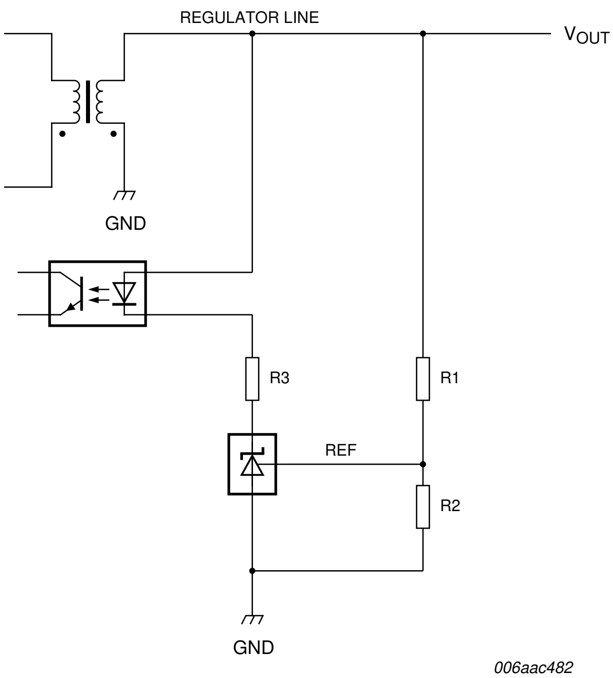


Fig 38. TL431 in control loop of SMPS

11. Test information

11.1 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

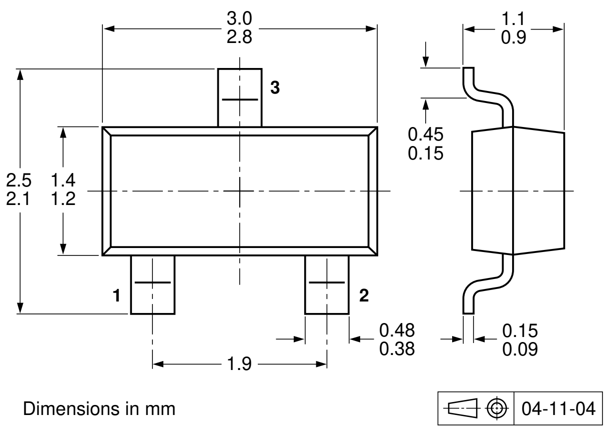


Fig 39. Package outline SOT23 (TO-236AB)

13. Soldering

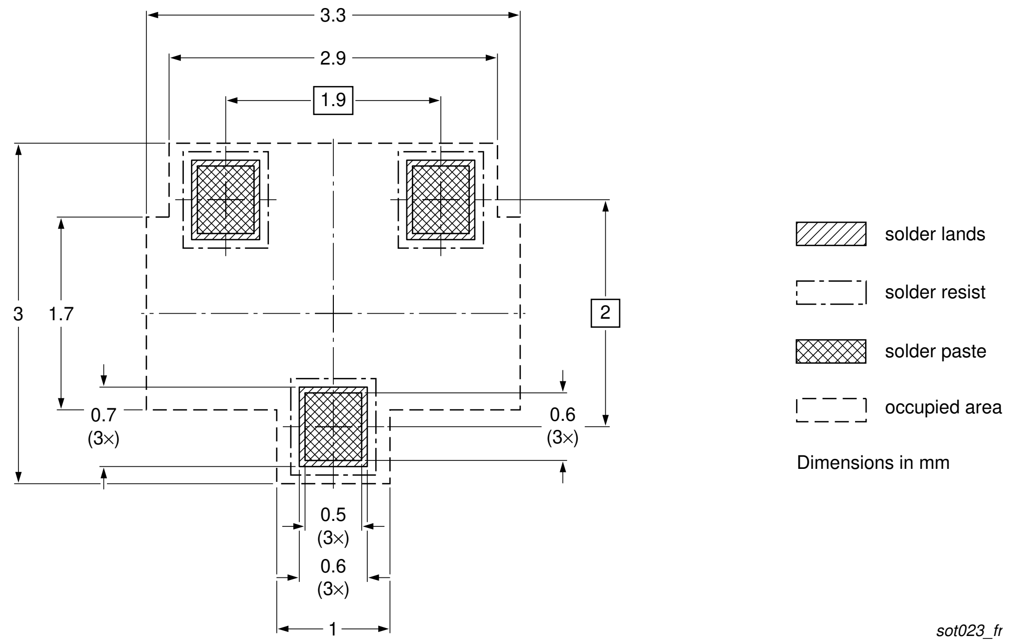


Fig 40. Reflow soldering footprint SOT23 (TO-236AB)

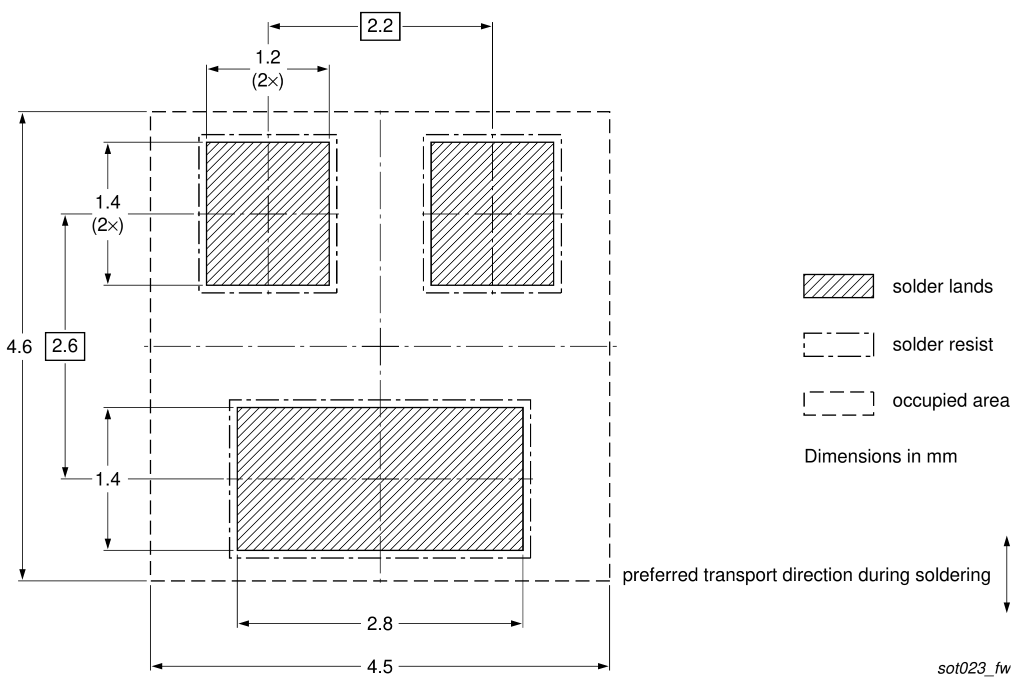


Fig 41. Wave soldering footprint SOT23 (TO-236AB)

14. Revision history

Table 11. Revision history

Document ID	Release date	Data sheet status	Change notice	Supersedes
TL431_FAM v.5	20150901	Product data sheet	-	TL431_FAM v.4
Modifications:	• Figure 18: Capacitor value corrected			
TL431_FAM v.4	20110630	Product data sheet	-	TL431_FAM v.3
TL431_FAM v.3	20101105	Product data sheet	-	TL431_FAM v.2
TL431_FAM v.2	20100120	Product data sheet	-	TL431_FAM v.1
TL431_FAM v.1	20090806	Product data sheet	-	-