



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 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: $0.2\ \Omega$
- 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)

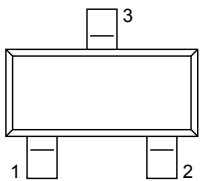
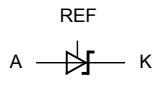
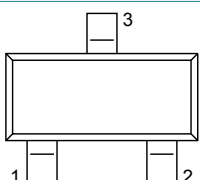
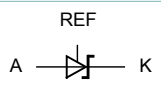
1.4. Quick reference data

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 | $V_{KA} = V_{ref}; I_K = 10 \text{ mA};$ $T_{amb} = 25 \text{ }^\circ\text{C}$ | | | | |
| | • 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 |
|---|--------|-------------|--|--|
| 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 | | 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_{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 | $T_{amb} \leq 25\text{ °C}$ | [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 cm².
- [3] Device mounted on a ceramic PCB, Al₂O₃, standard footprint.

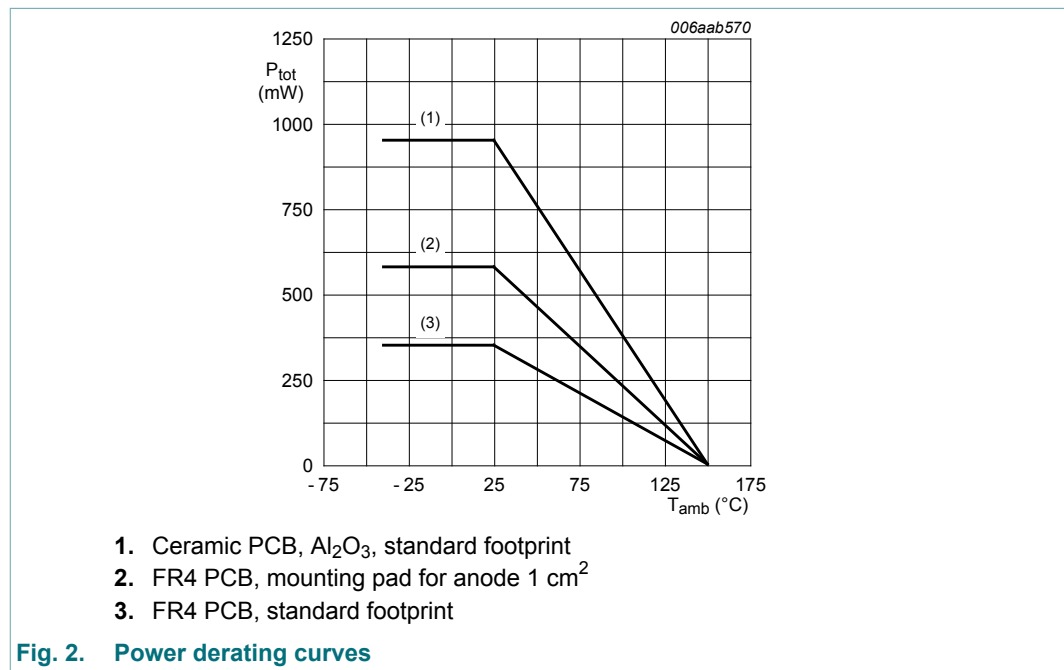


Table 7. ESD maximum ratings

$T_{amb} = 25\text{ °C}$ 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 cm².
 [3] Device mounted on a ceramic PCB, Al₂O₃, 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 |
| ΔV_{ref} | reference voltage variation | $V_{KA} = V_{ref}$; $I_K = 10\text{ mA}$ | | | | |
| | TL431CDBZR | $T_{amb} = 0\text{ °C}$ to 70 °C | - | 9 | 16 | mV |
| | TL431IDBZR | $T_{amb} = -40\text{ °C}$ to 85 °C | - | 17 | 34 | mV |
| | TL431QDBZR | $T_{amb} = -40\text{ °C}$ to 125 °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 V | - | -1 | -2 | mV/V |
| I_{ref} | reference current | $I_K = 10\text{ mA}$; $R1 = 10\text{ k}\Omega$; $R2 = \text{open}$ | - | 2 | 4 | μA |
| ΔI_{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 °C | - | 0.4 | 1.2 | μA |
| | TL431IDBZR | $T_{amb} = -40\text{ °C}$ to 85 °C | - | 0.8 | 2.5 | μA |
| | TL431QDBZR | $T_{amb} = -40\text{ °C}$ to 125 °C | | | | |
| | TL431FDT TL431MFDT | | | | | |
| $I_{K(\min)}$ | minimum cathode current | $V_{KA} = V_{ref}$ | - | 0.4 | 1 | mA |
| I_{off} | off-state current | $V_{KA} = 36\text{ V}$; $V_{ref} = 0$ | - | 0.1 | 1 | μA |
| Z_{KA} | dynamic cathode-anode impedance | $I_K = 0.1\text{ mA}$ to 100 mA ; $V_{KA} = V_{ref}$; $f < 1\text{ kHz}$ | - | 0.20 | 0.5 | Ω |
| A-Grade (1 %): TL431ACDBZR; TL431AIDBZR; TL431AQDBZR; TL431AFDT; TL431AMFDT | | | | | | |
| V_{ref} | reference voltage | $V_{KA} = V_{ref}$; $I_K = 10\text{ mA}$ | 2470 | 2495 | 2520 | mV |
| ΔV_{ref} | reference voltage variation | $V_{KA} = V_{ref}$; $I_K = 10\text{ mA}$ | | | | |
| | TL431ACDBZR | $T_{amb} = 0\text{ °C}$ to 70 °C | - | 9 | 16 | mV |
| | TL431AIDBZR | $T_{amb} = -40\text{ °C}$ to 85 °C | - | 17 | 34 | mV |
| | TL431AQDBZR | $T_{amb} = -40\text{ °C}$ to 125 °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 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 | μA |

| Symbol | Parameter | Conditions | Min | Typ | Max | Unit |
|--|--|---|------|------|------|---------------|
| ΔI_{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 | μA |
| | TL431AIDBZR | $T_{\text{amb}} = -40 \text{ }^\circ\text{C}$ to $85 \text{ }^\circ\text{C}$ | - | 0.8 | 2.5 | μA |
| | 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 | 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_{off} | off-state current | $V_{KA} = 36 \text{ V}$; $V_{\text{ref}} = 0$ | - | 0.1 | 0.5 | μA |
| Z_{KA} | dynamic cathode-anode impedance | $I_K = 0.1 \text{ mA}$ to 100 mA ; $V_{KA} = V_{\text{ref}}$; $f < 1 \text{ kHz}$ | - | 0.2 | 0.5 | Ω |
| B-Grade (0.5 %): TL431BCDBZR; TL431BIDBZR; TL431BFDT; TL431BMFDT | | | | | | |
| V_{ref} | reference voltage | $V_{KA} = V_{\text{ref}}$; $I_K = 10 \text{ mA}$ | 2483 | 2495 | 2507 | mV |
| ΔV_{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 | mV |
| | TL431BIDBZR | $T_{\text{amb}} = -40 \text{ }^\circ\text{C}$ to $85 \text{ }^\circ\text{C}$ | - | 17 | 34 | 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_{ref} | - | -1.4 | -2.7 | mV/V |
| | | $\Delta V_{KA} = 36 \text{ V}$ to 10 V | - | -1.0 | -2.0 | mV/V |
| I_{ref} | reference current | $I_K = 10 \text{ mA}$; $R1 = 10 \text{ k}\Omega$; $R2 = \text{open}$ | - | 2.0 | 4.0 | μA |
| ΔI_{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 | μA |
| | TL431BIDBZR | $T_{\text{amb}} = -40 \text{ }^\circ\text{C}$ to $85 \text{ }^\circ\text{C}$ | - | 0.8 | 2.5 | μA |
| | 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 | 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_{off} | off-state current | $V_{KA} = 36 \text{ V}$; $V_{\text{ref}} = 0$ | - | 0.1 | 0.5 | μA |
| Z_{KA} | dynamic cathode-anode impedance | $I_K = 0.1 \text{ mA}$ to 100 mA ; $V_{KA} = V_{\text{ref}}$; $f < 1 \text{ kHz}$ | - | 0.2 | 0.5 | Ω |



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

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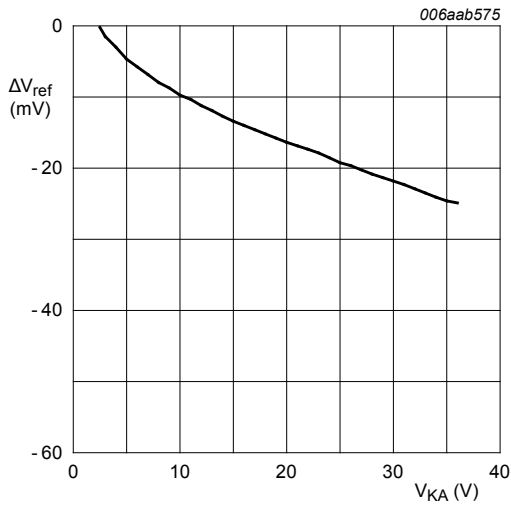
$I_K = 10 \text{ mA}; V_{KA} = V_{ref}$

Fig. 5. Test circuit to Figures 3 and 4



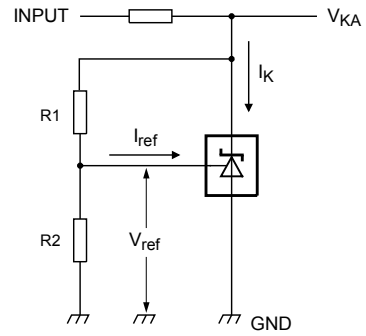
$I_K = 10 \text{ mA}; R1 = 10 \text{ k}\Omega; R2 = \text{open}$

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



I_K = 10 mA; T_{amb} = 25 °C

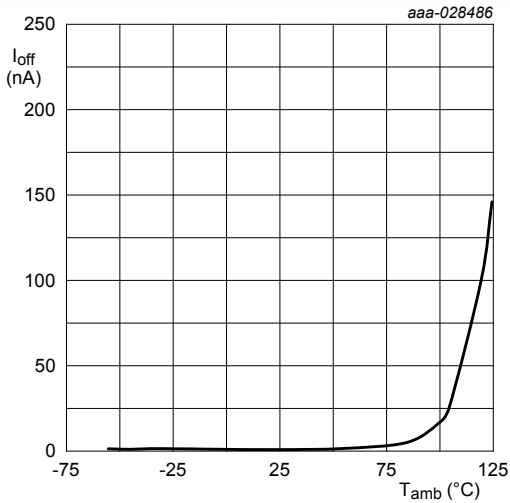
Fig. 7. Reference voltage variation as a function of cathode-anode voltage; typical values



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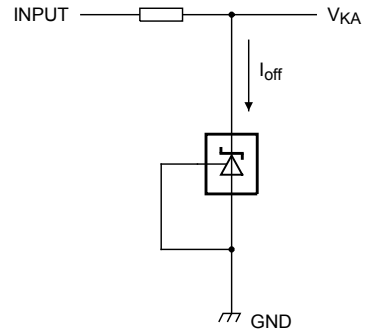
$$V_{KA} = V_{ref} \times \left(1 + \frac{R1}{R2}\right) + I_{ref} \times R1$$

Fig. 8. Test circuit to Figures 6 and 7



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

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



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



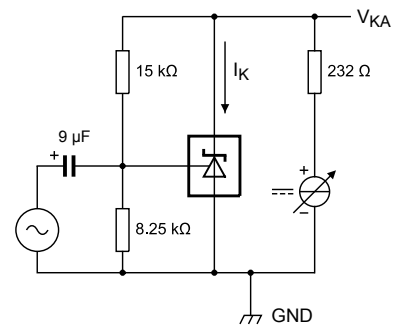
$T_{amb} = 25\text{ }^{\circ}\text{C}$

Fig. 12. Test circuit to Figure 11



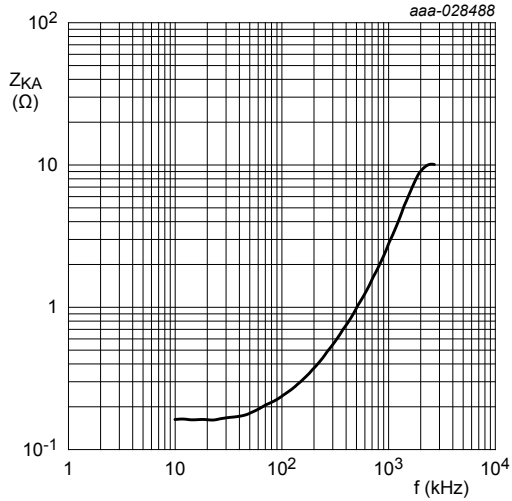
$I_K = 10\text{ mA}$; $T_{amb} = 25\text{ }^{\circ}\text{C}$

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



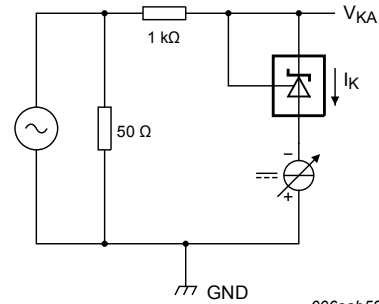
$I_K = 10\text{ mA}$; $T_{amb} = 25\text{ }^{\circ}\text{C}$

Fig. 14. Test circuit to Figure 13



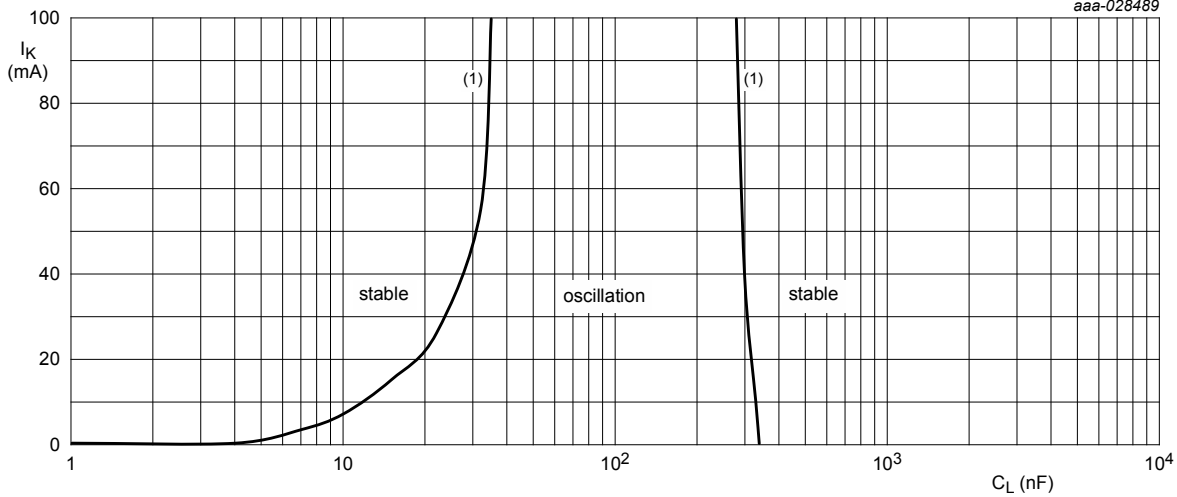
$I_K = 10 \text{ mA}; T_{\text{amb}} = 25 \text{ }^\circ\text{C}$

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



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

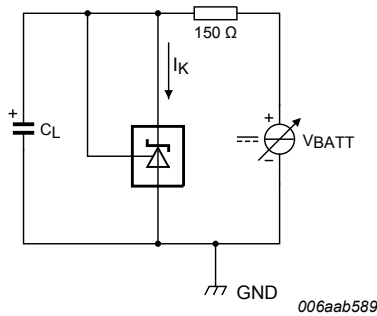
(1) $V_{KA} = V_{\text{ref}}$

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

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

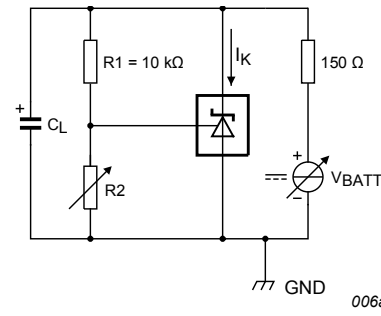
$V_{KA} = 15 \text{ V};$ no oscillation

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



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

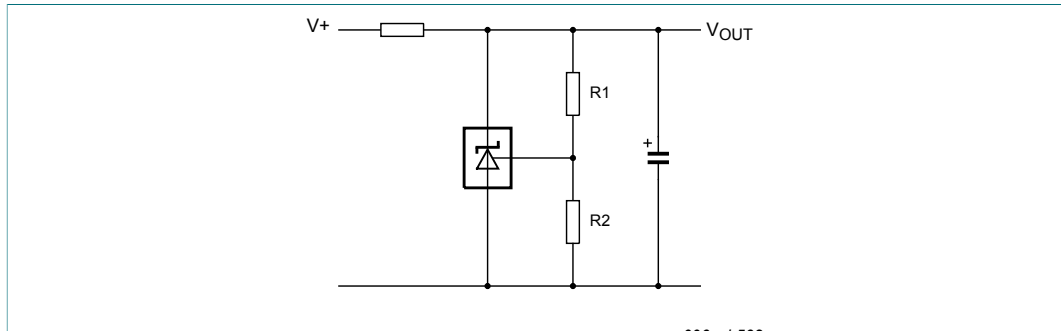
Fig. 18. Test circuit to Figure 17



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

Fig. 19. Test circuit to Figure 17

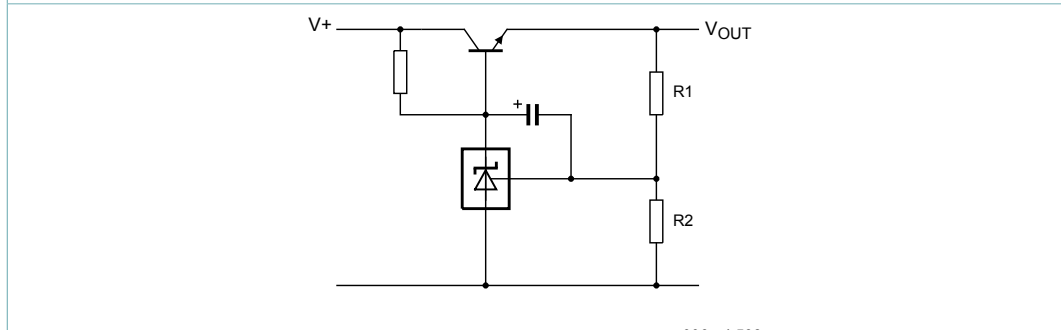
10. Application information



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

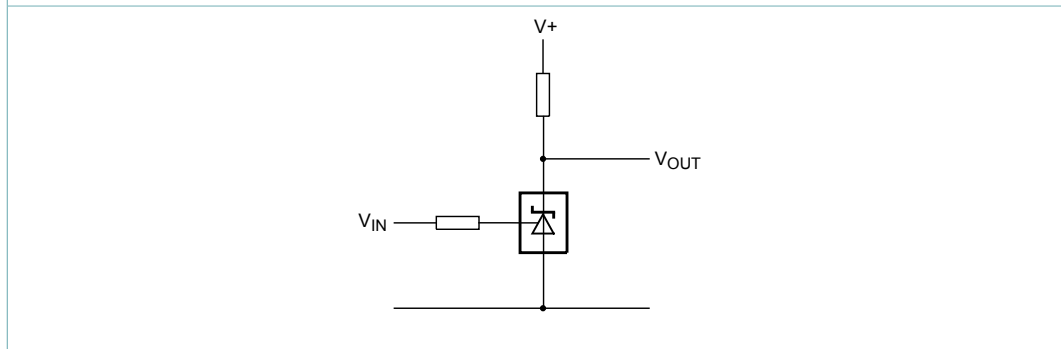
Fig. 20. Shunt regulator



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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



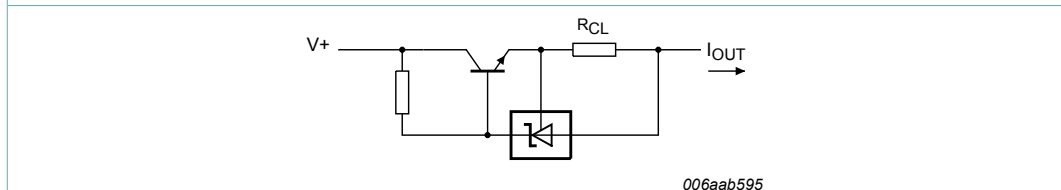
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$$T_{th} = V_{ref}$$

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

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

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



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

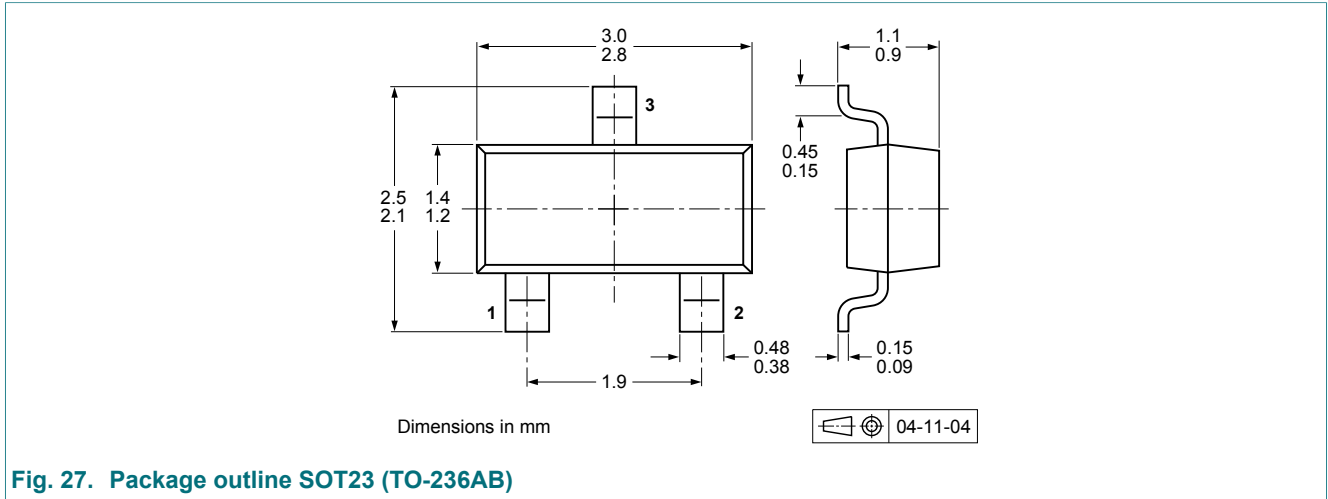


Fig. 27. Package outline SOT23 (TO-236AB)

13. Soldering

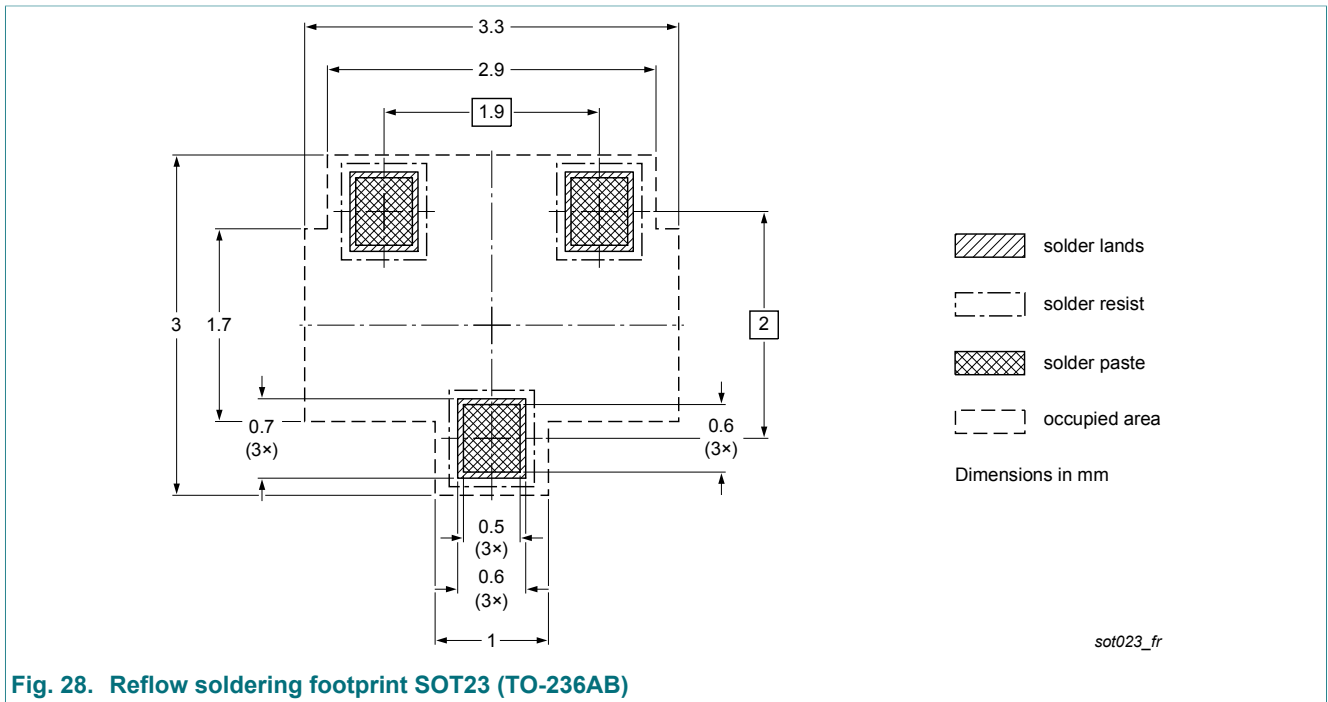


Fig. 28. Reflow soldering footprint SOT23 (TO-236AB)



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"> • 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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