Application Report
SNVA809–January 2018

TL431 Pin FMEA

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ABSTRACT

The TL431 and TL432 are three-terminal adjustable shunt regulators with specified thermal stability over automotive, commercial, and military temperature ranges. The TL431 devices have sharp turnon time and can act as replacements for Zener diodes in many applications.

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1 Pin FMEA

This application note provides a Failure Modes and Effects Analysis (FMEA) for the device pins of the TL431. The failure conditions covered in this document include the typical pin-by-pin failure scenarios:

- Pin short-circuited to Ground;
- Pin short-circuited to TL431 V_{IN};
- Pin short-circuited to an adjacent pin; and
- Pin is open circuited.

This application note also details how these pin conditions affect the device:

- Does the pin condition cause permanent damage?
- Is the device is functional under the pin condition?
- How does a particular pin condition affect the device operation?

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2 Scope

The TL431 is composed of an error amplifier and a transistor that has two modes: open-loop mode and closed-loop mode.

- Closed-Loop mode is where the input voltage pin, REF, is connected to the output voltage pin, Cathode. In this configuration, the output voltage is regulated to a specified value based on the feedback loop that is connected to the REF pin.
- Open-Loop mode is where the input voltage pin, REF, has no connection path to the output voltage pin, Cathode. In this configuration, the output voltage has no feedback loop connection to the REF pin, and thus the cathode voltage is dependant on the voltage on the REF pin. This configuration is commonly known as the comparator mode configuration as the REF pin is used as a comparator.

In many applications, the most common configuration is the closed-loop mode because the cathode voltage is stable in this mode and is regulated across temperature so long as the parameters are is within the recommend operating range. Having the TL431 in open-loop mode is beyond the scope of this report.

For the purposes of this report:

- Unless otherwise specified, the voltage applied to the CATHODE and REF are within the TL431 recommended operating range.
- The V_{IN} for the purposes of document is the CATHODE pin as it provides voltage to the error amplifier.
- The feedback network in closed-loop has gain due to R1 and R2, but the CATHODE voltage is still within the recommended operating range.

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3 TL431 Pin Configurations and Functions

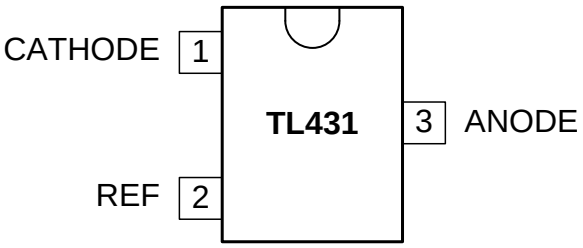

Figure 1. 3-Pin SOT-23 Package (Top View)

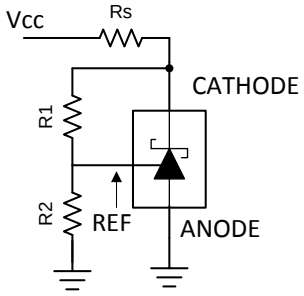

Figure 2. TL431 Schematic

Pin Functions

PIN		I/O	DESCRIPTION
NUMBER	NAME		
1	CATHODE	I/O	Shunt Current/ Voltage input
2	REF	I	Threshold relative to common anode
3	ANODE	O	Common pin, normally connected to ground

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4 FMEA Analysis

Table 1. Pin FMEA Analysis for Pin Short Circuit to Ground

PIN		SHORT TO V_{IN}		
NUMBER	NAME	DAMAGE	FUNCTIONAL	COMMENTS
1	CATHODE	No	No	No damage to device. Increases leakage.
2	REF	No	Yes	Cathode voltage is unregulated
3	ANODE	No	Yes	No effect

Table 2. Pin FMEA Analysis for Pin Short Circuit to V_{IN}

PIN		SHORT TO V_{IN}		
NUMBER	NAME	DAMAGE	FUNCTIONAL	COMMENTS
1	CATHODE	No	Yes	No Effect
2	REF	No	Yes	Voltage might be regulated differently depending on the feedback of the device
3	ANODE	No	No	No damage to device. Increases leakage.

Table 3. Pin FMEA Analysis for Pin Short Circuit to an Adjacent Pin

PIN		SHORT TO PIN		SHORT TO ADJACENT PIN		
NUMBER	NAME	NUMBER	NAME	DAMAGE	FUNCTIONAL	COMMENTS
1	CATHODE	2	REF	No	Yes	Voltage might be regulated differently depending on the gain of the device
2	REF	3	ANODE	No	Yes	Cathode voltage is unregulated
3	ANODE	1	CATHODE	No	No	No damage to device. Increases leakage.

Table 4. Pin FMEA Analysis for Pin Open Circuit

PIN		OPEN		
NUMBER	NAME	DAMAGE	FUNCTIONAL	COMMENTS
1	CATHODE	No	No	No output voltage.
2	REF	No	No	Output is not regulated
3	ANODE	No	No	Output is not regulated

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