

Accuracy of shunt voltage references in programmable mode

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1 INTRODUCTION

When an adjustable shunt voltage reference like TL431 is used in programmable mode, we may encounter some errors due to the programming. This application note will give to the reader a method to determine the relative error on the output voltage.

The schematic used to program a shunt voltage reference is presented on [Figure 1](#). The voltage reference provide some relative errors: this is what we call the inner precision. As we have to use an external resistor bridge configuration, we

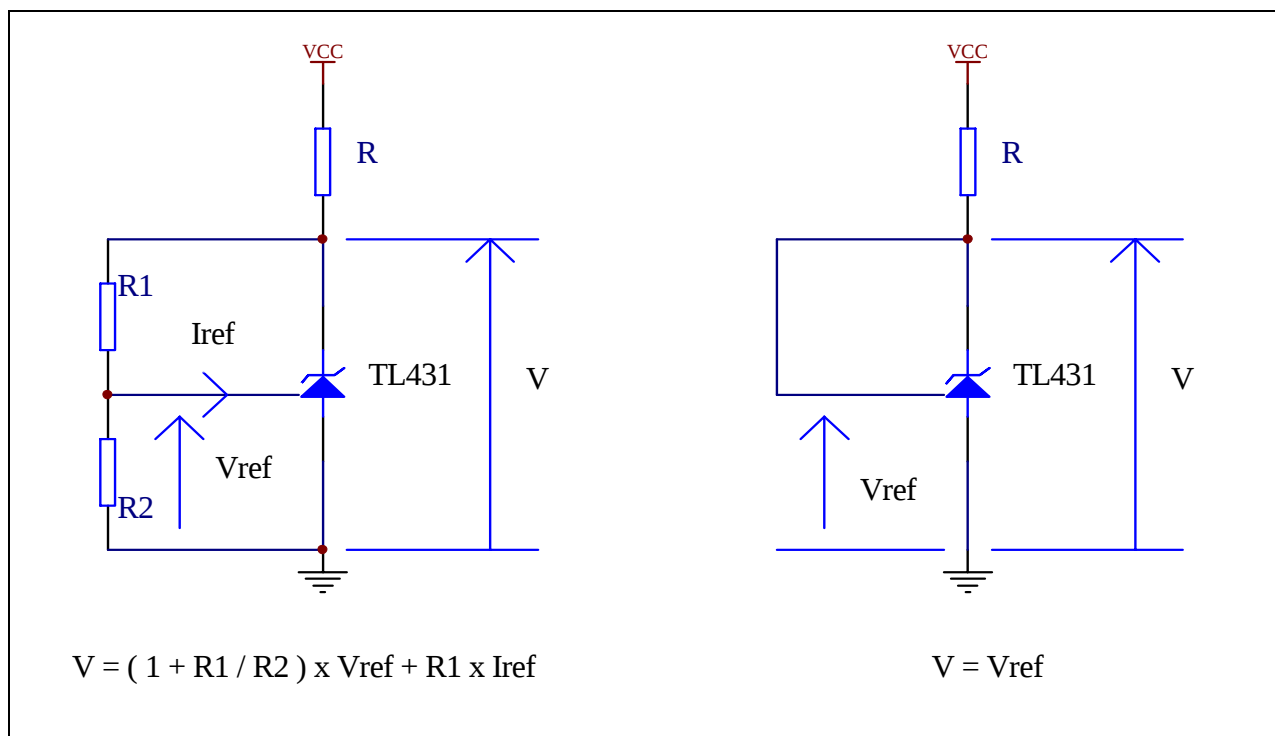
obviously have some additional errors as all resistor elements are not perfects.

The application note will present the calculation in order to reach a final formula which can be used easily to calculate the relative error of the global schematic.

The following elements are taken into account:

- the inner precision of the voltage reference.
- the precision of resistors.

Fig. 1: Typical application schematic of a shunt voltage reference



2 CALCULATIONS OF THE ACCURACY

Based on the schematic used to program the voltage reference, we can write:

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

Where V stands for Cathode voltage, V_{ref} is for the voltage present on the ref pin and I_{ref} is the input reference pin current. I_{ref} is a very low current in the range of a few μA we will neglect if the term $R1 \cdot I_{ref}$ is low enough regarding the other terms of the equation. Most of the time, this simplification can be done. Thus, if we write the total equation of the partial derivative, we obtain:

$$dV = \frac{\partial V}{\partial V_{ref}} \cdot dV_{ref} + \frac{\partial V}{\partial R1} \cdot dR1 + \frac{\partial V}{\partial R2} \cdot dR2$$

with

$$\frac{\partial V}{\partial V_{ref}} = 1 + \frac{R1}{R2}$$

$$\frac{\partial V}{\partial R1} = \frac{V_{ref}}{R2}$$

$$\frac{\partial V}{\partial R2} = \frac{-R1 \cdot V_{ref}}{(R2)^2}$$

So, the total equation gives

$$dV = \left(1 + \frac{R1}{R2}\right) \cdot dV_{ref} + \frac{V_{ref}}{R2} \cdot dR1 - \frac{R1 \cdot V_{ref}}{R2^2} \cdot dR2$$

And if we try to make terms like dx / x appear, we obtain:

$$dV = \left(1 + \frac{R1}{R2}\right) V_{ref} \cdot \left(\frac{dV_{ref}}{V_{ref}}\right) + \left(\frac{R1}{R2}\right) V_{ref} \cdot \left(\frac{dR1}{R1}\right) - \left(\frac{R1}{R2}\right) V_{ref} \cdot \left(\frac{dR2}{R2}\right)$$

And by operating some simplifications, we finally have:

$$\frac{dV}{V} = \frac{dV_{ref}}{V_{ref}} + \frac{R1}{R1 + R2} \cdot \left(\frac{dR1}{R1} - \frac{dR2}{R2}\right)$$

Then, if we consider small variations of all parameters around their values, we have the final expression which can be used to calculate the relative error:

$$\left|\frac{\Delta V}{V}\right| = \left|\frac{\Delta V_{ref}}{V_{ref}}\right| + \frac{R1}{R1 + R2} \cdot \left(\left|\frac{\Delta R1}{R1}\right| + \left|\frac{\Delta R2}{R2}\right|\right)$$

As an application, let us consider a TL431A ($\pm 1\%$ precision) programmed at 5V with $R1=R2$ at $\pm 2\%$ precision. Using the above formula, we can calculate the 5V output precision:

$$\left|\frac{\Delta V}{V}\right| = 1 + \frac{1}{2} \cdot (2 + 2) = \pm 3\%$$

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