APPLICATION NOTE
AN1761

TL431
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 programmation. This application note will give to the reader a method to determine the relative error on the output voltage.

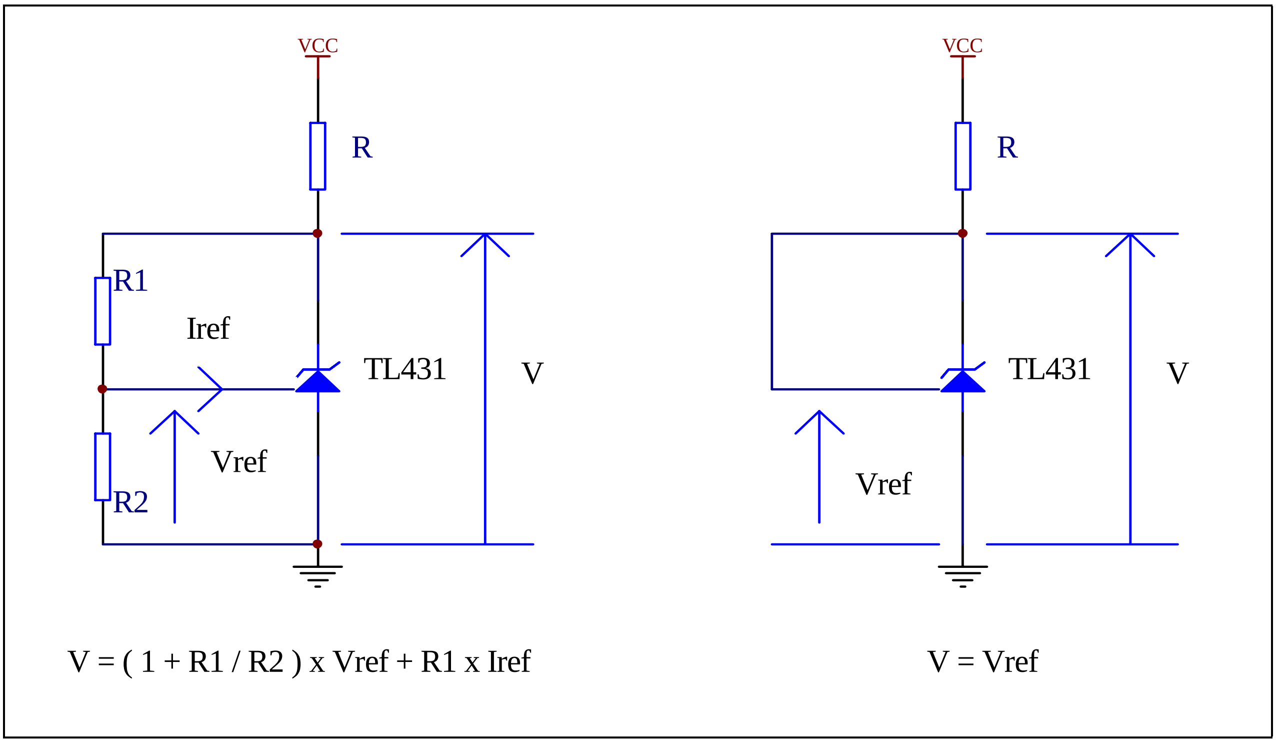
The schematic used to program a shunt voltage reference is presented on *Figure 1*. The voltage reference provide some relative errors: this is what we call the inner precision. As we have to use an external resistor bridge configuration, we obviously have some additional errors as all resistor elements 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:

$$V = \left(1 + \frac{R1}{R2}\right) \bullet Vref + R1 \bullet Iref$$

Where V stands for Cathode voltage, *Vref* is for the voltage present on the ref pin and *Iref* is the input reference pin current. *Iref* is a very low current in the range of a few µA we will neglect if the term R1**.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:

$$dV = \frac{\partial V}{\partial Vref} \bullet dVref + \frac{\partial V}{\partial R1} \bullet dR1 + \frac{\partial V}{\partial R2} \bullet dR2$$

with

$$\frac{\partial V}{\partial Vref} = 1 + \frac{R1}{R2} \qquad \frac{\partial V}{\partial R1} = \frac{Vref}{R2} \qquad \frac{\partial V}{\partial R2} = \frac{-R1 \bullet Vref}{(R2)^2}$$

So, the total equation gives

$$dV = \left(1 + \frac{R1}{R2}\right) \bullet dVref + \frac{Vref}{R2} \bullet dR1 - \frac{R1 \bullet Vref}{R2^2} \bullet dR2$$

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

$$dV = \left(1 + \frac{R1}{R2}\right) Vref \bullet \left(\frac{dVref}{Vref}\right) + \left(\frac{R1}{R2}\right) Vref \bullet \left(\frac{dR1}{R1}\right) - \left(\frac{R1}{R2}\right) Vref \bullet \left(\frac{dR2}{R2}\right)$$

And by operating some simplifications, we finally have:

$$\frac{dV}{V} = \frac{dVref}{Vref} + \frac{R1}{R1 + R2} \bullet \left(\frac{dR1}{R1} - \frac{dR2}{R2}\right)$$

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:

$$\boxed{\left|\frac{\Delta V}{V}\right| = \left|\frac{\Delta Vref}{Vref}\right| + \frac{R1}{R1 + R2} \bullet \left(\left|\frac{\Delta R1}{R1}\right| + \left|\frac{\Delta R2}{R2}\right|\right)}$$

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

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