Application Report
SNOAA00–August 2018

Designing with the Improved TL431LI

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ABSTRACT

The TL431LI is TI's latest addition to its adjustable shunt regulator family. This device is an alternative and offers improvements over its industry standard counterparts which make it more design friendly.

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Trademarks

1 Advancements

- Improved system accuracy due to very low reference current
  - I_{ref} = 0.8 µA (max)
  - $I_{I(dev)}$= 0.4 µA (max)
- Improved Stability

2 TL431LI Improved System Accuracy

The TL431LI allows for improved system accuracy over the industry standard TL431 due to its decrease in I_{ref} and $I_{I(dev)}$. The accuracy advantage due to this lower I_{ref} can be seen in AC/DC or DC/DC optocoupler applications. Figure 1 shows a typical example of an AC/DC isolated optocoupler application. In this application the accuracy of the output is dependent on the error of the feedback loop which includes the errors from the TL431LI, optocoupler, and external resistors. Managing this area can often be a challenge to designers when the shunt regulator contributes a high error of 1% or greater over temperature.

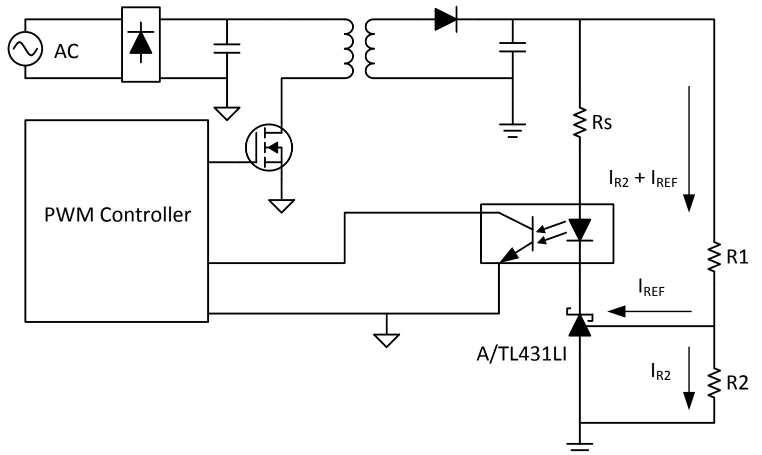

Figure 1. Typical AC/DC Isolated Optocoupler with A/TL431LI

Looking at the output voltage of a shunt regulator in Equation 1, the deviation of I_{ref} at 25C has a direct effect on accuracy depending on the value of R1. The accuracy advantage of the TL431LI comes from a direct reduction of I_{ref} from 4µA (max from 431 competition) to 0.8µA (max) which is a 5x reduction.

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

Table 1 shows a comparison of the accuracy of an industry standard TL431 and the TL431LI in terms of I_{ref}. When performing error budgeting, due to the lot to lot variation, the maximum possible current values must be taken into account. In the case of a 5V Vout, the error of the system can be reduced by using a TL431LI.

Table 1. TL431LI I_{REF} Error Calculation Comparison

	I_{REF}	R1	mV Error of a 5V Output	Percent Error of a 5V Output	ppm Error of a 5V Output
Industry Standard TL431	4.0 µA	10 kΩ	40 mV	0.80 %	8000 ppm
TL431LI	0.8 µA	10 kΩ	8 mV	0.16 %	1600 ppm

The lowered I_{ref} accuracy advantage is also reflected in the I_{ref} tolerance over temperature, $I_{I(dev)}$, as the TL431LI has a lower tolerance which can result in a lower error. By looking at the I_{ref} and $I_{I(dev)}$ errors combined it is possible to have a more precise and accurate output by using the TL431LI.

Table 2. TL431LI $I_{I(dev)}$ Error Calculation Comparison

	$I_{I(dev)}$	R1	mV Error of a 5V Output	Percent Error of a 5V Output	$I_{I(dev)}$ ppm Error
Industry Standard TL431	2.5 µA	10 kΩ	25 mV	0.50 %	30 ppm/C
TL431LI	0.4 µA	10 kΩ	4 mV	0.08 %	5 ppm/C

One of the drawbacks of a shunt regulator is the overall high error due to the high initial accuracy and temperature coefficient. With the TL431LI it is possible to lower the BOM cost and/or increase the system accuracy and efficiency compared to an industry standard TL431. Typically the main selection of a shunt regulator depends on the accuracy and temperature grade. The most common industry initial accuracy grades are 2%, 1%, and 0.5%. If the total error of a shunt regulator can be improved by at least 0.5% by using the TL431LI due to its improved I_{ref} and $I_{I(dev)}$ then it is possible to realize system cost benefits. For example, a 0.5% TL431 can be replaced by a 1% TL431LI achieve similar system accuracy due to the lower I_{ref} error improving the over all accuracy of the TL431LI by 0.5%. The improvement in accuracy for error budgeting can also be spread to the accuracy tolerances of the R1/R2 resistors as they can also be less accurate to yield additional cost savings or increased for power savings.

3 TL431LI Stability

In the Industry standard TL431, stability is one of the most common design challenges. Due to the low system BOM cost nature of these devices, there are boundaries of instability that are dependent on the C_{Load} on the V_{KA} pin. One problem with stability is that the industry is not consistent on the areas of stability due to each company having their own variation. Typical TL431 stability charts have a large boundary of instability at low currents and low Vka. The result of this is that very large C_{LOAD} values must be used to ensure stability and decoupling or a very small capacitor with reduced decoupling effects. Also the area of instability varies from lot to lot and temperature so it is always important to add a margin of error from the instability line to ensure that there is significant margin.

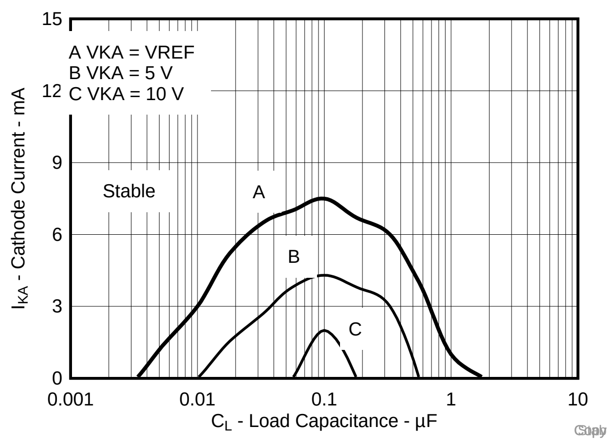

Figure 2. Stability Boundary Conditions for TL431LI

In the TL431LI, here has been an improvement in stability as depicted in Figure 2. This improvement allows for designers to be able to use a 1µF CLoad at voltage outputs while still maintaining stability at no C_{Load} conditions. Due to this, the TL431LI is more design friendly than industry standard TL431s that cannot tolerate a 1µF C_{Load}.

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