Application Report
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Designing with the ATL431LI in Flyback Converters

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ABSTRACT

Power adapters are ubiquitous given the increase in the number of electronic devices. This is especially common in household appliances and portable electronics that each require a separate AC/DC power supply adapter. With the increase in power adapters, the standby power in households has increased dramatically to over 300kWh/yr. Currently there are several government organizations, such as the US Department of Energy (DoE) and the EU Code of Conduct (CoC), that have implemented power requirement standards to lower the power consumption of power supplies. This has forced power supply manufacturers to change their designs to meet these new regulation standards for their respective markets, but it is not uncommon to see universal power adapters that need to meet all the global requirements. One common device in all flyback converters is the industry standard TL431LI precision shunt regulator. The TL431LI is used in the feedback network to regulate the output voltage and it also drives the power consumption of the feedback network. The need for low standby power has caused designers to look for improvements in the TL431LI feedback network. One simple solution to this is to replace the TL431LI with an ATL431LI, as this new device can operate at a lower $I_{KA(min)}$ which translates to a lower system standby power. This application note will go over the flyback converter topology with optocoupler feedback and will explain how the ATL431LI can help reduce the system standby power. In addition to this, other possible design considerations, such as optocouplers and stability, will be discussed.

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1 Shunt Regulators in Flyback Converters

The flyback converter is the most popular switched mode power supply topology, as the inductor is split to form the transformer and it offers isolation. This design is very common in all power adapters that need to convert high voltage AC to an isolated DC for power electronic devices at high efficiency.

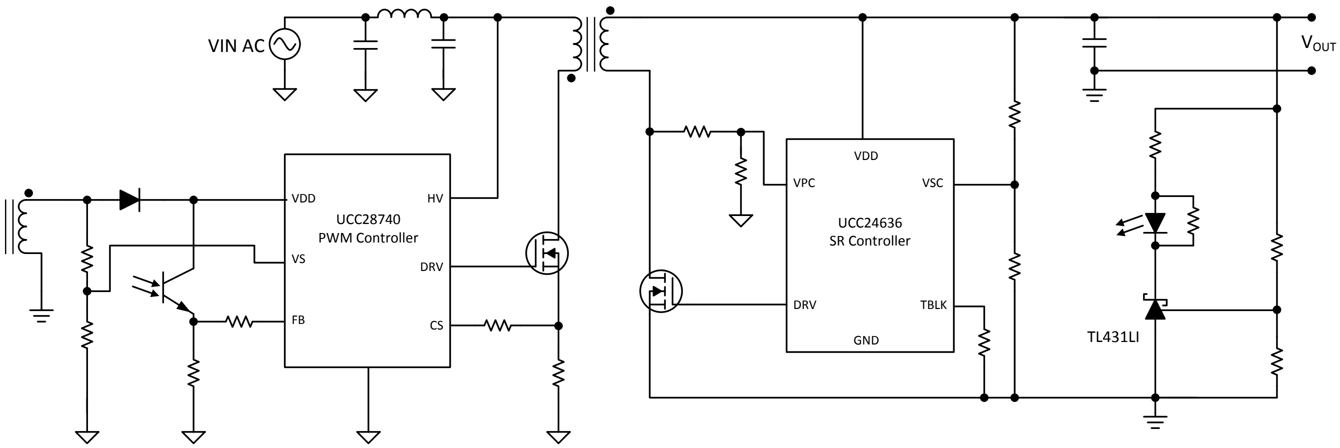

Figure 1. Schematic Diagram for a Flyback Converter

Figure 1 shows the simplified basic flyback converter that uses a shunt regulator such as TL431LI or ATL431LI. The primary purpose of the A/TL431LI is to help in the regulation of the control loop due to its internal error amplifier and internal voltage reference. By using resistors R1 and R2, the A/TL431LI device sets the output voltage of the loop through negative feedback. The A/TL431LI acts as a voltage to current controller to drive the optocoupler. It is important to design a control loop that is capable of driving the feedback pin of the PWM controller, such as UCC28740, over its complete dynamic operating range.

2 Power Savings with the ATL431LI

The TL431LI is the most commonly used shunt regulator for flyback converters due its low cost and high accuracy. The TL431LI does require at least 1mA of cathode current (I_{ka}) for proper operation but generally the TL431 is biased at a higher cathode current than 1mA due to an improvement in stability. This is a design challenge because the optocoupler in the feedback loop does not require as much current as the TL431LI to operate to its full range, thus generating a significant amount of wasted power.

The ATL431LI aims to lower the power required by the feedback loop by replacing the TL431LI. The ATL431LI has a much lower $I_{KA(min)}$ requirement of 80uA compared to the TL431LI that allows for a lower biasing point of I_{ka} for lower power consumption.

3 Flyback Power Breakdown Application Example

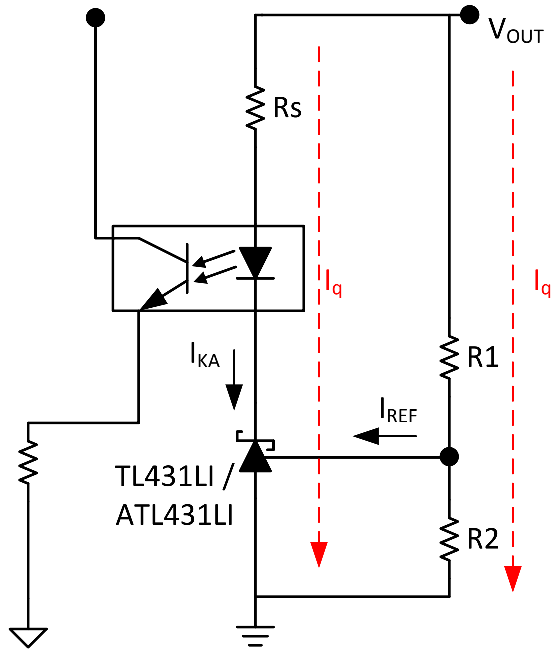

Figure 2. Current Paths in the Secondary Control Loop

Figure 2 shows the output voltage regulation by either the ATL431LI or TL431LI and the optocoupler, which offers feedback to the isolated primary side. In this simplified flyback converter, the I_{KA} bias current is limited by the value of Rs which is used to bias the optocoupler and A/TL431LI. When the system is on standby, the I_{KA} and current going through the feedback resistors are not reduced and heavily count towards the standby system I_q.

Table 1. Example Specifications of a Flyback Power Adapter

System Specifications	
Output Voltage	20V
Output Current	2.25A
Total Output Power	45W

Table 2. Standby Energy Standard Requirements

Output Power	Standby Power
US DoE Level VI (≤ 49 W)	< 100 mW
US DoE Level VI (50 W to 249 W)	< 210 mW
US DoE Level VI (> 249 W)	< 500 mW
EU CoC Tier 2 (≤ 49 W)	< 75 mW
EU CoC Tier 2 (> 50 W)	< 150 mW

Table 1 shows example system requirements of a system under a no load condition based on Table 2. It is important to be aware of the current standby power requirements in countries such as USA and in Europe. The USA requires that all power adapters must meet the DoE Level VI standby power requirements and currently in Europe the CoC tier 1 are in the process of being updated to the CoC tier 2. Because most manufactures want to ensure universally-compliant power adapters, this example will focus on the highest standard, the CoC tier 2.

Table 3. Example TL431LI Based Flyback Converter Standby Power

Specifications	UCC28740	TL431LI	MOSFET	UCC24636 SR	Other Components
Power (mW)	15	40	15	2.2	30
Total Power (mw)	102.2				

Let's take an example of a flyback converter using TL431LI. The systems standby power breakdown is shown in Table 3. This example assumes a system such as the one shown in Figure 1 and Figure 2, where there is a PWM controller, such as the low power UCC28740 and UCC24636, to control the high speed switching. Other power loss components consist of leakage current from passives that are used in the flyback converter. In this example, the TL431LI is biased above 1 mA to allow for the maximum gain and a boost in phase margin for better performance. During standby, the bias current is also larger because during standby the voltage across the TL431LI decreases which increases the current through the optocoupler. In such a system the standby power of the loop cannot meet tier 2 or level VI and there is no margin for leaky passive component power losses.

Table 4. ATL431LI Based Flyback Converter Standby Power

Specifications	UCC28740	ATL431LI	MOSFET	UCC24636 SR	Other Components
Power (mW)	15	4	15	2.2	30
Total Power (mw)	66.2				

In Table 4, the ATL431LI was used to replace the TL431LI and Rs was increased to allow for a lower I_{ka} while keeping the other system devices constant. In Table 3, the standby power for the ATL431LI is 4 mW which is a drastic improvement over the 40 mW used in the TL431LI. Further improvements in standby power can be done by choosing a lower Idd optocoupler with higher current transfer ratio (CTR) or better passive components to allow for a larger margin for leaks. In this example, the ATL431LI-based system can meet both Level VI and CoC tier 2 as shown in the total power row in Table 4.

4 Feedback with ATL431LI Design Considerations

When designing a flyback converter with the ATL431LI, the are external components and devices such as the optocoupler and compensation network will affect the stability and loop gain of the system. In the case of the optocoupler, the CTR and response time of the optocoupler must be changed to improve the frequency response and standby current with the ATL431LI. Another design choise is the stability and bandwidth of the ATL431LI as flyback converters typically require a compensation network to stabilize the shunt regulator. The ATL431LI has changes and improvements in the bandwidth and stability compared to other TL431-like devices that a designer can use for optimization. Due to this, the compensation network might require modification. Compensation network design is beyond the scope of this document, for more information on compensation networks check out SLUA671.

4.1 Optocoupler Considerations for Level VI and European CoC Power Supply Designs

With the ATL431LI's reduced $I_{ka(min)}$ of 80uA it is also important to ensure the optocoupler will have sufficient CTR without sacrificing the optocoupler speed. This typically makes ATL431LI-like devices be biased with an additional current margin for a higher CTR but which increases leakage current. One way to minimize the leakage current is to choose the appropriate optocoupler. One such example of optocoupler selection would be optocouplers with “817” in their part number, which corresponds to pin-to-pin compatible optocouplers. Table 5 shows an example of 817 devices with different CTR ranges denoted by a single letter suffix. In TL431LI designs a '817' optocoupler with the suffix "A" or "B" can be suitable for its I_{KA} but for the lower ATL431LI I_{KA} a 'C' or D' can allow for lower leakage. For Class VI and European CoC power supply designs, one must select an optocoupler with high CTR while satisfying the feedback voltage requirement for the PWM controller in the flyback system. For further details on how to select and properly bias an optocoupler in a flyback system, please refer to this article for more information.

Table 5. Typical '817' Optocoupler Suffix Decoder

Part No. Suffix	CTR Min	CTR Max
A	80%	160%
B	130%	260%
C	200%	400%
D	300%	600%
None	80%	600%

4.2 ATL431LI Bandwidth

The ATL431LI offers lower I_q, greater stability, and still offers a high unity gain bandwidth of 2MHz. The high unity gain bandwidth allows for greater flexibility when designing flyback converter compensation networks to achieve higher efficiency. This is because the typical bandwidth of a flyback converter is kept around 10kHz, which is usually much less than the bandwidth of the ATL431LI. Lower bandwidth shunt regulators can restrict certain designs. This is because optocouplers normally have a low frequency pole due to parasitic capacitance at 2-5kHz, which limits the mid-band gain of the system and cuts off high frequencies. Having a flat and high gain bandwidth from the ATL431LI, as shown in Figure 3, allows designers to achieve higher system cutoff frequencies that allow for a larger mid-band gain. A larger mid-band gain will help the dynamic response of the system and allow higher frequency power supplies.

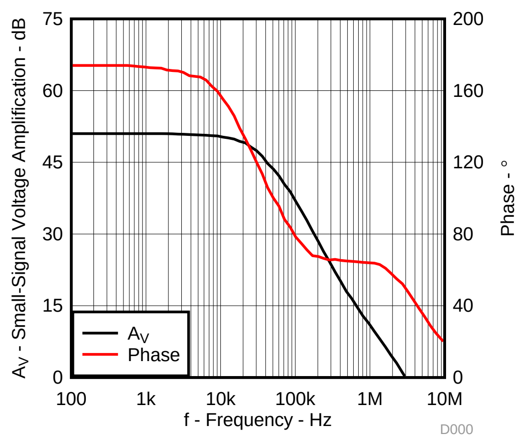

Figure 3. Gain and Bandwidth for ATL431LI

4.3 ATL431LI Stability

In a closed loop configuration such as in Figure 2, the ATL431LI and industry standard TL431 form a feedback loop between its cathode and reference pin. One design challenge is that this feedback loop is susceptible to instability depending on the output load capacitance and sink current. In Figure 4 the region of instability occurs due to the shift of the dominant pole from the addition of an external capacitor load. This is because there are certain bias conditions that the dominant pole changes from being an internal pole to an output pole. In the ATL431LI, the instability region was reduced compared to the TL431 which allows for a greater selection of load capacitor as shown in Figure 5.

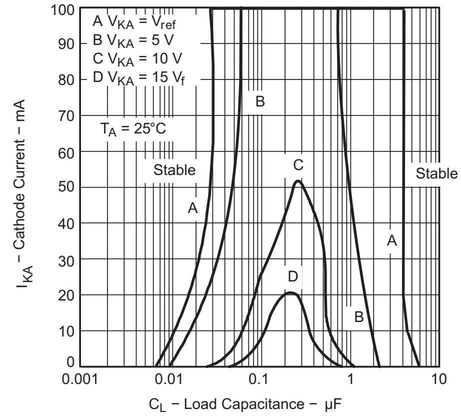

Figure 4. Stability for TL431

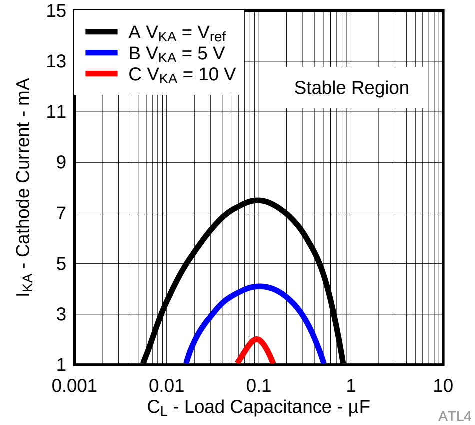

Figure 5. Stability for ATL431LI

5 Conclusion

The ATL431LI is a lower quiescent current device compared to the TL431LI due to the ATL431LI's lower $I_{ka(min)}$ of 80μA. This is a benefit for systems due to the TL431LI having a quiescent current of 1mA, which can be larger than other more expensive components. Systems where the power budget is critical, such as 20V power adapters that need to meet power standards like the DoE Level VI or European CoC, the ATL431LI's $I_{ka(min)}$ of 80uA can offer a substantial power savings. In the simplified example provided by this application note, the ATL431LI is able to lower the Iq of the system by 40 mW. Additionally the ATL431LI has a large bandwidth that makes it versatile for optocoupler compensation network designs. The stability of the ATL431LI was also optimized over the industry standard TL431, which allows for the usage of more common capacitor values at lower bias currents.

6 References

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- MOSFET power losses and how they affect power-supply efficiency SLY664
- Improving Power Supply Efficiency – The Global Perspective http://www.ti.com/download/trng/docs/seminar/Topic1BM.pdf

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