ASTEC

AS431
Application Note 2

Secondary Side Error Amplifier Using the AS431

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I. Introduction

One of the most important safety regulations to which an off-line power supply must conform is input to output electrical isolation. This isolation requirement prevents the power supply control IC from directly sensing both the input line and output voltages. In the case of primary side control the output regulation information, an error voltage, must be transferred from the secondary side. This application note discusses a simple way of transmitting regulation information across the electrical isolation using an AS431 and a conventional 4N27 opto-coupler.

II. Power Supply Circuit

Figure 1 illustrates a simple flyback regulator. The AS3842, a low-cost current mode control IC, is configured to regulate the power supply from the primary side. The AS431 acts as a reference and a feedback error amplifier to sense the output voltage and generate a corresponding error voltage. This error voltage is then converted to an error current and coupled to the primary side through a 4N27 opto-coupler.

III. Opto-Coupler

Recently, opto-coupler manufacturers have made major improvements in opto-coupler processing and packaging technologies, resulting in tighter current transfer ratio (CTR) tolerances and better long-term reliability.

When designing the opto-coupler feedback circuitry, the designer should note the opto-coupler forward diode current. The forward diode current sets the device's CTR and effects the long-term reliability of the device. Similar to a lamp

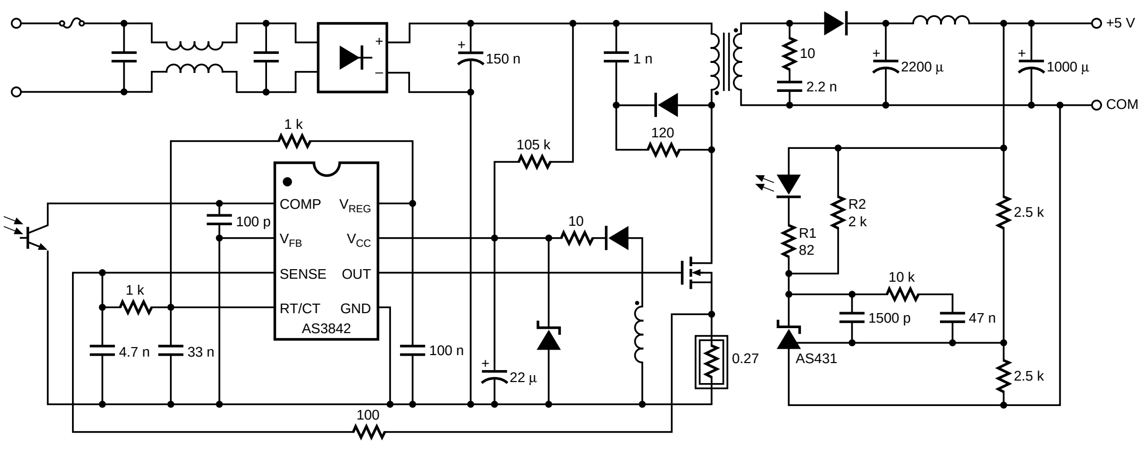


Figure 1. A 40W Flyback Power Regulator

filament, the opto-coupler diode can be worn out or degraded more quickly if it is subjected to higher current. Also, the opto-coupler's unity gain bandwidth increases with forward diode current. The modulation of the gain bandwidth is caused by variations in the transconductance of the output transistor. In addition, the Miller capacitor from the base to collector of the output transistor damps out the effects of the opto-coupler's gain variance. A properly designed opto-coupler circuit not only increases long-term reliability of the regulator but also ensures a superior loop response.

IV. Design Example

Figure 2 shows the amplifier feedback section of the flyback power supply. To keep the 5 V output regulated, the V_{COMP} voltage must track the output voltage. The output voltage is first divided down by two 2.5 kΩ resistors, and its result is fed into an AS431 error amplifier network. The error amplifier output, $V_{CATHODE}$, is then converted to a proportional opto-coupler diode current. The opto-coupler bridges the isolation barrier and generates an output collector current proportional to the input diode current. Since the opto-coupler output is connected to the V_{COMP} pin, the opto-coupler output current is the I_{COMP} source current. In a normal operating condition, a higher output voltage causes $V_{CATHODE}$ to drop and results in a high diode current and I_{COMP} source current and consequently a lower V_{COMP}. A lower V_{COMP} decreases the PWM duty cycle and therefore decreases the regulator output voltage. The result is a regulated output. A determination of the opto-coupler diode operating current and small signal loop gain follows.

IVa. Opto-Coupler Operating Current

This design example shows the diode operating current as determined by the maximum I_{COMP} source current. In order for V_{COMP} to decrease linearly with increasing I_{COMP} source current, I_{COMP} has to operate in a linear region slightly above the maximum I_{COMP} source current. The

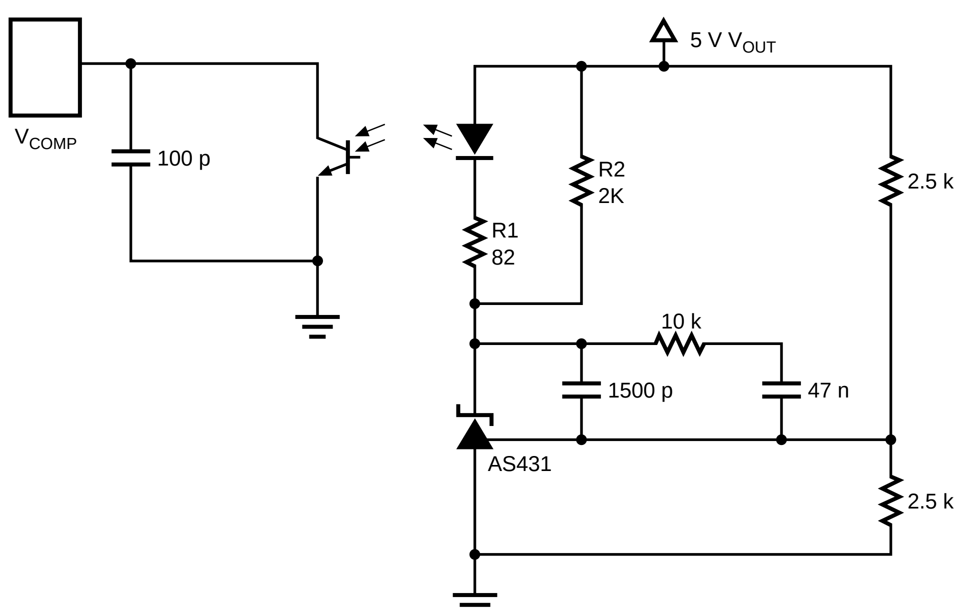


Figure 2.

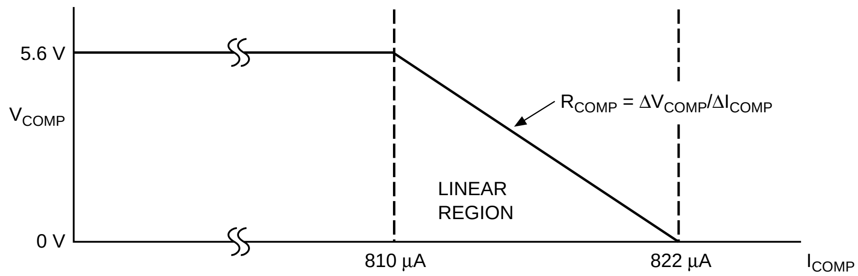
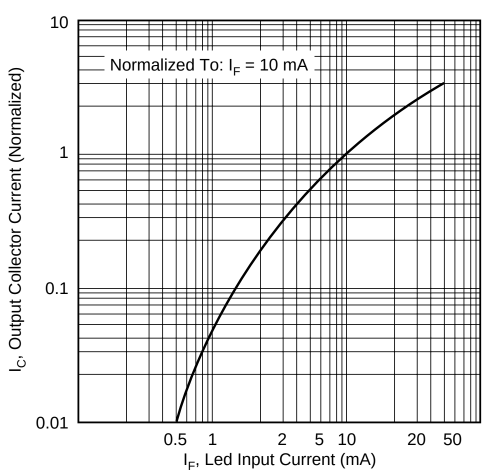


Figure 3. V_{COMP} vs I_{COMP}

linear region is depicted in Figure 3.

Since the I_{COMP} source current is equal to the opto-coupler output current, the opto-coupler output current also modulates in the same I_{COMP} linear region. With a known opto-coupler output current, the input diode current, I_{DIODE}, can then be obtained from the output current versus diode current curve on the opto-coupler data sheet. Figure 4 illustrates the output current versus diode current curve of the 4N27 opto-coupler.



The 4N27 data sheet guarantees a minimum of 0.1 CTR at 10 mA diode current.

The typical AS3842 maximum I_{COMP} source current is 800 µA. Using Figure 4, and assuming 0.1 CTR at 10 mA diode current, the forward diode current required to generate 800 µA of opto-coupler current is 8 mA.

IVb. AC Gain Analysis

Once the opto-coupler diode current is determined, the current limiting resistor R1 of Figure 2 can then be chosen to guarantee good output regulations and proper dynamic loop response. The AS431 cathode voltage, $V_{CATHODE}$, is a function of the diode operating current, I_{DIODE}, and the value of R1. Also, $V_{CATHODE}$ must be greater than 2.5 V for proper operation.

$$\begin{aligned} V_K &= V_O - V_D - (I_D \cdot R1) > 2.5\ V \quad (1) \\ &= 5.0\ V - 1.2\ V - (8\ mA \cdot R1) > 2.5\ V \\ &= 3.8 - (8\ mA \cdot R1) > 2.5\ V \\ R1 &< 162\ \Omega \\ &= 82\ \Omega\ (chosen) \\ V_K &= 3.14\ V \end{aligned}$$

R1 also plays a significant role in controlling the open loop gain of the power supply. The following equations derive the small signal AC gain from $V_{CATHODE}$ to V_{COMP}.

$$\begin{aligned} I_{COMP} &= I_D \cdot CTR \quad (2) \\ &= \frac{(V_O - V_K)}{R1} \cdot CTR \end{aligned}$$

$$\frac{\Delta I_{COMP}}{\Delta V_K} = -\frac{CTR}{R1} \quad (3)$$

At the steady state condition, V_{COMP} is in the linear region,

$$\frac{\Delta V_{COMP}}{\Delta V_K} = \frac{\Delta I_{COMP}}{\Delta V_K} \cdot \frac{\Delta V_{COMP}}{\Delta I_{COMP}} = \frac{CTR}{R1} \cdot R_{COMP} \qquad (4)$$

From figure 3:

$$R_{COMP} = \frac{\Delta V_{COMP}}{\Delta I_{COMP}} = \frac{5.6\ V}{(822 - 810)\ \mu A} = 509\ k\Omega$$

Applying equation (4):

$$\frac{\Delta V_{COMP}}{\Delta V_K} = \frac{0.1}{82\ \Omega} \cdot (509\ k\Omega) = 620 = 55.9\ dB$$

IVc. Other Considerations

R2, a 2 kΩ resistor in parallel with the opto-coupler diode and R1, provides the minimum cathode current required to keep the AS431 operating when a minimum opto-coupler diode current is required. In addition, a small filter capacitor is placed close to the V_{COMP} pin of the control IC to attenuate high frequency switching noise being picked up by the metal trace from the opto-coupler to the control IC. Since the location of the pole in the opto-coupler small signal response varies significantly with the dc operating point of the opto-coupler, a resistor can be added from the V_{REG} to V_{COMP} pin to supply additional bias current to stabilize the loop.

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