Shunt Reference Considerations for Flyback Converters with Optocoupler Feedback

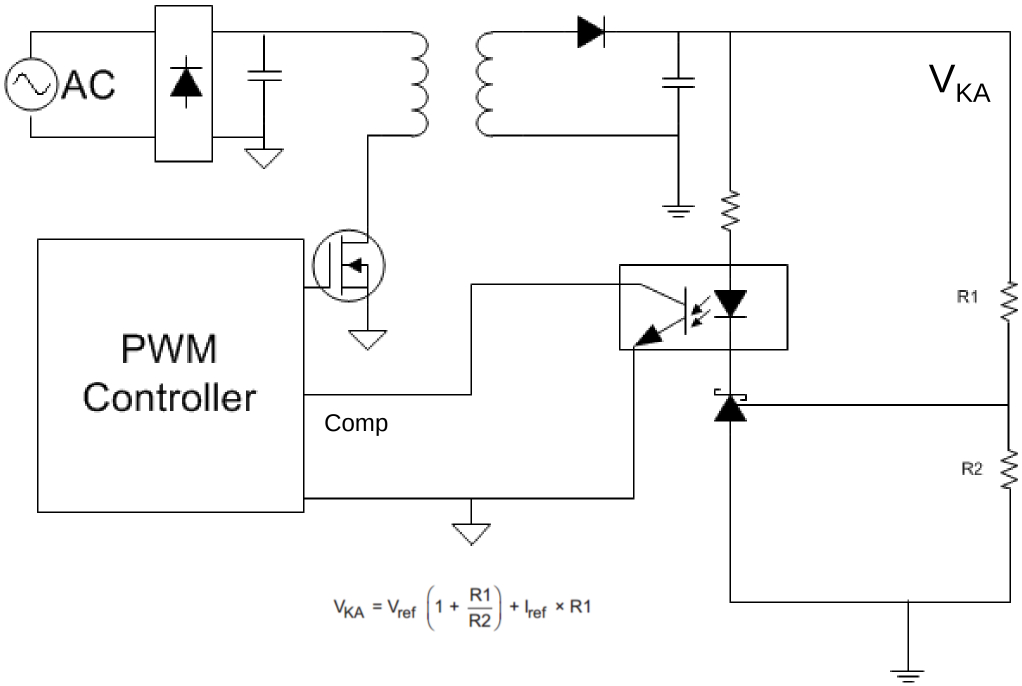
A Voltage Reference Deep Dive

Texas Instruments

Agenda

- Why do I need a shunt voltage reference in flyback systems with optocoupler feedback?
- Feedback process example
- Importance of lower I_{ref} and I_{ref} delta
- Importance of lower $I_{I(dev)}$ and $I_{I(dev)}$ delta
- Total system accuracy calculations
- Stand by power (Class VI) standards

AC/DC Flyback systems with optocoupler feedback



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

- Secondary side regulation
- Drives optocoupler as a current controller
- Senses output voltage and feeds information back via optocoupler

Feedback process

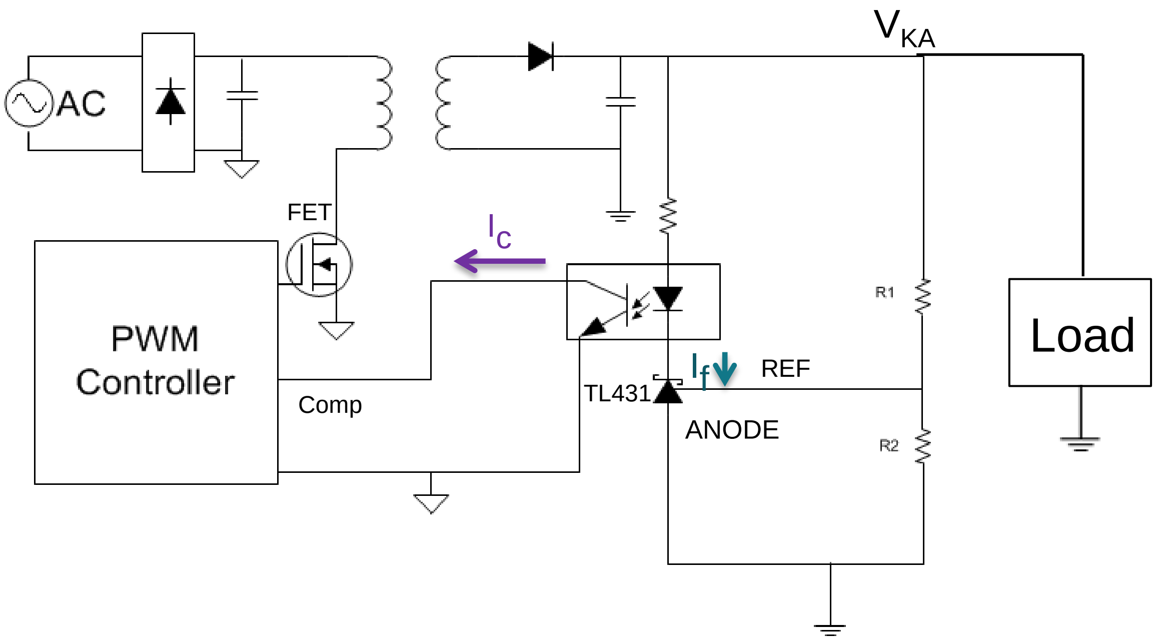


Figure 1: AC/DC Flyback system with optocoupler feedback

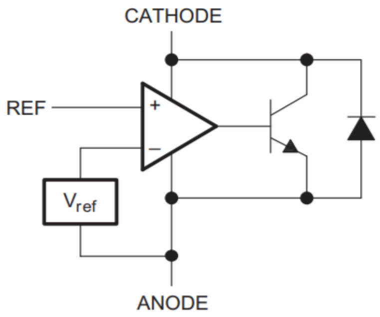


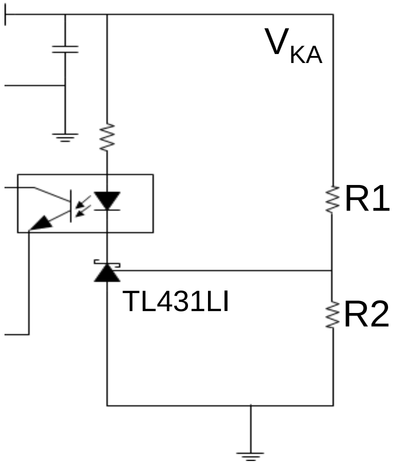
Figure 2: TL431 internal circuit

Notes:

- V_{KA} can fluctuate
- R1 and R2 have high resistance (10KΩ or higher)

Output voltage (V_{ka}) error due to discrete resistor choices

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



For V_{ka} = 5V and R1 = 10KΩ:

- R2 = 10.1KΩ for Iref = 4uA
- R2 = 10.01KΩ for Iref = 0.4uA

Part	I_{ref} Max
TL431	4uA
TL431LI	0.4uA

Standard Resistor Values: 9.1KΩ, 10KΩ, 11KΩ

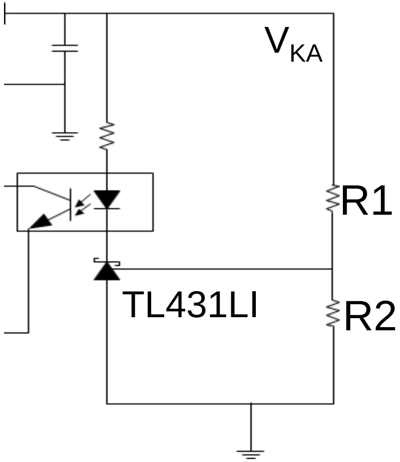
Error in $V_{ka} = I_{ref} * R1$

TL431 Error = I_{ref} * R1 = 4uA * 10KΩ = 40mV (0.8% of a 5V system)

TL431LI Error = I_{ref} * R1 = 0.4uA * 10KΩ = 4mV (0.08% of a 5V system)

Importance of lower I_{ref} delta

Error $V_{ka} = I_{ref} * R1$



For R1 = 10KΩ, Error V_{ka} is calculated as:

- **Industry standard TL431: Part-to-part variation (ΔI_{ref}) is 2uA**

				Typ	Max	
I_{ref}	Reference input current	See Figure 21	I_{KA} = 10 mA, R1 = 10 kΩ, R2 = ∞	2	4	μA

TL431 ΔI_{ref} = 4uA – 2uA = 2uA

Error V_{ka} = ΔI_{ref} * R1 = 2uA * 10KΩ = 20mV

- **TL431LI: Part-to-part variation (ΔI_{ref}) is only 0.2uA**

				Typ	Max	
I_{ref}	Reference Input Current	See Figure 15	I_{KA} = 1 mA, R1 = 10kΩ, R2 = ∞	0.2	0.4	μA

TL431LI, ΔI_{ref} = 0.4uA – 0.2uA = 0.2uA

Error V_{ka} = ΔI_{ref} * R1 = 0.2uA * 10KΩ = 2mV

Initial accuracy improvement with lower $I_{(Idev)}$

Error $V_{ka} = I_{ref} * R1$

$I_{I(dev)}$ is I_{ref} over full operating temperature (-40°C to 125°C)

Industry standard TL431:

$I_{I(dev)}$ Error $V_{ka} = I_{I(dev)} * R1 = 1.2uA * 10K\Omega = 12mV$ (0.24% of a 5V system)

$\Delta I_{I(dev)}$ $\Delta I_{I(dev)} = 1.2uA - 0.4uA = 0.8uA$
Error $V_{ka} = \Delta I_{I(dev)} * R1 = 0.8uA * 10K\Omega = 8mV$

				Typ	Max	
$I_{I(dev)}$	Deviation of reference input current over full temperature range (1)	See Figure 21	I_{KA} = 10 mA, R1 = 10 kΩ, R2 = ∞	0.4	1.2	μA

TL431LI:

$I_{I(dev)}$ Error $V_{ka} = I_{I(dev)} * R1 = 0.3uA * 10K\Omega = 3mV$ (0.06% of a 5V system)

$\Delta I_{I(dev)}$ $\Delta I_{I(dev)} = 0.3uA - 0.1uA = 0.2uA$
Error $V_{ka} = \Delta I_{I(dev)} * R1 = 0.2uA * 10K\Omega = 2mV$

				Typ	Max	
$I_{I(dev)}$	Deviation of reference input current over full temperature range (1)	See Figure 15	I_{KA} = 1 mA, R1 = 10kΩ, R2 = ∞	0.1	0.3	μA

Cost savings

Error $V_{ka} = (I_{ref} + I_{I(dev)}) * R1$

Let R1 = 10KΩ

$I_{ref} = I_{ref} \pm I_{I(dev)}$ over full operating temperature

Part	Resistor Accuracy	Error V_{ka}
TL431	10%	= 5.2uA * 11KΩ = 57.2 mV
	1%	= 5.2uA * 10.1KΩ = 52.5 mV
TL431LI	10%	= 0.7uA * 11KΩ = 7.7 mV
	1%	= 0.7uA * 10.1KΩ = 7.07mV

	TL431	TL431LI
Iref (μA)	4	**0.4**
II(dev) (μA)	1.2	**0.3**
Max Iref (μA)	5.2	**0.7**

Resistors cost saving with 10% resistors			
Volume	**1% SMD resistor price**	**10% SMD resistor price**	**Total cost saved per system (Two resistors)**
10,000	$0.004	$0.002	$0.004

Save on resistors!

Efficiency standards for under 50W power supplies

- Stricter requirements for no-load power consumption
- Adopted by Europe, China, Canada, and US
- US enforces Class VI standard

	Class IV	Class V	Class VI
No load power requirement	500mW	300mW	75mW

Class VI power supply design considerations

System requirements with no load condition:

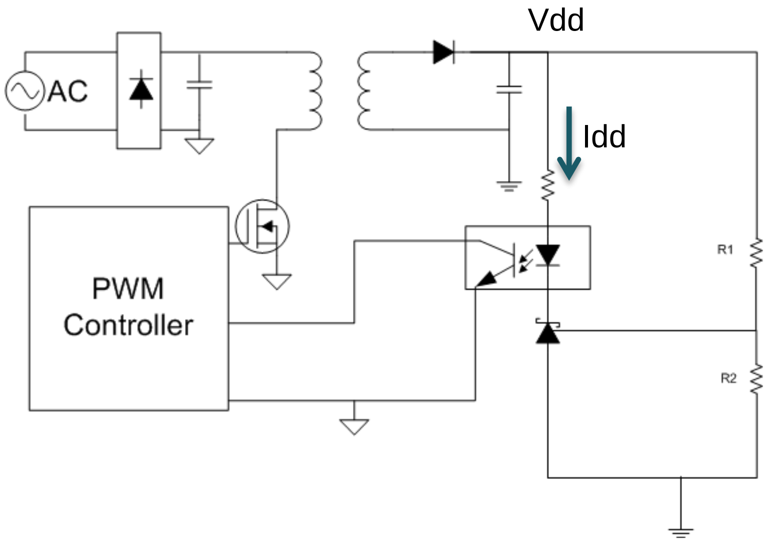
European COC	75mW	Adapter power <49W

Power consumed by TL431 branch = Vdd * Idd

Ex.
TL431: Vdd = 20V, Idd = 2mA given practical design using the **TL431** and a regular optocoupler

ATL431LI: Vdd = 20V, Idd = 200uA given practical design using the **ATL431LI** and an advanced optocoupler

230V AC input	TL431LI	*Components	ATL431LI	*Components
Power (mW)	40	40	4	40
Total (mW)	80		44	



***Components consist of: MOSFETs, controllers, etc**

Thanks for Watching

- Please visit ti.com/vref