Technical Article

How to simplify AC/DC flyback design with a self-biased converter

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The demand for smaller, lighter, and more efficient AC/DC USB power delivery (PD) chargers is always a challenge for power-supply design engineers. Below 100W, the quasi-resonant flyback is still the dominating topology, and gallium nitride (GaN) technology can push the power density and efficiency further.

However, providing bias power for the primary controller requires an auxiliary winding on the transformer as well as rectifying and filtering circuitry. To make things worse, the USB PD charger output voltage has a wide range. For example, the USB PD standard power range covers output voltages from 5V to 20V, and the latest USB PD extended power range allows the output voltage to go as high as 48V.

Since the auxiliary voltage is proportional to the output voltage, the bias voltage range on the primary controller will increase, requiring extra circuitry and degrading efficiency. In this power tip, I'll introduce a self-biased flyback converter solution to address these design challenges.

Dealing with wide bias voltages

Figure 1, Figure 2, Figure 3, and Figure 4 show four different ways to deal with the wide bias voltage range in USB PD charger applications. Conventional methods include using a linear regulator, a tapped auxiliary winding, or even adding an extra DC/DC switching converter to regulate the bias voltage. All of these methods will increase component count, add cost, or increase power losses. Alternatively, self-biasing totally removes external components and increases efficiency.

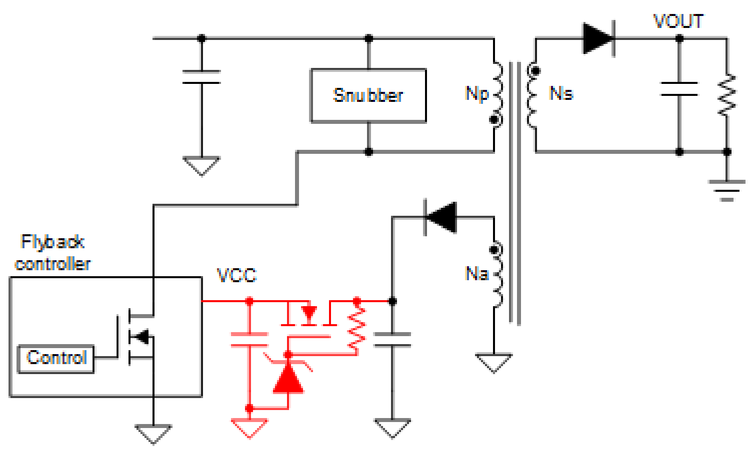

Figure 1. Bias circuits for applications with wide output voltage ranges using a discrete linear regulator. Source: Texas Instruments

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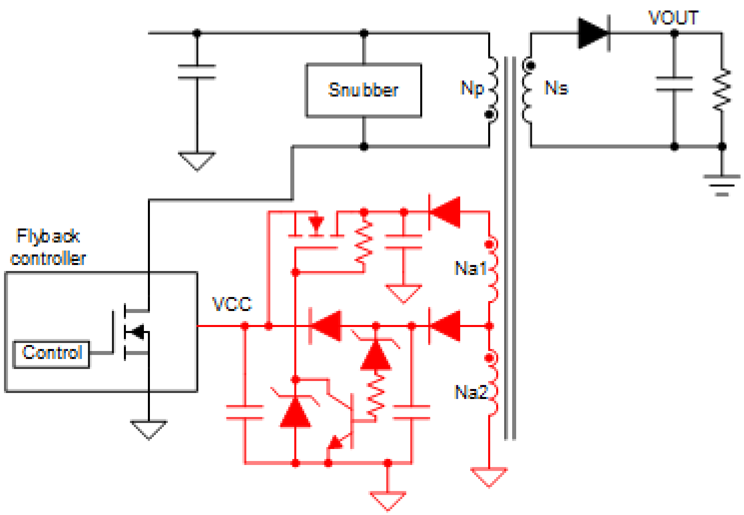

Figure 2. Bias circuits for applications with wide output voltage ranges using a tapped auxiliary winding. Source: Texas Instruments

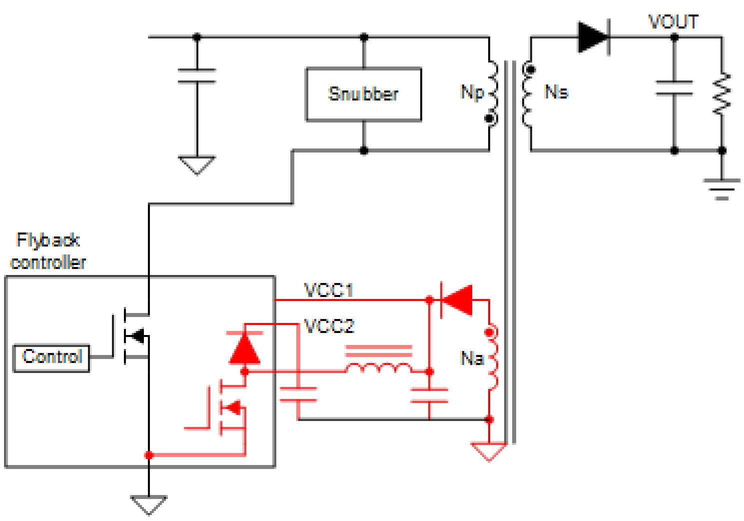

Figure 3. Bias circuits for applications with wide output voltage ranges using boost converter. Source: Texas Instruments

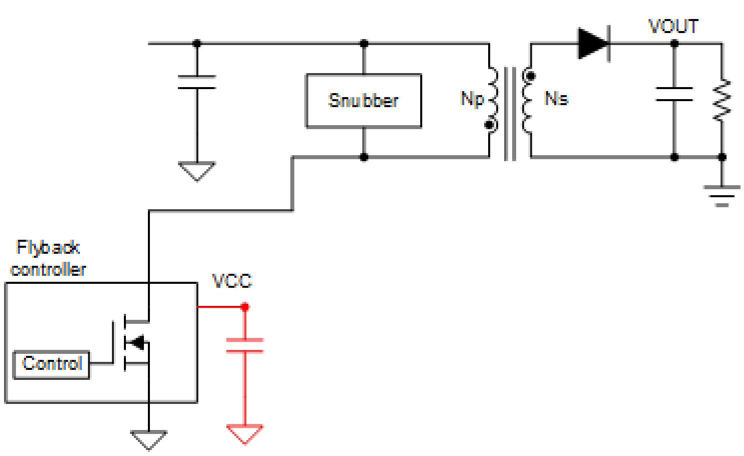

Figure 4. Bias circuits for applications with wide output voltage ranges using a self-biased VCC. Source: Texas Instruments

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VCC self-biasing

The flyback controller can always get bias power directly from the rectified AC input voltage, but this results in excessive power losses. The key to self-biasing is to harvest energy from the power stage, which can come from two sources. One is the switch-node capacitor stored energy; the other is energy stored in the primary-side winding of the transformer. As shown in Figure 5, an integrated self-biasing circuit can ideally do both, based on the input and output conditions.

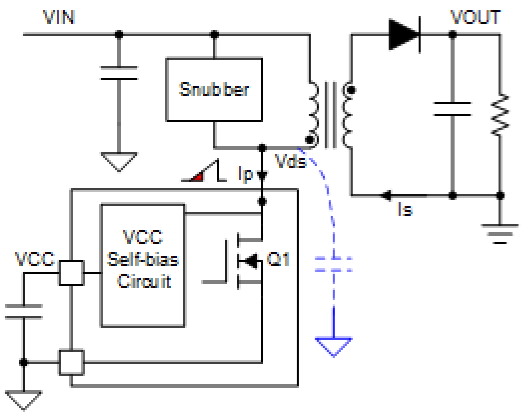

Figure 5. The self-bias circuit harvests energy from the switch-node capacitance or magnetizing inductance. Source: Texas Instruments

Figure 6 shows the energy harvesting from the switch-node capacitor. This can save efficiency as it recycles the energy storage in switching node capacitor in every switching cycle. In cases such as AC low-line input when the reflected output voltage is identical to the input voltage, natural zero voltage switching will occur, and there is no energy in the switch-node capacitor, inductor energy harvesting will take effect, where a small portion of the primary switching current is directed to the VCC cap through an internal path.

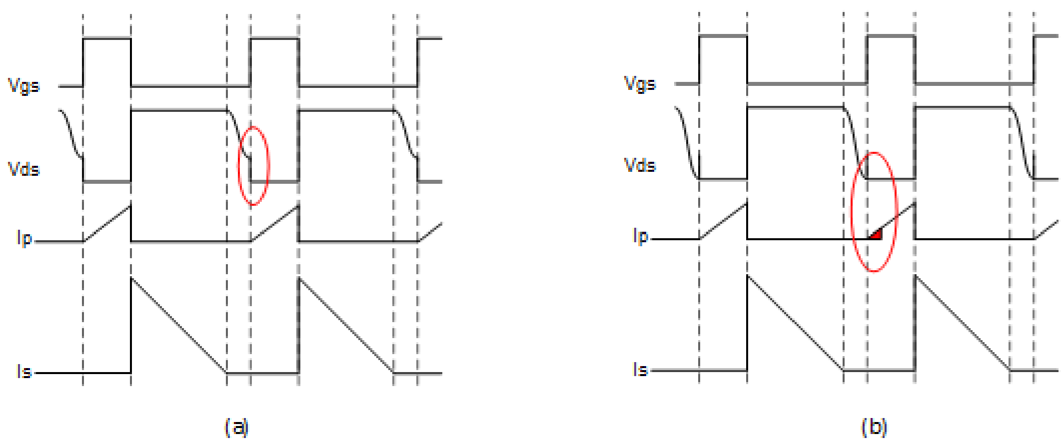

Figure 6. VCC self-bias operation: (a) capacitor energy harvesting on the switching node and (b) inductor energy harvesting through the primary current. Source: Texas Instruments

Achieving auxless sensing

Many flyback controllers use the auxiliary winding to sense the input and output voltages and detect conditions such as output overvoltage or input undervoltage. With self-biased flyback converters, it is possible to use the switching-node voltage for input and output voltage sensing. As shown in Figure 7, the sensed voltage is the sum of the input and reflected output voltage. Since the average voltage across the primary winding is zero, the average of the switch-node voltage is equal to the input voltage.

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For output voltage sensing, it can sample the reflected output voltage, and the controller needs to be informed of the exact turns ratio of the transformer with the use of a resistor-programmable pin [the TR pin in the Texas Instruments (TI) UCG28826].

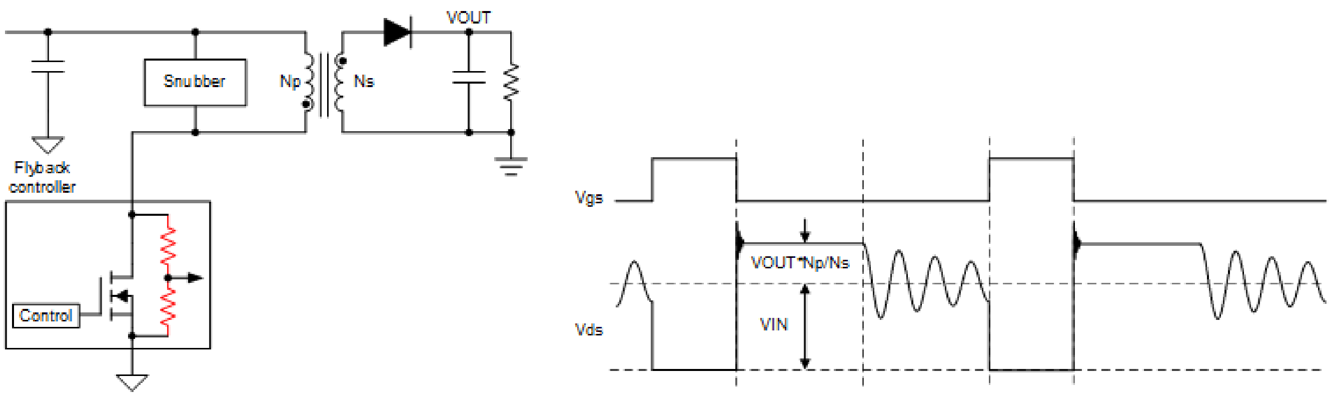

Figure 7. Auxless voltage sensing where the sensed voltage is the sum of the input and reflected output voltage. Source: Texas Instruments

Once properly configured, self-biased devices such as the UCG28826 can accurately provide various protections like overpower and overvoltage protection. Figure 8 shows the UCG28826 in a USB PD application.

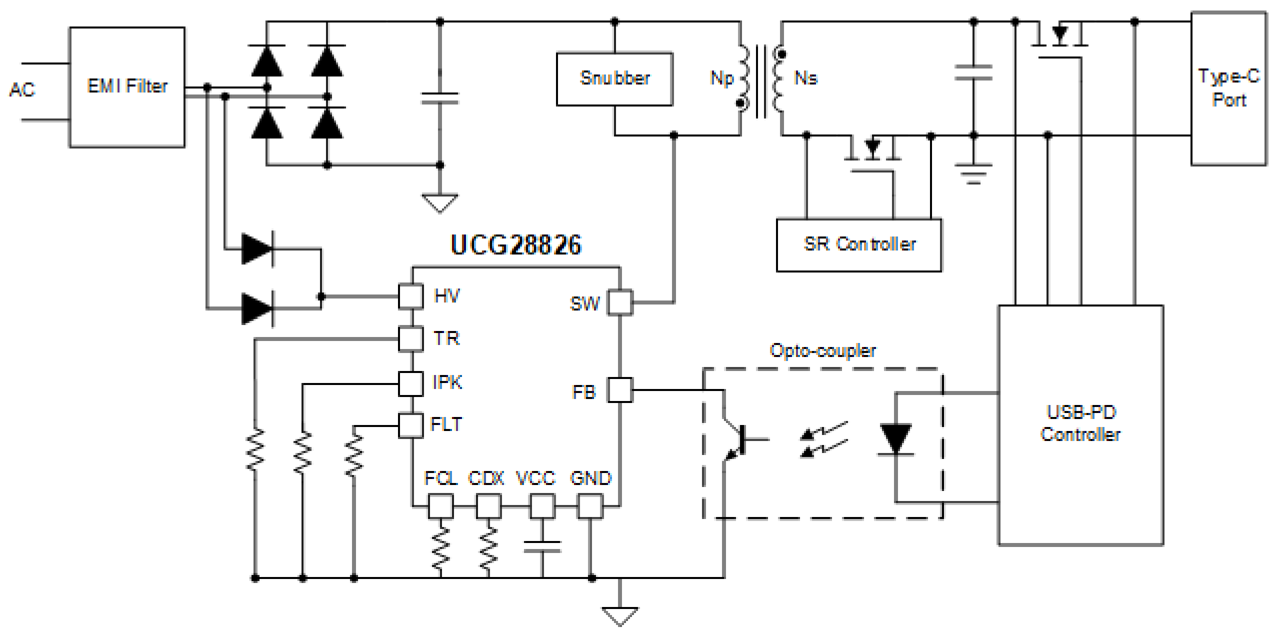

Figure 8. A self-biased USB PD design using the UCG28826 that can accurately provide various protections like overpower and overvoltage protection. Source: Texas Instruments

Figure 9 shows the overvoltage protection waveforms after intentionally disconnecting the feedback pin which is a single fault condition. The controller senses the output voltage and triggers overvoltage protection accordingly when the output ramps up to around 24.4V for a nominal 20V output.

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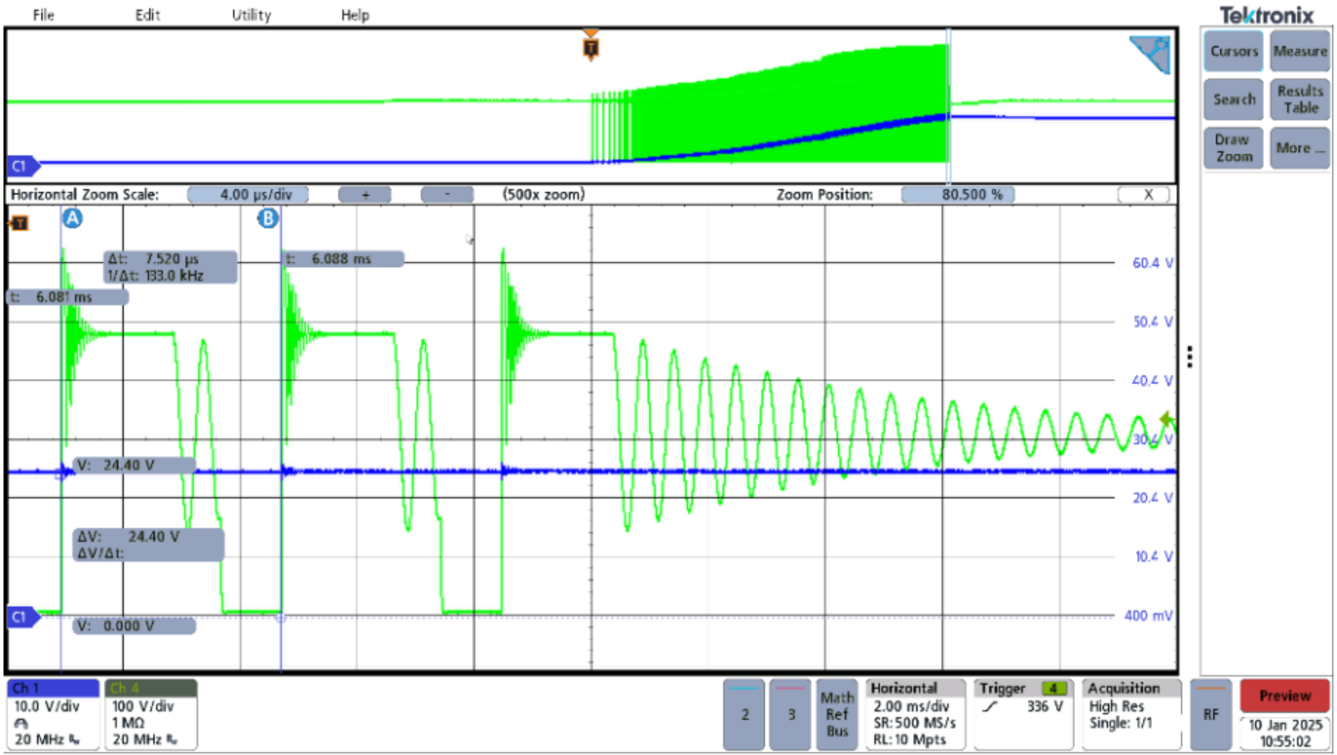

Figure 9. Auxless sensing example for overvoltage protection. Channel 1 (CH1) is Vout and channel 2 (CH2) is Vsw. Source: Texas Instruments

Prototype and test result

Figure 10 shows the TI universal AC-input 65W dual USB type-C port USB PD charger reference design with an integrated GaN power switch. Due to the simplified self-bias feature and integrated GaN switch in the UCG28826, the reference design achieves a power density of 2.3 W/cm^3 and 93.2% efficiency for the AC/DC stage. The auxless design also simplifies transformer manufacturing and reduces costs. Table 1 summarizes the design parameters of 65W design for reference.

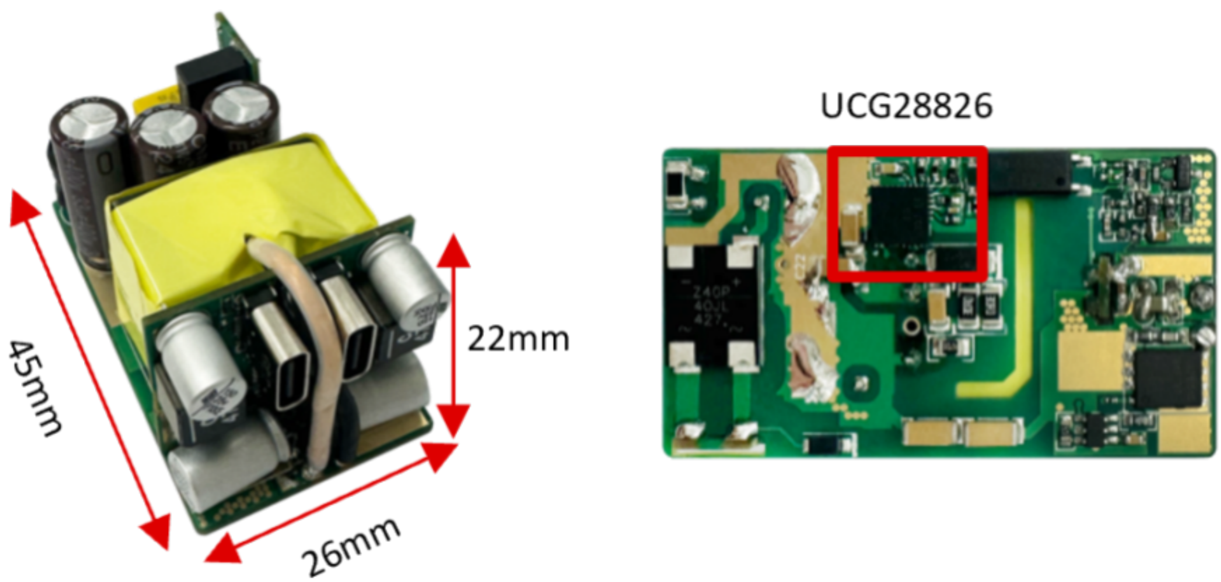

Figure 10. A universal AC-input 65W reference design board. Source: Texas Instruments

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Table 1. Universal AC-input 65W reference design parameters.

Parameter	Value
AC input voltage	90-264V_{AC}
Output voltage and current	5-20V, 3.25A maximum
Transformer	ATQ23-14
Turns ratio	7-to-1
Transformer inductance	200µH
Switching frequency (full load)	90-140kHz
Efficiency	93.2% at 90V_{AC} (AC/DC stage only)
Power density	2.3W/cm^3

Simplified USB PD charger

A high-level integration with a controller and GaN switch can simplify USB PD charger design, but the bias circuitry for the controller and associated auxiliary winding on the transformer are still there, degrading efficiency and affecting size and cost.

An integrated self-biasing circuit can eliminate that portion of the circuit and increase the power density for power supplies with wide-range outputs. Additionally, it is still possible to achieve proper input and output voltage sensing in the absence of an auxiliary winding on the transformer.

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