Application Note

Design a Fixed Output Voltage Flyback with the UCG2882x Family of Devices

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ABSTRACT

UCG2882x is a high-frequency, quasi-resonant flyback converter with built-in 750V GaN high electron mobility transistor (HEMT) for AC to DC power conversion. UCG2882x is best suited for high power density applications such as cell phone fast chargers and notebook adapters. The key feature of this device is the self-bias and auxless sensing scheme which eliminates the need of the auxiliary winding and simplifies the USB-PD adapter design with higher efficiency. The device can also be used for fixed output voltage applications. In this application note, the design steps for the fixed output voltage Flyback using UCG2882x family is discussed.

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1 Introduction

UCG2882x is a high-frequency, quasi-resonant flyback converter with integrated GaN HEMT. With the advanced technologies like self-biasing and auxless sensing, UCG2882x greatly simplifies the USB-PD adapter design, achieving high efficiency, how power density and low standby power.

UCG2882x integrates all the essential functions for UBS-PD adapter design, minimizes the external component count. However, because the device features are designed targeting for USB-PD, when used for non-USB-PD applications, some design tricks are needed to make the design work.

2 UBS-PD versus Non-USB-PD

USB Power Delivery (USB-PD) is a charging protocol that allows USB port to deliver more power to the load, provide faster charging speed and powering up more end equipment. USB-PD allows USB-C® port to vary the output voltage other than 5V. With higher voltage, higher power can be delivered.

Table 2-1 shows the evolution of USB-PD standards. With the USB-PD 3.1/3.2, output voltage is supported up to 48V and output current is supported up to 5A. With up to 240W power handling capability, a USB-C port can charge a load much faster.

Table 2-1. USB-PD Standard Evolution

Specification	Maximum Voltage	Maximum Current	Maximum Power
USB BC 1.2	5V	1.5A	7.5W
USB Type-C® 1.2	5V	3A	15W
USB PD3.0	20V	5A	100W
USB PD 3.1 and USB PD 3.2	48V	5A	240W

The USB-PD operates based on the load requirement. When the equipment such as a phone is plugged into a power adapter USB-C port, a negotiation process happens. The power adapter (source) and the phone (sink) negotiate the voltage and current level that source can provide and the sink can take. Then, the source modifies the USB-C port output voltage to the corresponding level. And, then the charge happens. Through this process, the output voltage of the USB-C port can vary between 5V to the maximum voltage. According to Figure 2-1, for a 65W USB-PD adapter, the maximum voltage supported is 20V.

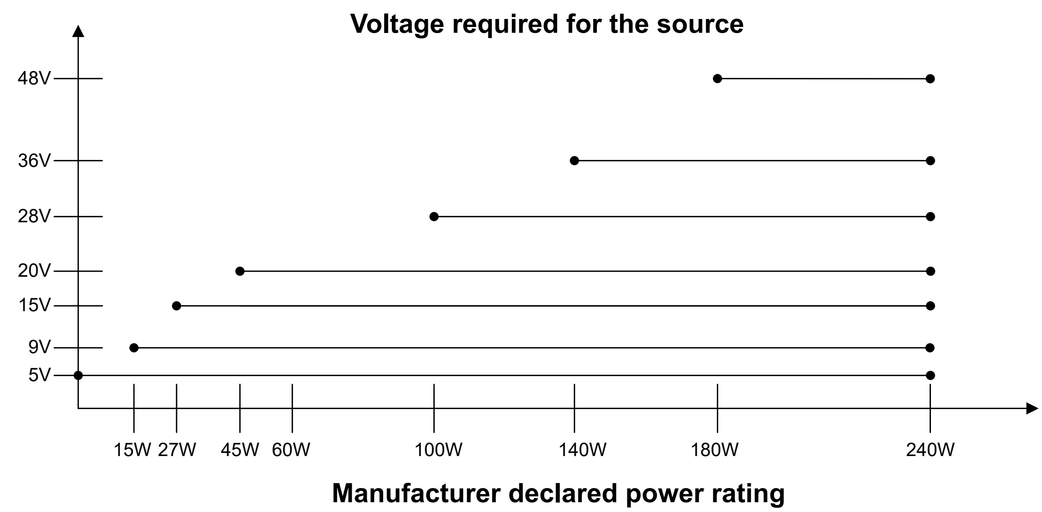

Figure 2-1. USB-C Port Voltage and Power Rating

When designed for USB-PD application, UCG2882x receives a feedback signal through an optocoupler. The feedback signal is generated by the secondary side USB-PD controller, which controls the output voltage level. As shown in Figure 2-2, the USB-PD controller connected with USB-C port generates the feedback signal through the integrated control loop.

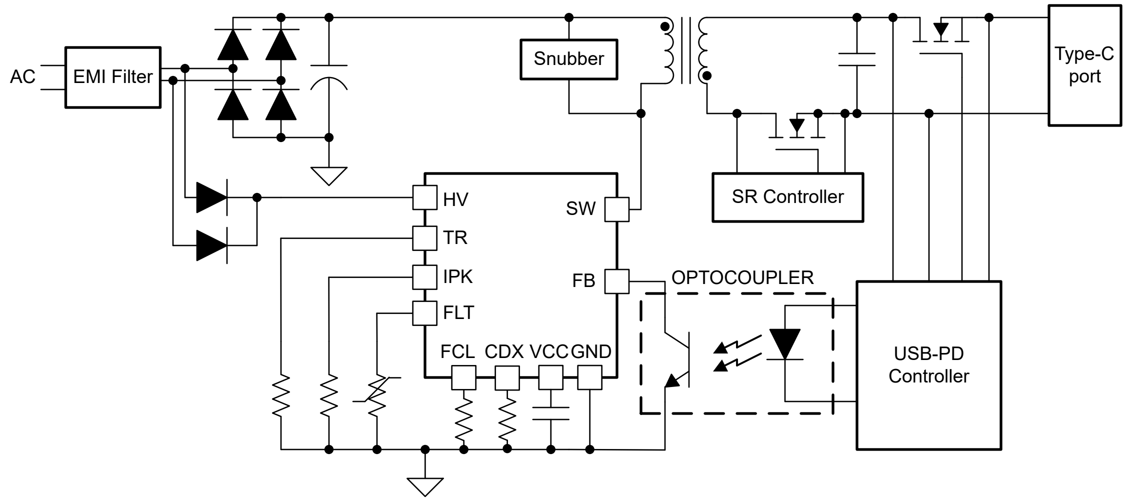

Figure 2-2. Simplified Circuit for USB-PD Implementation

When designed with non-USB-PD applications, the output voltage is fixed. A TL431 is often used to close the output voltage regulation loop. The TL431 generates the feedback signal and transfers the signal back to UCG2882x through an optocoupler. This implementation is illustrated in Figure 2-3.

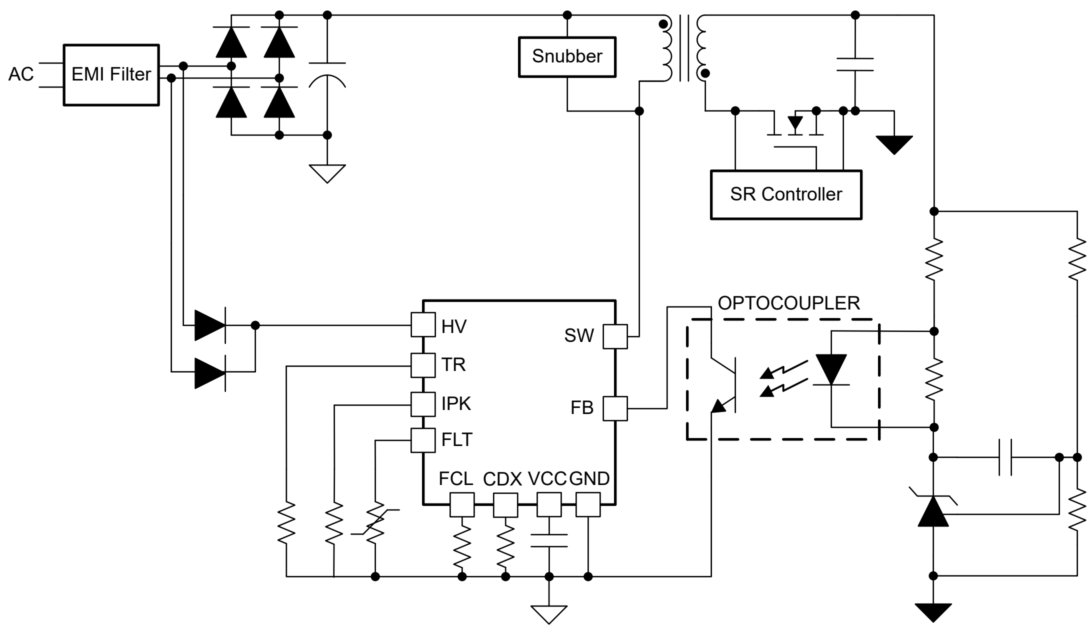

Figure 2-3. Non-USB-PD Flyback Implementation

3 Auxless Sensing Technology

Traditionally, the Flyback converter uses an auxiliary winding on the Flyback transformer to provide the controller's biasing voltage. Due to the variable output voltage, the controller's biasing voltage changes together with the output voltage. The large voltage range on the biasing causes higher power loss and requires more external components to regulate the biasing voltage. UCG2882x uses self-biasing technology, directly harvesting energy from the power stage, solving the design challenge associated with the variable output voltage for USB-PD.

Additionally, UCG2882x eliminates the transformer auxiliary winding through auxless sensing technology. As illustrated in Figure 3-1, with integrated voltage divider, the switch node voltage is sensed. Through signal post precessing, the input voltage and the reflected output voltage can be derived from the sensed switch node voltage.

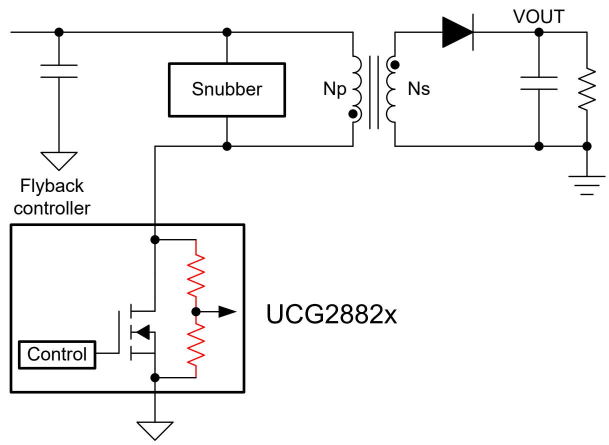

Figure 3-1. Auxless Sensing Technology

Because the output voltage regulation is achieved through the feedback loop on the secondary side, the output voltage sensed on the primary side is only needed for protection purposes. When sensed on the primary side, the auxless sensing technology only detects the reflected output voltage through the transformer, instead of the absolute value of the output voltage. Therefore, the transformer primary side to secondary side turns ratio is needed to calculate the absolute value of the output voltage.

In UCG2882x, the transformer turns ratio is set through a programming pin TR. The TR pin setting is summarized in Table 3-1. When design for USB-PD application, with universal AC input (85V to 264V), the transformer turns ratio is normally within this range and designer can select the corresponding setting to match the transformer turns ratio. With the turns ratio setting, the output over voltage protection threshold is set at 25V, which is appropriate for the 20V output in USB-PD applications.

Table 3-1. Turns Ratio Setting Resistor Values

TR Pin Resistor (kΩ)	Turns Ratio
0	7.875
5.23	6
6.34	6.125
7.68	6.25
9.31	6.375
11.3	6.5
13.7	6.625
16.9	6.75
20.5	6.875
25.5	7
31.6	7.125
39.2	7.25

Table 3-1. Turns Ratio Setting Resistor Values (continued)

TR Pin Resistor (kΩ)	Turns Ratio
51.1	7.375
66.5	7.5
84.5	7.625
113	7.75
174	7.875

However, for a non-USB-PD application, or when the output voltage is not 20V, the transformer turns ratio can be outside of this range, Sometimes, even when the turns ratio can be setup to match the design, the 25V OVP can be inappropriate, some setting changes are required.

As discussed earlier, UCG2882x senses the reflected output voltage, together with the programmed transformer turns ratio, the output voltage OVP can be set to 25V. Instead of calculating the output voltage by dividing the reflected voltage by transformer turns ratio, UCG2882x uses the TR pin setting to change the primary side OVP threshold, so equivalently achieves the same output OVP level with different turns ratios settings. Follow that principle, a third column is added, Table 3-1 turns into Table 3-2, which is the same as Table 7-1 in UCG2882x data sheet. The TR pin is really an output OVP setting pin. Instead of setting the absolute value for the output OVP level, the TR pin sets the output OVP level based on the reflected output voltage.

Table 3-2. TR Pin Resistor Settings for Output OVP

TR Pin Resistor (kΩ)	Turns Ratio	V_{OUT} OVP Threshold (V, Reflected to Primary)
0	7.875	196.9
5.23	6	150
6.34	6.125	153.1
7.68	6.25	156.2
9.31	6.375	159.4
11.3	6.5	162.5
13.7	6.625	165.6
16.9	6.75	168.7
20.5	6.875	171.9
25.5	7	175
31.6	7.125	178.1
39.2	7.25	181.2
51.1	7.375	184.4
66.5	7.5	187.5
84.5	7.625	190.6
113	7.75	193.7
174	7.875	196.9

The principle of primary side OVP using auxless sensing is illustrated in Figure 3-2.

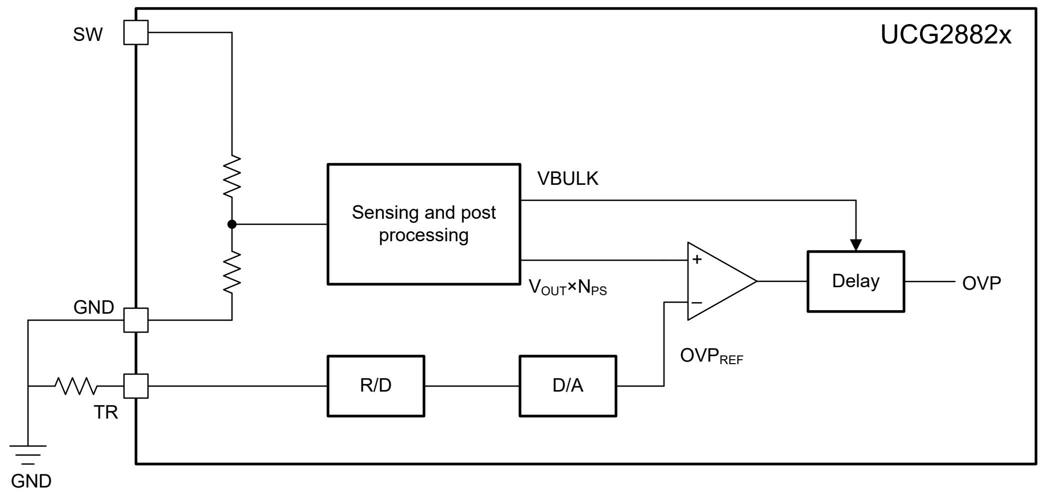

Figure 3-2. Functional Block for OVP

4 Design Examples

When designing for non-USB-PD applications, or in case the output voltage is not 20V, the TR pin needs to be programmed differently than the default 20V output, and to set the appropriate output OVP level.

A universal input, a 12V output design and a 24V output design are used to demonstrate the design process. The transformer is firstly designed to optimize the power stage performance. The RT pin then can be programmed according to the transformer design.

For a universal input, 12V output design, the transformer turns ratio is normally around 10:1, which reflects 120V to the primary side when the output voltage is regulated at 12V. This provides enough margin for the integrated GaN HEMT voltage stress. Additionally, 10:1 turns ratio is outside of the transformer turns ratio setting in the data sheet.

For the 12V output, the desired OVP level is normally 20% above the regulation level. Therefore, the output OVP is calculated as

$$V_{OVP} = 12\text{V} \times 1.2 = 14.4\text{V} \tag{1}$$

With 14.4V OVP level, the output voltage reflecting to the primary side becomes

$$V_{reflect} = V_{OVP} \times N_{PS} = 14.4V \times 10 = 144V \tag{2}$$

According to Table 3-2, 3rd column, the TR pin setting is 5.23kΩ, which gives OVP setting at 150V reflected output voltage. The real OVP accomplished can be calculated as

$$V_{OVP} = \frac{V_{reflect}}{N_{PS}} = \frac{150V}{10} = 15V \tag{3}$$

From this example, when TR pin is set to 5.23kΩ. According to Table 3-1, the turns ratio setting is 6 instead of the real turns ratio of 10.

For a universal input, 24V output design, the transformer turns ratio is normally around 5.5:1, which reflects 132V to the primary side. The 5.5:1 turns ratio is also outside of the transformer turns ratio setting in the data sheet.

For the 24V output, we can set the OVP at 30% above the regulation level. Therefore, the output OVP is calculated as

$$V_{OVP} = 24\text{V} \times 1.3 = 31.2\text{V} \tag{4}$$

With 31.2V OVP level, the output voltage reflecting to the primary side becomes

$$V_{reflect} = V_{OVP} \times N_{PS} = 31.2V \times 5.5 = 171.6V \tag{5}$$

According to Table 3-2, 3rd column, the TR pin setting is 20.5kΩ, which gives OVP setting at 171.9V reflected output voltage. The real OVP accomplished can be calculated as

$$V_{OVP} = \frac{V_{reflect}}{N_{PS}} = \frac{171.9V}{5.5} = 31.25V \tag{6}$$

From this example, when TR pin is set to 20.5kΩ. According to Table 3-1, the turns ratio setting is 6.875 instead of the real turns ratio of 5.5.

From these examples, when the output voltage is not 20V, the transformer turns ratio setting through TR pin can be completely different than the turns ratio implemented in the transformer. The TR pin needs to be set based on the output OVP needs, instead based on the transformer turns ratio implementation.

5 Summary

UCG2882x is developed to optimize the USB-PD adapter design. When used for non-USB-PD applications, the TR pin setting method needs to be changed. Instead of using TR pin to set the transformer turns ratio, when designed for non-USB-PD application, TR pin is programmed to set the reflected output voltage level based on the desired OVP threshold.

6 References

1. Texas Instruments, UCG2882x Self-Biased High Frequency QR Flyback Converter With Integrated GaN, data sheet
2. Texas Instruments, Using the UCG28826EVM-093 65W USB-C PD HighDensity GaN Integrated Quasi-Resonant Flyback Converter, EVM user's guide
3. Texas Instruments, PMP41145 — Universal AC-input, 65W, 20V 3.25A flyback with integrated GaN reference design

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