High-Voltage Switcher Achieves 5 Percent Current Regulation Accuracy

In chargers it is often necessary to adjust the output current in addition to the output voltage. In recent years primary side regulation (PSR) methods without optical coupler are gaining popularity. Such methods pose challenges on the accuracy that we can obtain because of the indirect sensing of the output current and voltage. The UCC28910 is the first TI high-voltage switcher that achieves output current regulation accuracy within 5% – without external components. **Rosario Davide Stracquadaini, System Engineer, Texas Instruments, Catania, Italy**

The UCC28910 is the first TI high-voltage switcher that incorporates a controller. This 700-V Power FET has a 700 V current source for start-up and is dedicated to off-line isolated flyback power converters. It uses primary-side regulation and senses all the needed quantities to perform output voltage and current regulation, from auxiliary winding, without the need for an optical coupler.

Operation principle

The device's working mode is forced into discontinuous conduction mode (DCM) with valley-switching to reduce switching losses. Figure 1 shows a typical offline converter schematic where a minimal component count is visible.

The output voltage is sensed sampling the transformer auxiliary winding voltage through pin VS. The device's internal circuitry can detect when the ringing amplitude on the auxiliary waveform goes below an acceptable value and closes the sampler switch. The ringing here is the ringing that follows resetting of the leakage inductance. The same circuitry also can sense the knee of the auxiliary waveform at the end of the demagnetization time when the sampler switch is closed.

The sampled value of the auxiliary winding waveform gives information about the output voltage level, which is used when the converter regulates the output voltage. The length of the transformer demagnetization time is used when the converter regulates the output current.

The output-current regulation level on this switcher is established by setting the peak value of the primary current and the transformer turn ratio according to equation 1;

$$I_{OUT} = \frac{1}{2} \cdot N_{PS} \cdot I_{PK} \cdot f_{SW} \cdot T_{DEMAG} \qquad (1)$$

where N_{PS} is the transformer primary to the secondary turn ratio; I_{PK} is the primary peak current which is equal to the UCC28910 internal MOSFET peak current; T_{DEMAG} is the transformer demagnetization time; f_{SW} is the switching frequency that is modulated to keep constant the product $F_{SW} \cdot T_{DEMAG}$ The peak value of the internal MOSFET is set selecting the value of the resistance connected between the device's IPK and GND pins.

Because of the MOSFET switch-off delay (t_d in Figure 3 and in equation 2), the primary peak current depends on the slope of the primary current (S_{IP}) in equation 2:

$$I_{PK} = I_{PK_{TARGET}} + S_{IP} \cdot t_d = I_{PK_{TARGET}} + \frac{V_{¿}}{L_P} \cdot t_d \qquad (2)$$

Here the slope of the current depends on the converter's input voltage (V_{IN}) and the value of the transformer's primary inductance (LP). As the input voltage changes, the primary peak current also changes. According to equation 1 the output current also changes.

The previous consideration states that the output current regulation level will not be accurate, if the effect of the switch-off delay is not properly compensated.

In state-of-the-art ICs dedicated to this

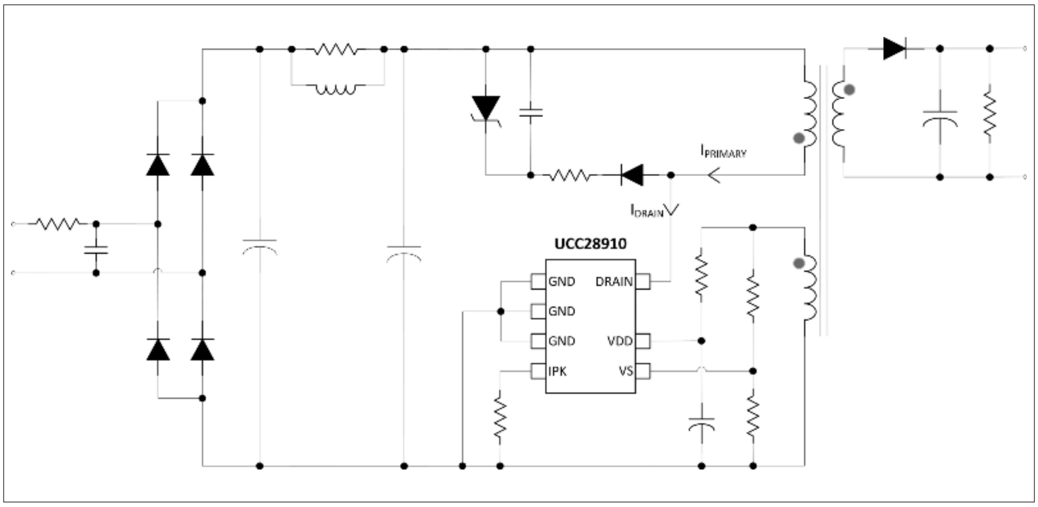
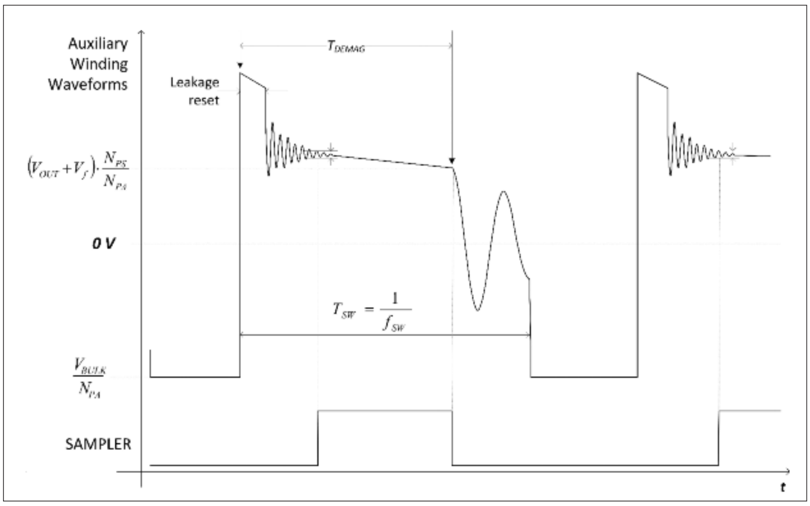
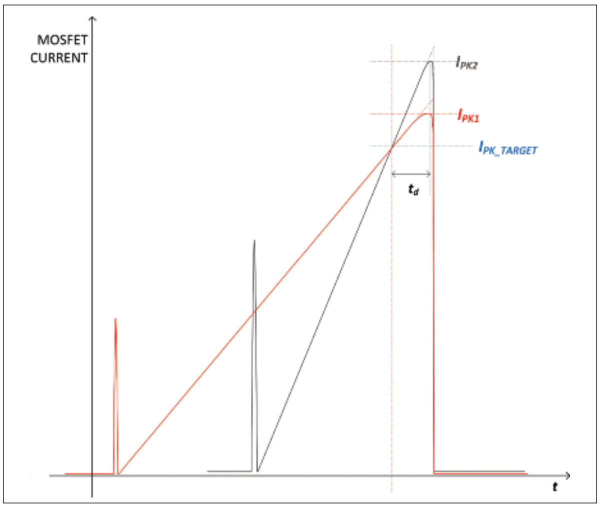


Figure 1: A typical application schematic for the UCC28910 switcher



ABOVE Figure 2: Auxiliary winding waveforms



LEFT Figure 3: MOSFET current at different converter input voltage

kind of converter, this compensation is performed sensing the input voltage and adjusting the pulse-width modulation (PWM) comparator level, or the switching frequency according to the sensed input voltage value. In doing so, the inductance voltage spread is not compensated. You may need additional components to sense the converter input voltage. At a minimum, you will need to tune one or more external components to adjust the compensation amount to obtain almost constant output current on the entire input voltage range.

The UCC28910 uses a fully integrated proprietary, solution to compensate for the converter's input voltage and primary inductance variations, achieving accuracy within ±5% in output-current regulation. The solution compensates the IPK variation adjusting the switching frequency to satisfy equation 3:

$$I_{PK} \cdot f_{SW_{adj}} \cdot T_{DEMAG} = I_{PK_{TARGET}} \cdot f_{SW} \cdot T_{DEMAG} \quad (3)$$

Here IPK is the primary peak current; fSW_adj is the value of the switching frequency after compensation; IPK_TARGET is the target value of the primary peak current that is the value of the primary peak current, if td is zero (see Figure 3). With this device, equation 1 becomes equation 4:

$$I_{OUT} = \frac{1}{2} \cdot N_{PS} \cdot I_{PK} \cdot f_{SW_{adj}} \cdot T_{DEMAG} = \frac{1}{2} \cdot N_{PS} \cdot I_{PK_{TARGET}} \cdot f_{SW} \cdot T_{DEMAG} \quad (4)$$

The peak-current variation caused by the primary inductance spread, and by the input voltage variation, is almost perfectly compensated by the UCC28910 internal circuitry. It is mandatory to say "almost" because the compensation method is based on equation 2, which supposes that the primary current is a perfectly triangular waveform. Looking at the top of the waveform in Figure 3 we see that the peak of the current is rounded. This implies an amount of error in respect to equation 4. The device takes this error into account, even if it cannot compensate for it 100 %. What is important is that all the necessary quantities that this device needs to sense are internal to the device. This means that there is no need for additional external components. Moreover, there is no need to tune the amount of compensation because it is already exactly what it needs to be. Ultimately, the user just need to set up the output current value by setting the transformer turn ratio and the MOSFET peak-current value.

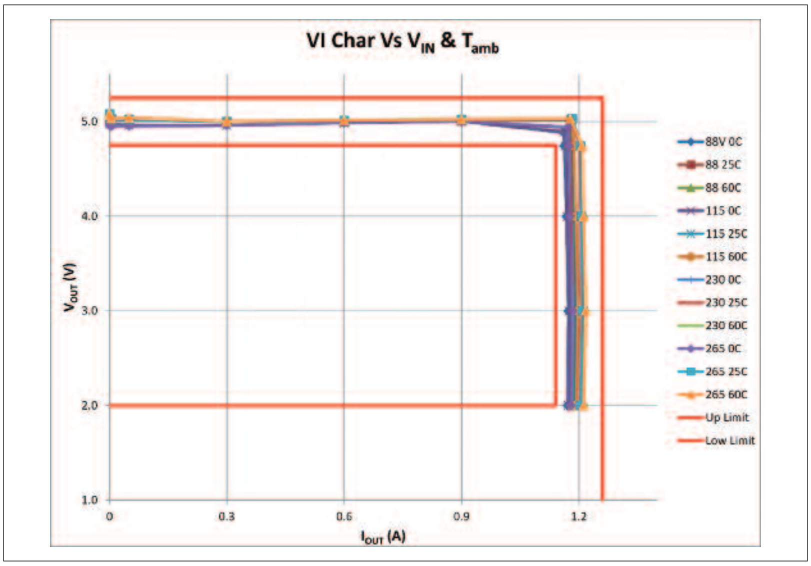
Figure 4 shows the results of experimental tests performed on a demo-board with input voltages ranging from 88 V AC to 265 V AC. The ambient temperature ranges from 0°C to 60°C. The target regulation level for the output current is 1.2 A and 5 V for the output voltage. As is evident, the output current is within the ±5% limits (see red lines) with some margin.

Conclusion

Once the transformer turn ratio is fixed, we have only to fix the value of the MOSFET current-peak proper by selecting and tuning the resistance connected on the device's I_{PK} pin, which fixes the output current regulation level. No other components are needed to achieve a fine-working compensation, thus eliminating the need to turn off the delay effect.

Literature

UCC28910 datasheet



RIGHT Figure 4: Converter voltage / current output curves