

Increasing Power Density With the Active Clamp Flyback Controller (UCC28780)

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In low-power, AC-to-DC, offline, power-converter applications, such as USB adaptors and battery chargers, the discontinuous-mode quasi resonant flyback (QRF) converter is a popular choice due to its low-component count and ability to achieve valley switching for higher efficiency. These converters can have efficiency as high as 90% to 91% using synchronous rectification and run at switching frequencies of less than 100 kHz, to minimize switching losses and reduce heating. However, there is a push in the industry to cut down the size of these power converters and increase their power densities, which requires operating more efficiently at higher switching frequencies (f_{SW}) to reduce the magnetic size without adding heating. This technical note discusses how a Transition-Mode active clamp flyback (ACF) converter can be used to recover leakage energy and reduce or remove switching losses, compared to a QRF. When an ACF converter is used instead of a QRF flyback converter, it will allow designers to run their flyback converter at much higher switching frequencies without penalizing efficiency, allowing them to reduce the magnetic size and increase the power density of the system.

Passive Clamps Dissipate Power:

To protect the main switch in a flyback converter, a diode clamp or a resistor capacitor (RCD) clamp is needed, to provide a path to dissipate the energy stored in the leakage inductance (L_{LK}) of the transformer (T_1) and protect the main switch (Q_1) of the converter from electrical overstress (see Figure 1). The only problem with doing this method is that the clamp dissipates power and heat, which penalizes the overall system efficiency. These clamp power losses only increase with switching frequency (f_{SW}). This can be observed by studying flyback passive-clamp power dissipation (P_{CLAMP}). In Equation 1, the variable V_{CLAMP} is the voltage across the clamp when Q_1 is off, N_p/N_s is the turns ratio of T_1 , and I_p is the peak primary current of the transformer.

$$P_{CLAMP} = \frac{V_{CLAMP}}{V_{CLAMP} - \frac{N_p}{N_s} \times V_{OUT}} \times \frac{1}{2} \times L_{LK} \times I_p^2 \times f_{SW} \quad (1)$$

The active clamp (see Figure 1) consists of a clamp switch (Q_C) and a clamp capacitor (C_C) that replaces a RCD or diode clamp. This design provides a place for the leakage inductance (L_{LK}) of T_1 to be discharged and stored, to protect Q_1 from electrical overstress. Because Q_C allows bidirectional clamp current (I_C), the leakage energy can be returned to the output through the transformer primary-to-secondary turns ratio (N_p/N_s) of the flyback converter every switching cycle, making the active clamp almost lossless and a better choice than a QRF in higher frequency designs (200 kHz +).

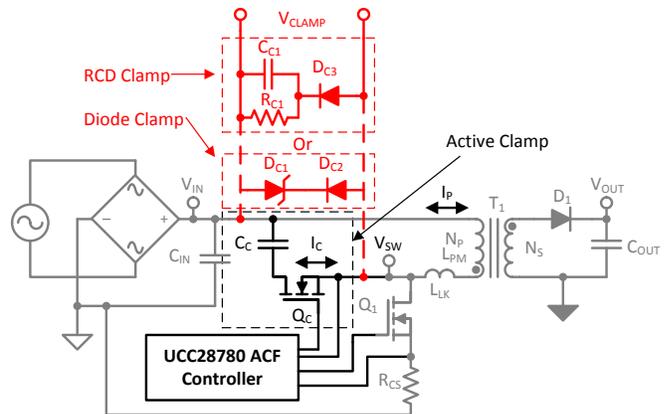


Figure 1. Active Clamp Recycles Leakage Energy and Achieves ZVS That Improves System Efficiency

Valley Switching Dissipates Power:

In low-power, offline, flyback converters, the QRF has been a popular choice due to its valley switching (VS) operation, which is much more efficient than a hard-switched, DCM, flyback converter. However, the QR flyback converter does have switching losses that increase with switching frequency and input voltage. This loss can be observed by studying Equation 2, which describes the QRF switch node (V_{SW}) switching losses ($P_{SW(QRF)}$), where the variable C_{SW} is the switch-node capacitance of the flyback converter.

$$P_{SW(QRF)} = \frac{1}{2} \times C_{SW} \times \left(V_{IN} - \frac{N_p}{N_s} \times V_{OUT} \right)^2 \times f_{SW} \quad (2)$$

ACF Recovers Leakage Energy and Achieves ZVS:

The UCC28780 active clamp flyback controller was designed to take advantage of the bidirectional current in Q_C and the primary current (I_P) of T1 in the flyback converter. The clamp capacitor (C_C) is not only used to store and recycle leakage energy, but to also store some of the energy from the primary magnetizing inductance (L_{PM}) of the transformer. This energy can be used to achieve zero voltage switching in the power converter if used correctly, even at high-line input. The UCC28780 device monitors the switch-node voltage (V_{SW}) and adjusts Q_C on-time, to allow additional energy from C_C to be used to develop negative transformer primary current (I_P). This current discharges the switch-node capacitance to ground when Q_C is turned off, generating near loss-less zero-voltage switching. This technique is a more efficient switching technique when compared to a QRF converter. See [Figure 2](#) for a comparison of the critical waveforms of an ACF versus a QRF converter.

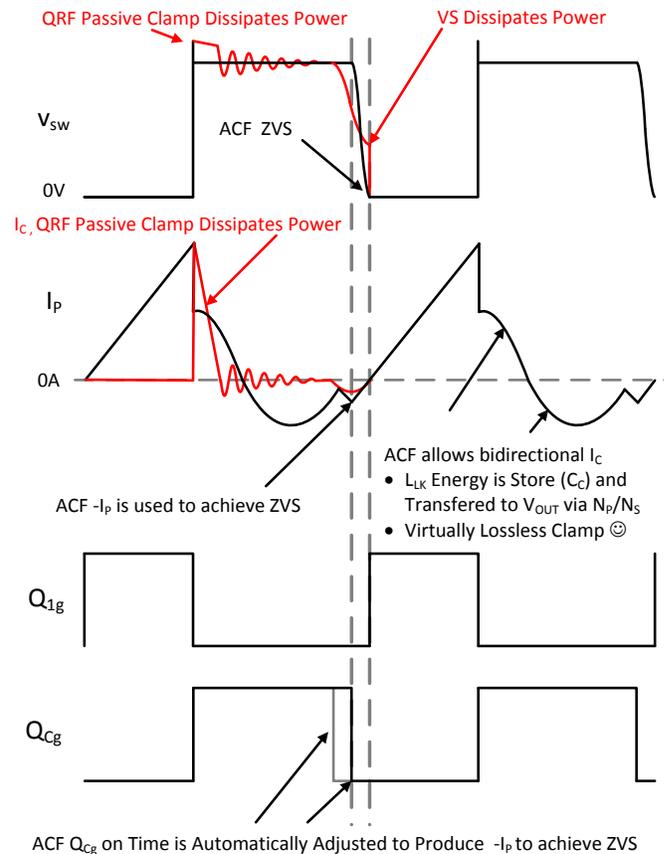


Figure 2. ACF Achieves ZVS, While QRF Achieves VS

Summary:

To recap, the active clamp flyback topology recycles transformer leakage energy making the clamp near lossless, which is much more efficient compared to using a diode or RCD passive clamp. The UCC28780 ACF controller adjusts the clamp switch (Q_C) on-time to produce negative primary current to produce ZVS switching, making the design more efficient compared to QRF. Having a loss-less clamp and ZVS allows the power supply to be designed for higher-switching frequencies, 200 kHz or more, without additional heating caused by clamp and Q1 switching losses. This setup enables the designer to reduce the magnetic size, increasing the power density of the system. Designers have achieved efficiencies of 94% to 95%.

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