Save power with a soft Zener clamp

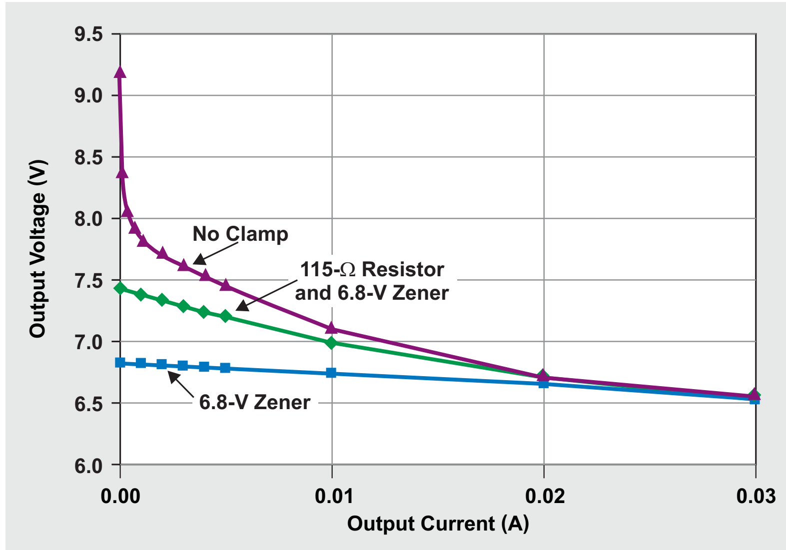
By John Betten
Applications Engineer and
Senior Member, Technical Staff

Flyback converters are wildly popular due to their low cost, their isolation, and the ease with which additional output voltages can be implemented. For multiple-output flybacks, one output voltage—typically the highest-power output—is tightly regulated by means of feedback to the control circuit. Additional outputs are usually added by tightly coupling transformer windings to the main regulated winding. Linear regulators or DC/DC switchers may be added, or the outputs can be left unregulated. This last option is the most efficient, but many times voltage regulation suffers when the outputs are heavily or lightly loaded while the main output voltage has the opposite load level. This cross-regulation problem is highly dependent on the transformer leakage and winding structure, as well as on other parasitic circuit components. One of the worst scenarios is when the main output is heavily loaded and the unregulated winding is completely unloaded. Any voltage ringing present on the transformer's secondary winding is often peak-detected by the output rectifier, causing the unregulated output voltage to greatly increase. It is not uncommon for the output voltage to rise to twice its nominal voltage in this situation. This can be catastrophic to any downstream load that cannot tolerate a higher voltage or that does not present minimal loading at all times to dissipate the leakage energy.

Several solutions can remedy this no-load overvoltage condition. The simplest solution would be to add a preload to the unregulated output in the form of a resistor. This will load the output enough to dissipate the leakage energy and to lower the output voltage to an acceptable level. Unfortunately, this load will always be present and causes a loss of efficiency that is often considered unacceptable.

A second option is to simply add a Zener diode to the unregulated output. The diode's voltage rating must be set higher than the nominal output voltage after the typical 5% or 10% part tolerance is included. This means the diode won't conduct or dissipate power until the output voltage rises high enough. While this may seem like an ideal solution, several potential problems exist. Once the Zener diode conducts, its impedance drops significantly and provides little resistance to current flow. The current flow into the diode, and hence the power dissipated in it, is determined by parasitic circuit components and thus is hard to control. Higher-power converters can potentially source a large current and easily destroy a Zener diode. For this reason, it is risky to add a small Zener diode and difficult to calculate the power dissipated.

Figure 1. Zener diode with resistor provides soft clamp for no-load output voltage



Another option is to use a snubber to dissipate the leakage energy. This generally dissipates more power than using a preload resistor and does not always provide as much no-load voltage reduction on the output.

A soft Zener clamp, which consists of a resistor in series with a Zener diode, can provide a good compromise. It can clamp the unregulated output voltage to a level that is lower than that of the unclamped output voltage but higher than that of a Zener diode alone. To determine the resistor's value, the output can be loaded with just enough current to reduce the high output voltage to the desired safe level. Figure 1 shows an example where the desired no-load output voltage is 7.4 V. The series resistor's value can be calculated by subtracting the Zener diode's nominal voltage from this voltage and dividing the result by the preload current. The benefit of this circuit is that it does not dissipate power at loads that would typically be seen in operation. Under extreme cross-load conditions, this circuit clamps the "runaway" output voltage to a much more predictable level.

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