Options of Driving Forward Synchronous Rectifier in a Single Ended Forward Converter

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Single-ended forward converters have two secondary rectifiers which can be replaced with Synchronous Rectifiers. This application note deals specifically with the options available to drive the forward Synchronous Rectifier.

Simple Passive Self-driven Technique

CCM/Heavy Load Operation:

Unlike the freewheel position, the forward position Synchronous Rectifier lends itself well to self-driven S.R. techniques. In its simplest form, the gate of the forward S.R. is tied to the positive end of the transformer. When the primary switch is turned ON, a positive voltage appears across the transformer secondary side, and turn ON the forward S.R. Similarly, the forward S.R. is turned OFF when the primary switch is turned OFF. (Figure 1)

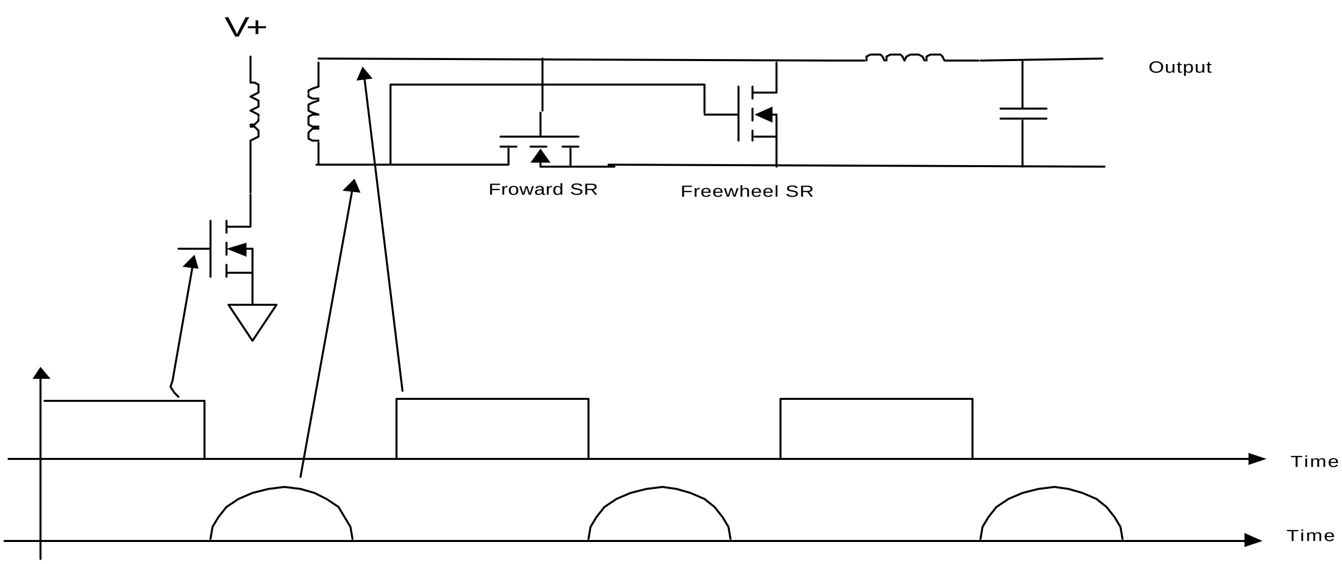
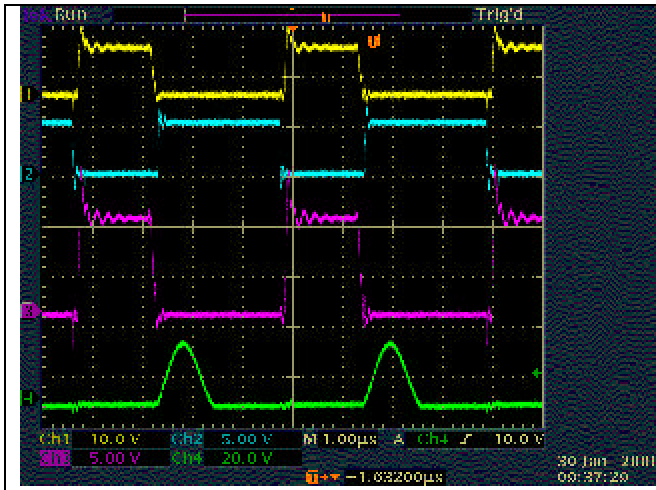


Figure 1. The positive node of the transformer drives the Forward S.R. Damping resistor and gate protection Zener not shown.

Typically, a small damping resistance is added between the gate and the positive end of the transformer, and care must be taken so that the peak secondary side transformer voltage does not exceed the maximum gate voltage rating of the Synchronous Rectifier.

For most stand-alone systems, this is a very cost effective and highly efficiency way of driving forward Synchronous Rectifier. The experimental waveforms are shown in Figure 2, notice that there is no forward body diode conduction.



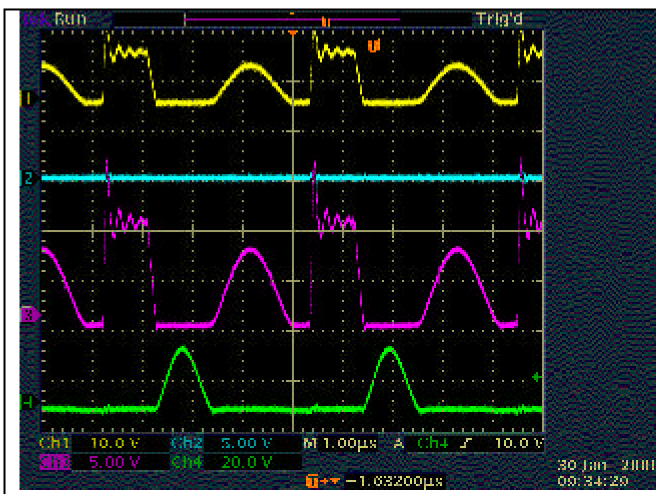
Positive node of transformer secondary same node as Vds of freewheel Synchronous Rectifier. (10V/div, top trace)
Freewheel Synchronous Rectifier Vgs, controlled by SP6002. (5V/div)
Forward Synchronous Rectifier Vgs, tied to positive node of transformer via a damping resistor. (5V/Div)
Transformer reset voltage as seen from the secondary side, same as Vds of forward Synchronous Rectifier. (20V/div, bottom trace)

Figure 2. Experimental data, where the freewheel S.R. is controlled by SP6002. driven by the transformer voltage (self-driven) in CCM or heavy load.

DCM/Deep-Light-Load Operation:

In light loads, the converter enters Discontinuous Current Mode (DCM) operation, where the voltage at the positive end of the transformer oscillate (high impedance/parasitic resonate oscillation). Because this node drives the forward S.R., the forward S.R. is turned ON more than once in one cycle.

This problem only occurs in light load, if the false forward S.R. turn ON does not interrupt the transformer reset, there is little consequences of this false (resonate) turn ON as shown in Figure 3.



Positive node of transformer secondary same node as Vds of freewheel Synchronous Rectifier. Showing light load resonate oscillation (10V/div, top trace)
Freewheel Synchronous Rectifier Vgs, controlled by SP6002. (5V/div). The SP6002 disables freewheel SR in deep light load.
Forward Synchronous Rectifier Vgs, tied to positive node of transformer via a damping resistor. (5V/Div)
Transformer reset voltage as seen from the secondary side, same as Vds of forward Synchronous Rectifier. (20V/div, bottom trace)

Figure 3. Experimental data, where the freewheel S.R. is controlled by SP6002 . driven by the transformer voltage (self-driven) in deep light load operation. It shows that resonate false turn ON of the forward S.R. has little to no consequences.

DCM/CCM Boundary Operation:

When the converter is near the boundary of DCM and CCM operation, the resonate turn ON of the forward S.R. may interrupt the transformer reset in one DCM cycle and then force the converter into CCM in the next cycle as shown in Figure 4. Because the transformer reset was interrupted in the previous cycle, the transformer reset voltage is higher than normal. Thus may require higher voltage rated power MOSFETs on the primary and forward Synchronous Rectifier.

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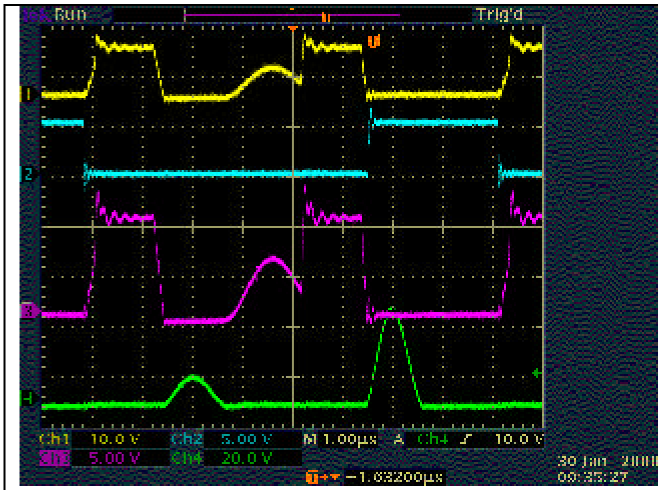
<tr><td rowspan="4">
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Figure 4. Experimental data, where the freewheel S.R. is controlled by SP6002 . driven by the transformer voltage (self-driven) in light load operation. The resonate turn ON of the forward S.R. may interrupt the transformer reset in one DCM cycle and then force the converter into CCM in the next cycle. Because of the higher transformer reset voltage, a higher voltage rated power MOSFET may have to be used.

Because higher voltage rated power MOSFET often translate into larger RON switches, and higher RON switches reduces overall converter efficiency (even when transformer reset is not interrupted).

It is often wise to Zener clamp the reset voltage on the primary side, such that higher transformer reset voltage (which only occurs in a narrow light load range) is clamped. The reset clamping Zener is selected such that it only clamps the higher than normal reset voltage in this mode, thus the power loss in the clamping Zener is in significant, and the switches rated voltage can be kept low for small RON.