

Figure 2. Output inductor voltage-based (VL) freewheel synchronous rectifier driving circuit

There are, however, two major problems with VL based synchronous rectifier drive schemes. They are discussed below:

1) Turn off synchronous rectifier cross conduction

The ideal operation requires the freewheel synchronous rectifier to turn off before the primary switch turns on. Otherwise, large reverse conduction (cross conduction with primary switch) in the freewheel synchronous rectifier occurs. This reverse conduction negates synchronous rectifier efficiency, causes conduction and EMI noises and at worst, may even cause destruction of the converter.

In the VL based synchronous rectifier driving schemes, the freewheel synchronous rectifier is on as long as inductor voltage (VL) is negative and the inductor is discharging. But the inductor voltage remains negative and remains in the discharging state as long the freewheel synchronous rectifier is on. This interlocking relationship can only be reversed when the primary switch and the freewheel synchronous rectifier goes through a substantial cross conduction as shown in Figure 3. This substantial cross conduction is required at every cycle to turn OFF the freewheel synchronous rectifier.

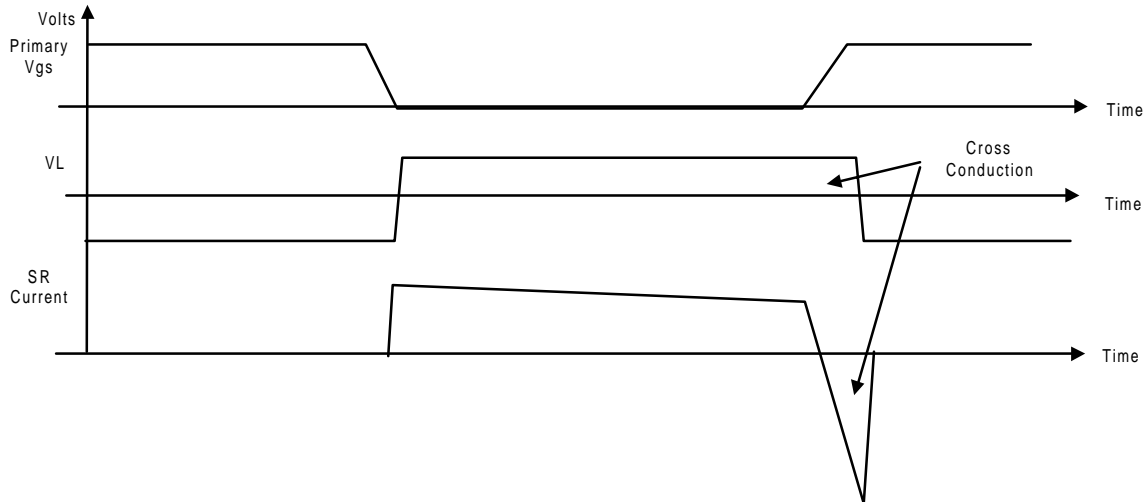


Figure 3. The interlocking relationship of synchronous rectifier Vgs and VL makes synchronous rectifier cross conduction unavoidable at every cycle

2) Light load synchronous rectifier reverse conduction

Similar to the active clamped forward converters, the output inductor voltage (VL) based controlled freewheel synchronous rectifier reverse conduct in light load, thus the converter goes into the forced continuous current mode (F-CCM) as shown in Figure 4. Except for the Japanese market and some N+1 systems, forced continuous current mode may not be an issue.

SYNCHRONOUS RECTIFIER CONTROLLER IC (SR-CIC)

The recently introduced Synchronous Rectifier Controller IC (SR-CIC) uses prediction technology to control the operation of synchronous rectifiers.

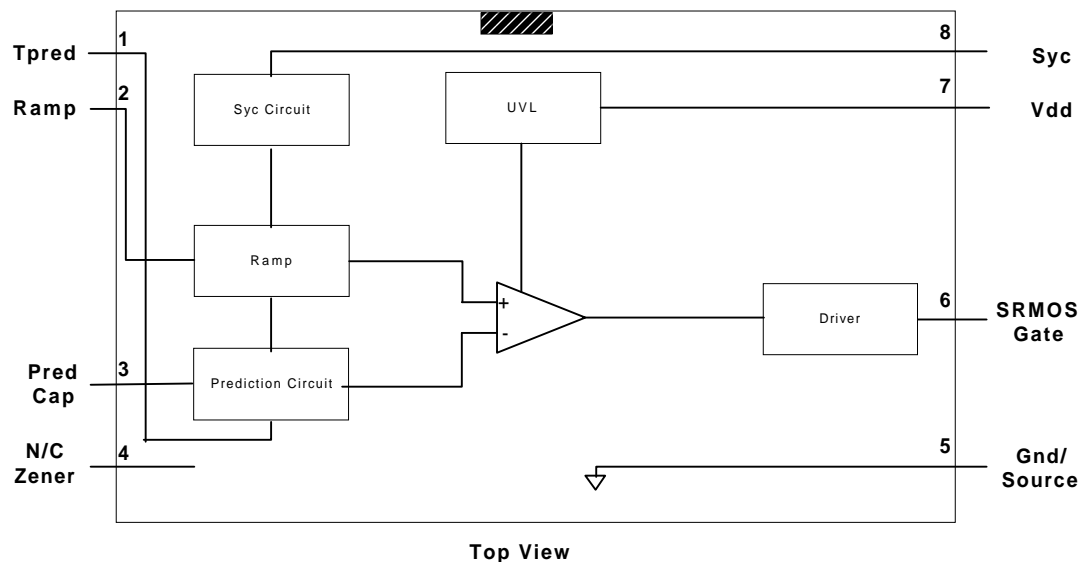


Figure 4. Block diagram of the Synchronous Rectifier Controller IC (SR-CIC)

In the SR-CIC, this prediction intelligence is achieved by using previous primary switch timing information to predict the present timing, and synchronous rectifier cross conduction and reverse conduction are avoided. The previous cycle timing information is sensed at the drain of the freewheel synchronous rectifier MOS. The SR-CIC synchronizes this node (or other nodes with similar timing information), but allows the synchronous rectifier body diode to conduct for a small (adjustable at about 50ns) amount of time, so as to avoid reverse current through the channel of synchronous rectifiers. This is achieved by keeping a timing gap between the falling edge of the synchronous rectifier Vgs and the rising edge of the freewheel synchronous rectifier drain voltage (for the forward position, the timing gap is between the rising edge of the synchronous rectifier Vgs and rising edge of the freewheel synchronous rectifier drain voltage). This timing gap is referred to as the prediction time. During this timing gap, the body diode carries the current.

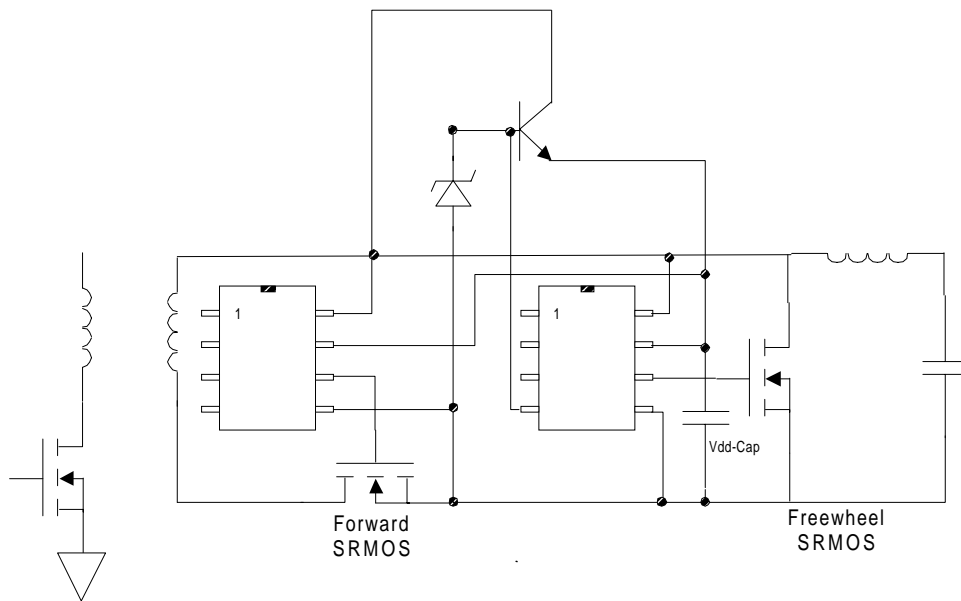


Figure 5. Forward converter schematic utilizing SR-CIC for both positions

The block diagram of the SR-CIC is shown in Figure 4, and schematic for a forward converter implemented by using SR-CIC is shown in Figure 5. The complete prediction-timing diagram is shown in Figure 6. In the same figure, comparison was also made with the output inductor based (VL) self-driven synchronous rectifier timing.

By using this SR-CIC, synchronous rectifier reverse conduction is avoided while achieving very high converter efficiency. We are able to obtain over efficiency over 92 percent in a 3.3V, 10A and 250Khz forward converter using the SR-CIC in both the forward and freewheel position.

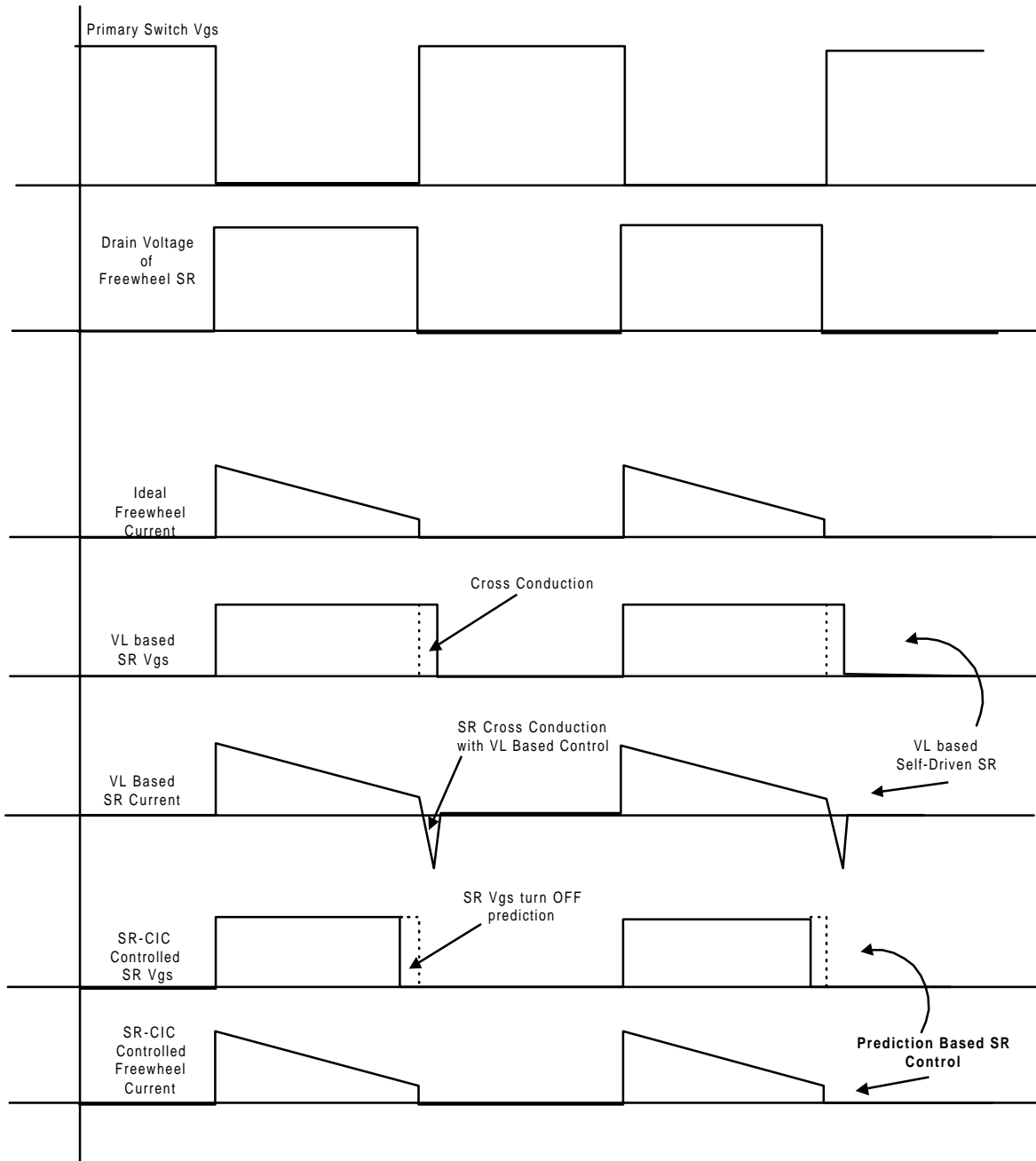


Figure 6. Comparison of timing diagram between SR-CIC (prediction) controlled and VL based Self-Driven synchronous rectifier

CONCLUSION

Most self-driven synchronous rectifier control methods are messy to use and require significant design effort. Still, many problems (mostly related to synchronous rectifier reverse conduction) cannot be easily resolved. With today's time to market pressure, the cumbersome self-driven method desperately needs alternatives.

SYNC POWER CORP.

The easy-to-use SR-CIC offers significant savings in effort, while providing high-converter efficiency as shown in the table below. Because the SR-CIC does not allow reverse synchronous rectifier conduction, the converter operates much like a traditional diode was in place, but at higher efficiency.

250KHz Forward	Typical Efficiency
Schottky	Low 80%
Self-Driven Synchronous Rectifier	Mid to High 80%
SR-CIC	Low 90%