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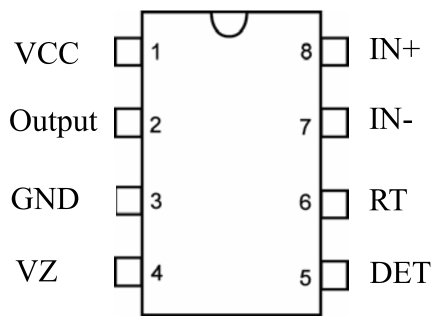
ABSTRACT

This application note describes a detailed design strategy for a high efficiency, compact flyback converter. Design considerations and mathematical equations are presented. A 12V, 120W demo board is built to evaluate the performance improvement by the SG6203.

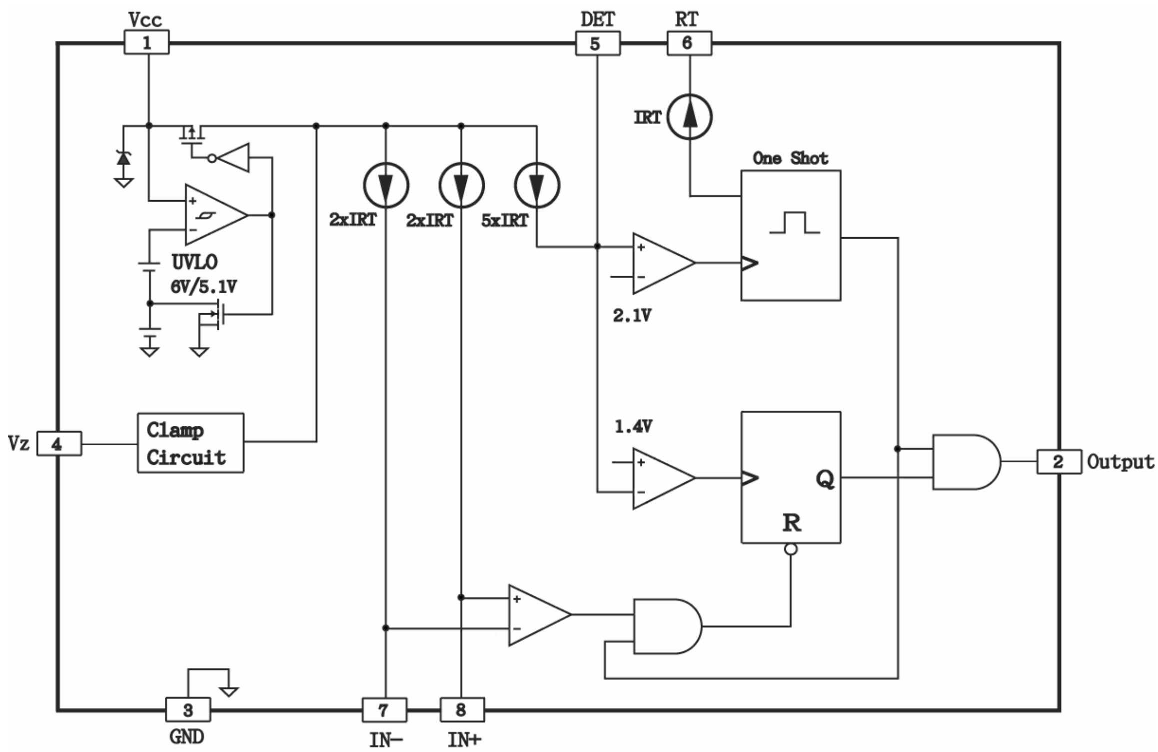
PIN CONFIGURATION



FEATURES OVERVIEW

- Low operation current (1.7mA)
- One resistor for timing setting
- Internal automatic tracking for optimum dead time
- No reverse energy flow at light load
- Best suited for primary green mode PWM IC
- Wide supply voltage range from 6V to 20V
- Built in 18V zener diode
- Optional current sensing
  - Current shunt
  - RC network for better efficiency

BLOCK DIAGRAM



Description

Generally, the conduction loss of the output diode is the dominant loss component in low output voltage power supplies. This loss can be reduced by replacing a low on resistance MOSFET. Therefore, an improved efficiency can be obtained and a smaller heat sink can be used.

The SG6203 is designed to control and drive the synchronous rectifier for the flyback converter. The synchronous signal of the primary switch is obtained by a single diode connected between the transformer secondary winding and the SG6203. Using the SG6203, no additional transformer winding is required and the circuit complexity can be minimized.

In heavy load, the flyback converter is usually designed to operate in continuous conduction mode (CCM) to have higher efficiency. To prevent the so called "shoot through" or "cross conduction" problem in synchronous rectifier applications, one external resistor and an internal automatic tracking circuit is used to program a suitable dead time for the primary switch and the synchronous rectifier.

On the other hand, the converter will enter into discontinuous conduction mode (DCM) in light load. To improve the light load efficiency, the synchronous rectifier is turned off when the stored energy in the transformer is fully released to the output. This feature can prevent reverse energy flow and hence green mode PWM IC in the primary side can be used. To detect the secondary current flow and hence determine the driving signal for the synchronous rectifier, a current shunt or RC network for the output capacitor can be used. Usually, an RC network is recommended for better efficiency.

Detail operation principle and its application information of the SG6203 are presented in the following section. Finally, a 12V, 120W demo board using the SG6203 is built and the performance is measured on this unit to show its improvement on the efficiency.

Synchronization

To achieve correct and proper control of the synchronous rectifier in the secondary side, the switching timing signal of the primary switch should be obtained.

The synchronization of the primary switch is obtained from the transformer secondary winding. As shown in Figure 1, a detecting diode connected from DET pin to the transformer secondary winding is used to detect the on/off information of the primary switch. Once the primary switch turns on, the voltage on the cathode of the DET diode will be high enough to push the DET diode to reversed state. The high level on the DET pin will initialize an internal one shot signal to mark the beginning of a new switching cycle.

While the primary switch turns off, the voltage on the primary switch starts to increase. Meanwhile, the secondary winding voltage begins to reverse accordingly. Once the voltage on the secondary winding is large enough to forward conduct the rectifier diode, D2, the energy stored in the transformer starts to release to the secondary side. At that time, the DET diode will turn to forward-biased, and the low level is on the DET pin then. Once the DET pin reduces to low and the one shot signal keeps in high status, the SG6203 output stage will become high to drive the external synchronous rectifier.

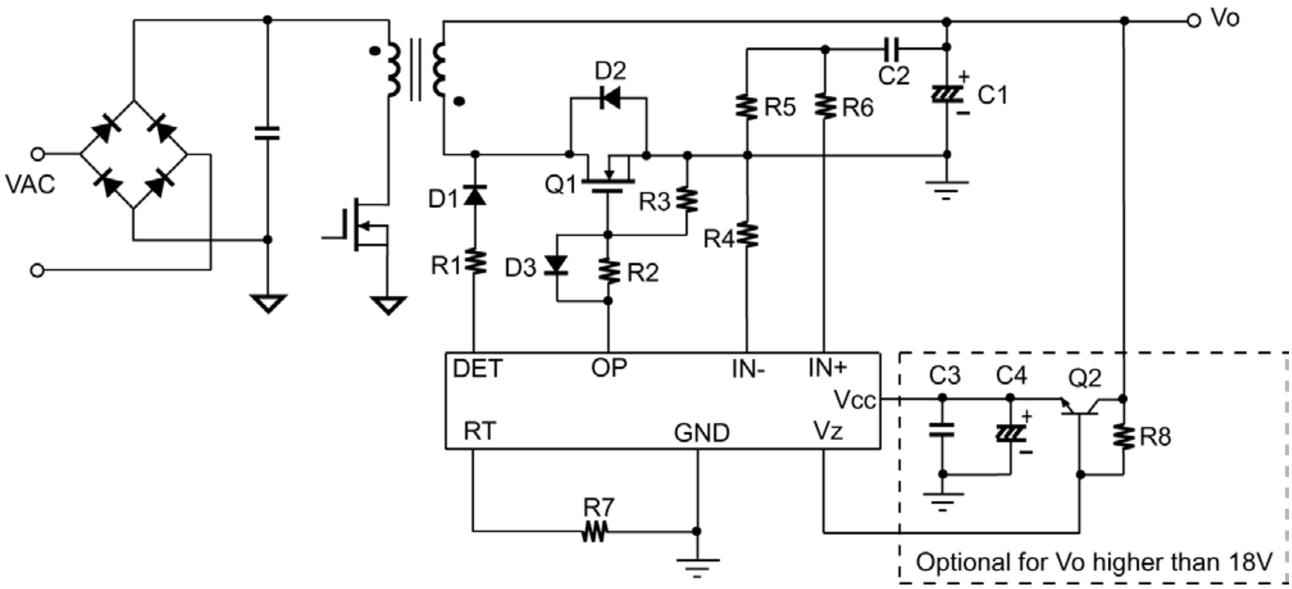


Figure 1. Circuit configure to obtain the primary switch synchronous signal

The high duration of the internal one shot signal is programmed by an external resistor connected between RT to GND pins. Also, an internal automatic tracking mechanism will automatically extend the original one shot signal to maximum 180% to have a suitable dead time between the primary switch and the secondary synchronous rectifier in continuous conduction mode (CCM). This will result in better efficiency improvement than just a fixed dead time mechanism. The duration of this one shot signal can be expressed as:

$$T = \frac{15 \times RT(K\Omega)}{24}(u\,\mathrm{sec})$$

If the resistor is too small, the synchronous rectifier may be turned off even when the secondary rectifier diode is still conducting, and hence decrease efficiency. However, if the RT resistor is too large, there will be no dead time. However, the output of the SG6203 will be shut off immediately once the voltage on DET pin goes high before the one shot signal reduces to low. The recommended value for the RT resistor is to set the original one shot signal to around 75% compared to the primary PWM period.

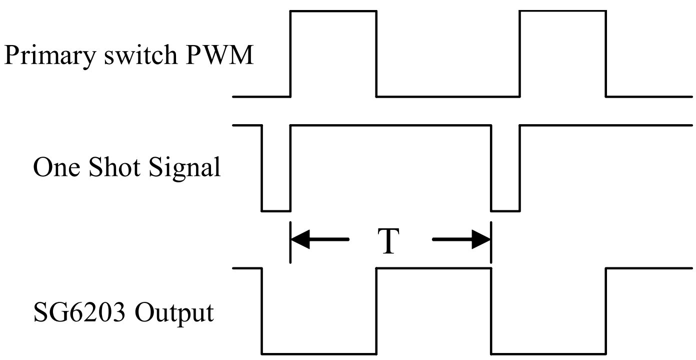


Figure 2. Timing of the one shot signal

Continuous Conduction Mode (CCM)

When the flyback converter is operated under CCM, the secondary rectifier diode will not turn off until the primary switch is turned on. Therefore, an anti-shoot through mechanism is needed to prevent the cross conduction of the primary switch and the secondary synchronous rectifier. To achieve this, an internal automatic tracking circuit is performed to maintain a suitable dead time under CCM conditions.

Discontinuous Conduction Mode (DCM)

When operated under DCM, the energy stored in the transformer during the on time of the primary switch is completely released during the subsequent off time. Therefore, the secondary current will reduce to zero before the primary switch is turned on. To prevent the discharge of the output capacitor through the conducting synchronous rectifier, the synchronous rectifier must be terminated once the secondary current reaches zero, or a short while thereafter. Accordingly, a zero current crossing detector is needed when the converter is operated under DCM.

To achieve this, two different configurations can be used: current sensing resistor method and output capacitor ESR method.

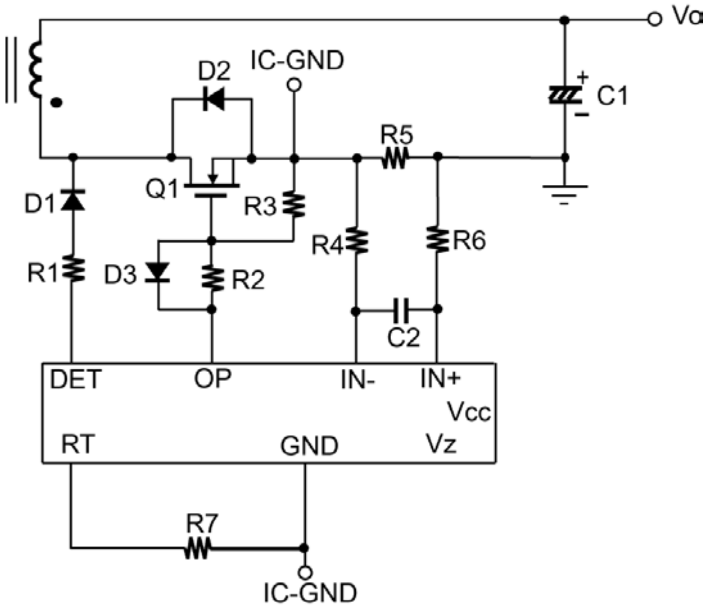


Figure 3. Current sensing resistor method

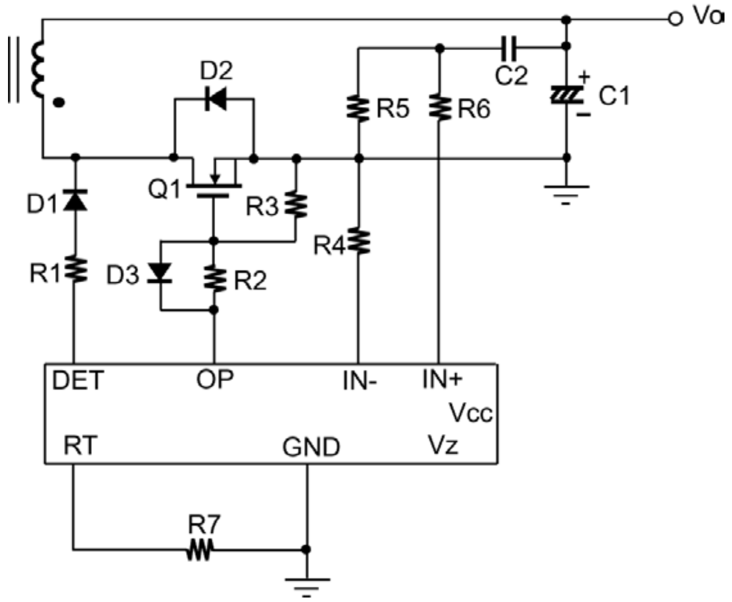


Figure 4. Output capacitor ESR method

As shown in Figure 3, a current sensing resistor, R5, is used to sense the secondary winding current. Be careful that this sensing resistor is placed within the current rectifier loop (Nsec→C1→D2), but not after C1. This is different with the usual secondary over current protection application which puts a current sensing resistor after C1, and a DC value that represents the output loading is obtained. Here, what we need is just the discharging current waveform. Then we can obtain the zero current crossing timing signal. Once zero current crossing happens, the voltage on IN+ will be lower than that on IN-, the driving signal for the synchronous rectifier will be turned off to prevent the excessive energy circulating between the primary and secondary.

The internal current I_{IN+} and I_{IN-} from IN+ and IN- respectively will result in a dc value on these two pins. Adjusted external resistors connected outside IN+ and IN- can modulate the turn off current level of the synchronous rectifier. To prevent switching noise interfering with the operation of the comparator, an external capacitor with 2.2nF to 4.7nF is recommended to place between IN+ and IN- pin.

Figure 4 shows another current sensing method. This method uses a high pass RC (R5 and C2) network to capture the discharging current waveform of the secondary winding across the R5 resistor. The resistors (R4 & R6) connected to IN+ and IN- is used to adjust the dc level on these two pins, and then adjust the turn off timing.

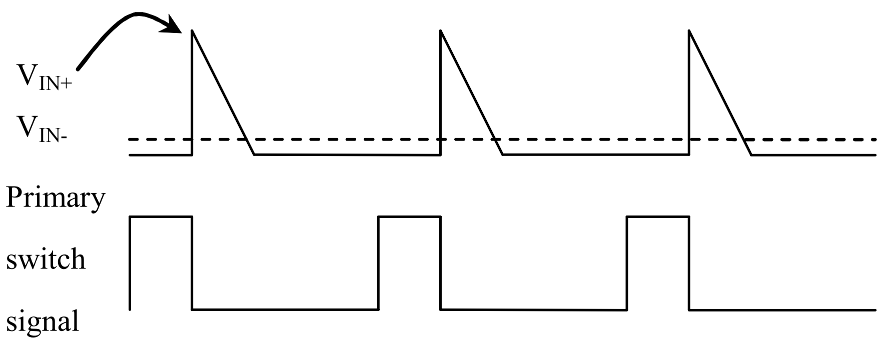


Figure 5. IN+/- and Primary switch signal

Because the synchronization signal of the primary switch is through the transformer secondary winding, some false trigger condition may be happened in very light load. To prevent this, a series resistor (R1: 2~3kohm) in the DET diode and a capacitor (C5: 22~47pF) connecting from DET pin to GND is recommended.

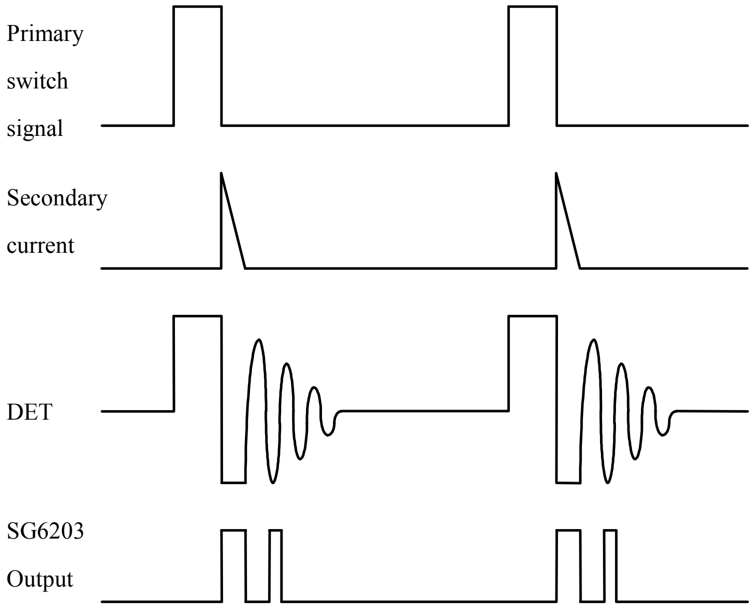


Figure 6. False synchronization caused by ringing on the transformer winding.

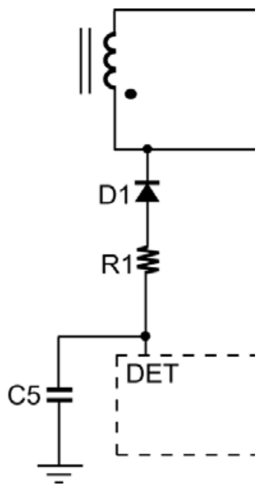


Figure 7. Add RC filter to prevent false trigger

Built-in 18V zener diode

An 18V zener diode is built in to the SG6203. When the converter output voltage is higher than 18V, a linear regulator formed by a BJT and the internal zener can be used to limit the voltage supplied to the SG6203 then clamp the driving voltage for the synchronous rectifier to a safe level. If the converter output voltage is lower than 18V, then the SG6203 can be directly powered by the output voltage. The operating voltage of the SG6203 can be from 6 to 20V.

Demo board Description

A 12V, 120W demo board with full range input voltage (90~264Vac) and PFC function is built to evaluate the performance improvement contributed by the synchronous rectifier. The SG6902 combo controller is used to control the primary switches (PFC & PWM). The measured performance on this demo board is shown as below:

Table 1. Performance comparison between diode rectifier and MOSFET synchronous rectifier

Io (A)	Efficiency (%)			
	90Vac		264Vac	
	20A Schottky	MOS (15mohm Rds) + 1A Schottky	20A Schottky	MOS (15mohm Rds) + 1A Schottky
1	81.8	80.2	81.8	79.1
2	83.2	85.4	82.4	81.5
3	82.6	85.0	83.6	85.8
4	81.7	83.5	83.1	85.7
5	82.0	84.3	82.9	85.3
6	81.8	84.1	83.5	85.4
7	81.4	83.7	83.3	85.4
8	80.8	83.0	83.1	84.7
9	80.2	82.1	83.1	84.8
10	79.5	81.3	82.7	84.3

The efficiency improvement is around 1.7~3% in heavy load. Also, the improvement is highly dependent on the synchronous MOSFET rectifier which is chosen to replace the diode rectifier. The lower the Rds-on the chosen synchronous has, the larger the improvement that will be achieved.

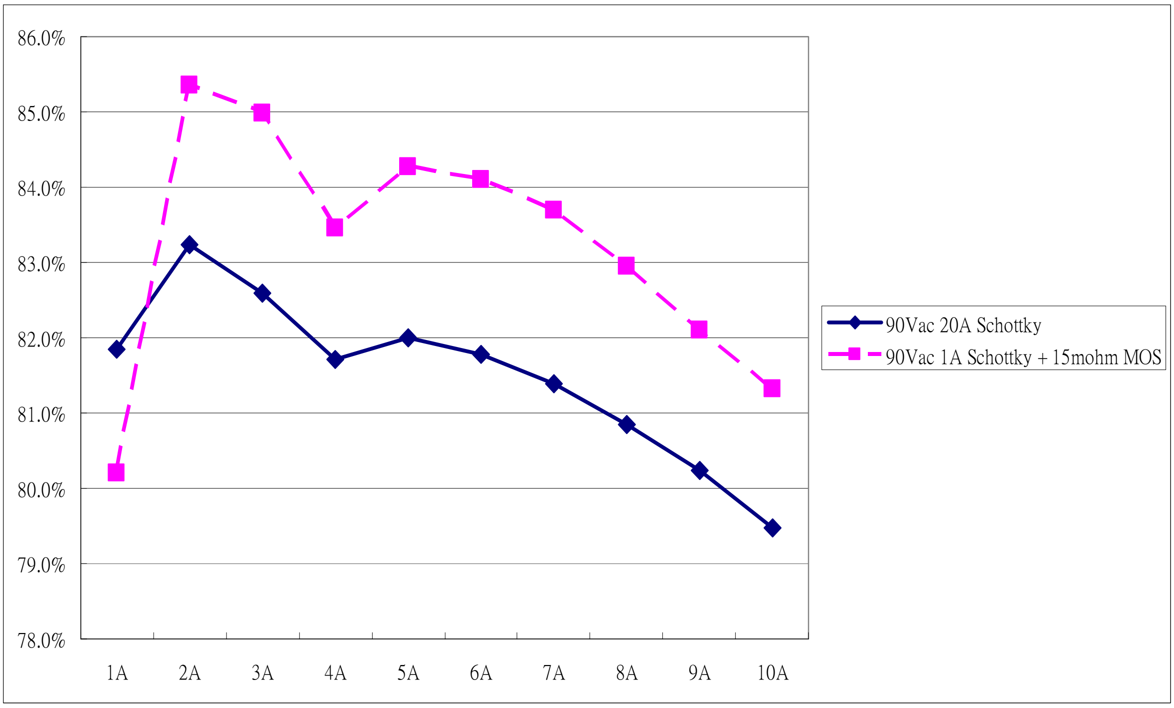


Figure 8. Performance comparison between diode rectifier and MOSFET synchronous rectifier at 90Vac

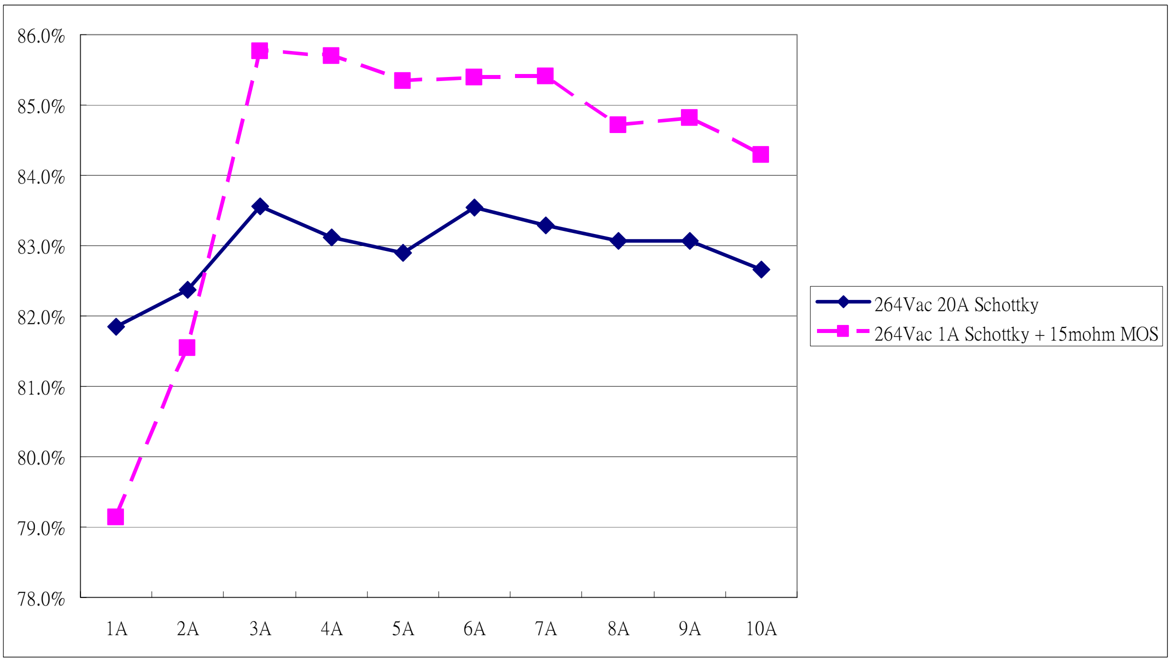


Figure 9. Performance comparison between diode rectifier and MOSFET synchronous rectifier at 264Vac

The bill of materials related to the SG6203 is shown in Table 2.

Table 2. Demo board bill of materials

Ref Des	Part Number	Description
C2		0.1uF
C5		22pF
D1	FR102	100V/1A
D2	SB1100	100V/1A
D3	1N4148	100V/0.2A
Q1	PSMN015-110P	110V/75A; 15mohm
R1		2.2 Kohm
R2		22 ohm
R3		47 Kohm
R4		1.8 Kohm
R5		2 Kohm
R6		0
R7		16.2 kohm

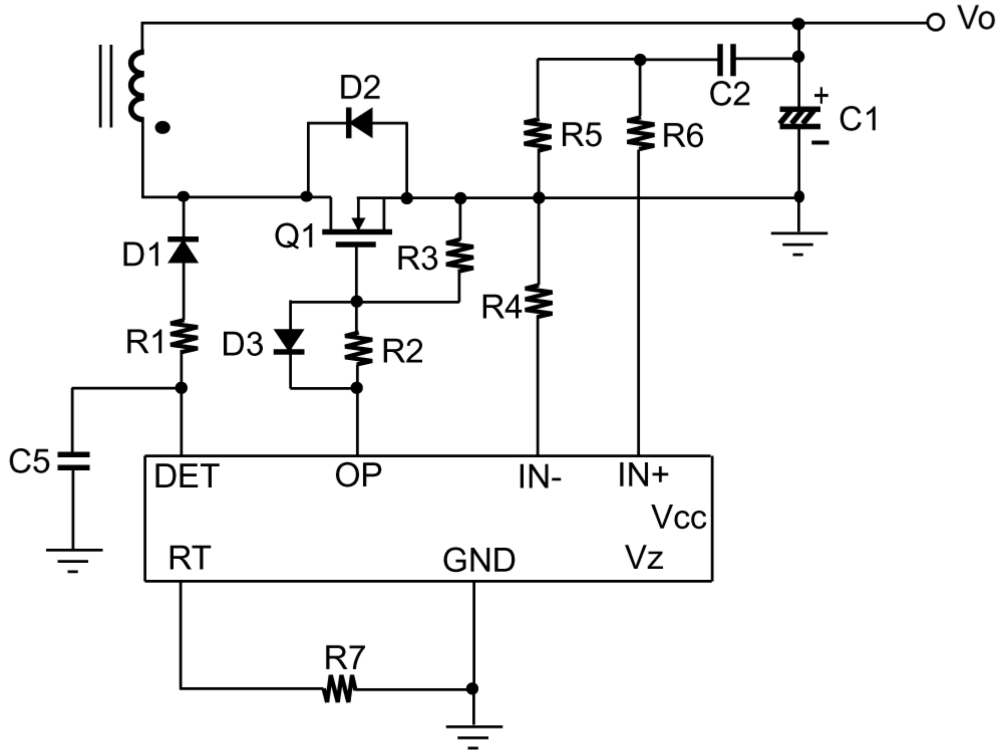


Figure 10. Demo board schematic

Lab Note

Before rework or solder/desolder on the power supply, it is suggested to **discharge the primary capacitors by an external bleeding resistor**. Otherwise the PWM IC may be destroyed by external high voltage during solder/desolder.

This device is sensitive to ESD discharge. To improve production yield, the production line should be ESD protected according to ANSI ESD S1.1, ESD S1.4, ESD S7.1, ESD STM 12.1, and EOS/ESD S6.1.

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