ZXGD3101EV2 EVALUATION BOARD USER GUIDE

Description

This document describes how to connect and evaluate the ZXGD3101EV2 evaluation board, Figure 1. The purpose of this board is to demonstrate synchronous rectification and driving of a MOSFET as a Schottky/ultra-fast recovery diode replacement in Flyback converters. When the board is used to drive a synchronous MOSFET, it will yield efficiency improvement, whilst maintaining design simplicity and incurring minimal component count. The ZXGD3101 senses the voltage across the MOSFET and generates the gate drive voltage when a negative voltage is detected across the drain-source pin. This evaluation guide also includes useful guidelines on conditioning of Flyback converters, as well as a design tip to overcome premature driver turn-off and maximize the effectiveness of synchronous rectification.

Note: The evaluation board is not recommended to be used with Flyback converters above 100kHz switching frequency.

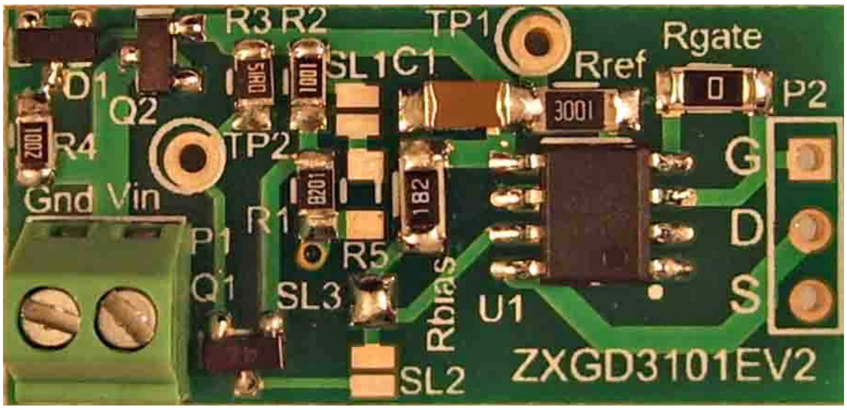


Figure 1 Evaluation board layout and connection diagram

Reference design

The ZXGD3101EV2 is configured to the reference design in Figure 2. The target application for the device is external adapters where the typical output voltage ranges from 12V to 20V. However, the evaluation board will work with output voltages up to 40V.

Power, which could be sourced directly from the output of the power supply, is applied to the terminal block P1. At the other end of the board is a location for a three way header, P2. This is not fitted, so as to allow flexibility of mounting (forward or reverse). The purpose of the header is to allow the board to be soldered directly across a TO220 packaged synchronous MOSFET.

R4, Q2, D1 and C1 are configured as a simple series regulator to maintain a stable Vcc. The values of Rref and Rbias in Figure 2 are based on a 10.3V Vcc. For supply voltages below this, these resistor values need to be reduced proportionally to maintain 5.3mA and 3.2mA into the ‘REF’ and ‘BIAS’ pins respectively. Refer to the datasheet for further information on selection of the resistor value.

A fixed-bias-point constant current source (Q1, R2, R1//R5 and R3) is included on the board. The current source is not active in the original board setting and is only intended for elimination of premature turn-off problem on the controller (refer to the section ‘Overcoming premature turn-off’ for details).

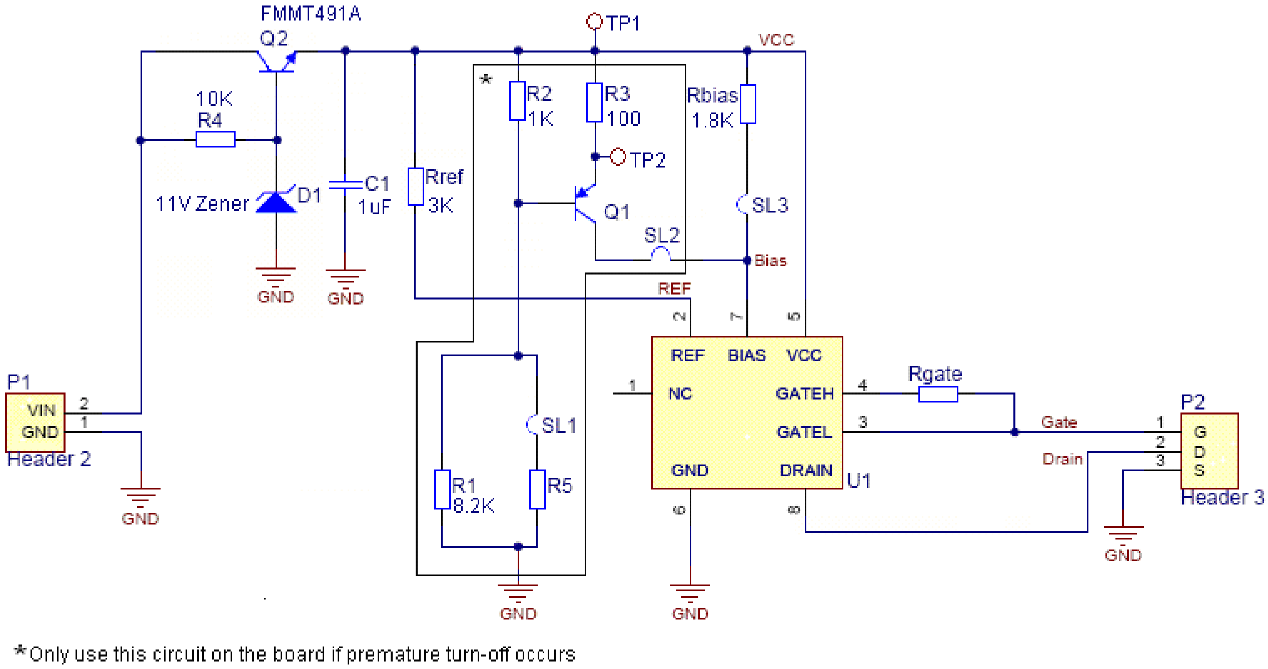


Figure 2: Evaluation board schematic diagram and connection

Please note that the component part numbers are given as a guide only. Due to continual component development, all parts quoted should be checked for suitability and availability with their respective manufacturers.

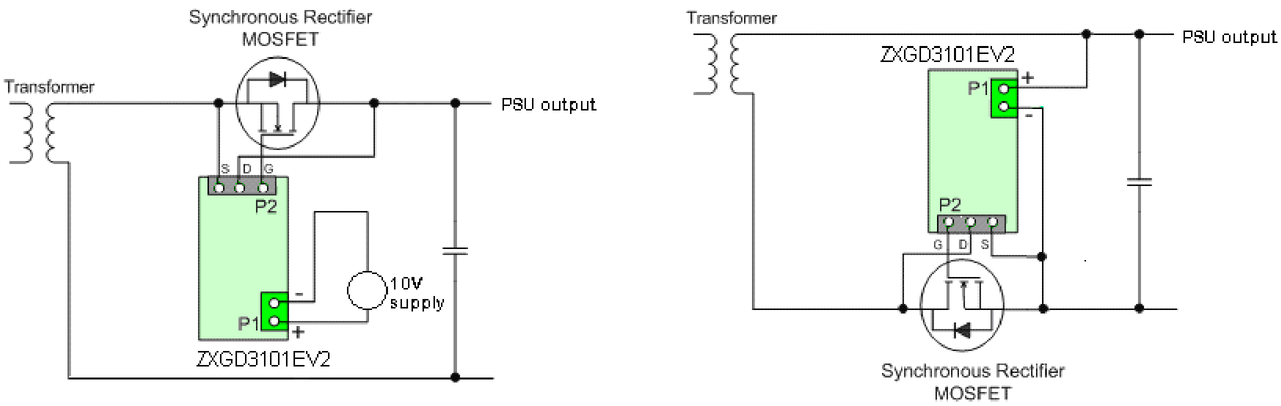
Table 1: Evaluation board component details (BOM)

Ref.	Value	Package	Part number	Manufacturer	Notes
U1	**ZXGD3101**	**SO8**	**ZXGD3101N8**	**Diodes Zetex**	
Q1	**FMMTA92**	**SOT23**	**FMMTA92**	**Diodes Zetex**	
Q2	**FMMT491A**	**SOT23**	**FMMT491A**	**Diodes Zetex**	**500mW**
D1	**11V Zener**	**SOT23**	**BZX84C11**	**Diodes Inc.**	**300mW**
C1	1uF 50V	1206	C1206X105K5RAC	Kemet	X7R 10%
R1	8.2kΩ	0805	Generic		125mW, 1%, 200ppm/ºC
R2	1KΩ	0805	Generic		125mW, 1%, 200ppm/ºC
R3	100Ω	0805	Generic		125mW, 1%, 200ppm/ºC
R4	10kΩ	0805	Generic		125mW, 1%, 200ppm/ºC
Rbias	1.8kΩ	1206	Generic		125mW, 5%, 200ppm/ºC
Rgate	0R	1206	Generic		125mW, 5%, 200ppm/ºC
Rref	3KΩ	1206	Generic		125mW, 5%, 200ppm/ºC
P1	2-way terminal		Generic		
P2	3-way header		Generic		

Evaluation procedure and operation

To perform a quick functional test of the ZXGD3101, the evaluation board can be used to drive a MOSFET as a diode replacement in high-side-rectification (see Fig. 3a), as the board can float to any potential. In practice, the supply voltage could be derived from an auxiliary supply winding across the transformer secondary. If the board is used for comparison against an existing synchronous rectification solution, the existing controller must disabled before proceed with the testing.

The recommended device implementation is low side synchronous rectification (Fig. 3b), due to the ease of acquiring the required supply voltage directly, either from the power supply output post bleeder resistor, or from the emitter-follower-configured transistor. Before doing this test, it is important that the existing diode has been removed and/or a short has been applied across its cathode and anode terminals. The track linking the negative terminal of the converter's output capacitor to the transformer secondary-side output should then be cut, and a MOSFET should be inserted. In general, the MOSFET should be selected to drop between 50 to 150mV at the peak of the secondary-side current to ensure MOSFET enhancement. The breakdown voltage of the MOSFET must be higher than the maximum drain-source voltage stress, plus some margin. Designers interested in squeezing the last percent of efficiency out of the module can place an additional Schottky or Ultra-fast-recovery diode in parallel with MOSET. The diode prevents body-diode conduction, so the trace inductance between it and the MOSFET should be kept small to create an efficient circulating energy flow path.

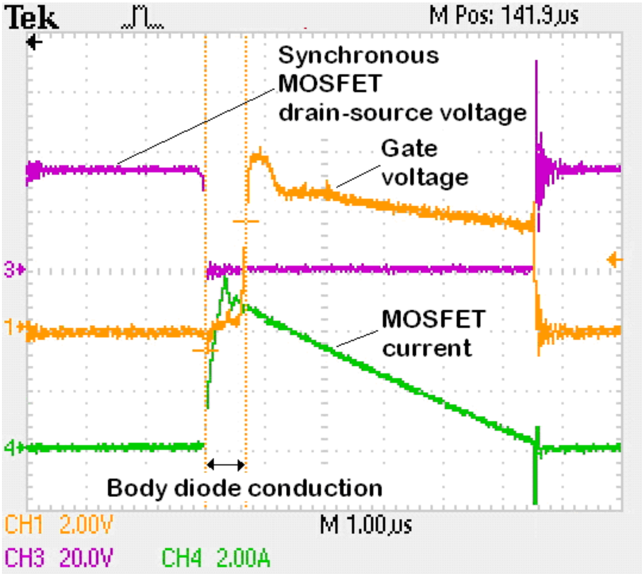


(a) (b)

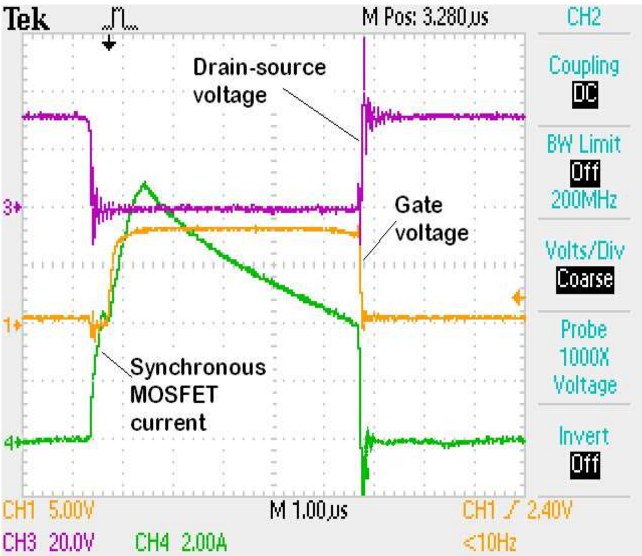
Figure 3: Test options for ZXGD3101EV2 a) high side and b) low side

To check for functionality, the circuit waveforms should be probed using an oscilloscope probe with a minimal length for the ground pin, and the probe should be connected directly to the pins of the device. If a current probe or transformer is used to measure reverse current flow, excessive wire-loop-inductance and injection of noise, which could disturb normal functioning of the controller, should be avoided.

At synchronous MOSFET turn-on, current starts to flow through the body-diode after the primary switch turn-off (see Fig. 4). When this occurs, the drain of the MOSFET will be around -1.25V with respect to ground, due to body-diode conduction. The detector stage within the ZXGD3101 determines when the MOSFET needs to turn on by measuring the change in polarity of the V_{SD} differential voltage, which, in turn, determines when the current is flowing through the secondary side. The turn-off phase of the ZXGD3101 happens differently depending on the mode of operation. It should be noted that the device is most suited to discontinuous and critical conduction mode, however it can also be used in continuous conduction mode. In discontinuous and critical conduction mode, the MOSFET current decays linearly and the controller proportionately backs off its gate-drive output when the on-resistance-induced conduction voltage drop is less than -50mV. Upon the conduction voltage crossing the turning off threshold, the gate drive is turned off quickly to eliminate any reverse current flow (see Figure 4a). If the board is evaluated with a converter in continuous conduction mode, the secondary side circulating current does not decay to zero prior to primary MOSFET turn-on. The controller then turns off the MOSFET quickly when the primary MOSFET current starts rising in less than 50ns delay time, as shown in Fig. 4b, so the possibility of cross conduction is minimized. This is critical because cross conduction due to the primary side MOSFET and secondary rectification MOSFET conducting simultaneously will degrade efficiency due to the nature of the fast transition.



(a)



(b)

Figure 4: Synchronous rectification operating waveforms (a) Critical conduction mode and (b) Continuous conduction mode

Conditioning the power supply to maximize efficiency of ZXGD3101

The ZXGD3101 can be susceptible to noise if a proper snubbing circuit on the primary side is not devised. Any high-frequency-resonance-ringing on the drain of the primary MOSFET will be reflected across the transformer as multiple synchronous MOSFET V_{SD} transitions, which will cause spurious turn-on to occur. The controller is then not able to fully enhance the MOSFET until the oscillation is stabilized. To prevent this problem, the user is advised to strengthen the primary switch snubber circuit through either a damping resistor R_d (see Fig. 5) or alternatively an additional snubbing R-C network. These have the effect of eliminating the oscillation by limiting the peak D_{clamp} reverse recovery current and soften its reverse recovery characteristic. The improvement on the rising edge of the gate drive can be observed as in Figure 6.

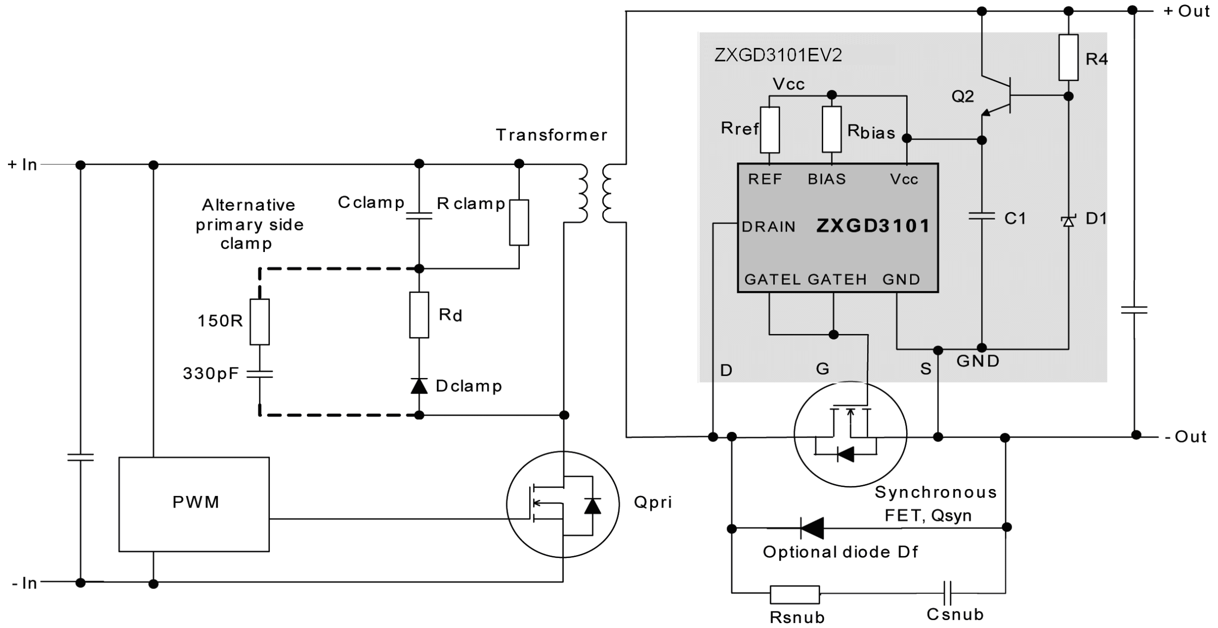
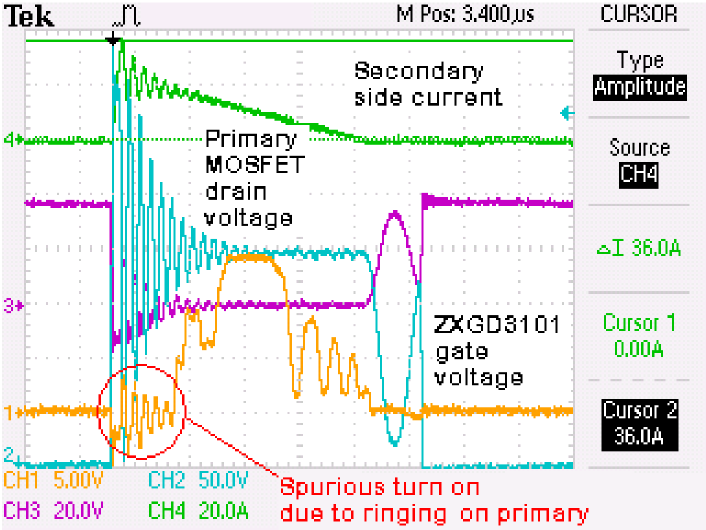


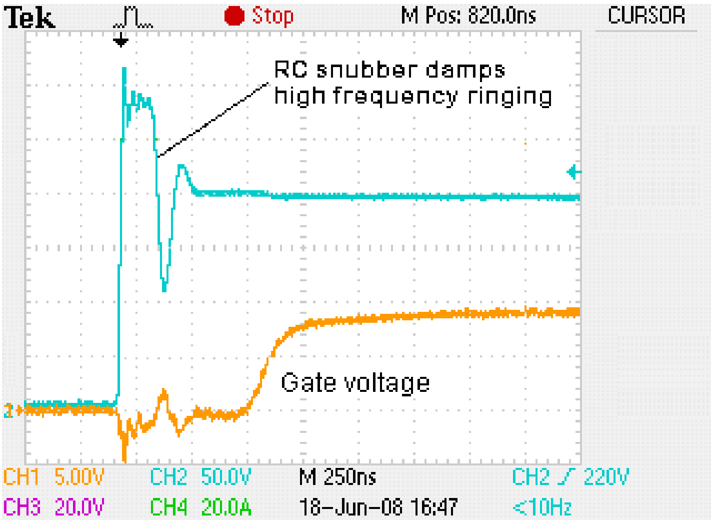
Figure 5: Recommended design for a synchronous rectified Flyback converter

Another snubber network comprising of R_{snub} and C_{snub} should be fitted across the synchronous MOSFET to dampen out high frequency oscillations at the MOSFET's fast turn-off edge. If the amplitude of oscillations is high, then the drain voltage could ring below the turn-on threshold. The controller could then be falsely triggered and provide an output high to drive the MOSFET gate. Apart from preventing premature turn-on of the controller, this also has the added benefit of reducing conducted EMI generation and device voltage stress.

Furthermore, any parasitic inductance due to a combination of printed circuit board traces and component leads can also cause the voltage at the drain input of the ZXGD3101 to ring about ground. Proper layout attention must be paid to ensure the integrity of the V_{SD} differential voltage. To mitigate noise induced malfunction, it is important to keep the drain input on the controller as close as possible to the synchronous MOSFET, preferably within 10mm. A minimal gate drive loop will also negate the effect of loop inductance inducing oscillation to the controller's output gate drive voltage, reducing the requirement for series gate resistor damping.



(a)



(b)

Figure 6: Oscillation-induced spurious turn on reduces efficiency of synchronous rectification (a) Oscillation due to clamp diode recovery (b) Improved clamp circuit

Overcoming premature turn-off

The high current di/dt coupled with low $R_{DS(on)}$ voltage drop causes V_{SD} to rise rapidly toward zero, which could make the controller more susceptible to closed-loop instability-induced malfunction under this circumstance. One phenomenon that could occur particularly with a sub-10mΩ MOSFET is a sudden fall of the ZXGD3101's internal bias transistor voltage gain, which causes the gate drive voltage to back off, even though the MOSFET is still conducting substantial current. When this happens it leads to premature fall-off of the controller gate drive voltage (refer to Fig. 7a) which causes inadequate enhancement of the MOSFET and reduces the effectiveness of synchronous rectification. To make matters worse, the subsequent ringing incurs additional gate charge loss and further deteriorates the efficiency.

If the above mentioned problem is observed, the on-board constant bias current source should be used instead. This could be easily implemented using Q1 alongside R1, R2 and R3 (refer to Fig. 2).

Although the board is originally tracked for Rbias biasing, the set up can be altered by using the solder links SL2 and SL3.

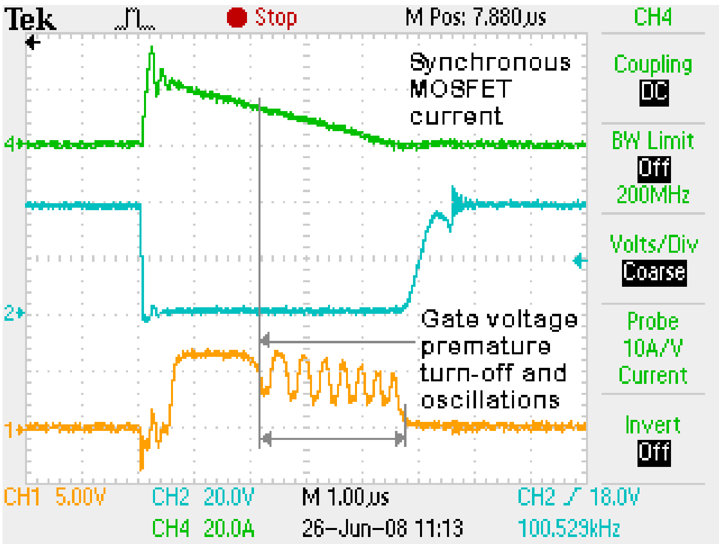
To use the constant bias current source on the evaluation board,

1. Ensure that SL2 is shorted and SL3 is open.
2. Use a multimeter to check that the voltage across test points TP1 and TP2 is approximately 500mV, to ensure that 5mA is sourced into the bias pin.

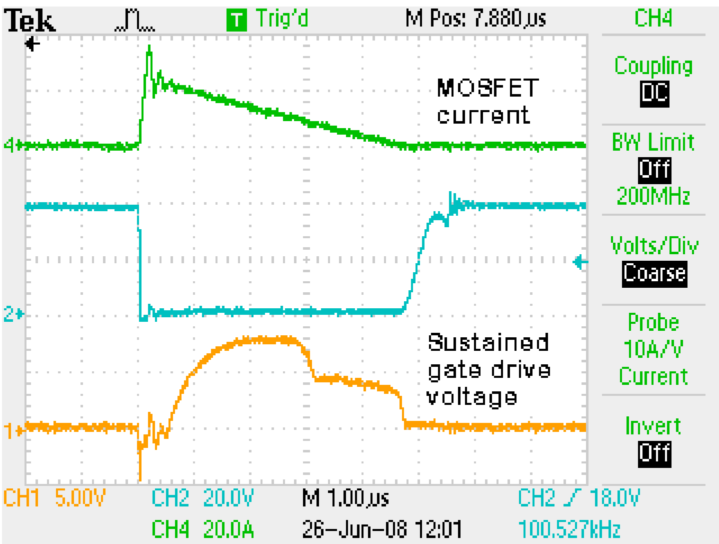
To use the constant current source when VIN is less than 10V,

1. Adjust the value of R1 and R2 accordingly to give 500mV across R3
2. Select new value for Rref according to the formula in the datasheet to source approximately 3mA into the Ref pin.

The set up has the positive effect of sustaining the gate voltage for a longer period within the conduction cycle and thus improving efficiency. The gate drive voltage also has slight amplitude increase yielding better enhancing of the MOSFET. Most importantly, the back-end oscillations observed previously have also been eliminated as shown in Fig. 7b.



(a)



(b)

Figure 7 DCM gate drive voltage a) showing premature turn off and b) premature turn-off and oscillations eliminated using a constant bias current source

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