

User Guide 1.0

IRAC11662-100W

+16V Low-side Smart Rectification 100W Flyback Demo Board User's Guide

by

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1.0 INTRODUCTION

Generally, Schottky diodes are traditional devices use in passive rectification in order to have low conduction loss in secondary side for switching power supplies. The proliferations of synchronous rectification (SR) idea - which is mostly use in buck-derive topologies - have reached the domain of flyback application in recent years. The use of low-voltage-low-Rdson mosfet has become so attractive to replace the Schottky rectifiers in high current applications because it offers several system advantages such as dramatic decrease in conduction loss and better thermal management of the whole system by reducing the cost investment in heat sink and PCB space.

A number of techniques in the implementation of SR in flyback converters are continuously growing from a simple self-driven (secondary winding voltage detection) to a more complex solution using “current transformer sensing” or combinations of both to improve the existing technology. The idea has become quite complicated though and additional discrete devices have made the cost and part counts issue even worse. Moreover, the issue of reverse current conduction (-due to the delay in sensing the sharp drop of secondary current during turn-off phase of the SR) still lingers on in different input line/ output load conditions. The use of a simple fast-rate-direct-sensing of voltage drop across the mosfet (Vsd) using integrated solution has pave the way for a much simpler and effective means of controlling the SR mosfets as well as alleviating the reverse current and multiple-pulse gate turn-ON issues.

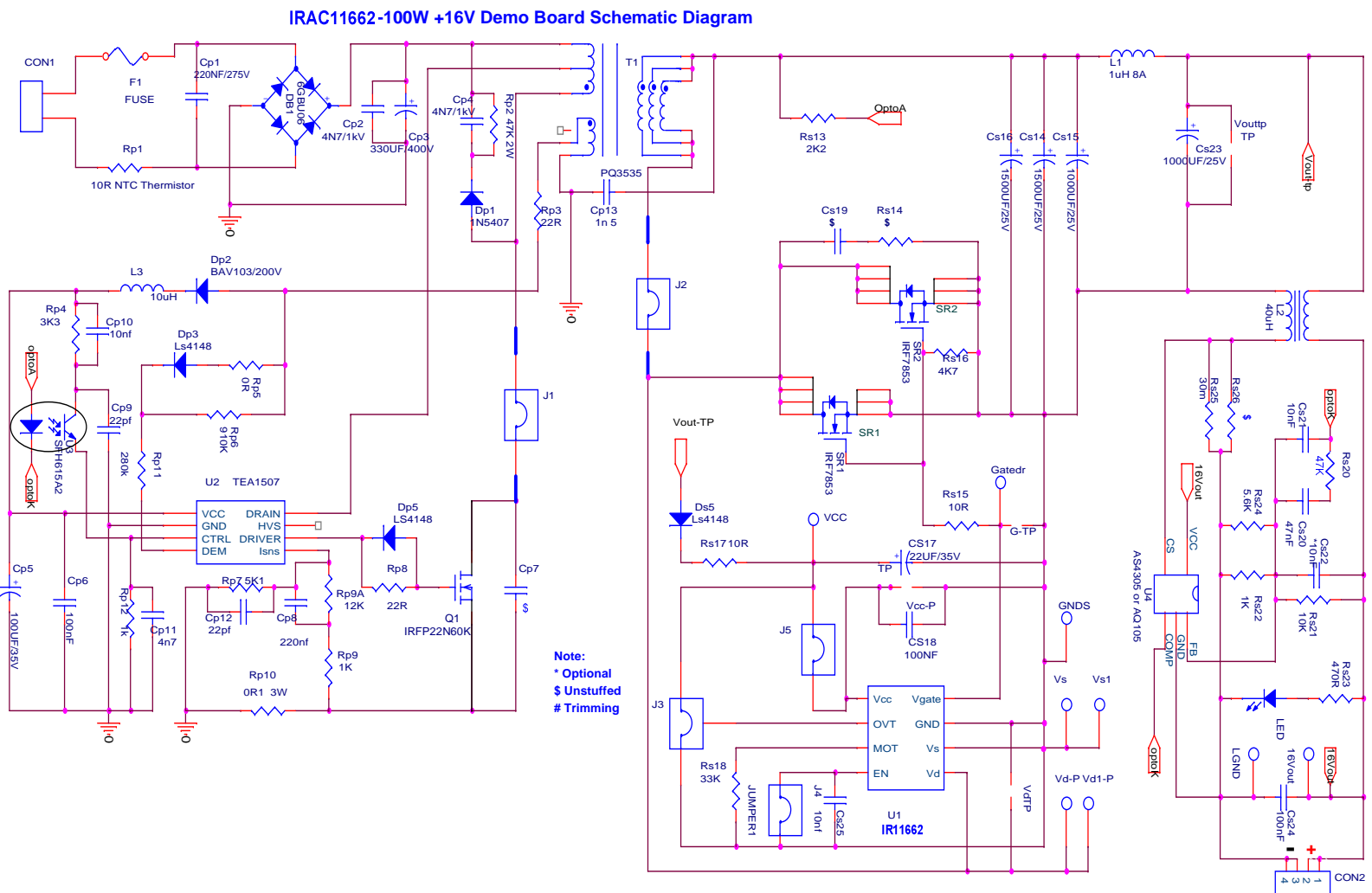
The objective of this user guide is to show the advantages of SR application using integrated IC approach and study the practical limits of the efficiency improvements vs. the normal rectification method.

2.0 GENERAL DESCRIPTION

The IRAC11662-100W demo board is a universal-input flyback converter with single DC output capable of delivering continuous 100W (@ +16V x 6.25A) during active rectification mode. This demo board is primarily designed to study synchronous rectification using IR11662 in low-side configuration to take advantage of simpler derivation of Vcc supply from converter’s output. It is equipped with necessary jumpers to ease exploring the conduction behavior of synchronous rectifiers SRs in quasi-resonant mode, so discussion would be confined to variable frequency switching in Critical Conduction Mode.

It features the fast Vsd sensing of the IR11662 Smart Rectifier Control IC with gate output drive capability of +1A/-4A. It drives 2 pcs. of SRs in parallel (100V N-ch mosfet IRF7853 in SO-8 package with very low Rdson in its class : 18 mΩ max). This had greatly simplified the overall mechanical design for not having those bulky and heavy heat sinks normally seen in high current flyback design using passive rectification.

FIGURE 1. IRAC11662-100W SCHEMATIC DIAGRAM

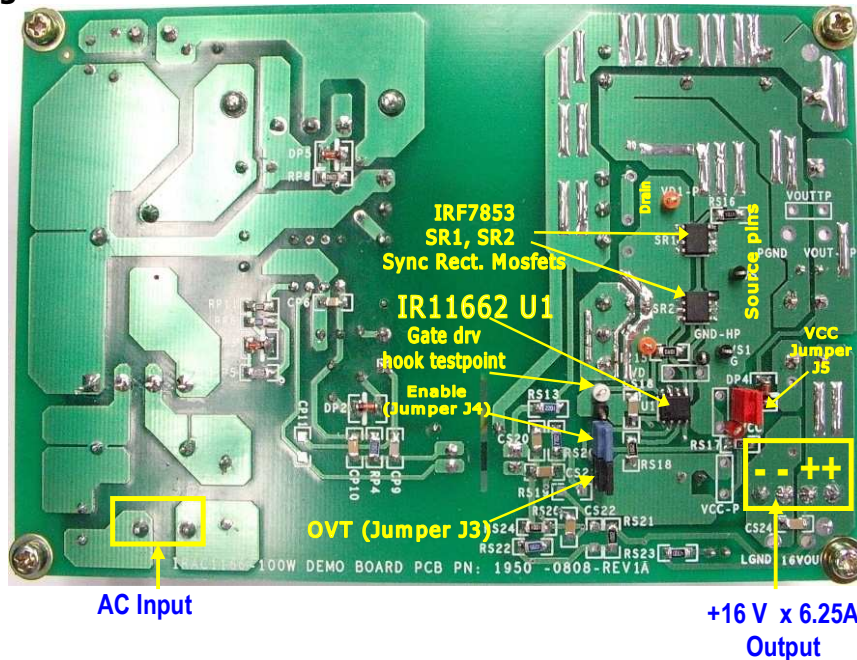


2.1 IRAC11662-100W Demo Board Pictures

Figure 2A. Top side of the IRAC11662-100W Demo Board



Figure 2B. Bottom side of the IRAC11662-100W Demo Board



2.2 PCB Layout for IRAC11662-100W

Figure 3A. Top layer etch with silkscreen print

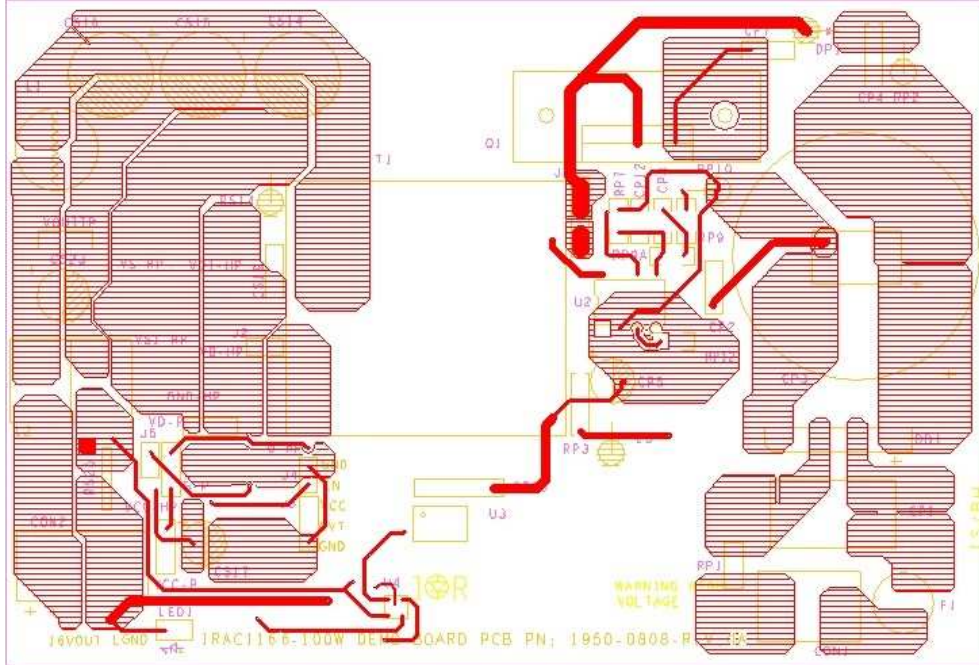
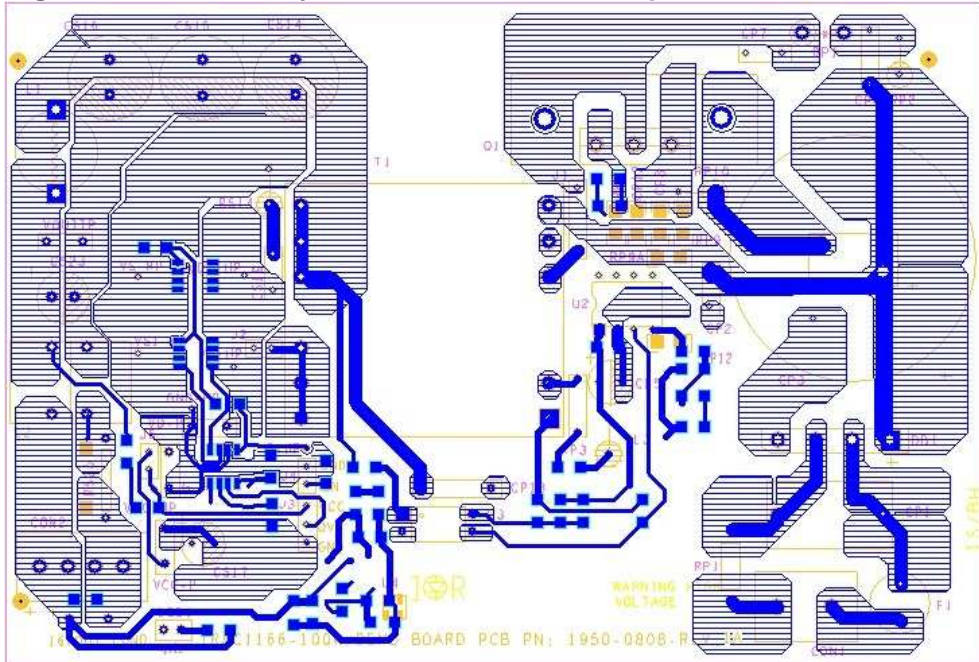


Figure 3B. Bottom layer etch with silkscreen print.



3.0 CIRCUIT DESCRIPTION

The PCB design is basically optimized as a test platform to evaluate of active rectification using Smart synchronous rectification and as well as basic features of flyback converter operating in quasi-resonant mode.

This demo board has 2-pin connector (CON1) for AC input and a time-lag type 3.5A fuse for input current overload protection. Minimum input filtering is provided (Cp1-Xcap) before AC input voltage (90-264VAC) is routed to a 6Amp-bridge rectifier (DB1).

Primary side controller (U2) basically drives the primary Mosfet Q1 to operate in Critical-Conduction mode to eliminate turn-ON switching loss thru ZVS (zero voltage switching only occurs when $nV_{sec} > V_{dcin}$) or thru LVS (low-voltage switching when $nV_{sec} < V_{dcin}$) to reduce capacitive losses of Q1 especially at high line condition. The switching frequency F_{sw} at full load varies from ~38 to ~84kHz typically from low to high input condition and falls back to minimum value (fixed ~ 6 -10kHz) to reduce input power during light load condition.

Auxiliary winding is loosely monitored by demagnetization pin4 of U2 through Dp3, Rp5 and Rp11 network that sets the OVP limit with Rp6 and Rp11 sets the over power limit of the converter.

Optocoupler U3 provides isolated output voltage feedback to the primary side. The output voltage level across load connector CON2 (+16Vo) is monitored and regulated by the V/I Secondary error amplifier U4 (AQ105 or AS4305) that also manages the output current limiting function by monitoring the voltage across the RS25-26 current sense resistors.

The power stage of the secondary is using 2-SO8 low IRF7853 synch-fets (SR) in parallel to implement the low-side synchronous rectification. In this configuration, it is simpler to derive the Vcc supply for the U1 (IR11662 SO8-IC) controller directly from the DC output Vout. Jumper J5 is used to isolate U1's Vcc from Vout so that user may easily evaluate IC's power consumption especially during standby load condition. In the absence of a sensitive low current probe, the quiescent current I_{cc} through Dp4 can be calculated from the differential voltage across the Rs17. The decoupling capacitor Cs17 and Cs18 provides additional filtering which is necessary to clean high frequency noise especially when U1 is driving several mosfets (SR1 // SR2) with high Qg parameters normally associated with high current-low voltage mosfets.

The Vd and Vs sense pins monitor the voltage (Vsd) across the sync rect mosfets and proper attention was taken during PCB routing to ensure the integrity of differential voltage Vsd. This is done by directly taking the signal Vd from the drain pins of SR1//SR2 using a dedicated trace.

Probe points as well as redundant test hook points are provided to facilitate easy probing of essential test waveforms.

4.0 TEST CONNECTION AND SETUP DIAGRAM

4.1 Recommended setup for Voltage and Current probing

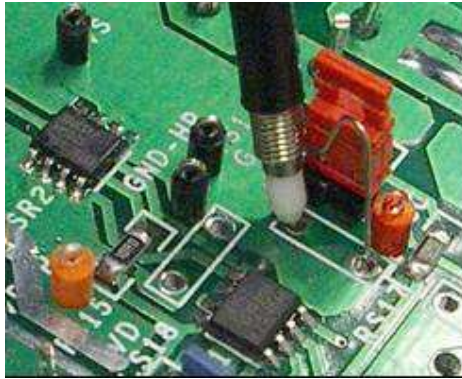


Fig. 4A Direct gate voltage probing using tip & gnd spring.



Fig. 4C Connecting O-scope probe to hook Gate drive test points.

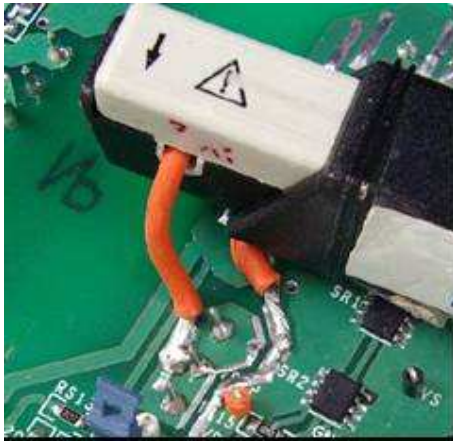


Fig. 4B Recommended probing of secondary current waveform.



Fig. 4D Recommended probing of Vout's Ripple & Noise voltage.

5.0 CIRCUIT FEATURES

5.1 OVT setting:

The Offset Voltage Threshold can be easily selected by changing the position of jumper J3 according to system mode of operation as shown on Table 1 below. Since the demo board is practically designed to operate in **Critical conduction mode**, OVT pin can be left floating or grounded to prolong the MOSFET's channel conduction period a bit compared to connecting it to Vcc. As a result, this would give the advantage of further reducing the conduction period of the MOSFET's (SR1 & SR2) body diode, thus achieving more efficient operation. Reducing the chance of having reverse current during the fast turn-off phase of the sync-fets is another strong reason for having this feature available.

Table 1

| System mode of operation | OVT connected to |
|--------------------------|---------------------------------------|
| DCM or CrCM | Ground, $V_{TH1} = -3.5\text{mV}$ |
| Boundary CCM | Floating, $V_{TH1} = -10.5\text{mV}$ |
| CCM | V_{CC} , $V_{TH1} = -19.0\text{mV}$ |

The general observation during light load condition (~10-20% full load) is that a ~0.5 to ~1.2% efficiency improvement was seen for OVT=Gnd compared to OVT=floating. This small difference is no longer significant when the load becomes heavy for CrCM operation.

5.2 Enable setting:

The IC is enabled by default knowing that EN pin is tied internally to VCC through a resistor. Having a jumper on J4 location will connect EN pin to Gnd and will immediately disable the internal gate drive circuit of the IR11662 IC. By putting a jumper J4 in/out would help the user to quickly evaluate the effect in efficiency by investigating the change in input power as a result of having SR fets working compared to just having an ordinary passive rectification offered by the body diode(s) when the gate drive is disabled.

CAUTION :

This demo board is basically designed for evaluation of functionality of IR11662 IC. The users may disable the IC by shorting J4 EN to GND for quick testing at full load but with care should be taken. It is strongly advise not to load more than 4.6 - 6Amp with IR11662 disabled for a prolong period of time (>1min). This is to prevent damaging the MOSFET's body diode due to overheating when the load current passes through the mosfets' body diode while SRs are turned-OFF. Never power-up the unit without shorting J5.

5.3 Minimum ON Time (MOT) setting:

MOT setting is used to de-sensitize the IC from multiple change in Vsd during the turn-ON phase of SRs which is cause by the ringing of the secondary winding voltage (Vsec). MOT can be adjusted through Rs18 (according to AN1087 simplified equation $R_{MOT} = 2.5 \times 10^{10} * t_{mot}$) and is chosen to be 1.2us which is usually enough to ignore the parasitic noises at Vsd in a quasi-resonant switching converters such as this demo board.

5.4 Mosfet Selection Design Tips

Application note AN1087 has made it easy to understand the calculations required in flyback sync-rect driving circuits using IR116x series ICs. Choosing the right mosfet(s) to satisfy the performance–cost requirement of any sync rect design should be simple as well.

Voltage rating:

SRs should also follow similar equation in most flyback design as shown below:

$V_{sd} > k * [V_o + (V_{DCin_{max}} / (N_{pri} / N_{sec}))]$ where $k = 1.1$ to 1.4 as a guard band for startup stress due to leakage spike.

RdsON rating:

Generally, it is easy to meet >1% system efficiency improvement if the conduction loss of the SRs becomes twice smaller than normal passive rectification approach. This is to achieve better thermal performance especially if the designer wishes to consider not having too bulky and heavy heatsink in the design, but take note that it would still be largely dependent on the size PCB copper area allotted to the SRs. We should also consider the estimated RdsON at 25°C (normally shown in the datasheet) would be approximately ~1.8 times higher at Tj=125°C. As a rule of thumb, we will base our calculation on these assumptions to simplify the mosfet selection criteria.

For typical 100V Schottky rectifiers, Vf is around ~ 600 mV (@Tj=125°C), so in this case we should find a 100-V mosfet(s) with lower RdsON which will have a ~150mV max Vsd at rated full load current (Io_ave). For quick estimation of Isec_rms, designer might find Fig. 9.1 useful to quickly estimate Isec_rms since Io_ave is normally given as standard design specs.

Calculating the rms value of secondary current is easier for CrCM mode where

$$D = N * V_{sec} / (N * V_{sec} + V_{dcin_{min}}) \quad \text{eqn. 1}$$

$$N = N_{pri} / N_{sec}, \quad N = 31/5$$

Let V_sec = 16.1, Vdcm=100, D= ~50%

$$h = V_f (\text{Schottkydiode}) / V_{sd}(\text{mosfet}) \quad \text{eqn.2}$$

$$P_{dis SR} < 1/h * V_{fdiode} * I_{o_{ave}} \quad \text{eqn.3}$$

With $h > 2$,

$$\text{Target } V_{SD(@Tj=125^\circ C)} \leq 600mV / 2$$

$$\leq \underline{300mV}$$

$$I_{sec_{rms}}^2 * R_{dsON} (@Tj=125^\circ C) \leq 300 mV * I_{o_{ave}} \quad \text{eqn.4}$$

$$R_{dsON} (@Tj=125^\circ C) = \sim 1.8 * R_{dsON} (@Tj=25^\circ C) \quad \text{eqn.5}$$

$$I_{sec_{rms}} = \frac{2I_{o_{ave}} \sqrt{(1-D)/3}}{(1-D)} \quad \text{eqn.6}$$

Combining equations 4, 5, and 6

$$R_{DS_{ON}} @Tj=25^\circ C \leq \frac{166mV [3(1-D)]}{4I_{o_{ave}}} \quad \text{eqn.7}$$

$$R_{DS_{ON}} \leq \frac{0.125 * (50\%)}{I_{o_{ave}}} = \frac{0.125 * 0.5}{6.25} = 0.010\Omega$$

$$R_{dsON} @Tj=25^\circ C \leq \underline{10 m\Omega}$$

We can use 2-SO8 mosfets (IRF7853) in parallel having equivalent RdsON (@Tj=25°C) of ~9 mΩ.

Note : Vsd(@Tj=125°C) < 100mV would yield lower RdsON and can be achieve better thermal performance but it would mean raising the parts count and cost.

6.0 TEST WAVEFORMS

6.1.1 Transient Test

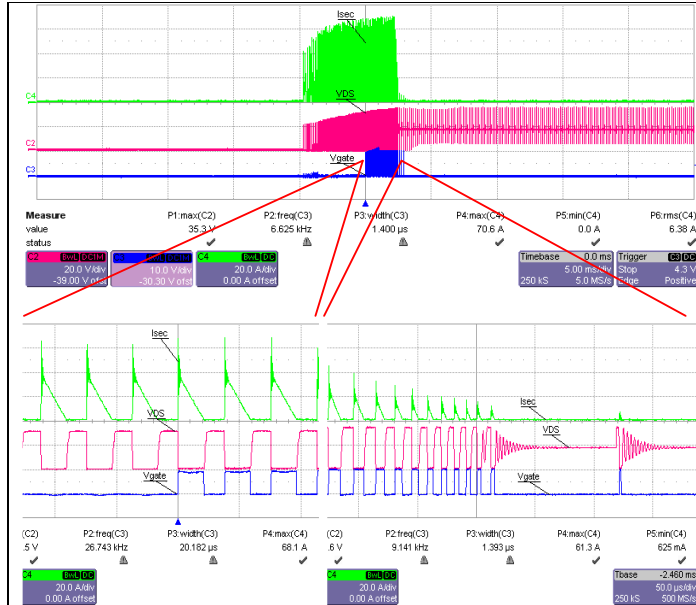


Fig 6A - 90 Vacin startup @ no load.

Ch2 : Vsd of sync rect (SR)
 Ch3 : Vgate of SR1 & SR2
 Ch4 : Isd

Vsd of sync rects are quite clean. IR11662 starts operation when Vcc exceeds Vcc turn on threshold. Prior to the activation of the IC, the body diodes of the sync rect mosfets act as the passive rectifiers. The VD (fsw : ~10kHz) pulses became so narrow after the output voltage stabilizes and reached the regulation at no load condition. After the output voltage getting stable, IR11662 detects the light load situation and disables gate output. (-see Fig. 6G for more details).

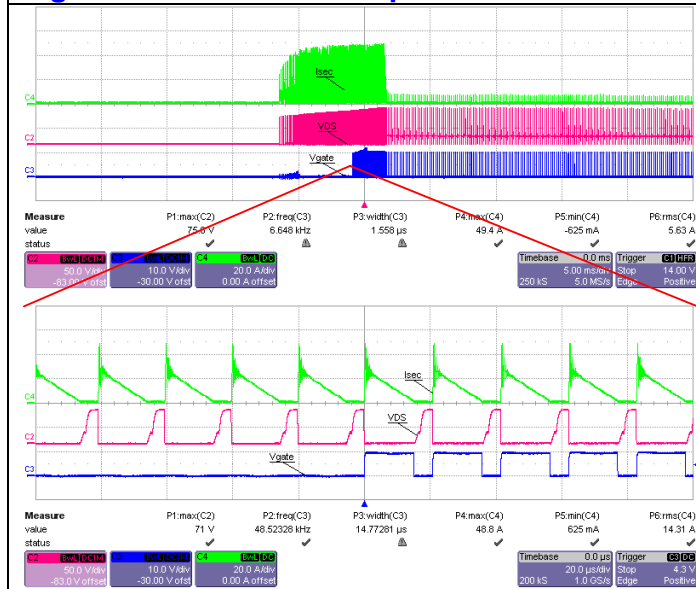


Fig 6B - 265 Vacin -startup @ no load.

Ch2 : Vsd of sync rect (SR)
 Ch3 : Vgate,
 Ch4 : Isd

Vsd of sync-rects is uniform and switching regularly.

Gate drive pulses become narrow at light load condition and the switching frequency decreases after the output voltage reached its regulation level.

The zoom view shows no reverse current during startup at no load.

The gate voltage of IR11662 is clamped at ~10V. The clamping circuit kicks in when Vcc voltage is approximate 13V.

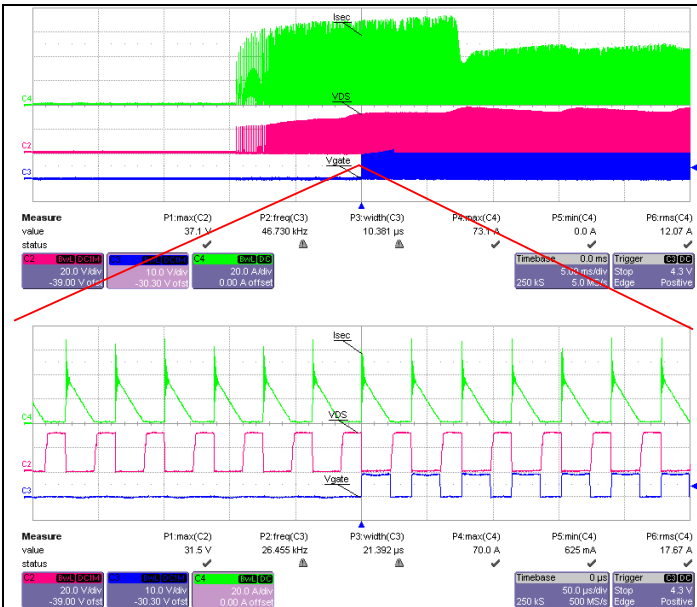


Fig 6C - 90 Vacin 100W full load startup.

Ch2 : Vsd of sync rect (SR)
Ch3 : Vgate of SR1 & SR2
Ch4 : Isd

IR11662 gate drive started ~10ms after power-up.

The zoom view shows no reverse current during startup at full load.

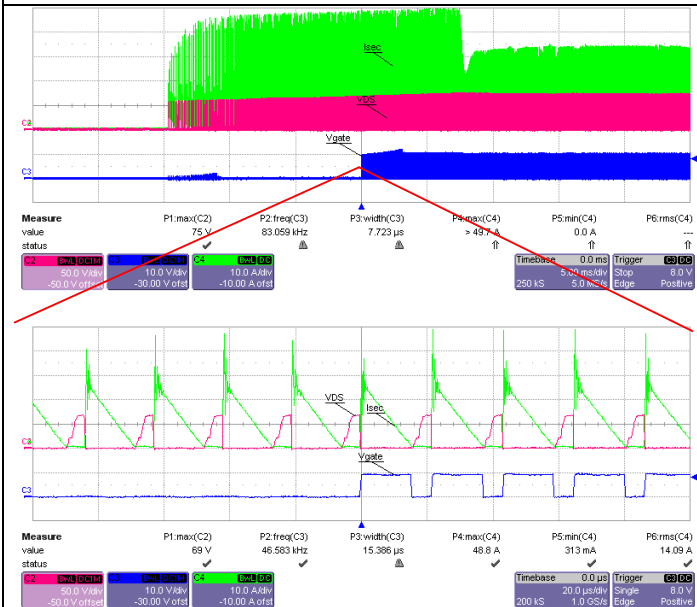
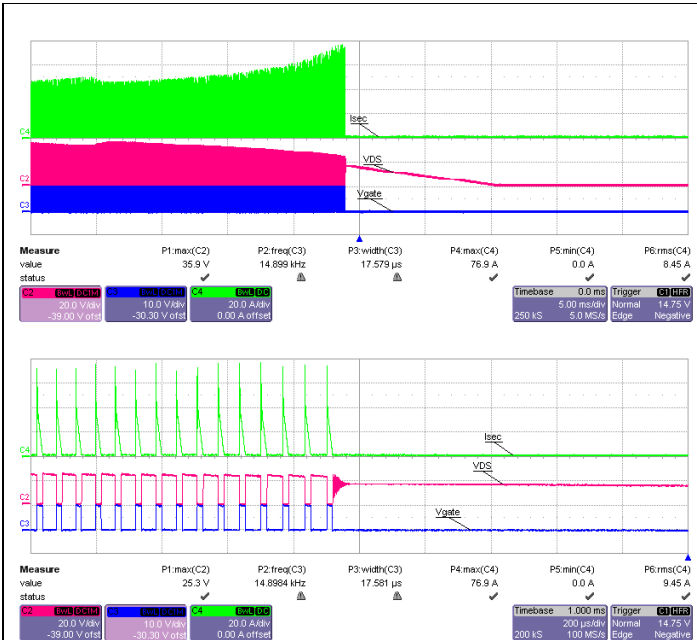


Fig 6D - 265 Vacin 100W full load startup.

Ch2 : Vsd of sync rect (SR)
Ch3 : Vgate of SR1 & SR2
Ch4 : Isd

IR11662 gate drive started ~15ms after power-up.

The zoom view shows no reverse current during startup at full load.

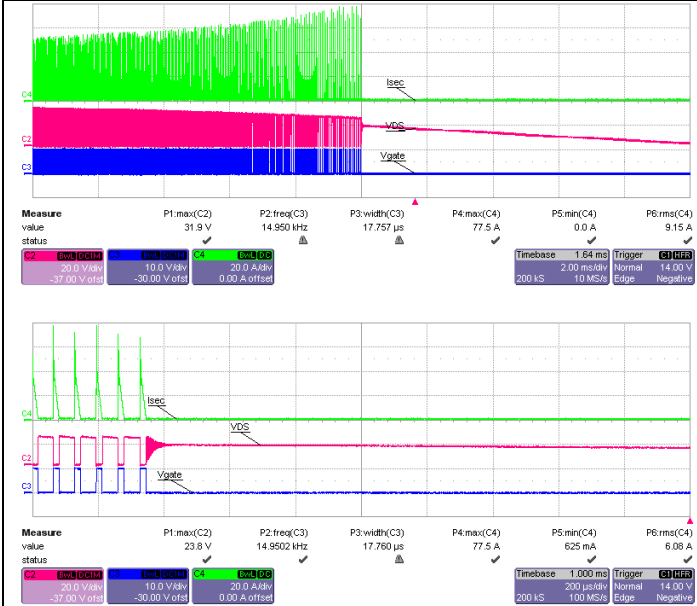


Ch2 : Vsd of sync rect (SR)
Ch3 : Vgate of SR1 & SR2
Ch4 : Isd

Vsd of sync-rects switching freq. drops to ~15kHz at power shutdown.

The zoom view shows no reverse current during power-off.

Fig 6E - Power down @ 90Vacin @ 100W full load



Ch2 : Vsd of sync rect (SR)
Ch3 : Vgate of SR1 & SR2
Ch4 : Isd

No reverse current during power-off.

Fig 6F - Power down @ 265Vacin @ 100W full load

6.1.2 Static Load Test

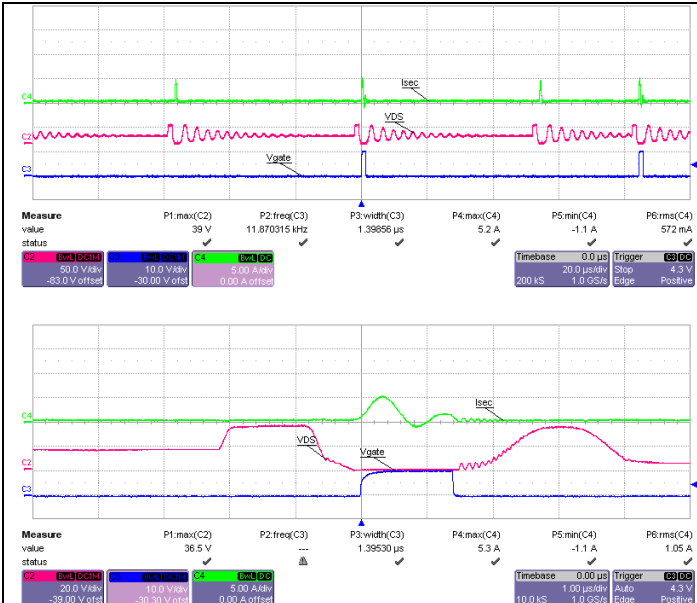


Fig. 6G - 90Vac in, 16Vout / no load

Ch2 : Vsd of sync rect (SR)
Ch3 : Vgate of SR1 & SR2
Ch4 : Isd

Vsd of sync-rects are switching at ~foldback freq (~12kHz DCM oper'n) at no output load condition.

Vgate became a narrow (~1.4us) pulses during no load standby operation. As the secondary current conduction time is very close to the set MOT time, IR11662 disables gate output every other cycle (cycle skipping).

The standby power at 90Vac is 0.98W with 28mA/ 460mW dummy load.

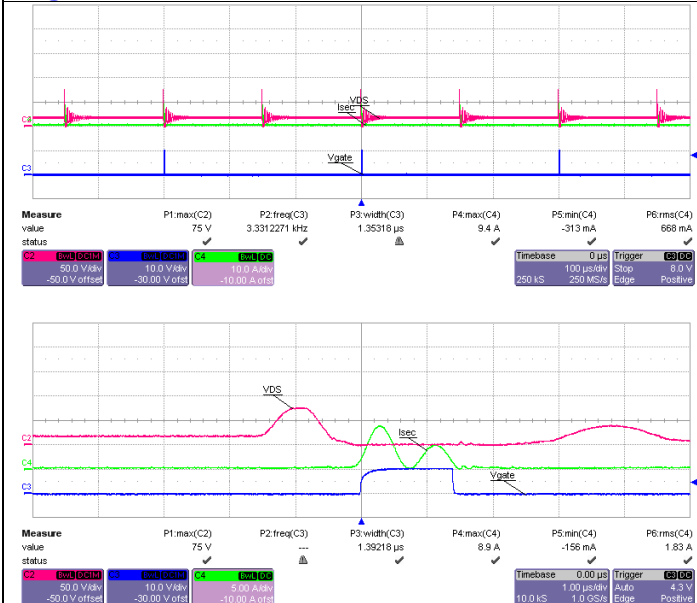


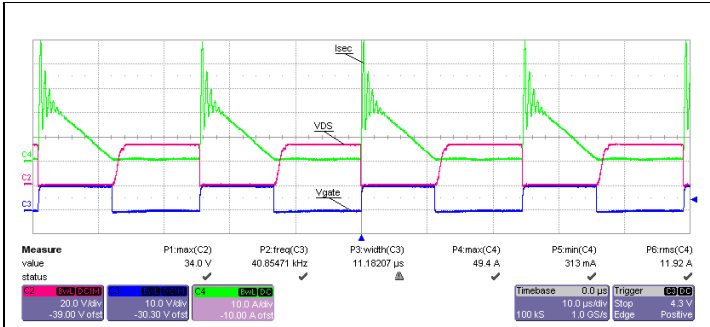
Fig. 6H - 265Vac in, 16Vout / no load

Ch2 : Vsd of sync rect (SR)
Ch3 : Vgate of SR1 & SR2
Ch4 : Isd

Fsw falls back to a fix low frequency around ~6kHz with gate pulse width reduce to a narrow ~1.4usec.

IR11662 has cycle skipping at high line - no load condition. This helps to reduce the gate driver losses.

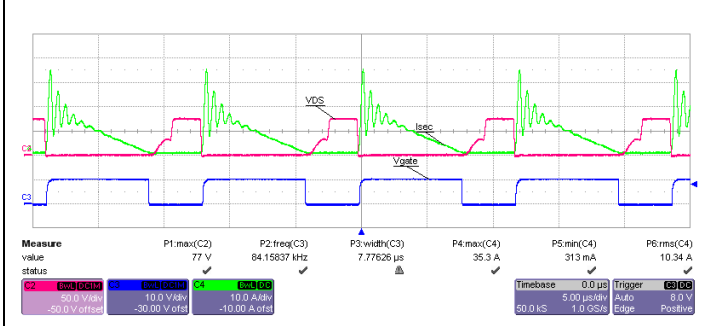
The standby power at 265Vac is 1.1W. This is under 28mA/ 460mW dummy load (Rs23 and the Green LED) condition.



Ch2 : Vsd of sync rect (SR)
Ch3 : Vgate of SR1 & SR2
Ch4 : Isd

Fsw : ~40 kHz

Fig. 6I - 90Vacin, 16Vout / 6.25A full 100W load

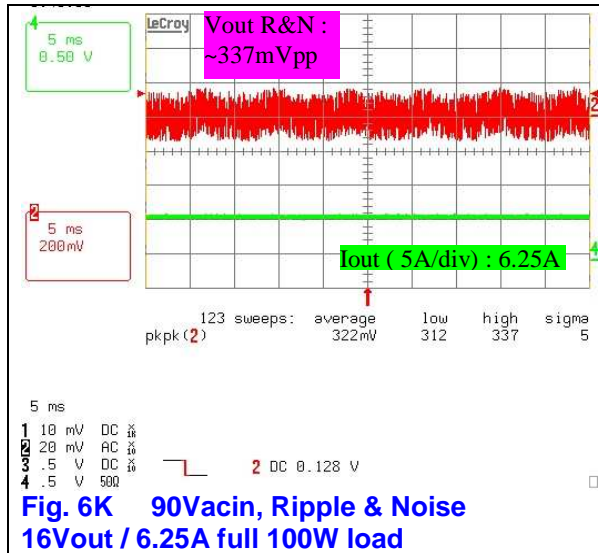


Ch2 : Vsd of sync rect (SR)
Ch3 : Vgate of SR1 & SR2
Ch4 : Isd

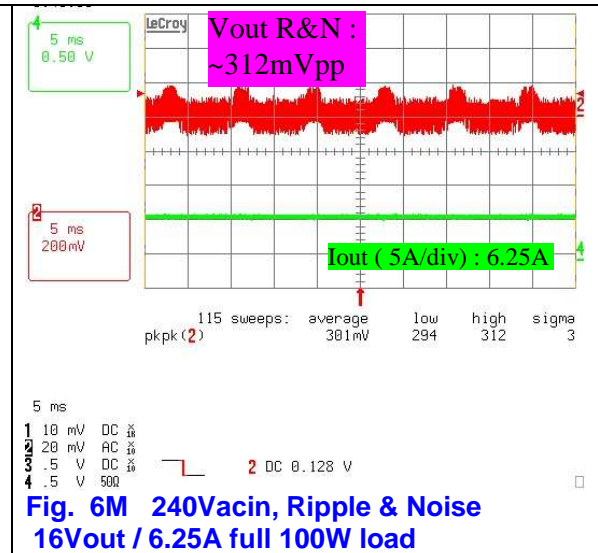
Fsw : ~84 kHz

Fig. 6J - 265Vacin, 16Vout / 6.25A full 100W

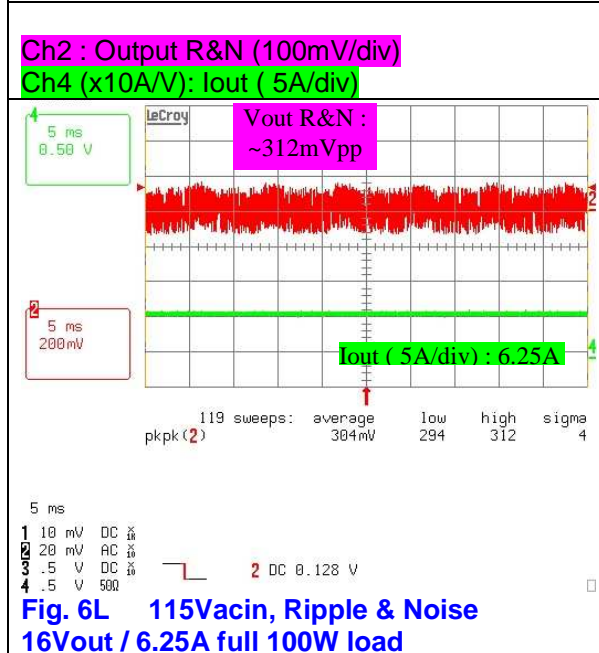
6.2 Ripple & Noise Measurement



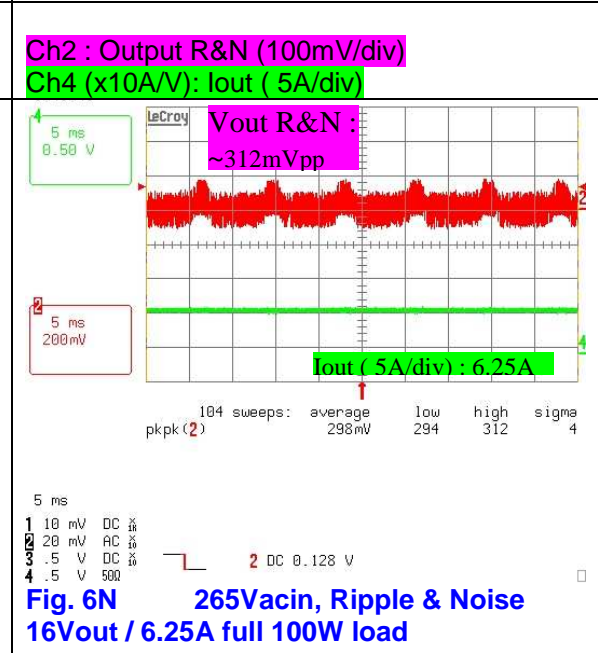
**Fig. 6K 90Vacin, Ripple & Noise
16Vout / 6.25A full 100W load**



**Fig. 6M 240Vacin, Ripple & Noise
16Vout / 6.25A full 100W load**



**Fig. 6L 115Vacin, Ripple & Noise
16Vout / 6.25A full 100W load**



**Fig. 6N 265Vacin, Ripple & Noise
16Vout / 6.25A full 100W load**

6.3 Dynamic Load Test (0 – 100% rated load, +/- 2.5A/usec)

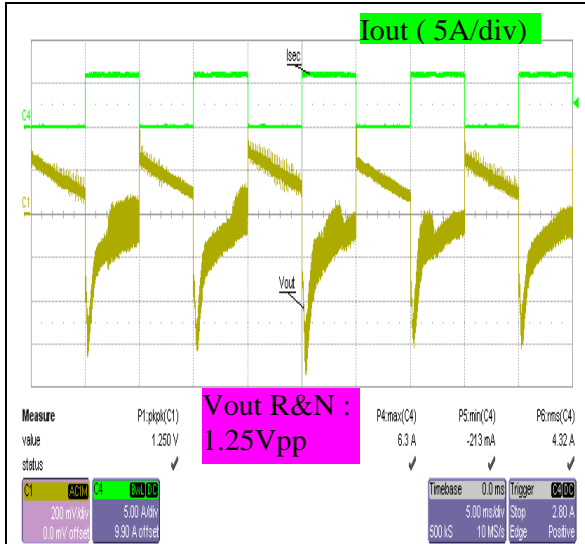


Fig. 6O 90Vacin, Ripple & Noise
+16Vout , 6.25A 5msec, 0A 5msec

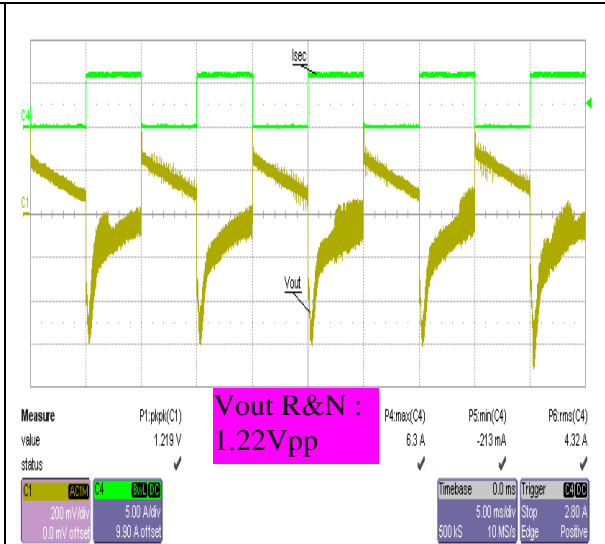


Fig. 5Q 240Vacin, Ripple & Noise
+16Vout , 6.25A 5msec, 0A 5msec

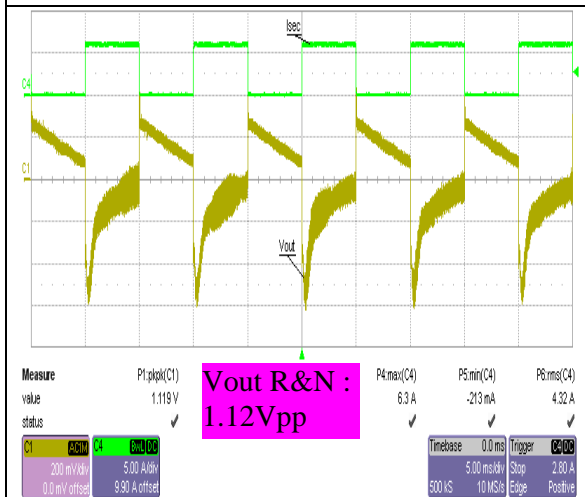


Fig. 5P 115Vacin, Ripple & Noise
+16Vout , 6.25A 5msec, 0A 5msec

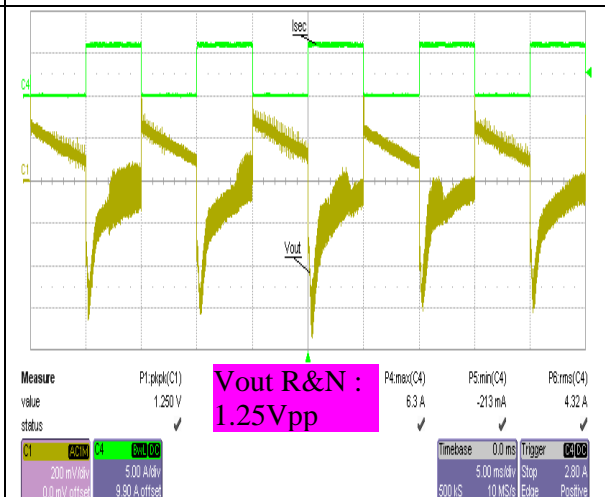


Fig. 5R 265Vacin, Ripple & Noise
+16Vout , 6.25A 5msec, 0A 5msec

7.0 LINE/ LOAD REGULATION TEST

7.1 IR11662 Demo Board V-I Characteristics

| Vin | 90 | 115 | 230 | 265 |
|----------|----------|----------|----------|----------|
| Iout (A) | Vout (V) | Vout (V) | Vout (V) | Vout (V) |
| 0 | 16.049 | 16.049 | 16.049 | 16.052 |
| 1 | 16.052 | 16.053 | 16.058 | 16.063 |
| 2 | 16.054 | 16.055 | 16.063 | 16.068 |
| 3 | 16.053 | 16.054 | 16.061 | 16.07 |
| 4 | 16.054 | 16.055 | 16.058 | 16.066 |
| 5 | 16.054 | 16.056 | 16.059 | 16.064 |
| 6 | 16.055 | 16.057 | 16.062 | 16.064 |
| 6.25 | 16.046 | 16.051 | 16.062 | 16.064 |
| 6.5 | 16.02 | 16.03 | 16.05 | 16.06 |
| 6.75 | 14.2 | 14.27 | 14.33 | 14.1 |
| 7 | 10.29 | 10.34 | 10.4 | 10.36 |
| 7.25 | Bounce | Bounce | Bounce | Bounce |

Table 2. V-I Characteristics

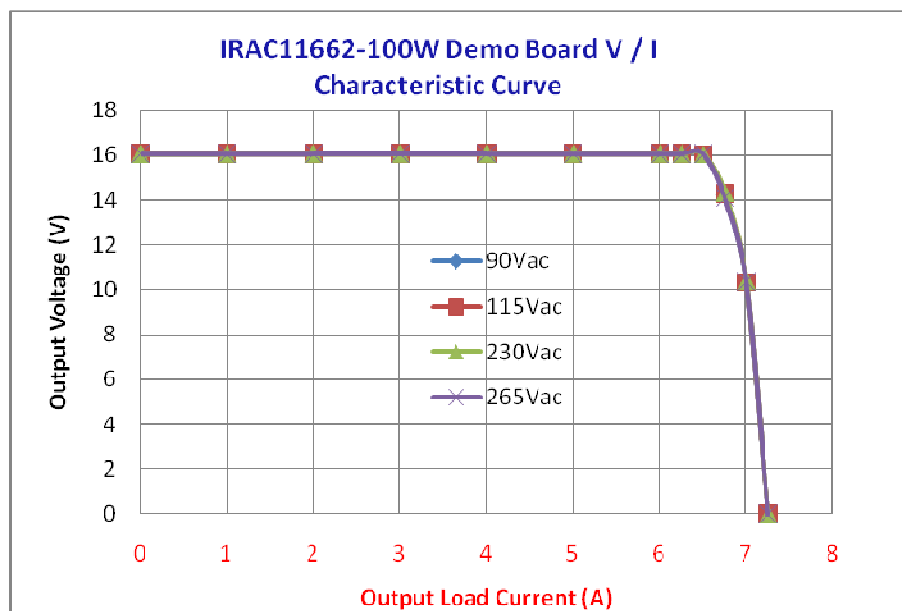


Figure 7.1. Output Voltage vs. Load Current Characteristic Curve

7.2 System Efficiency Test

Table 3

| VinAC | Vout V | Iout (A) | Pout (W) | Pin (W) | Efficiency |
|-------|--------|----------|----------|---------|------------|
| 90 | 16.046 | 6.244 | 100.2 | 117.3 | 85.41% |
| 115 | 16.051 | 6.244 | 100.2 | 115.5 | 86.77% |
| 230 | 16.062 | 6.244 | 100.3 | 115 | 87.21% |
| 265 | 16.064 | 6.244 | 100.3 | 116 | 86.47% |

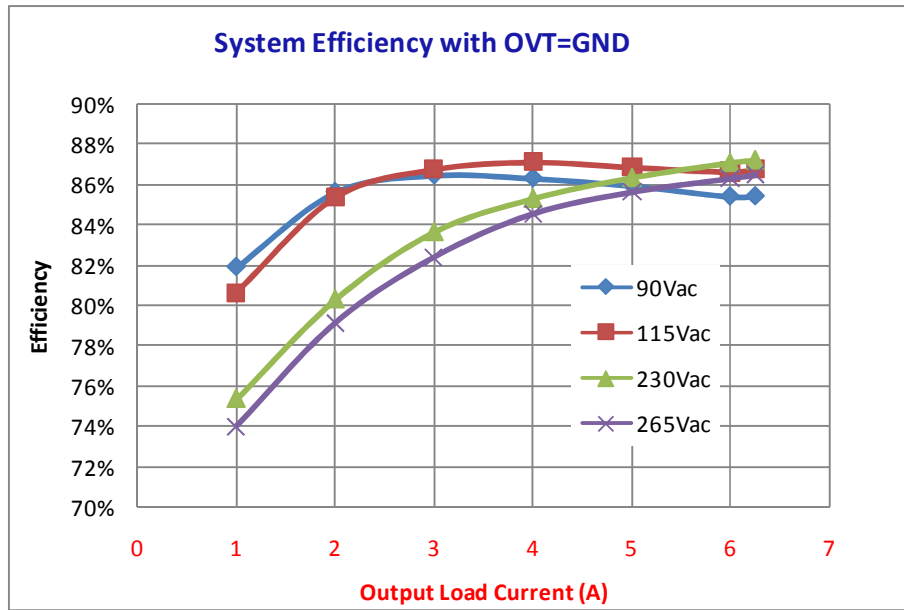


Fig. 7.2A System Efficiency with OVT = Gnd

7.3 Thermal Verification

Table 4

| IRAC11662-100W | 90VACin | 265VACin |
|----------------------------|----------------|-----------------|
| Ambient Temp | 26 | 26 |
| IR11662 (SO-8 IC) | 73 | 70 |
| SR1 (IRF7853 SO8 FET) | 95 | 84 |
| SR2 (IRF7853 SO8 FET) | 96 | 85 |
| Q1 (IRF22N60K) | 58 | 65 |
| DP1 (UF5407) Snubber diode | 62.5 | 69.5 |
| 330uF/400V MXR Bulk Ecap | 50 | 50 |
| Power transformer (PQ3535) | 75.5 | 76 |
| Input bridge rectifier | 67 | 49 |
| Pin (W) | 117.3 | 116 |
| Vout (A) | 16.05 | 16.06 |
| Iout (A) | 6.25 | 6.25 |
| Efficiency | 85.5% | 86.5% |

Note : All case temperature in °C.

8.0 Summary :

This demo board showcases the performance of IR11662 SmartRectifier Control IC to drive mosfets (as synchronous rectifiers) by simple fast-rate direct-voltage-sensing technique. It also featured the flexibility of the IC to cope with different current conduction modes of flyback converter designs.

The low-side synchronous rectification is fully demonstrated in this demo board, which operates in variable frequency critical conduction mode (VF-CrCM). This configuration has lead to achieve better efficiency and a much simpler overall system design normally required in single output flyback high current applications such those use in laptop power adaptors.

This 100W demo board has shown the efficiency improvement using low voltage SO8 mosfets – replacing the traditional Schottky rectifiers - has brought a string of advantages such as avoiding the use of heavy heat sinks and simple gate drive circuit for the synchronous mosfets. This design simplification has resulted to saving in PCB area due to reduction of part counts and elimination of bulky heat sink. IR11662 automatically disables or skips gate output at no load condition thus minimizes the standby power losses.

9.1 Transformer turns ratio, Duty Cycle and Secondary Current Relationship

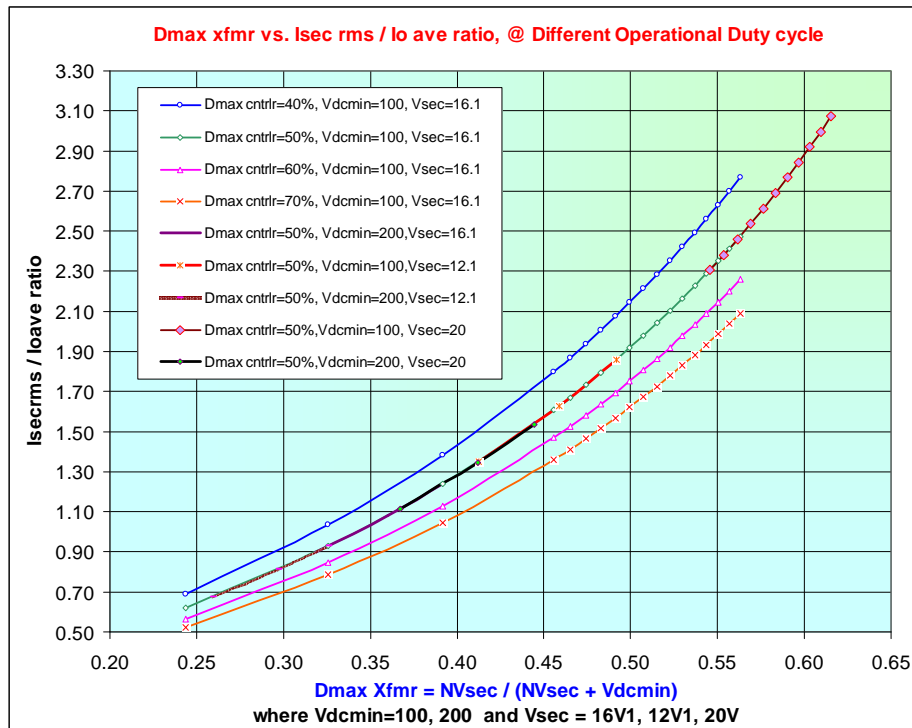


Fig. 9.1 Graphical estimation chart for $I_{sec\ rms} / I_{o\ ave}$

9.2 IRAC11662-100W +16V SR Demo Board Power Transformer Specification

Winding W1 : 15 turns 2 x AWG#20
 Winding W2 : 5 turns 3 x TIW (0.55 mm)
 Winding W3 : 5 turns 3 x TIW (0.55 mm)
 Winding W4 : 5 turns AWG#30
 Winding W5 : 5 turns 3 x TIW (0.55 mm)
 Winding W6 : 16 turns 2 x AWG#20
 Core type : PQ3535
 Ferrite material : PC44 TDK / Nicera equivalent

Lpri : 250uH +/-15% (pin 6-4)
 Finishing : Dip varnish / vacuum

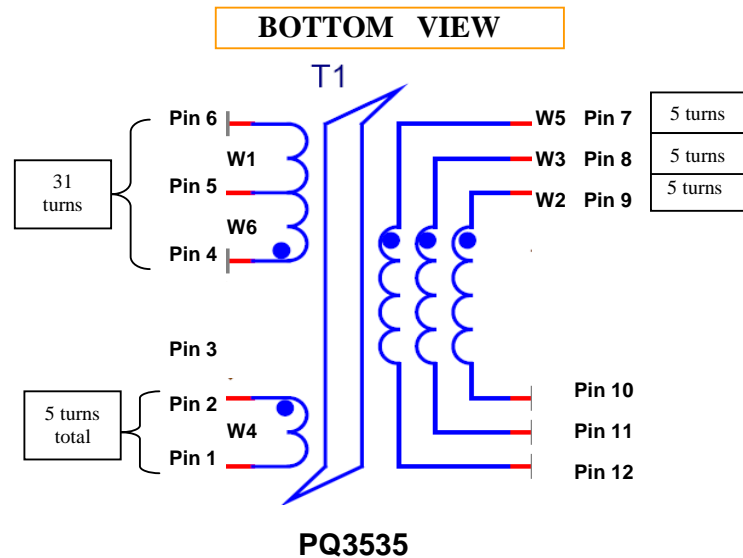


Fig. 9.2 Power transformer Winding Termination Diagram

Note : TIW = triple insulated wire

10.0 IRAC11662-100W +16V Demo Board Bill of Material (BOM)

Note: TH = Through-hole Date : 8-Mar-2010

| Item # | Qty. | Value | Part Ref. | Description | Manuf. PN. |
|--------|------|-----------------|------------------|---|--|
| 1 | 1 | 2-PIN | CON1 | 2 way connector (TH) | PN: 5417 or List No. : 39-26-3030 |
| 2 | 1 | 4-PIN | CON2 | 4 way connector (TH) | PN: 5417 or List No. : 39-26-3040 |
| 3 | 1 | 220NF/275V | CP1 | KNB1560 0.22UF 10% 275 L30 R15 (TH) | KNB1560 0.22UF 10% 275 L30 R15 |
| 4 | 1 | 4NF7/1KV | CP2 | CAPACITOR, 4.7NF 1000V (TH) | DEBF33A472ZC1B(Murata) |
| 5 | 1 | 330UF/400V | CP3 | CAPACITOR, 330UF 400V (TH) | 400MXR330M35X35 (Rubycon) or EET-ED2G331EA - (Panasonic) |
| 6 | 1 | 4NF7/1KV | CP4 | CAPACITOR, 4.7NF 1kV (TH) | DEBF33A472ZC1B (Murata) |
| 7 | 1 | 100UF/35V | CP5 | CAPACITOR, 100UF 35V (TH) | UPL1V101MPH NICHICON |
| 8 | 1 | 0.1UF | CP6 | CAPACITOR, 1206 100 NF 50V | 12065C104KAT00J |
| 9 | | UNSTUFFED | CP7 | UNSTUFFED | |
| 10 | 1 | 0.22UF | CP8 | CAPACITOR, 1206 220NF 50V | 12065G224ZAT2A (AVX) |
| 11 | 1 | 22PF | CP9 | CAPACITOR, 1206 22PF 50V | 12061A220JAT2A (AVX) |
| 12 | 1 | 10NF | CP10 | CAPACITOR, 1206 10NF 50V | 12065G103ZAT2A (AVX) |
| 13 | 1 | 4N7F | CP11 | CAPACITOR, 1206 4.7NF 50V | 12065C471KAT2A (AVX) |
| 14 | 1 | 22PF | CP12 | CAPACITOR, 1206 22PF 50V | 12061A220JAT2A (AVX) |
| 15 | 1 | 1N5 | CP13 | CAPACITOR, X1/Y1 1.5NF (TH) | DE1E3KX152MA5B (Murata) |
| 16 | 1 | 1000UF/25V | CS14, CS15 | CAPACITOR, 1000UF 25V (TH) | 25ZL1000M12.5X20 (Rubycon) |
| 17 | 1 | 1500UF/25V | CS16 | CAPACITOR, 1500UF 25V (TH) | 25ZL1500M12.5X25 (Rubycon) |
| 18 | 1 | 22UF/35V | CS17 | CAPACITOR, 22UF 50V (TH) | 50ZL22M5X11 (Rubycon) |
| 19 | 1 | 100NF | CS18, CS24 | CAPACITOR, 1206 100NF 50V | 12065C104KAT00J (AVX) |
| 20 | | UNSTUFFED | CS19 | UNSTUFFED | |
| 21 | 1 | 47NF | CS20 | CAPACITOR, 1206 47NF 50V | 12065C473KAT2A (AVX) |
| 22 | 2 | 10NF | CS21, CS22, CS25 | CAPACITOR, 1206 10NF 50V | 12065C103KAT2A (AVX) |
| 23 | 1 | 820UF/25V | CS23 | CAPACITOR 820UF, 25V (TH) | EEUFC1E821. |
| 24 | 1 | 6GBU06 | DB1 | 6-Amp 800V Bridge rectifier diode (TH) | 6GBU06 -(General Semiconductor) |
| 25 | 1 | 1n5407 | DP1 | DIODE, 3A 800V (TH) | 1N5407 (General Semiconductor) |
| 26 | 1 | BAV103/200V | DP2 | DIODE, SWITCHING SOD-80C | Philips BAV103 |
| 27 | 3 | LS4148 | DP3, DP4, DS5 | DIODE, QUADRO-MELF | LS4148 (VISHAY) |
| 28 | 1 | T3.15A/250V | F1 | FUSE, TR5 ANTISURGE 3.15A, (TH) | 19372K 3.15A. |
| 29 | 1 | Test hook point | GND,G | TERMINAL, PCB Raised Loop Black (TH) | 200-203 (W HUGHES) |
| 30 | 1 | Test hook point | Gate Drv | TERMINAL, PCB Raised Loop White (TH) | 200-201 (W HUGHES) |
| 31 | 1 | Wire Jumper | J1 | Jumper wire 0.7 diameter, 19 mm (TH) | |
| 32 | 1 | Wire Jumper | J2 | Jumper wire 0.7 diameter, 11mm (TH) | |
| 33 | 1 | JUMPER1 | J3 | Three way jumper (TH) | M22F2010305 (HARWIN) |
| 34 | 2 | JUMPER1 | J4, J5 | Two-way jumper (TH) | M22-2010205 (HARWIN) |
| 35 | 1 | | for J3 | Jumper Head (blue) | M22-1910005 (HARWIN) |
| 36 | 1 | | for J4 | Jumper Head (Black) | M22-1900005 (HARWIN) |
| 37 | 1 | | for J5 | Jumper Head (Red) | M22F19200005 (HARWIN) |
| 38 | 1 | 1uH | L1 | High current Ferrite Rod Inductor- (TH) prime | PG0203 -Pulse Electronics or 019-4698-00R - Precision Inc. |
| 39 | 1 | 40uH | L2 | Common mode choke -TH | 019-4685-00R - Precision Inc. |
| 40 | 1 | 10uH | L3 | Ferrite core inductor, axial (TH) | B78108-S1103-K -EPCOS |

| | | | | | |
|----|---|-----------------|---|---|---|
| 41 | 1 | LED | LED1 | LED Green - TH | L-1413GDT |
| 42 | 1 | IRFP22N60K | Q1 | TO-247 600V 22Amp N-ch Mosfet (TH) | IRFP22N60KPBF- VISHAY |
| 43 | 1 | 10R | RP1 | NTC Thermistor 10ohm 3Amp (TH) | B57235S100M - EPCOS |
| 44 | 1 | 47K 2W | RP2 | RESISTOR, 2W 5% 47K - (TH) | MCF 2W 47K |
| 45 | 1 | 22R | RP3 | RESISTOR, 0.25W 5% 22R (TH) | MCF 0.25W 22R. |
| 46 | 1 | 3k3 | RP4 | RESISTOR, 1206 3K3 | MC 0.125W 1206 1% 3K3 |
| 47 | 1 | 0R | RP5 | RESISTOR, 1206 0R 5% | MC 0.125W 1206 0R |
| 48 | 1 | 910K | RP6 | RESISTOR, 1206 910K | MC 0.125W 1206 5% 910K |
| 49 | 1 | 5.1k | RP7 | RESISTOR, 1206 5.1K; | MC 0.125W 1206 1% 5.1K |
| 50 | 1 | 22R | RP8 | RESISTOR, 1206 22R | MC 0.125W 1206 5% 22R |
| 51 | 3 | 1K | RP9, RP12, RS22 | RESISTOR, 1206 1K | MC 0.125W 1206 1% 1K |
| 52 | 1 | 12K | RP9A | RESISTOR, 1206 12K | MC 0.125W 1206 5% 12K |
| 53 | 1 | 0R1 | RP10 | RESISTOR, WW 3W 5% 0R1 (TH) | WELWYN W210R1J1 |
| 54 | 1 | 280K | RP11 | RESISTOR, RC12H 1206 280K | MC 0.125W 1206 5% 280K |
| 55 | 1 | 2K2 | RS13 | RESISTOR, 1206 2K2 | MC 0.125W 1206 5% 2K2. |
| 56 | | | RS14, RS26 | UNSTUFFED | |
| 57 | 2 | 10R | RS15, RS17 | RESISTOR, 1206 10R | MC 0.125W 1206 5% 10R |
| 58 | 1 | 4K7 | RS16 | RESISTOR, 1206 4K7 | MC 0.125W 1206 5% 4K7 |
| 59 | 1 | 33K | RS18 | RESISTOR, 1206 33K | MC 0.125W 1206 5% 33K |
| 60 | 1 | 47K | RS20 | RESISTOR, 1206 47K | MC 0.125W 1206 1% 47K |
| 61 | 1 | 10K | RS21 | RESISTOR, 1206 10K | MC 0.125W 1206 1% 10K |
| 62 | 1 | 470R | RS23 | RESISTOR, RC02H 1206 470R | RC-02H-470R-1P5. |
| 63 | 1 | 5.6k | RS24 | RESISTOR, 1206 5.6K; | MC 0.125W 1206 1% 5.6K |
| 64 | 1 | 30m | RS25 | RESISTOR, SMD 1% 0R030 | OARS1 - R030FI. |
| 65 | 2 | IRF7853 | SR1, SR2 | SO-8 N-ch 100V 18mohm MOSFET | IR |
| 66 | 1 | PQ3535 | T1 | PQ3535 100W Flyback Power Transformer (TH) | 019-4563-00 Rev 01 -Precision Inc. |
| 67 | 1 | IR11662 | U1 | SO-8 Flyback Sync Rectifier Smart Controller | IR |
| 68 | 1 | TEA1507 | U2 | GreenChip™ II SMPS control IC DIP8 (TH) | TEA1507 - NXP |
| 69 | 1 | SFH615A2 | U3 | SFH615A2 DIP 4 option G Optocoupler (TH) | SFH615A-2 -Vishay (Infineon) |
| 70 | 1 | AS4305 or AQ105 | U4 | SOT23-5 Secondary V-I Error amplifier | Siliconlink or Acutechnology |
| 71 | 1 | Test hook point | VCC-HP | TERMINAL, PCB Raised Loop - Red (TH) | 200-207 - W HUGHES |
| 72 | 2 | Test hook point | VD-HP, VD1-HP | TERMINAL, PCB Raised Loop- Yellow (TH) | 200-202 - W HUGHES |
| 73 | 1 | Test hook point | VS, VS1 | TERMINAL, PCB Raised Loop BLACK (TH) | 200-203 - W HUGHES |
| 74 | 1 | Pri - Heatsink | | 10.4DegC/W, Black anodized extruded heat sink - radial fins & notched base and solderable pins | 531102B02500G -Aavid Thermalloy HS191-ND -DIGI-KEY |
| 75 | 4 | Screw + washer | | SCREW with washer M3X6 P=.5 | SEM02030006FA (NETTLEFOLDS) |
| 76 | 1 | Screw | | M3x12 mm , For Primary heat sink | MB04030012007FA (NETTLEFOLDS) |
| 77 | 2 | Spring Washers | | M3 1mm thick, For Primary heat sink | WS21030081FA (unbranded) |
| 78 | 1 | Nut | | HEX NUT M3X0.5X1.8 | NC01030081FA (unbranded) |
| 79 | 1 | Insulator | for Q1 (TO247) | Silpad K-10 or K-4, 25.5mm x 19.1mm (0.2 - 0.4 degCin ² /W) | 0900 000 5350 (HARTING Bergquist) |
| 80 | 4 | Nylon Standoff | TRANSIPILLA R, HEX STYLE 3 M3X38; | Depth, thread:4.5mm; Diameter, External:7mm; Head type:Hexagonal; Height, spacer:38mm; Length / Height, external:38mm; Thread size:M3 | SCHURTER- 9633.83 |
| 81 | 1 | PCB | | 1.6mm thick 2-sided 2 oz, UL rated 94V-0 PCB | |