AN-EVAL ICE2QR2280G-1

20 W 5 V SMPS Evaluation Board with Quasi-Resonant CoolSET™ ICE2QR2280G-1

Application Note

About this document

Scope and purpose

This document is an engineering report that describes universal input 20 W 5 V off-line flyback converter using Infineon Quasi-Resonant CoolSET™ ICE2QR2280G-1 which offers high efficiency, very low standby power, wider V_{CC} operating range and various mode of protections for a high reliable system. This evaluation board is designed to evaluate the performance of ICE2QR2280G-1 in ease of use.

Intended audience

This document is intended for users of the ICE2QR2280G-1 who wish to design low cost, high efficiency Quasi-Resonant off-line SMPS for small power supply such as Blu-ray, DVD player, set-top box, game console, smart meter, charger and auxiliary power of high power system such as LED TV, etc.

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1 Abstract

This application note is a description of 20 W switching mode power supply evaluation board designed in a quasi resonant flyback converter topology using ICE2QR2280G-1 Quasi-resonant CoolSET™ .The target application of ICE2QR2280G-1 are for set-top box, portable game controller, DVD player, netbook adapter and auxiliary power supply for LCD TV, etc. With the CoolMOS™ integrated in this IC, it greatly simplifies the design and layout of the PCB. Due to valley switching, the turn on voltage is reduced and this offers higher conversion efficiency comparing to hard-switching flyback converter. With the DCM mode control, the reverse recovery problem of secondary rectify diode is relieved. And for its natural frequency jittering with line voltage, the EMI performance is better. Infineon's digital frequency reduction technology enables a quasi-resonant operation till very low load. As a result, the system efficiency, over the entire load range, is significantly improved compared to conventional free running quasi resonant converter implemented with only maximum switching frequency limitation at light load. In addition, numerous adjustable protection functions have been implemented in ICE2QR2280G-1 to protect the system and customize the IC for the chosen application. In case of failure modes, like open control-loop/over load, output overvoltage, and transformer short winding, the device switches into **Auto Restart Mode** or **Latch-off Mode**. By means of the cycle-by-cycle peak current limitation plus foldback point correction, the dimension of the transformer and current rating of the secondary diode can both be optimized.Thus, a cost effective solution can be easily achieved.

2 Evaluation board

This document contains the list of features, the power supply specification, schematic, bill of material and the transformer construction documentation. Typical operating characteristics such as performance curve and scope waveforms are showed at the rear of the report.

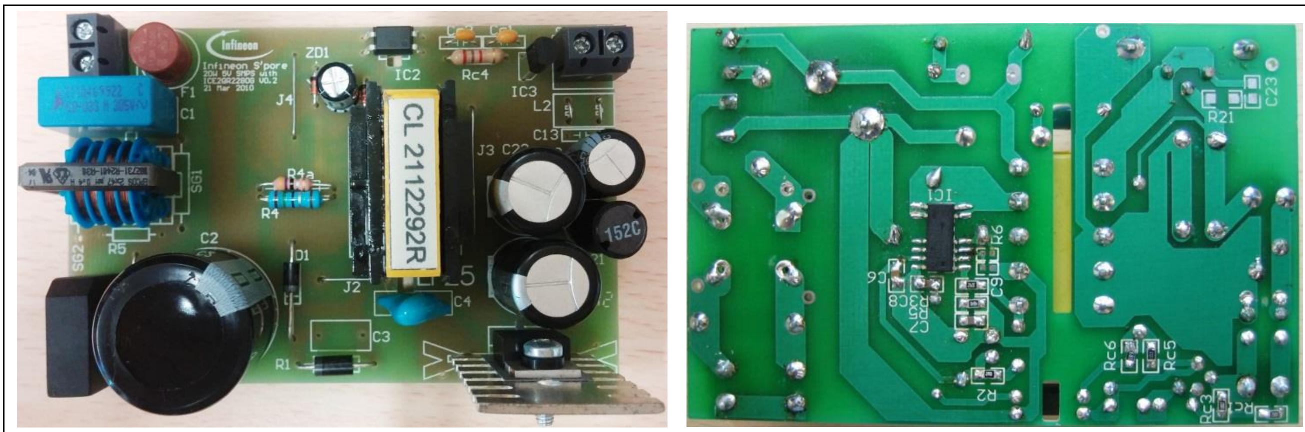


Figure 1 **EVAL ICE2QR2280G-1**

3 Specification of evaluation board

Table 1 Specification of EVAL ICE2QR2280G-1

Input voltage	85 V_{AC}~265 V_{AC}
Input frequency	50~60 Hz
Output voltage, current & power	5 V, 4 A, 20 W
Minimum switching frequency at full load and minimum input AC voltage	65 kHz
No-load power consumption	< 50 mW
Active mode four point average efficiency (25%,50%,75% & 100%load)	>80% at 115 V_{AC} & 230 V_{AC}

4 Features of ICE2QR2280G-1

Table 2 Features of ICE2QR2280G-1

800 V avalanche rugged CoolMOS™ with built-in startup Cell
Quasi resonant operation till very low load
Active burst mode operation for low standby input power (< 0.1 W)
Digital frequency reduction with decreasing load for reduced switching loss
Built-in digital soft-start
Foldback point correction, cycle-by-cycle peak current limitation and maximum on time limitation
Auto restart mode for V_{CC} over-voltage protection, under-voltage protection, over-load protection and overtemperature protection
Latch-off mode for adjustable output over-voltage protection and transformer short-winding protection
Lower V_{CC} turn off threshold

5 Circuit description

5.1 Mains input rectification and filtering

The AC line input side comprises the input fuse F1 as overcurrent protection. The X2 Capacitors C1 and Choke L1 form a main filter to minimize the feedback of RFI into the main supply. After the bridge rectifier BR1, together with a smoothing capacitor C2, provide a voltage of 70 V_{DC} to 380 V_{DC} depending on mains input voltage.

5.2 Integrated MOSFET and PWM control

ICE2QR2280G-1 is comprised of a power MOSFET and the Quasi-Resonant controller; this integrated solution greatly simplifies the circuit layout and reduces the cost of PCB manufacturing. The PWM switch-on is determined by the zero-crossing input signal and the value of the up/down counter. The PWM switch-off is determined by the feedback signal V_{FB} and the current sensing signal V_{CS}. ICE2QR2280G-1 also performs all necessary protection functions in flyback converters. Details about the information mentioned above are illustrated in the product datasheet.

5.3 Output stage

On the secondary side, 5 V output, the power is coupled out via a schottky diode D21. The capacitors C21 and C22 provide energy buffering followed by the L-C filters L21 and C23 to reduce the output ripple and prevent interference between SMPS switching frequency and line frequency considerably. Storage capacitors C21 and C22 are designed to have an internal resistance (ESR) as small as possible. This is to minimize the output voltage ripple caused by the triangular current.

5.4 Feedback loop

For feedback, the output is sensed by the voltage divider of Rc1 and Rc3 and compared to TL431 internal reference voltage. Cc1, Cc2 and Rc4 comprise the compensation network. The output voltage of TL431 is converted to the current signal via optocoupler IC2 and two resistors Rc5 and Rc6 for regulation control.

6 Circuit operation

6.1 Startup operation

Since there is a built-in startup cell in the ICE2QR2280G-1, there is no need for external start up resistor, which can improve standby performance significantly.
When VCC reaches the turn on voltage threshold 18V, the IC begins with a soft start. The soft-start implemented in ICE2QR2280G-1 is a digital time-based function. The preset soft-start time is 12ms with 4 steps. If not limited by other functions, the peak voltageon CS pin will increase step by step from 0.32V to 1V finally. After IC turns on, the V_{CC} voltage is supplied by auxiliary windings of the transformer.

6.2 Normal mode operation

The secondary output voltage is built up after startup. The secondary regulation control is adopted with TL431 and optocoupler. The compensation network Cc1, Cc2 and Rc4 constitute the external circuitry of the error amplifier of TL431. This circuitry allows the feedback to be precisely controlled with respect to dynamically varying load conditions, therefore providing stable control.

6.3 Primary side peak current control

The MOSFET drain source current is sensed via external resistor R4 and R4A. Since ICE2QR2280G-1 is a current mode controller, it would have a cycle-by-cycle primary current and feedback voltage control which can make sure the maximum power of the converter is controlled in every switching cycle.

6.4 Digital frequency reduction

During normal operation, the switching frequency for ICE2QR2280G-1 is digitally reduced with decreasing load. At light load, the MOSFET will be turned on not at the first minimum drain-source voltage time, but on the nth. The counter is in range of 1 to 7, which depends on feedback voltage in a time-base. The feedback voltage decreases when the output power requirement decreases, and vice versa. Therefore, the counter is set by monitoring voltage V_{FB}. The counter will be increased with low V_{FB} and decreased with high V_{FB}. The thresholds are preset inside the IC.

6.5 Burst mode operation

At light load condition, the SMPS enters into Active Burst Mode. At this stage, the controller is always active but the V_{CC} must be kept above the switch off threshold. During active burst mode, the efficiency increase significantly and at the same time it supports low ripple on V_{out} and fast response on load jump.

For determination of entering Active Burst Mode operation, three conditions apply:

1. the feedback voltage is lower than the threshold of V_{FBEB}(1.25 V). Accordingly, the peak current sense voltage across the shunt resistor is 0.18;
2. the up/down counter is 7;
3. and a certain blanking time (t_{BEB}).

Once all of these conditions are fulfilled, the Active Burst Mode flip-flop is set and the controller enters Active Burst Mode operation. This multi-condition determination for entering Active Burst Mode operation prevents mistriggering of entering Active Burst Mode operation, so that the controller enters Active Burst Mode operation only when the output power is really low during the preset blanking time.

During active burst mode, the maximum current sense voltage is reduced from 1 V to 0.34 V so as to reduce the conduction loss and the audible noise. At the burst mode, the FB voltage is changing like a sawtooth between 3.0 and 3.6 V.

The feedback voltage immediately increases if there is a high load jump. This is observed by one comparator. As the current limit is 34% during Active Burst Mode a certain load is needed so that feedback voltage can exceed V_{FBLB} (4.5 V). After leaving active busrt mode, maximum current can now be provided to stabilize V_O. In addition, the up/down counter will be set to 1 immediately after leaving Active Burst Mode. This is helpful to decrease the output voltage undershoot.

7 Protection features

7.1 V_{CC} over voltage and under voltage protection

During normal operation, the V_{CC} voltage is continuously monitored. When the V_{CC} voltage falls below the under voltage lock out level ($V_{CC,off}$) or the V_{CC} voltage increases up to $V_{CC,OVP}$, the IC will enter into autorestart mode.

7.2 Foldback point protection

For a quasi-resonant flyback converter, the maximum possible output power is increased when a constant current limit value is used for all the mains input voltage range. This is usually not desired as this will increase additional cost on transformer and output diode in case of output over power conditions.
The internal fold back protection is implemented to adjust the V_{CS} voltage limit according to the bus voltage. Here, the input line voltage is sensed using the current flowing out of ZC pin, during the MOSFET on-time. As the result, the maximum current limit will be lower at high input voltage and the maximum output power can be well limited versus the input voltage.

7.3 Open loop/over load protection

In case of open control loop, feedback voltage is pulled up with internally block. After a fixed blanking time 30 ms, the IC enters into auto restart mode. In case of secondary short-circuit or overload, regulation voltage V_{FB} will also be pulled up, same protection is applied and IC will auto restart.

7.4 Adjustable output overvoltage protection

During off-time of the power switch, the voltage at the zero-crossing pin ZC is monitored for output overvoltage detection. If the voltage is higher than the preset threshold 3.7 V for a preset period 100 µs, the IC is latched off.

7.5 Short winding protection

The source current of the MOSFET is sensed via two shunt resistors R4 and R4A in parallel. If the voltage at the current sensing pin is higher than the preset threshold V_{CSSW} of 1.68 V during the on-time of the power switch, the IC is latched off. This constitutes a short winding protection. To avoid an accidental latch off, a spike blanking time of 190 ns is integrated in the output of internal comparator.

7.6 Auto restart for over temperature protection

The IC has a built-in over temperature protection function. When the controller's temperature reaches 140 °C, the IC will shut down switch and enters into autorestart. This can protect power MOSFET from overheated.

8 Circuit diagram

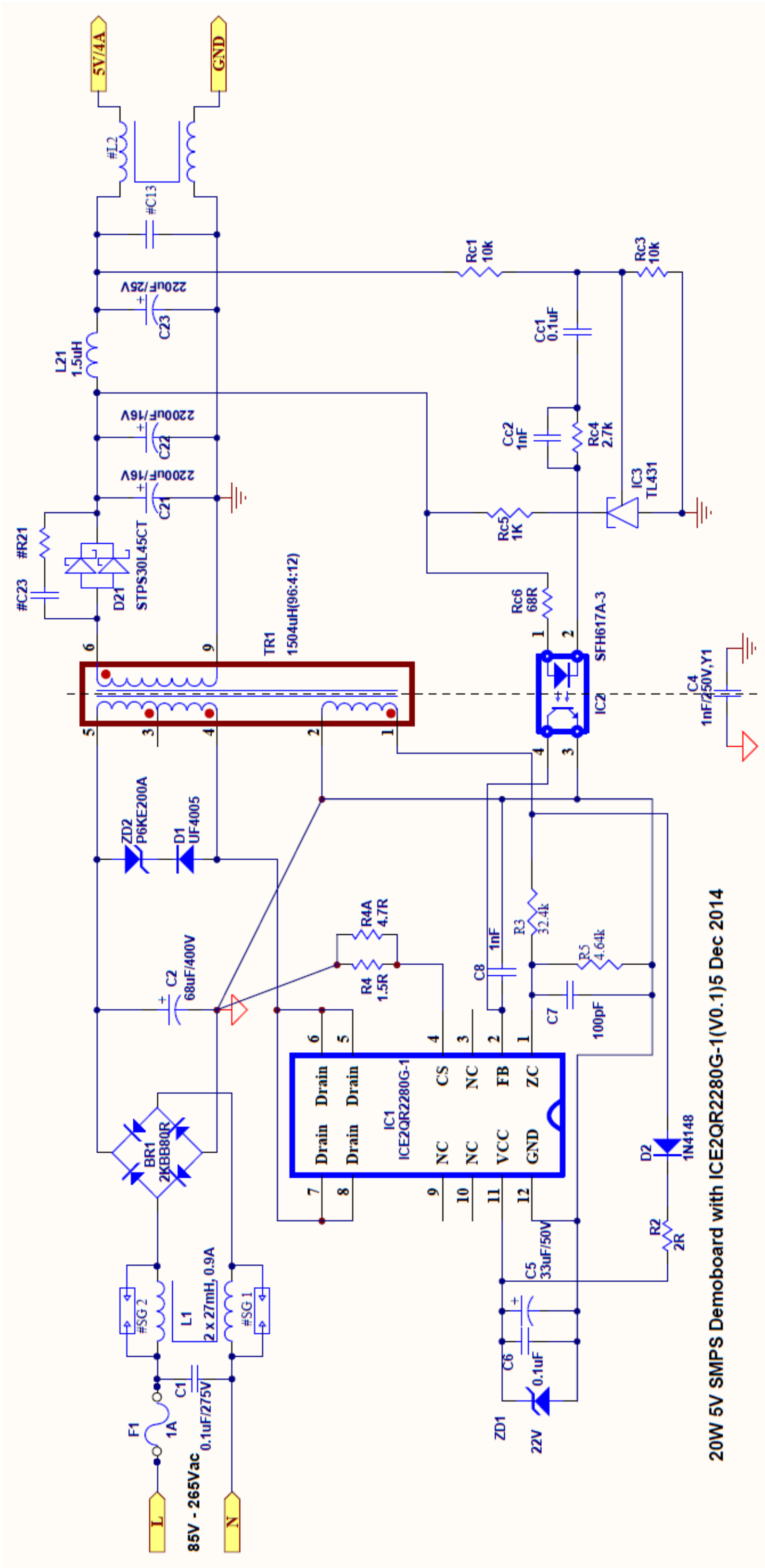


Figure 2 Schematic of EVAL ICE2QR2280G-1

9 PCB layout

9.1 Top side

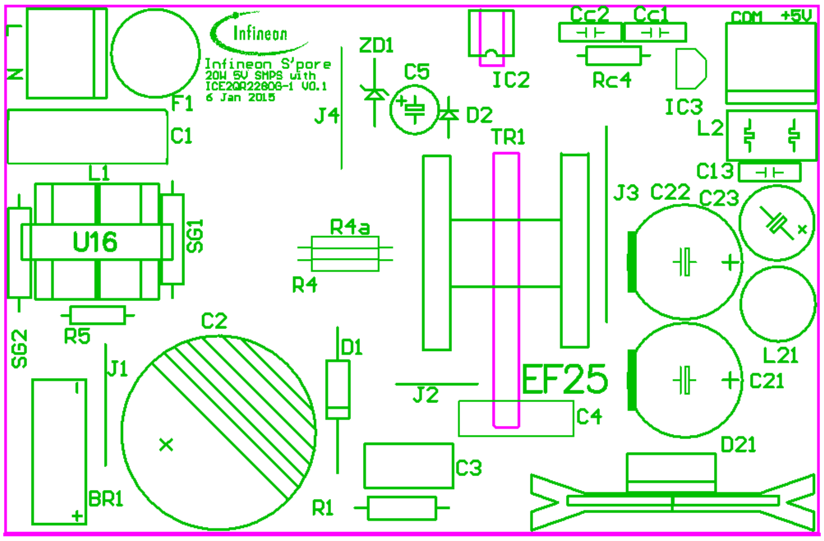


Figure 3 Top side component legend

9.2 Bottom side

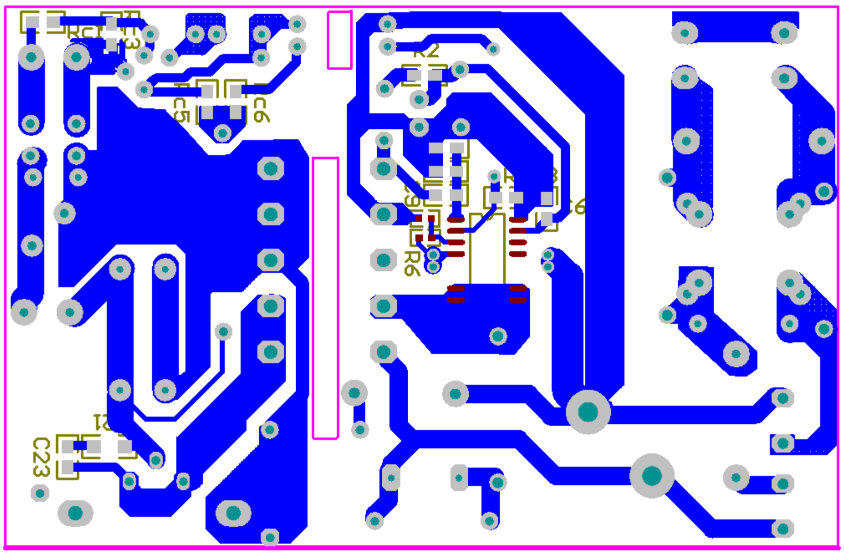


Figure 4 Bottom side copper and component legend

10 Component list

Table 3 Bill of materials

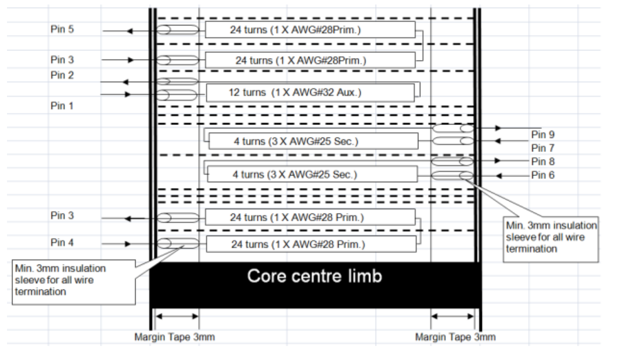
No.	Designator	Description	Part Number	Manufacturer
1	BR1	2KBB80R		
2	F1	1.6A/250Vac		
3	L21	1.5uH		
4	R2	2R, SMD		
5	R3	32.4k, SMD		
6	R4	1.5R		
7	R4A	4.7R, SMD		
8	R5	4.64k, SMD		
9	Rc1	10k, SMD		
10	Rc3	10k, SMD		
11	Rc4	2.7k		
12	Rc5	1K		
13	Rc6	68R		
14	C1	0.1uF/275V	B32922X2MKP/2H	Epcos
15	C2	68uF/400V	B43501A9686M	Epcos
16	C4	1nF/250V,Y1		
17	C5	33uF/50V	B41821	Epcos
18	C6	0.1uF, SMD		
19	C7	100pF		
20	C8	1nF		
21	C21	2200uF/16V		
22	C22	2200uF/16V		
23	Cc1	0.1uF		
24	Cc2	1nF		
25	C23	220uF/25V		
26	EMI	2 x 27mH, 0.9A	B82732R2901B30	Epcos
27	TR1	1504uH		
28	IC2	SFH617A-3		
29	IC3	TL431		
30	D1	UF4005	UF4005	Vishay
31	D2	1N4148		
32	ZD1	22V zener diode		
33	ZD2	Zener diode	P6KE200A	
34	D21	STPS30L45T		

11 Transformer construction

Core and material: EPCOS(N87)or TDK PC44 EF25/13/7

Bobbin: Vertical version

Primary Inductance, Lp=1504 µH(±10%), measured between pin 4 and pin 5



Start	Stop	No. of turns	Wire size	Layer
1	2	12	1XAWG#32	Auxiliary
3	5	48	1XAWG#28	½ Primary
7	9	4	3XAWG#25	Secondary
6	8	4	3XAWG#25	Secondary
4	3	48	1XAWG#28	½ Primary

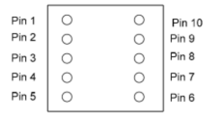


Figure 5 Transformer structure

12 Test results

12.1 Efficiency, regulations and output ripple

Table 4 Efficiency, regulation & output ripple

V_{in} (V_{AC})	P_{in} (W)	V_{out} (V_{DC})	I_{out} (A)	P_{out} (W)	Efficiency (%)	Average Efficiency (%)
85	0.0207	4.97	0.00			
	2.4000	4.97	0.40	1.99	82.83	
	6.1700	4.97	1.00	4.97	80.49	78.79
	12.4500	4.97	2.00	9.93	79.76	
	18.9300	4.96	3.00	14.89	78.67	
	26.0300	4.96	4.00	19.85	76.27	
115	0.0260	4.97	0.00			
	2.4900	4.97	0.40	1.99	79.84	
	6.1300	4.97	1.00	4.97	81.01	80.34
	12.3000	4.97	2.00	9.93	80.73	
	18.4900	4.96	3.00	14.89	80.54	
	25.1000	4.96	4.00	19.85	79.09	
230	0.0264	4.97	0.00			
	2.5700	4.97	0.40	1.99	77.35	
	6.2500	4.97	1.00	4.97	79.46	80.65
	12.3000	4.97	2.00	9.93	80.73	
	18.3500	4.96	3.00	14.89	81.16	
	24.4300	4.96	4.00	19.85	81.26	
265	0.0308	4.97	0.00			
	2.5800	4.97	0.40	1.99	77.05	
	6.3200	4.97	1.00	4.97	78.58	80.19
	12.3600	4.97	2.00	9.93	80.34	
	18.4300	4.96	3.00	14.89	80.80	
	24.5000	4.96	4.00	19.85	81.03	

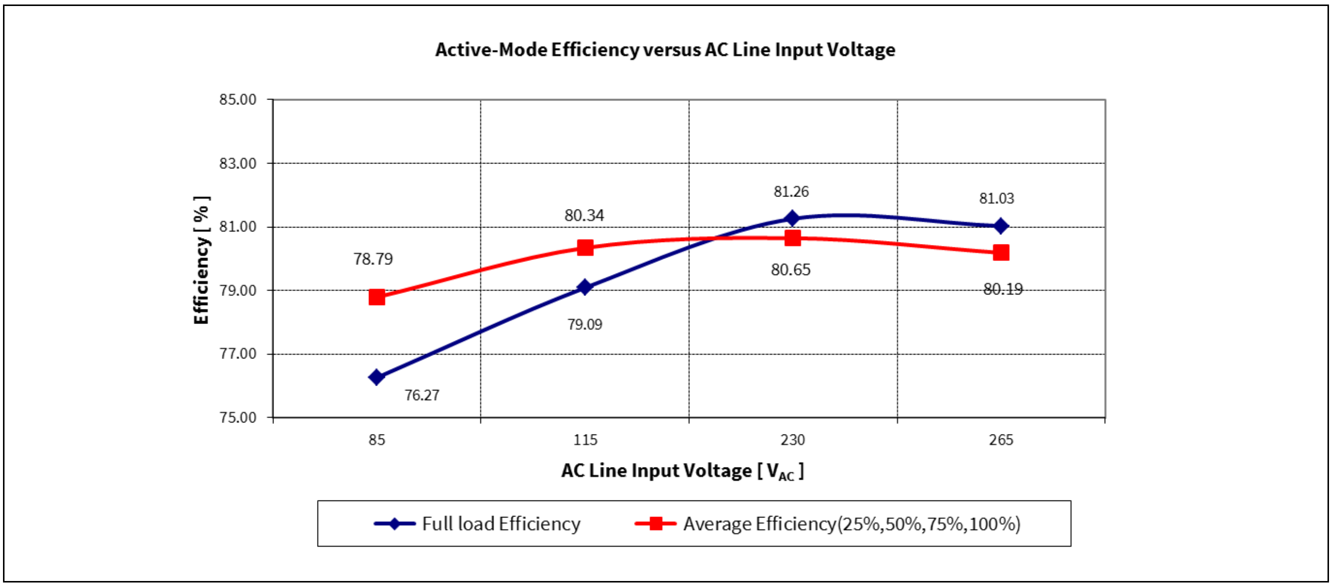


Figure 6 **Efficiency vs AC line input voltage**

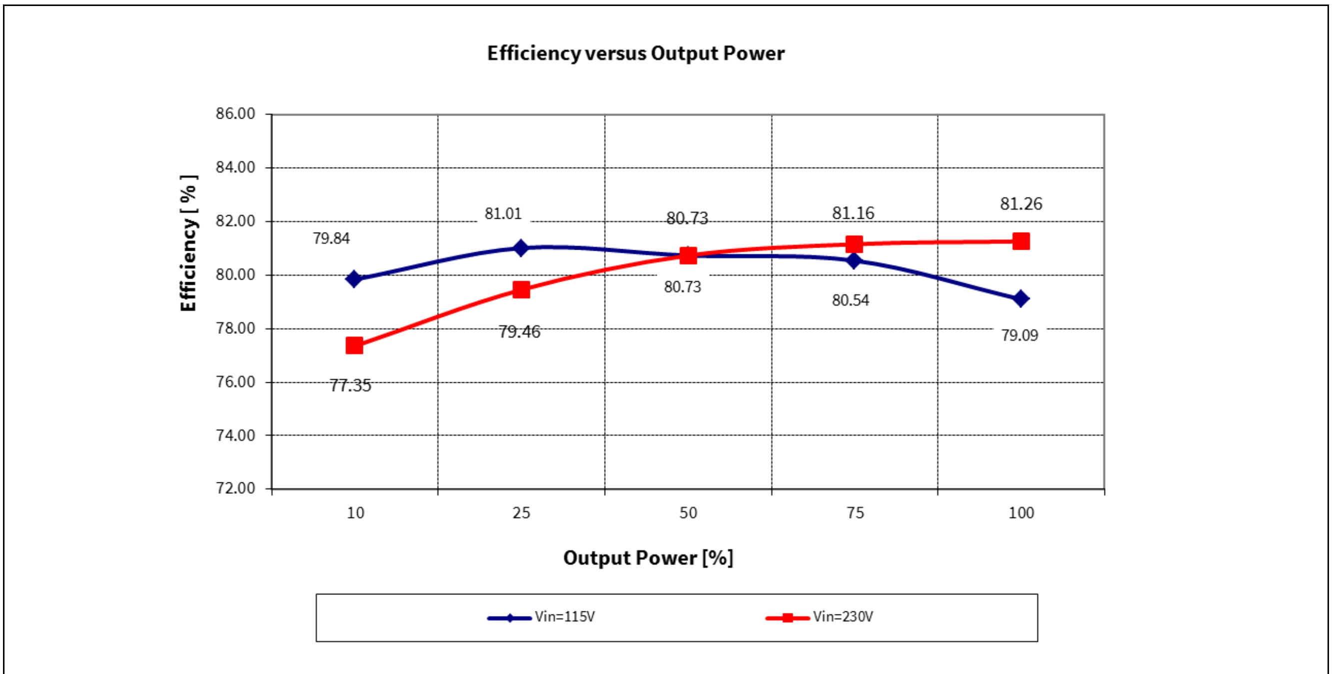


Figure 7 **Efficiency vs output power @ 115 V_{AC} and 230 V_{AC} line**

12.2 Standby power

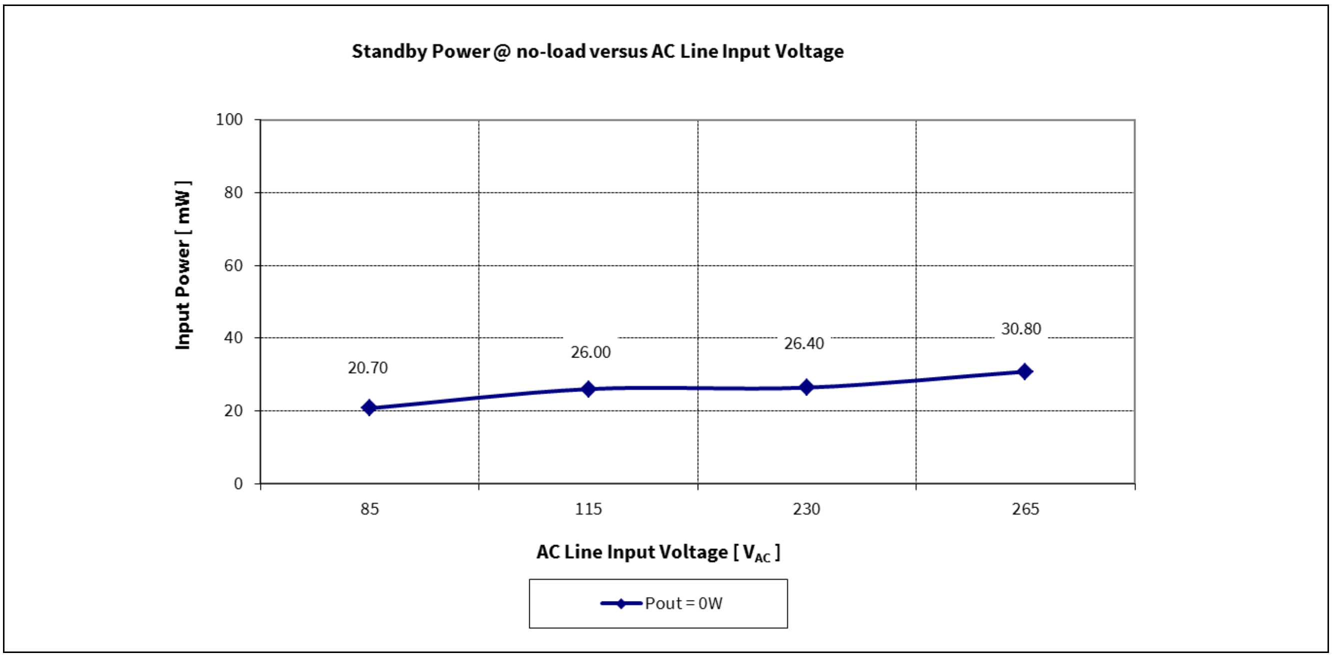


Figure 8 Standby power vs AC line input voltage (measured by Yokogawa WT210 power meter - integration mode)

13 References

[1] ICE2QR2280G-1 data sheet, Infineon Technologies AG
[2] ICE2QRxx65/80x Quasi- Resonant CoolSET™ Design Guide. [ANPS0053]

Revision History

Major changes since the last revision

Page or Reference	Description of change
--	Name change to EVAL

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