

INTRODUCTION

This document describes tests for checking certain key aspects of the electrical design and performance of Resonant Discontinuous Forward Converters (RDFCs) implemented with CamSemi's C2470 family of controllers. It is recommended that these tests be incorporated in a comprehensive program of design verification testing during the development phase of any RDFC-based product.

The purpose of the tests specified here is to enable a designer to check critical performance characteristics and conformance to design practices that are generally recommended for applications using CamSemi's RDFC controller ICs (C2471, C2472 and C2473). Because of component tolerances, PSU performance will vary from unit to unit so a suitable number of samples should be tested to give an indication of the spread to be expected in production.

In this document, the RDFC application unit may be referred to as the "PSU", "power supply", "unit under test" or "unit".

This document should be read in conjunction with the relevant RDFC controller IC datasheets and design guides shown in Table 1.

Controller IC Type	Datasheet	Design Guide
C2471	DS-1639	DG-2128
C2472, C2473	DS-1423	DG-1694

Table 1: Document References for RDFC Controller Datasheets and Basic Design Guides

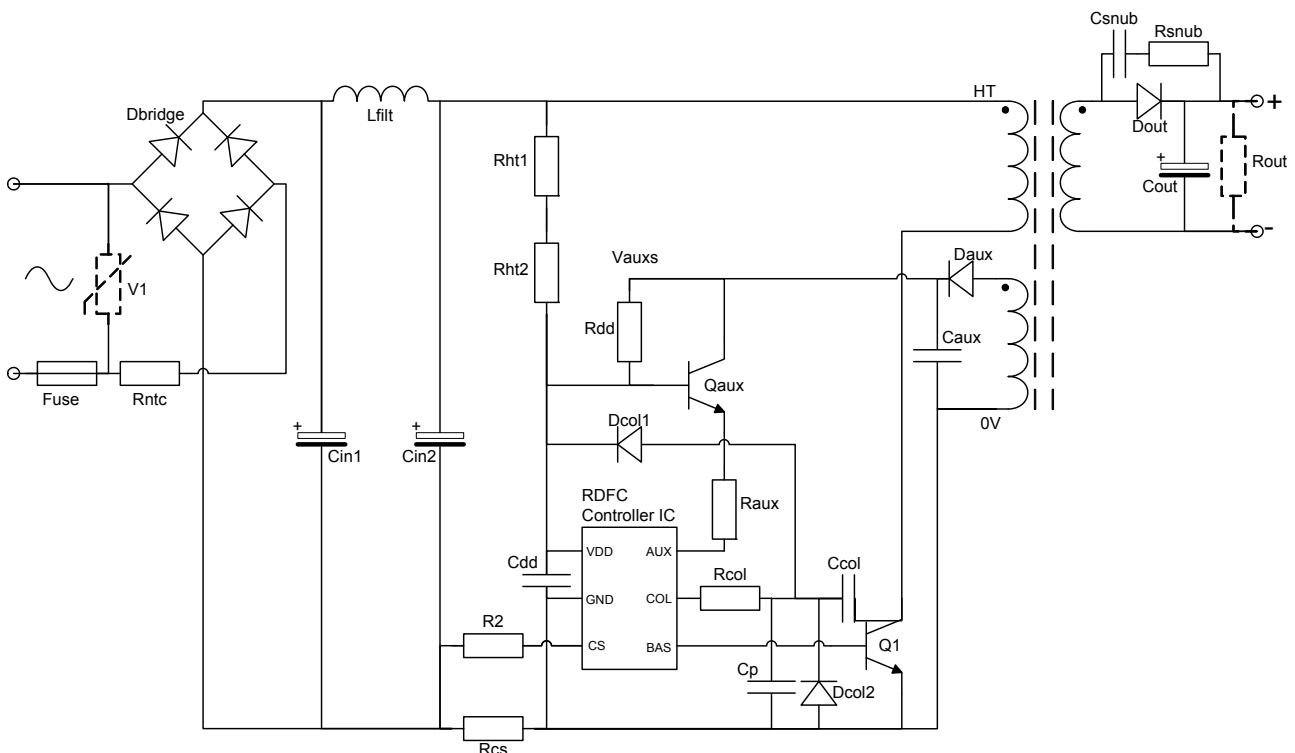


Figure 1: Typical RDFC Application Schematic

Please visit www.camsemi.com to obtain the latest versions of the RDFC datasheets, design guides, application notes and other useful documentation.

SAFETY

Offline power supplies exhibit safety hazards including, but not limited to, electric shock, high temperatures, fire and smoke. Some common tests deliberately take the PSU under test to the point of destruction. Prototypes should be tested and worked on only by competent and suitably trained personnel. The following general advice is offered but cannot take account of risks associated with any particular prototype or test set up. It is best practice to conduct a risk assessment in accordance with local prevailing safety procedures. If you are in any doubt as to the safety of any unit or test procedure, please consult a competent adviser before proceeding.

- Before operating the unit:
 - Prototypes are often modified in the course of development. Only proceed if you are satisfied that the unit is as intended and in a suitable condition for the testing to be performed;
 - Ensure general safety of the test set-up. For example, minimise the risk of inadvertent contact with the unit under test and injury from material which may be ejected from it in the event of a "catastrophic" failure;
- While operating the unit:
 - Do not connect the unit direct to the mains utility. Use a suitable isolated supply for the type of unit and the tests to be performed;
 - Remember that insulation between high voltage and low voltage parts of a prototype may not provide full safety isolation;
 - Regard all parts of the unit as potentially LIVE and HAZARDOUS;
- After disconnecting the supply:
 - Hazardous voltages will persist for some time after the supply is disconnected due to charge stored in capacitors. If necessary, capacitors can be safely and quickly discharged using a suitable resistor.
 - Allow the unit to cool before handling it.

DEFINITIONS AND ABBREVIATIONS

Parameter description	Symbol	Comments
RMS input voltage	V_{IN}	
Power Supply Unit	PSU	
Load pull-up capability	-	The load that the PSU can start into, or recover into from short-circuit. High leakage transformers make it easier to pull-up constant current loads
Maximum load capacitance	C_{LOAD}	
CamSemi's RDFC controller IC	controller	
Proportional Base Drive	PBD	The controller adjusts base current to control Q1 collector voltage.
Force On current	FON	To minimise turn-on loss, Q1 base current is initially forced to its maximum level.
Over-Current Protection	OCP	To protect Q1, the base drive is turned off if emitter current rises too high – sensed by the CS input voltage falling below a preset negative voltage threshold.
Primary-side power-switching transistor	Q1	
Collector-emitter voltage	V_{ce}	
Collector-base voltage with emitter open	V_{cbo}	This is a transistor rating.
High Voltage	HV	Use a high voltage probe for measurements.
Auxiliary supply resistor	R_{aux}	The resistor connected to the AUX pin of the controller.
Reverse Safe Operating Area	RBSOA	Important to Q1
Forward Safe Operating Area	FBSOA	Important to Q1
Output voltage	V_{OUT}	
Output current	I_{OUT}	
Output voltage and current characteristics	V-I curve	

Table 2: Definitions and Abbreviations

CHECKLIST OF KEY MEASUREMENTS FOR DESIGN VERIFICATION

- Test a large enough sample of units (at least three) to enable an assessment of unit-to-unit variations.
- Unless otherwise stated, it is recommended that tests are performed in normal room conditions with an ambient temperature of 20°C to 30°C.
- Ensure instruments are adequate for the intended test measurements.

References

- [1] CamSemi application note AN-2497 describes the conditions during which the highest Q1 collector voltage occurs and how to measure it. AN-2497 can be obtained at www.camsemi.com.

RDFC Controller Operating Modes

The RDFC controller has a number of different operating modes that depend on conditions such as input voltage and output load. Components experience different levels of stress (voltage, current, power and thermal) in the different operating modes. The purpose of the tests in this section is to observe component stresses so that the designer can check components remain within their ratings.

- When describing operating conditions (for example, input voltage) in the following tables, it is not possible to state absolute values. Therefore, by default, the values are with respect, and relative, to the values in the requirements specification for the PSU.
- It is for the designer to determine acceptable margin for component stresses.
- These tests should be conducted at temperatures reflecting the full range specified for the PSU.

Controller Operating Mode	Method	Conditions	Monitored points	Measurements	Comments
Start up	Connect load Apply input voltage	$V_{IN} = \text{min, nom, max}$ Load = no load Load = 100% $C_{LOAD} = \text{max}$	Q1 Collector (HV) Q1 collector current Controller VDD pin	Peak collector voltage Peak collector current Peak VDD voltage	Expect max input voltage and max load to be most stressful conditions Check Q1 Vcbo ratings not exceeded during fully resonant operation, during no-load start-up Check for excessive collector voltages, collector currents or VDD voltages Confirm Q1 is operating inside FBSOA and RBSOA
Standby B	Test at no load Apply input voltage	$V_{IN} = \text{min, nom, max}$ Load = zero	Q1 Collector on-state voltage Q1 Collector (HV) CS pin	Vce-on Turn off delay On time No-load power consumption Minimum off time	Collector voltage during turn-on must be low enough not to cause excessive dissipation (In order to avoid oscilloscope input saturation, measurement requires a technique for rejecting the high voltages present) Turn off delay is typically < 500 ns Check OCP is not triggered Operates at maximum off-time (approx 200 μs)
Standby B	Test at no load Apply input voltage	$V_{IN} = \text{max}$ Load = 0	Voltage at both ends of 10 Ω resistor in series with COL pin	Current out of COL pin.	If COL pin not protected by diodes and series resistor, then confirm that current into and out of COL pin is not above limits specified in controller datasheet (Put a 10 Ω resistor in series with COL pin; Use oscilloscope to measure voltage at each end of resistor and deduce current) Worst case current out of the COL pin when transistor switches on during Standby B

Controller Operating Mode	Method	Conditions	Monitored points	Measurements	Comments
Standby A	Apply input voltage Vary load to find transition points	V_{IN} = min, nom, max. Load = 0 to 100%	AUX pin Other end of Raux Q1 Collector (HV) V_{OUT} I_{OUT} CS pin	Maximum peak-peak output voltage ripple (low frequency) Voltage across Raux (to find Q1 base current) Turn off delay Peak collector voltage Load at transition - Standby A and Standby B Load at transition - Standby A and Normal	Confirm peak to peak ripple is within specification No PBD oscillations (BAS output current oscillation within a switching cycle) No sub-harmonic oscillations (large cycle-to-cycle differences Q1 collector voltage) No excessive peak collector voltage During transitions, no excessive V_{OUT} ripple (typically < 10 Hz) Check OCP is not triggered
Normal	Apply input voltage Vary load up to 100 %	V_{IN} = min, nom, max. Load up to 100%	BAS pin Q1 Collector (HV) AUX pin Other end of Raux V_{OUT} CS pin	Peak-peak output voltage ripple Voltage across Raux (to find Q1 base current) Turn off delay Peak collector voltage	Peak to peak ripple within the specification Base current should be below FON and should not oscillate OCP might be triggered but check it does not cause poor load regulation Confirm that Q1 is operating inside FBSOA and RBSOA
Overload and Foldback	Apply input voltage Apply increasing load	V_{IN} = min, nom, max. Load > 100%	Q1 Collector (HV) Q1 Collector on-state voltage V_{OUT} I_{OUT}	Foldback threshold (I_{OUT} and V_{OUT}), with constant-voltage load Burst on-time Burst current Peak collector voltage in foldback Peak collector current in foldback On-state collector voltage Q1, controller, transformer and output diode operating temperatures during continuous load slightly less than foldback current	Overload conditions are thermally stressful and should only be tested if the PSU specification requires. Because of the risk of damage, it may be best to conduct this test last Check for excessive collector voltage or collector current Confirm safe component operating temperatures Transformer, RDFC IC, Q1 temperature should be below the maximum allowable temperature Confirm that Q1 is operating inside FBSOA and RBSOA
Foldback	Apply input voltage Apply increasing load	V_{IN} = min, nom, max. Load = short		Current into COL pin	If COL pin not protected by diodes and series resistor, then confirm current into and out of COL pin is not above limits specified in controller datasheet (Put a 10 Ω resistor in series with COL pin; Use oscilloscope to measure voltage at each end of resistor and deduce current) Worst case current into COL pin when the transistor switches off during Foldback

Table 3: Controller Operating Modes

PSU Electrical Characteristics

PSU Characteristic	Method	Conditions	Monitored Points	Measurements	Comments
V-I curve	Apply constant-current load from zero to high overload. Measure V_{OUT} and I_{OUT} Measure in-burst current Apply constant-voltage load from moderate load (below 100%) to high overload (near-zero voltage) Measure V_{OUT} and I_{OUT} and find Foldback point	V_{IN} = min, nom, max. Load = no-load to short-circuit	V_{OUT} , I_{OUT} , with meters I_{OUT} with current probe	V_{OUT} I_{OUT}	In-burst current is maximum output current during periodic bursts while in overload Foldback point is V_{OUT} and I_{OUT} at which a slight reduction in load voltage causes sudden large decrease in load current
Average Efficiency	Apply input voltage Vary the load current	V_{IN} = nom Load = 25, 50, 75, 100% of nom rated current		Input power, V_{OUT} , I_{OUT} Calculate efficiency at each of 4 load points Calculate numeric average of 4 efficiencies	Limit and precise method depends on the PSU specification and prevailing standards
No-load Input Power	Test at no load Apply input voltage	V_{IN} = nom Load = 0		Input power	Limit and precise method depends on the PSU specification and prevailing standards
Output ripple voltage	Apply input voltage Vary the load current	V_{IN} = min, nom, max Load = nom rated current	V_{OUT}	V_{OUT} ripple voltage	2 frequencies: - 2x mains input frequency - switching frequency
Switching Frequency	Apply input voltage Apply load	V_{IN} = nom Load = nom rated current	Q1 Collector (HV)	Q1 collector switching frequency	Confirm switching frequency meets design aim

Table 4: PSU Electrical Characteristics

Abnormal and Transient Conditions

PSU Characteristic	Method	Conditions	Monitored Points	Measurements	Comments
Load Transient Response	Apply input voltage Vary load	$V_{IN} = \text{nom}$ Load = 0 to 100% to 0; 1 Hz, 50% duty; minimum 1 A/ms	V_{OUT} I_{OUT}	V_{OUT} deviation V_{OUT} overshoot and undershoot Time for V_{OUT} to settle	This is a suggested test, but method and limits depend on the PSU specification
Turn-on Delay	Apply load Apply input voltage	$V_{IN} = \text{nom}$ Load = nom rated current.	V_{IN} V_{OUT}	Time between V_{IN} being applied and V_{OUT} reaching 90% of final value	Depends on PSU specification, for example, start-up load might be different
Abnormal Input Voltage Withstand	Apply load Apply input voltage	$V_{IN} = \text{extremes of abnormal conditions}$	Q1 Collector (HV)	Peak Q1 collector voltage	Check V_{cbo} ratings with appropriate margin are not exceeded
Load Pull-up	Apply load Apply input voltage	$V_{IN} = \text{min, nom, max}$ Load = variable, above nom rated	V_{OUT}	Check V_{OUT} establishes in an acceptable way	Depends on PSU specification
Short Circuit	Apply input voltage Short the output	$V_{IN} = \text{min}$	VDD pin	VDD voltage	Check VDD does not dip during short-circuit. Real requirement is auxiliary voltage (generated by the transformer) is high enough to provide current into controller and base of the auxiliary transistor (if fitted). Base current requirements are complex but calculable from VDD input current, auxiliary transistor gain and average BAS output current.
Long Duration Short Circuit	Apply input voltage Short the output	$V_{IN} = \text{max}$ Load = short circuit Maximum ambient temperature	Component temperatures	Conduct thermal survey as per Thermal Survey section on page 8	Test should be conducted for long enough to enable all component temperatures to stabilise

Table 5: Abnormal and Transient Conditions

Environmental Testing

Any of the tests may be performed in conditions of extended ambient temperature and humidity, depending on the PSU Specification.

If environmental and mechanical factors (for example, a plastic enclosure) are not compatible with test access, then appropriate allowances must be made.

Stress Analysis

Ascertain the electrical and thermal stresses on each component, during both normal and abnormal operating conditions. Compare with component ratings. Give special attention to the transformer because it is safety-critical.

Input Current Protection

This document is not intended to cover safety implications of single faults. However, the designer should be aware of the possibility of the switching transistor failing catastrophically and possibly allowing high fault current to flow in the transformer primary. This current must be limited so as not to cause excessive heating of the transformer, which might compromise the insulation system.

Thermal Survey

Operating temperatures of the switching transistor (Q1), transformer windings and output diode should be measured under the specified ambient temperature conditions after the UUT has reached thermal equilibrium.

CONTACT DETAILS

Cambridge Semiconductor Ltd
St Andrew's House
St Andrew's Road
Cambridge
CB4 1DL
United Kingdom

Phone: +44 (0)1223 446450
Fax: +44 (0)1223 446451
Email: sales.enquiries@camsemi.com
Web: www.camsemi.com

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