

Connecting Two UCC28064A Interleaved PFC Power Stages in Parallel



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ABSTRACT

Most AC/DC switched mode power-supply designs employ PFC (Power Factor Correction) to achieve high Power Factor and low Total Harmonic Distortion (THD). Typically, transition mode (TM) topologies with phase interleaving are used for high-resolution televisions and large panel display applications. This application note describes how to parallel two UCC28064A PFC TM Interleaved controllers to provide 1kW of load-shared power.

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1 Introduction

A 1kW PFC pre-regulator can be designed with a single-stage boost converter or more effectively, with parallel interleaved CCM. However, each of these topologies have weaknesses in supplying high power. Notably, parallel interleaved CCM solutions are more expensive than the TM counterpart due to the larger boost inductors, higher performance rectifier diodes and larger, more expensive FETs that are required. Parallel Interleaved TM can achieve similar electrical performance, including PF, THD, and audible noise immunity at a lower overall cost.

2 Normal Theory of Multi Phases Control UCC28070 and UCC28064A Operation

The UCC28070 external synchronization facilitates using more than two phases for interleaving. Multiple UCC28070s can easily be paralleled to add an even number of additional phases for higher-power applications. An odd number of phases can be accommodated, however, an even number of phases are recommended due to the optimal ripple current cancellation at 50% duty cycle. With two phases per controller, for 2- 4- or 6-phase solution, each controller should receive a SYNC signal which is $360/n$ degrees out of phase with each other (where n = the number of UCC28070 controllers). With appropriate phase-shifting of the synchronization signals, even more input and output ripple current cancellation can be obtained.

For a 4-phase interleaved application with two controllers, SYNC1 should be 180° out of phase with SYNC2 for optimal ripple cancellation. Similarly for a 6-phase system, SYNC1, SYNC2, and SYNC3 should be 120° out of phase with each other for optimal ripple cancellation. [Figure 2-1](#) illustrates the paralleling of two controllers for a four-phase 90-degree-interleaved PFC system. However, because the UCC28064A does not have a synchronization feature like the UCC28070, it is not as straightforward to parallel multiple controllers.

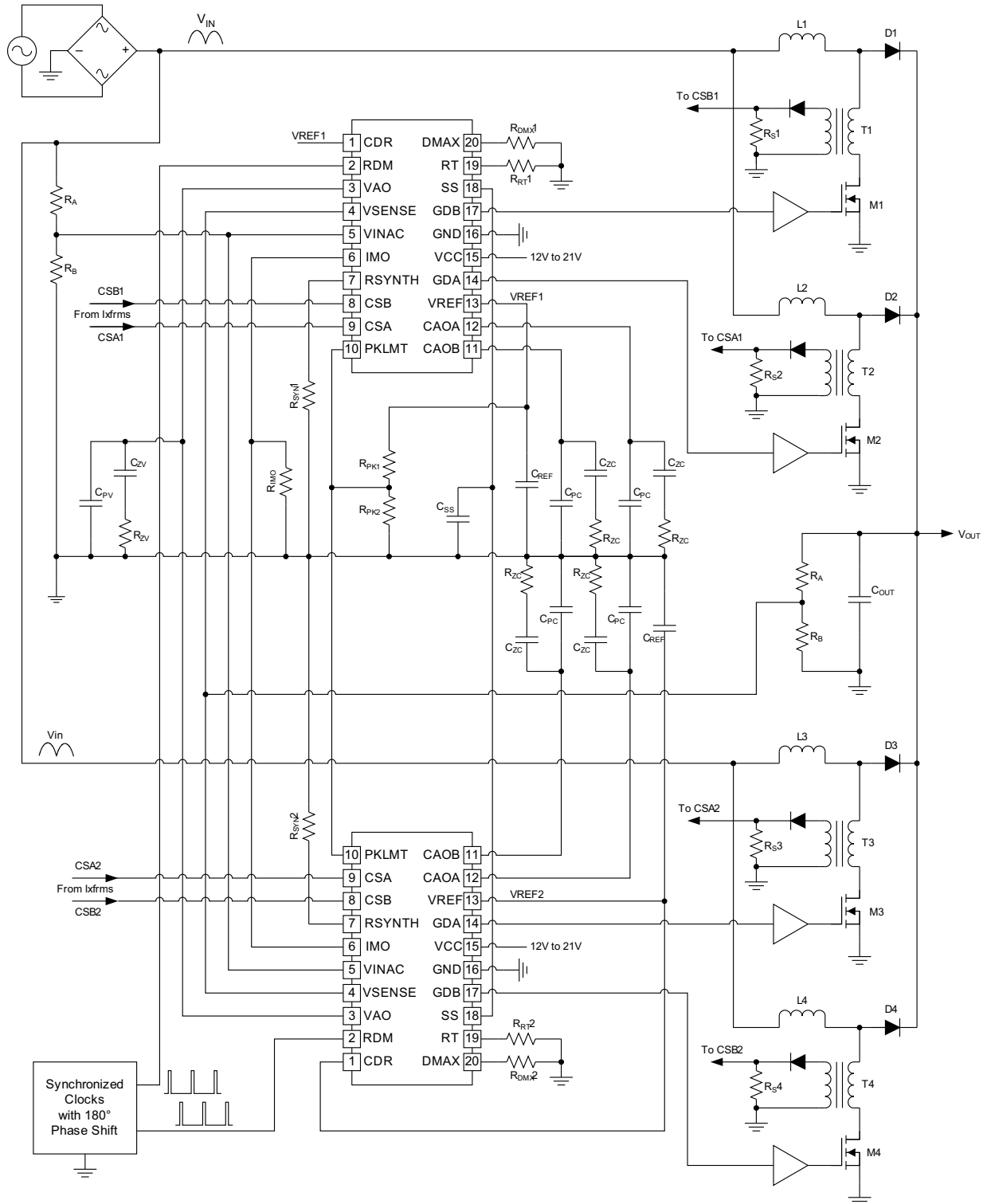


Figure 2-1. Simplified Four-Phase PFC Application Using Two UCC28070 Devices

3 Achieving Adjustable Phase Control Operation with UCC28064A

The voltage on the PHB pin can be set using a simple resistor divider connected to the VREF pin. Another important feature, that allows optimization of phase management is that it is possible to set different thresholds whether the PFC input voltage is in the range of 90 to 132 VRMS (US mains) or in the range of 180 to 265 VRMS (European mains). If the peak voltage sensed by the VINAC pin exceeds 3.5 V, the converter assumes that the input voltage is in the range of 180 to 265 VRMS and starts sourcing from PHB a small current ($3\mu\text{A}$ typically) that increases the voltage on PHB pin.

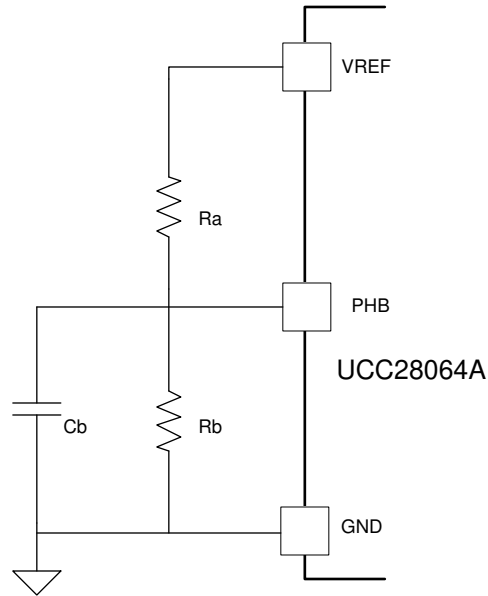


Figure 3-1. Original Adjustable Phase Control Circuit with UCC28064A

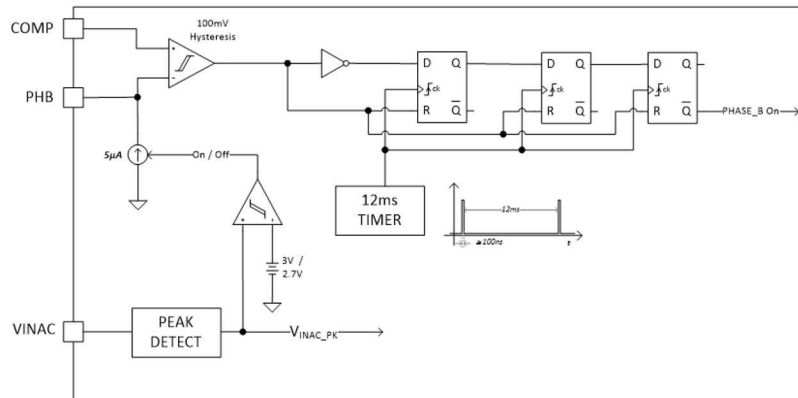


Figure 3-2. Internal Block of Phase Control with UCC28064A

4 Achieving Multi Phases Control Operation

4.1 Disable Feedback of Secondary (Connecting VSENSE and VREF Directly)

Auto recovery function is disable due to offset current of secondary.

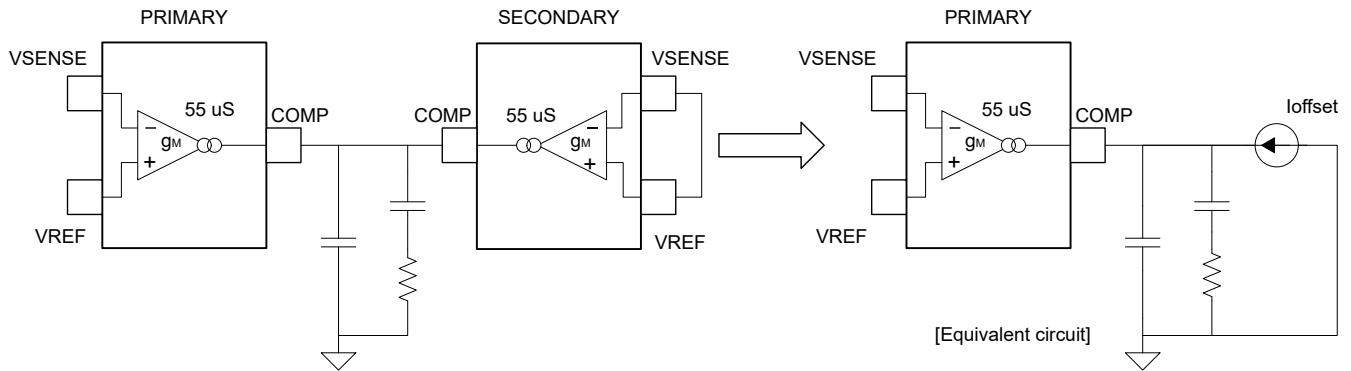


Figure 4-1. Disable Feedback of Secondary with UCC28064A-1

4.2 Disable Feedback of Secondary (Connecting VSENSE and VREF with Diode)

Negative offset is always guaranteed ($V_{sense} > V_{ref}$).

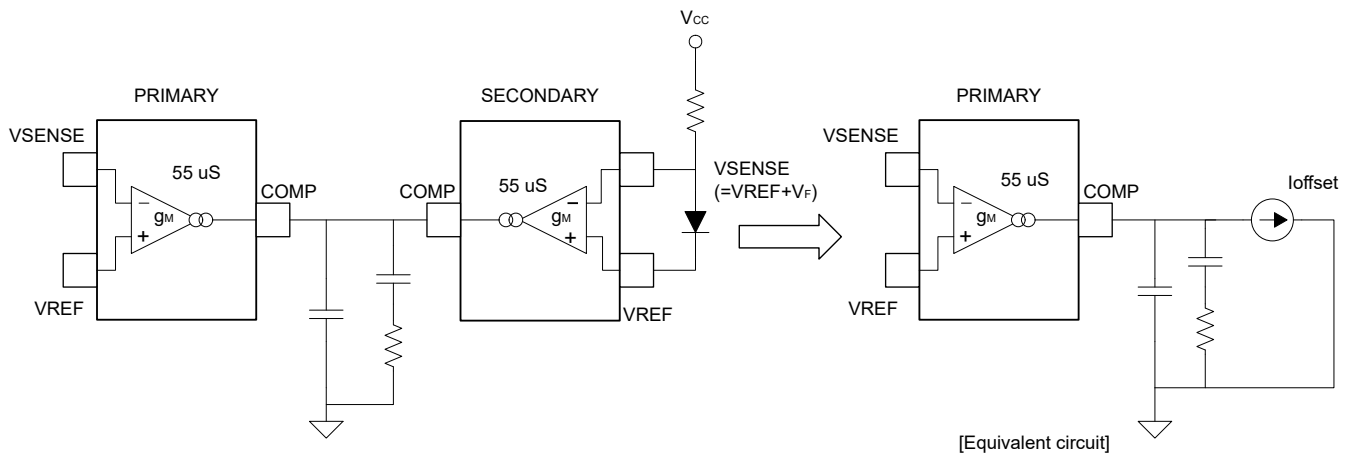


Figure 4-2. Disable Feedback of Secondary with UCC28064A-2

4.3 External 4 Multi-phase Mode Control Circuit of UCC28064A

Figure 4-3 shows how to accurately achieve paralleling and current sharing of TM PFC power stage.

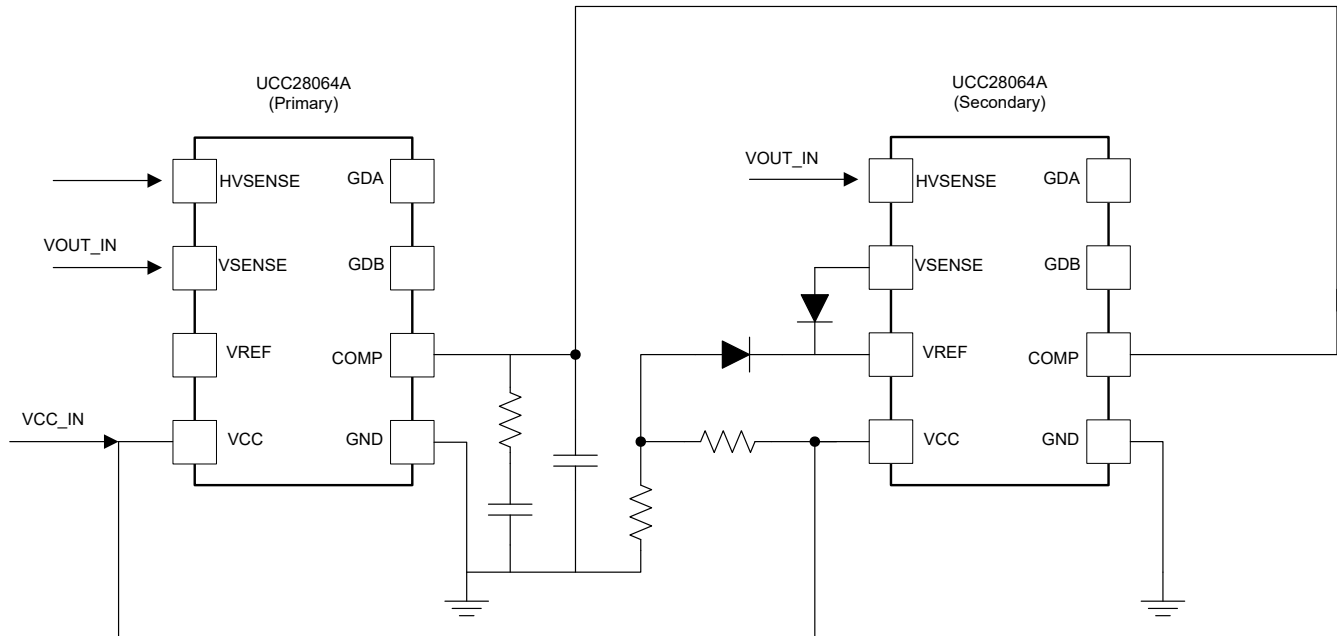


Figure 4-3. External Circuit for Paralleling Two Power Stages with Two UCC28064A

4.4 Detail Operating for External Paralleling Two-Power Stages Control Circuit of UCC28064A

There are 2 TM PFC control IC's, a primary and secondary. Each one has internal comparators and reference voltages which are independent of the other. When COMP is connected between the two pins, both 20-mV COMP-Discharge comparators must be satisfied before each load on COMP will be released.

There are several important highlights to note from Figure 4-3. By connecting VSENSE to VREF with a diode, the feedback of the secondary controller is disabled. Also, because both the primary and secondary controllers share a common COMP pin, they will have the same constant on time. The two UCC28064s will have their own zero cross detection (ZCD) and other protections such as 1st OVP, 2nd OVP, OCP and OTP can be set individually.

4.5 Test result for External Paralleling two power stages control circuit of UCC28064A

Figure 4-4 shows setting external circuit components value for optimizing 4-phase control with UCC28064A (Primary) and UCC28064A (Secondary). Testing power rating is PIN 1.5 kW and VINAC range is from 90 VAC to 264 V_{AC}

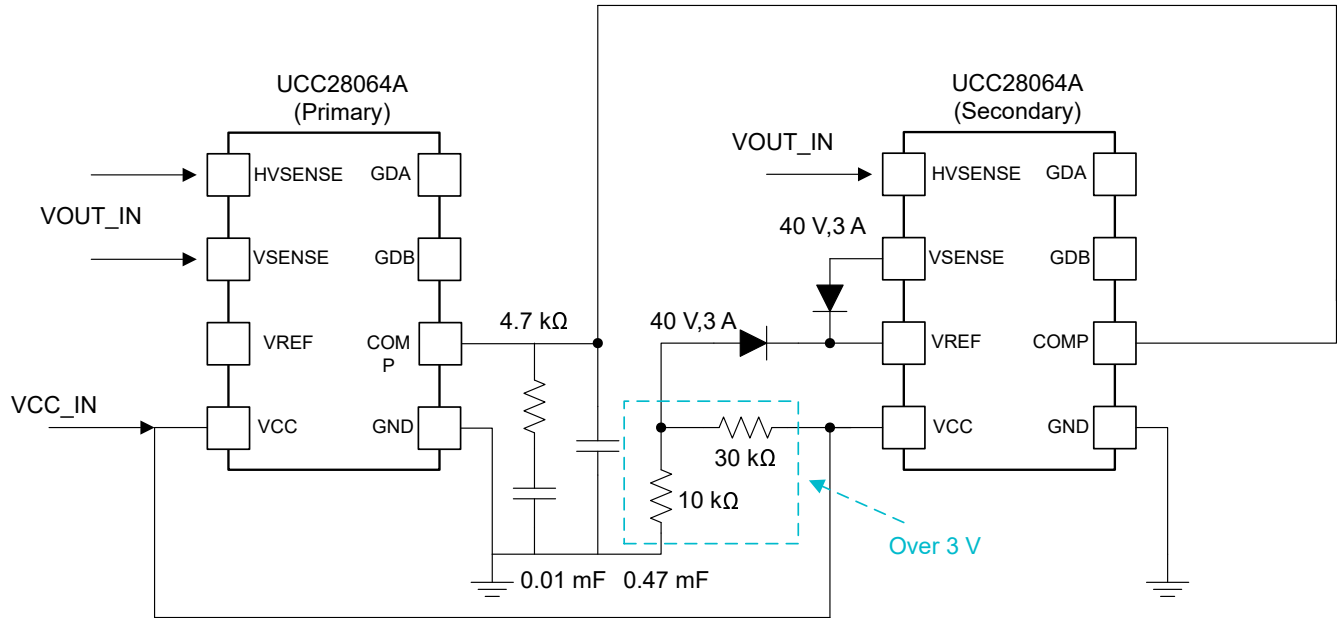


Figure 4-4. External Circuit for Paralleling Two-Power Stages Operating with Two UCC28064A (Additional Detail)

* Adjustable voltage range 3.0V ~5V in the Blue square dotted line

Table 4-1 shows measuring current level value of load sharing multi- phase operating depends on input power rating conditions.

Table 4-1. Measuring Load Sharing Regulation and Current Primary and Secondary

Input Power(W)	100W	300W	500W	800W	1000W	1500W
Output Current (A)	0.244	0.744	1.243	1.986	2.484	3.75
Primary Output Diode Current(A)	0.134	0.373	0.619	0.99	1.243	1.85
Secondary Output Diode Current (A)	0.11	0.371	0.623	0.996	1.241	1.9
Load Share Regulation (%)	9.84%	0.27%	0.4%	0.3%	0.08%	1.33%

Figure 4-5 waveforms show how well the paralleled TM PFC stages shared currents at different power levels.



Figure 4-5. Waveform of Multi-operating (100W)



Figure 4-6. Waveform of Multi-operating (300W)



Figure 4-7. Waveform of Multi-operating (500W)



Figure 4-8. Waveform of Multi-operating (800W)



Figure 4-9. Waveform of Multi-operating (1000W)



Figure 4-10. Waveform of Multi-operating (1500W)

Figure 4-11 shows how well the paralleled TM Interleaved PFC boost stages share current from a 100 W to 1500W loading.

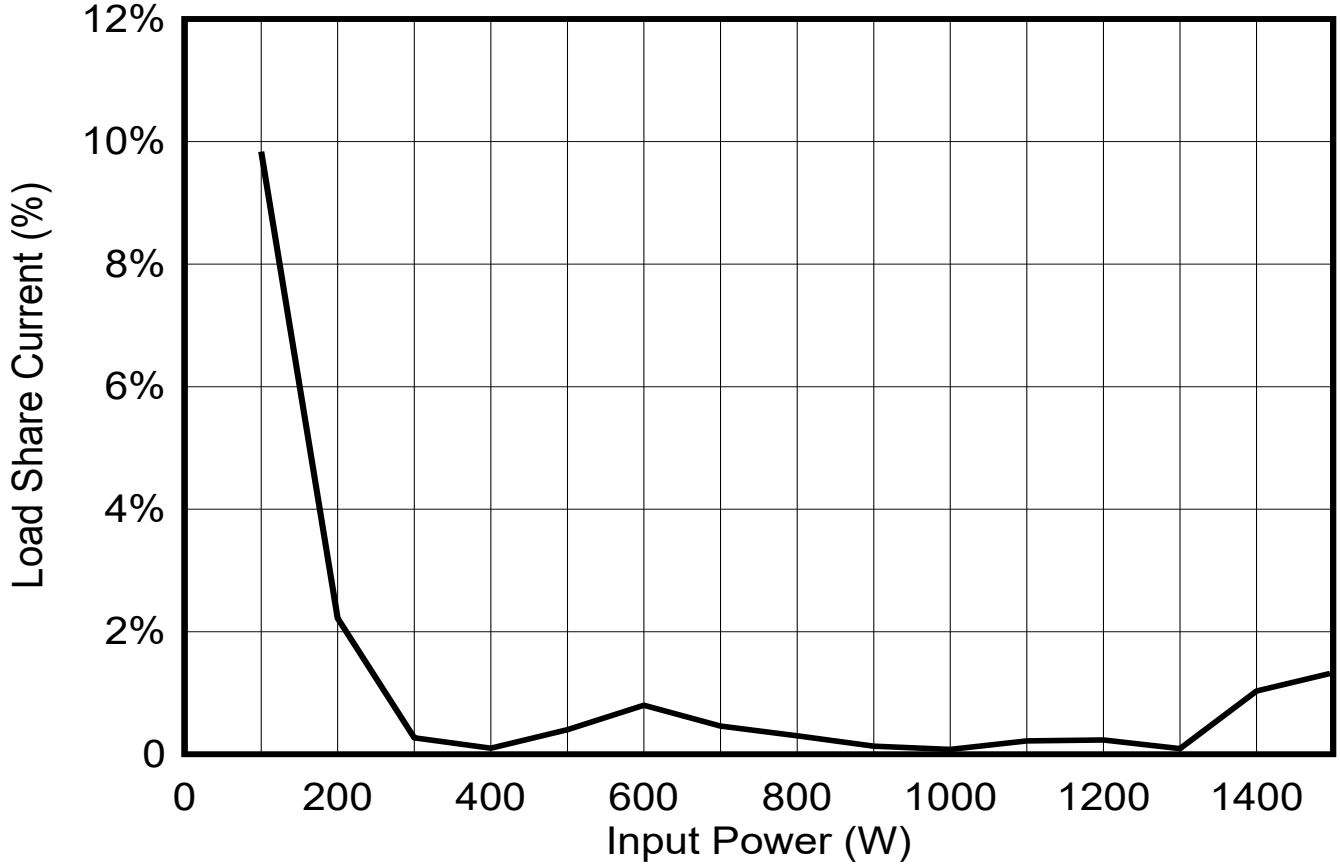


Figure 4-11. Comparison Variation Current and Power Rating

5 Summary

From the test results and accompanying waveforms, it was demonstrated that the paralleled TM interleaved PFC controller using simple external components was able to achieve natural load balance without requiring an additional load-sharing device. Additionally, this solution lends itself to smaller inductors, lower switching frequencies and smaller peak currents resulting in high Power Factor (PF) and low Total Harmonic Distortion (THD). It was demonstrated that multi-phase load sharing can be accomplished through a simple parallel solution consisting of two UCC28064A controllers.

6 References

- Texas Instruments, [UCC28064A Natural Interleaving™ Transition-Mode PFC Controller with High Light-Load Efficiency](#) data sheet.
- Texas Instruments, [UCC28070 Interleaving Continuous Conduction Mode PFC Controller](#) data sheet.

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