Test Report: PMP23421

Multi-Phase Four-Switch Buck-Boost DC/DC Converter Reference Design

TEXAS INSTRUMENTS

Description

This reference design is a digitally controlled, gallium nitride (GaN) based, four-switch buck-boost DC/DC converter used for battery back-up (BBU) application. This design has a total of seven phases. Six phases are connected in parallel for battery discharging operation providing up to 8.1kW discharging power. The seventh phase is used for battery charging operation. The converter works in either buck, buck-boost, or boost mode depending on V_{IN} and V_{OUT} voltage, and transitions smoothly between each mode.
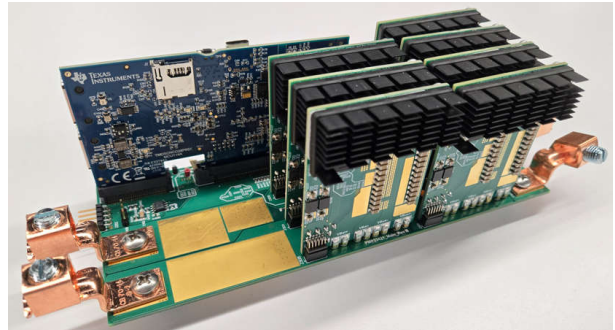
Features

- One MCU controls seven phases simultaneously
- Peak current mode control, fast load transient
- Multi-mode operation: buck, buck/boost, boost
- Current balancing among each phase
- 99% Peak efficiency
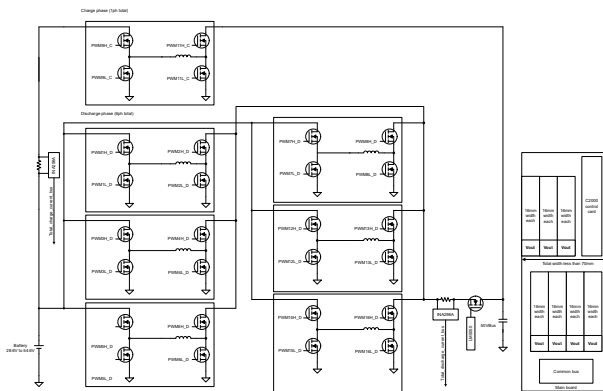- Meets Open Rack Base Version 3 (OCP-V3) 50V BBU specification

Applications

- Battery backup unit
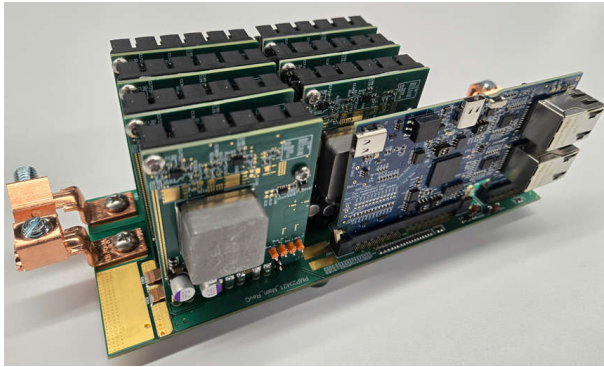
Front View Photo

Back View Photo

PMP23421 Block Diagram

1 Key System Specification

Table 1-1. Specifications

PARAMETER	SPECIFICATION
V_{IN} (Battery)	28.6V to 54.6V
V_{OUT} (DC bus)	50V
Switching frequency	300kHz
Control loop frequency	150kHz
Maximum discharge current (DC side)	162A
Maximum charge current (battery side)	5A
Peak efficiency	99%

2 Test Prerequisites

2.1 Required Equipment

- DC source: 50V, 300A
- Electronics load: 50V, 160A
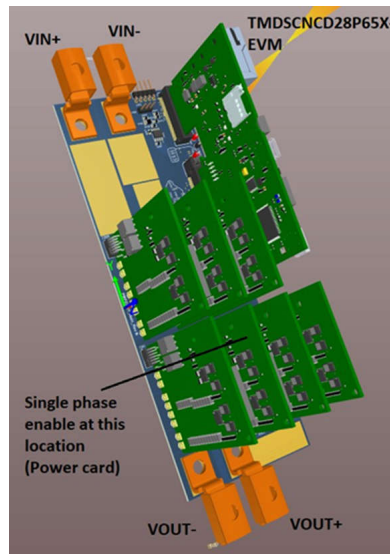- DC source: 12V, 1A
- DC source: 12V, 2A
- Fan

2.2 Test Setup
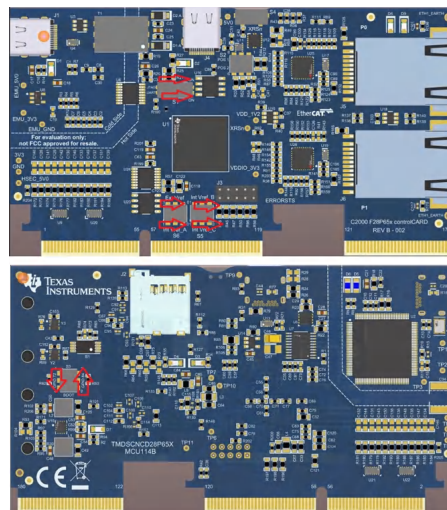

Figure 2-1. Main Board and PS Daughter Card Setup

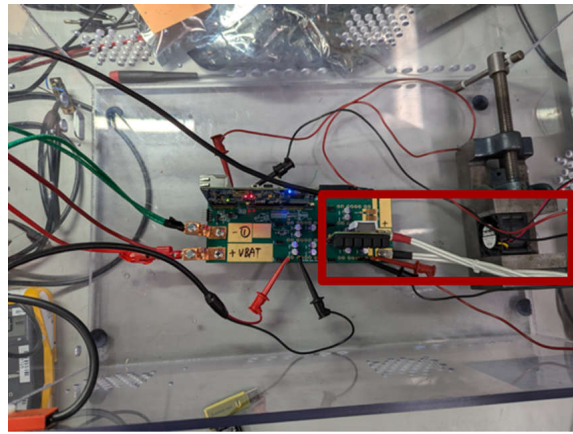**Figure 2-2. C2000™ Control Card Setup**

Figure 2-3. Cooling Setup

3 Test Results

3.1 Efficiency Graphs

Figure 3-1, Figure 3-2, and Figure 3-3 show the efficiency graphs.
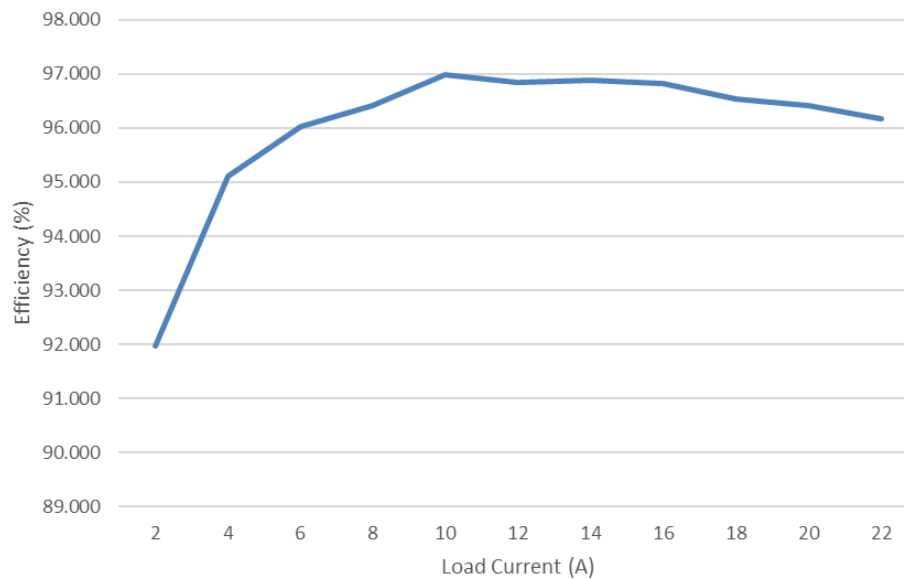

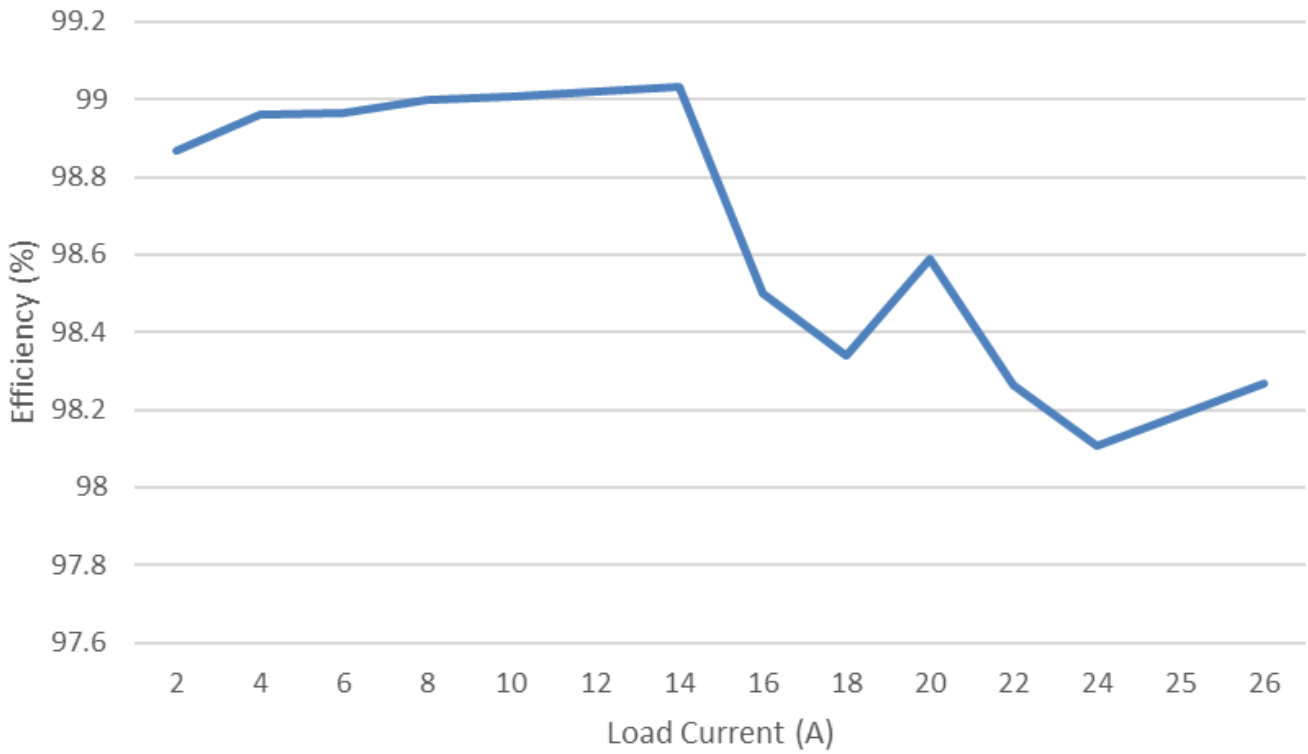**Figure 3-1. Efficiency at V$_{IN}$ = 26.8V, V$_{OUT}$ = 50V, Open Loop**

Figure 3-2. Efficiency at V_{IN} = 44V, V_{OUT} = 50V, Close Loop
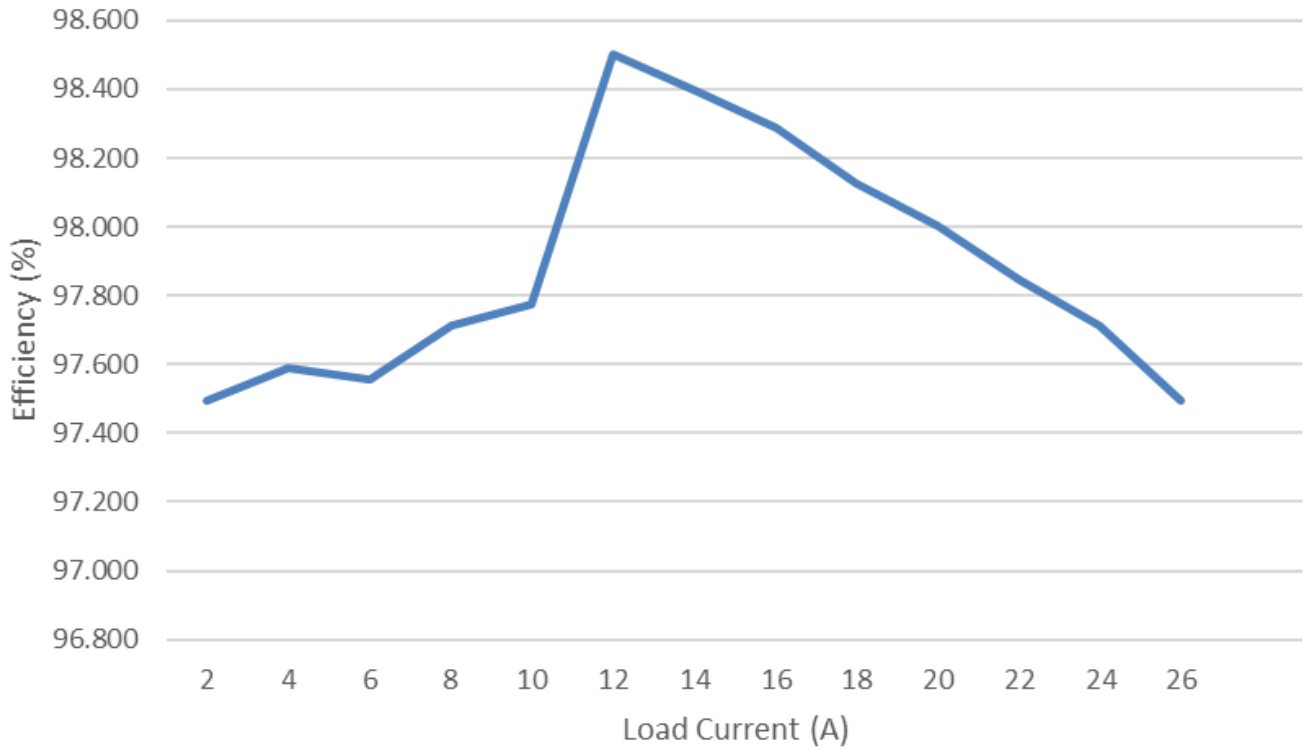

Figure 3-3. Efficiency at V_{IN} = 54V, V_{OUT} = 50V, Close Loop

3.2 Efficiency Data

Efficiency data is shown in Table 3-1, Table 3-2, and Table 3-3.

Table 3-1. Efficiency Data at V_{IN} = 28.6V

V_{IN}	I_{IN}	P_{IN}	V_{OUT}	I_{OUT}	P_{OUT}	Efficiency
28.600	3.799	108.655	50.040	1.997	99.930	91.970
28.600	7.348	210.161	50.010	3.997	199.890	95.113
28.600	10.897	311.667	49.910	5.997	299.310	96.035
28.60	14.597	417.463	50.330	7.997	402.489	96.413
28.600	18.096	517.539	50.210	9.997	501.949	96.988
28.600	21.695	620.475	50.090	11.997	600.930	96.850
28.600	25.244	721.982	49.970	13.997	699.430	96.876
28.600	28.793	823.488	49.840	15.997	797.290	96.819
28.600	32.392	926.424	49.690	17.997	894.271	96.529
28.600	36.292	1037.938	50.045	19.997	1000.750	96.417
28.600	39.891	1140.874	49.880	21.997	1097.210	96.173

Table 3-2. Efficiency Data at V_{IN} = 44V

V_{IN}	I_{IN}	P_{IN}	V_{OUT}	I_{OUT}	P_{OUT}	EFFICIENCY
44	2.299	101.176	50.09	1.997	100.03	98.867
44	4.599	202.353	50.1	3.997	200.25	98.961
44	6.898	303.529	50.09	5.997	300.39	98.966
44	9.198	404.706	50.1	7.997	400.65	98.998
44	11.497	505.882	50.1	9.997	500.85	99.005
44	13.797	607.059	50.105	11.997	601.11	99.02
44	16.096	708.235	50.11	13.997	701.39	99.033
44	18.496	813.81	50.11	15.997	801.61	98.501
44.1	20.795	917.066	50.11	17.997	901.83	98.339
44	23.095	1016.163	50.1	19.997	1001.85	98.591
44	25.494	1121.739	50.11	21.997	1102.27	98.264
44.1	27.794	1225.694	50.11	23.997	1202.49	98.107
44	28.993	1275.703	50.11	24.997	1252.6	98.189
44.2	29.993	1325.691	50.11	25.997	1302.71	98.266

Table 3-3. Efficiency Data at V_{IN} = 54V

V_{IN}	I_{IN}	P_{IN}	V_{OUT}	I_{OUT}	P_{OUT}	EFFICIENCY
54.000	1.900	102.600	50.090	1.997	100.030	97.495
54.000	3.800	205.200	50.100	3.997	200.250	97.588
54.030	5.700	307.971	50.100	5.997	300.450	97.558
53.950	7.600	410.020	50.100	7.997	400.650	97.715
53.920	9.500	512.240	50.100	9.997	500.850	97.776
54.000	11.300	610.200	50.100	11.997	601.050	98.500
54.000	13.200	712.800	50.110	13.997	701.390	98.399
54.000	15.100	815.400	50.100	15.997	801.450	98.289
54.050	17.000	918.850	50.100	17.997	901.650	98.128
54.100	18.900	1022.490	50.110	19.997	1002.050	98.001
53.900	20.900	1126.510	50.110	21.997	1102.270	97.848
54.000	22.790	1230.660	50.110	23.997	1202.490	97.711
53.900	24.790	1336.181	50.110	25.997	1302.710	97.495

3.3 Thermal Images

Figure 3-4. Thermal Image at 28.6V V_{in}, 50V V_{out}, and 22A I_{out}
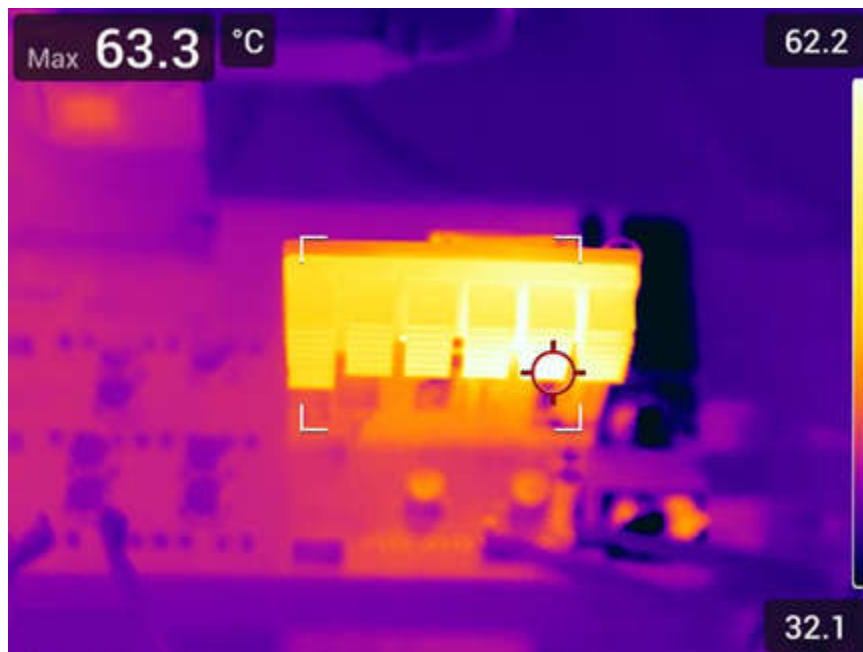

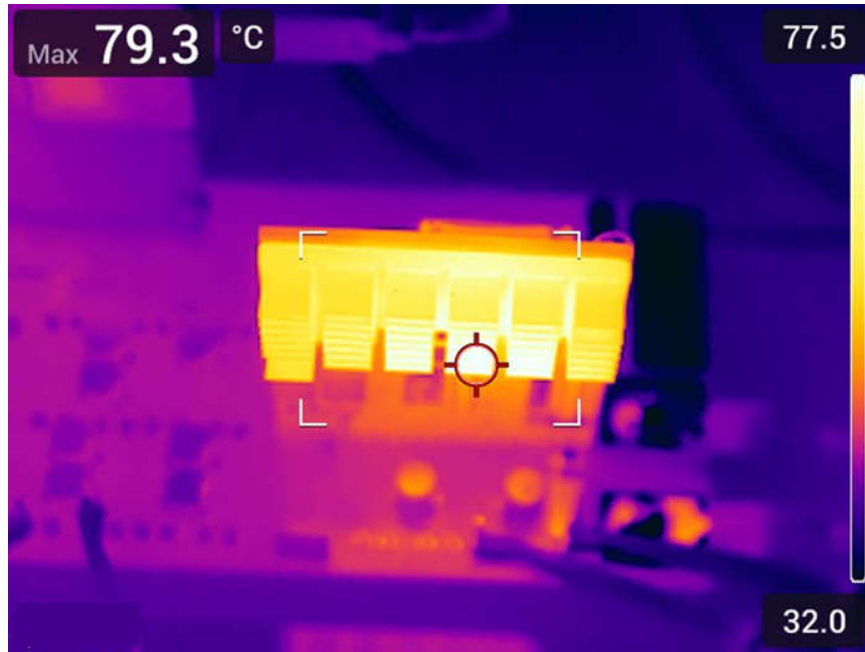**Figure 3-5. Thermal Image at 44V V_{in}, 50V V_{out}, and 26A I_{out}**

Figure 3-6. Thermal Image at 54V V$_{in}$, 50V V$_{out}$, and 26A I$_{out}$

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