LM5175 Synchronous 4-Switch Buck-Boost Converter

TI reference design number: PMP10594 REV A

Input: 4.5V to 22.5V DC
Output: 9.2V @ 12.5A

DC – DC Test Results

Table of Contents

1 Test Specifications

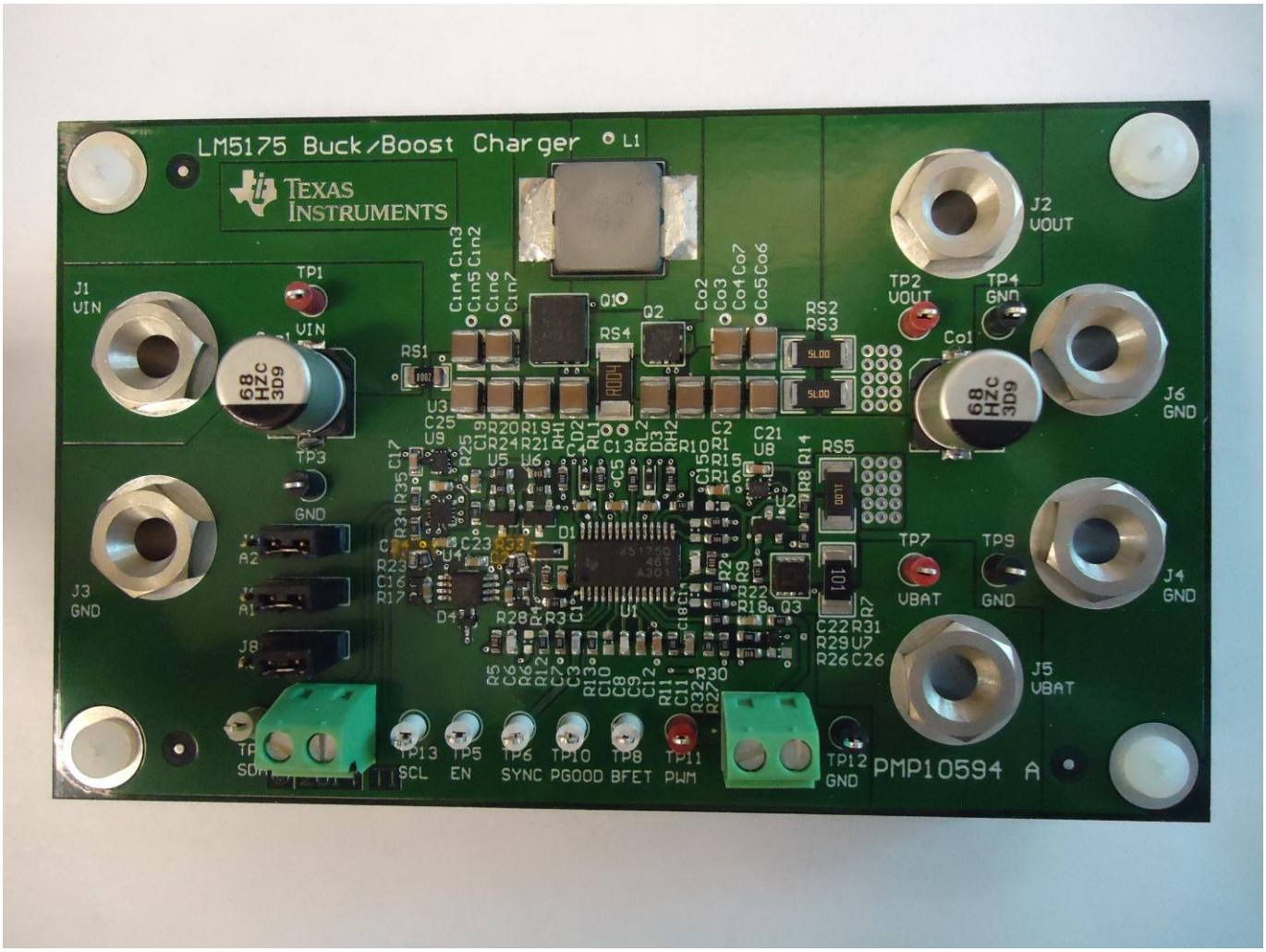
Vin min	**4.5V**
Vin max	**22.5V**
Vout	**9.2V**
Iout	**12.5A**

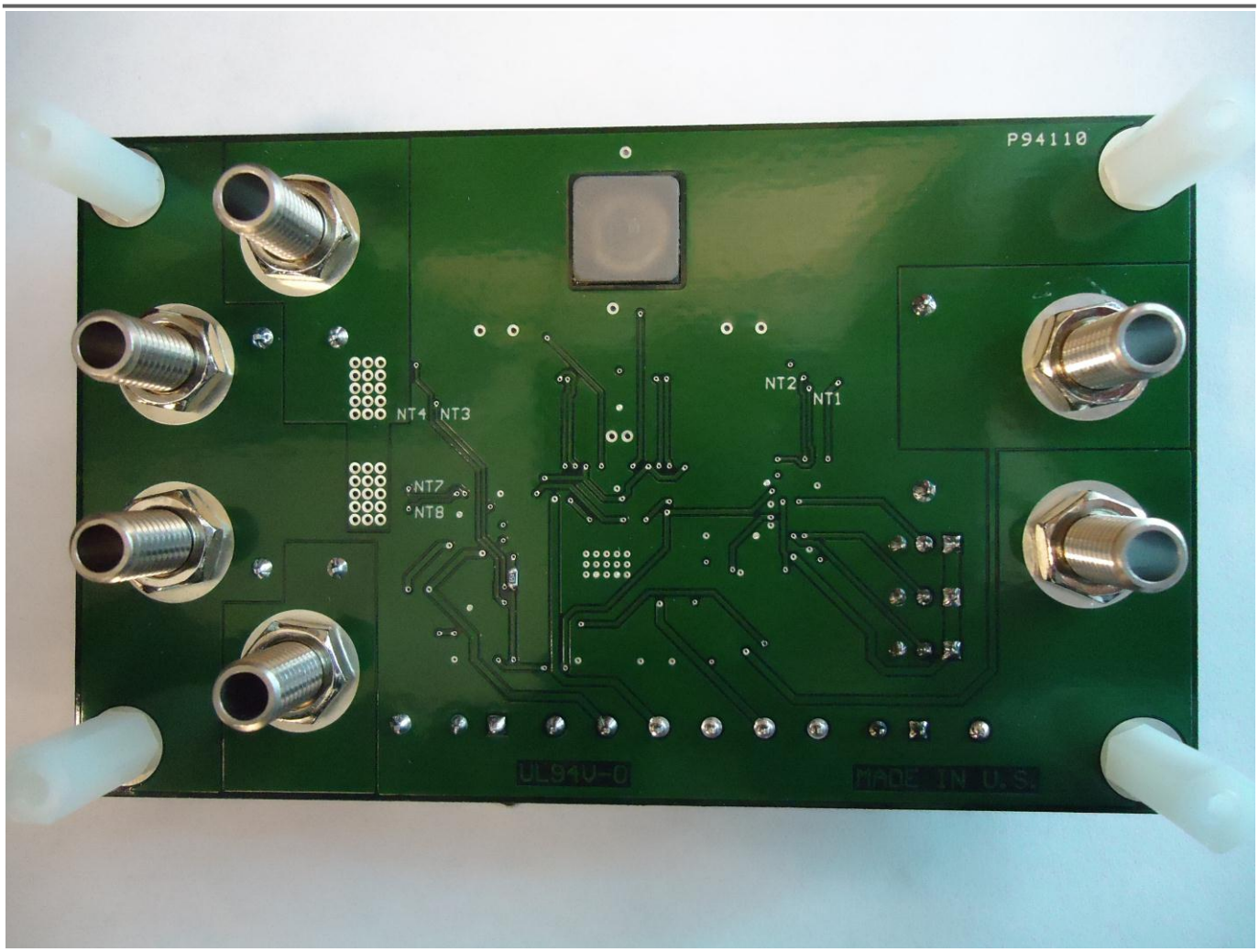
2 Circuit Description

PMP10594 is a synchronous 4-switch buck-boost converter which utilizes the LM5175 controller for battery charger applications. The output voltage set point can be adjusted by a PWM signal over the range of 7.1V to 9.2V. I2C programming allows independent control of the average input current and charge current. Full scale input current limiting is 6A, while charge current is programmable to 12.5A. The LM5175 average current loop sets a maximum output current of 20A, which should never engage under normal circumstances. Additional pulse-by-pulse current limiting is inherent in the current-mode controller, making this a very robust design. A battery disconnect switch is used to provide trickle charging if the battery voltage is less than 6V.

3 Board Photos

The design is built on PMP10594 Rev A printed circuit board. This is a 4-layer PCB with 2 oz. copper on external layers and 1 oz. copper on internal layers. PCB dimensions are 4.3 x 2.6 inch.




P94110
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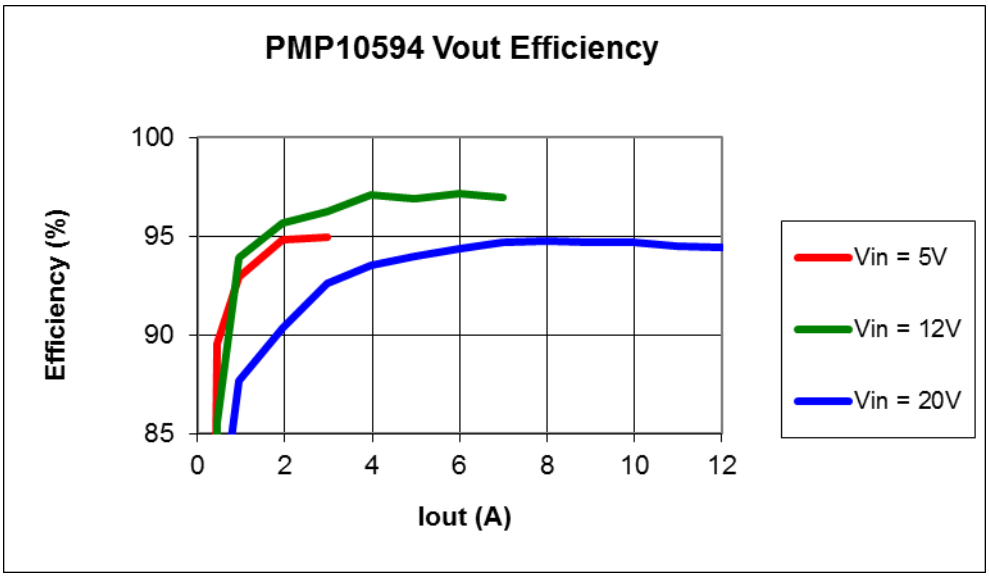
4 Efficiency

4.1 Vout Efficiency Results



4.2 Vout Efficiency Data

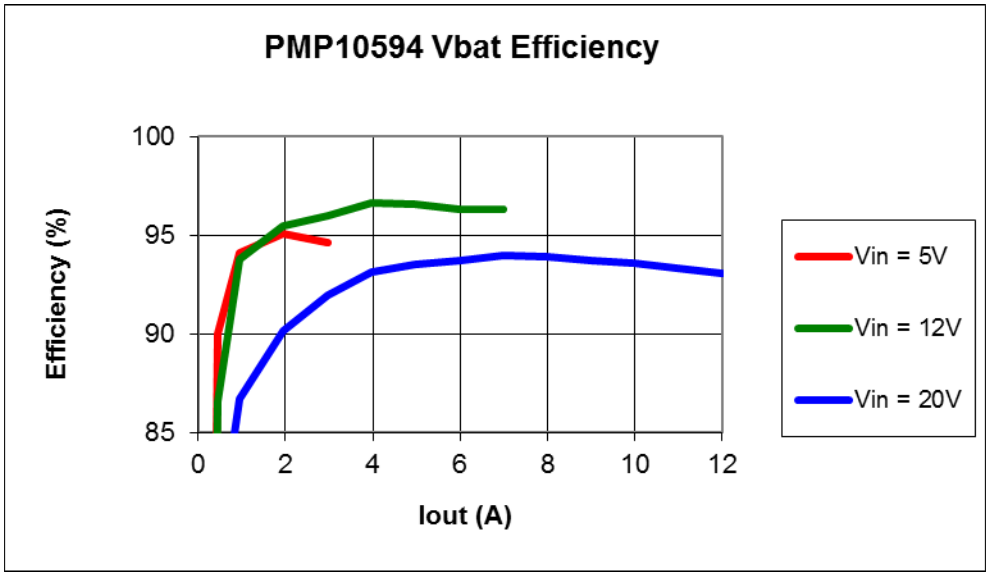
The output current is increased above the maximum value to test current limit.

Vin (V)	Iin (A)	Vout (V)	Iout (A)	Pin (W)	Pout (W)	Pdis (W)	Efficiency (%)
5.004	0.050	9.153	0.000	0.25	0.00	0.25	0.000
5.004	0.940	9.158	0.460	4.70	4.21	0.49	89.560
5.004	1.890	9.155	0.960	9.46	8.79	0.67	92.929
5.004	3.780	9.153	1.960	18.92	17.94	0.98	94.844
5.004	5.700	9.152	2.960	28.52	27.09	1.43	94.976
5.004	6.010	7.237	3.980	30.07	28.80	1.27	95.774
5.004	6.005	5.628	4.980	30.05	28.03	2.02	93.272
5.004	6.000	4.738	5.980	30.02	28.33	1.69	94.369
5.004	6.000	3.945	6.980	30.02	27.54	2.49	91.714
5.004	6.000	3.332	7.980	30.02	26.59	3.43	88.560
5.004	6.000	2.934	8.980	30.02	26.35	3.68	87.754
5.004	6.000	2.570	9.980	30.02	25.65	4.38	85.427
5.004	6.000	2.260	10.980	30.02	24.81	5.21	82.650
5.004	6.005	1.982	12.000	30.05	23.78	6.27	79.151
5.004	6.010	1.728	13.000	30.07	22.46	7.61	74.696
5.004	6.005	1.675	14.000	30.05	23.45	6.60	78.039
5.004	6.000	1.498	15.020	30.02	22.50	7.52	74.940

Vin (V)	Iin (A)	Vout (V)	Iout (A)	Pin (W)	Pout (W)	Pdis (W)	Efficiency (%)
12.002	0.030	9.155	0.000	0.36	0.00	0.36	0.000
12.002	0.410	9.154	0.460	4.92	4.21	0.71	85.572
12.002	0.780	9.157	0.960	9.36	8.79	0.57	93.902
12.002	1.560	9.136	1.960	18.72	17.91	0.82	95.639
12.002	2.340	9.134	2.960	28.08	27.04	1.05	96.268
12.001	3.120	9.133	3.980	37.44	36.35	1.09	97.079
12.002	3.910	9.133	4.980	46.93	45.48	1.45	96.920
12.001	4.700	9.133	6.000	56.40	54.80	1.61	97.151
12.001	5.495	9.133	7.000	65.95	63.93	2.01	96.945
12.001	6.000	8.685	8.000	72.01	69.48	2.53	96.492
12.001	6.000	7.640	9.000	72.01	68.76	3.25	95.492
12.001	6.000	6.836	9.980	72.01	68.22	3.78	94.747
12.001	6.005	6.150	11.000	72.07	67.65	4.42	93.872
12.001	6.005	5.575	12.000	72.07	66.90	5.17	92.832
12.001	6.005	5.086	13.000	72.07	66.12	5.95	91.746
12.001	6.005	4.660	14.000	72.07	65.24	6.83	90.528
12.001	6.005	4.286	15.020	72.07	64.38	7.69	89.329

Vin (V)	Iin (A)	Vout (V)	Iout (A)	Pin (W)	Pout (W)	Pdis (W)	Efficiency (%)
20.010	0.020	9.157	0.000	0.40	0.00	0.40	0.000
20.010	0.265	9.137	0.460	5.30	4.20	1.10	79.263
20.010	0.500	9.137	0.960	10.01	8.77	1.23	87.671
20.010	0.990	9.134	1.960	19.81	17.90	1.91	90.372
20.010	1.460	9.142	2.960	29.21	27.06	2.15	92.626
20.010	1.940	9.124	3.980	38.82	36.31	2.51	93.545
20.010	2.415	9.122	4.980	48.32	45.43	2.90	94.006
20.009	2.890	9.122	5.980	57.83	54.55	3.28	94.334
20.009	3.370	9.122	7.000	67.43	63.85	3.58	94.696
20.009	3.850	9.122	8.000	77.03	72.98	4.06	94.731
20.009	4.335	9.123	9.000	86.74	82.11	4.63	94.660
20.009	4.805	9.123	9.980	96.14	91.05	5.10	94.700
20.009	5.300	9.124	10.980	106.05	100.18	5.87	94.468
20.009	5.795	9.125	12.000	115.95	109.50	6.45	94.436
20.009	6.005	8.677	13.000	120.15	112.80	7.35	93.880
20.009	6.005	7.974	14.000	120.15	111.64	8.52	92.911
20.009	6.005	7.376	15.020	120.15	110.79	9.37	92.205

4.1 Vbat Efficiency Results



4.2 Vbat Efficiency Data

The output current is increased above the maximum value to test current limit.

Vin (V)	Iin (A)	Vout (V)	Iout (A)	Pin (W)	Pout (W)	Pdis (W)	Efficiency (%)
5.004	0.050	9.154	0.000	0.25	0.00	0.25	0.000
5.004	0.935	9.155	0.460	4.68	4.21	0.47	90.009
5.004	1.865	9.148	0.960	9.33	8.78	0.55	94.103
5.004	3.765	9.137	1.960	18.84	17.91	0.93	95.056
5.004	5.705	9.126	2.960	28.55	27.01	1.53	94.624
5.004	6.005	7.188	3.980	30.05	28.61	1.44	95.205
5.004	6.000	5.539	4.980	30.02	27.58	2.44	91.874
5.004	0.225	0.003	0.080	1.13	0.00	1.13	0.021
5.004	0.225	0.003	0.080	1.13	0.00	1.13	0.021
5.004	0.225	0.003	0.080	1.13	0.00	1.13	0.021
5.004	0.225	0.003	0.080	1.13	0.00	1.13	0.021
5.004	0.225	0.003	0.080	1.13	0.00	1.13	0.021
5.004	0.225	0.003	0.080	1.13	0.00	1.13	0.021
5.004	0.225	0.003	0.080	1.13	0.00	1.13	0.021
5.004	0.225	0.003	0.080	1.13	0.00	1.13	0.021
5.004	0.225	0.003	0.080	1.13	0.00	1.13	0.021
5.004	0.225	0.003	0.080	1.13	0.00	1.13	0.021

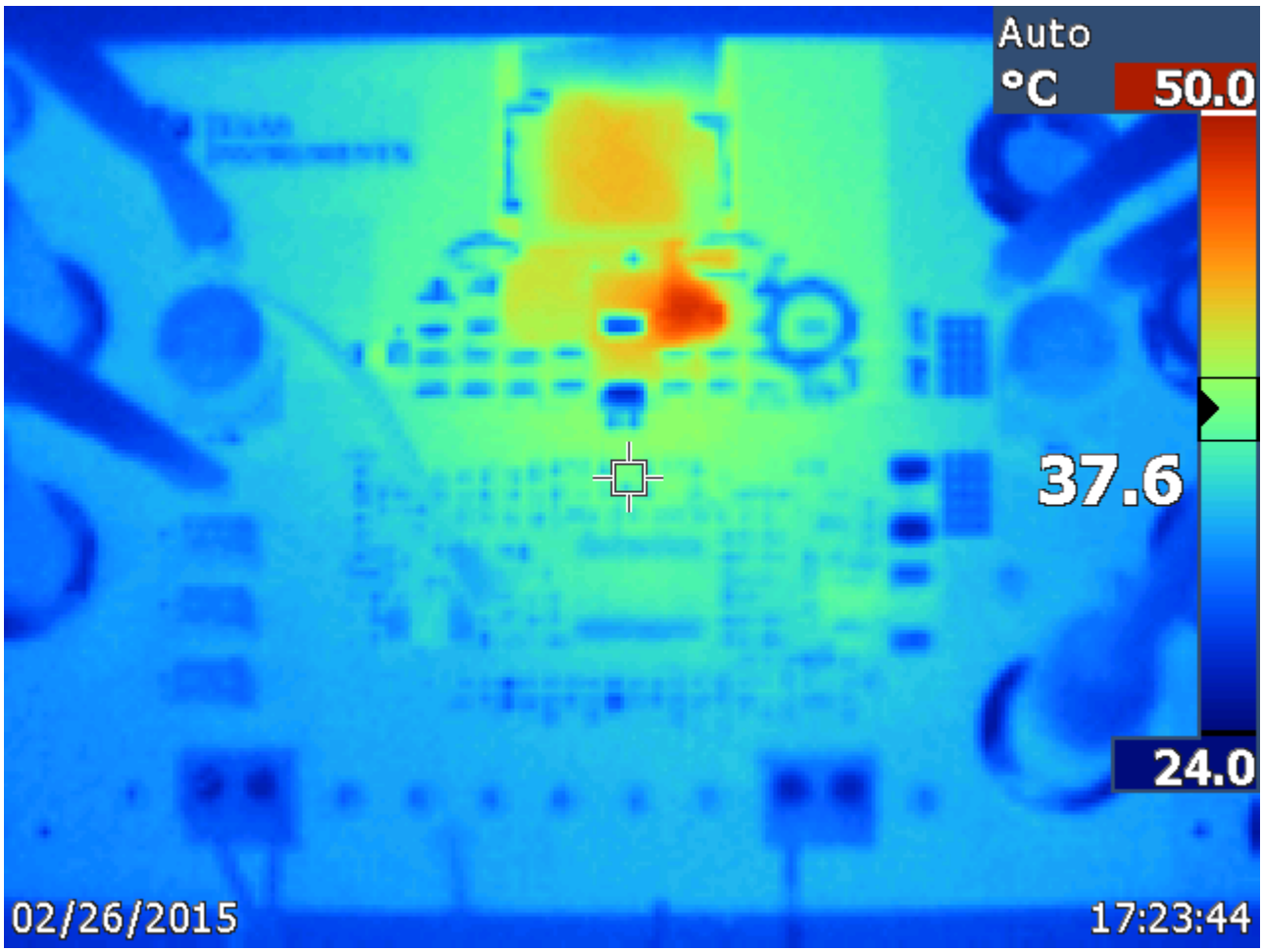
Vin (V)	Iin (A)	Vout (V)	Iout (A)	Pin (W)	Pout (W)	Pdis (W)	Efficiency (%)
12.001	0.035	9.153	0.000	0.42	0.00	0.42	0.000
12.001	0.405	9.148	0.460	4.86	4.21	0.65	86.579
12.001	0.780	9.147	0.960	9.36	8.78	0.58	93.808
12.001	1.560	9.116	1.960	18.72	17.87	0.85	95.437
12.001	2.340	9.105	2.960	28.08	26.95	1.13	95.971
12.001	3.120	9.094	3.980	37.44	36.19	1.25	96.664
12.001	3.905	9.085	4.980	46.86	45.24	1.62	96.542
12.001	4.695	9.075	5.980	56.34	54.27	2.08	96.315
12.001	5.490	9.065	7.000	65.89	63.46	2.43	96.311
12.001	6.005	8.613	8.000	72.07	68.90	3.16	95.612
12.001	6.005	7.550	9.000	72.07	67.95	4.12	94.289
12.001	6.005	6.725	9.980	72.07	67.12	4.95	93.131
12.001	6.005	6.015	11.000	72.07	66.17	5.90	91.812
12.001	0.105	0.003	0.080	1.26	0.00	1.26	0.019
12.001	0.105	0.003	0.080	1.26	0.00	1.26	0.019
12.001	0.105	0.003	0.080	1.26	0.00	1.26	0.019
12.001	0.105	0.003	0.080	1.26	0.00	1.26	0.019

Vin (V)	Iin (A)	Vout (V)	Iout (A)	Pin (W)	Pout (W)	Pdis (W)	Efficiency (%)
20.010	0.030	9.155	0.000	0.60	0.00	0.60	0.000
20.010	0.265	9.131	0.460	5.30	4.20	1.10	79.211
20.009	0.505	9.125	0.960	10.10	8.76	1.34	86.694
20.010	0.990	9.113	1.960	19.81	17.86	1.95	90.164
20.009	1.465	9.108	2.960	29.31	26.96	2.35	91.971
20.009	1.940	9.084	3.980	38.82	36.15	2.66	93.139
20.009	2.415	9.073	4.980	48.32	45.18	3.14	93.506
20.009	2.890	9.063	5.980	57.83	54.20	3.63	93.724
20.009	3.370	9.053	7.000	67.43	63.37	4.06	93.980
20.009	3.850	9.042	8.000	77.03	72.34	4.70	93.901
20.009	4.335	9.033	9.000	86.74	81.30	5.44	93.726
20.009	4.810	9.023	9.980	96.24	90.05	6.19	93.564
20.009	5.300	9.012	10.980	106.05	98.95	7.10	93.309
20.009	5.800	9.000	12.000	116.05	108.00	8.05	93.062
20.009	0.075	0.003	0.080	1.50	0.00	1.50	0.016
20.009	0.075	0.003	0.080	1.50	0.00	1.50	0.016
20.009	0.075	0.003	0.080	1.50	0.00	1.50	0.016

5 Thermal

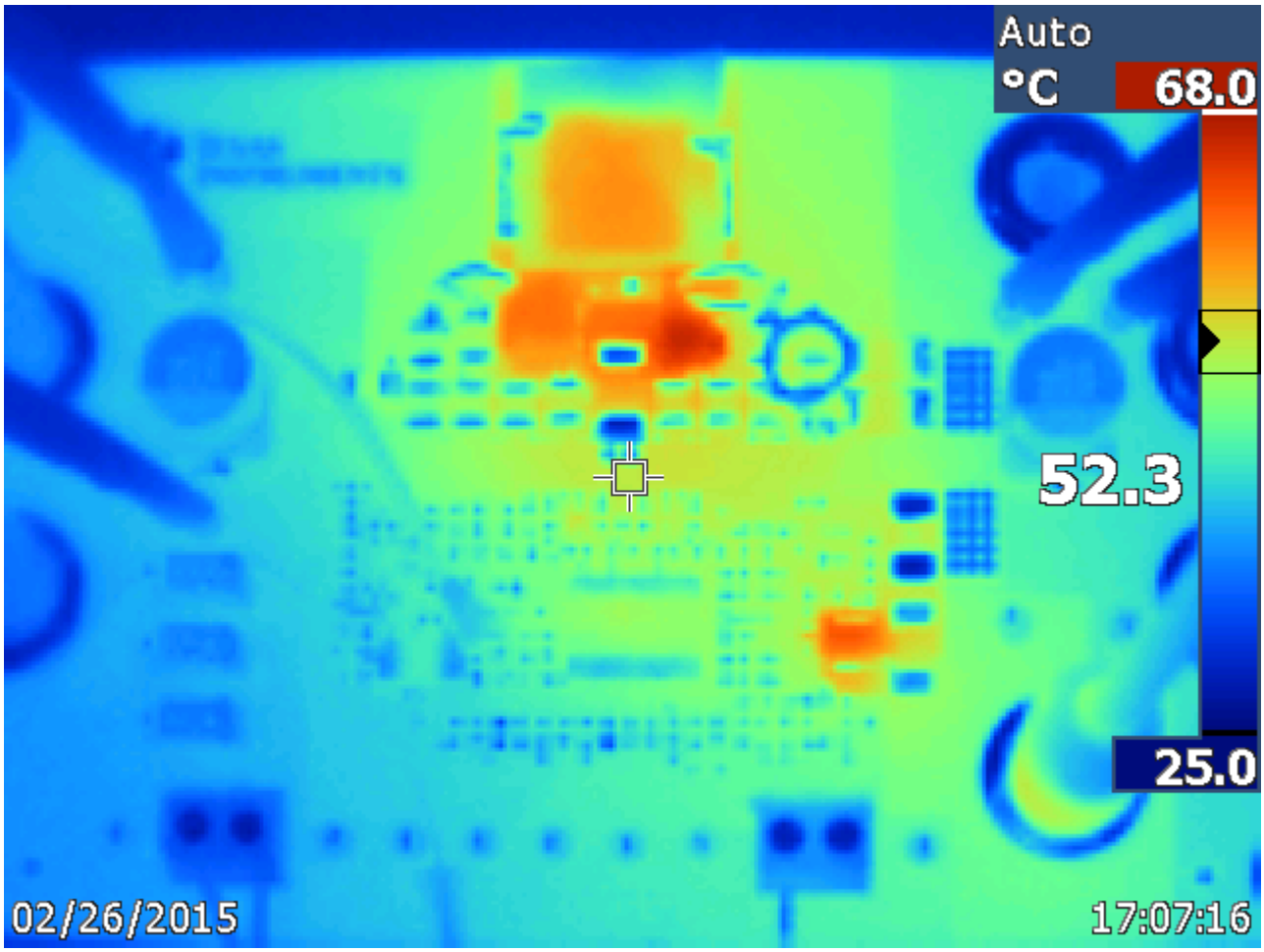
5.1 5V Input, 8V Constant Voltage Load

5Vin at 5.98A, 8.27Vout, 8.22Vbat at 3.44A, Pin=29.9W, Pout=28.3W, Pdis=1.6W



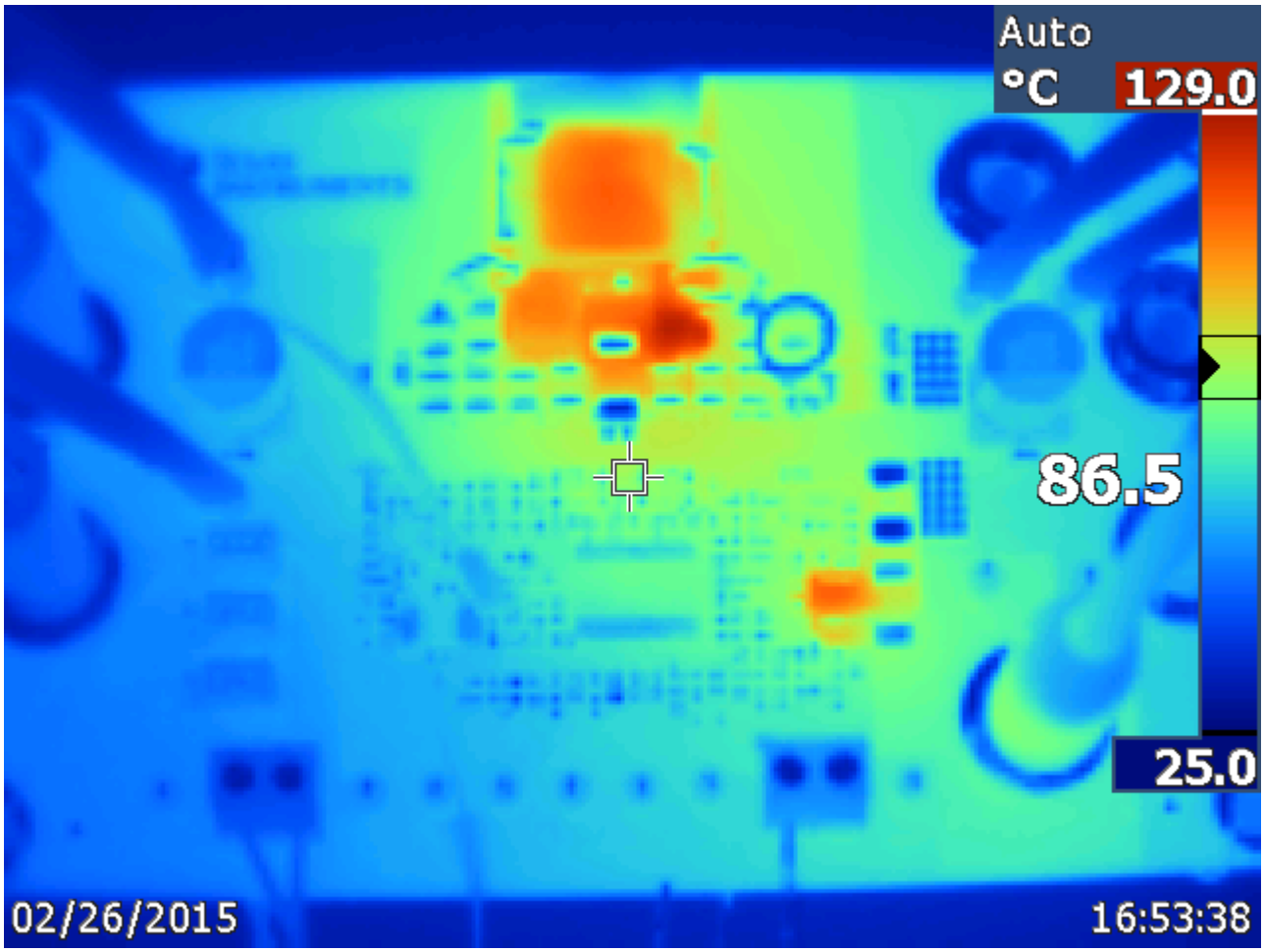
5.2 12V input, 8V Constant Voltage Load

12Vin at 5.95A, 8.63Vout, 8.50Vbat at 7.97A, Pin=71.4W, Pout=67.7W, Pdis=3.7W



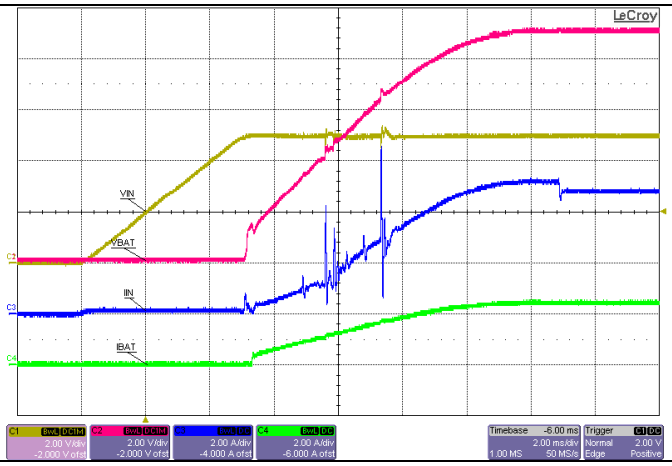
5.3 20V input, 8V Constant Voltage Load

20Vin at 5.70A, 8.90Vout, 8.77Vbat at 11.96A, Pin=114.0W, Pout=104.9W, Pdis=9.1W

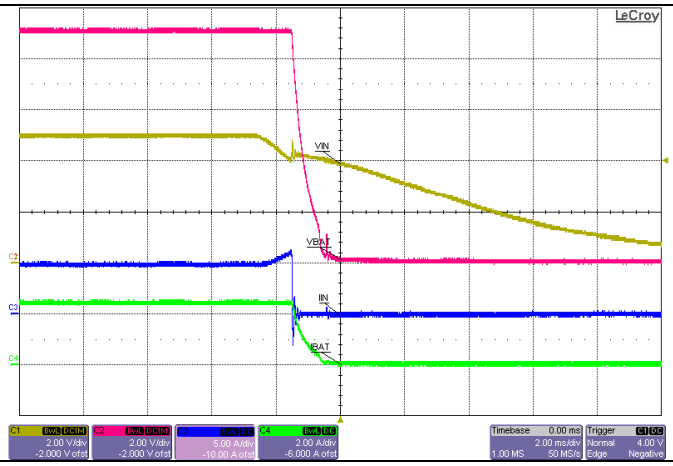


6 Startup and Shut Down

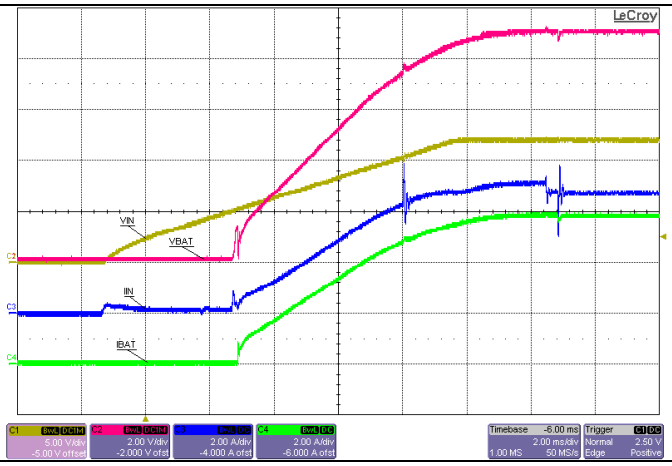
6.1 Startup and Shut Down



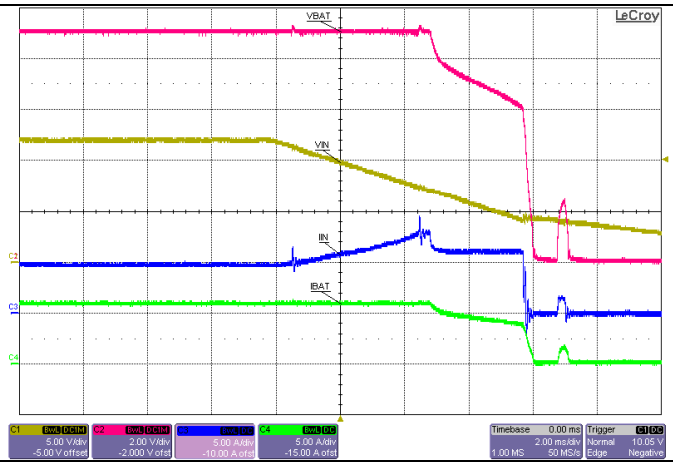
VIN VBAT IIN IBAT startup 5Vin 2.5A CR load



VIN VBAT IIN IBAT shutdown 5Vin 2.5A CR load



VIN VBAT IIN IBAT startup 12Vin 6A CR load



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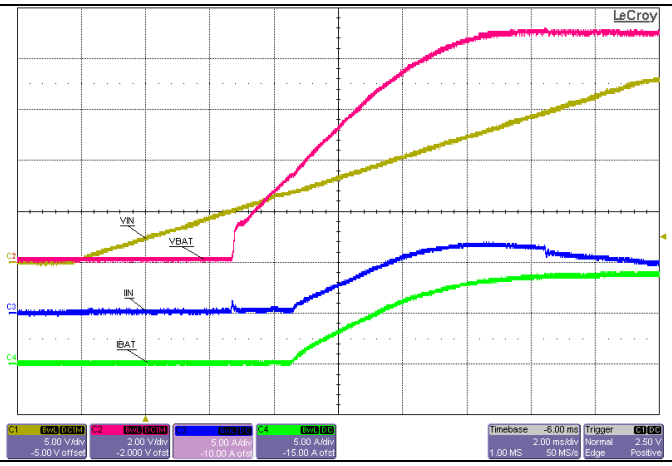
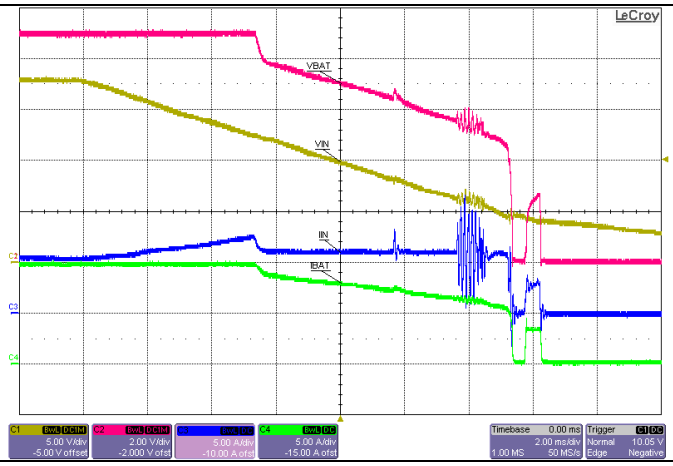


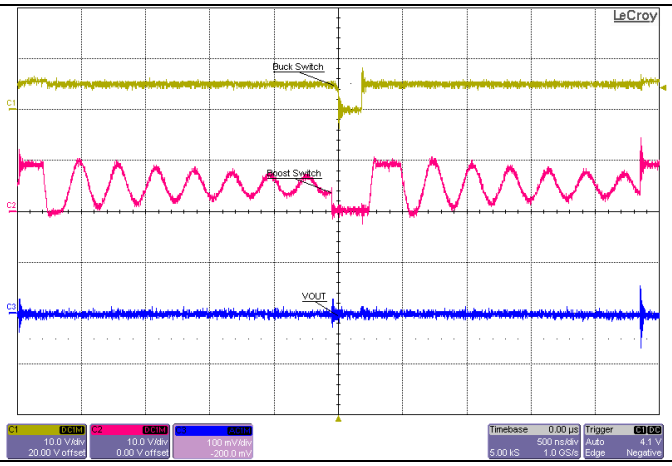
VIN VBAT IIN IBAT startup 18Vin 10A CR load



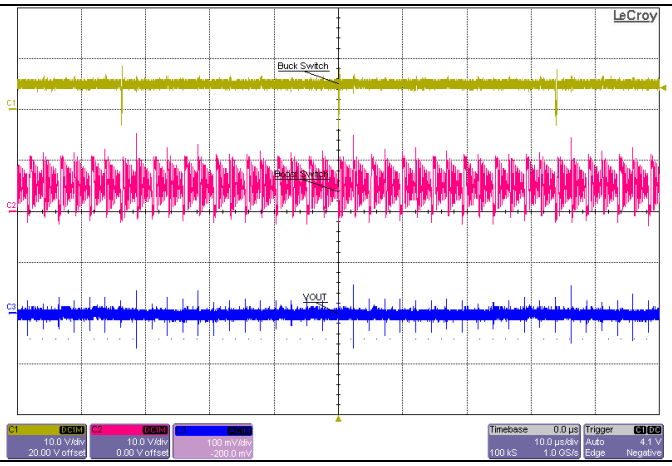
VIN VBAT IIN IBAT shutdown 18Vin 10A CR load

7 Switching and Ripple Voltage

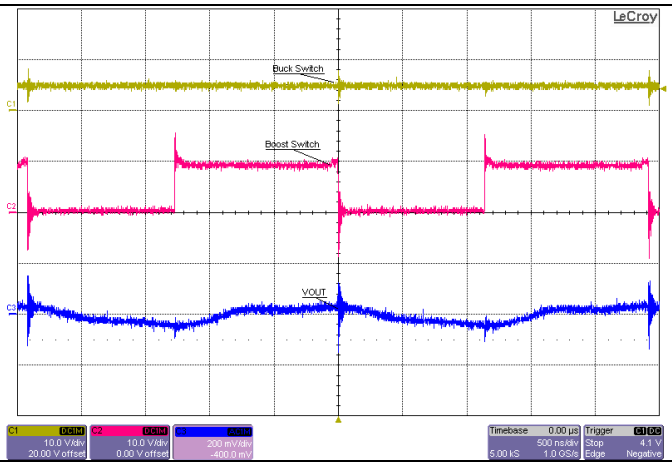
7.1 Switching and Ripple Voltage



BUCKSW BOOSTSW VOUT switching 5Vin 9.1Vout 0A load

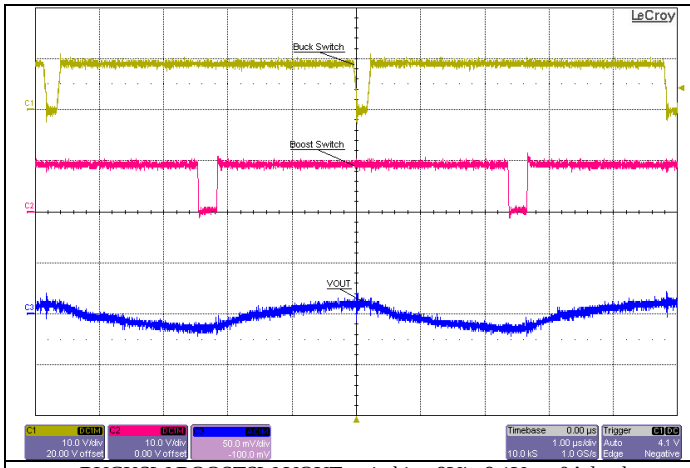


BUCKSW BOOSTSW VOUT switching 5Vin 9.1Vout 0A load

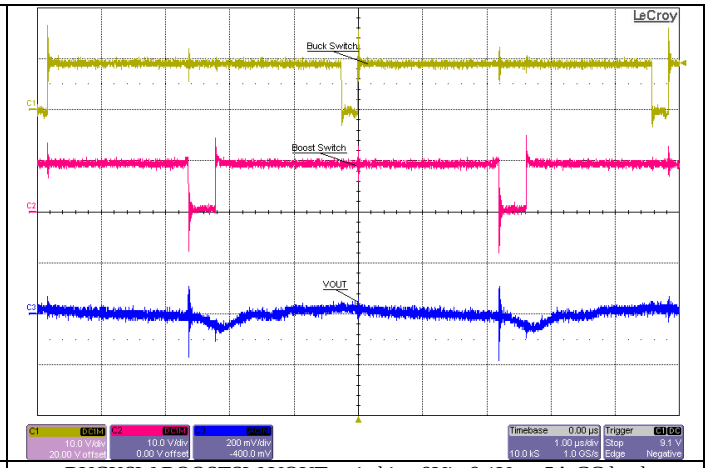


BUCKSW BOOSTSW VOUT switching 5Vin 9.1Vout 3A CC load

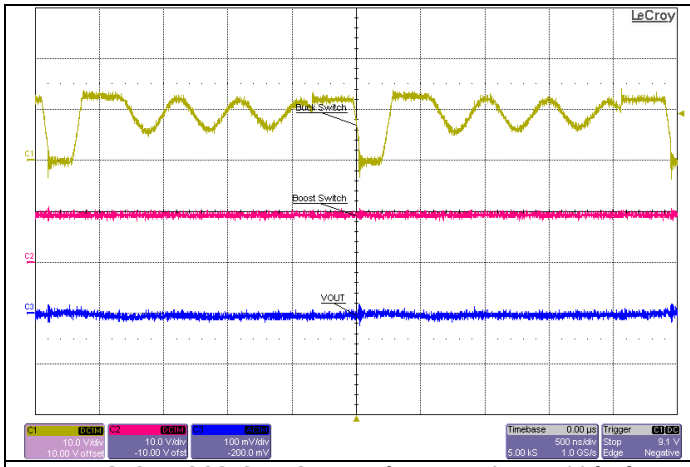
PMP10594 Test Results



BUCKSW BOOSTSW VOUT switching 9Vin 9.1Vout 0A load



BUCKSW BOOSTSW VOUT switching 9Vin 9.1Vout 5A CC load



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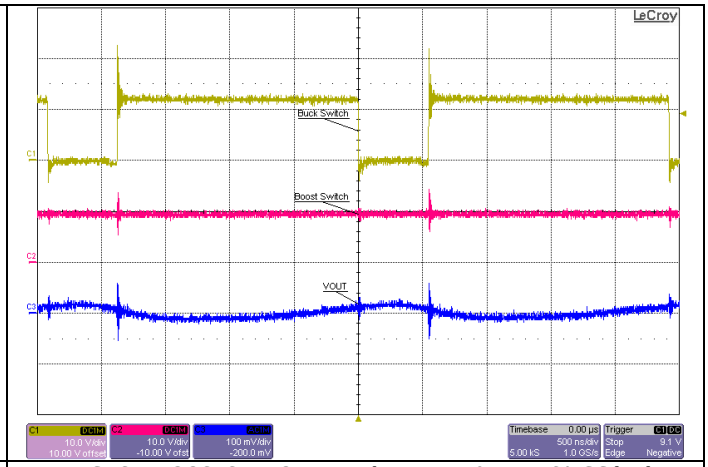
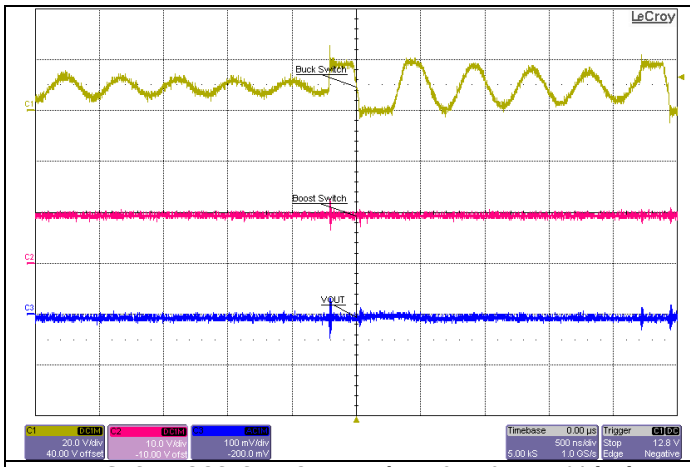
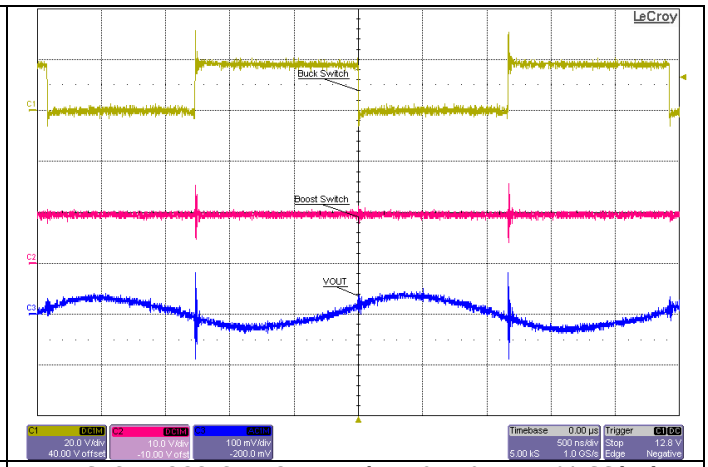


BUCKSW BOOSTSW VOUT switching 12Vin 9.1Vout 6A CC load



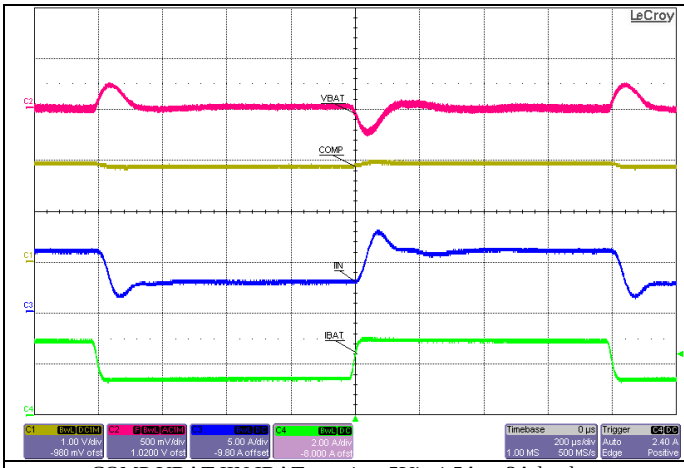
BUCKSW BOOSTSW VOUT switching 18Vin 9.1Vout 0A load



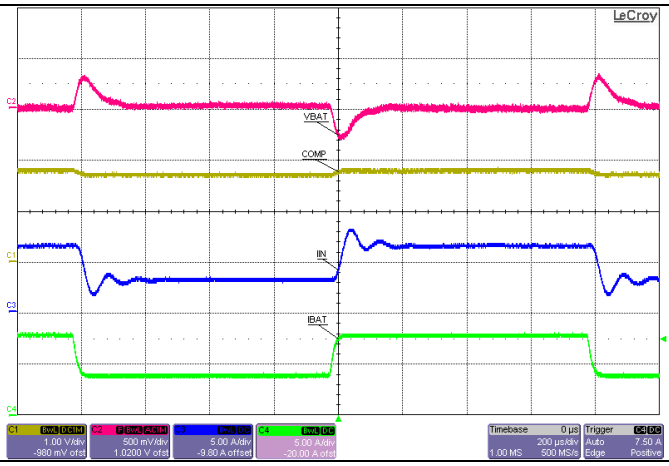
BUCKSW BOOSTSW VOUT switching 18Vin 9.1Vout 10A CC load

8 Load Transient Response

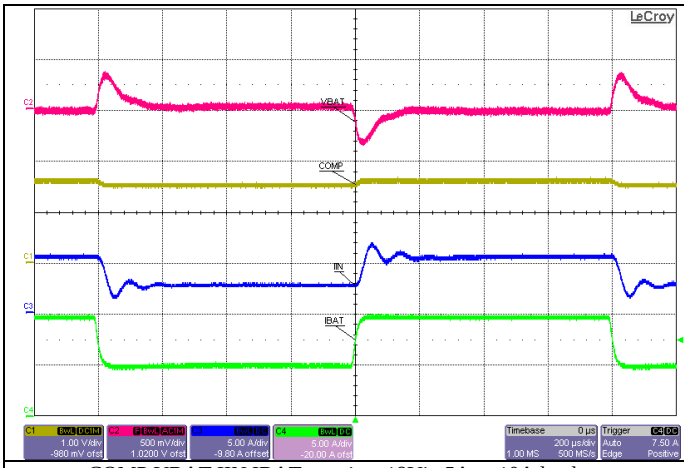
8.1 Voltage Control Loop with 9V Output



COMP VBAT IIN IBAT transient 5Vin 1.5A to 3A load step

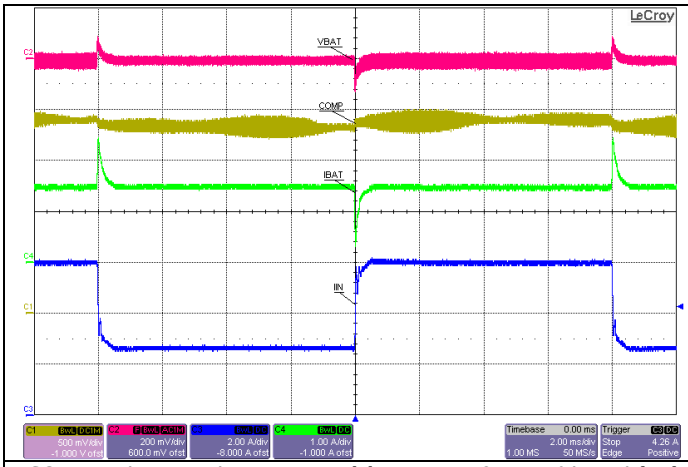


COMP VBAT IIN IBAT transient 12Vin 4A to 8A load step

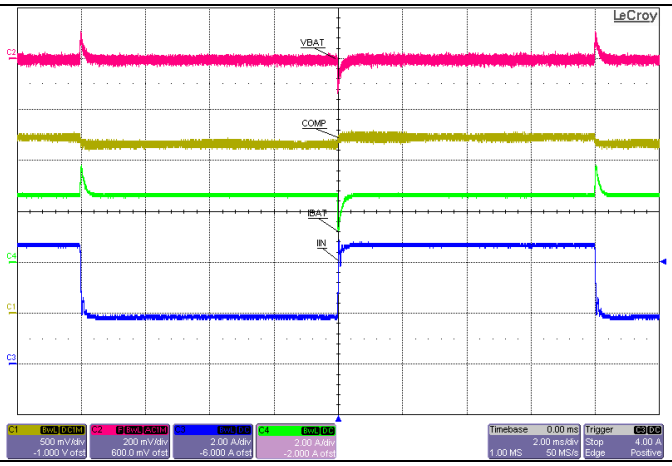


COMP VBAT IIN IBAT transient 18Vin 5A to 10A load step

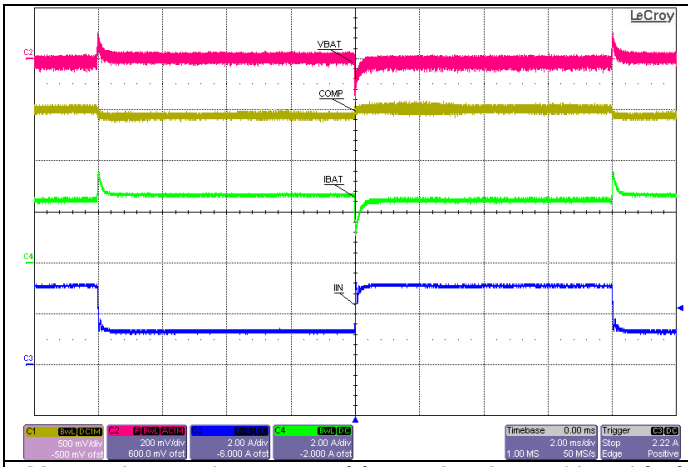
8.2 Voltage Control Loop with Battery



COMP VBAT IIN IBAT transient with battery 5Vin 8.1Vout 0A to 2A load step

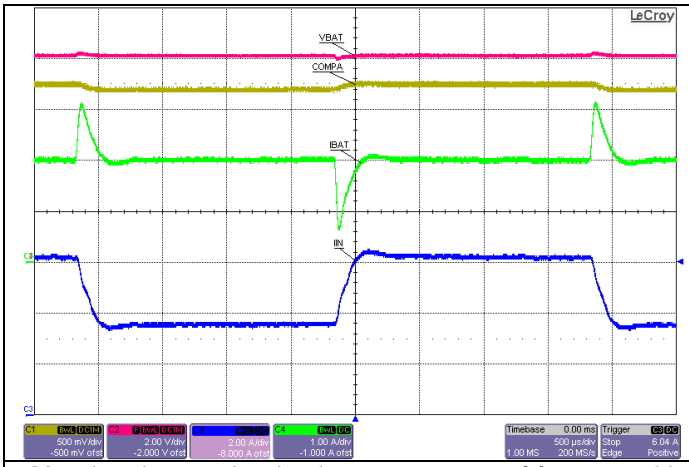


COMP VBAT IIN IBAT transient with battery 12Vin 8.1Vout 0A to 4A load step

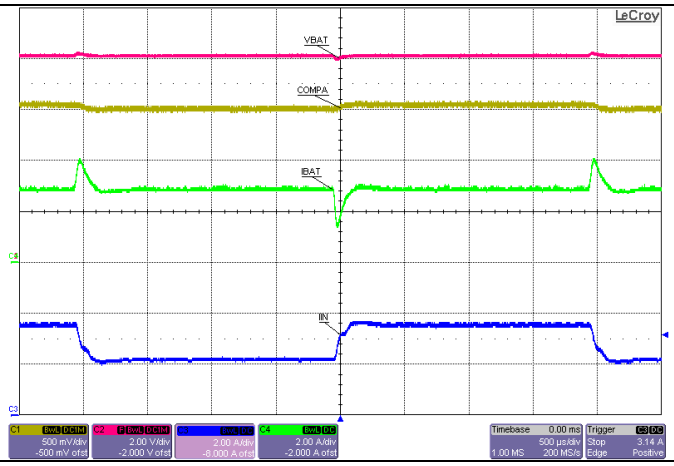


COMP VBAT IIN IBAT transient with battery 18Vin 8.1Vout 0A to 4A load step

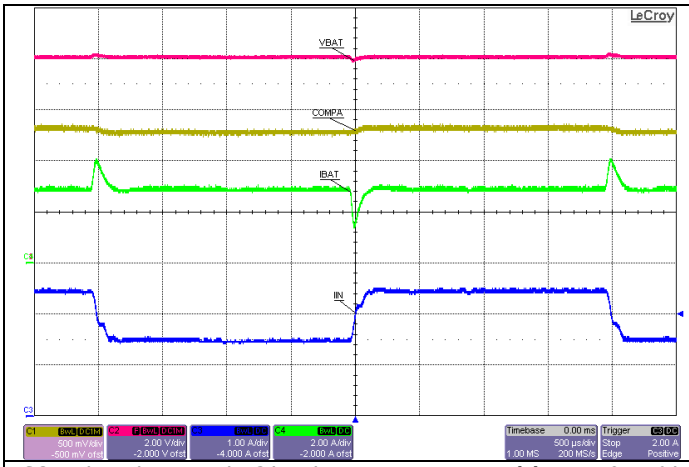
8.3 Charge Current Loop with Battery



COMPA VBAT IIN IBAT 2A IBAT_LIMIT transient with battery 5Vin 0A to 1.5A load step

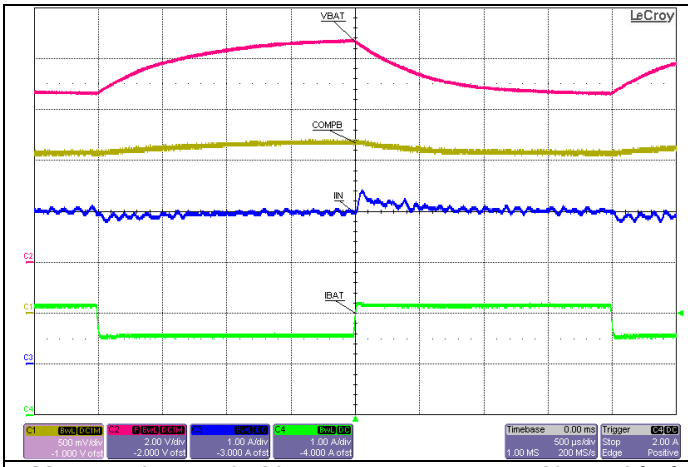


COMPA VBAT IIN IBAT 3A IBAT_LIMIT transient with battery 12Vin 0A to 2A load step

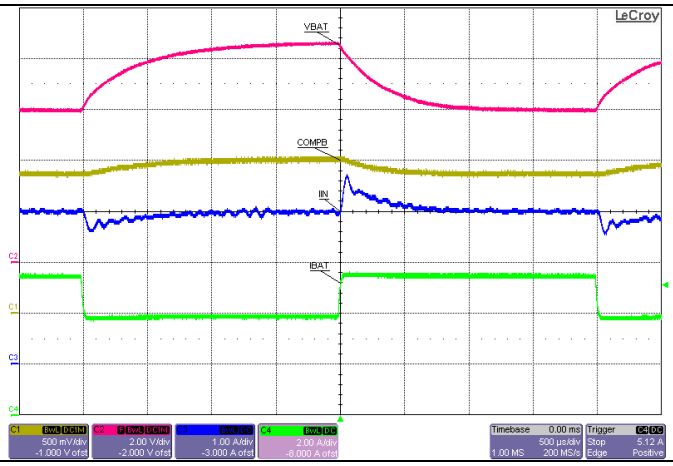


COMPA VBAT IIN IBAT 3A IBAT_LIMIT transient with battery 18Vin 0A to 2A load step

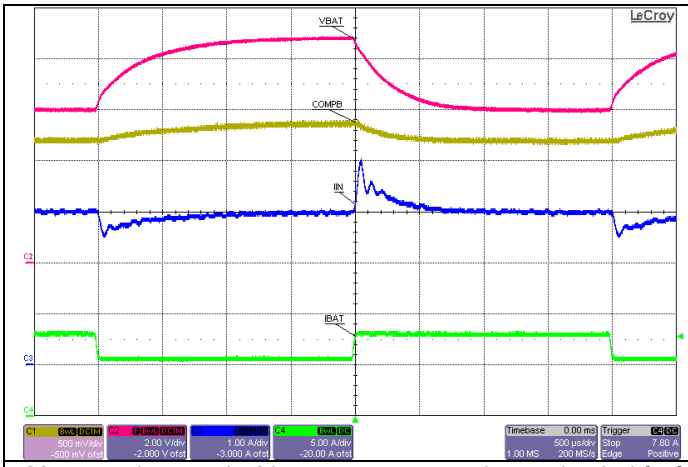
8.4 Input Current Loop



COMPB VBAT IIN IBAT 3A IIN_LIMIT transient 5Vin 1.6A to 2.2A load step

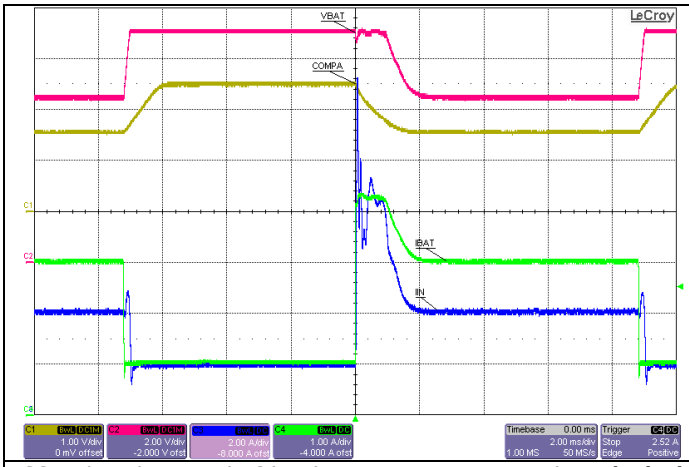


COMPB VBAT IIN IBAT 3A IIN_LIMIT transient 12Vin 4A to 5.6A load step

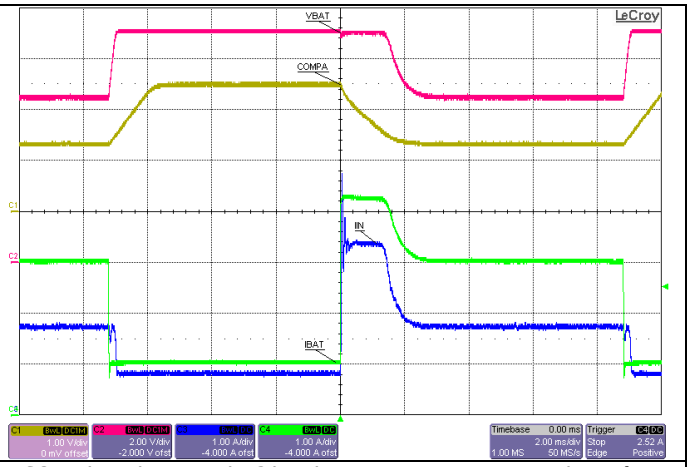


COMPB VBAT IIN IBAT 3A IIN_LIMIT transient 18Vin 5.7A to 8.2A load step

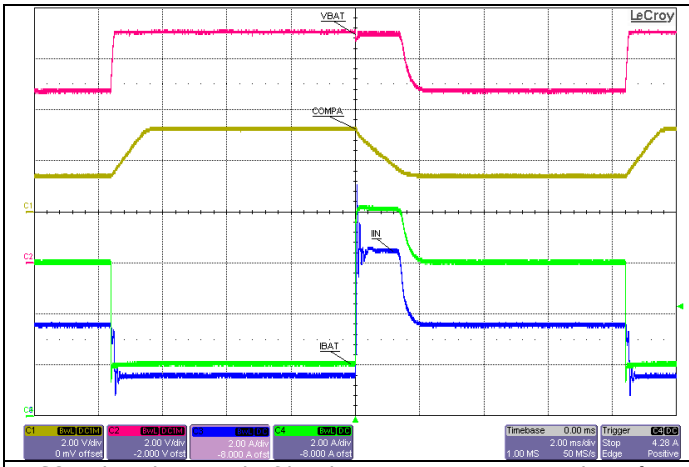
8.5 Voltage Loop to Charge Current Loop



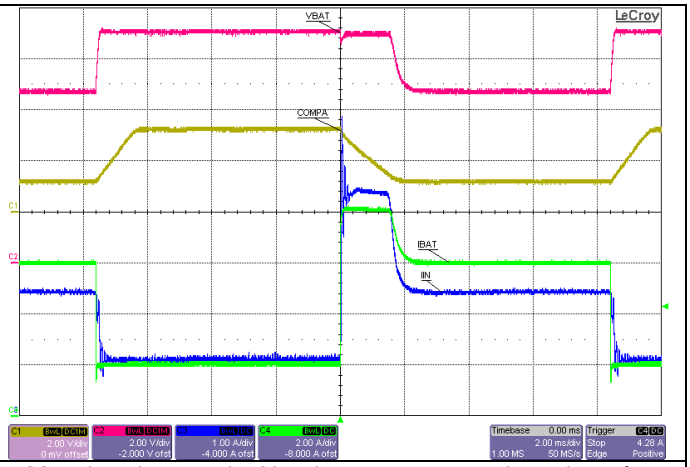
COMPA VBAT IIN IBAT 3A IBAT_LIMIT transient 5Vin 1A to 2ohm load step



COMPA VBAT IIN IBAT 3A IBAT_LIMIT transient 12Vin 1A to 2ohm load step

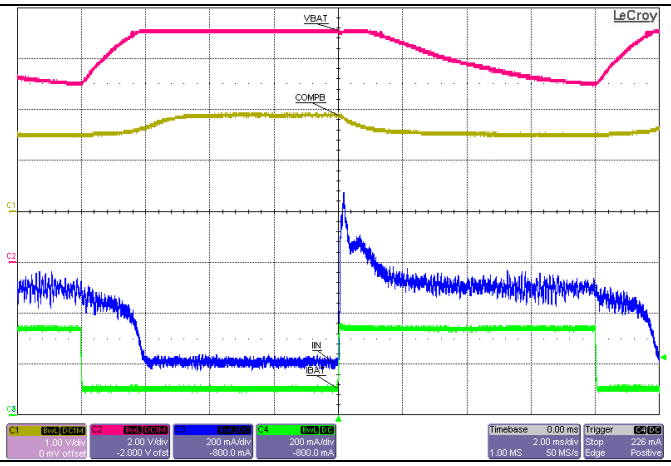


COMPA VBAT IIN IBAT 6A IBAT_LIMIT transient 12Vin 2A to 1ohm load step

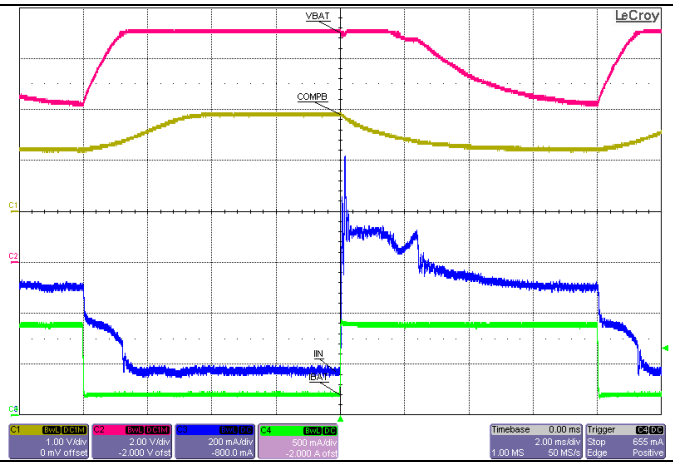


COMPA VBAT IIN IBAT 6A IBAT_LIMIT transient 18Vin 2A to 1ohm load step

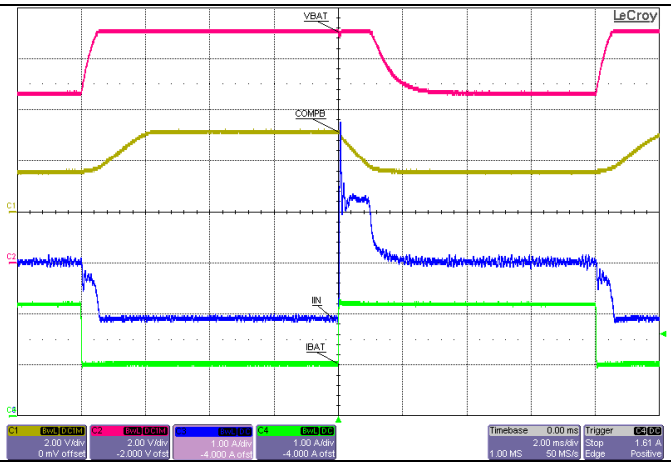
8.6 Voltage Loop to Input Current Loop



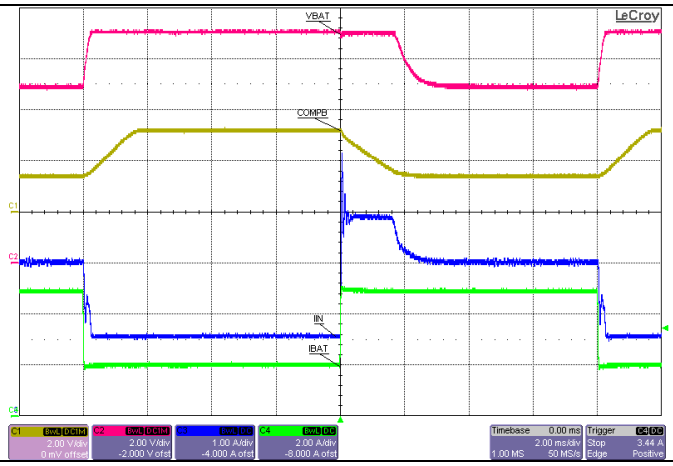
COMPB VBAT IIN IBAT 0p5A IIN_LIMIT transient 5Vin 0.1A to 0.34A load step



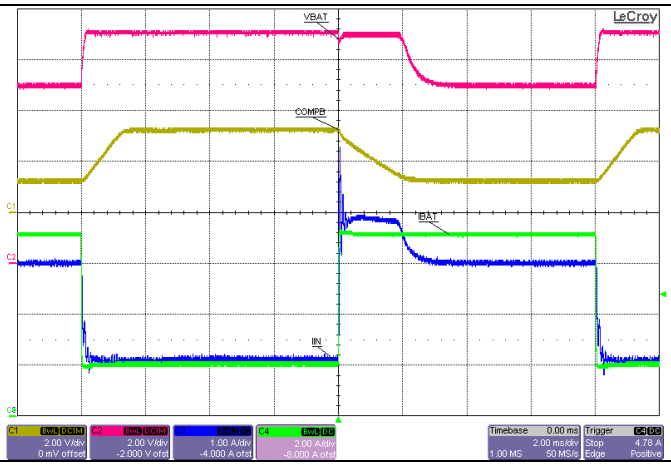
COMPB VBAT IIN IBAT 0p5A IIN_LIMIT transient 12Vin 0.2A to 0.9A load step



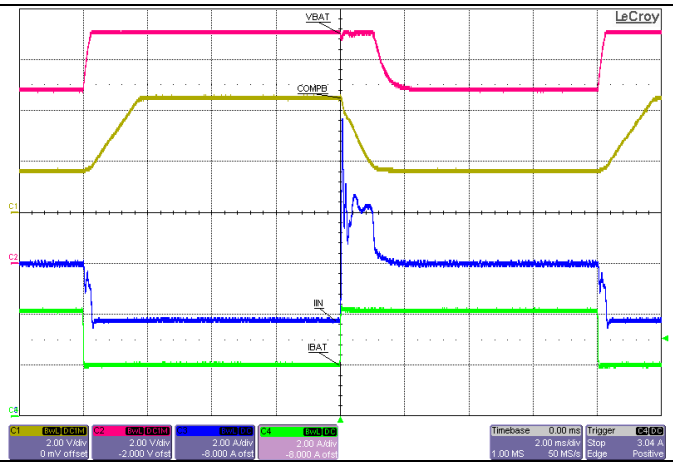
COMPB VBAT IIN IBAT 3A IIN_LIMIT transient 5Vin 1A to 2.2A load step



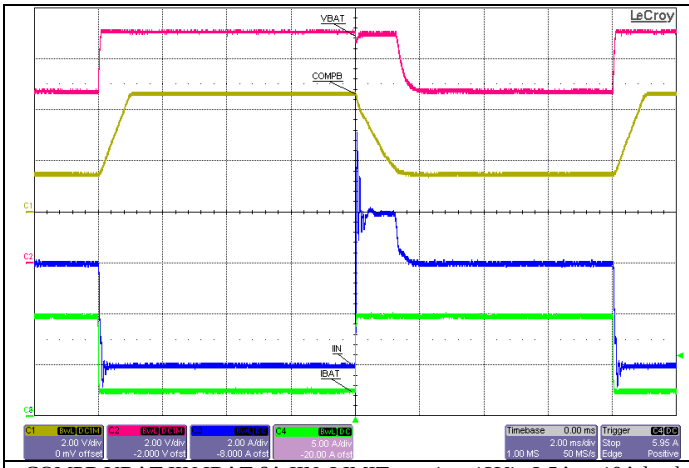
COMPB VBAT IIN IBAT 3A IIN_LIMIT transient 12Vin 2A to 5A load step



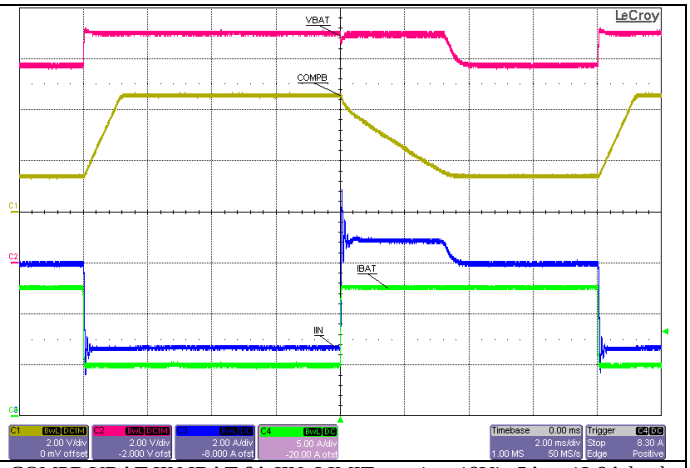
COMPB VBAT IIN IBAT 3A IIN_LIMIT transient 18Vin 2A to 7.2A load step



COMPB VBAT IIN IBAT 6A IIN_LIMIT transient 5Vin 2A to 4.2A load step

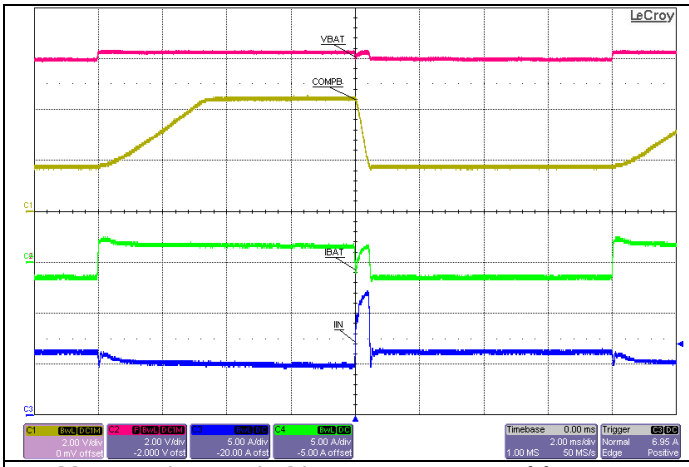


COMPB VBAT IIN IBAT 6A IIN_LIMIT transient 12Vin 2.5A to 10A load step

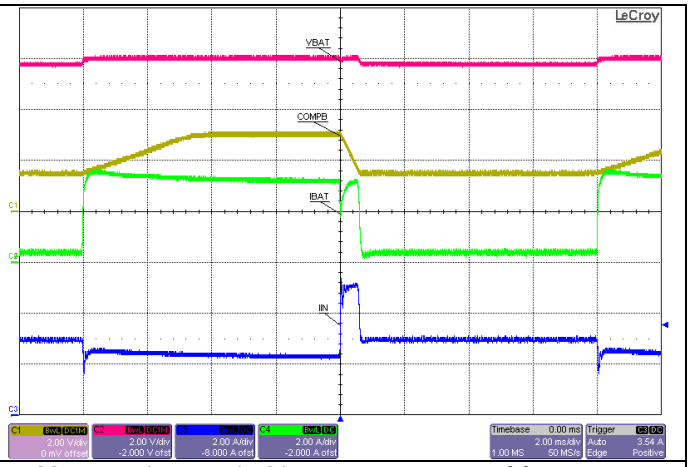


COMPB VBAT IIN IBAT 6A IIN_LIMIT transient 18Vin 5A to 12.8A load step

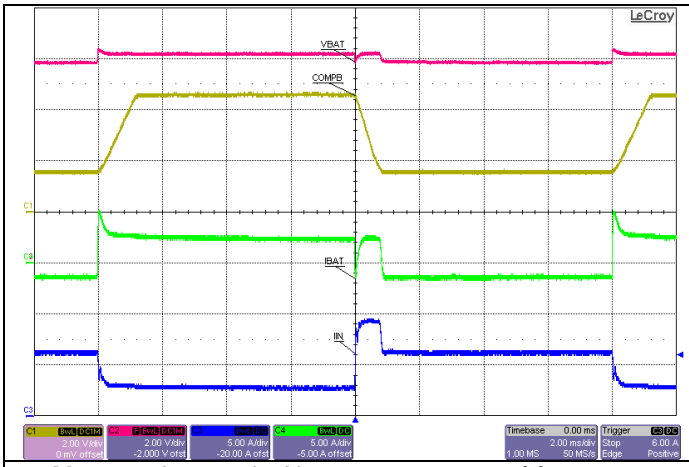
8.7 Voltage Loop to Input Current Loop with Battery



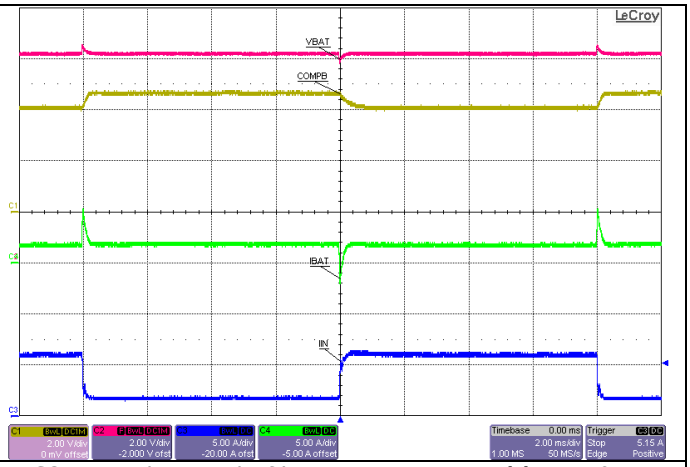
COMPB VBAT IIN IBAT 3A IIN_LIMIT transient with battery 5Vin 8.1Vout 1A to 5A load step



COMPB VBAT IIN IBAT 3A IIN_LIMIT transient with battery 12Vin 8.1Vout 0A to 4A load step



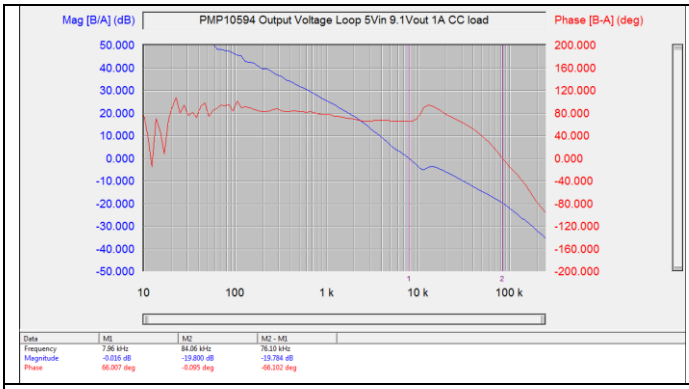
COMPB VBAT IIN IBAT 6A IIN_LIMIT transient with battery 12Vin 8.1Vout 1A to 10A load step



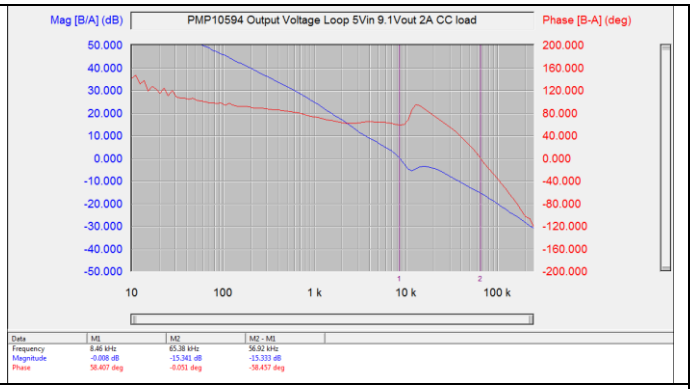
COMPB VBAT IIN IBAT 6A IIN_LIMIT transient with battery 18Vin 8.1Vout 1A to 10A load step

9 Frequency Response

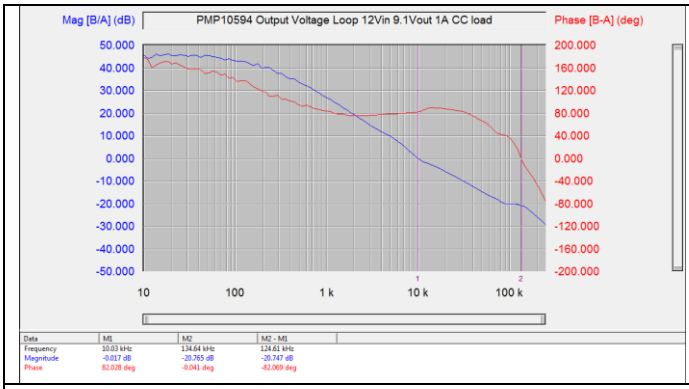
9.1 Voltage Control Loop



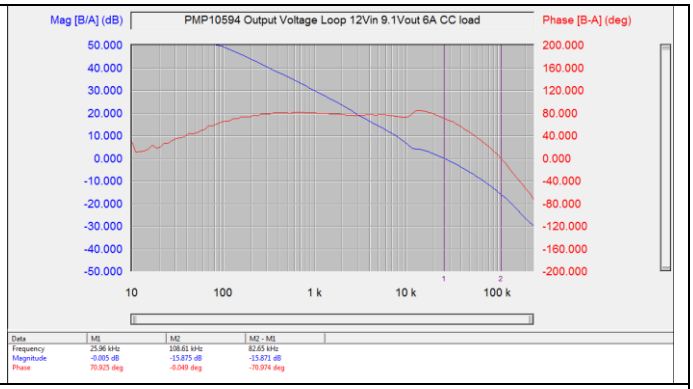
PMP10594 Output Voltage Loop 5Vin 9.1Vout 1A CC load



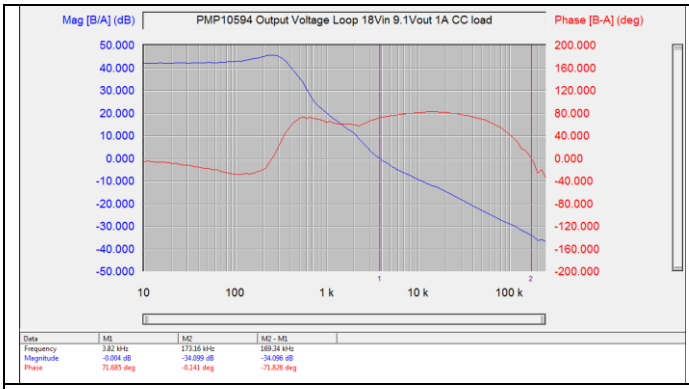
PMP10594 Output Voltage Loop 5Vin 9.1Vout 2A CC load



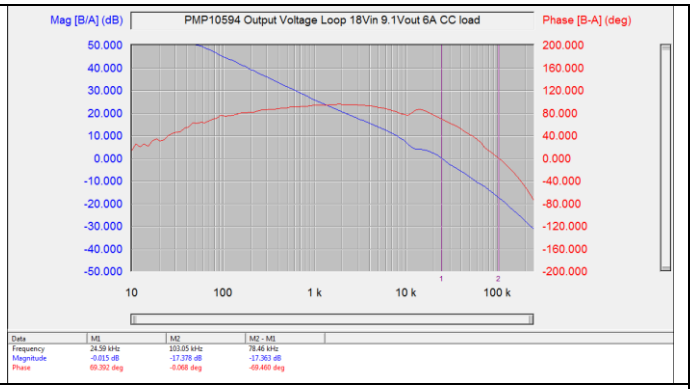
PMP10594 Output Voltage Loop 12Vin 9.1Vout 1A CC load



PMP10594 Output Voltage Loop 12Vin 9.1Vout 6A CC load

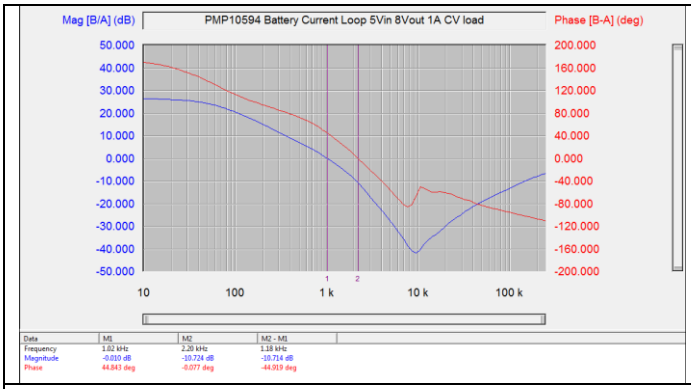


PMP10594 Output Voltage Loop 18Vin 9.1Vout 1A CC load

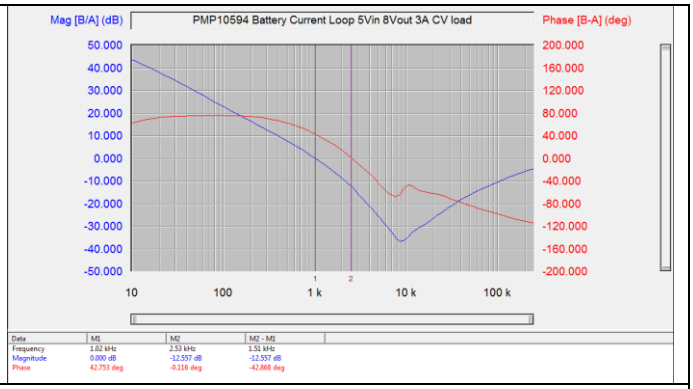


PMP10594 Output Voltage Loop 18Vin 9.1Vout 6A CC load

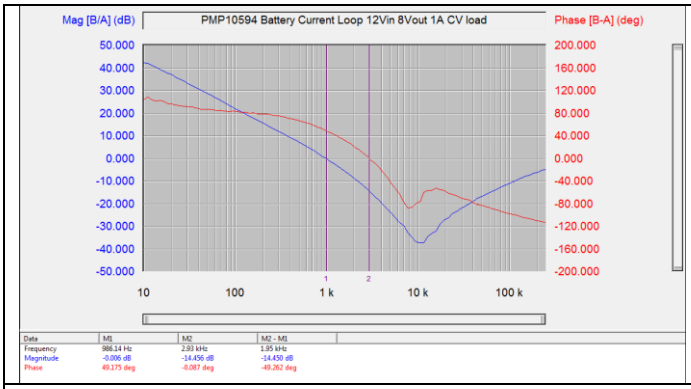
9.2 Charge Current Loop



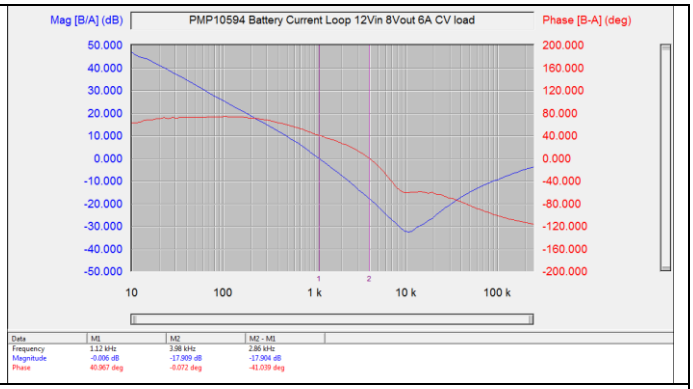
PMP10594 Battery Current Loop 5Vin 8Vout 1A CV load



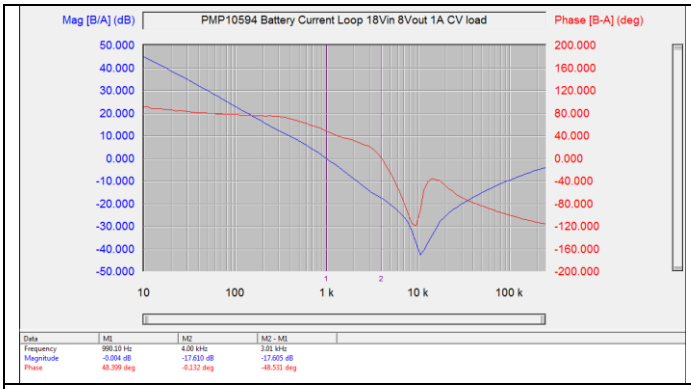
PMP10594 Battery Current Loop 5Vin 8Vout 3A CV load



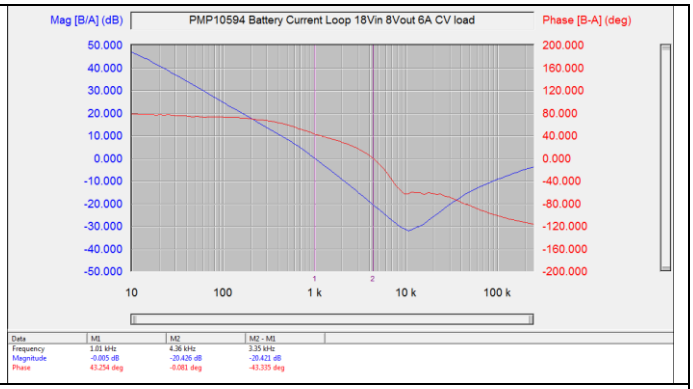
PMP10594 Battery Current Loop 12Vin 8Vout 1A CV load



PMP10594 Battery Current Loop 12Vin 8Vout 6A CV load

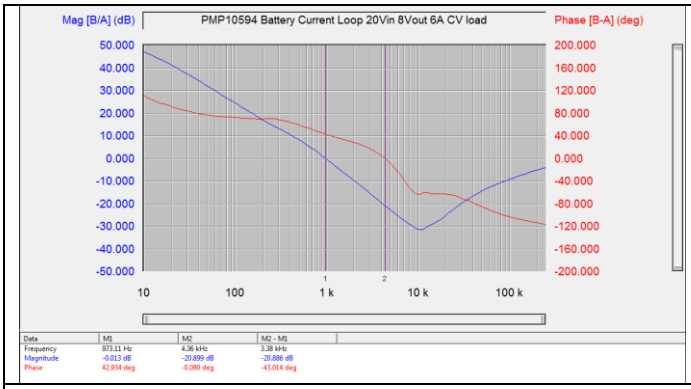


PMP10594 Battery Current Loop 18Vin 8Vout 1A CV load

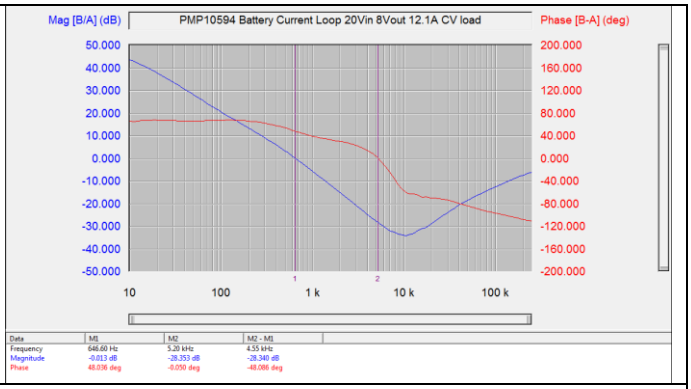


PMP10594 Battery Current Loop 18Vin 8Vout 6A CV load

PMP10594 Test Results

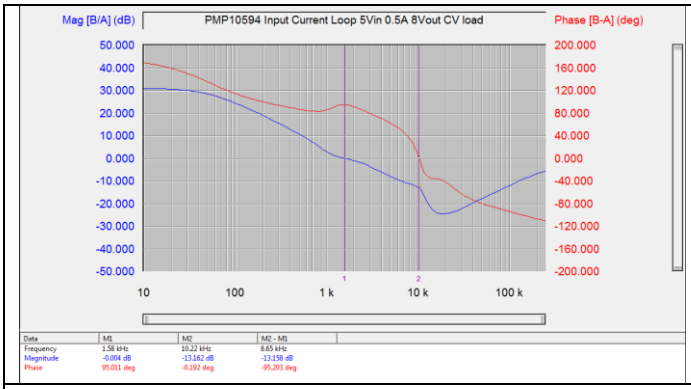


PMP10594 Battery Current Loop 20Vin 8Vout 6A CV load

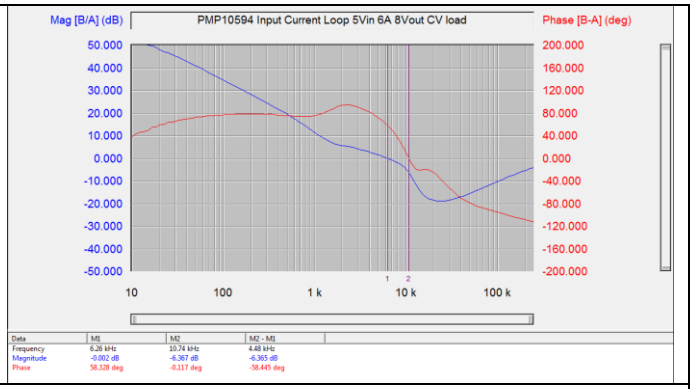


PMP10594 Battery Current Loop 20Vin 8Vout 12.1A CV load

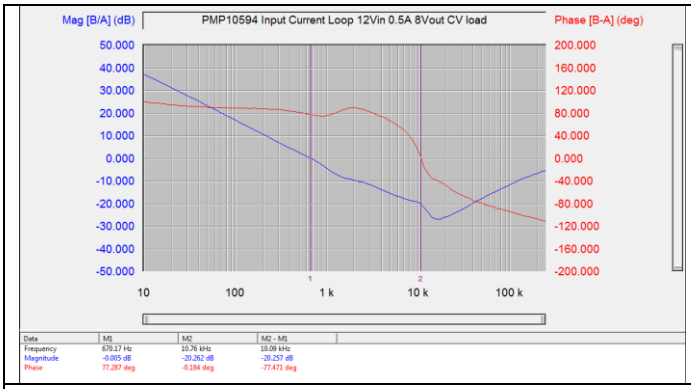
9.3 Input Current Loop



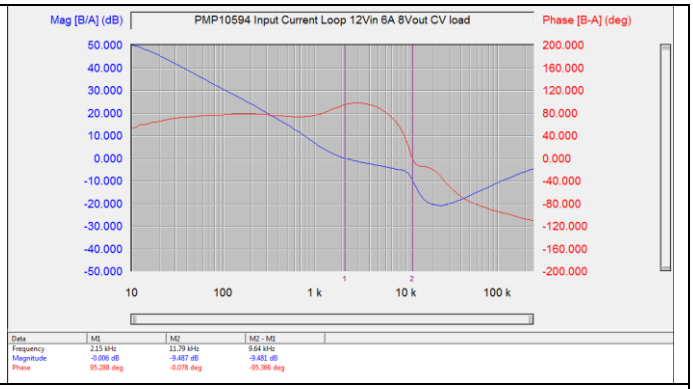
PMP10594 Input Current Loop 5Vin 0.5A 8Vout CV load



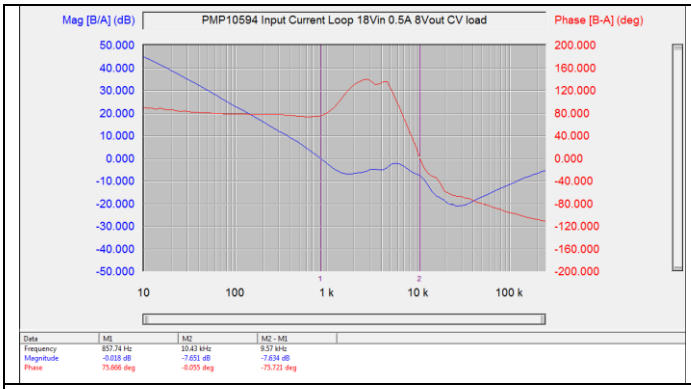
PMP10594 Input Current Loop 5Vin 6A 8Vout CV load



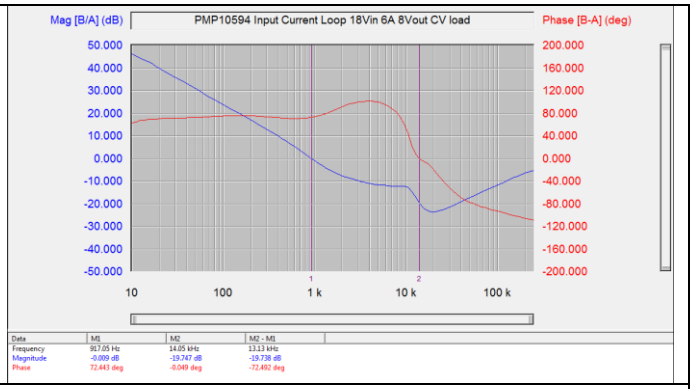
PMP10594 Input Current Loop 12Vin 0.5A 8Vout CV load



PMP10594 Input Current Loop 12Vin 6A 8Vout CV load



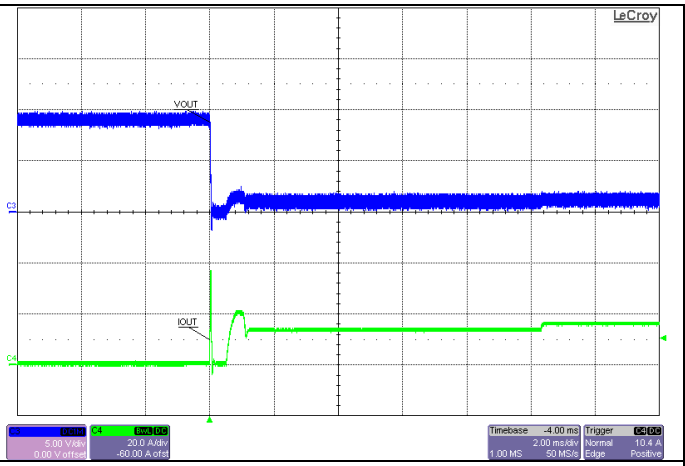
PMP10594 Input Current Loop 18Vin 0.5A 8Vout CV load



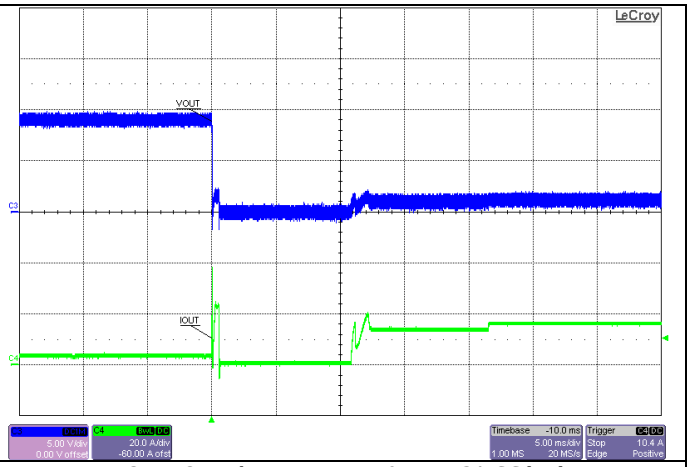
PMP10594 Input Current Loop 18Vin 6A 8Vout CV load

10 Short Circuit Tests

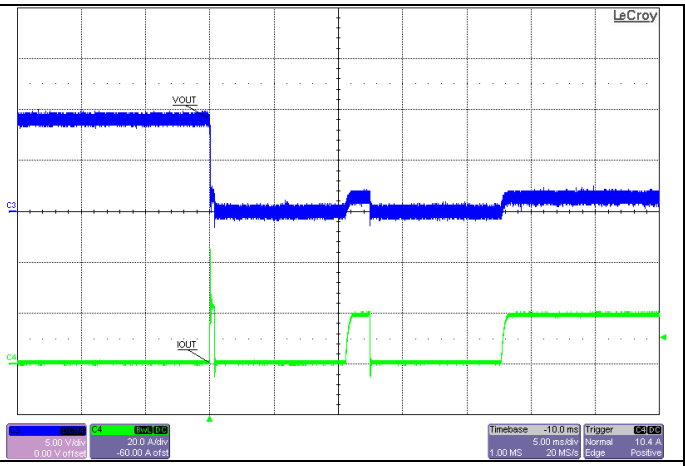
10.1 Output Short Circuit



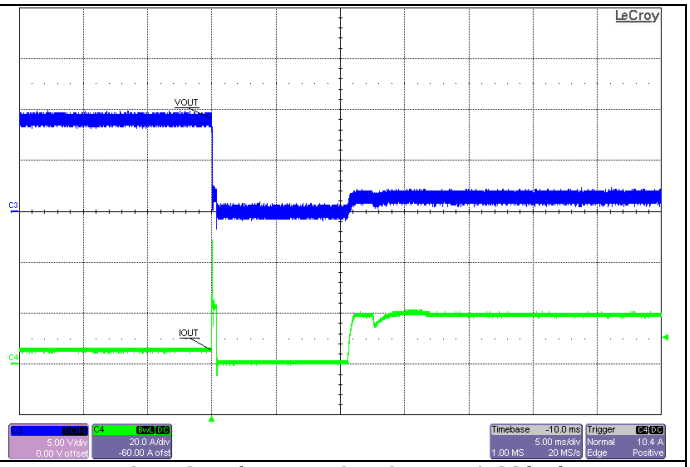
VOUT IOUT short circuit 5Vin 9.1Vout 0A load



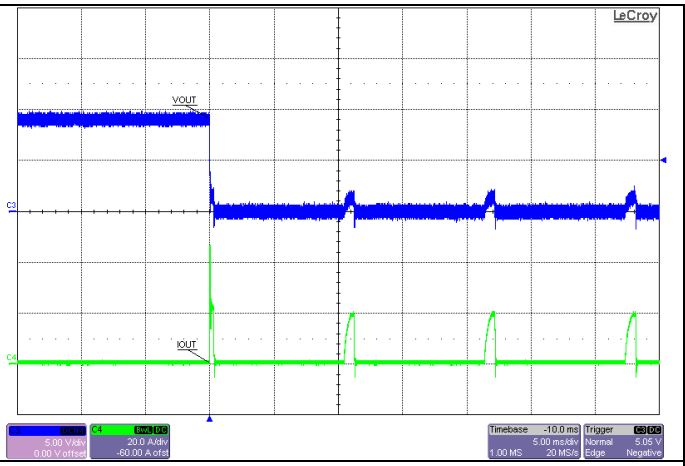
VOUT IOUT short circuit 5Vin 9.1Vout 3A CC load



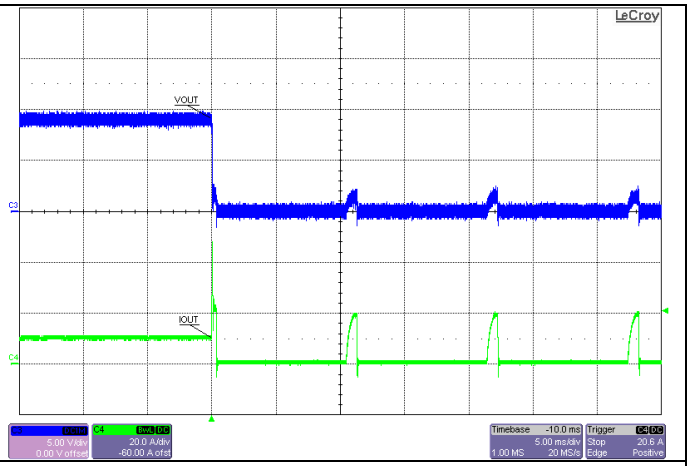
VOUT IOUT short circuit 9Vin 9.1Vout 0A load



VOUT IOUT short circuit 9Vin 9.1Vout 5A CC load

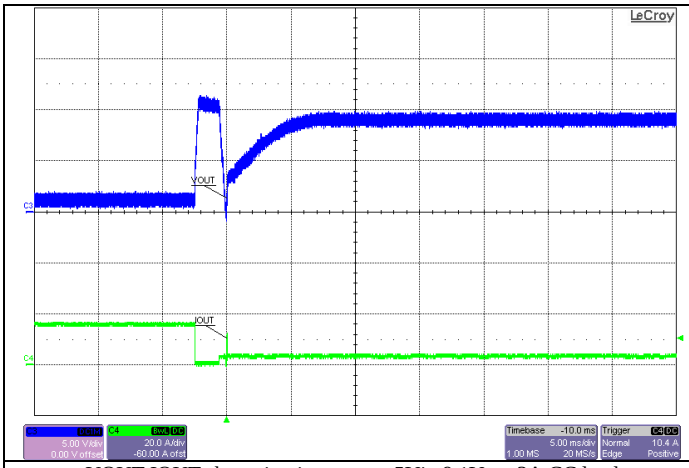


VOUT IOUT short circuit 18Vin 9.1Vout 0A load

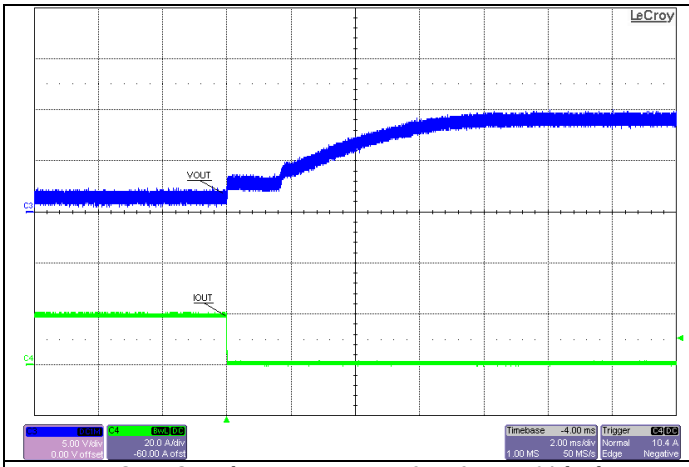


VOUT IOUT short circuit 18Vin 9.1Vout 10A CC load

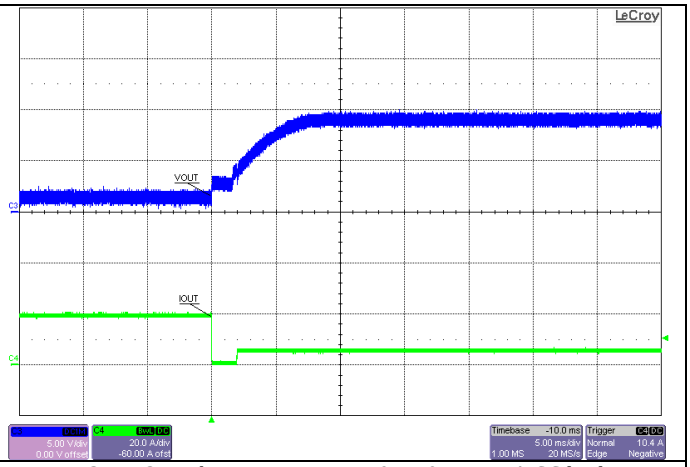
10.2 Output Short Circuit Recovery



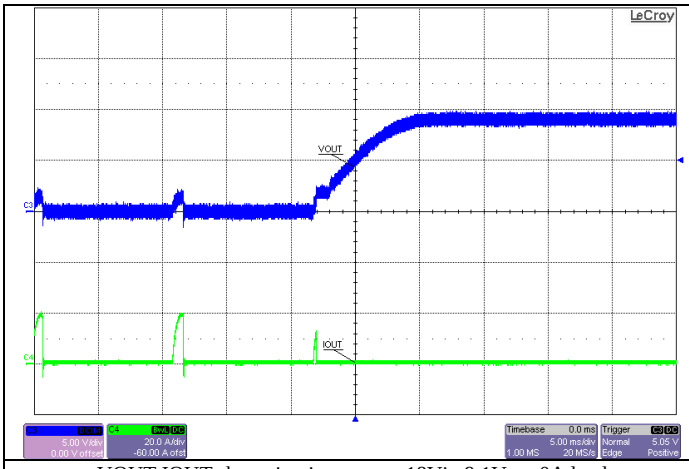
VOUT IOUT short circuit recovery 5Vin 9.1Vout 3A CC load



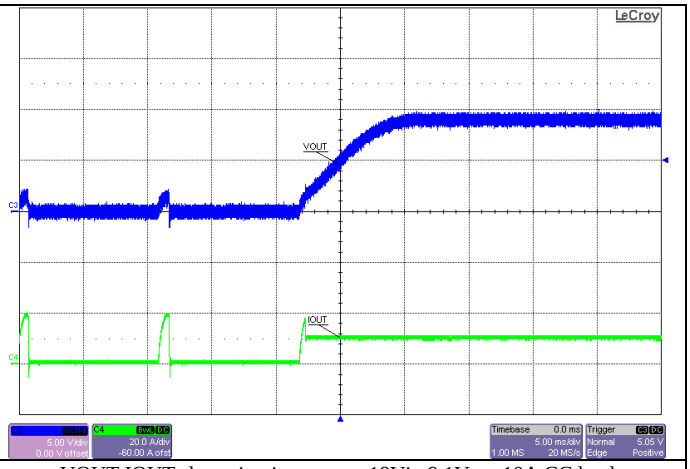
VOUT IOUT short circuit recovery 9Vin 9.1Vout 0A load



VOUT IOUT short circuit recovery 9Vin 9.1Vout 5A CC load



VOUT IOUT short circuit recovery 18Vin 9.1Vout 0A load



VOUT IOUT short circuit recovery 18Vin 9.1Vout 10A CC load

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