



LM5140-Q1 Dual Phase Synchronous Buck Converter

TI reference design number: PMP20440 Rev A

**Input: 6V to 17V
Output: 12V @ 11A**

DC – DC Test Results

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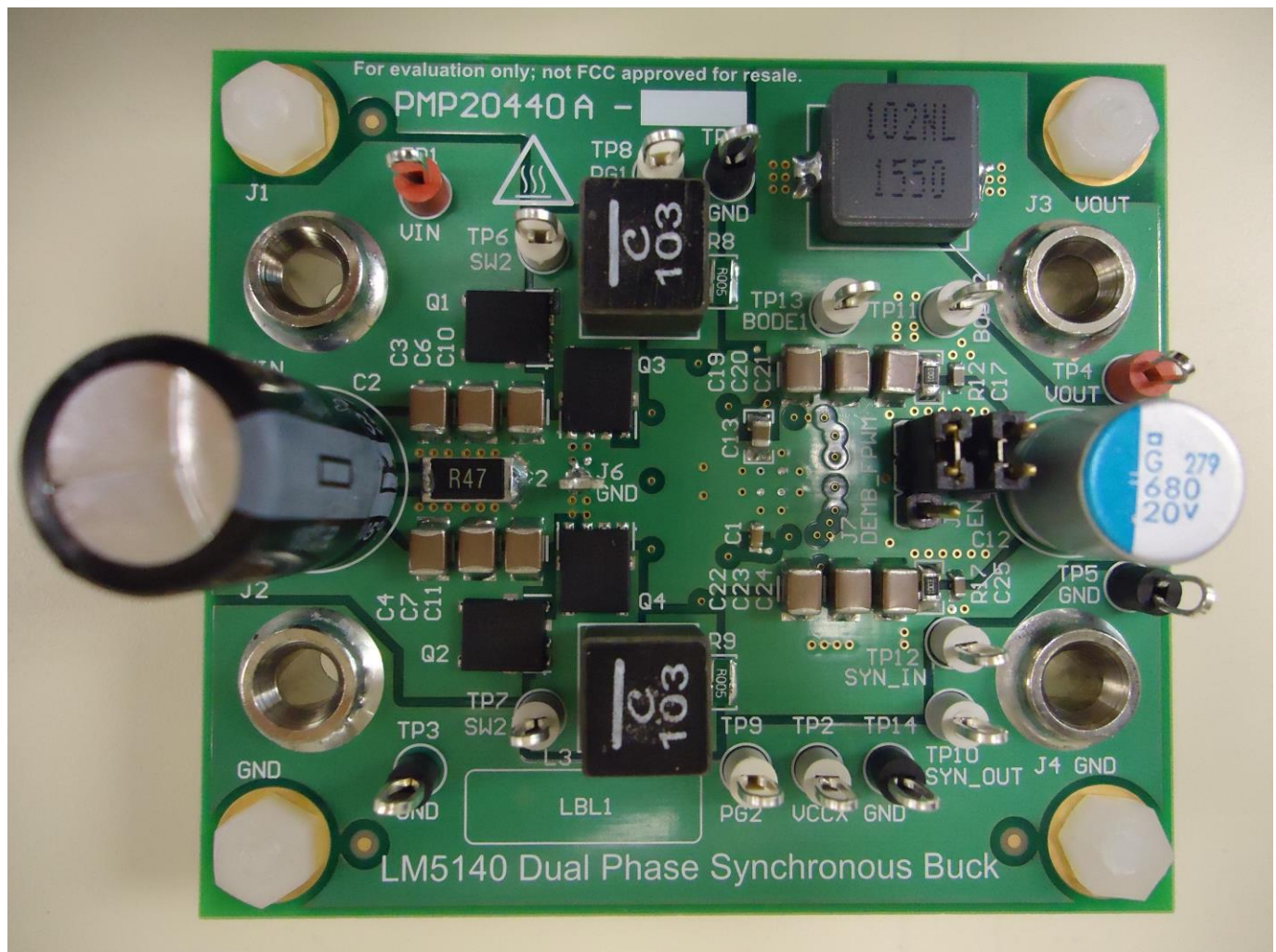
1 Circuit Description

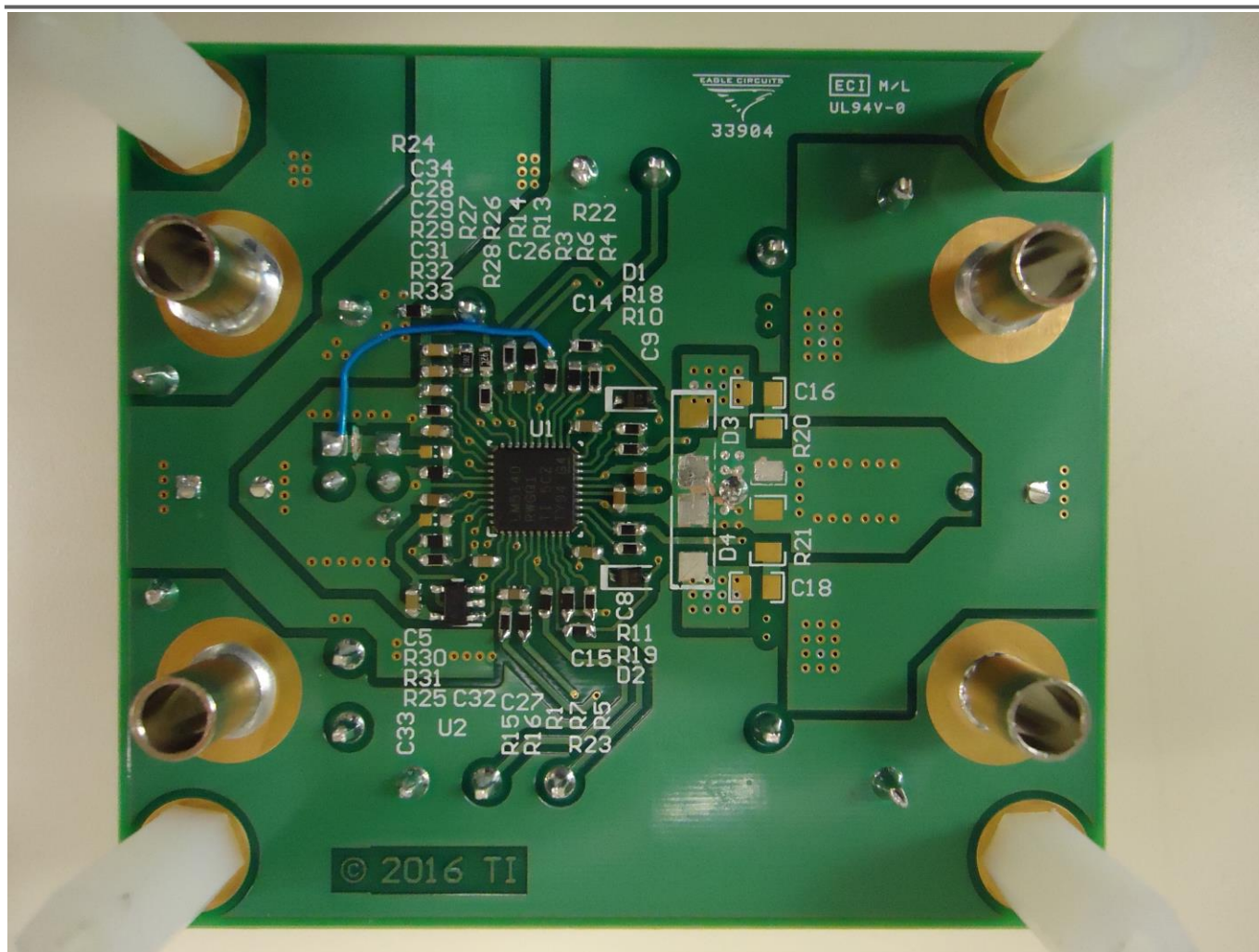
PMP20440 is a dual phase synchronous buck converter designed for 12V output at 11A from an input voltage of 6V to 17V. At an input voltage of 12V or less the output will follow with a small voltage drop. This design uses the LM5140-Q1 dual phase synchronous buck controller at a free-running switching frequency of 440 kHz. Features include external frequency synchronization, enable and power good.

At tests were performed at room temperature on an open bench.

2 Photos

The photographs below show the PMP20440 Rev A printed circuit board assembly. This is a 4 layer board using 2 ounce copper. The overall board dimensions are 2.4" x 2.7".

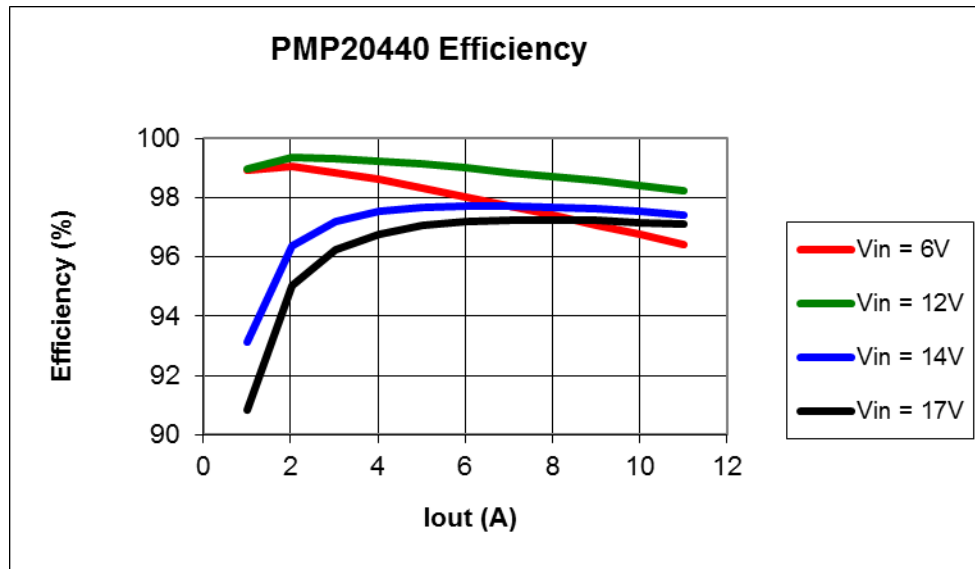




3 Efficiency

The efficiency data is shown in the tables and graphs below.

3.1 Efficiency at 440 kHz Switching Frequency



Vin (V)	Iin (A)	Vout (V)	Iout (A)	Pin (W)	Pout (W)	Losses (W)	Efficiency (%)
6.0004	0.0104	5.9386	0.0000	0.062	0.000	0.062	0.00
6.0001	0.9953	5.9129	0.9989	5.972	5.906	0.065	98.90
6.0000	2.0120	5.8888	2.0302	12.072	11.955	0.117	99.03
5.9995	2.9949	5.8675	3.0272	17.968	17.762	0.206	98.85
5.9994	3.9793	5.8471	4.0258	23.873	23.539	0.334	98.60
5.9992	4.9628	5.8273	5.0235	29.773	29.273	0.500	98.32
5.9990	5.9459	5.8072	6.0206	35.669	34.963	0.706	98.02
5.9985	6.9305	5.7872	7.0194	41.573	40.623	0.950	97.72
5.9983	7.9144	5.7672	8.0177	47.473	46.240	1.233	97.40
5.9979	8.8977	5.7471	9.0152	53.367	51.812	1.556	97.08
5.9975	9.8826	5.7269	10.0143	59.271	57.351	1.920	96.76
5.9971	10.8660	5.7069	11.0117	65.165	62.843	2.322	96.44

PMP20440 Rev A Test Results



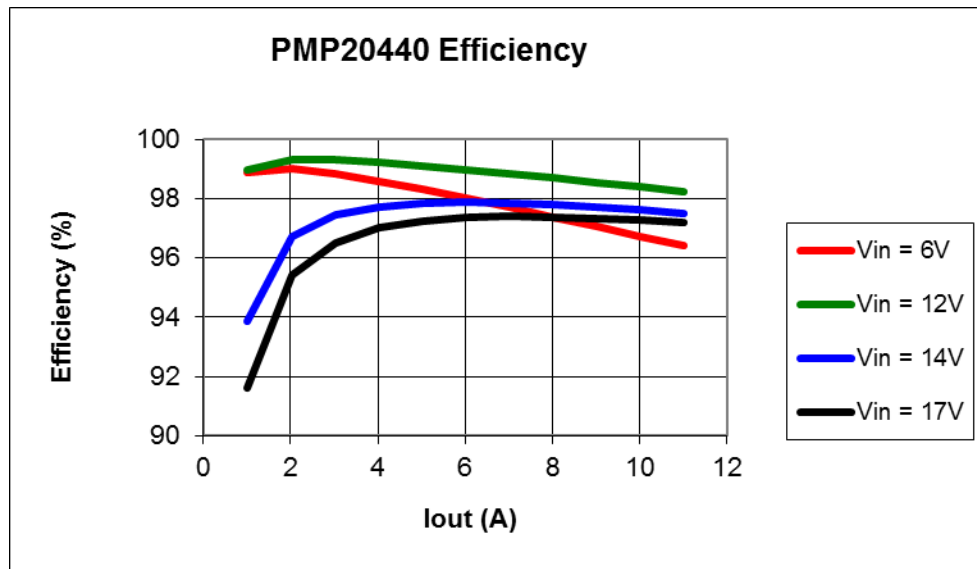
Vin (V)	Iin (A)	Vout (V)	Iout (A)	Pin (W)	Pout (W)	Losses (W)	Efficiency (%)
12.0057	0.0118	11.8830	0.0001	0.142	0.001	0.140	0.84
12.0054	0.9970	11.8558	0.9990	11.969	11.844	0.125	98.95
12.0050	2.0120	11.8284	2.0285	24.154	23.994	0.160	99.34
12.0052	2.9952	11.8043	3.0257	35.958	35.716	0.242	99.33
12.0049	3.9802	11.7825	4.0247	47.782	47.421	0.361	99.24
12.0047	4.9640	11.7613	5.0227	59.591	59.073	0.518	99.13
12.0045	5.9473	11.7407	6.0200	71.394	70.679	0.716	99.00
12.0041	6.9323	11.7204	7.0190	83.216	82.266	0.951	98.86
12.0041	7.9166	11.7005	8.0173	95.032	93.807	1.225	98.71
12.0036	8.9001	11.6804	9.0147	106.833	105.295	1.538	98.56
12.0032	9.8852	11.6599	10.0138	118.654	116.760	1.894	98.40
12.0030	10.8687	11.6395	11.0113	130.457	128.166	2.291	98.24

Vin (V)	Iin (A)	Vout (V)	Iout (A)	Pin (W)	Pout (W)	Losses (W)	Efficiency (%)
14.0059	0.0683	11.9252	0.0002	0.957	0.002	0.954	0.25
14.0058	0.9130	11.9219	0.9990	12.787	11.910	0.877	93.14
14.0056	1.7910	11.9186	2.0281	25.084	24.172	0.912	96.36
14.0054	2.6484	11.9155	3.0253	37.092	36.048	1.044	97.19
14.0054	3.5099	11.9122	4.0243	49.157	47.938	1.219	97.52
14.0050	4.3726	11.9091	5.0223	61.238	59.811	1.427	97.67
14.0051	5.2368	11.9059	6.0198	73.342	71.671	1.671	97.72
14.0047	6.1041	11.9026	7.0185	85.486	83.538	1.948	97.72
14.0047	6.9734	11.8994	8.0168	97.660	95.395	2.265	97.68
14.0045	7.8444	11.8963	9.0143	109.857	107.237	2.620	97.62
14.0043	8.7194	11.8930	10.0135	122.109	119.090	3.019	97.53
14.0037	9.5955	11.8898	11.0109	134.372	130.918	3.454	97.43

Vin (V)	Iin (A)	Vout (V)	Iout (A)	Pin (W)	Pout (W)	Losses (W)	Efficiency (%)
17.0082	0.0721	11.9263	0.0001	1.226	0.001	1.225	0.10
17.0077	0.7711	11.9231	0.9990	13.115	11.911	1.203	90.82
17.0078	1.4954	11.9198	2.0277	25.433	24.170	1.264	95.03
17.0077	2.2024	11.9165	3.0250	37.458	36.047	1.410	96.23
17.0075	2.9125	11.9132	4.0240	49.534	47.939	1.596	96.78
17.0070	3.6238	11.9100	5.0220	61.630	59.812	1.818	97.05
17.0071	4.3362	11.9068	6.0195	73.746	71.673	2.073	97.19
17.0069	5.0515	11.9035	7.0184	85.910	83.544	2.367	97.25
17.0069	5.7682	11.9003	8.0168	98.099	95.402	2.697	97.25
17.0065	6.4859	11.8970	9.0141	110.302	107.241	3.061	97.22
17.0065	7.2071	11.8938	10.0134	122.567	119.097	3.470	97.17
17.0065	7.9293	11.8906	11.0110	134.850	130.927	3.922	97.09

PMP20440 Rev A Test Results

3.2 Efficiency at 384 kHz Switching Frequency



Vin (V)	Iin (A)	Vout (V)	Iout (A)	Pin (W)	Pout (W)	Losses (W)	Efficiency (%)
6.0006	0.0103	5.9387	0.0000	0.062	0.000	0.062	0.00
6.0003	0.9956	5.9132	0.9989	5.974	5.907	0.067	98.88
6.0002	2.0113	5.8887	2.0292	12.068	11.949	0.119	99.02
5.9999	2.9945	5.8674	3.0264	17.967	17.757	0.210	98.83
5.9995	3.9792	5.8468	4.0253	23.873	23.535	0.338	98.58
5.9994	4.9632	5.8269	5.0234	29.776	29.271	0.506	98.30
5.9991	5.9466	5.8068	6.0209	35.675	34.962	0.712	98.00
5.9987	6.9313	5.7866	7.0199	41.579	40.621	0.958	97.70
5.9986	7.9155	5.7665	8.0181	47.482	46.237	1.245	97.38
5.9982	8.8988	5.7463	9.0156	53.377	51.807	1.570	97.06
5.9976	9.8839	5.7260	10.0148	59.280	57.345	1.935	96.74
5.9973	10.8673	5.7057	11.0122	65.174	62.832	2.342	96.41

PMP20440 Rev A Test Results



Vin (V)	Iin (A)	Vout (V)	Iout (A)	Pin (W)	Pout (W)	Losses (W)	Efficiency (%)
12.0057	0.0119	11.8831	0.0001	0.143	0.001	0.142	0.83
12.0054	0.9972	11.8557	0.9992	11.972	11.846	0.126	98.95
12.0052	2.0118	11.8282	2.0281	24.152	23.989	0.163	99.32
12.0050	2.9952	11.8041	3.0254	35.957	35.712	0.245	99.32
12.0050	3.9802	11.7818	4.0244	47.782	47.415	0.368	99.23
12.0044	4.9643	11.7605	5.0225	59.593	59.067	0.526	99.12
12.0045	5.9479	11.7401	6.0201	71.402	70.676	0.725	98.98
12.0043	6.9328	11.7197	7.0191	83.223	82.262	0.962	98.84
12.0037	7.9172	11.6996	8.0174	95.036	93.800	1.236	98.70
12.0036	8.9008	11.6795	9.0149	106.842	105.289	1.552	98.55
12.0035	9.8861	11.6590	10.0141	118.668	116.755	1.913	98.39
12.0027	10.8700	11.6384	11.0115	130.469	128.157	2.313	98.23

Vin (V)	Iin (A)	Vout (V)	Iout (A)	Pin (W)	Pout (W)	Losses (W)	Efficiency (%)
14.0055	0.0598	11.9255	0.0002	0.838	0.002	0.835	0.28
14.0055	0.9061	11.9224	0.9992	12.690	11.913	0.778	93.87
14.0055	1.7841	11.9190	2.0275	24.987	24.166	0.821	96.71
14.0058	2.6414	11.9157	3.0250	36.995	36.045	0.950	97.43
14.0054	3.5025	11.9126	4.0240	49.054	47.936	1.118	97.72
14.0054	4.3650	11.9094	5.0223	61.133	59.812	1.321	97.84
14.0050	5.2291	11.9061	6.0198	73.233	71.672	1.561	97.87
14.0050	6.0967	11.9029	7.0190	85.384	83.546	1.838	97.85
14.0045	6.9657	11.8997	8.0171	97.551	95.401	2.150	97.80
14.0043	7.8364	11.8964	9.0144	109.743	107.239	2.504	97.72
14.0038	8.7117	11.8933	10.0140	121.997	119.099	2.898	97.62
14.0041	9.5878	11.8899	11.0114	134.268	130.925	3.343	97.51

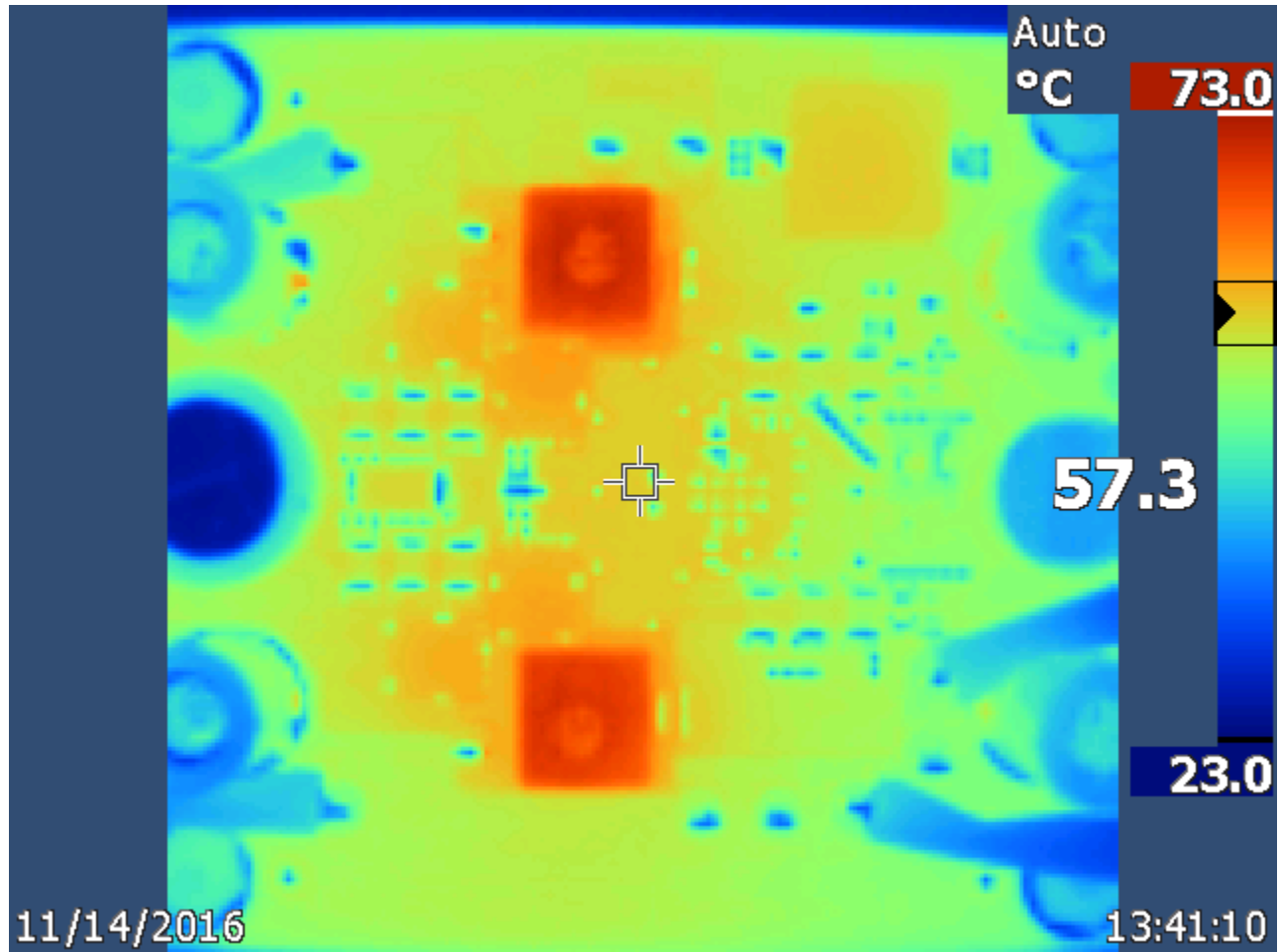
Vin (V)	Iin (A)	Vout (V)	Iout (A)	Pin (W)	Pout (W)	Losses (W)	Efficiency (%)
17.0077	0.0643	11.9264	0.0004	1.094	0.005	1.089	0.44
17.0075	0.7645	11.9232	0.9992	13.002	11.914	1.089	91.63
17.0074	1.4891	11.9198	2.0274	25.326	24.166	1.160	95.42
17.0073	2.1958	11.9166	3.0247	37.345	36.044	1.301	96.52
17.0074	2.9056	11.9133	4.0238	49.417	47.937	1.480	97.01
17.0071	3.6165	11.9101	5.0219	61.506	59.811	1.695	97.24
17.0069	4.3286	11.9068	6.0194	73.616	71.672	1.944	97.36
17.0070	5.0438	11.9035	7.0184	85.780	83.544	2.236	97.39
17.0071	5.7602	11.9003	8.0168	97.965	95.403	2.562	97.38
17.0069	6.4779	11.8971	9.0141	110.169	107.242	2.927	97.34
17.0066	7.1993	11.8940	10.0136	122.436	119.101	3.334	97.28
17.0064	7.9214	11.8905	11.0111	134.714	130.927	3.787	97.19

4 Thermal Tests

All tests were performed at room temperature on an open bench.

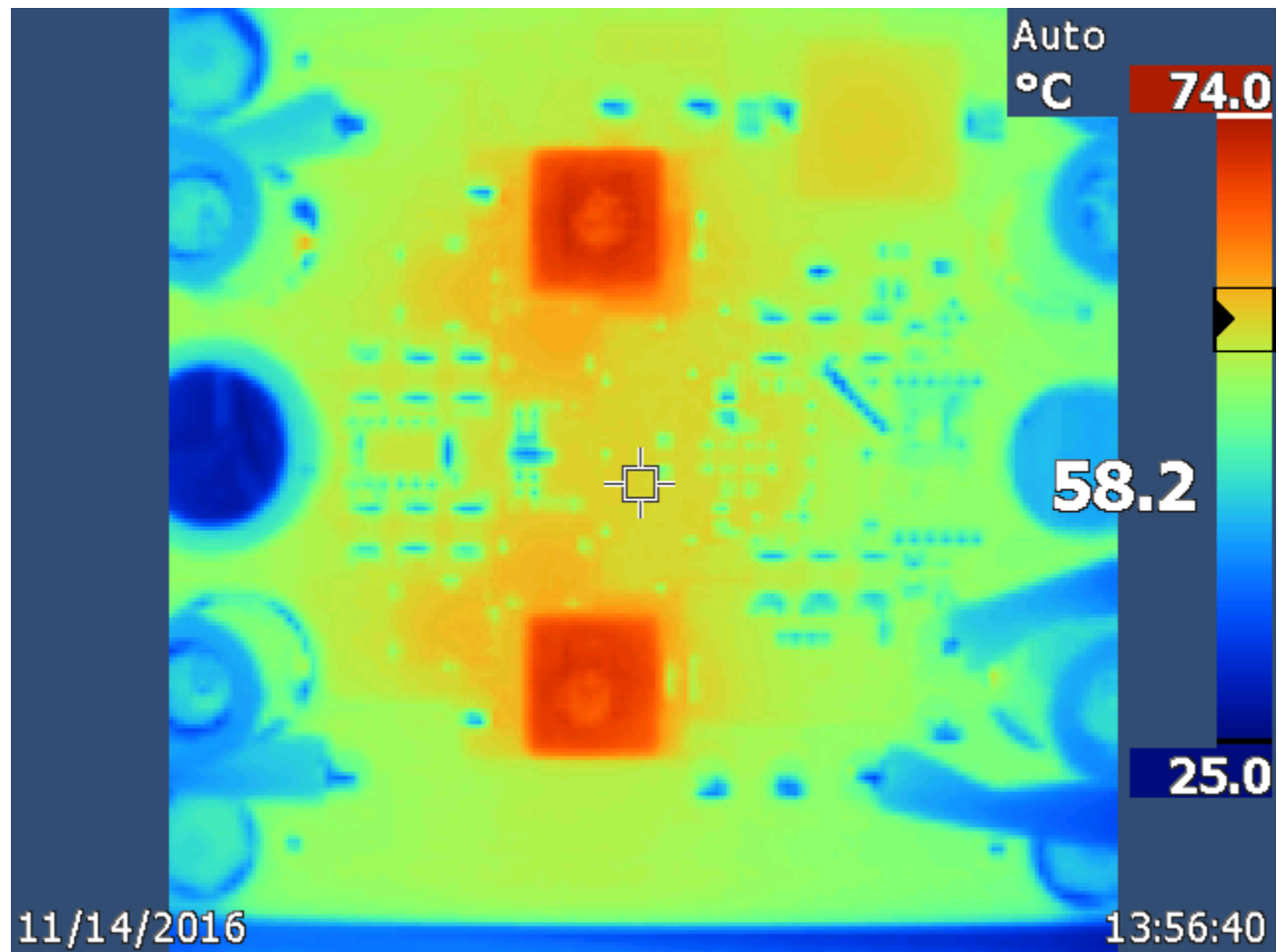
4.1 Thermal at 440 kHz Switching Frequency

14V input, 12V output, 11A load.



4.2 Thermal at 384 kHz Switching Frequency

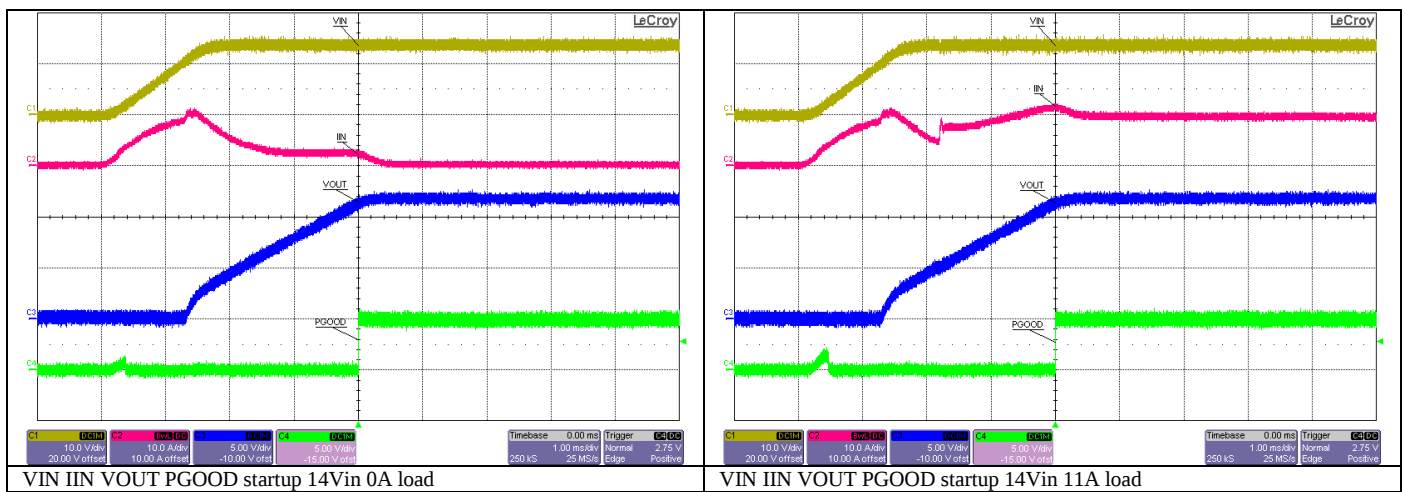
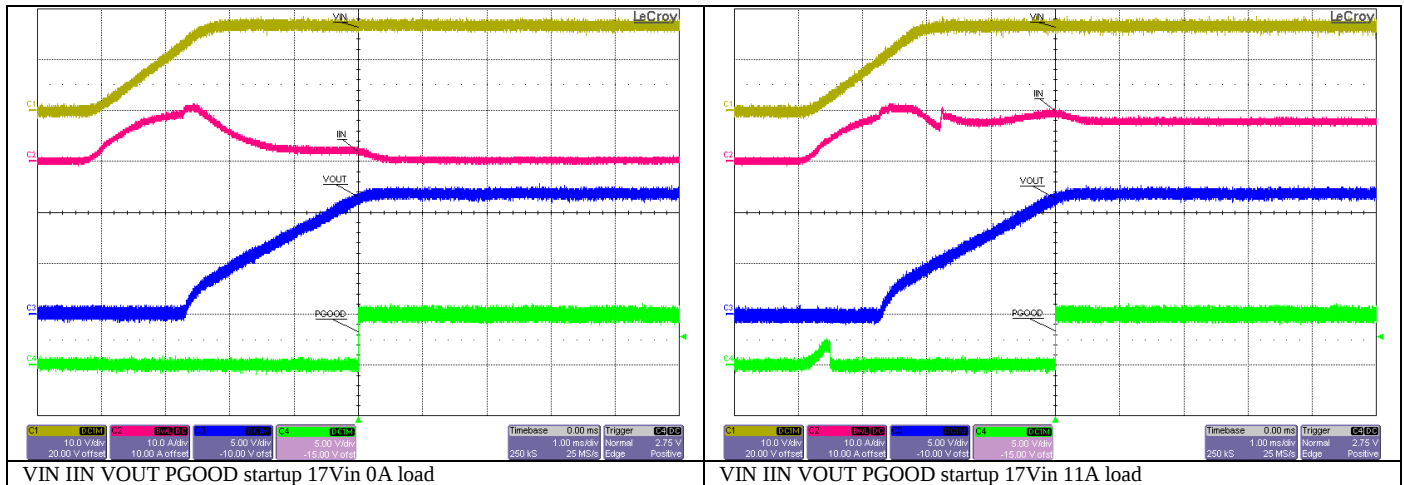
14V input, 12V output, 11A load.



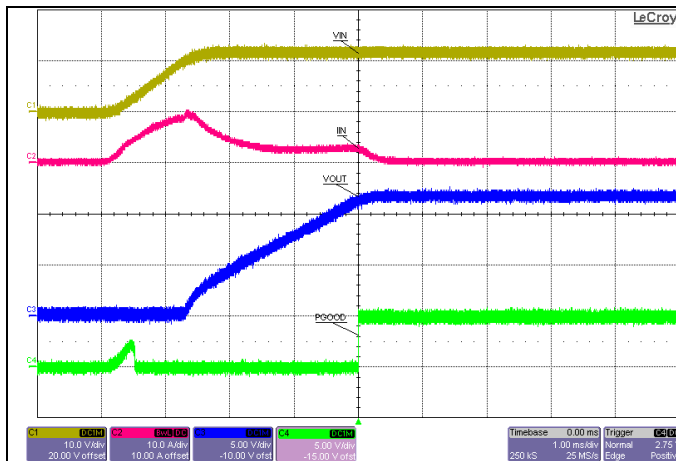
5 Startup and Shutdown Behavior

5.1 Startup from V_{in}

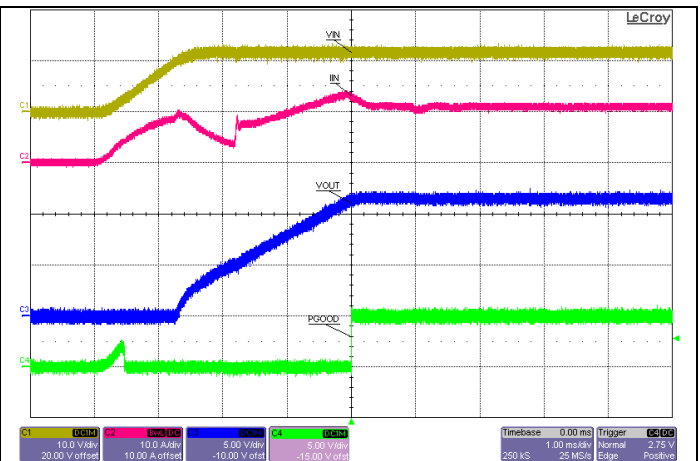
The output voltage is well controlled at startup.



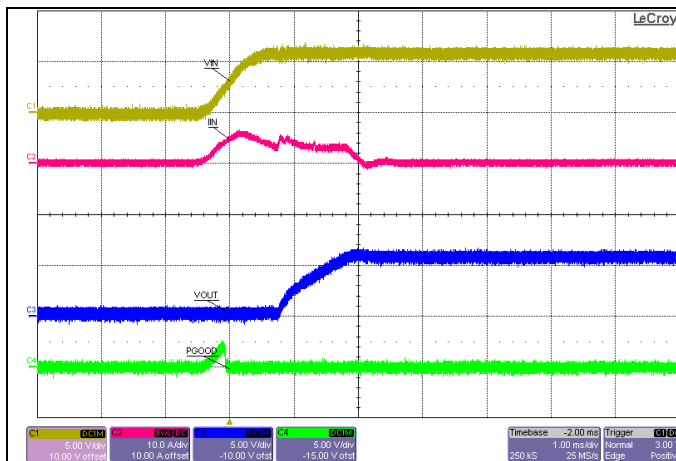
PMP20440 Rev A Test Results



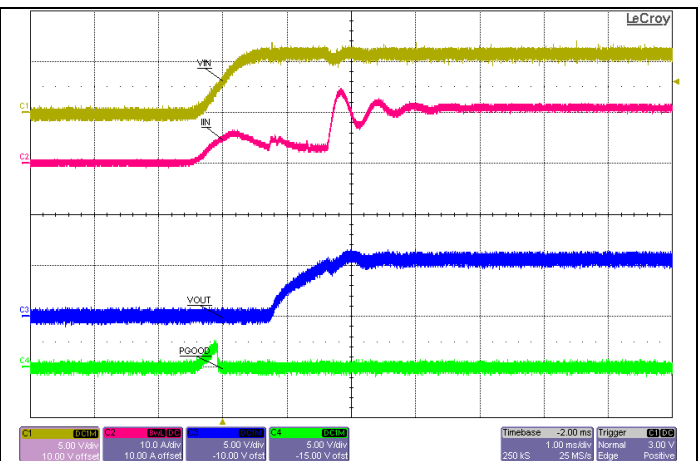
VIN IIN VOUT PGOOD startup 12Vin 0A load



VIN IIN VOUT PGOOD startup 12Vin 11A load



VIN IIN VOUT PGOOD startup 6Vin 0A load



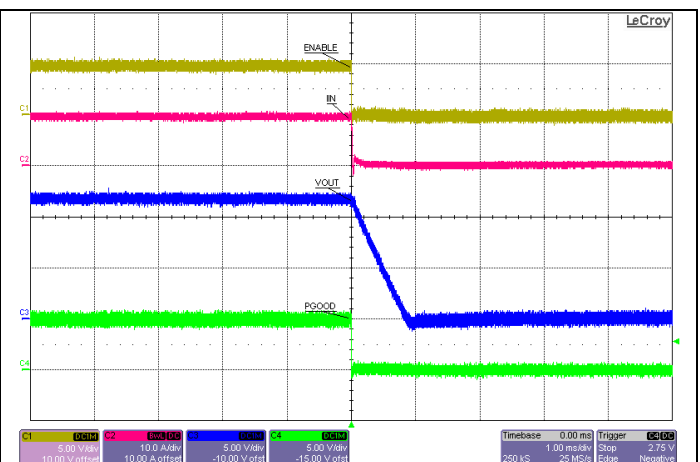
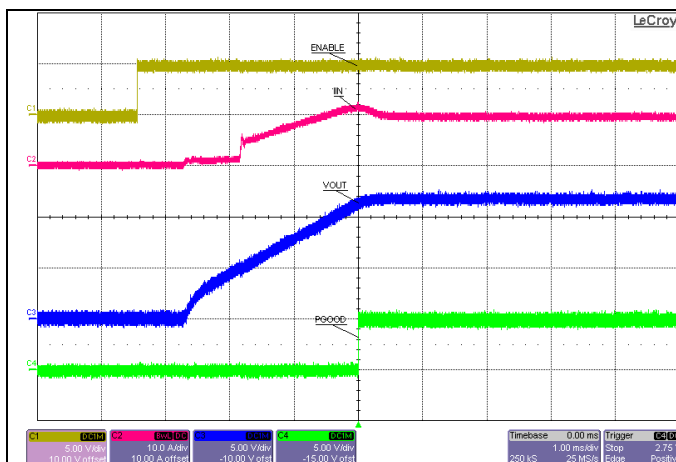
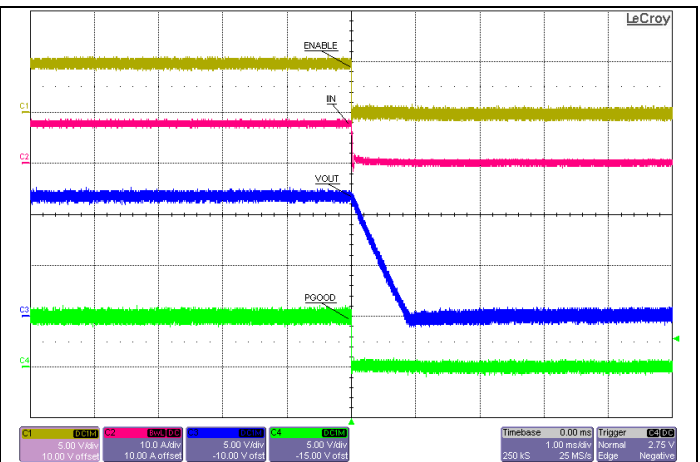
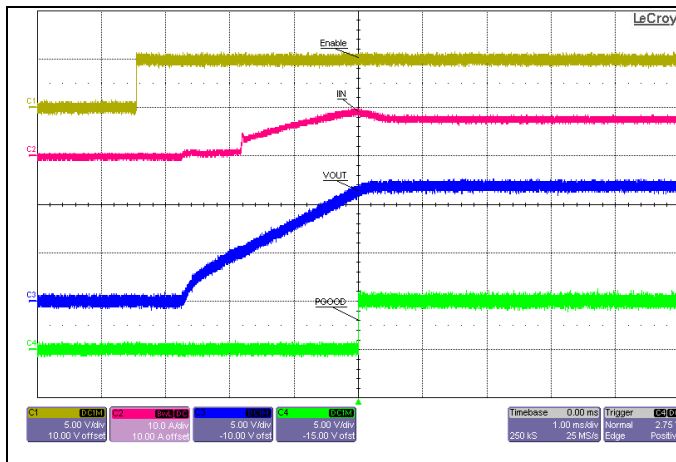
VIN IIN VOUT PGOOD startup 6Vin 11A load

PMP20440 Rev A Test Results

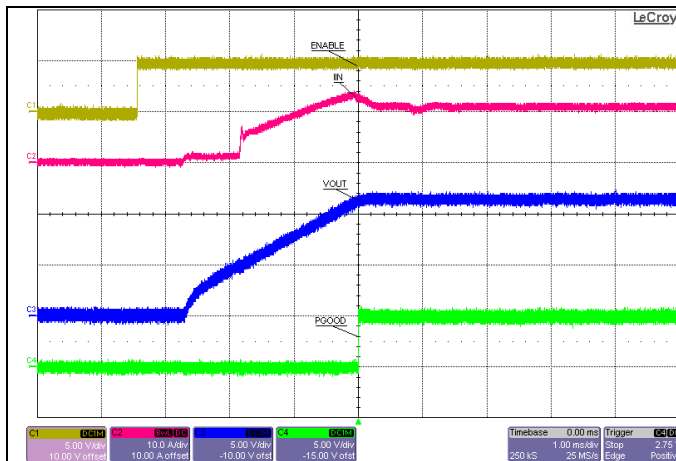


5.2 Startup and Shutdown from EN

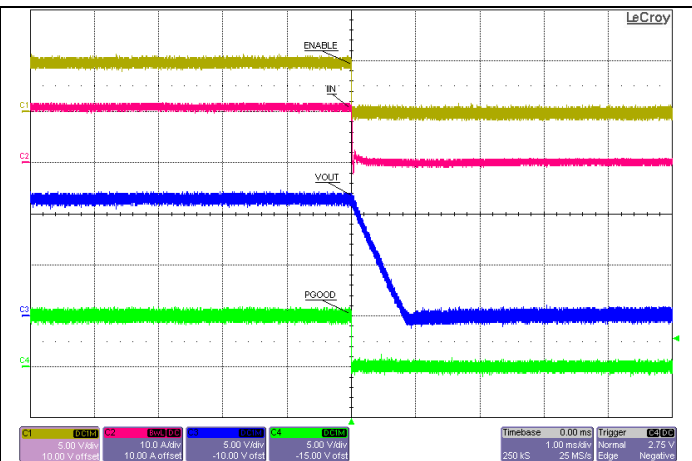
The output voltage is well controlled at startup.



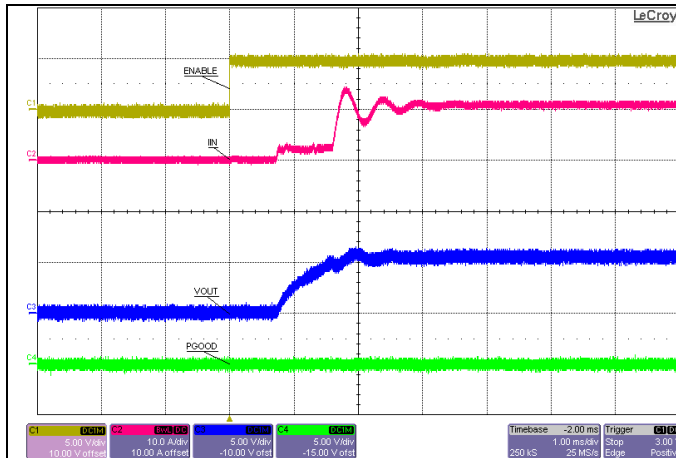
PMP20440 Rev A Test Results



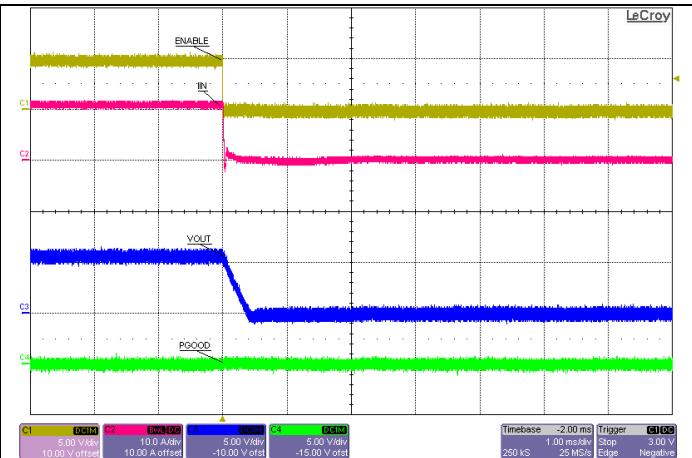
EN IIN VOUT PGOOD startup 12Vin 11A load



EN IIN VOUT PGOOD shutdown 12Vin 11A load



EN IIN VOUT PGOOD startup 6Vin 11A load

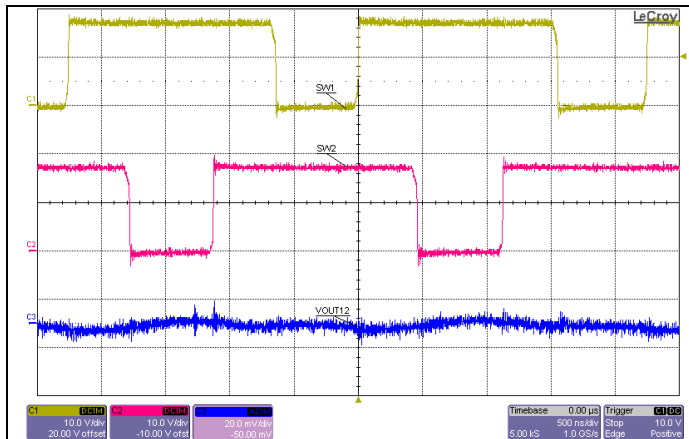


EN IIN VOUT PGOOD shutdown 6Vin 11A load

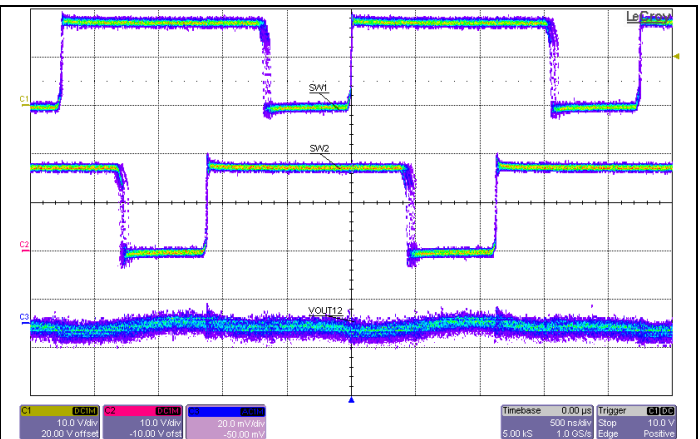
6 Switching and Ripple

6.1 Switching and Ripple

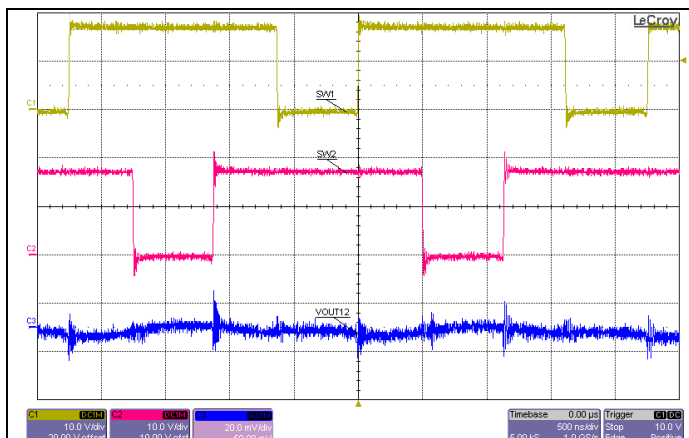
Switching and ripple were measured at full bandwidth using 500 MHz probes and 350 MHz oscilloscope. When operating in dropout at 12V input and below, the switching frequency is reduced and synchronization is not locked. Phase-to-phase jitter is typically 100ns.



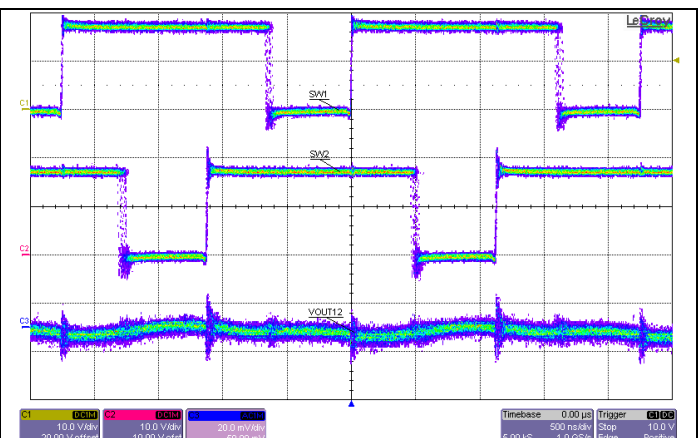
SW1 SW2 VOUT12 switching 17Vin 0A load



SW1 SW2 VOUT12 switching 17Vin 0A load

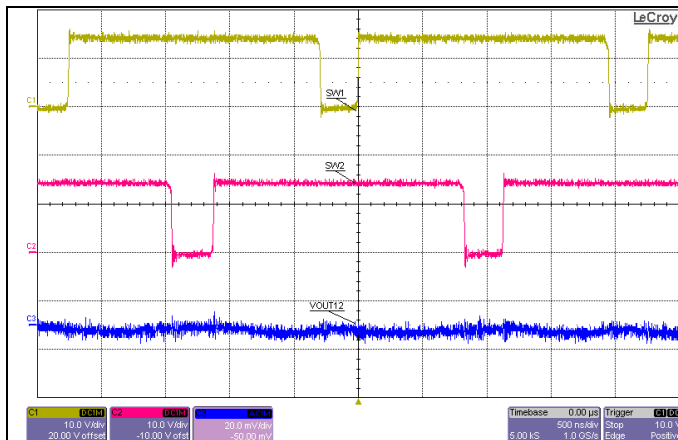


SW1 SW2 VOUT12 switching 17Vin 11A load

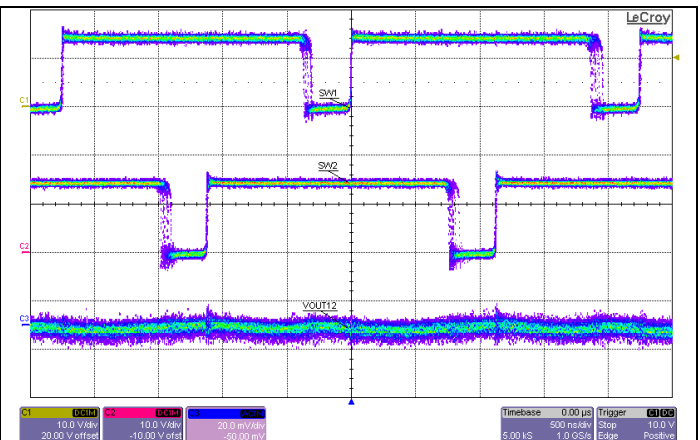


SW1 SW2 VOUT12 switching 17Vin 11A load

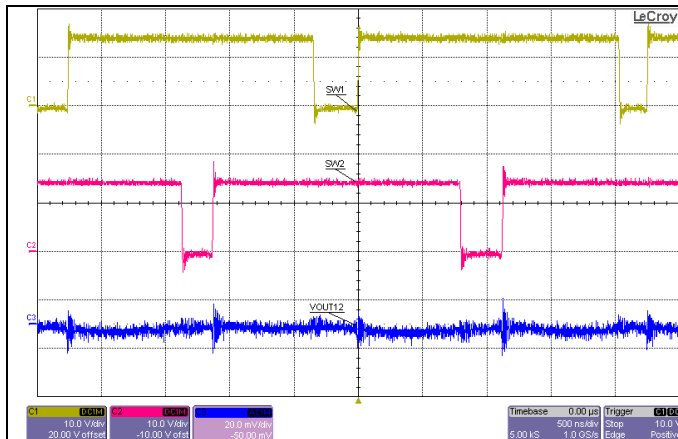
PMP20440 Rev A Test Results



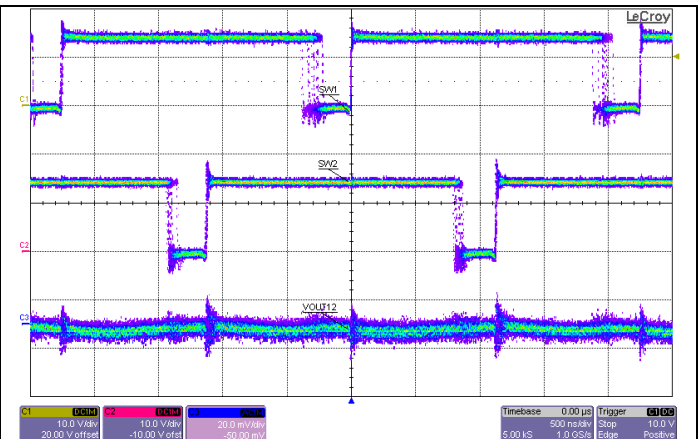
SW1 SW2 VOUT12 switching 14Vin 0A load



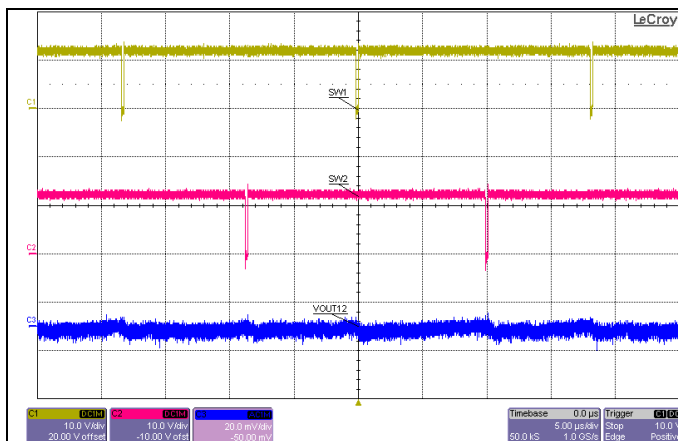
SW1 SW2 VOUT12 switching 14Vin 0A load



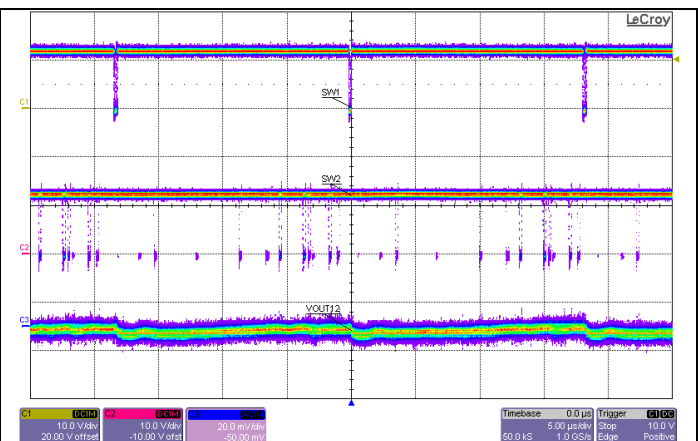
SW1 SW2 VOUT12 switching 14Vin 11A load



SW1 SW2 VOUT12 switching 14Vin 11A load

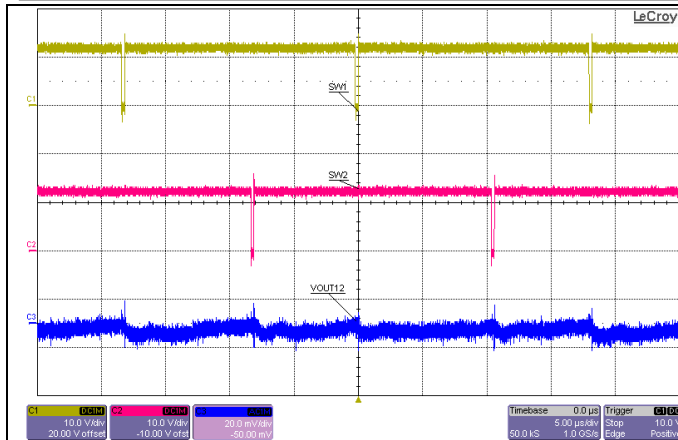


SW1 SW2 VOUT12 switching 12Vin 0A load

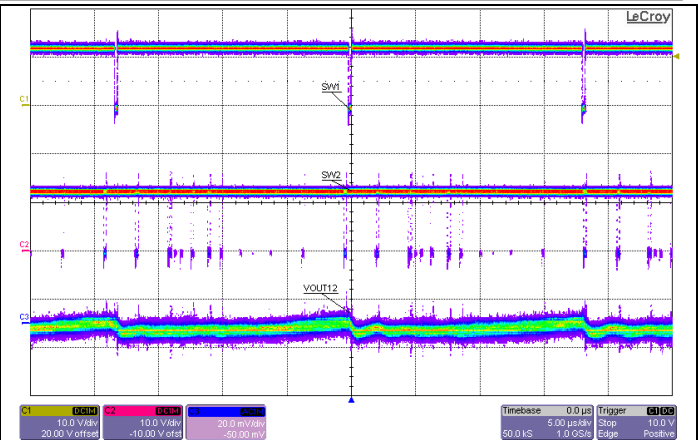


SW1 SW2 VOUT12 switching 12Vin 0A load

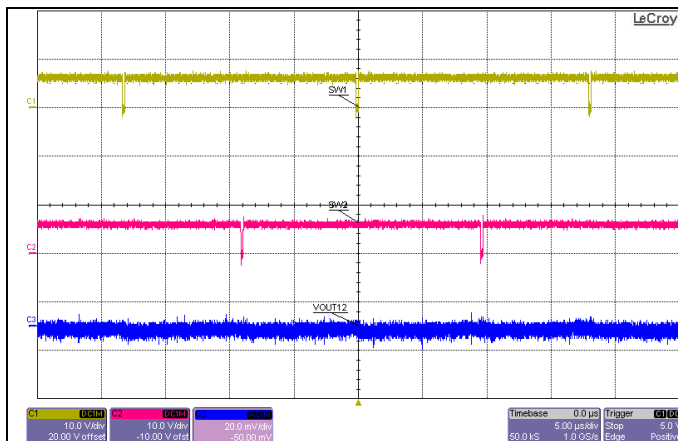
PMP20440 Rev A Test Results



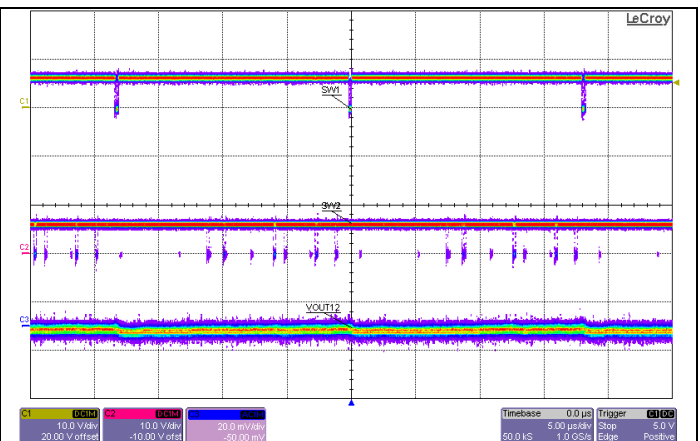
SW1 SW2 VOUT12 switching 12Vin 11A load



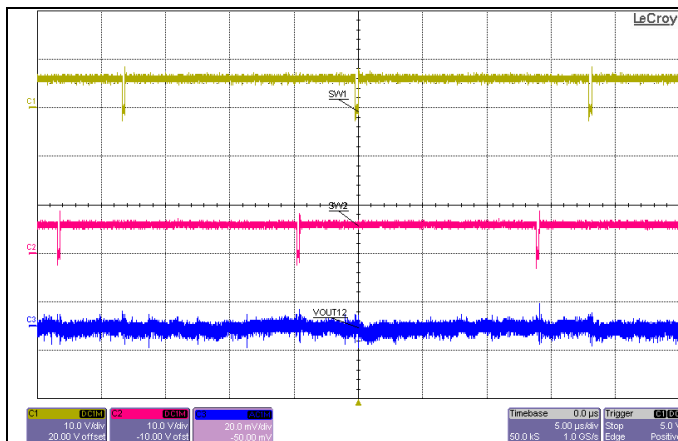
SW1 SW2 VOUT12 switching 12Vin 11A load



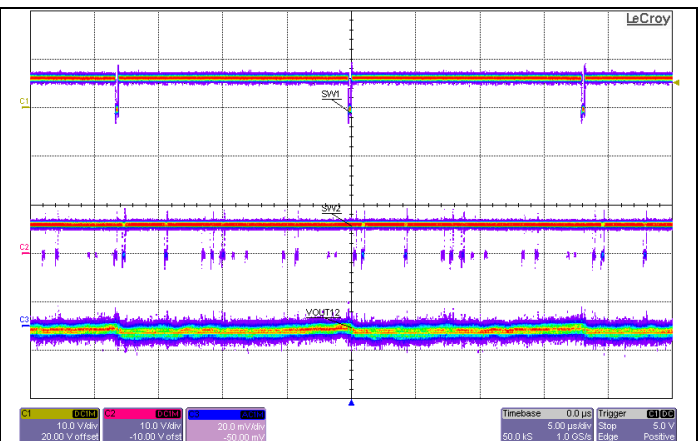
SW1 SW2 VOUT12 switching 6Vin 0A load



SW1 SW2 VOUT12 switching 6Vin 0A load



SW1 SW2 VOUT12 switching 6Vin 11A load

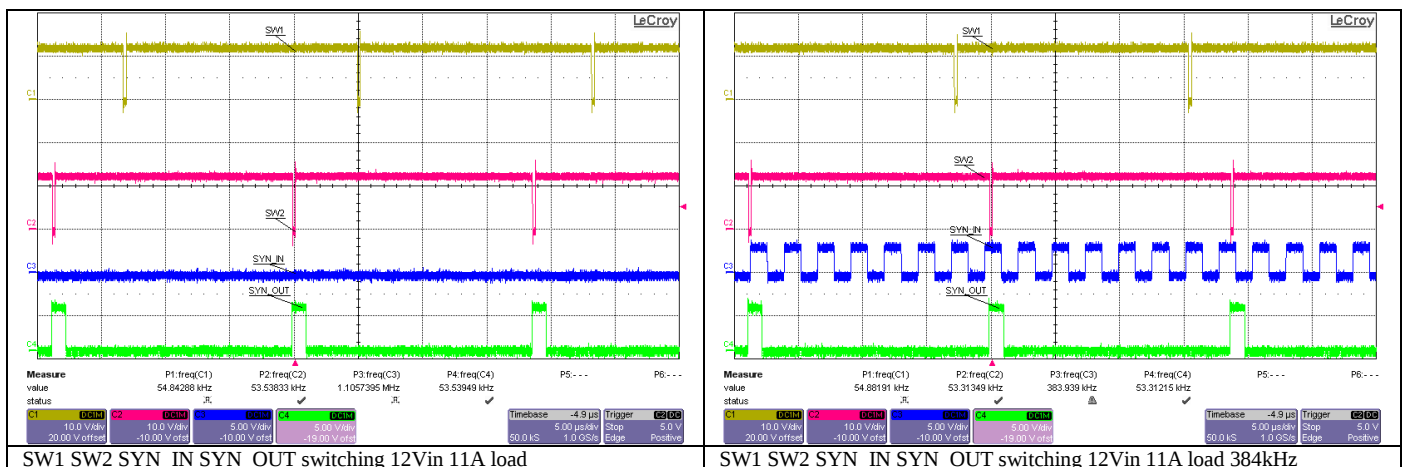
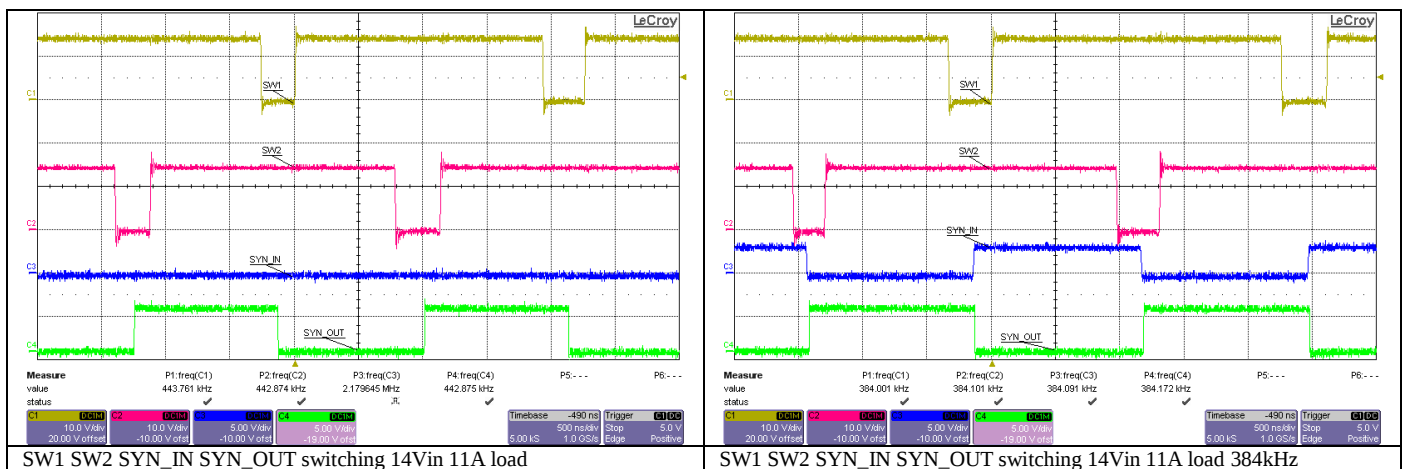
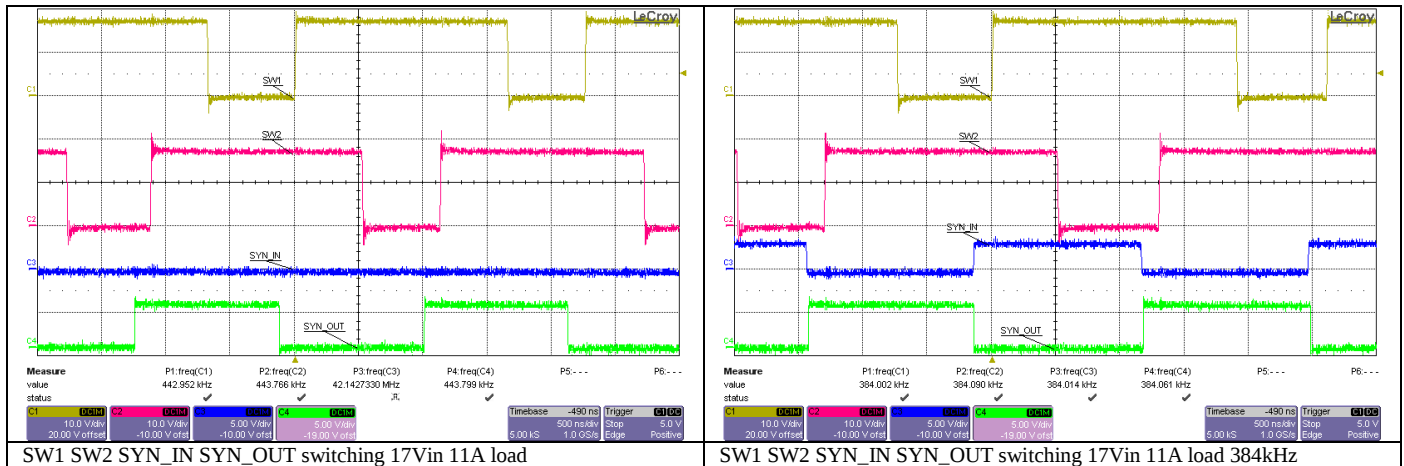


SW1 SW2 VOUT12 switching 6Vin 11A load

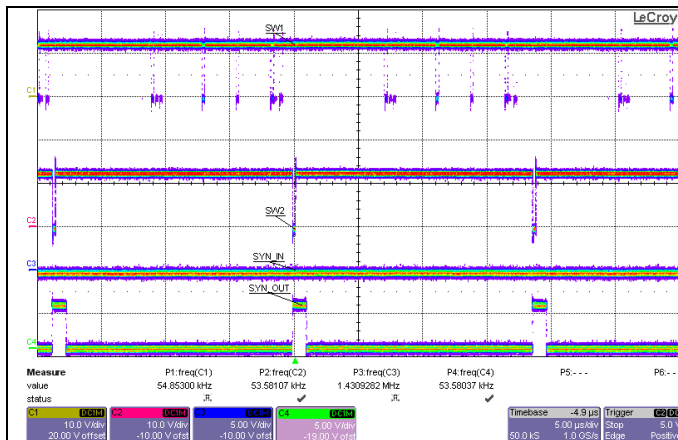
7 Synchronization

7.1 Synchronization

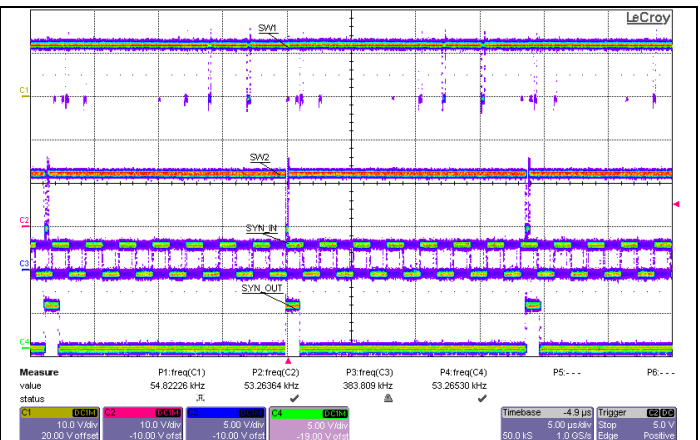
Switching and ripple were measured at full bandwidth using 500 MHz probes and 350 MHz oscilloscope. When operating in dropout at 12V input and below, the switching frequency is reduced and synchronization is not locked.



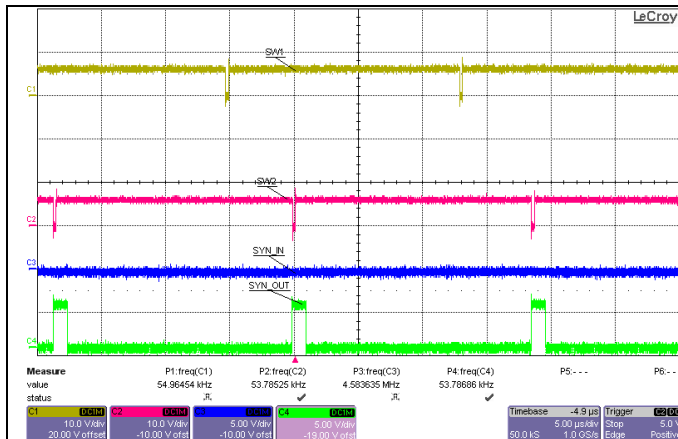
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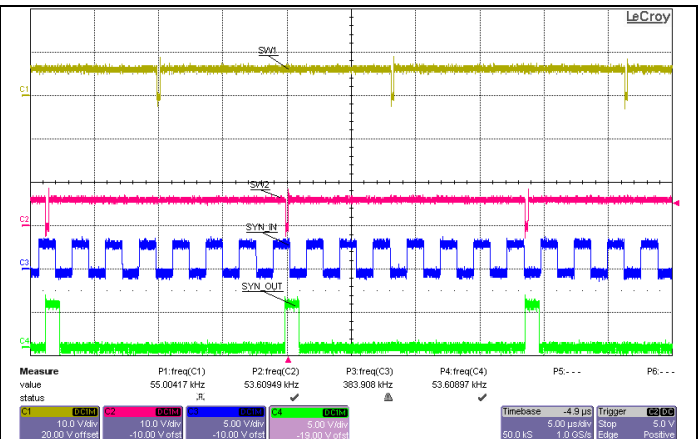
SW1 SW2 SYN_IN SYN_OUT switching 12Vin 11A load



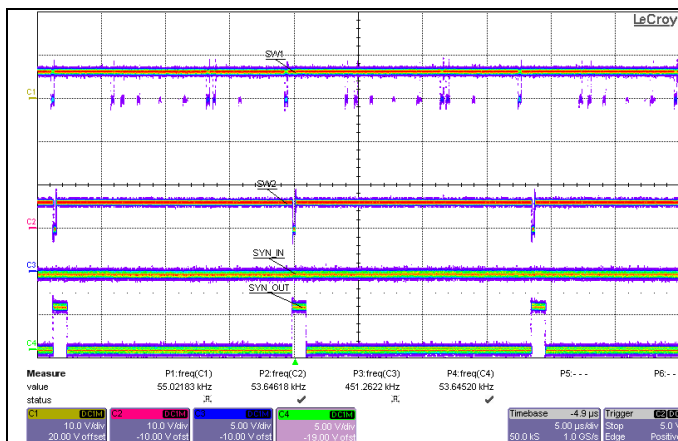
SW1 SW2 SYN_IN SYN_OUT switching 12Vin 11A load 384kHz



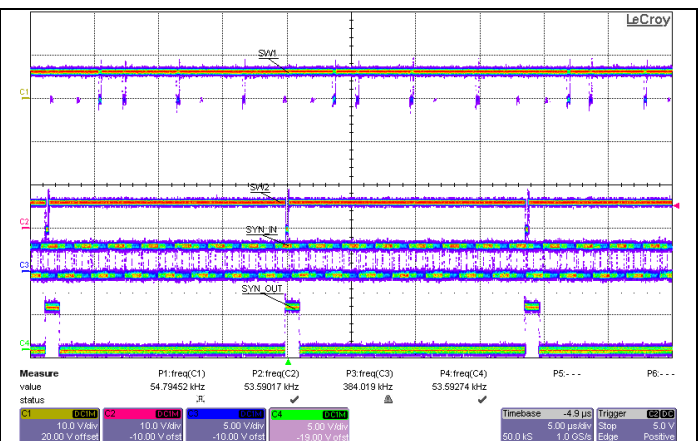
SW1 SW2 SYN_IN SYN_OUT switching 6Vin 11A load



SW1 SW2 SYN_IN SYN_OUT switching 6Vin 11A load 384kHz



SW1 SW2 SYN_IN SYN_OUT switching 6Vin 11A load

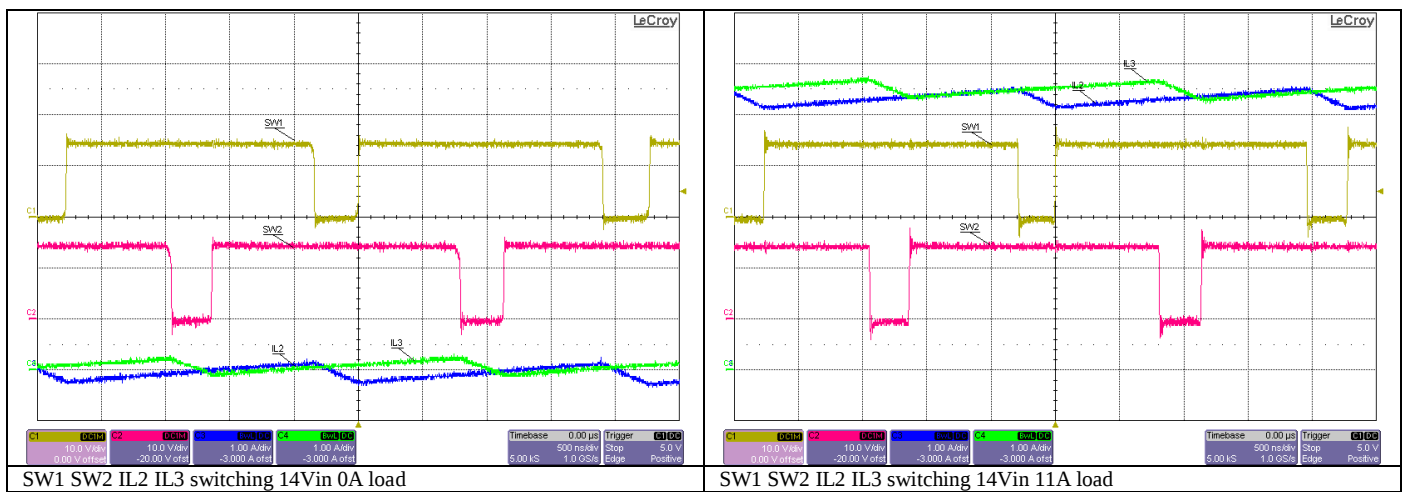
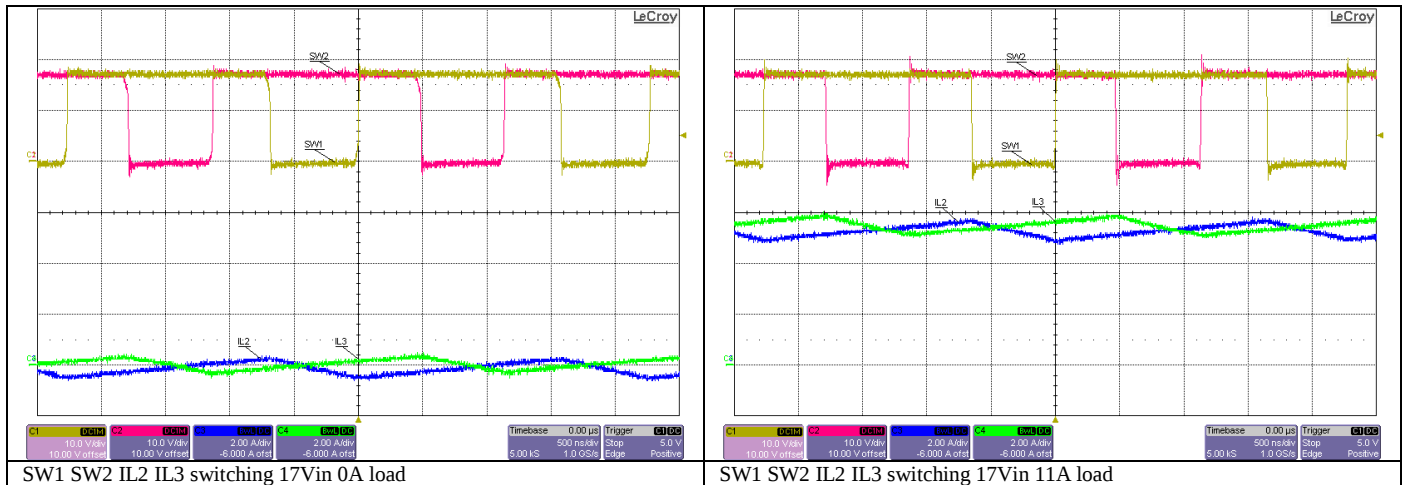


SW1 SW2 SYN_IN SYN_OUT switching 6Vin 11A load 384kHz

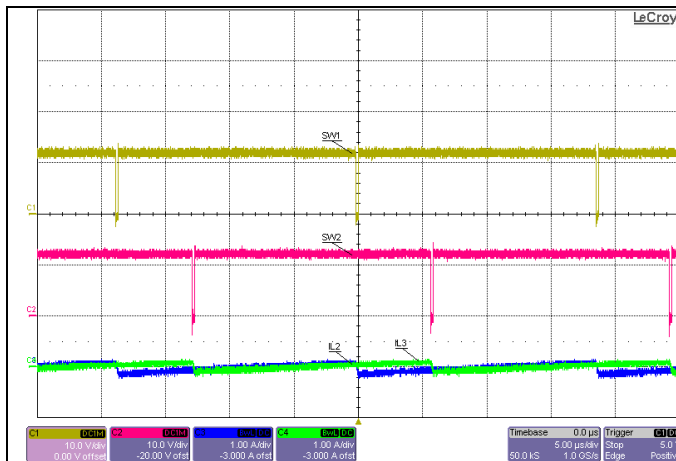
8 Current Sharing

8.1 Current Sharing

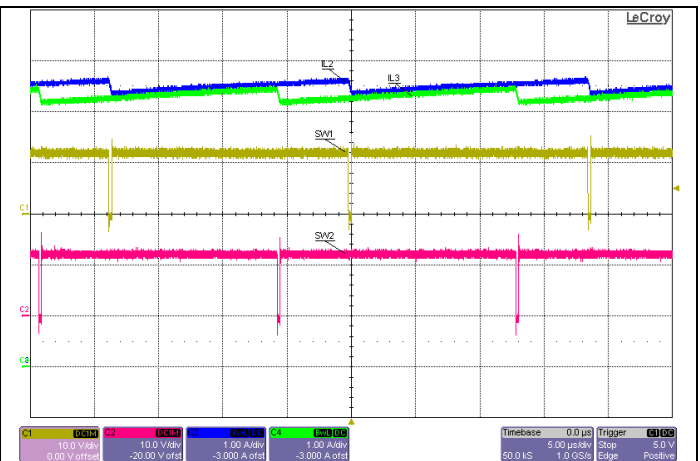
The inductor current is measured to demonstrate current sharing.



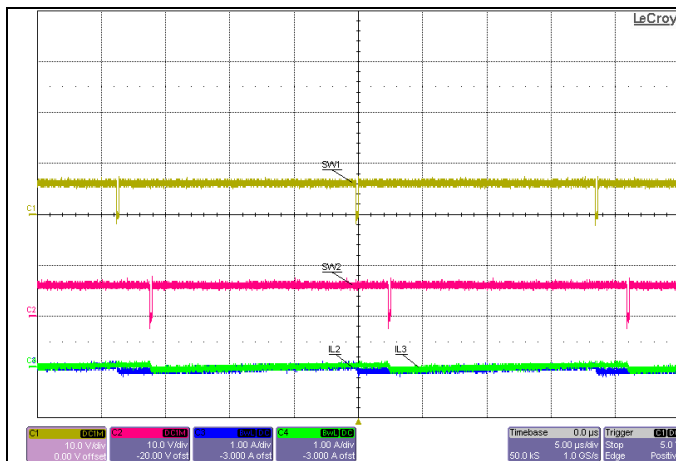
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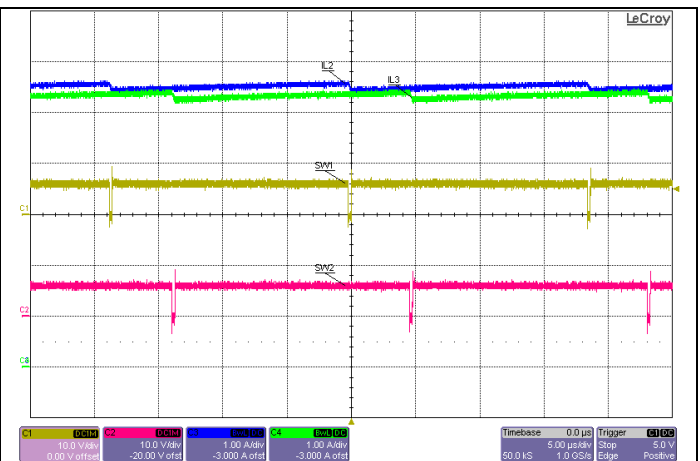
SW1 SW2 IL2 IL3 switching 12Vin 0A load



SW1 SW2 IL2 IL3 switching 12Vin 11A load



SW1 SW2 IL2 IL3 switching 6Vin 0A load

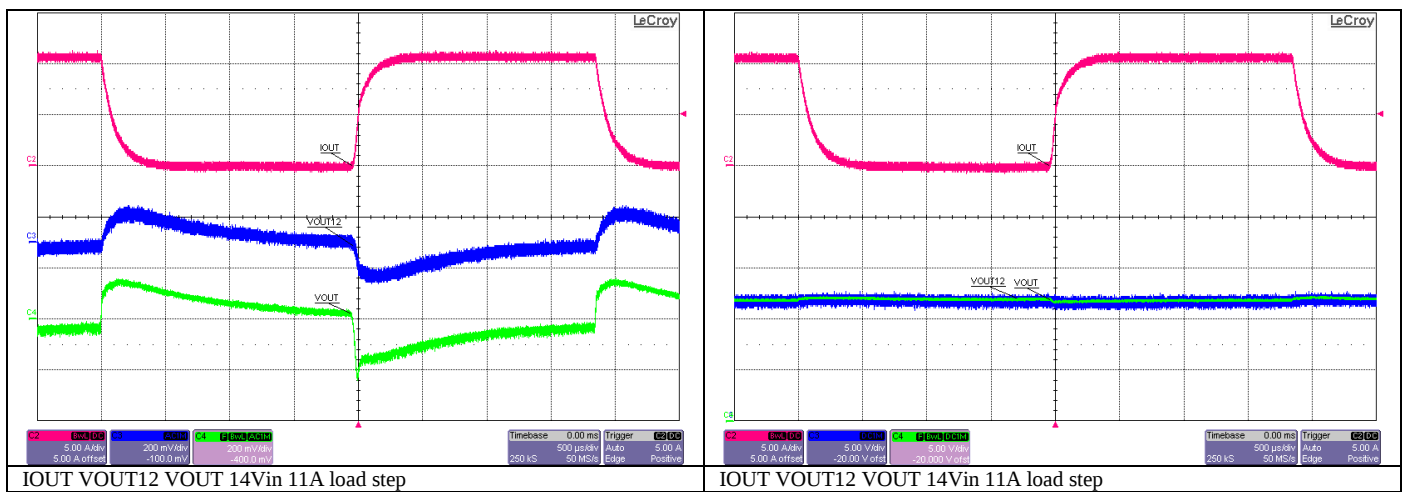
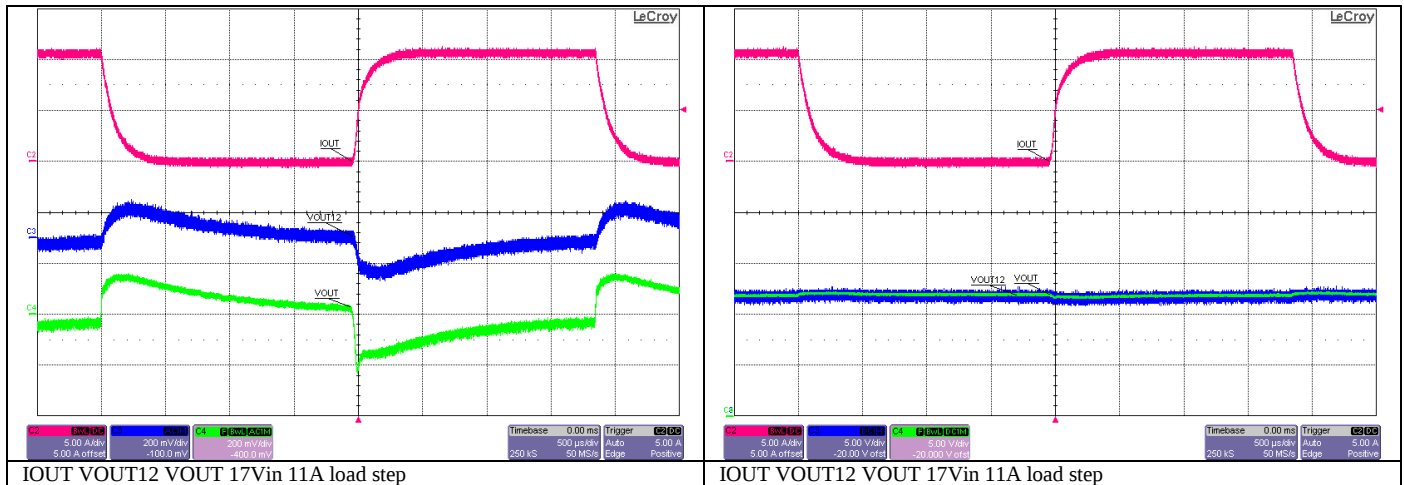


SW1 SW2 IL2 IL3 switching 6Vin 11A load

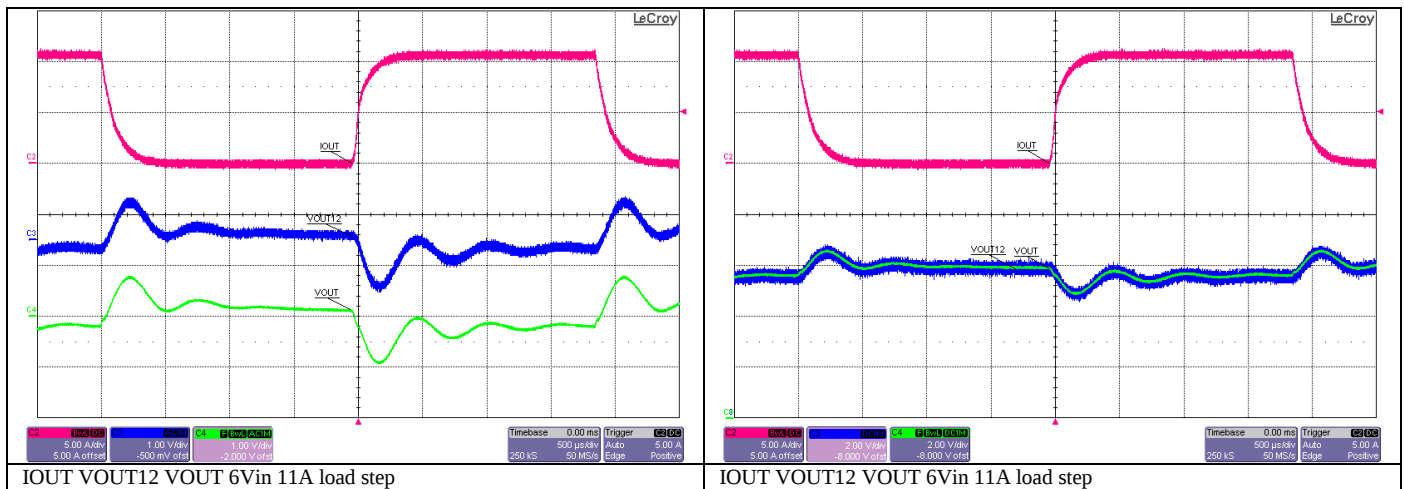
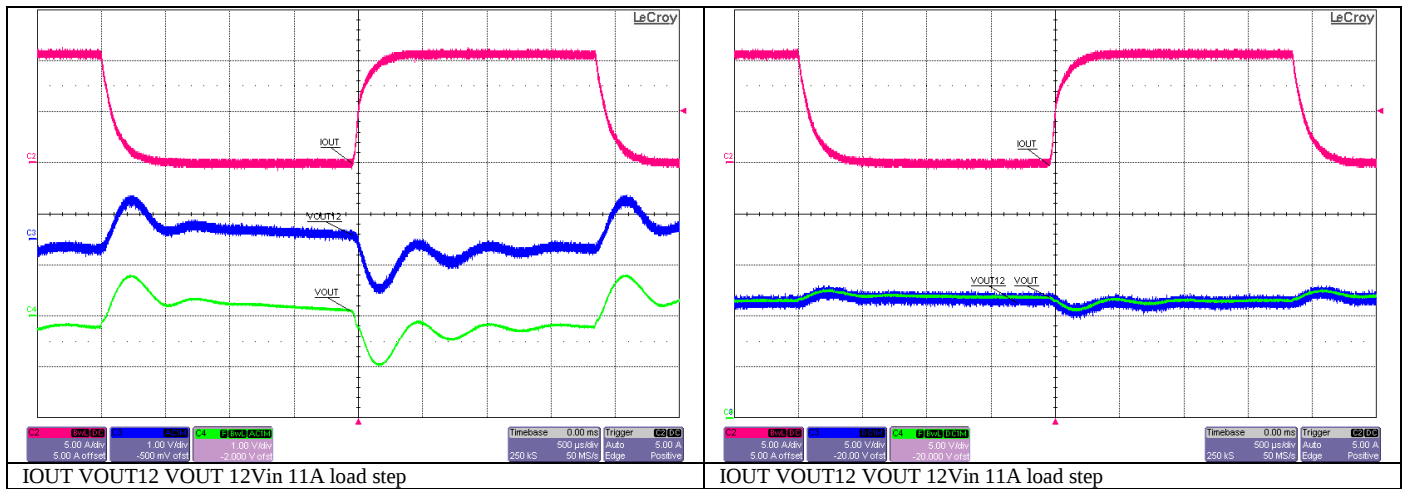
9 Load Transient Response

9.1 Load Transient Response

A constant current load was used to step the current.



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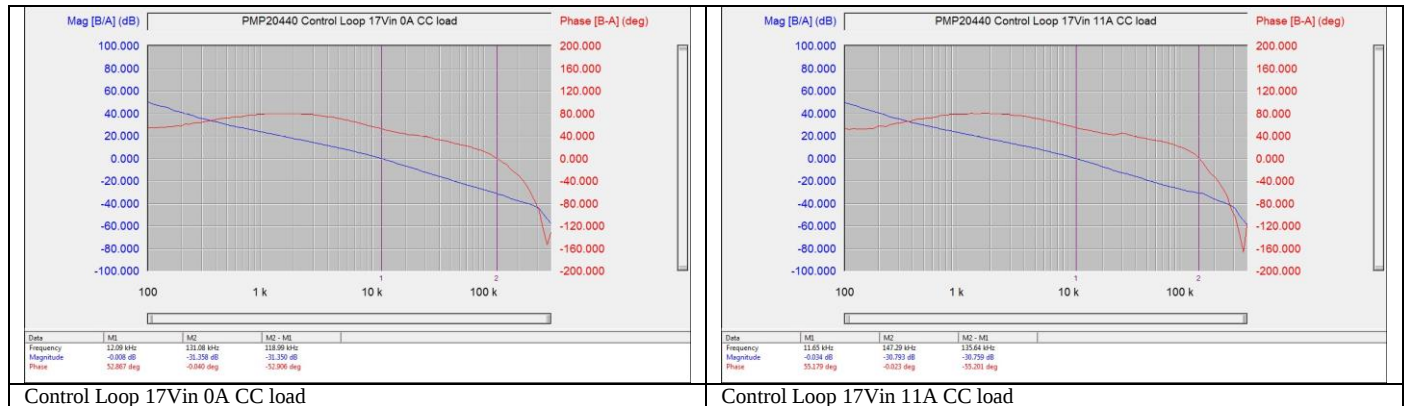
PMP20440 Rev A Test Results



10 Frequency Response

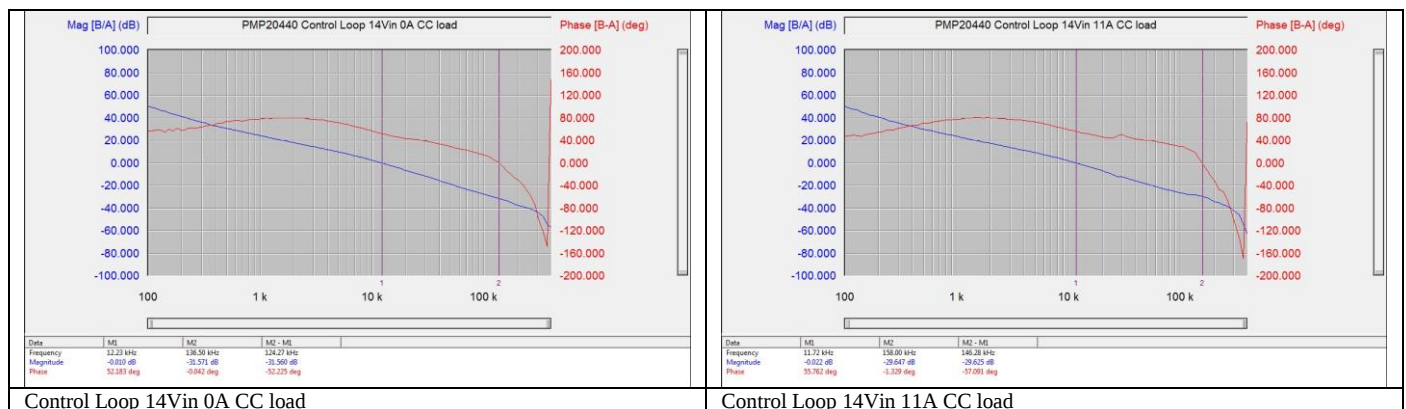
10.1 Frequency Response

Control loop bandwidth is around 12 kHz with greater than 50° of phase margin.



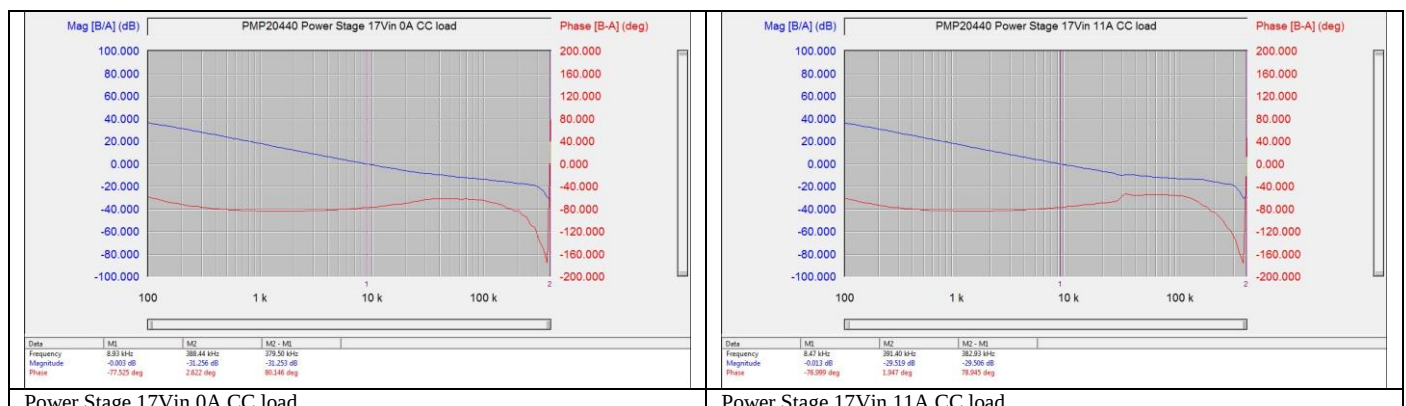
Control Loop 17Vin 0A CC load

Control Loop 17Vin 11A CC load



Control Loop 14Vin 0A CC load

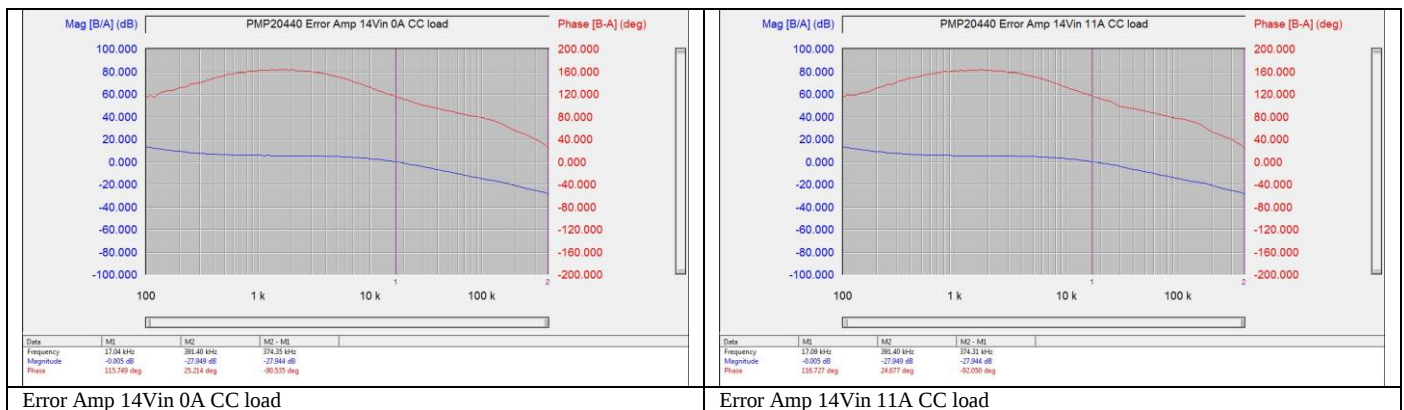
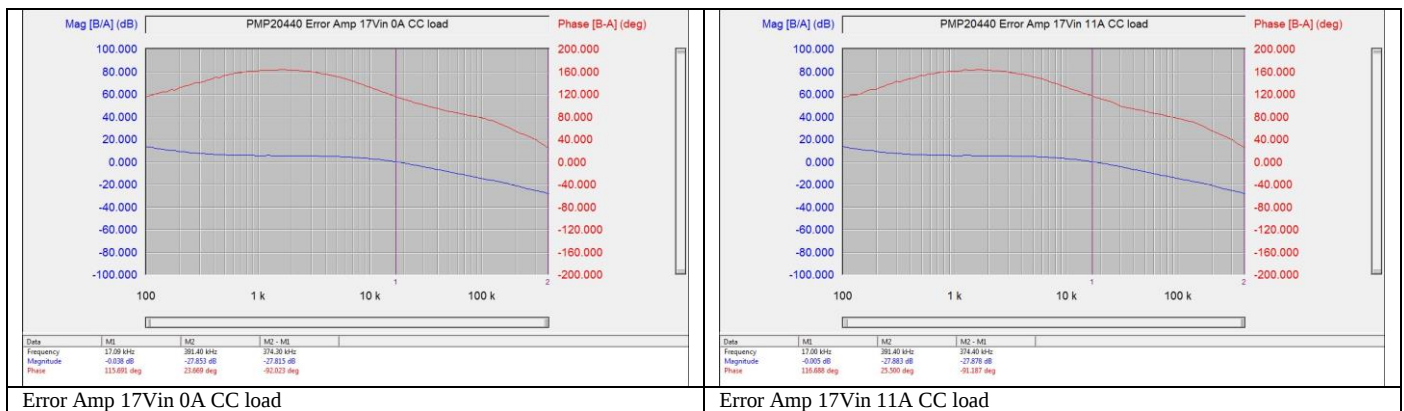
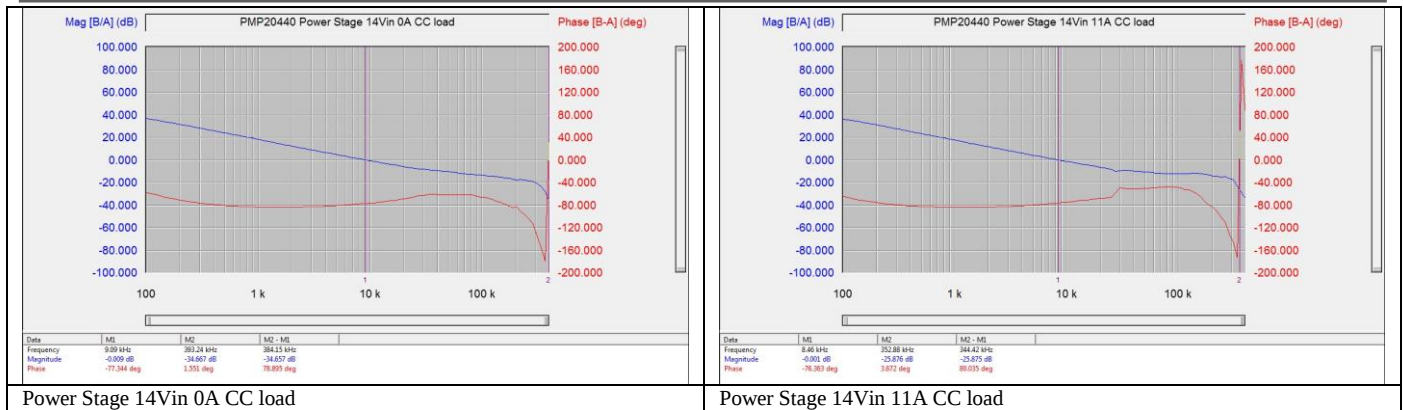
Control Loop 14Vin 11A CC load



Power Stage 17Vin 0A CC load

Power Stage 17Vin 11A CC load

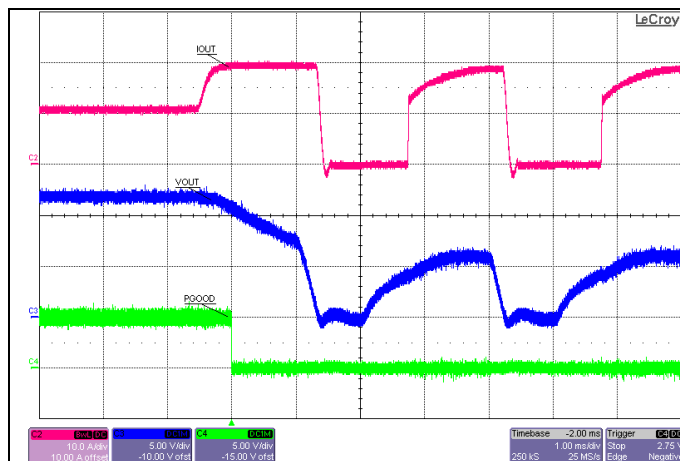
PMP20440 Rev A Test Results



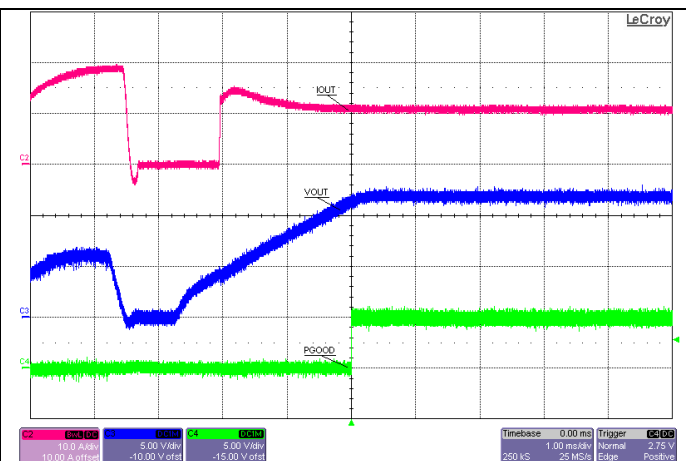
11 Short Circuit

11.1 Output Short Circuit and Recovery

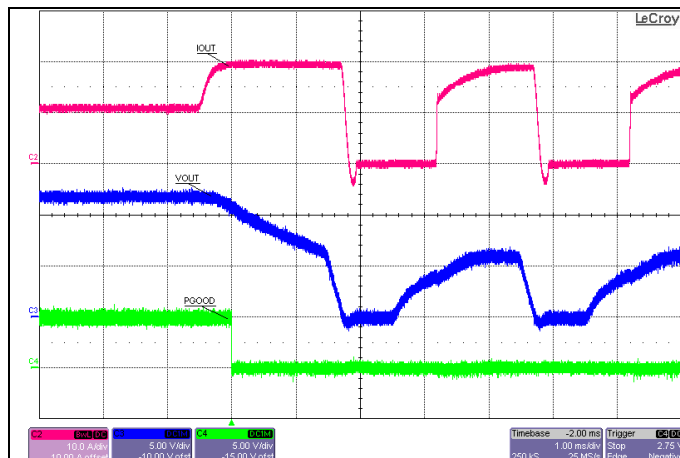
An electronic load was used for output short circuit tests.



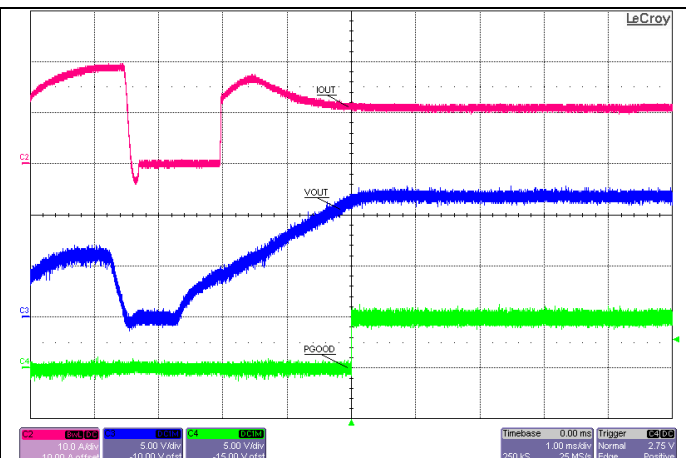
IOUT VOUT PGOOD short circuit 17Vin 11A load



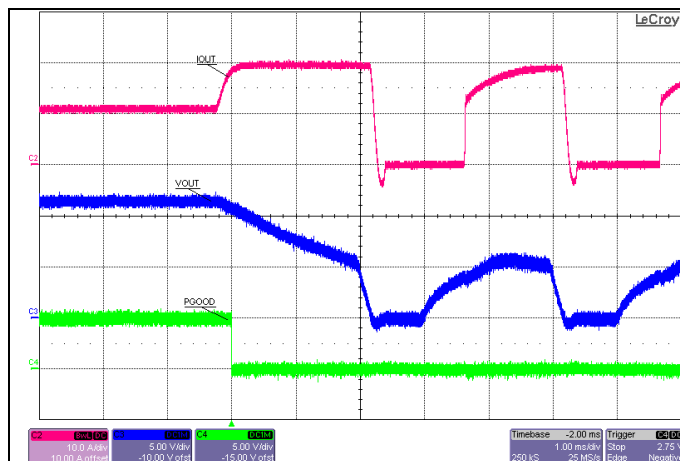
IOUT VOUT PGOOD short circuit recovery 17Vin 11A load



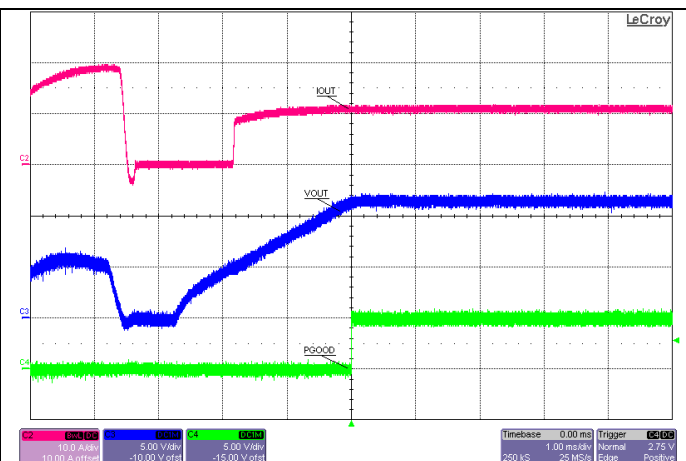
IOUT VOUT PGOOD short circuit 14Vin 11A load



IOUT VOUT PGOOD short circuit recovery 14Vin 11A load

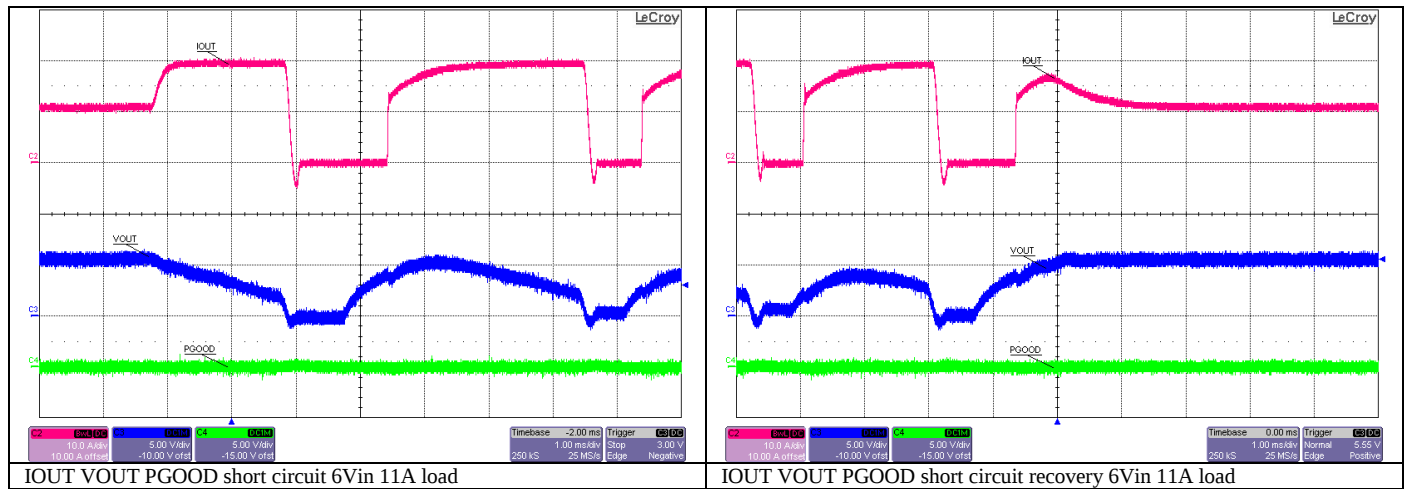


IOUT VOUT PGOOD short circuit 12Vin 11A load



IOUT VOUT PGOOD short circuit recovery 12Vin 11A load

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