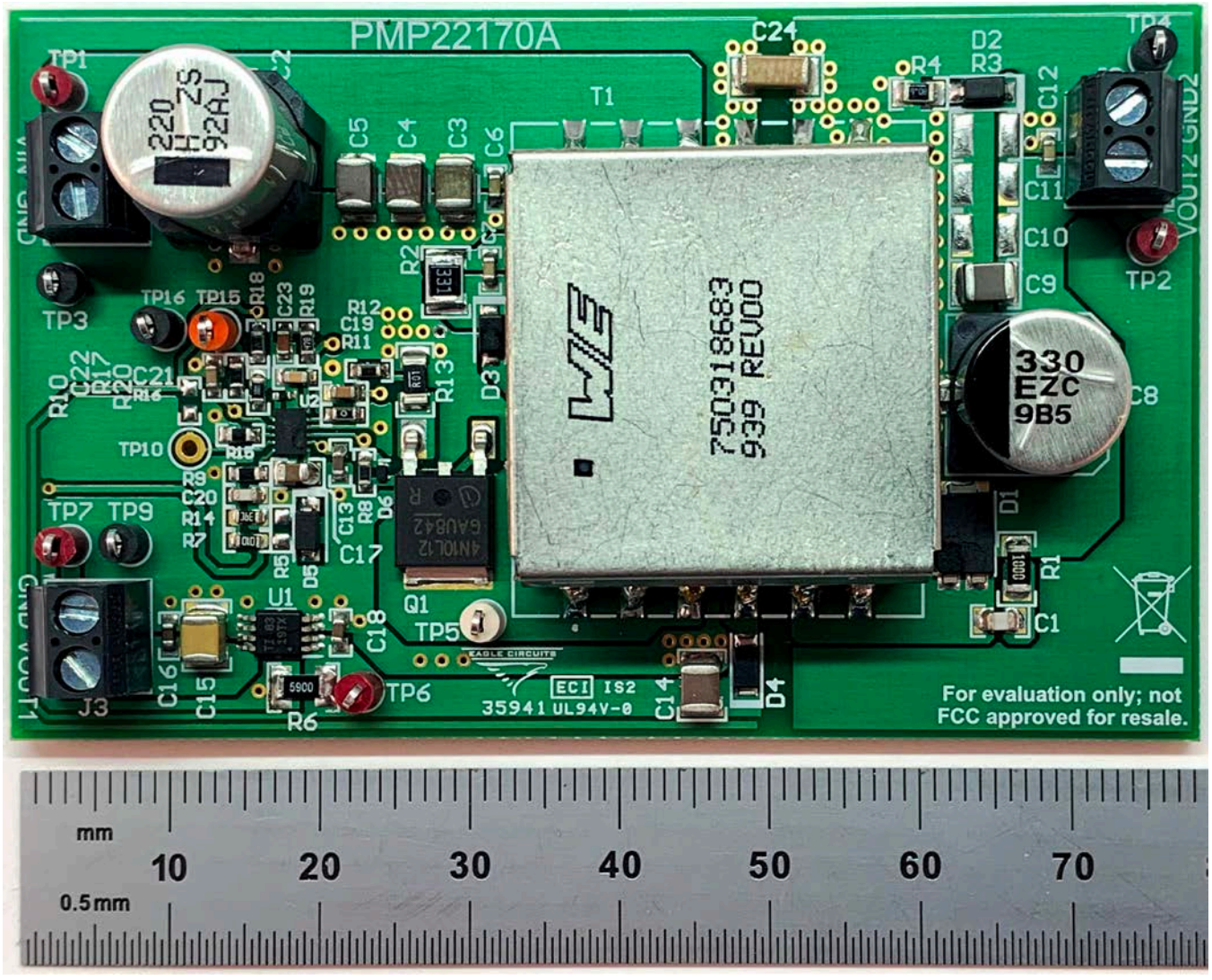
Test Report: PMP22170

Two Output Flyback Power Supply Reference Design for EV Motor/Generator Inverter Applications

TEXAS INSTRUMENTS

Description

This flyback converter supplies a non-isolated 5 V/0.25 A regulated output and an isolated 10 V/1.5 A unregulated output voltage. It uses primary-side regulation to reduce component count and operates over a wide automotive input voltage range of 5 V - 40 V.



1 Test Prerequisites

1.1 Voltage and Current Requirements

Table 1. Voltage and Current Requirements

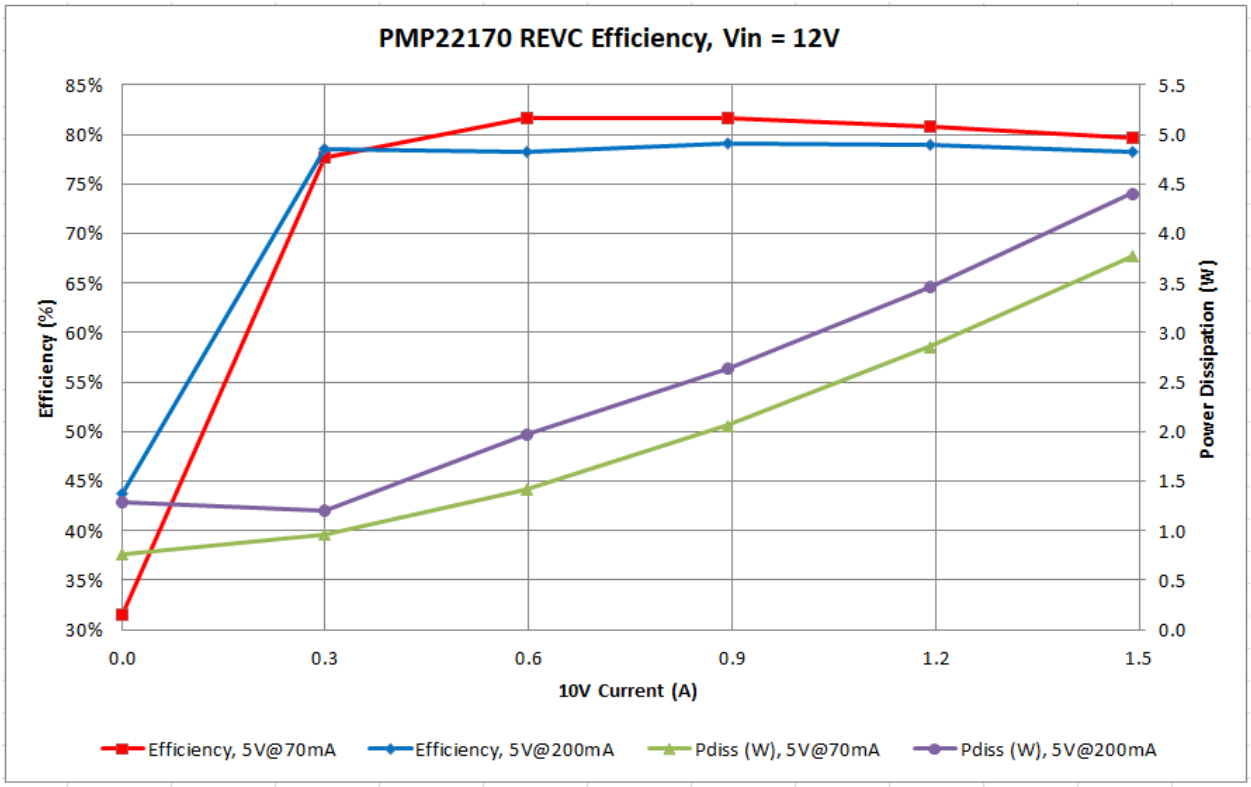
PARAMETER	SPECIFICATIONS
Input voltage range	6 V – 18V, typical (5 V – 40 V transient)
Output voltage and current	5 V/0.25 A, regulated, non-isolated 10 V/0.8 A (typical)/1.5 A (peak), unregulated, isolated
Switching frequency	300kHz
Isolation	10 V/1.5 A, 700VDC (1 sec)

1.2 Required Equipment

- Two electronic loads (15W and1.25W minimum) and/or power resistors (resistor decade boxes)
- Power supply capable of 50V and 5A (minimum)
- Oscilloscope and probes
- Digital Multimeters
- Stability measurement device (Venable or Bode100)

2 Testing and Results

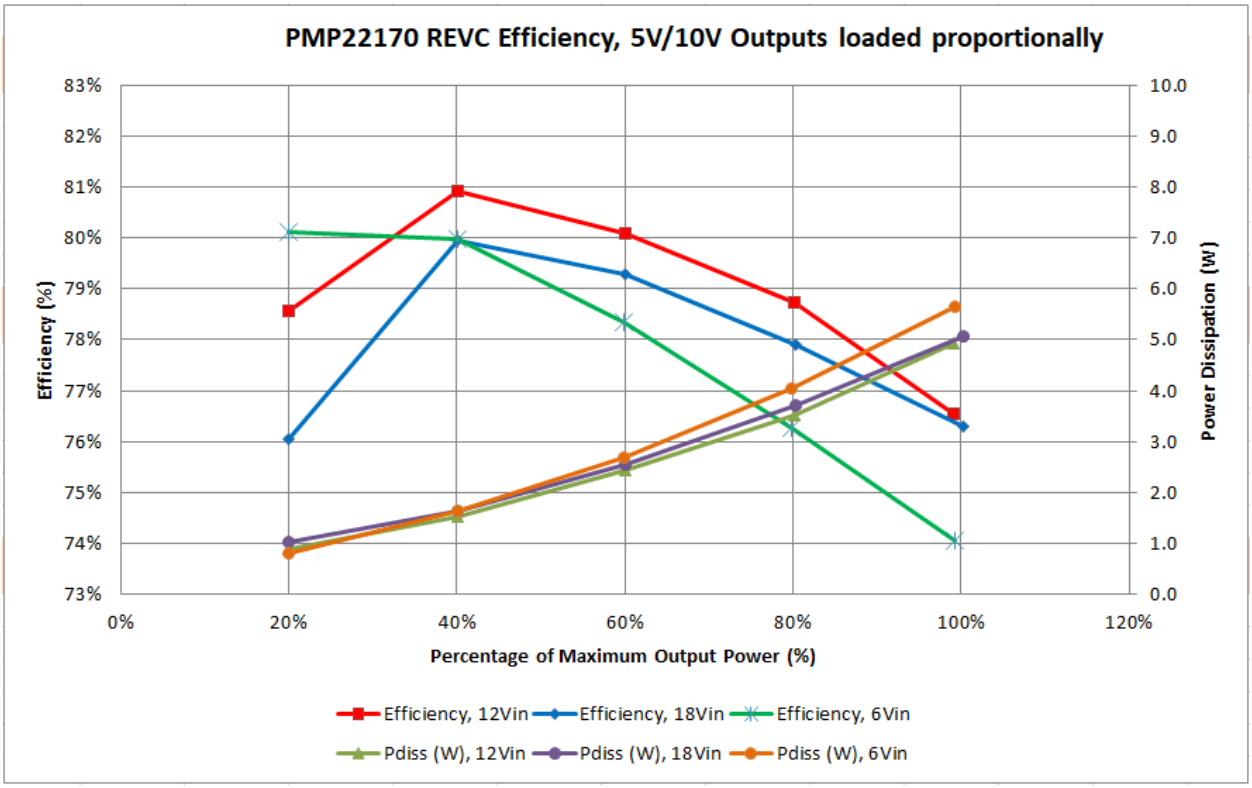
2.1 Efficiency and Power Dissipation Graphs



Vin	Iin	Vout1	Iout1	Vout2	Iout2	Po	Pin	Efficiency, 5V@70mA	Pdiss (W), 5V@70mA
12.2204	0.0908	5.000	0.0699	10.853	0.0000	0.350	1.110	31.5%	0.760
12.1937	0.3541	5.000	0.0699	10.067	0.2984	3.354	4.318	77.7%	0.964
12.1659	0.6328	5.000	0.0699	9.954	0.5965	6.287	7.699	81.7%	1.412
12.1363	0.9261	5.000	0.0699	9.870	0.8944	9.177	11.239	81.7%	2.062
12.1070	1.2296	5.000	0.0699	9.795	1.1924	12.029	14.887	80.8%	2.858
12.0768	1.5418	5.000	0.0699	9.720	1.4908	14.840	18.620	79.7%	3.780

Vin	Iin	Vout1	Iout1	Vout2	Iout2	Po	Pin	Efficiency, 5V@200mA	Pdiss (W), 5V@200mA
12.2110	0.1880	4.998	0.2011	11.357	0.0000	1.005	2.296	43.8%	1.291
12.1847	0.4561	4.998	0.2011	11.248	0.2984	4.362	5.557	78.5%	1.196
12.1574	0.7414	4.999	0.2009	10.134	0.5965	7.049	9.013	78.2%	1.964
12.1281	1.0420	4.999	0.2008	10.060	0.8944	10.001	12.637	79.1%	2.636
12.0994	1.3537	4.998	0.2009	9.996	1.1924	12.923	16.379	78.9%	3.456
12.0696	1.6749	4.998	0.2008	9.933	1.4905	15.809	20.215	78.2%	4.406

The above graph displays the efficiency and power dissipation of the converter with the 5V output loaded to either 70mA or 200mA as the 10V load is varied. The input voltage was set to 12V.



Vin	Iin	Vout1	Iout1	Vout2	Iout2	Po	Pin	Efficiency, 12Vin	Pdiss (W), 12Vin	Percentage of Maximum Pout
12.1476	0.3408	5.000	0.0501	10.014	0.2998	3.253	4.140	78.6%	0.887	20%
12.0237	0.6691	5.000	0.0992	10.011	0.6008	6.511	8.045	80.9%	1.534	40%
12.0949	1.0076	4.999	0.1494	10.009	0.9005	9.760	12.187	80.1%	2.427	60%
12.0187	1.3771	4.999	0.2032	10.002	1.2014	13.032	16.551	78.7%	3.519	80%
12.0371	1.7475	4.998	0.2552	9.886	1.4995	16.100	21.035	76.5%	4.935	99%

Vin	Iin	Vout1	Iout1	Vout2	Iout2	Po	Pin	Efficiency, 18Vin	Pdiss (W), 18Vin	Percentage of Maximum Pout
18.0711	0.2367	5.000	0.0501	10.011	0.2999	3.253	4.277	76.0%	1.025	20%
18.0069	0.4524	5.000	0.0992	10.014	0.6008	6.512	8.146	79.9%	1.634	40%
18.0392	0.6827	4.999	0.1494	10.017	0.9002	9.764	12.315	79.3%	2.551	60%
18.0187	0.9296	4.998	0.2031	10.016	1.2013	13.047	16.750	77.9%	3.703	80%
18.0480	1.1829	4.997	0.2552	10.009	1.4997	16.286	21.349	76.3%	5.063	100%

Vin	Iin	Vout1	Iout1	Vout2	Iout2	Po	Pin	Efficiency, 6Vin	Pdiss (W), 6Vin	Percentage of Maximum Pout
6.0059	0.6762	5.001	0.0501	10.017	0.2998	3.254	4.061	80.1%	0.808	20%
6.0488	1.3452	5.000	0.0992	10.006	0.6008	6.508	8.137	80.0%	1.629	40%
6.0457	2.0550	4.999	0.1494	9.981	0.9002	9.732	12.424	78.3%	2.692	60%
6.0370	2.8160	4.998	0.2031	9.948	1.2014	12.967	17.000	76.3%	4.034	80%
6.0262	3.6130	4.997	0.2550	9.903	1.4997	16.126	21.773	74.1%	5.647	99%

The above graph displays the efficiency and power dissipation of the converter with the 5V and 10V outputs loaded proportionally. The input voltage was set to 6V, 12V or 18V.

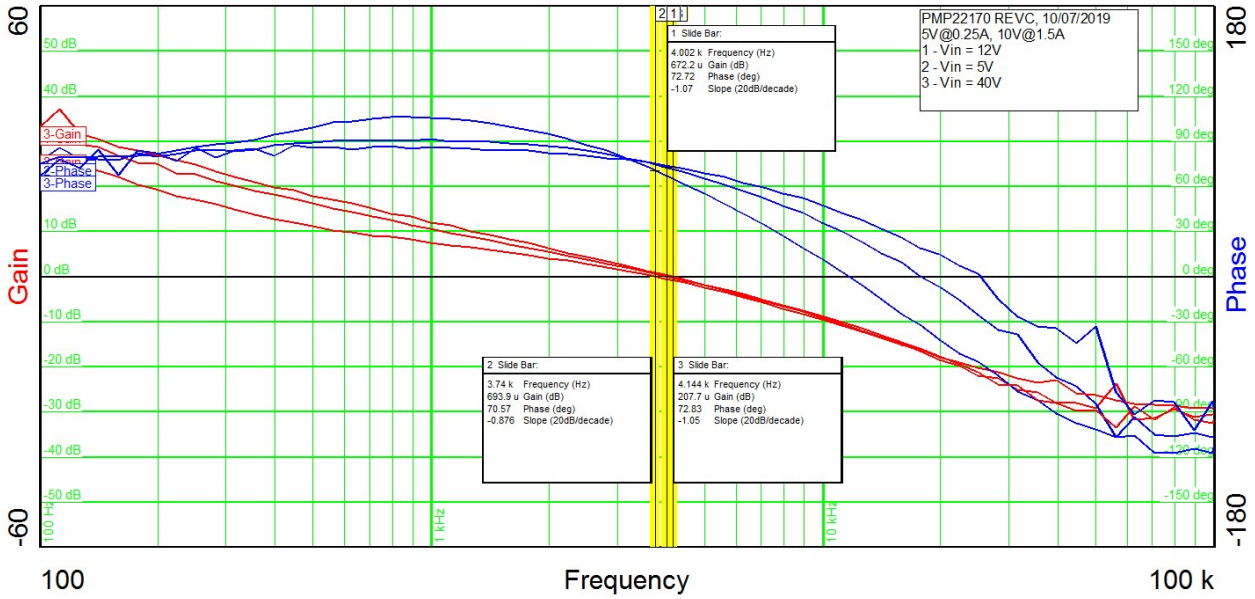
2.2 Cross Regulation

Voltage Regulation Data						
VIN (V)	I IN(A)	VREG (V)	VOUT 5V (V)	IOUT 5V (A)	VOUT 10V (V)	IOUT 10V (A)
No Load Conditions						
5.2087	0.0565	7.057	5.002	0.0000	10.3070	0.0000
12.2261	**0.0348**	**7.057**	**5.001**	**0.0000**	**10.3200**	**0.0000**
40.0380	0.0117	7.057	5.001	0.0000	10.4440	0.0000
Typical Load Conditions						
5.2087	1.9906	7.059	5.000	0.0700	9.8370	0.8008
5.1370	2.3310	7.059	4.999	0.2015	10.1040	0.8006
5.1820	3.7650	7.058	5.000	0.0700	9.4777	1.5011
5.1752	4.1600	7.058	4.998	0.2014	9.7800	1.5011
12.0550	**0.8418**	**7.059**	**5.000**	**0.0700**	**9.9052**	**0.8006**
12.0643	**0.9542**	**7.059**	**4.999**	**0.2013**	**10.0900**	**0.8008**
12.0406	**1.5694**	**7.058**	**4.999**	**0.0699**	**9.7170**	**1.5011**
12.0779	**1.6967**	**7.058**	**4.998**	**0.2015**	**9.9280**	**1.5009**
40.0640	0.2751	7.058	5.000	0.0700	9.9315	0.8006
40.0080	0.9452	7.059	4.999	0.2011	10.0820	0.8007
40.0510	1.5694	7.059	4.999	0.0699	9.8390	1.5011
40.1060	1.6967	7.058	4.997	0.2013	10.0030	1.5010
Full Load Conditions						
5.1530	4.3130	7.057	4.998	0.2470	9.8500	1.5010
12.0609	**1.7425**	**7.057**	**4.998**	**0.2490**	**9.9820**	**1.5010**
40.0070	0.5833	7.055	4.997	0.2470	10.0310	1.5010
Cross Loading						
5.2000	3.1770	7.057	5.002	0.0000	8.3310	1.5010
5.2165	0.5019	7.057	4.998	0.2470	11.5150	0.0000
12.0935	**1.4124**	**7.057**	**5.002**	**0.0000**	**9.0467**	**1.5010**
12.2073	**0.2183**	**7.057**	**4.998**	**0.2490**	**11.5030**	**0.0000**
40.0180	0.4970	7.056	5.001	0.0000	9.4770	1.5010
40.0340	0.0840	7.056	4.998	0.2470	11.5320	0.0000

This table shows the voltage regulation of the 5V and 10V outputs under various load conditions.

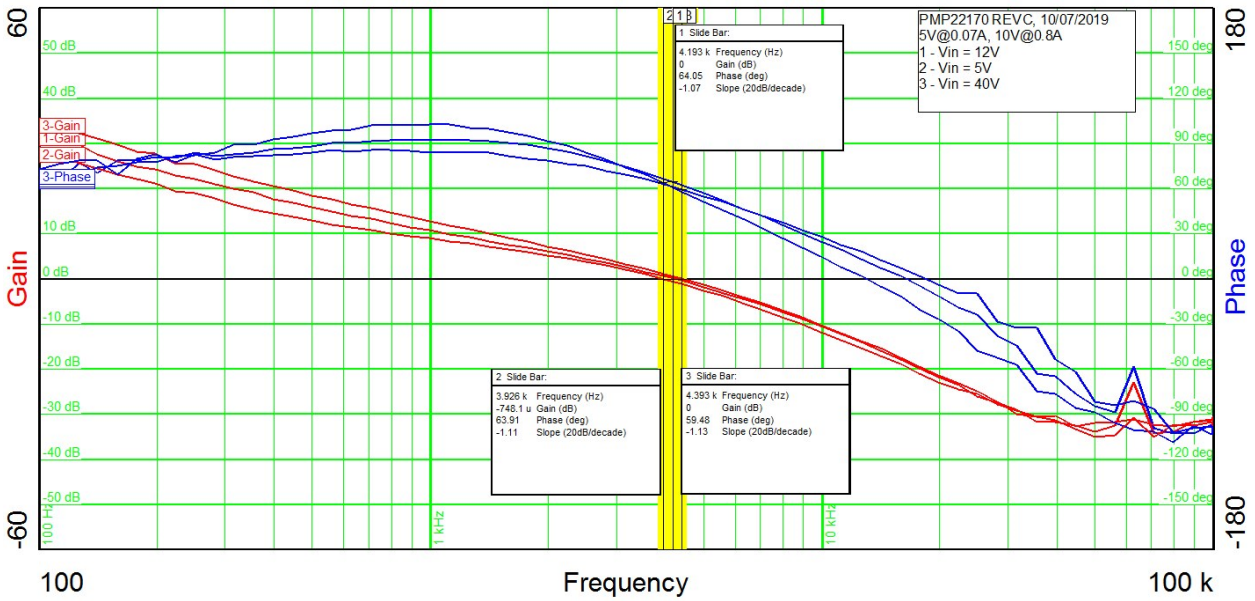
2.3 Loop Gain

Graph 1. **5V @ 0.25A, 10V @ 1.5A**



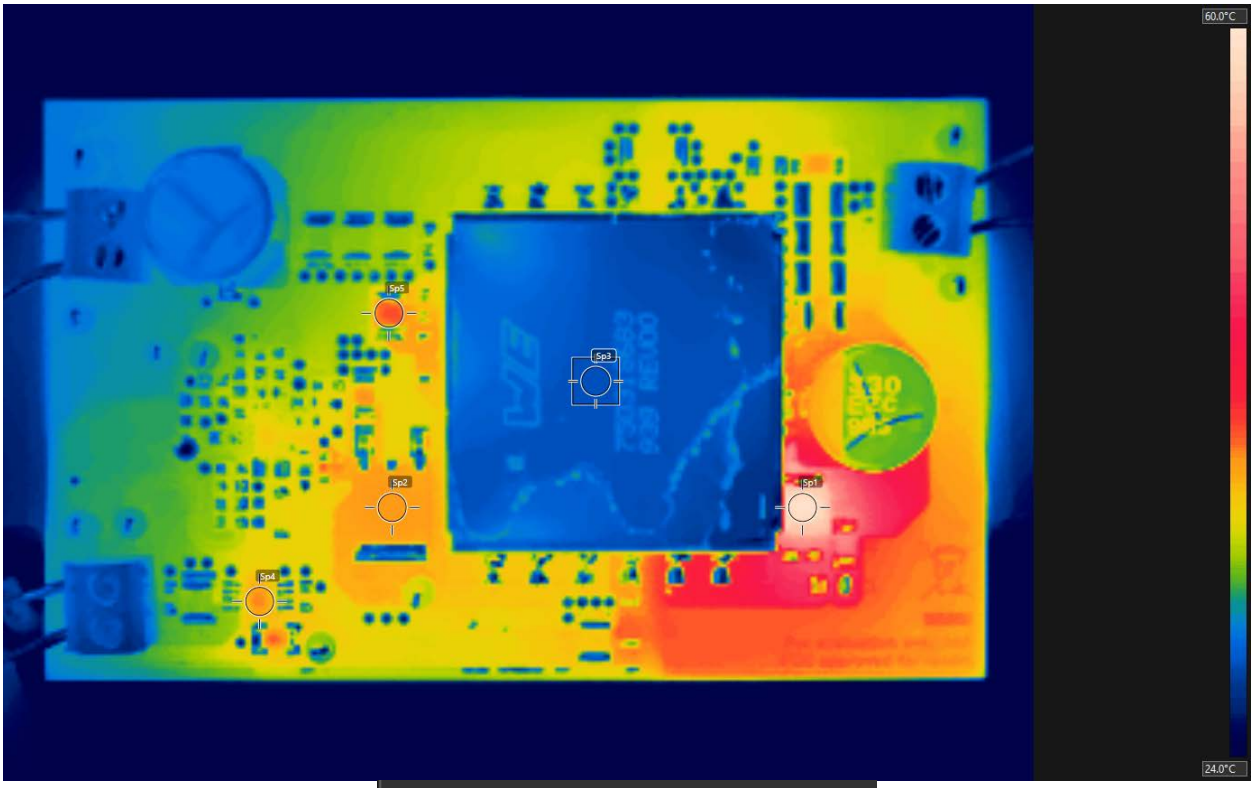
1) Vin = 12V Bandwidth = 4.00 kHz Phase Margin = 72.7 degrees
2) Vin = 5V Bandwidth = 3.74 kHz Phase Margin = 70.6 degrees
3) Vin = 40V Bandwidth = 4.14 kHz Phase Margin = 72.8 degrees

Graph 2. **5V @ 0.07A, 10V @ 0.8A**



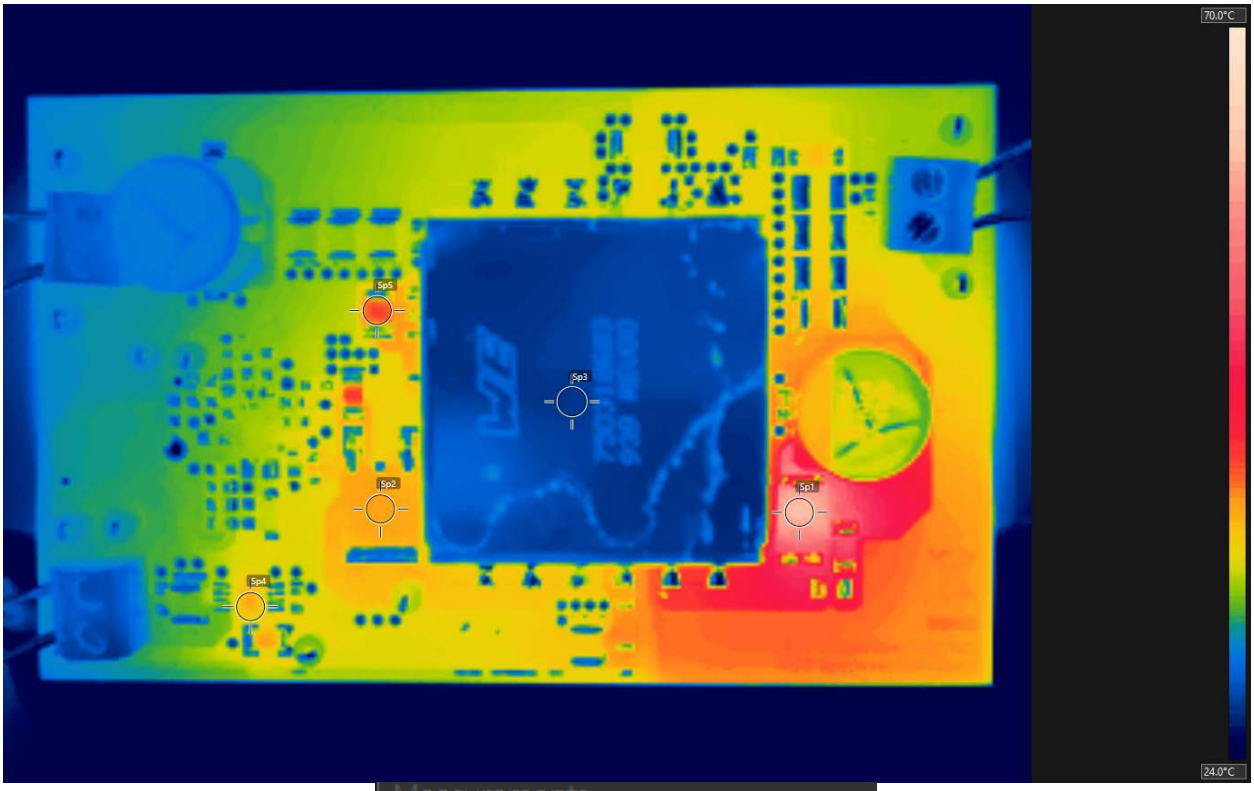
1) Vin = 12V Bandwidth = 4.19 kHz Phase Margin = 64.1 degrees
2) Vin = 5V Bandwidth = 3.93 kHz Phase Margin = 63.9 degrees
3) Vin = 40V Bandwidth = 4.39 kHz Phase Margin = 59.5 degrees

2.4 Thermal Images



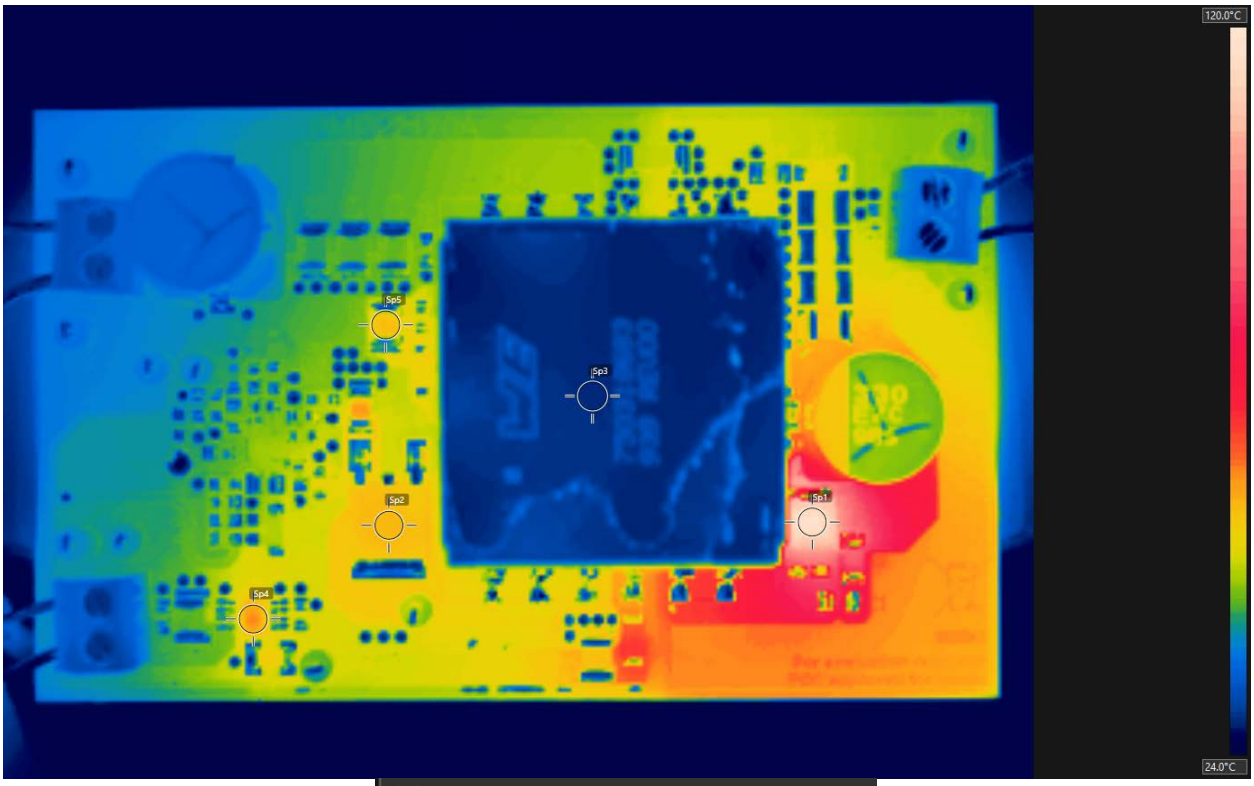
Measurements	
Sp1	59.2 °C
Sp2	39.8 °C
Sp3	29.3 °C
Sp4	40.4 °C
Sp5	41.6 °C

This thermal image shows the operating temperature of the board with 12V input and 5V@0.07A and 10V@0.8A. The image was captured at room temperature after operating for 30 minutes.



Measurements	
Sp1	63.1 °C
Sp2	41.6 °C
Sp3	28.0 °C
Sp4	41.2 °C
Sp5	44.6 °C

This thermal image shows the operating temperature of the board with 6V input and 5V@0.07A and 10V@0.8A. The image was captured at room temperature after operating for 30 minutes.

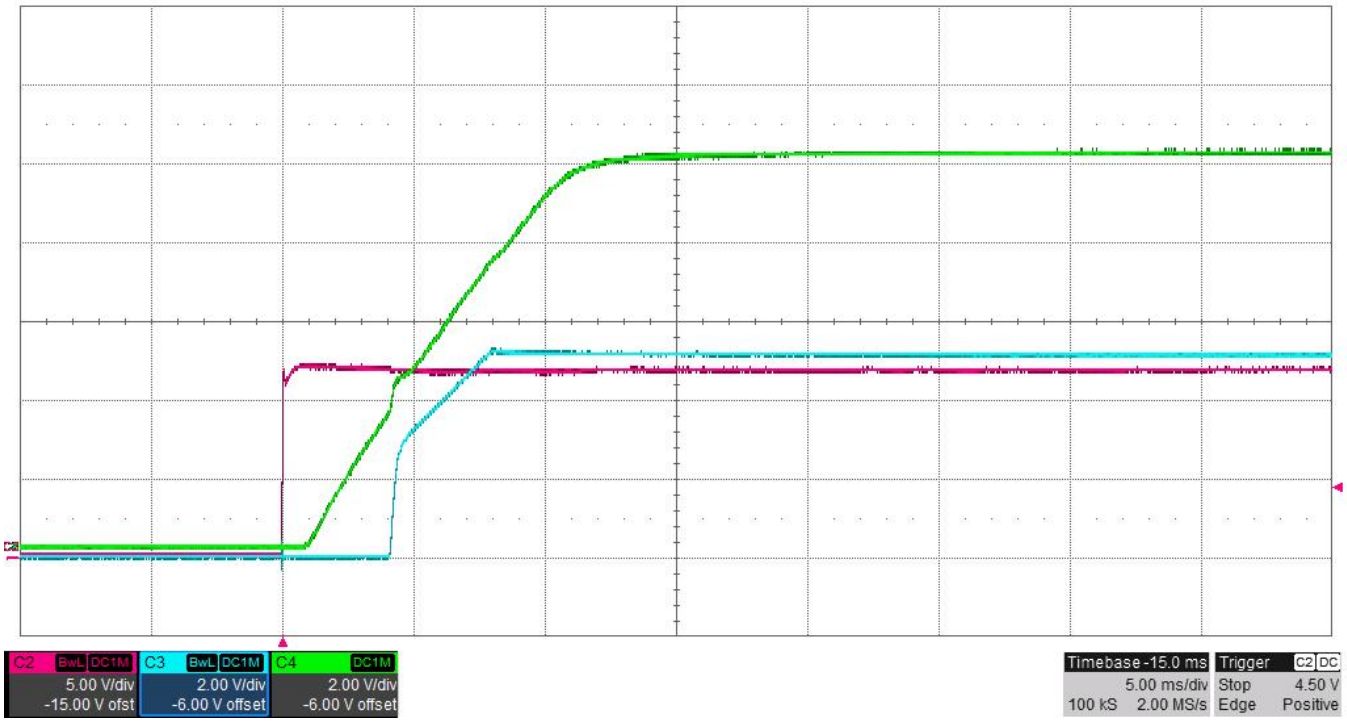


Measurements	
Sp1	117.6 °C
Sp2	64.0 °C
Sp3	30.1 °C
Sp4	69.2 °C
Sp5	63.3 °C

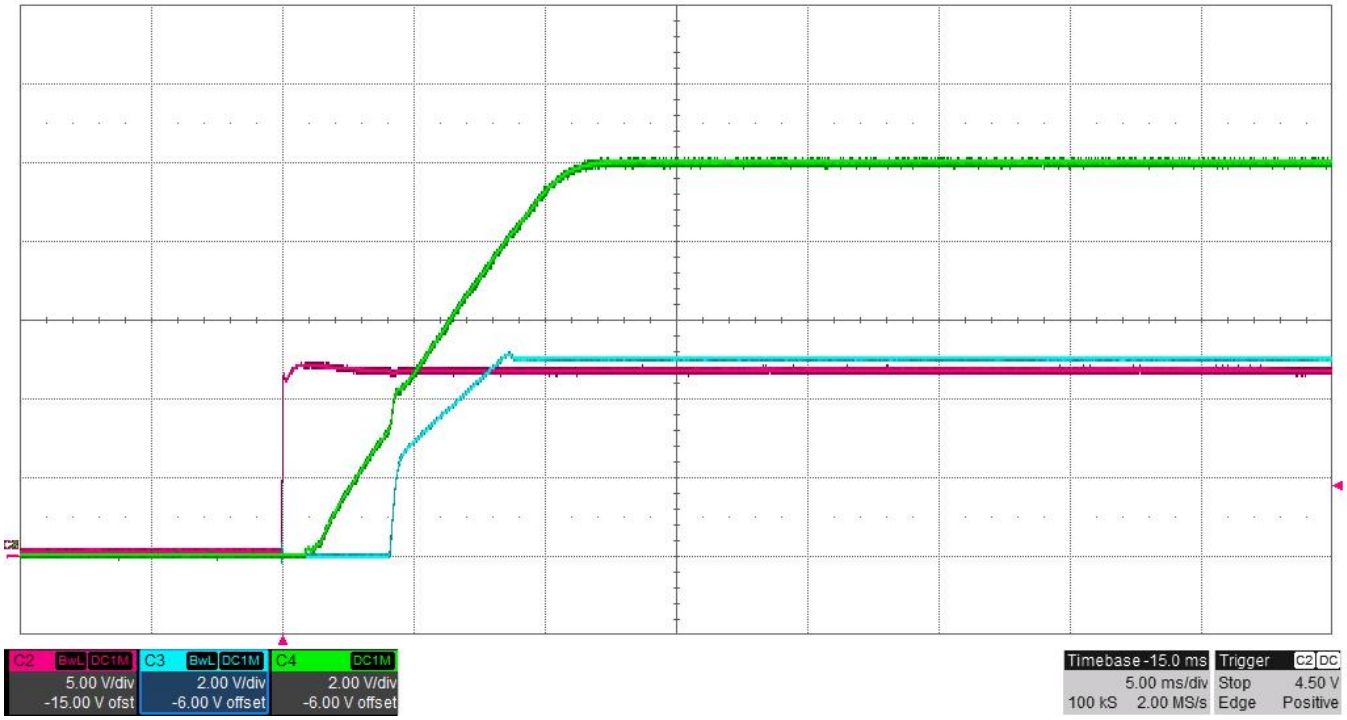
This thermal image shows the operating temperature of the board with 12V input and 5V@0.25A and 10V@1.5A. The image was captured at room temperature after operating for 30 minutes.

3 Waveforms

3.1 Startup Sequence

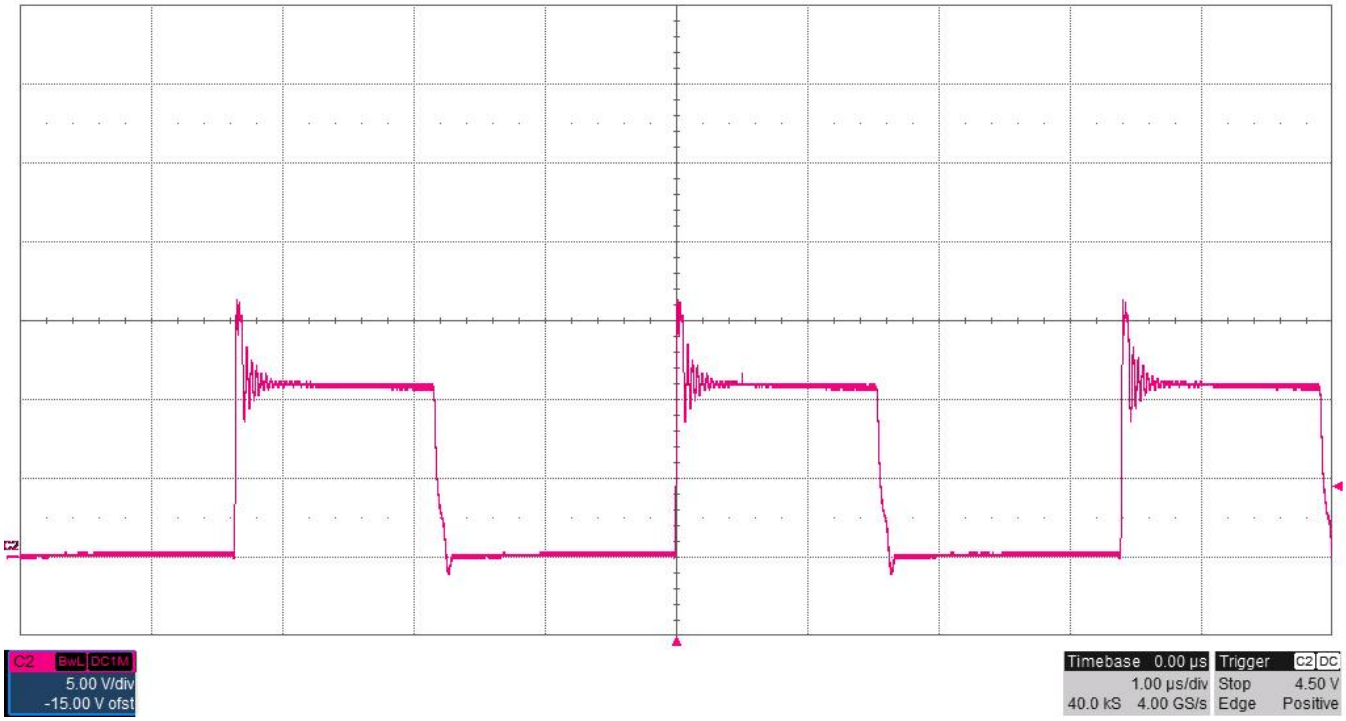


Start-up sequence for Vin = 12V (Red), 5V @ 0A (Blue), 10V @ 0A (Green)

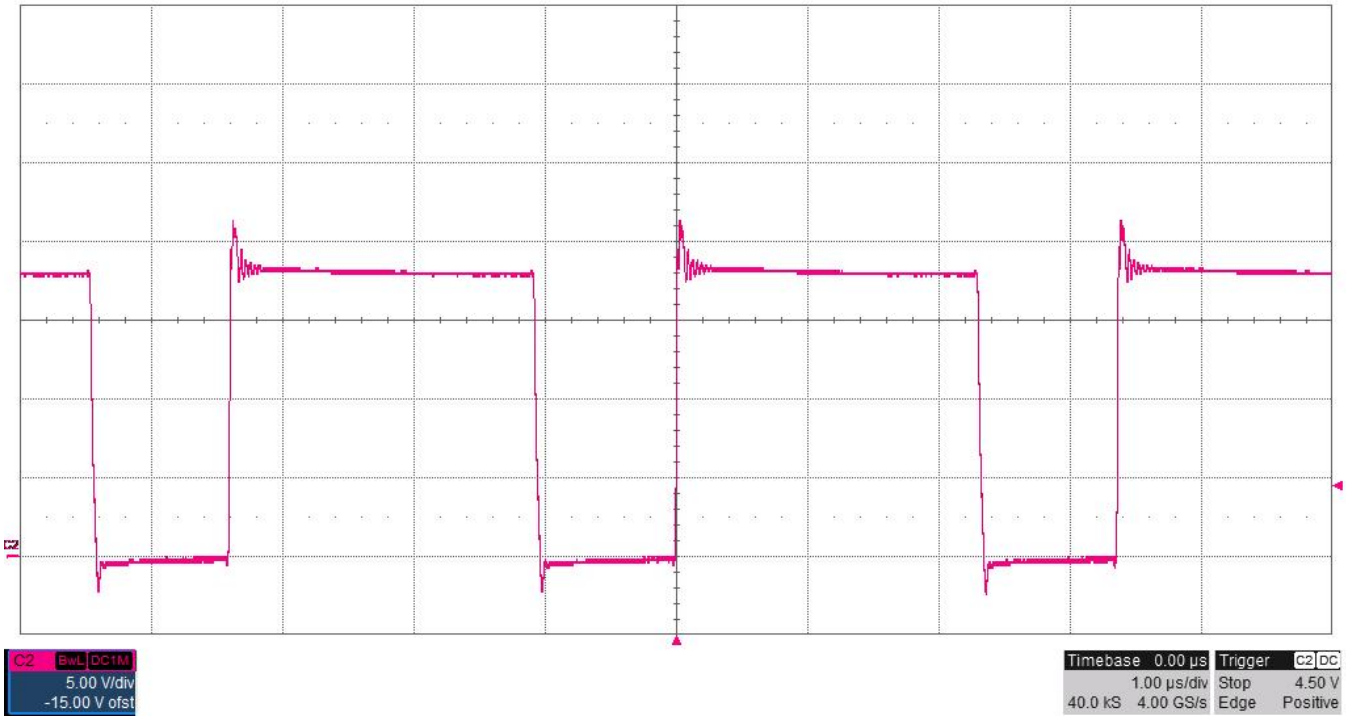


Start-up sequence for Vin = 12V (Red), 5V @ 0.25A (Blue), 10V @ 1.5A (Green)

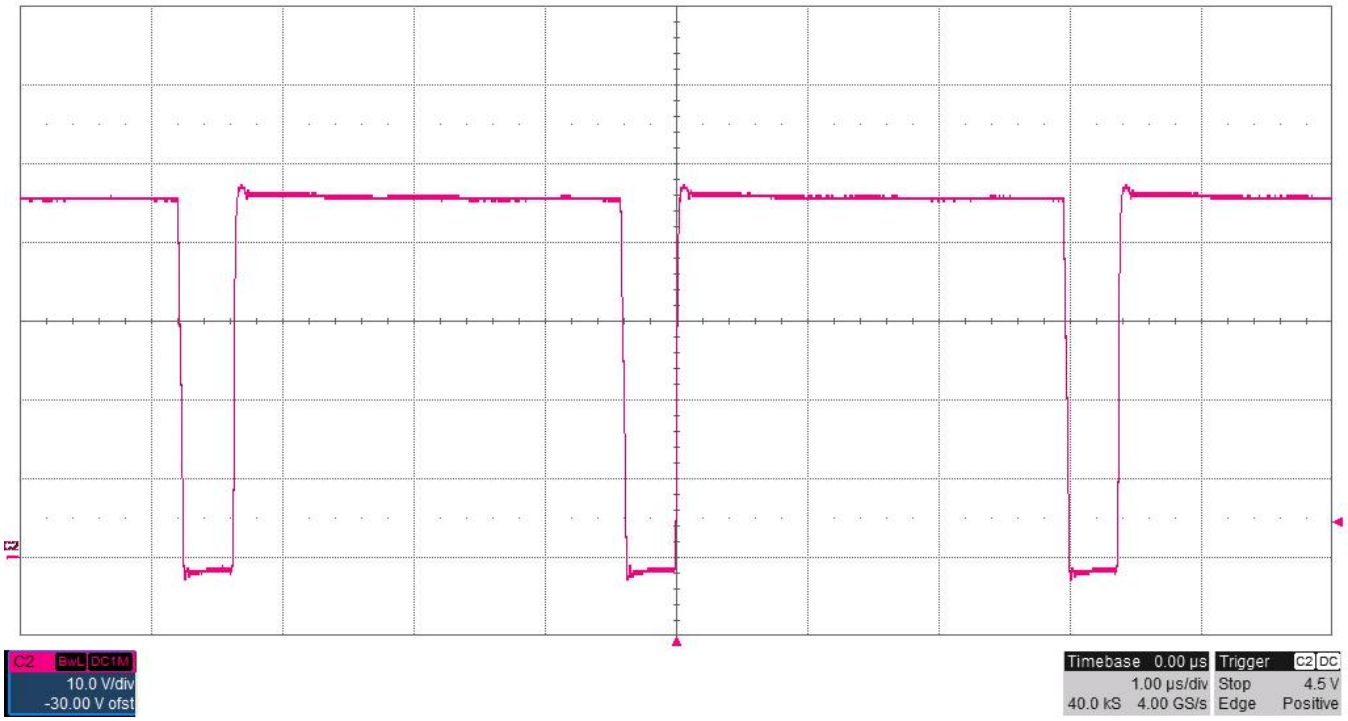
3.2 FET Switch Node



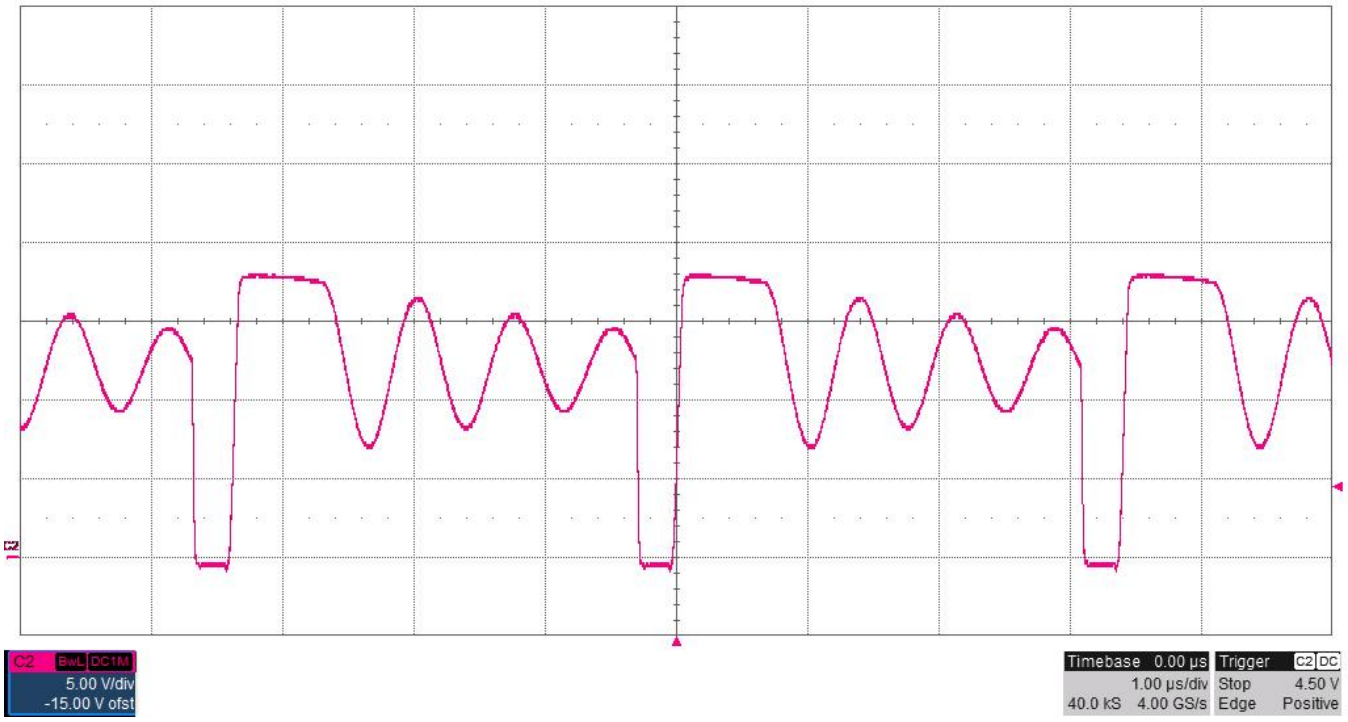
Switch node of FET with Vin = 5V, 5V @ 0.25A, 10V @ 1.5A



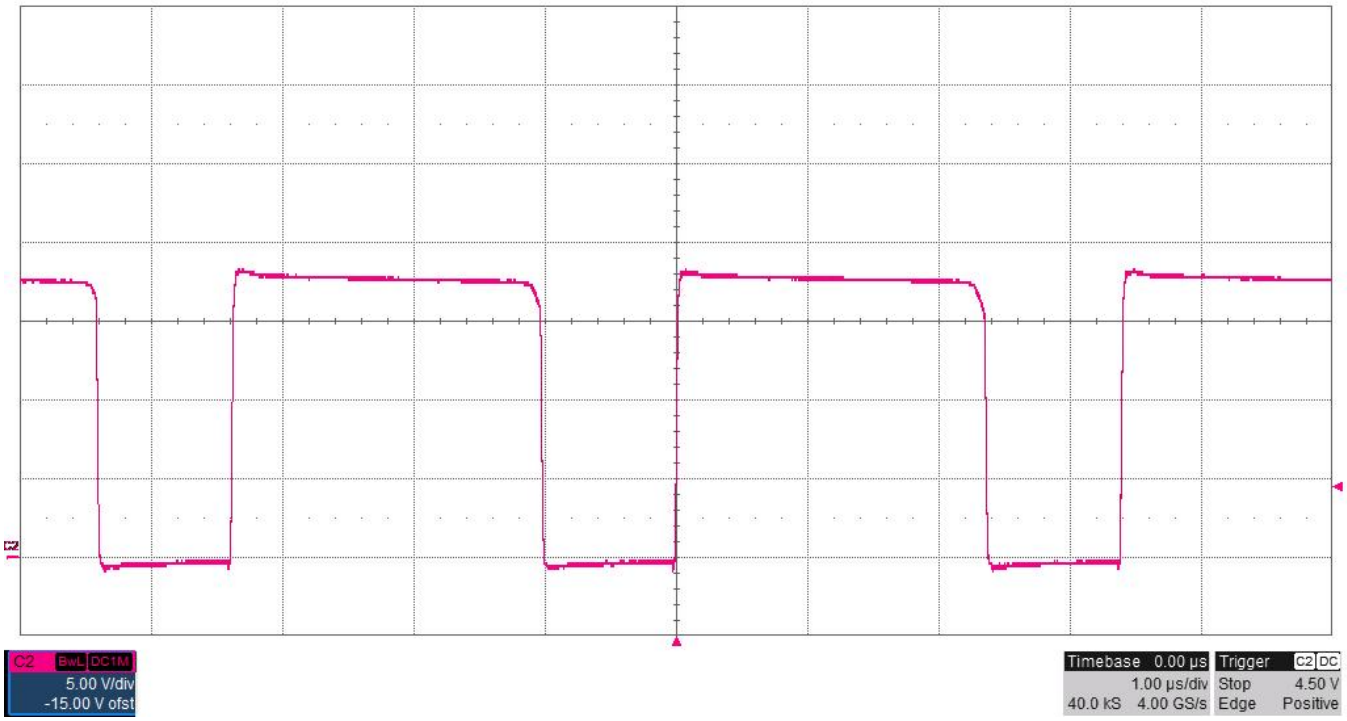
Switch node of FET with Vin = 12V, 5V @ 0.25A, 10V @ 1.5A



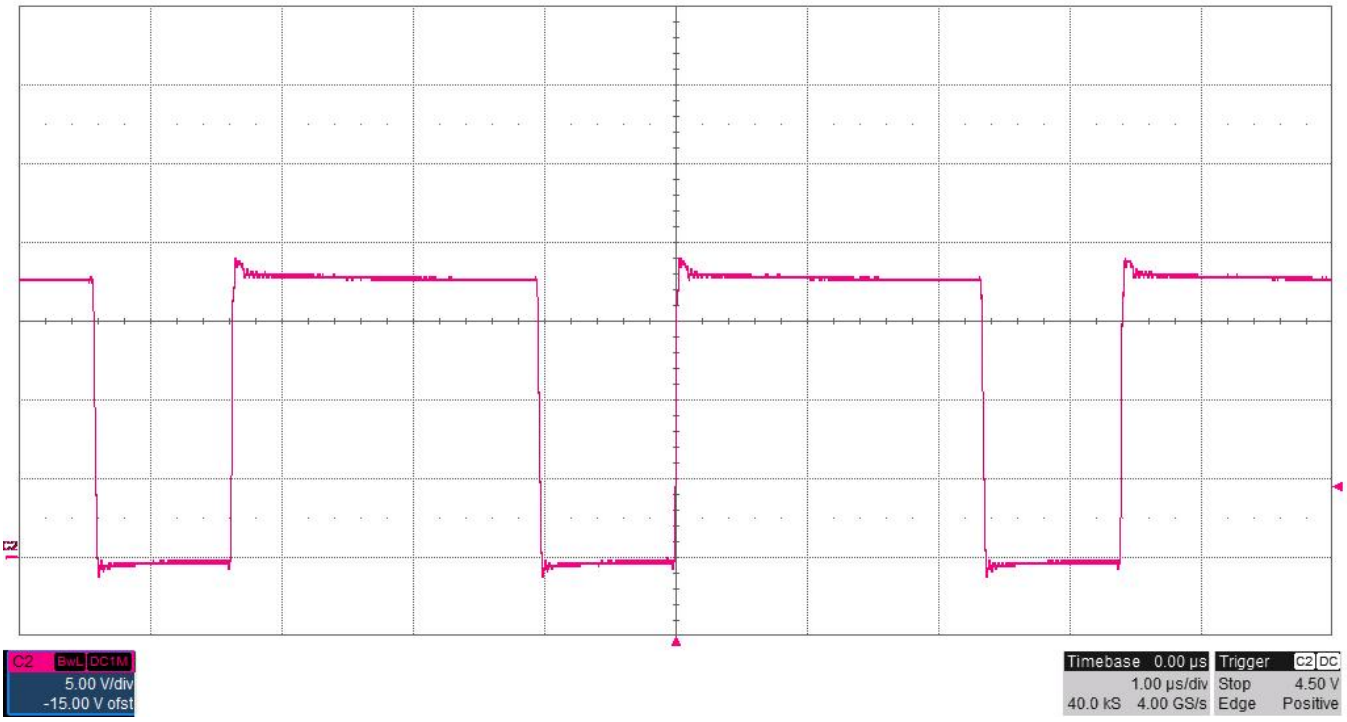
Switch node of FET with Vin = 40V, 5V @ 0.25A, 10V @ 1.5A



Switch node of FET with Vin = 12V, 5V @ 0A, 10V @ 0A (DCM operation)

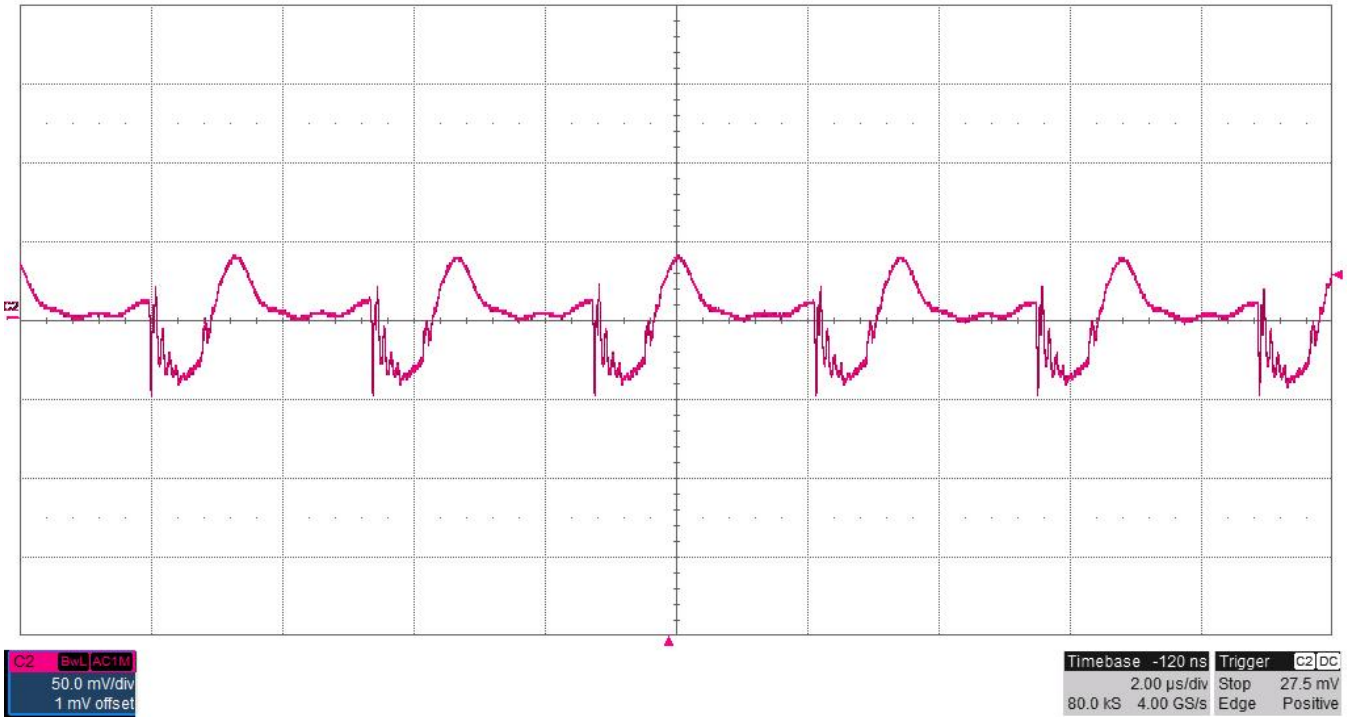


Switch node of FET with Vin = 12V, 5V @ 0.05A, 10V @ 0.22A (DCM operation threshold)

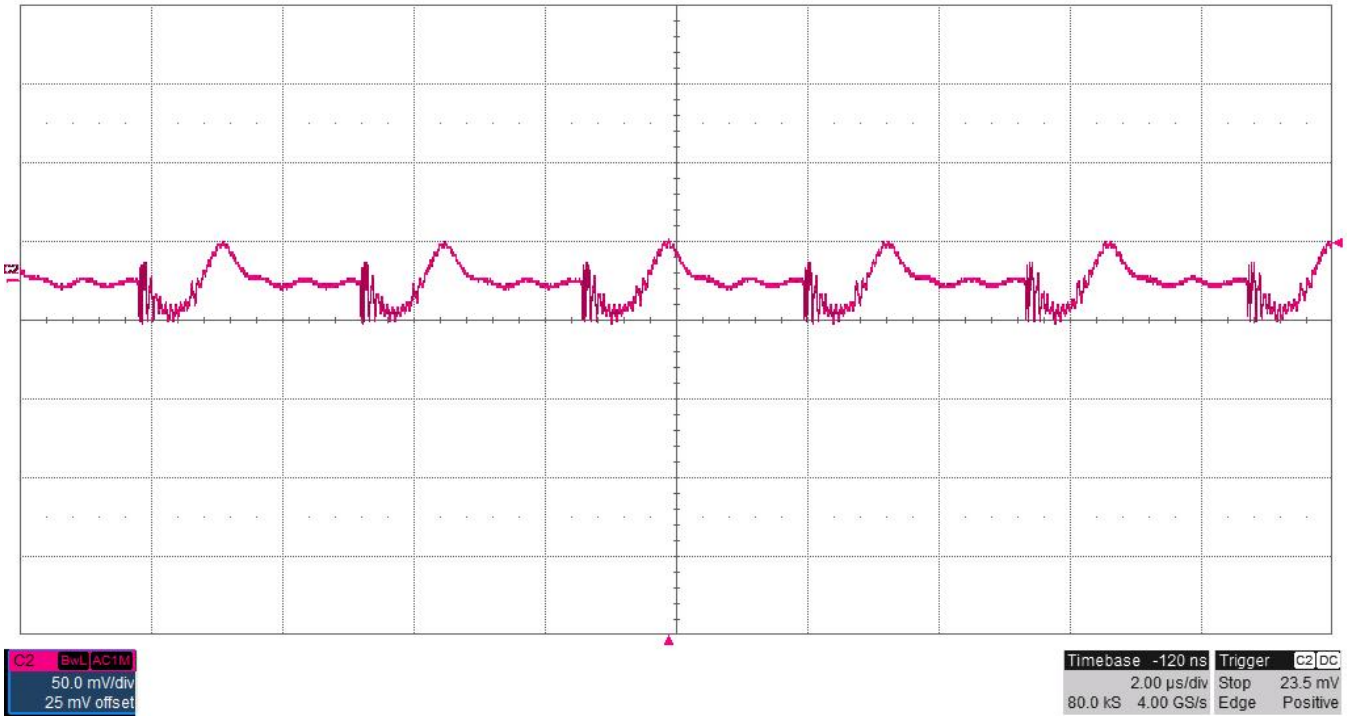


Switch node of FET with Vin = 12V, 5V @ 0.1A, 10V @ 0.8A (typical load)

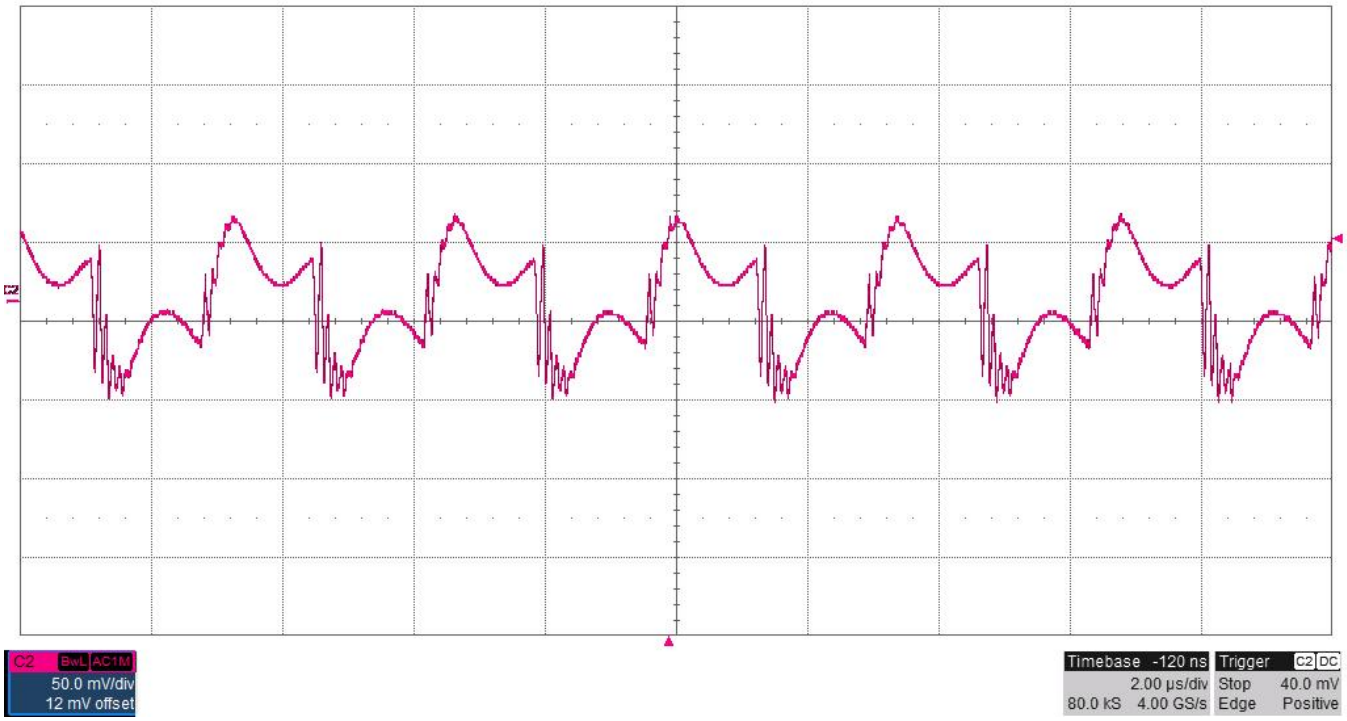
3.3 Output Voltage Ripple



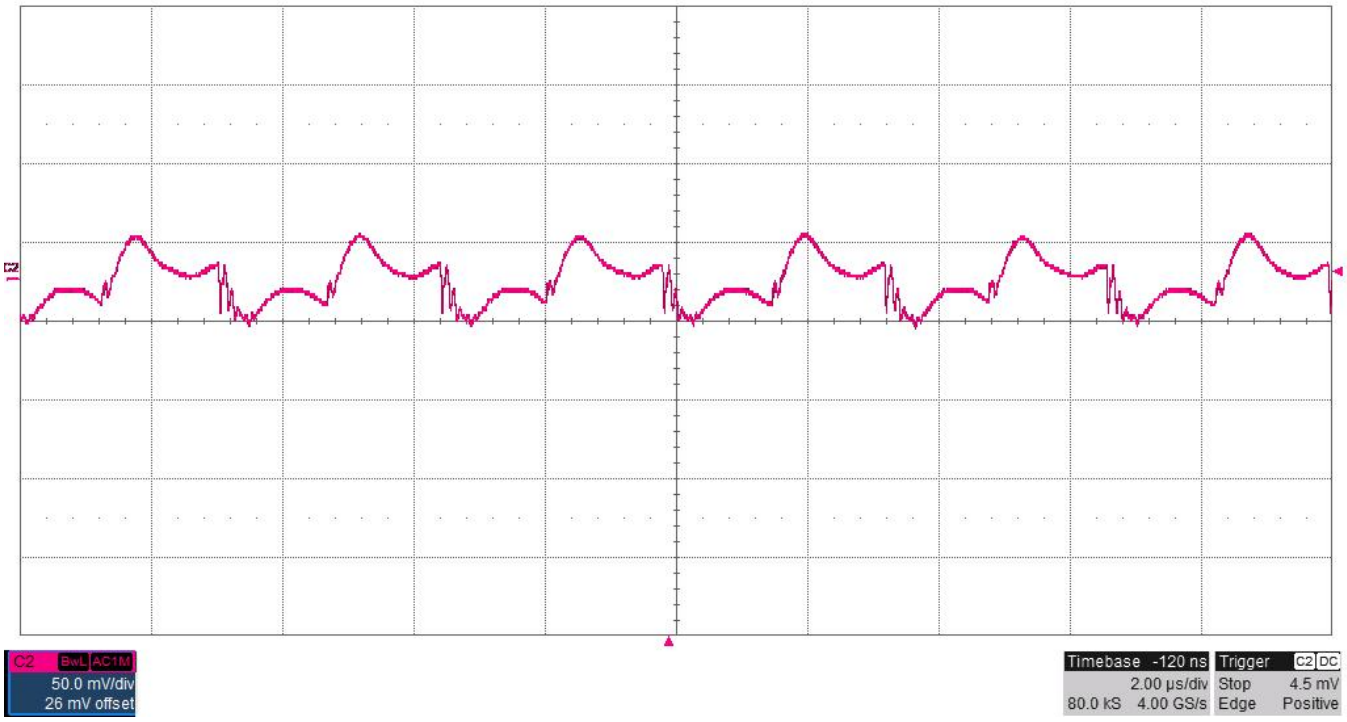
10V ripple voltage with Vin = 18V, 5V @ 0.25A, 10V @ 1.5A, Bandwidth = 20MHz



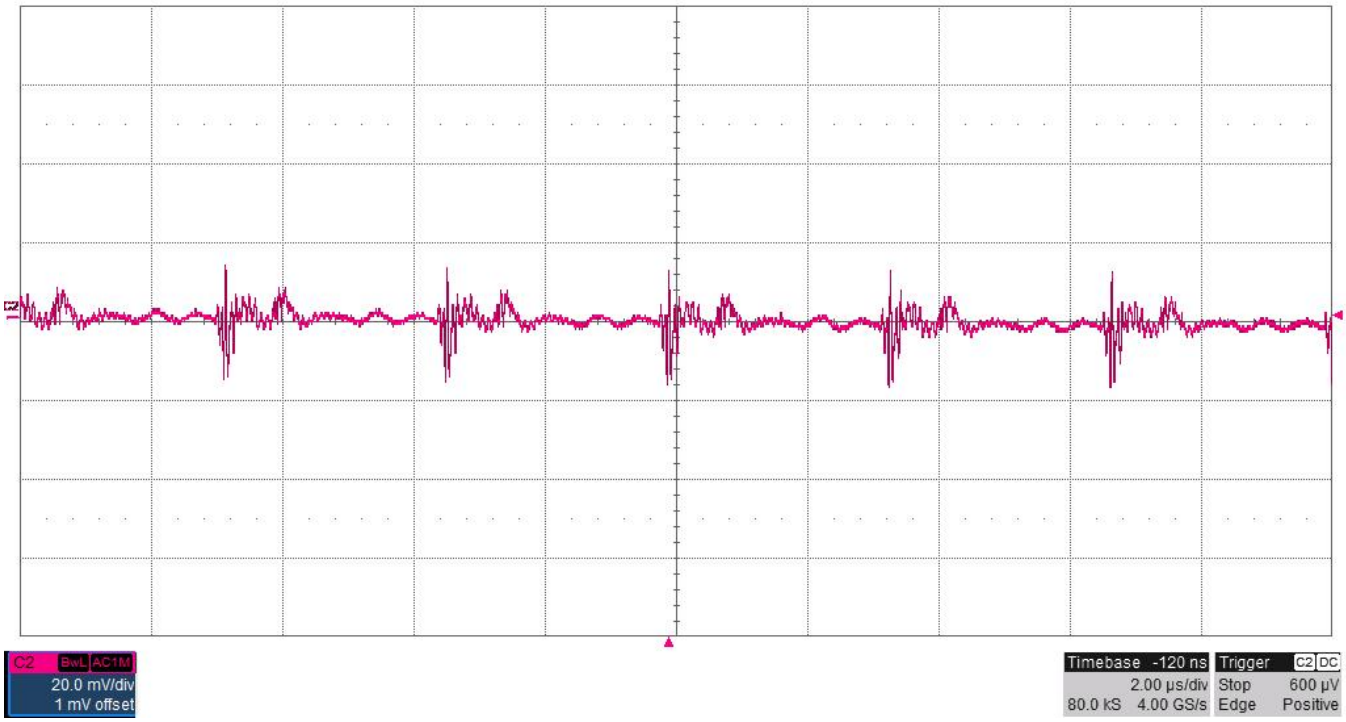
10V ripple voltage with Vin = 18V, 5V @ 0.07A, 10V @ 0.8A, Bandwidth = 20MHz



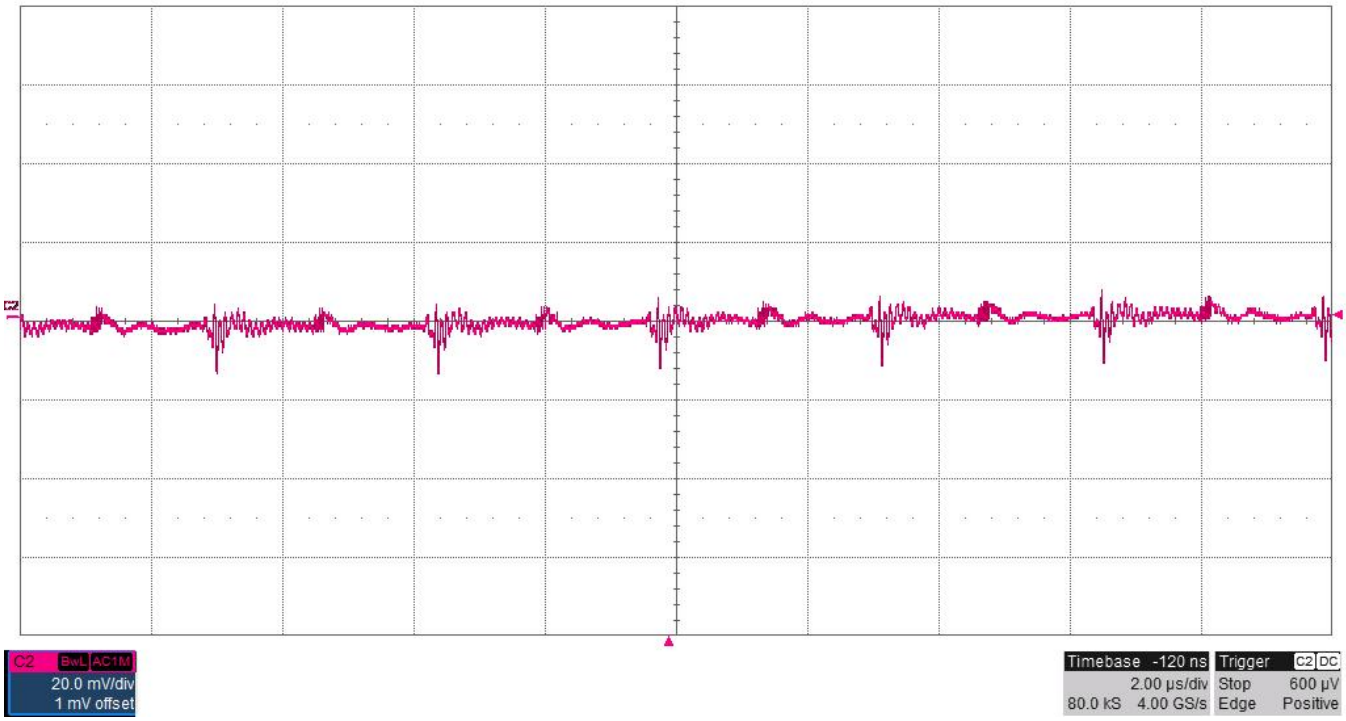
10V ripple voltage with Vin = 6V, 5V @ 0.25A, 10V @ 1.5A, Bandwidth = 20MHz



10V ripple voltage with Vin = 6V, 5V @ 0.07A, 10V @ 0.8A, Bandwidth = 20MHz

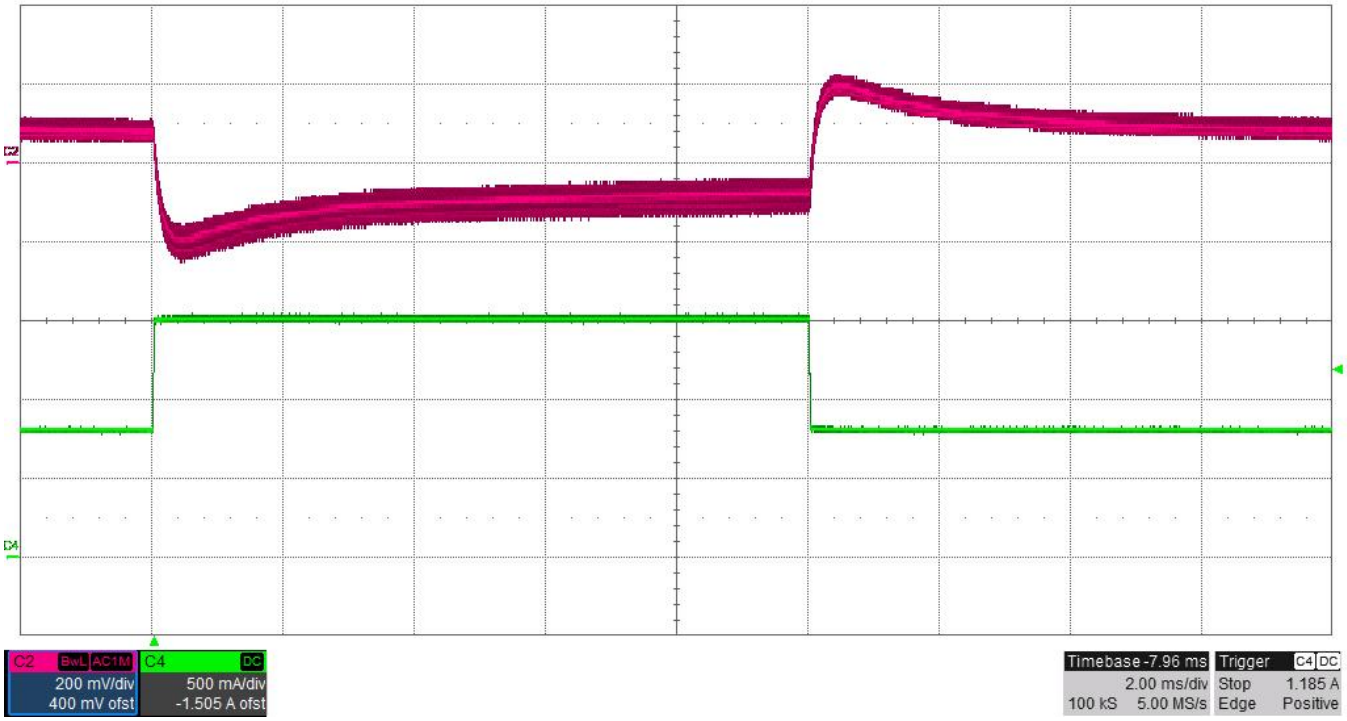


5V ripple voltage with Vin = 18V, 5V @ 0.25A, 10V @ 1.5A, Bandwidth = 20MHz

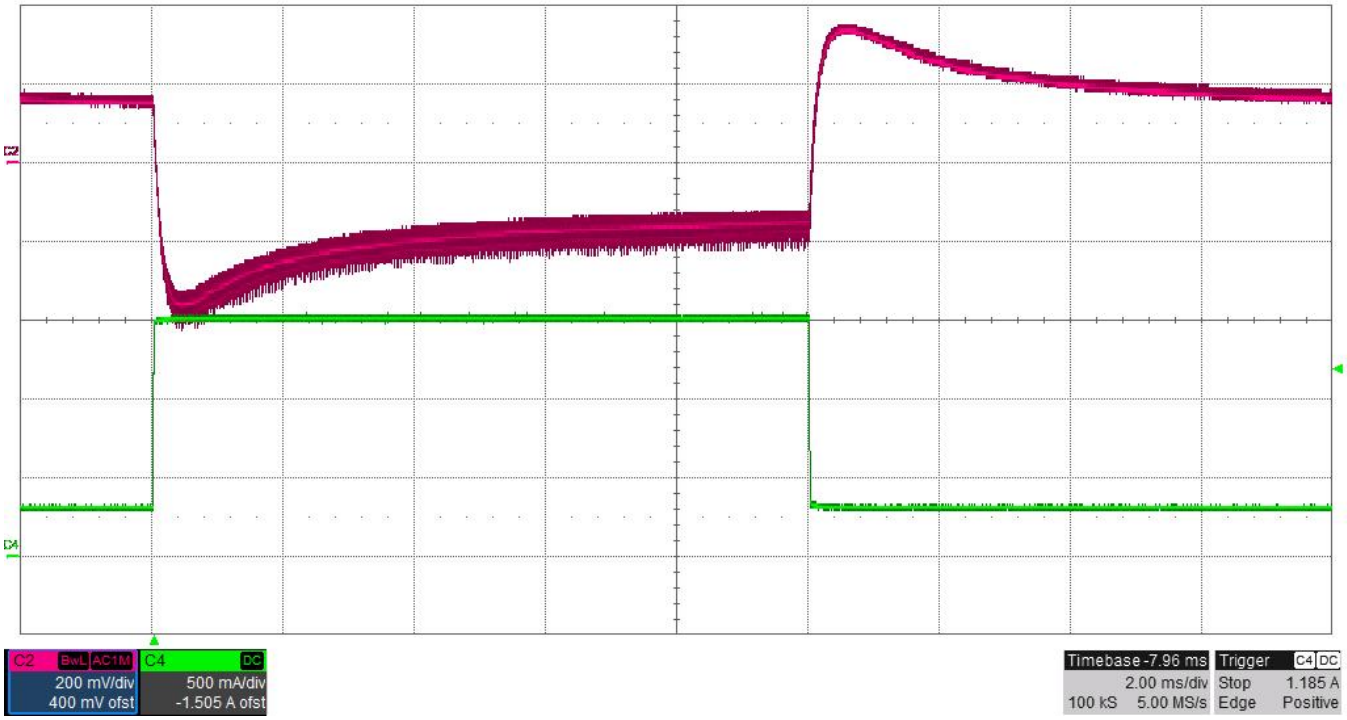


5V ripple voltage with Vin = 6V, 5V @ 0.25A, 10V @ 1.5A, Bandwidth = 20MHz

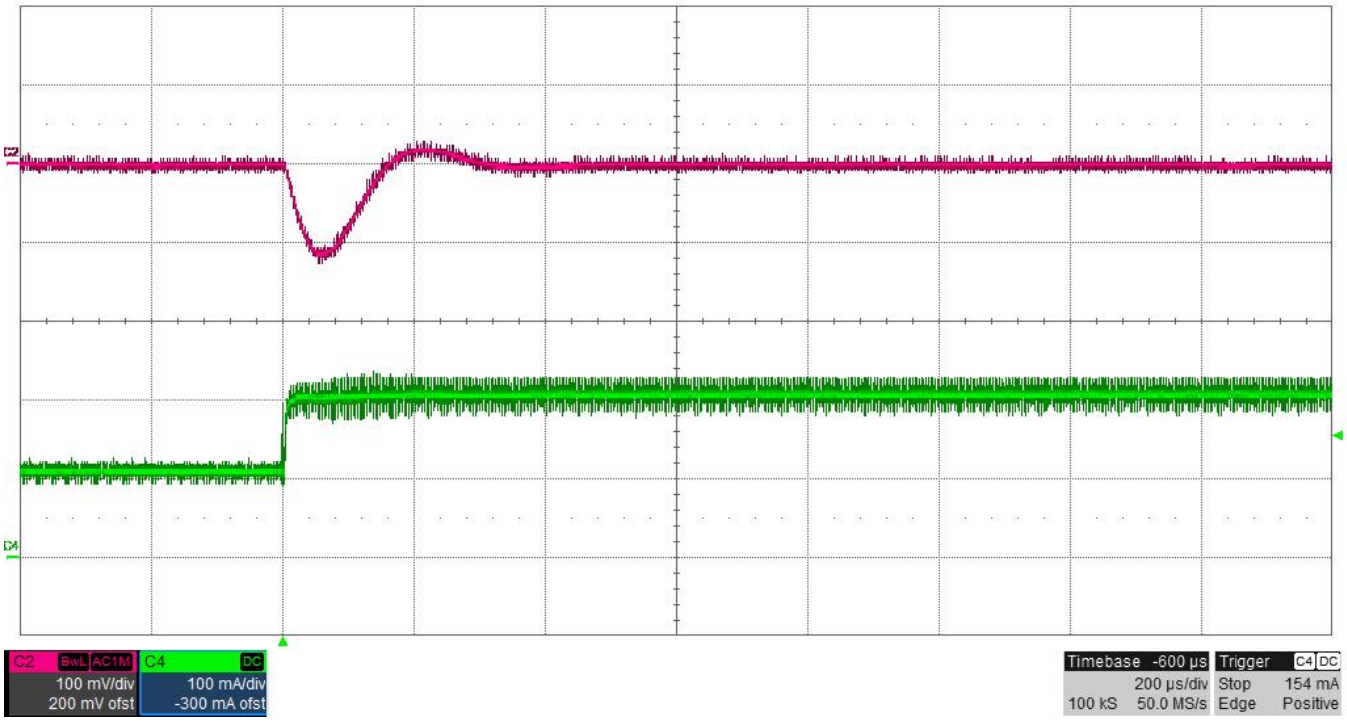
3.4 Load Transients



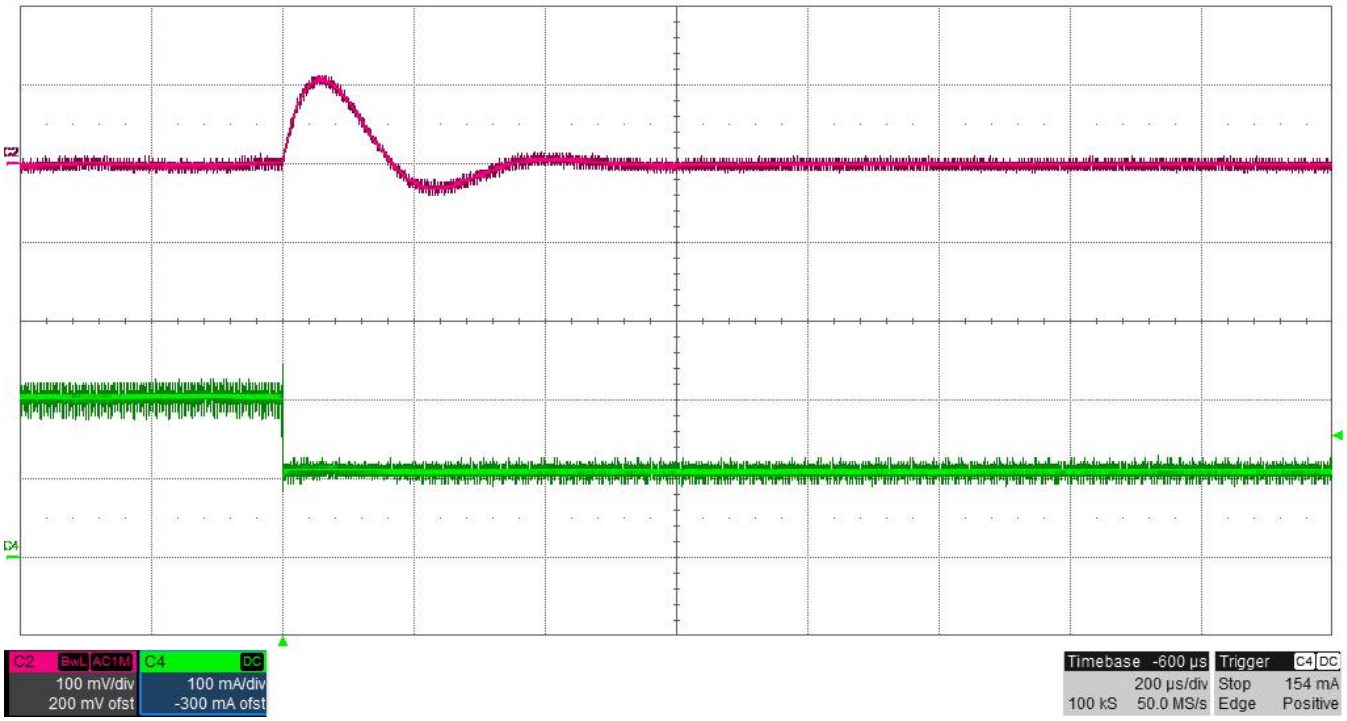
0.8A to 1.5A load transient (Green) on the 10V output (Red) for Vin = 12V, 5V @ 0.25A



0.3A to 1.5A load transient (Green) on the 10V output (Red) for Vin = 12V, 5V @ 0.25A



0.1A to 0.2A load transient (Green) on the 5V output (Red) for Vin = 12V, 10V @ 0.8A



0.2A to 0.1A load transient (Green) on the 5V output (Red) for Vin = 12V, 10V @ 0.8A

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