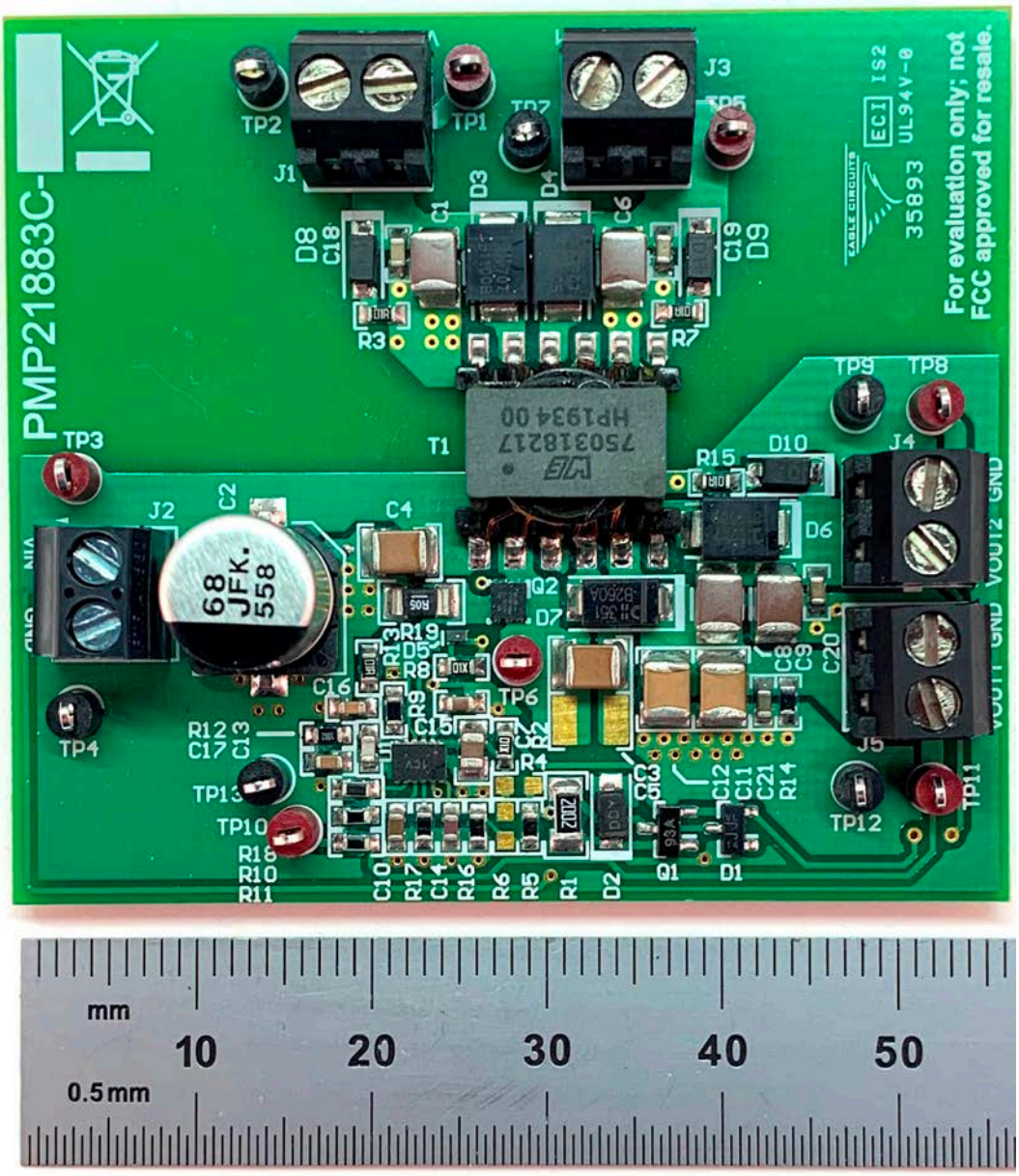
Test Report: PMP21883

Four-Output, SEPIC-Converter-Bias Power Supply Reference Design for Solar Panel Applications

Description

This design supplies two non-isolated and two isolated output voltages. A regulated 3.3 V/0.25 A and an unregulated 12 V/0.05 A output are primary-side referenced while two 12 V/0.025 A unregulated outputs are isolated. It operates over an input voltage range of 7 V - 45 V and offers low cost and a compact form factor. This SEPIC converter features minimal voltage ringing on the FET for lower stress and reduced EMI.



1 Test Prerequisites

1.1 Voltage and Current Requirements

Table 1. Voltage and Current Requirements

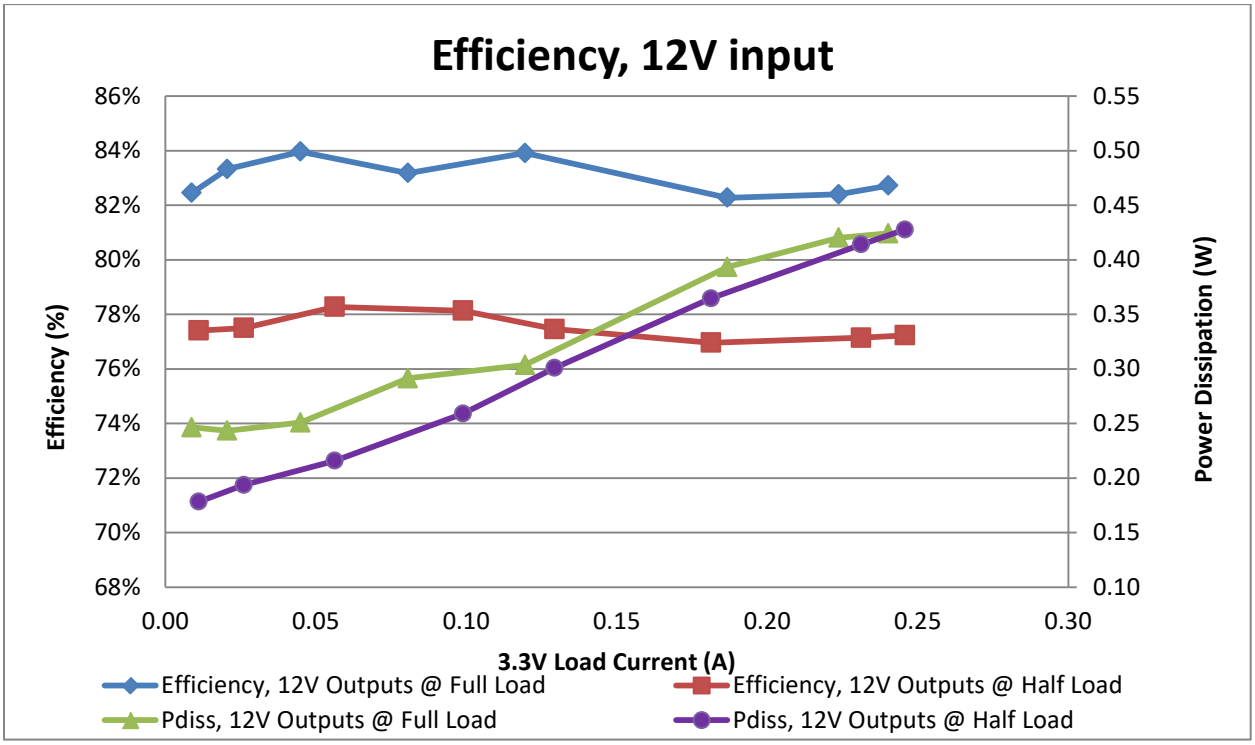
PARAMETER	SPECIFICATIONS
Input voltage range	7V - 45V
Output voltage and current	3.3 V/0.25 A, regulated 12 V/0.05A, unregulated (2x) 12 V/0.025 A, unregulated
Switching frequency	500kHz
Isolation	(2x) 12 V/0.025 A, 1875VAC (1 sec)

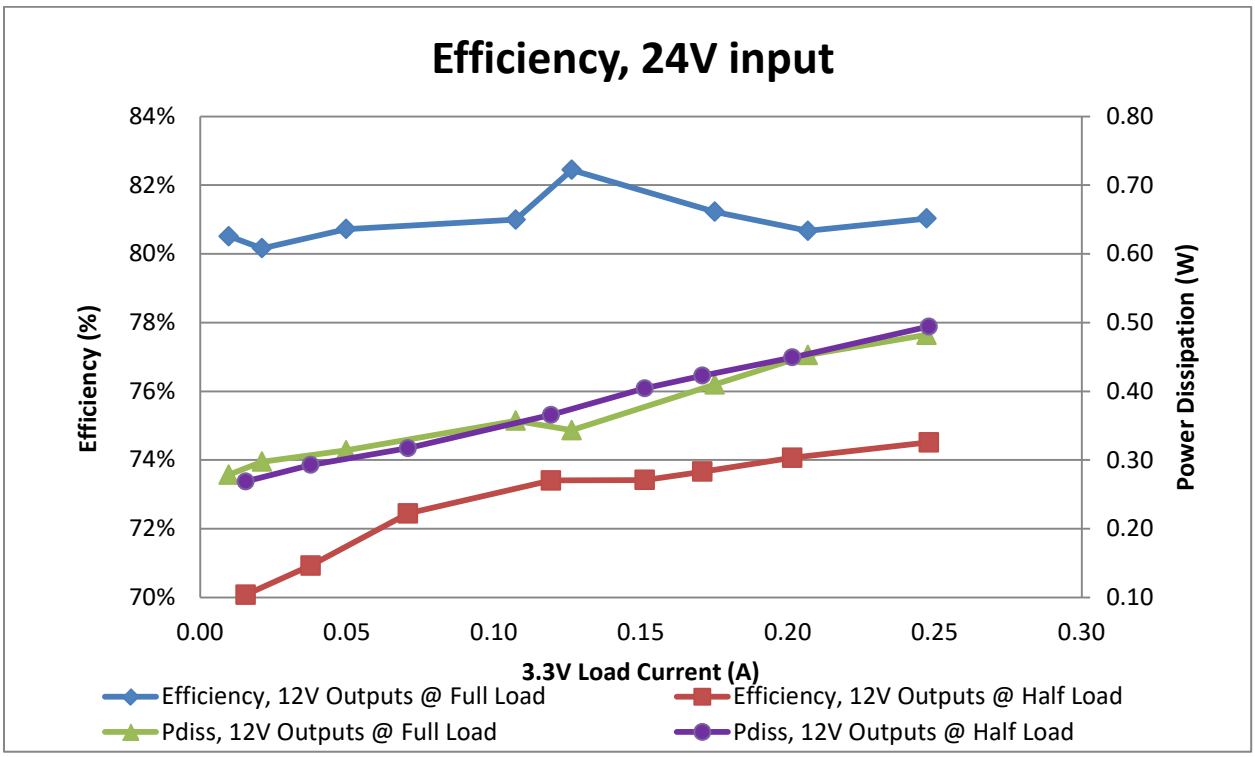
1.2 Required Equipment

- Four electronic loads (1W each) and/or power resistors (resistor decade boxes, 1W each)
- Power supply capable of 50V and 1A
- Oscilloscope and probes
- Digital Multimeters
- Stability measurement device (Venable or Bode100)

2 Testing and Results

2.1 Efficiency and Power Dissipation Graphs





These graphs display the efficiency and power dissipation of the converter with all 12V outputs loaded to either 50% or 100% of their full load as the 3.3V load is varied. The input voltage was set to either 12V or 24V.

2.2 Efficiency and Power Dissipation Data

The following table shows the efficiency data for the converter with a 12V input.

Table 1. 12V Outputs @ Full Load

Output	LOAD (A)	VOUT (V)	VIN (V)	IVIN (A)	Pin (W)	Pout (W)	EFF (%)	Pdiss (W)
3.3V	0.00879	3.328	11.988	0.11714	1.4042	1.1579	82.5%	0.246
12V non-iso	0.04790	11.664						
12V iso1	0.02442	11.724						
12V iso2	0.02419	11.725						
3.3V	0.02058	3.328	11.986	0.12174	1.4592	1.2159	83.3%	0.243
12V non-iso	0.04830	11.712						
12V iso1	0.02482	11.771						
12V iso2	0.02460	11.773						
3.3V	0.04493	3.328	11.986	0.13055	1.5647	1.3139	84.0%	0.251
12V non-iso	0.04870	11.795						
12V iso1	0.02502	11.864						
12V iso2	0.02470	11.867						
3.3V	0.08058	3.328	11.984	0.14447	1.7313	1.4400	83.2%	0.291
12V uniso	0.04870	11.880						
12V iso1	0.02502	11.955						
12V iso2	0.02460	11.959						
3.3V	0.11949	3.328	11.982	0.15749	1.8870	1.5834	83.9%	0.304
12V non-iso	0.04910	11.944						
12V iso1	0.02502	12.027						
12V iso2	0.02480	12.030						
3.3V	0.18676	3.328	11.978	0.18532	2.2197	1.8263	82.3%	0.393
12V non-iso	0.04940	12.046						
12V iso1	0.02522	12.137						
12V iso2	0.02500	12.142						
3.3V	0.22367	3.328	11.975	0.19933	2.3871	1.9669	82.4%	0.420
12V non-iso	0.04980	12.100						
12V iso1	0.02553	12.193						
12V iso2	0.02530	12.200						
3.3V	0.24023	3.329	11.978	0.20494	2.4548	2.0306	82.7%	0.424
12V non-iso	0.05000	12.122						
12V iso1	0.02573	12.220						
12V iso2	0.02540	12.225						

Table 2. 12V Outputs @ Half Load

Output	LOAD (A)	VOUT (V)	VIN (V)	IVIN (A)	Pin (W)	Pout (W)	EFF (%)	Pdiss (W)
3.3V	0.01105	3.329	11.995	0.06578	0.7890	0.6107	77.4%	0.178
12V non-iso	0.02410	11.736						
12V iso1	0.01241	11.806						
12V iso2	0.01225	11.810						
3.3V	0.02611	3.329	11.994	0.07178	0.8610	0.6673	77.5%	0.194
12V non-iso	0.02420	11.817						
12V iso1	0.01241	11.892						
12V iso2	0.01235	11.892						
3.3V	0.05623	3.328	11.992	0.08280	0.9929	0.7772	78.3%	0.216
12V non-iso	0.02440	11.911						
12V iso1	0.01251	11.996						
12V iso2	0.01245	11.996						
3.3V	0.09891	3.328	11.990	0.09882	1.1848	0.9257	78.1%	0.259
12V non-iso	0.02460	12.015						
12V iso1	0.01251	12.105						
12V iso2	0.01235	12.111						
3.3V	0.12928	3.328	11.988	0.11133	1.3346	1.0338	77.5%	0.301
12V non-iso	0.02470	12.079						
12V iso1	0.01261	12.176						
12V iso2	0.01245	12.181						
3.3V	0.18124	3.328	11.985	0.13206	1.5827	1.2180	77.0%	0.365
12V non-iso	0.02490	12.179						
12V iso1	0.01271	12.281						
12V iso2	0.01265	12.288						
3.3V	0.23120	3.328	11.982	0.15118	1.8114	1.3973	77.1%	0.414
12V non-iso	0.02520	12.261						
12V iso1	0.01291	12.372						
12V iso2	0.01285	12.379						
3.3V	0.24576	3.328	11.980	0.15678	1.8783	1.4505	77.2%	0.428
12V non-iso	0.02520	12.326						
12V iso1	0.01302	12.445						
12V iso2	0.01285	12.451						

The following table shows the efficiency data for the converter with a 24V input.

Table 1. 12V Outputs @ Full Load

Output	LOAD (A)	VOUT (V)	VIN (V)	IVIN (A)	Pin (W)	Pout (W)	EFF (%)	Pdiss (W)
3.3V	0.00979	3.329	24.005	0.05957	1.4300	1.1513	80.5%	0.279
12V non-iso	0.04760	11.632						
12V iso1	0.02422	11.695						
12V iso2	0.02409	11.699						
3.3V	0.02109	3.329	24.005	0.06247	1.4997	1.2022	80.2%	0.297
12V non-iso	0.04800	11.696						
12V iso1	0.02422	11.762						
12V iso2	0.02429	11.764						
3.3V	0.04970	3.329	24.004	0.06788	1.6294	1.3152	80.7%	0.314
12V non-iso	0.04830	11.779						
12V iso1	0.02462	11.852						
12V iso2	0.02440	11.852						
3.3V	0.10744	3.329	24.003	0.07829	1.8792	1.5221	81.0%	0.357
12V non-iso	0.04870	11.856						
12V iso1	0.02472	11.928						
12V iso2	0.02450	11.933						
3.3V	0.12652	3.329	24.002	0.08150	1.9561	1.6127	82.4%	0.343
12V non-iso	0.04900	11.940						
12V iso1	0.02522	12.027						
12V iso2	0.02520	12.030						
3.3V	0.17522	3.329	24.000	0.09101	2.1842	1.7741	81.2%	0.410
12V non-iso	0.04900	12.018						
12V iso1	0.02492	12.106						
12V iso2	0.02480	12.111						
3.3V	0.20685	3.329	24.000	0.09761	2.3428	1.8899	80.7%	0.453
12V non-iso	0.04940	12.061						
12V iso1	0.02502	12.154						
12V iso2	0.02480	12.157						
3.3V	0.24726	3.329	23.998	0.10592	2.5420	2.0598	81.0%	0.482
12V uniso	0.05010	12.118						
12V iso1	0.02593	12.217						
12V iso2	0.02560	12.221						

Table 2. 12V Outputs @ Half Load

Output	LOAD (A)	VOUT (V)	VIN (V)	IVIN (A)	Pin (W)	Pout (W)	EFF (%)	Pdiss (W)
3.3V	0.01556	3.328	24.010	0.03744	0.8990	0.6300	70.1%	0.269
12V non-iso	0.02410	11.783						
12V iso1	0.01241	11.837						
12V iso2	0.01245	11.840						
3.3V	0.03765	3.329	24.010	0.04195	1.0072	0.7144	70.9%	0.293
12V non-iso	0.02440	11.879						
12V iso1	0.01251	11.939						
12V iso2	0.01255	11.944						
3.3V	0.07079	3.329	24.010	0.04796	1.1514	0.8342	72.4%	0.317
12V non-iso	0.02450	11.964						
12V iso1	0.01271	12.041						
12V iso2	0.01265	12.048						
3.3V	0.11949	3.329	24.007	0.05727	1.3748	1.0092	73.4%	0.366
12V non-iso	0.02470	12.067						
12V iso1	0.01281	12.162						
12V iso2	0.01295	12.167						
3.3V	0.15137	3.329	24.006	0.06337	1.5214	1.1170	73.4%	0.404
12V non-iso	0.02480	12.122						
12V iso1	0.01281	12.222						
12V iso2	0.01275	12.228						
3.3V	0.17095	3.329	24.005	0.06688	1.6054	1.1826	73.7%	0.423
12V non-iso	0.02480	12.155						
12V iso1	0.01291	12.257						
12V iso2	0.01255	12.262						
3.3V	0.20158	3.329	24.004	0.07218	1.7327	1.2834	74.1%	0.449
12V non-iso	0.02490	12.199						
12V iso1	0.01261	12.314						
12V iso2	0.01245	12.319						
3.3V	0.24802	3.329	24.003	0.08079	1.9393	1.4451	74.5%	0.494
12V non-iso	0.02490	12.269						
12V iso1	0.01271	12.379						
12V iso2	0.01265	12.389						

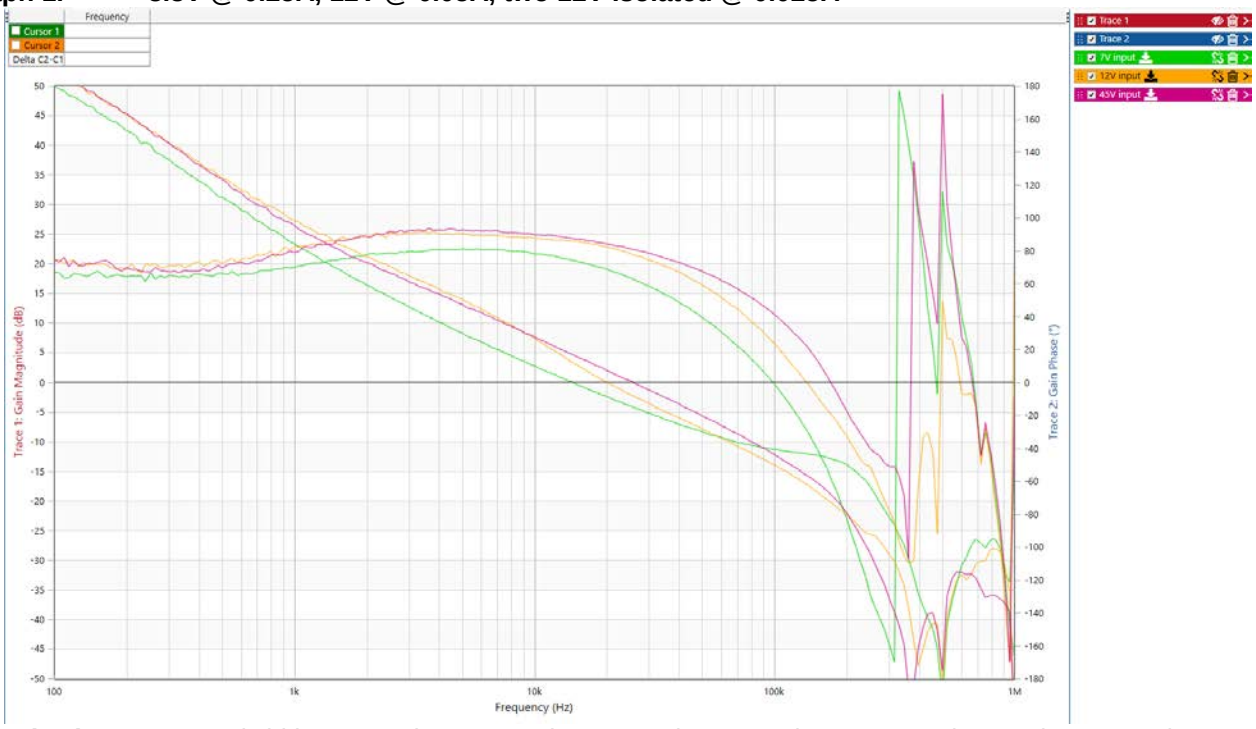
2.2.1 Cross Regulation

Voltage Regulation Data								
VIN (V)	VOUT 3.3V (V)	IOUT 3.3V (mA)	VOUT 12V (V)	IOUT 12V (mA)	VOUT 12V iso(V)	IOUT 12V iso(mA)	VOUT 12V iso(V)	IOUT 12V iso(mA)
No Load Conditions								
7	3.328	0	11.861	0	12.051	0	12.101	0
12	3.328	0	11.854	0	12.056	0	12.104	0
45	3.328	0	11.992	0	12.126	0	12.158	0
Full Load Conditions								
7	3.328	250	12.258	50	12.287	25	12.292	25
12	3.328	250	12.217	50	12.249	25	12.255	25
45	3.328	250	12.211	50	12.268	25	12.274	25
Cross Loading								
7	3.328	250	**12.706**	0	**12.860**	0	**12.872**	0
7	3.328	0	11.832	0	11.376	25	11.379	25
7	3.328	250	12.236	50	12.621	0	12.639	0
7	3.328	0	11.536	50	12.087	0	12.139	0
7	3.328	0	11.518	50	11.579	25	11.581	25
7	3.328	250	12.207	50	12.610	0	12.629	0
12	3.328	250	12.701	0	12.853	0	12.864	0
12	3.328	0	11.832	0	11.382	25	11.385	25
12	3.328	250	12.328	50	12.619	0	12.637	0
12	3.328	0	11.538	50	12.083	0	12.135	0
12	3.328	0	**11.506**	50	**11.573**	25	**11.574**	25
12	3.328	250	12.184	50	12.576	0	12.592	0
45	3.328	250	12.701	0	12.852	0	12.863	0
45	3.328	0	11.807	0	11.575	25	11.575	25
45	3.328	250	12.213	50	12.586	0	12.602	0
45	3.328	0	11.537	50	12.094	0	12.146	0
45	3.328	0	11.509	50	11.594	25	11.594	25
45	3.328	250	12.362	50	12.657	0	12.670	0

This table shows the voltage regulation of the outputs under various extreme cross load conditions.

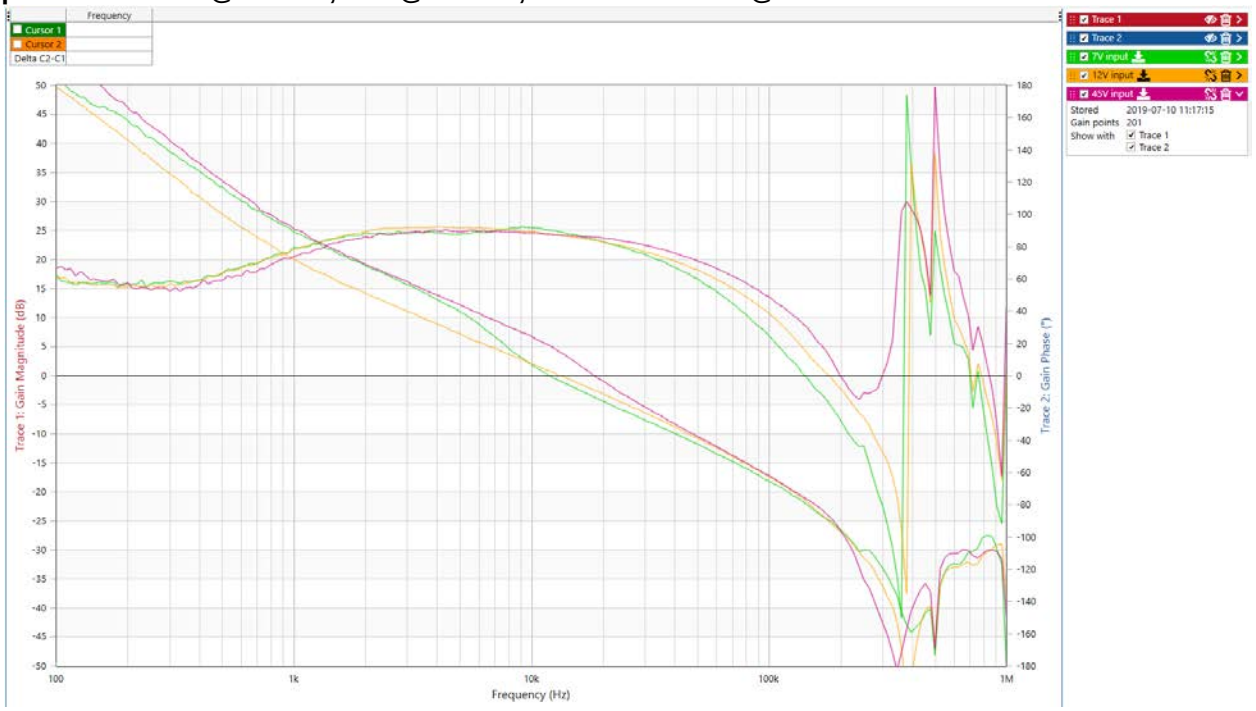
2.3 Loop Gain

Graph 1. 3.3V @ 0.25A, 12V @ 0.05A, two 12V Isolated @ 0.025A



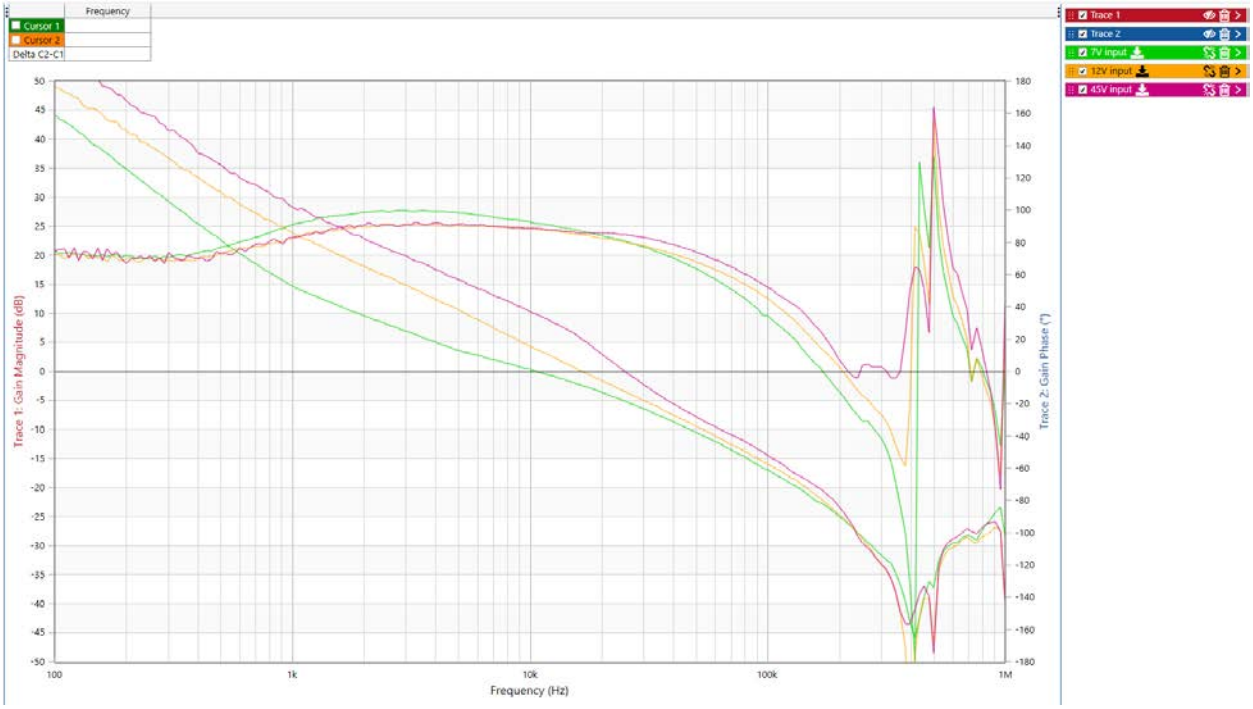
Green) Vin=7V Bandwidth = 14.47 kHz Phase Margin = 74.3 degrees Gain Margin= 11.24 dB
Yellow) Vin=12V Bandwidth = 20.11 kHz Phase Margin = 82.3 degrees Gain Margin= 17.21 dB
Pink) Vin=45V Bandwidth = 25.85 kHz Phase Margin = 80.9 degrees Gain Margin= 18.86 dB

Graph 2. 3.3V @ 0.125A, 12V @ 0.025A, two 12V Isolated @ 0.0125A



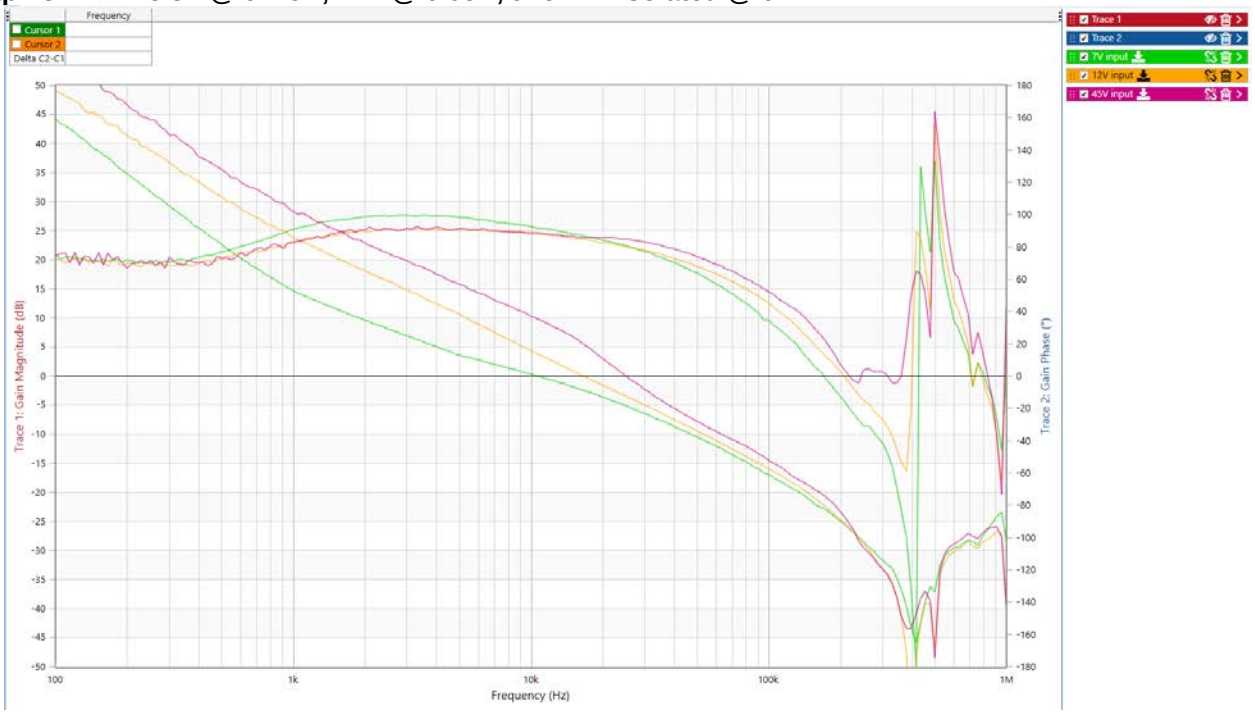
Green) Vin=7V Bandwidth = 11.94 kHz Phase Margin = 90.2 degrees Gain Margin= 21.91 dB
Yellow) Vin=12V Bandwidth = 13.23 kHz Phase Margin = 83.9 degrees Gain Margin= 25.07 dB
Pink) Vin=45V Bandwidth = 18.44 kHz Phase Margin = 85.9 degrees Gain Margin= 26.62 dB

Graph 3. 3.3V @ 0.125A, 12V @ 0.025A, two 12V Isolated @ 0A



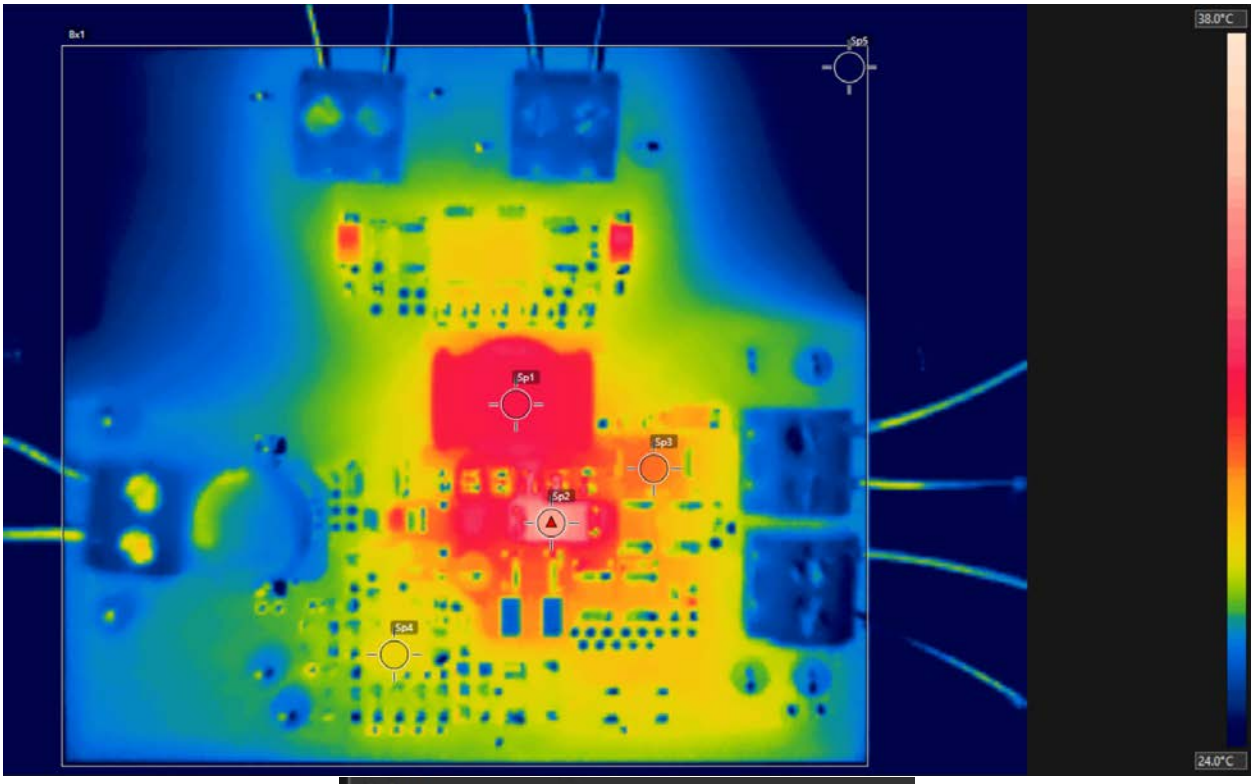
Green) Vin=7V Bandwidth = 10.64 kHz Phase Margin = 91.8 degrees Gain Margin= 22.81 dB
Yellow) Vin=12V Bandwidth = 16.65 kHz Phase Margin = 84.7 degrees Gain Margin= 25.17 dB
Pink) Vin=45V Bandwidth = 25.18 kHz Phase Margin = 84.9 degrees Gain Margin= 24.09 dB

Graph 3. 3.3V @ 0. 25A, 12V @ 0.05A, two 12V Isolated @ 0A



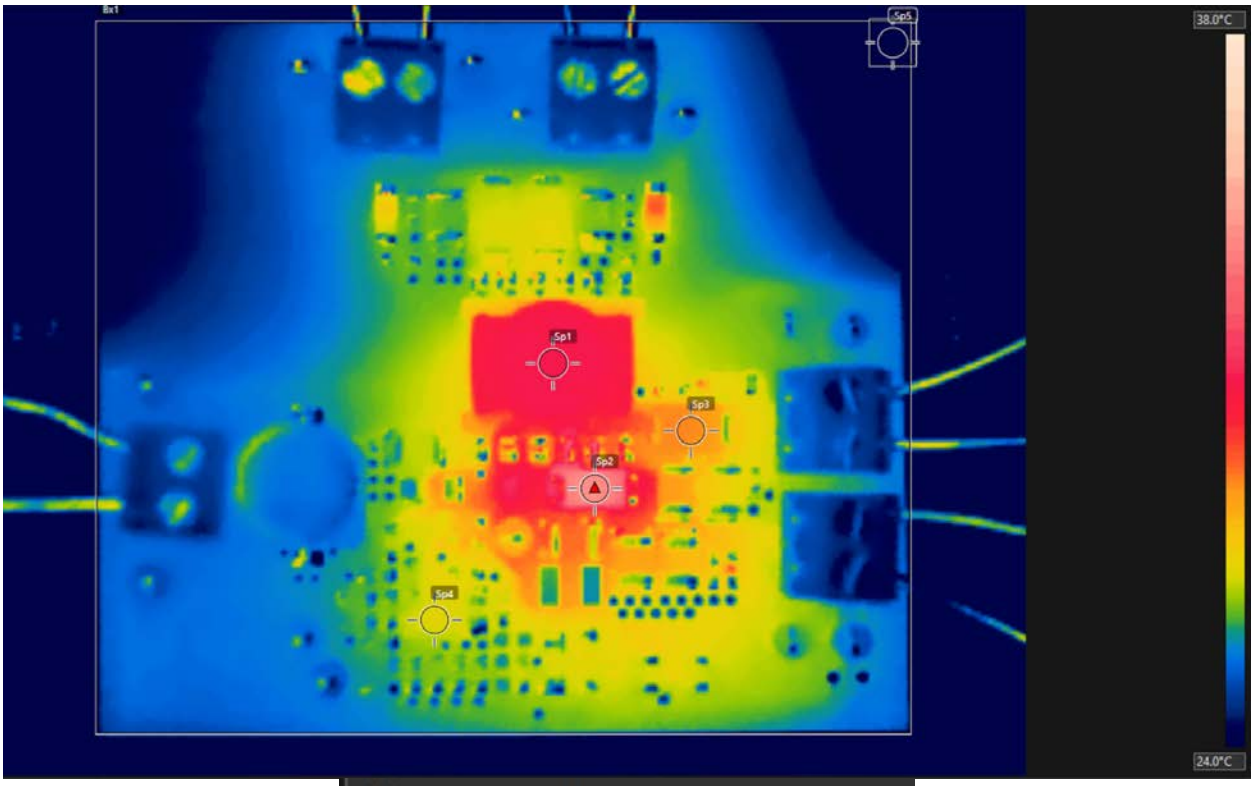
Green) Vin=7V Bandwidth = 26.81 kHz Phase Margin = 70.8 degrees Gain Margin= 10.64 dB
Yellow) Vin=12V Bandwidth = 21.94 kHz Phase Margin = 82.0 degrees Gain Margin= 17.82 dB
Pink) Vin=45V Bandwidth = 36.04 kHz Phase Margin = 76.2 degrees Gain Margin= 17.86 dB

2.4 Thermal Images



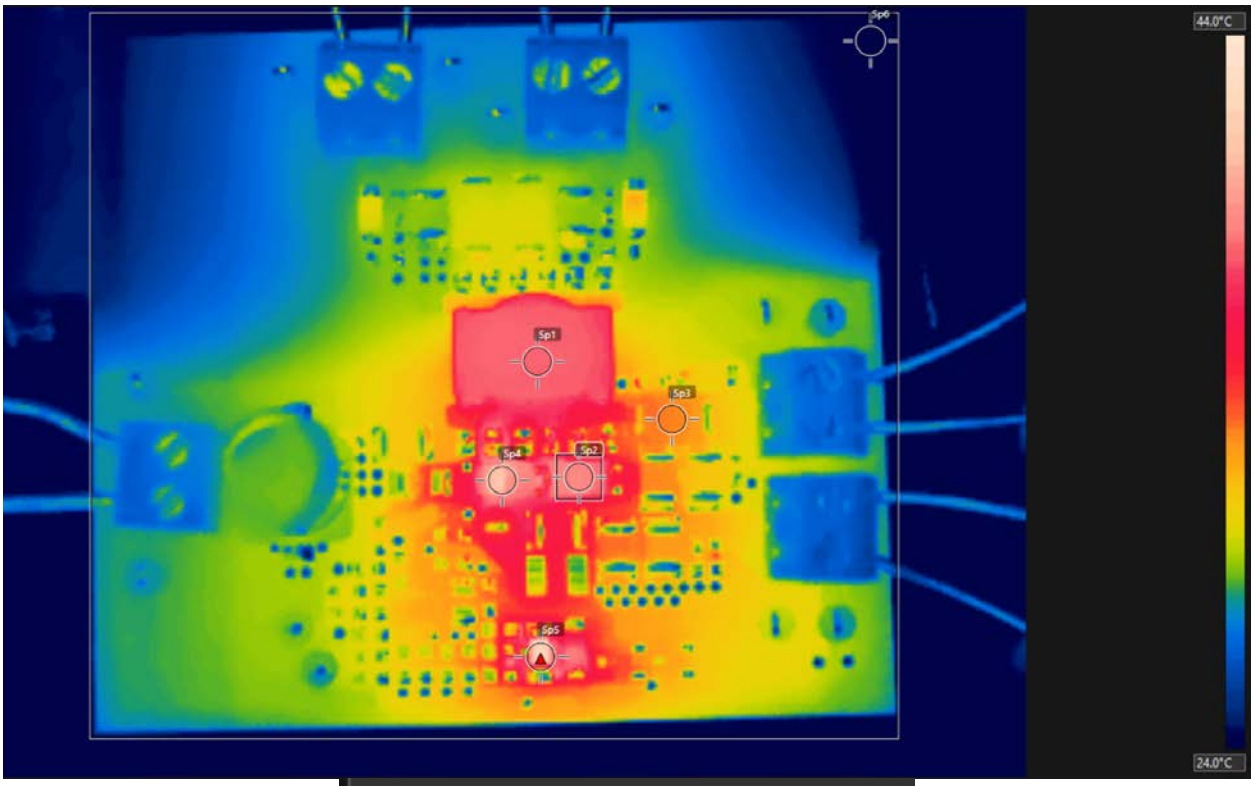
Measurements		
Bx1	Max	35.0 °C
Sp1		31.4 °C
Sp2		35.0 °C
Sp3		29.8 °C
Sp4		28.1 °C
Sp5		23.3 °C

This thermal image shows the operating temperature of the board with 7V input and all outputs at full load. The image was captured at room temperature after operating for 25 minutes.



Measurements		
Bx1	Max	34.4 °C
Sp1		31.4 °C
Sp2		34.3 °C
Sp3		29.4 °C
Sp4		27.7 °C
Sp5		22.9 °C

This thermal image shows the operating temperature of the board with 12V input and all outputs at full load. The image was captured at room temperature after operating for 25 minutes.

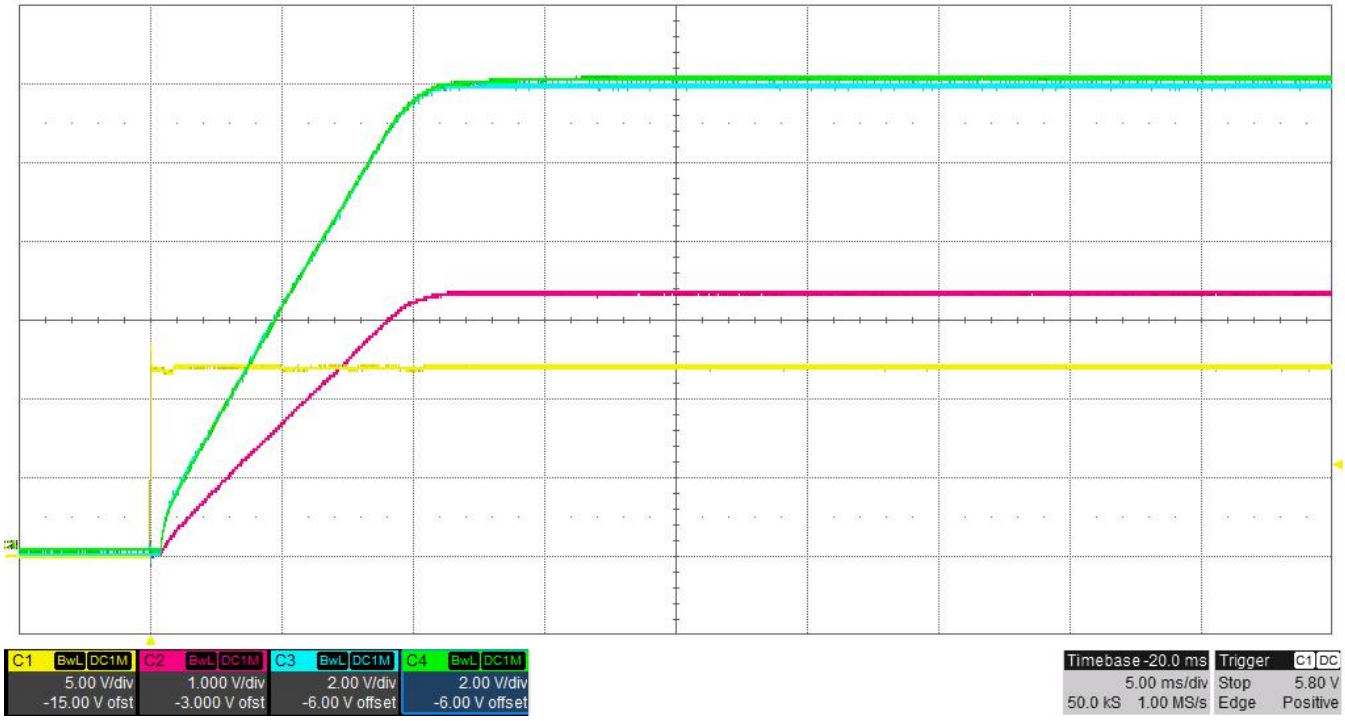


Measurements		
Bx1	Max	42.2 °C
Sp1		38.3 °C
Sp2		39.2 °C
Sp3		33.3 °C
Sp4		41.1 °C
Sp5		41.7 °C
Sp6		23.9 °C

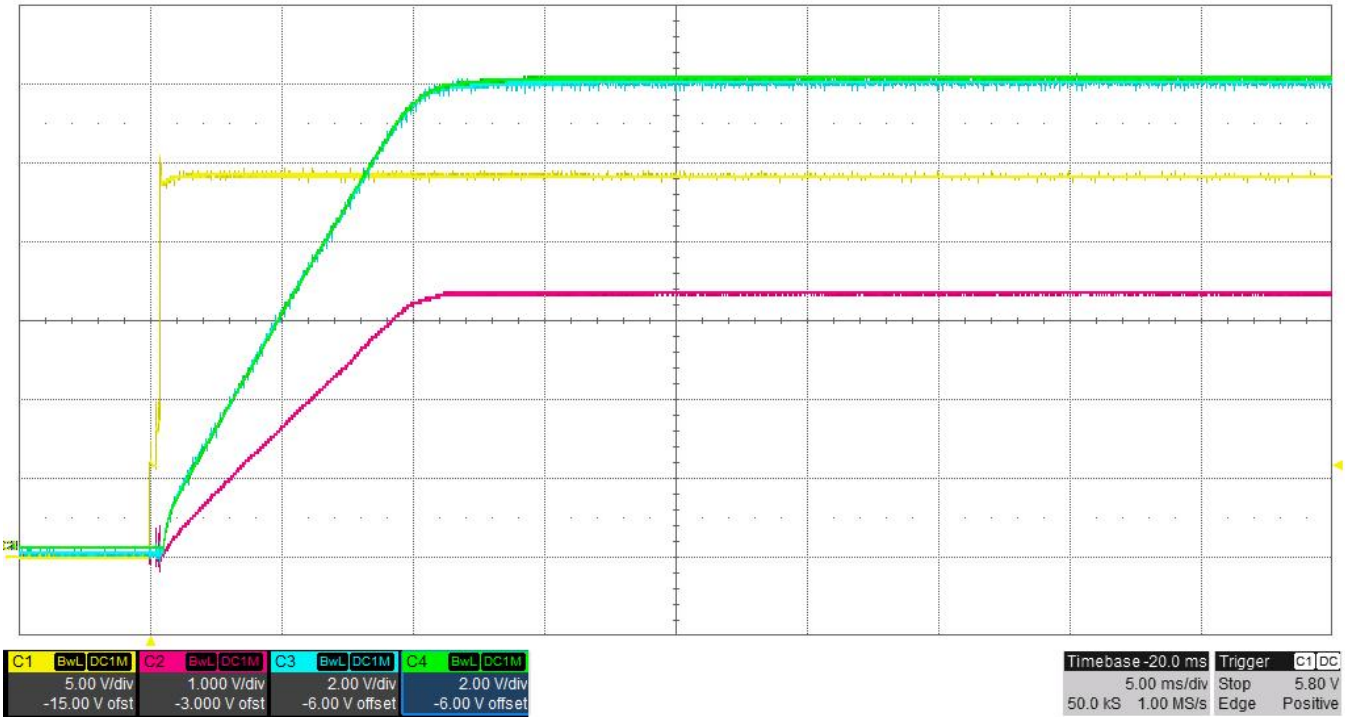
This thermal image shows the operating temperature of the board with 45V input and all outputs at full load. The image was captured at room temperature after operating for 25 minutes.

3 Waveforms

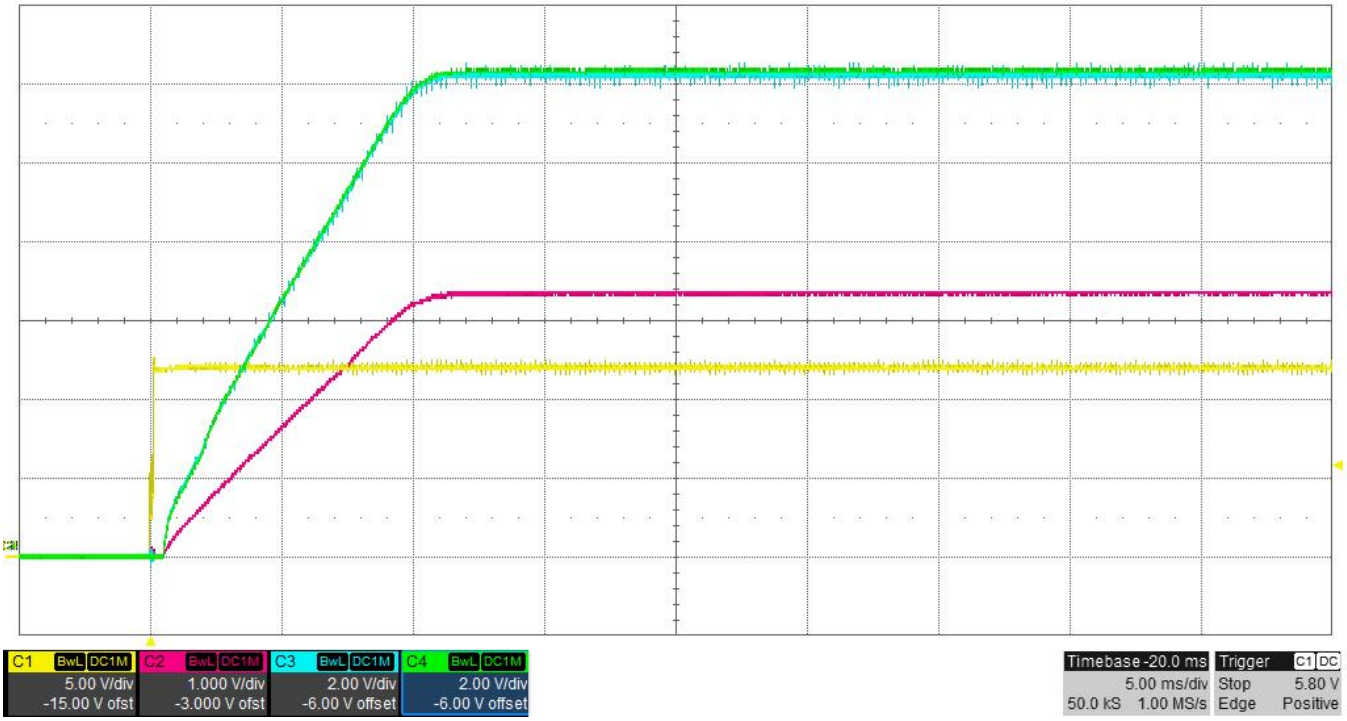
3.1 Startup Sequence



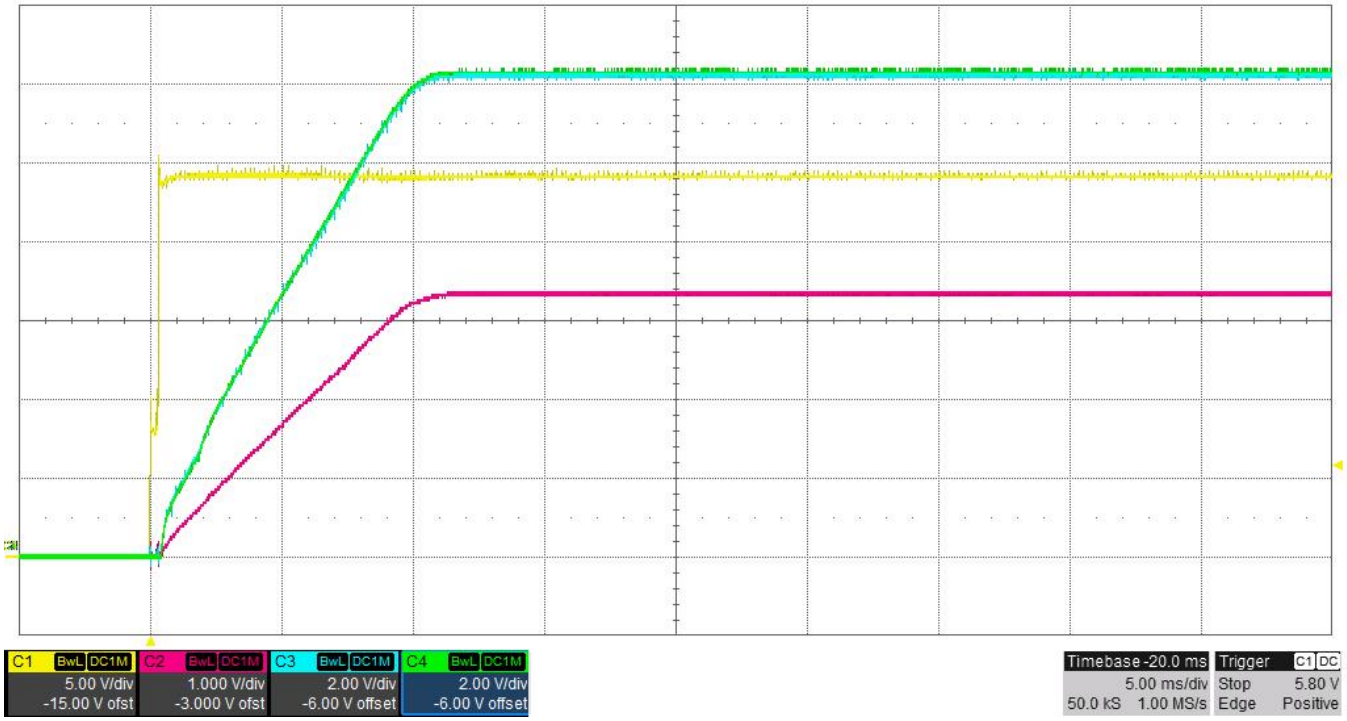
Start-up sequence for Vin = 12V (Yellow), 3.3V @ 0A (Red), 12V @ 0A (Blue), single 12V isolated @ 0A (Green)



Start-up sequence for Vin = 24V (Yellow), 3.3V @ 0A (Red), 12V @ 0A (Blue), single 12V isolated @ 0A (Green)

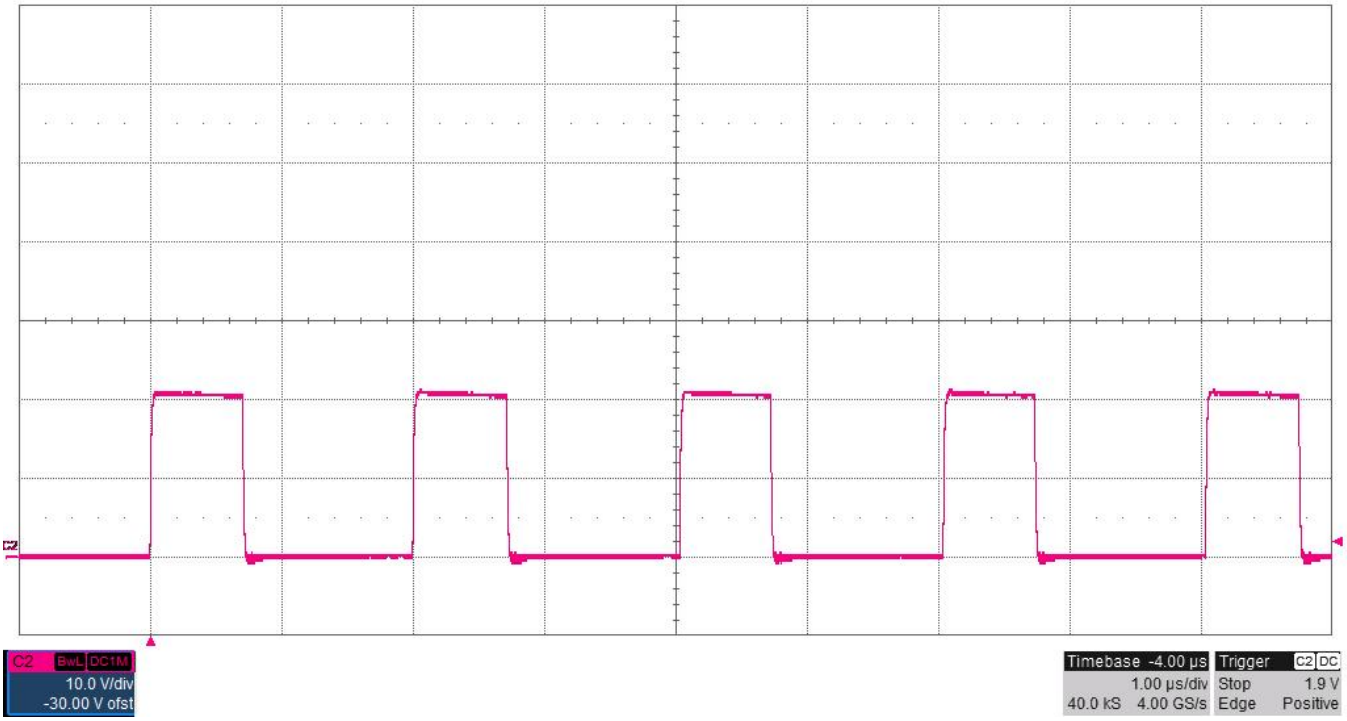


Start-up sequence for Vin = 12V (Yellow), 3.3V @ 0.25A (Red), 12V @ 0.050A (Blue), single 12V isolated @ 0.025A (Green)

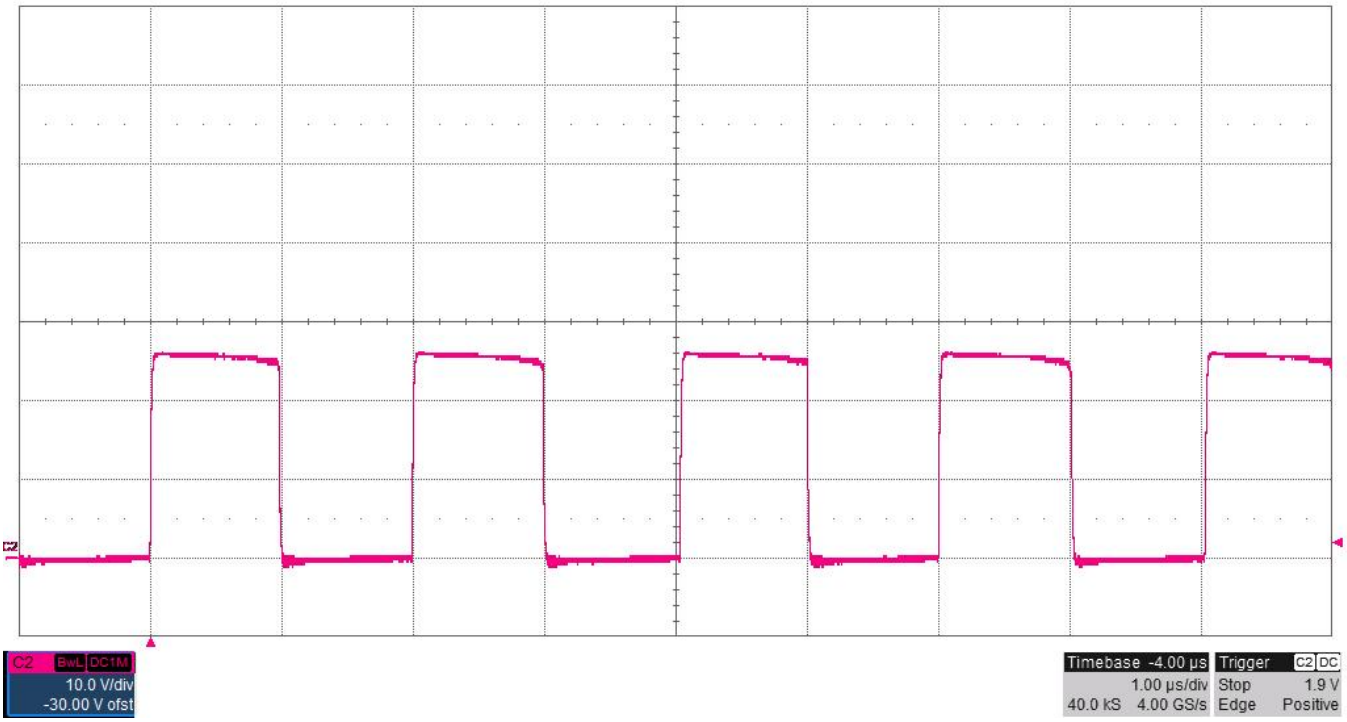


Start-up sequence for Vin = 24V (Yellow), 3.3V @ 0.25A (Red), 12V @ 0.050A (Blue), single 12V isolated @ 0.025A (Green)

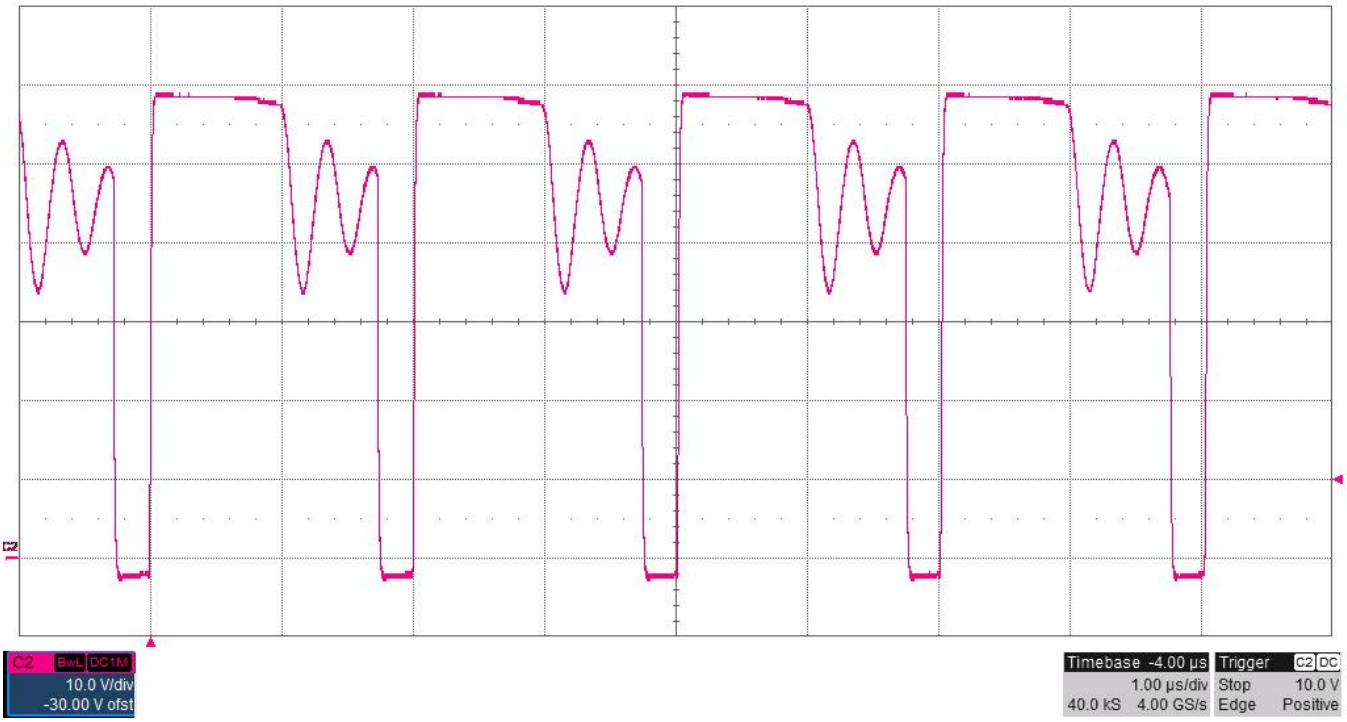
3.2 FET Switch Node



Switch node of FET with Vin = 7V, 3.3V @ 0.25A, 12V @ 0.050A, two 12V isolated @ 0.025A.

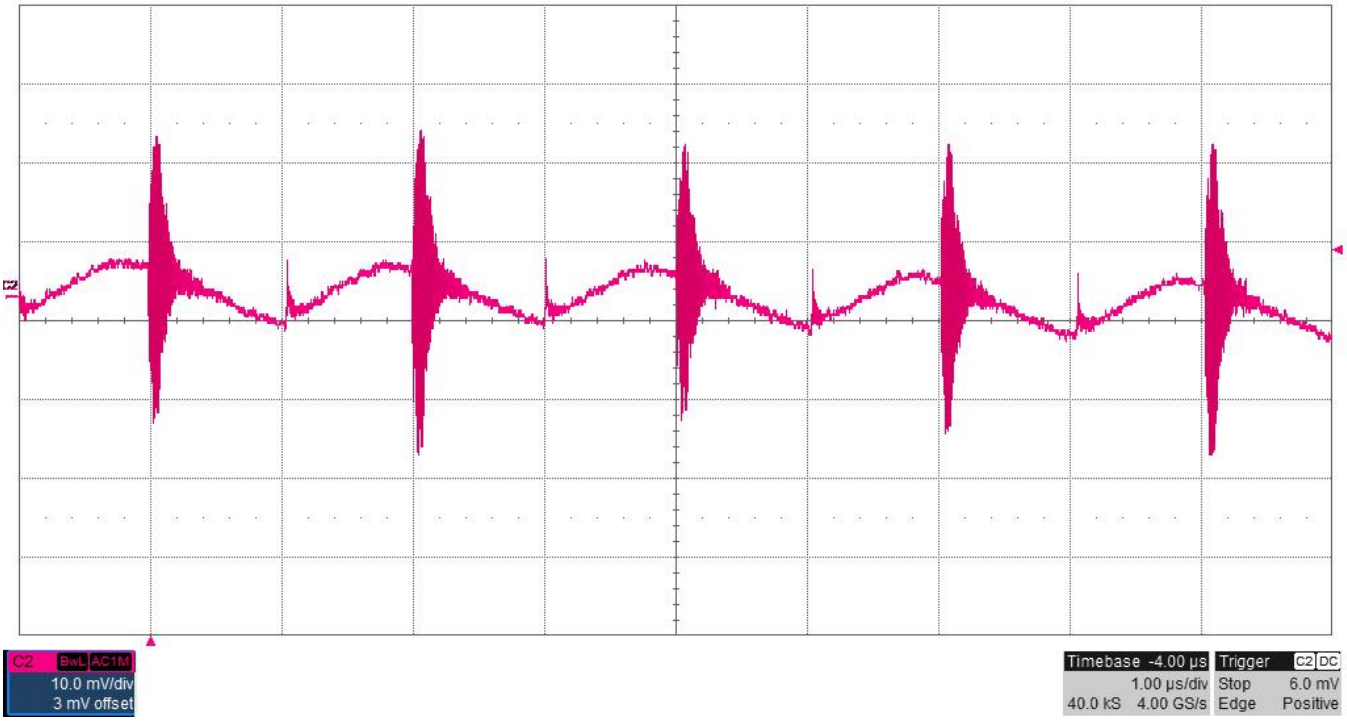


Switch node of FET with Vin = 12V, 3.3V @ 0.25A, 12V @ 0.050A, two 12V isolated @ 0.025A.

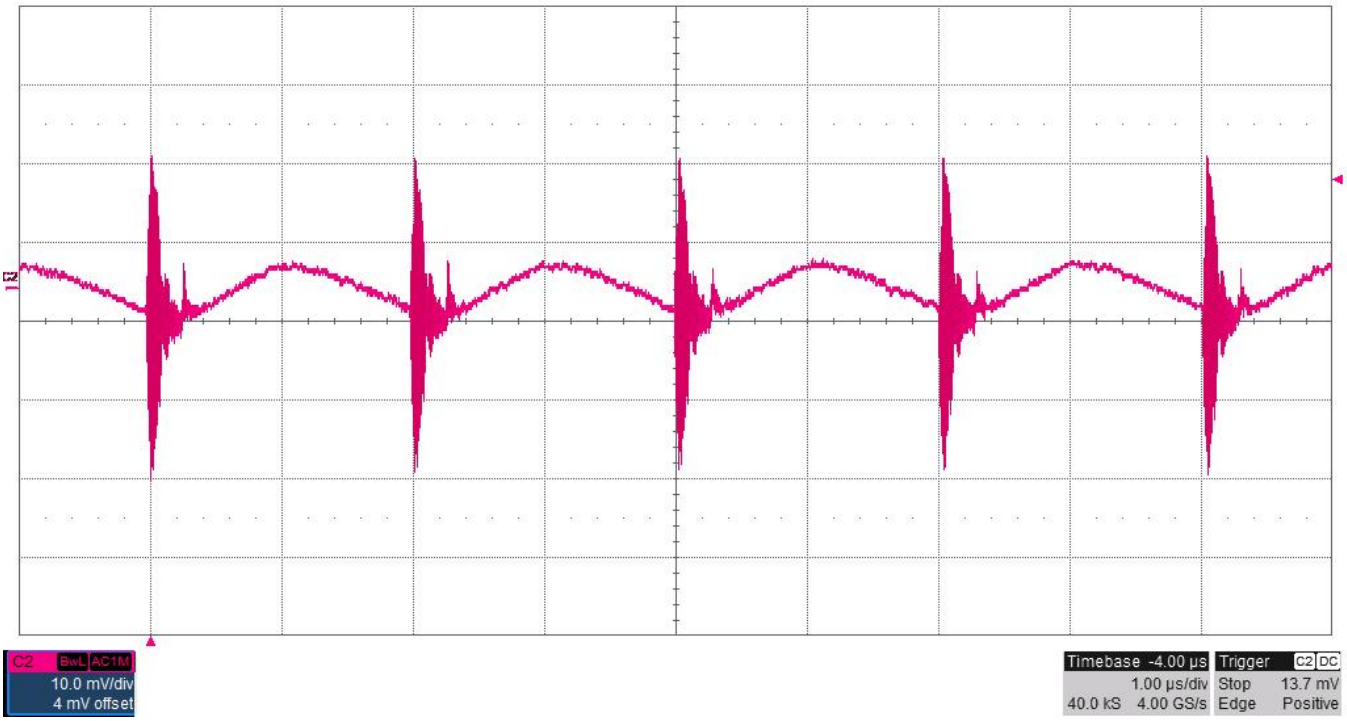


Switch node of FET with Vin = 45V, 3.3V @ 0.25A, 12V @ 0.050A, two 12V isolated @ 0.025A.

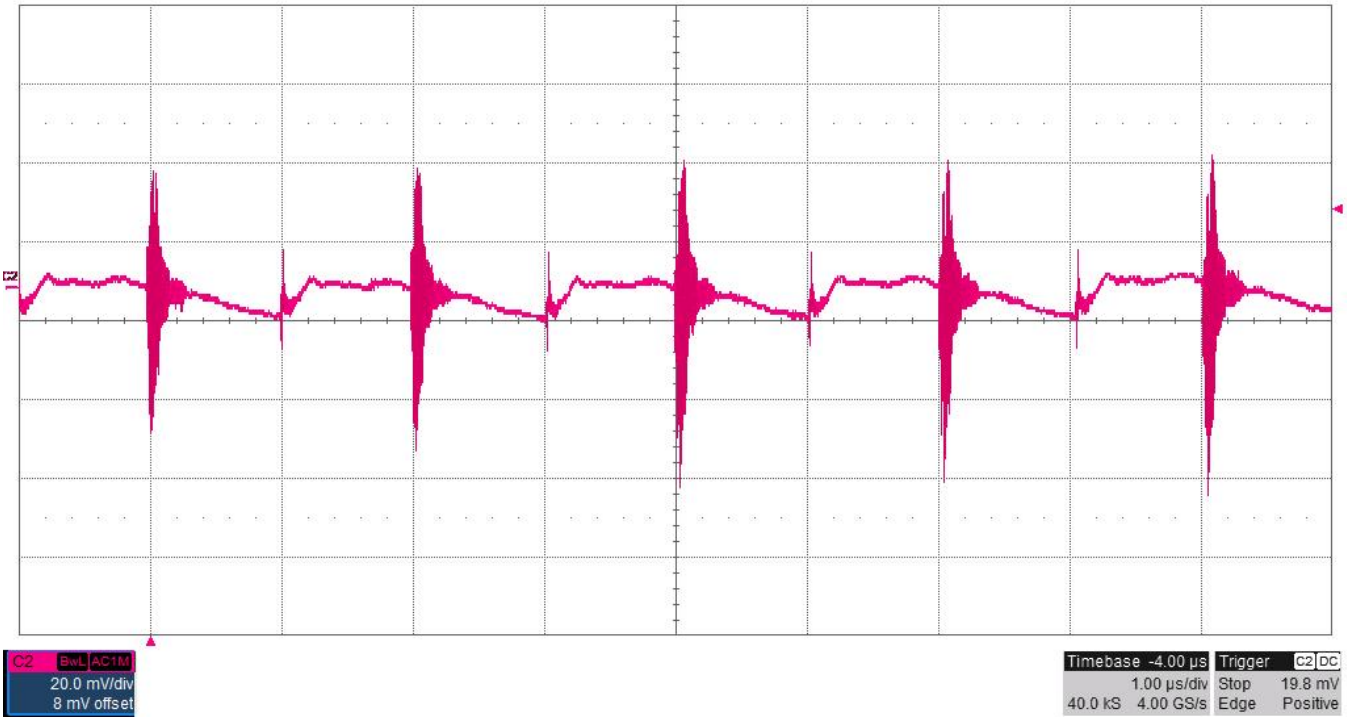
3.3 Output Voltage Ripple



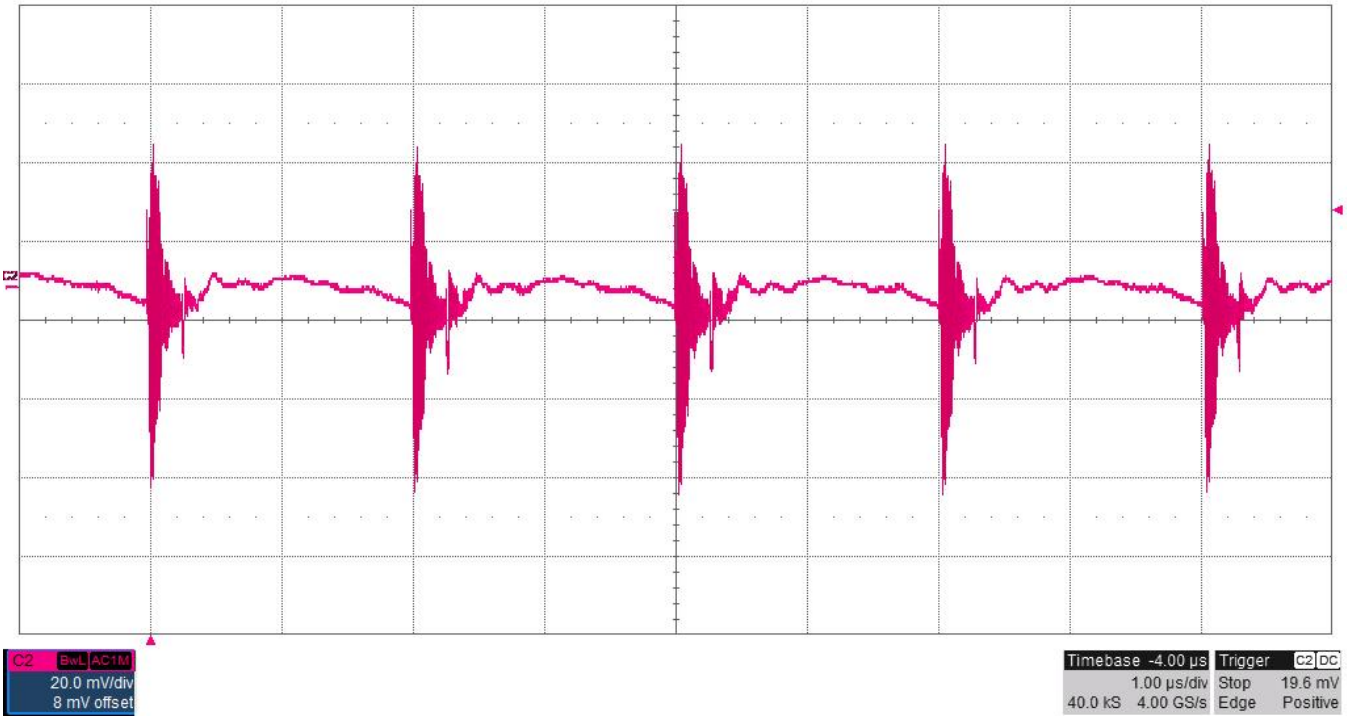
3.3V ripple voltage with Vin = 12V, 3.3V @ 0.25A, 12V @ 0.050A, two 12V isolated @ 0.025A.
Bandwidth = 20MHz



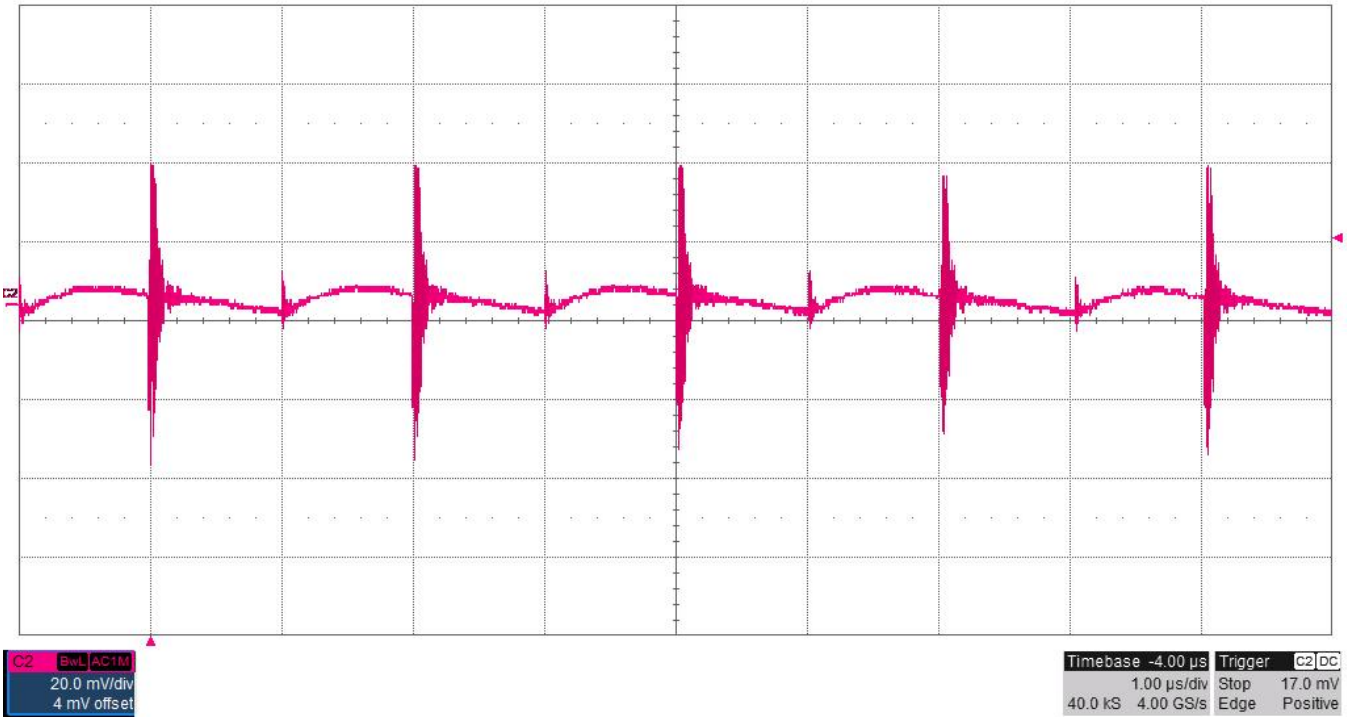
3.3V ripple voltage with Vin = 45V, 3.3V @ 0.25A, 12V @ 0.050A, two 12V isolated @ 0.025A.
Bandwidth = 20MHz



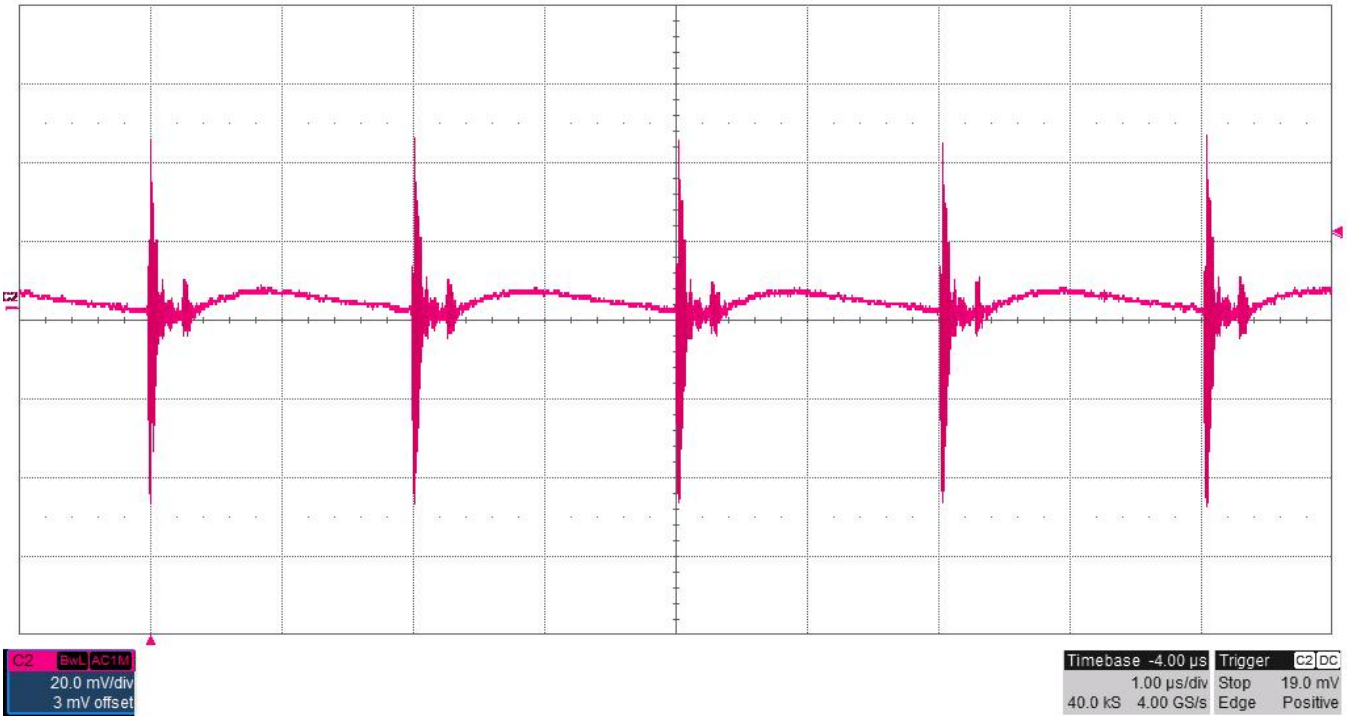
12V non-isolated ripple voltage with Vin = 12V, 3.3V @ 0.25A, 12V @ 0.050A, two 12V isolated @ 0.025A. Bandwidth = 20MHz



12V non-isolated ripple voltage with Vin = 45V, 3.3V @ 0.25A, 12V @ 0.050A, two 12V isolated @ 0.025A. Bandwidth = 20MHz

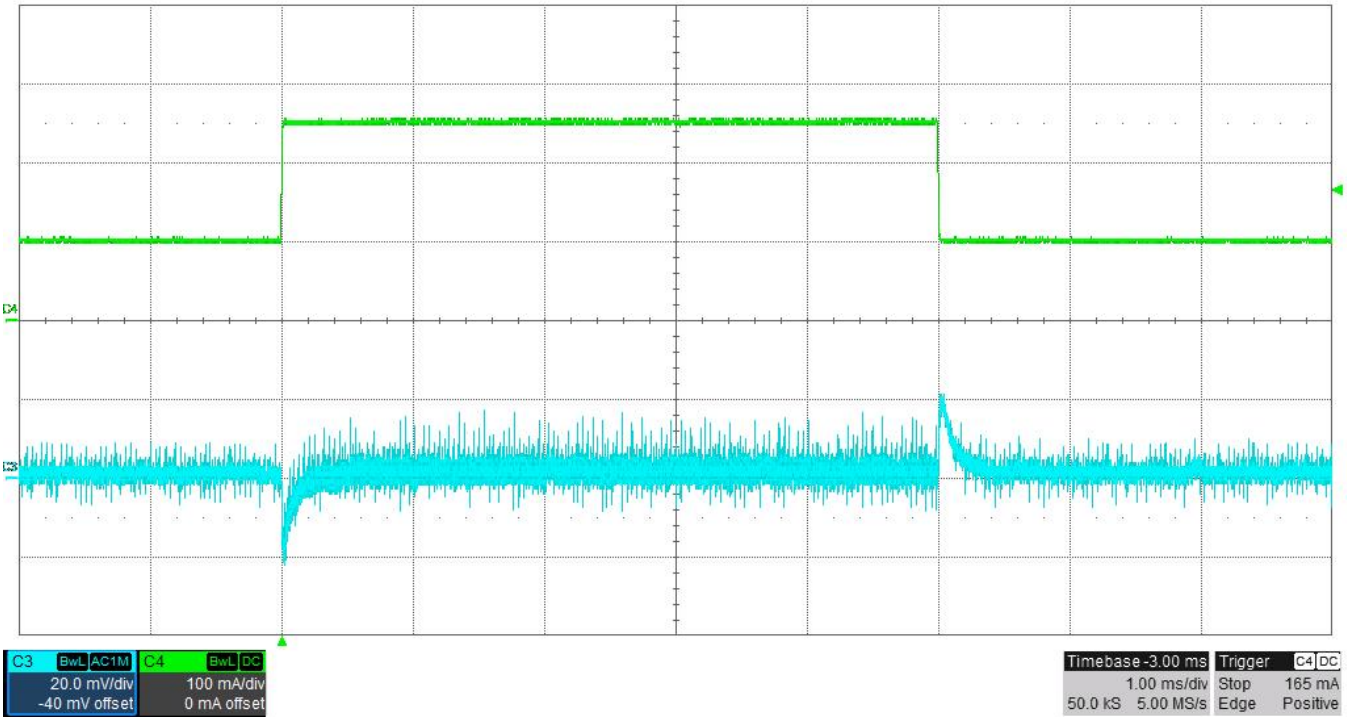


12V isolated ripple voltage with Vin = 12V, 3.3V @ 0.25A, 12V @ 0.050A, two 12V isolated @ 0.025A. Bandwidth = 20MHz

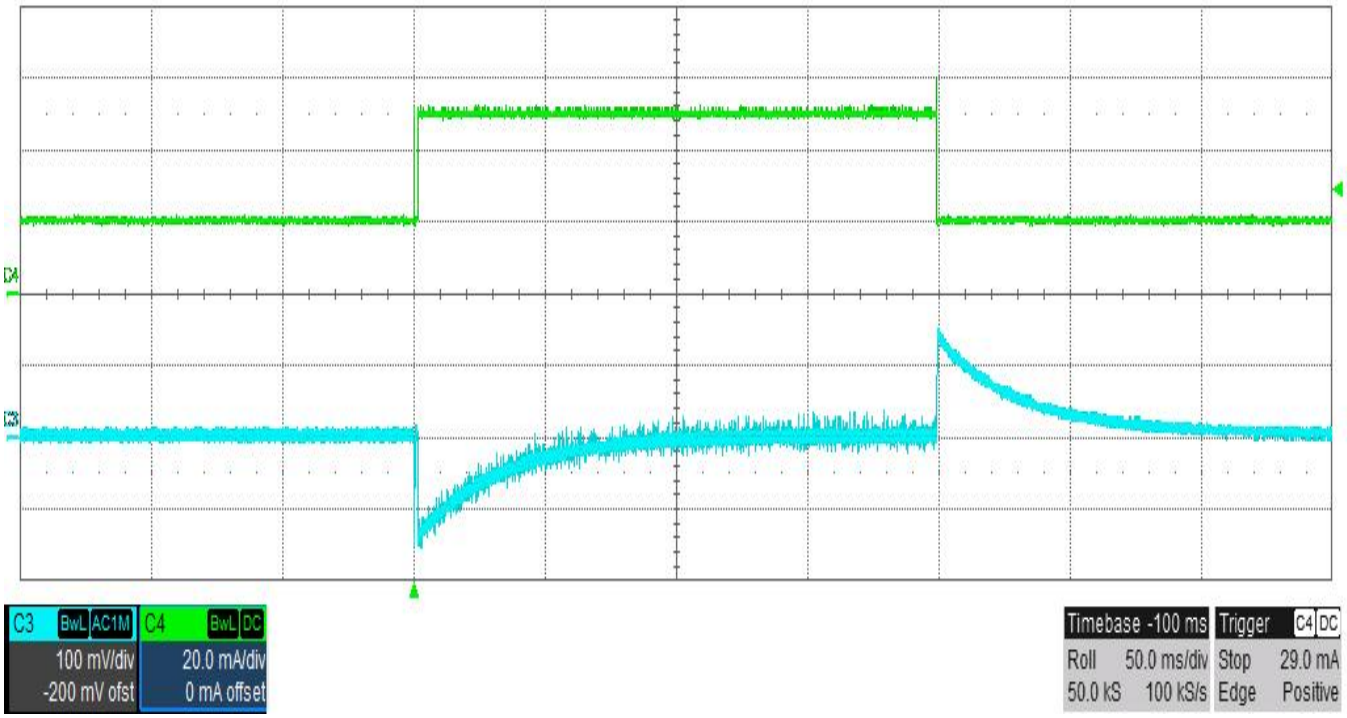


12V isolated ripple voltage with Vin = 45V, 3.3V @ 0.25A, 12V @ 0.050A, two 12V isolated @ 0.025A. Bandwidth = 20MHz

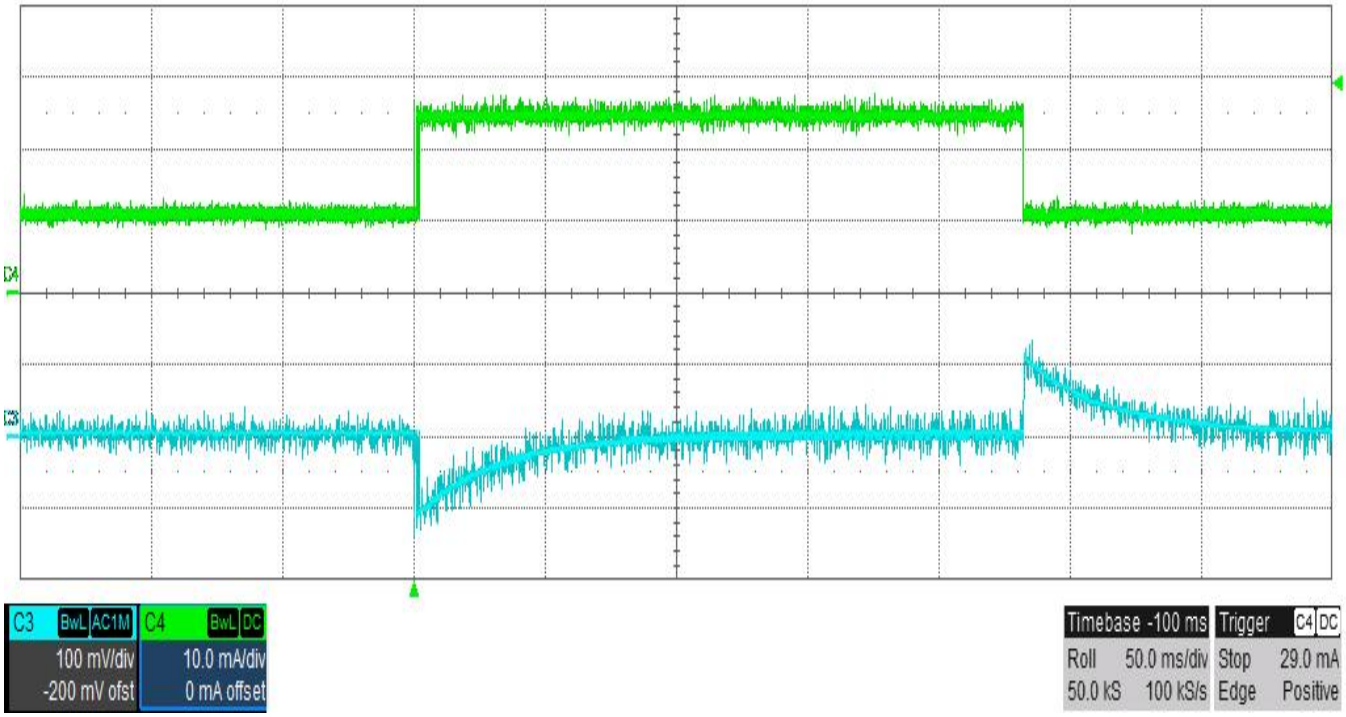
3.4 Load Transients



100mA to 250mA load transient (green) on the 3.3V output (blue) for Vin = 12V, two 12V Isolated @ 0.025A and 12V @ 0.05A.



20mA to 50mA load transient (green) on the 12V output (blue) for Vin = 12V, two 12V Isolated @ 0.025A and 3.3V @ 0.25A.



10mA to 25mA load transient (green) on the isolated 12V output (blue) for Vin = 12V, 12V @ 0.05A and 3.3V @ 0.25A.

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