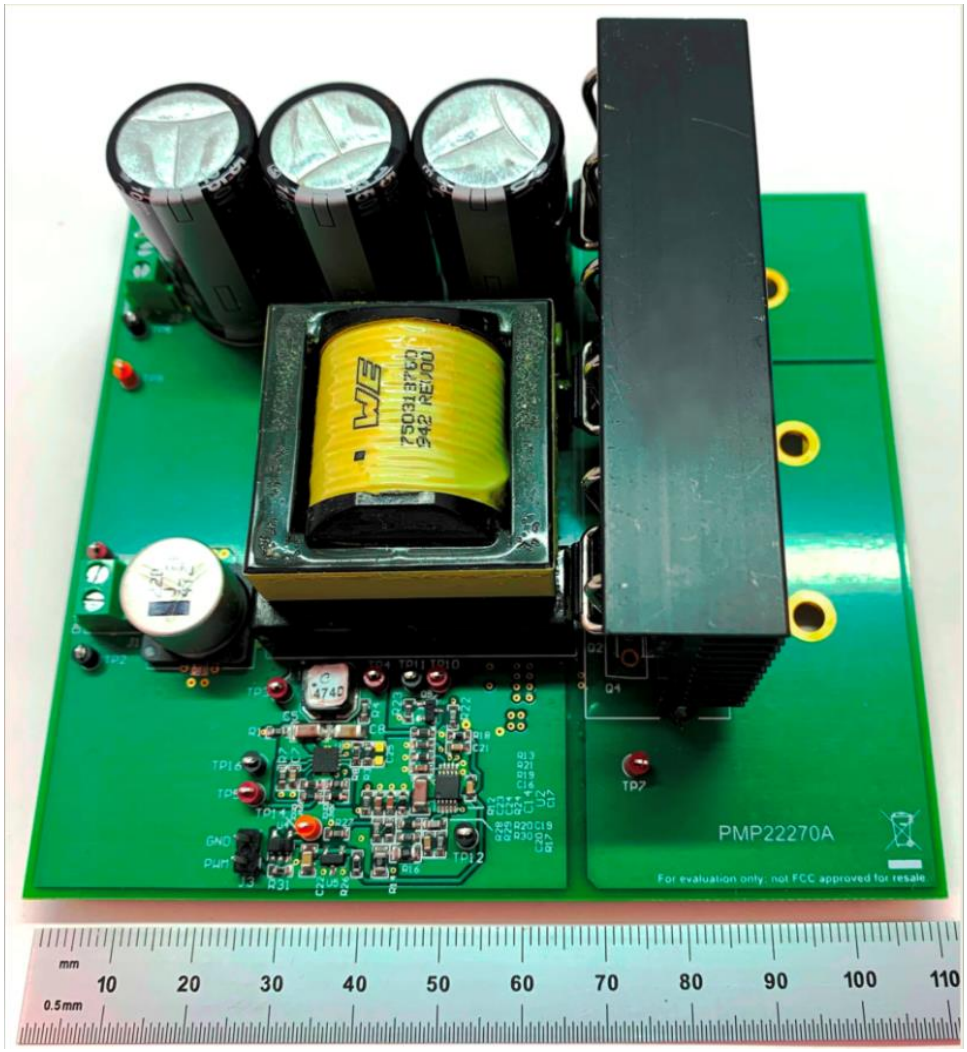
Test Report: PMP22270

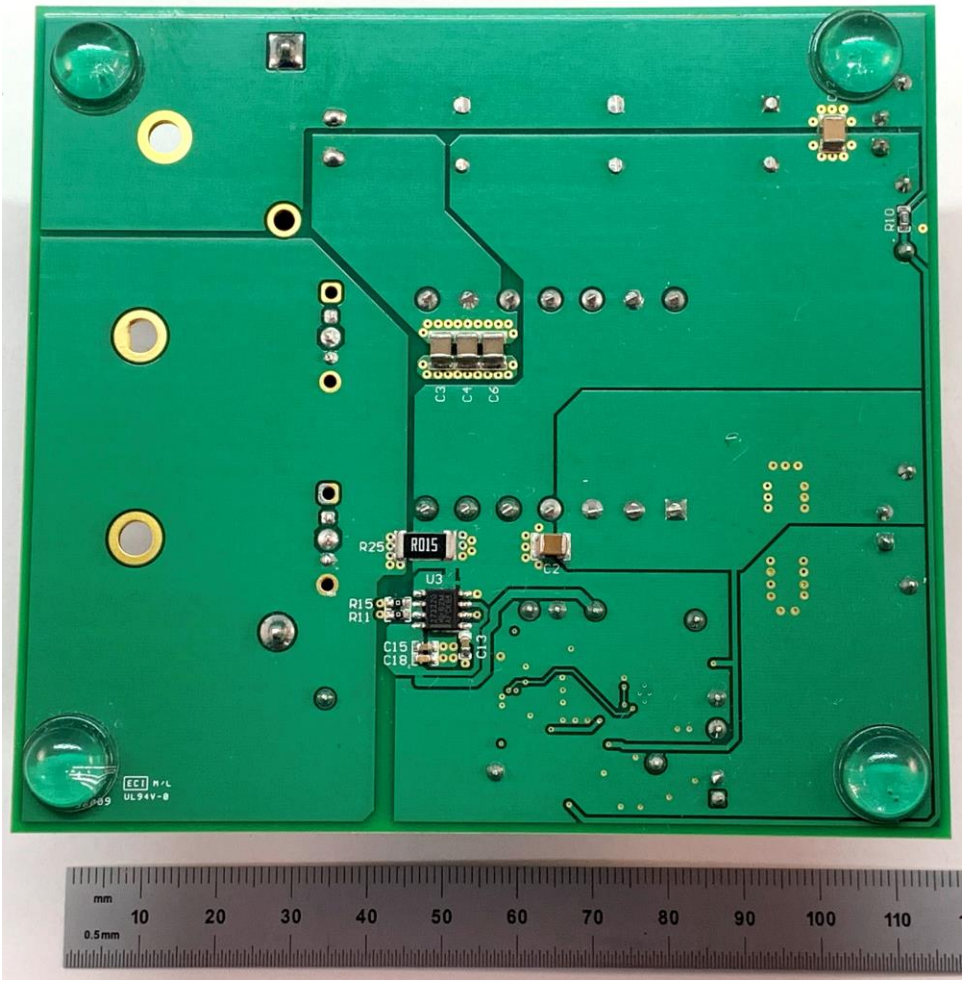
Adjustable Output Voltage 200-W SEPIC Power Supply Reference Design

TEXAS INSTRUMENTS

Description

This 200-W SEPIC converter supplies a non-isolated adjustable 5-V to 200-V output voltage with a maximum output current of 4 A. Output voltage is set using a 0% to 100% duty-cycle, pulse-width-modulation (PWM) input.





1 Test Prerequisites

1.1 Voltage and Current Requirements

Table 1. Voltage and Current Requirements

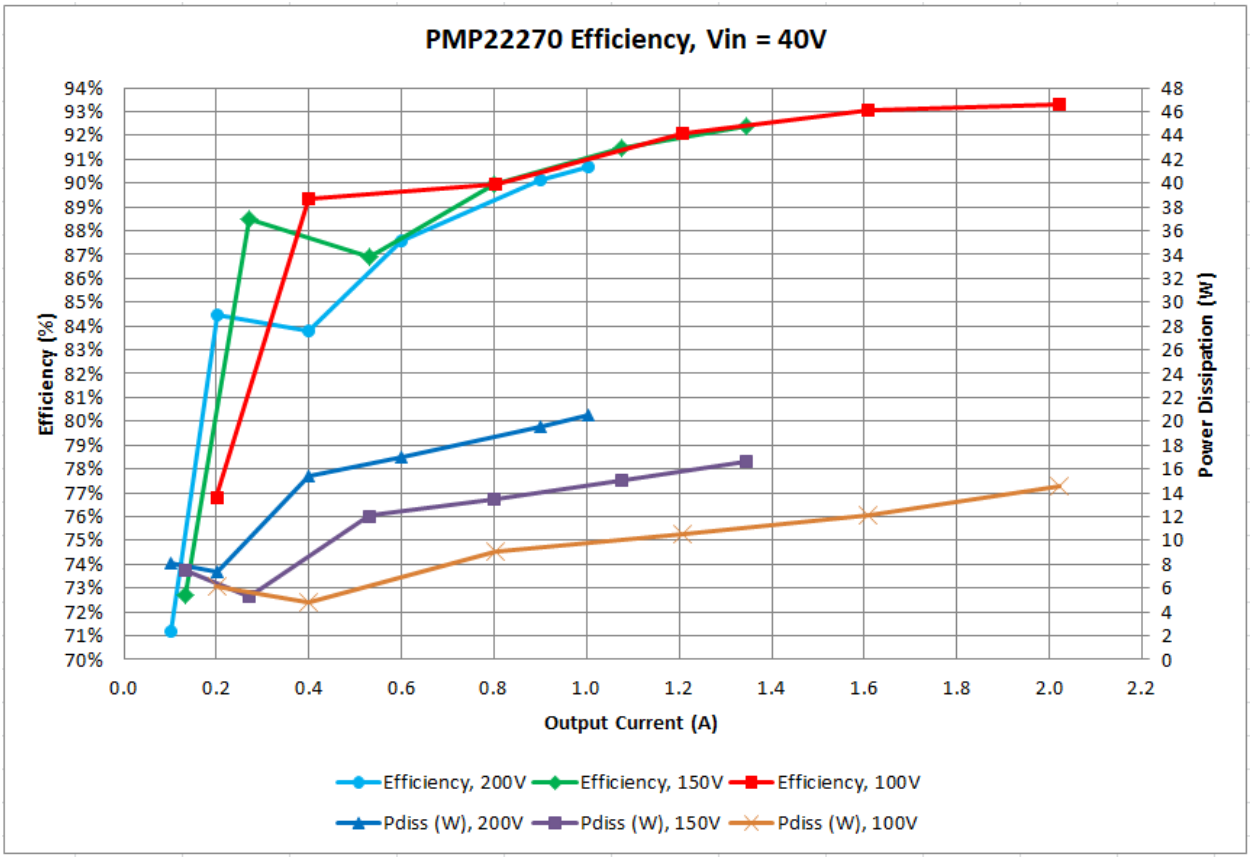
PARAMETER	SPECIFICATIONS
Input voltage range	38 V – 42 V, 40 V typical
Output voltage and current	5 V to 200 V, 4A maximum, non-isolated 200 V/1 A (200 W), PWM = 100 % duty cycle 100 V/2 A (200 W) , PWM = 49 % duty cycle 50 V/4 A (200 W) , PWM = 22 % duty cycle 5 V/4 A (20 W) , PWM = 0 % duty cycle
Switching frequency	250kHz +/- 20%
PWM input	1.5 V to 3.3 V, 100KHz, 0 % to 100 % duty cycle

1.2 Required Equipment

- Electronic or resistive load (200 W/ 5 A/ 200 V)
- Power supply capable of 50V and 8A (minimum)
- Oscilloscope and probes
- Digital Multimeters
- Function generator with adjustable amplitude, frequency and duty cycle
- Stability measurement device (Venable, 200V rated)

2 Testing and Results

2.1 Efficiency and Power Dissipation Graphs

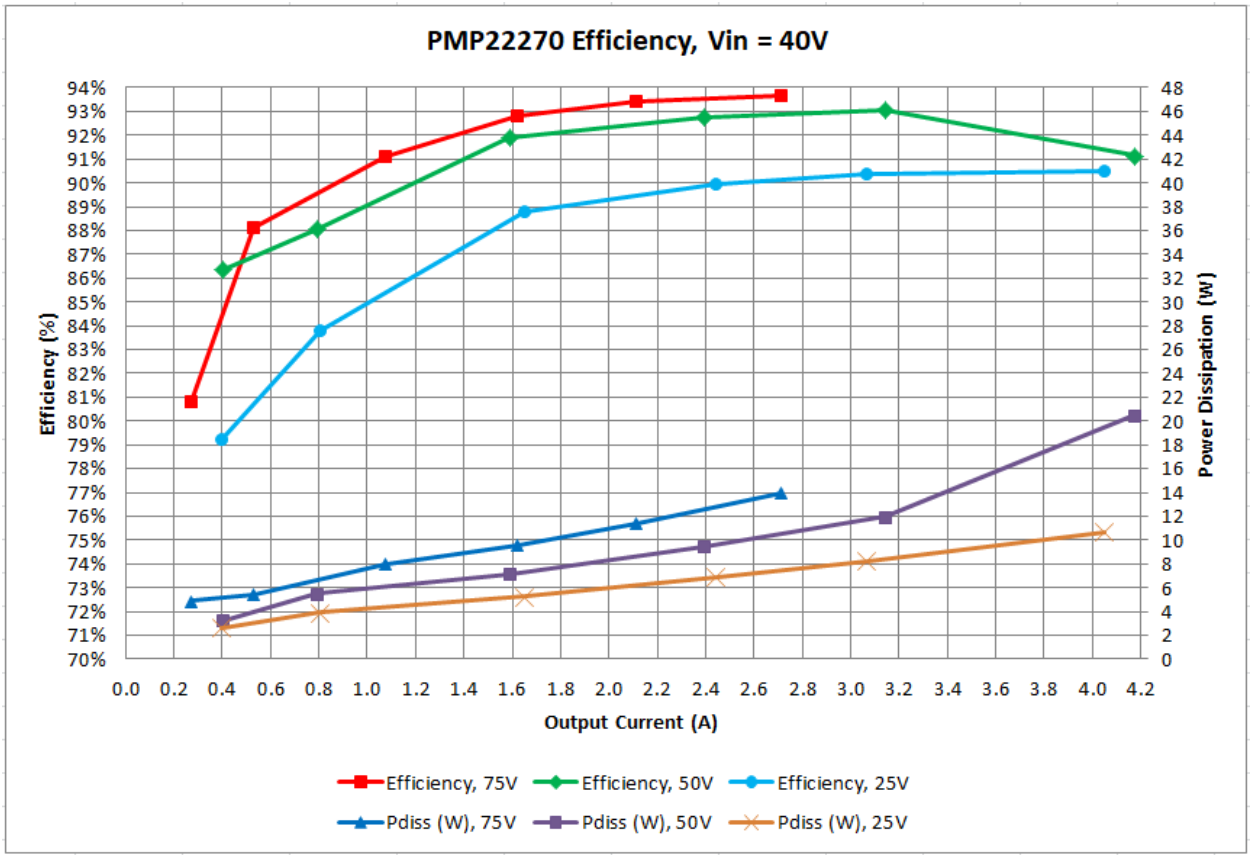


The above graph displays the efficiency and power dissipation of the converter with the output voltage set to 200V, 150V and 100V. Maximum output power was limited to 200W. The input voltage was set to 40V.

Vin	Iin	Vout	Iout	Po	Pin	Efficiency, 200V	Pdiss (W), 200V
40.3944	0.6947	199.546	0.100100	19.975	28.062	71.2%	8.087
40.1185	1.1813	199.530	0.200600	40.026	47.392	84.5%	7.366
40.0446	2.3800	199.535	0.400200	79.854	95.306	83.8%	15.452
40.0795	3.4130	199.537	0.600200	119.762	136.791	87.6%	17.029
40.1311	4.9510	199.158	0.899500	179.143	198.689	90.2%	19.546
40.0971	5.4930	199.057	1.003100	199.674	220.253	90.7%	20.579

Vin	Iin	Vout	Iout1	Po	Pin	Efficiency, 150V	Pdiss (W), 150V
40.3952	0.6819	150.595	0.133000	20.029	27.545	72.7%	7.516
40.3675	1.1373	150.574	0.269800	40.625	45.910	88.5%	5.285
40.2969	2.2810	150.595	0.530300	79.861	91.917	86.9%	12.057
40.2330	3.3290	150.421	0.801100	120.502	133.936	90.0%	13.433
40.1691	4.3960	150.316	1.074600	161.530	176.583	91.5%	15.054
40.1036	5.4550	150.345	1.344200	202.094	218.765	92.4%	16.671

Vin	Iin	Vout	Iout1	Po	Pin	Efficiency, 100V	Pdiss (W), 100V
40.3954	0.6512	101.000	0.200000	20.200	26.305	76.8%	6.105
40.3683	1.1190	101.005	0.399600	40.362	45.172	89.4%	4.811
40.3007	2.2400	101.096	0.803100	81.190	90.274	89.9%	9.083
40.2372	3.2920	101.064	1.206600	121.944	132.461	92.1%	10.517
40.1695	4.3520	101.082	1.609100	162.651	174.818	93.0%	12.167
40.0962	5.4590	101.075	2.021000	204.273	218.885	93.3%	14.613



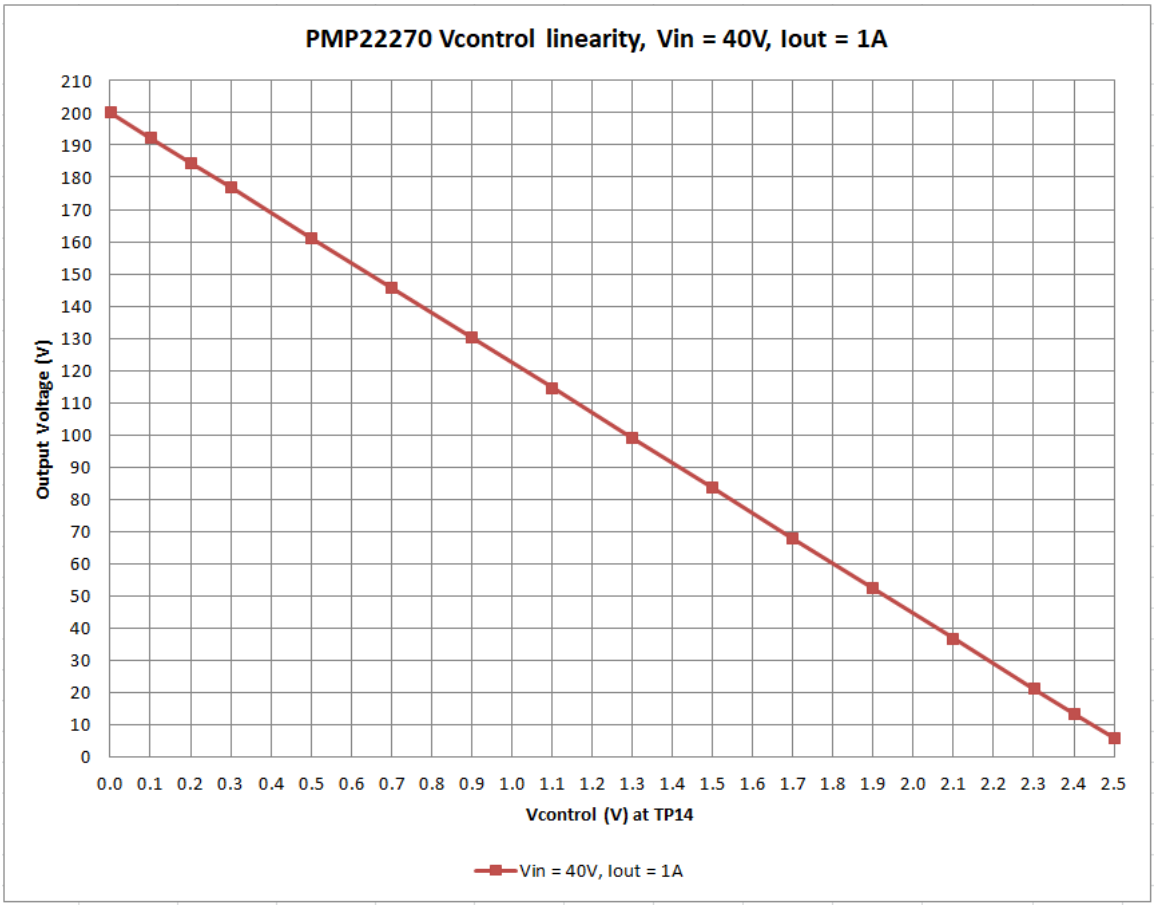
The above graph displays the efficiency and power dissipation of the converter with the output voltage set to 75V, 50V and 25V. Maximum output power was limited to 200W or 4A. The input voltage was set to 40V.

Vin	Iin	Vout	Iout1	Po	Pin	Efficiency, 75V	Pdiss (W), 75V
40.3870	0.6271	75.880	0.269700	20.465	25.327	80.8%	4.862
40.3479	1.1323	75.878	0.530500	40.253	45.686	88.1%	5.433
40.2676	2.2250	76.094	1.072900	81.641	89.595	91.1%	7.954
40.1879	3.3020	76.080	1.618400	123.128	132.700	92.8%	9.573
40.1134	4.2900	76.026	2.114000	160.719	172.086	93.4%	11.368
40.0330	5.5100	76.252	2.710000	206.643	220.582	93.7%	13.939

Vin	Iin	Vout	Iout1	Po	Pin	Efficiency, 50V	Pdiss (W), 50V
40.3719	0.5806	50.481	0.401000	20.243	23.440	86.4%	3.197
40.3222	1.1371	50.765	0.795300	40.373	45.850	88.1%	5.477
40.2330	2.1810	50.782	1.587500	80.616	87.748	91.9%	7.132
40.1696	3.2590	50.783	2.391000	121.422	130.913	92.8%	9.491
40.0985	4.2780	50.767	3.144000	159.611	171.541	93.0%	11.930
40.0102	5.7690	50.361	4.177000	210.358	230.819	91.1%	20.461

Vin	Iin	Vout	Iout1	Po	Pin	Efficiency, 25V	Pdiss (W), 25V
40.3142	0.3131	25.105	0.398300	9.999	12.622	79.2%	2.623
40.3727	0.5960	25.090	0.803800	20.167	24.062	83.8%	3.895
40.3131	1.1560	25.044	1.651900	41.370	46.602	88.8%	5.232
40.2634	1.6915	25.060	2.444000	61.247	68.106	89.9%	6.859
40.2537	2.1100	25.056	3.063000	76.747	84.935	90.4%	8.189
40.2067	2.7900	25.052	4.051000	101.486	112.177	90.5%	10.691

2.2 Vcontrol-to-output voltage linearity graph



This graph displays the measured output voltage when Vcontrol is varied between 0V-2.5V. The input voltage was set to 40V input and the output was loaded to 1A.

2.2.1 Vcontrol-to-output voltage linearity data

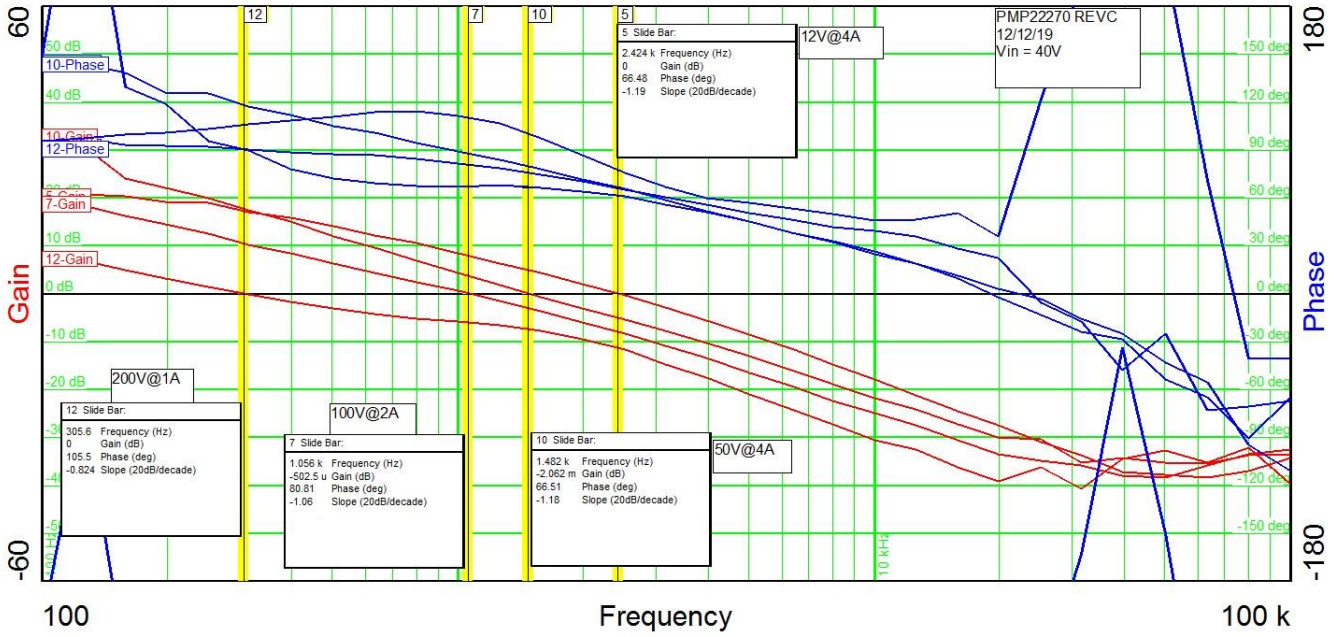
Vin = 40V, Iout = 1A

Duty Cycle (%)	Vcontrol TP14 (V)	Vout (V) actual	Vout (V) calc	Vout error (%)
100	0.000	200.09	200.18	0.0
96	0.100	192.35	192.37	0.0
92	0.200	184.56	184.56	0.0
88	0.300	176.80	176.74	0.0
80	0.500	161.24	161.12	0.1
72	0.700	145.78	145.49	0.2
64	0.900	130.21	129.86	0.3
56	1.100	114.66	114.24	0.4
48	1.300	99.09	98.61	0.5
40	1.500	83.50	82.98	0.6
32	1.700	67.98	67.36	0.9
24	1.900	52.39	51.73	1.3
16	2.100	36.83	36.10	2.0
8	2.300	21.25	20.48	3.8
4	2.400	13.43	12.66	6.0
0	2.500	5.64	4.85	16.3

This table displays the measured output voltage from the graph above when Vcontrol is varied between 0V-2.5V. The calculated duty cycle input (ideal) and output voltage (ideal) are also listed along with the output voltage error.

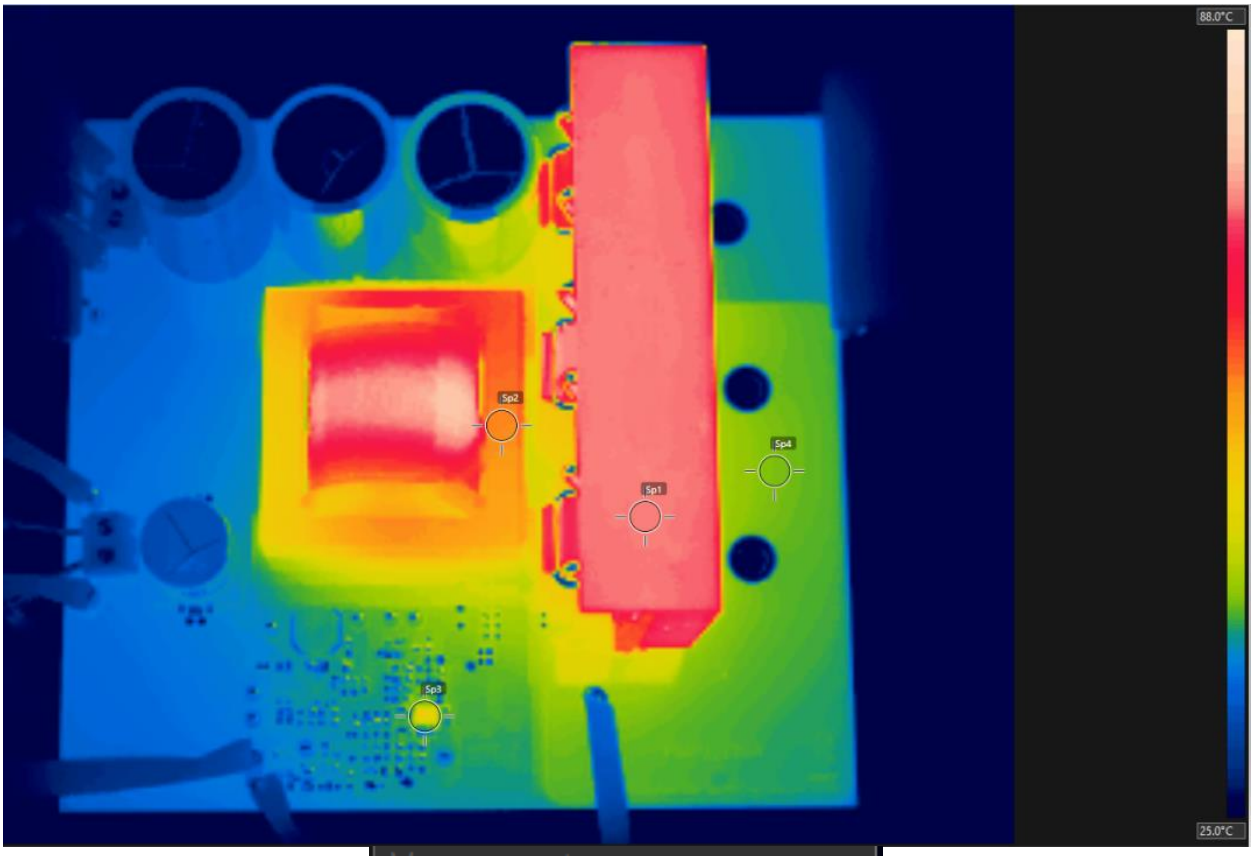
2.3 Loop Gain

Graph 1. Vin = 40V



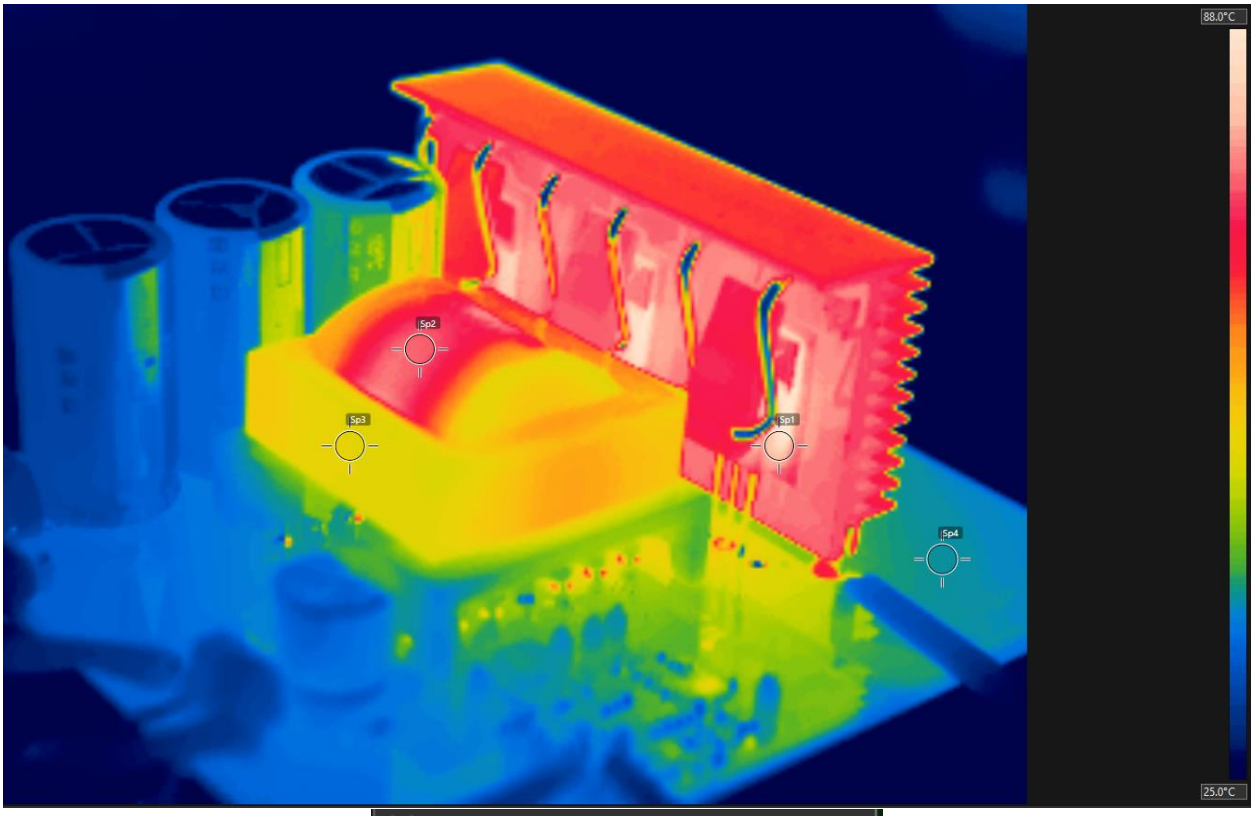
Vout = 200V@1A (200W)	Bandwidth = 0.31 kHz	Phase Margin = 106 degrees
Vout = 100V@2A (200W)	Bandwidth = 1.06 kHz	Phase Margin = 80.8 degrees
Vout = 50V@4A (200W)	Bandwidth = 1.48 kHz	Phase Margin = 66.5 degrees
Vout = 12V@4A (48W)	Bandwidth = 2.42 kHz	Phase Margin = 66.5 degrees

2.4 Thermal Images

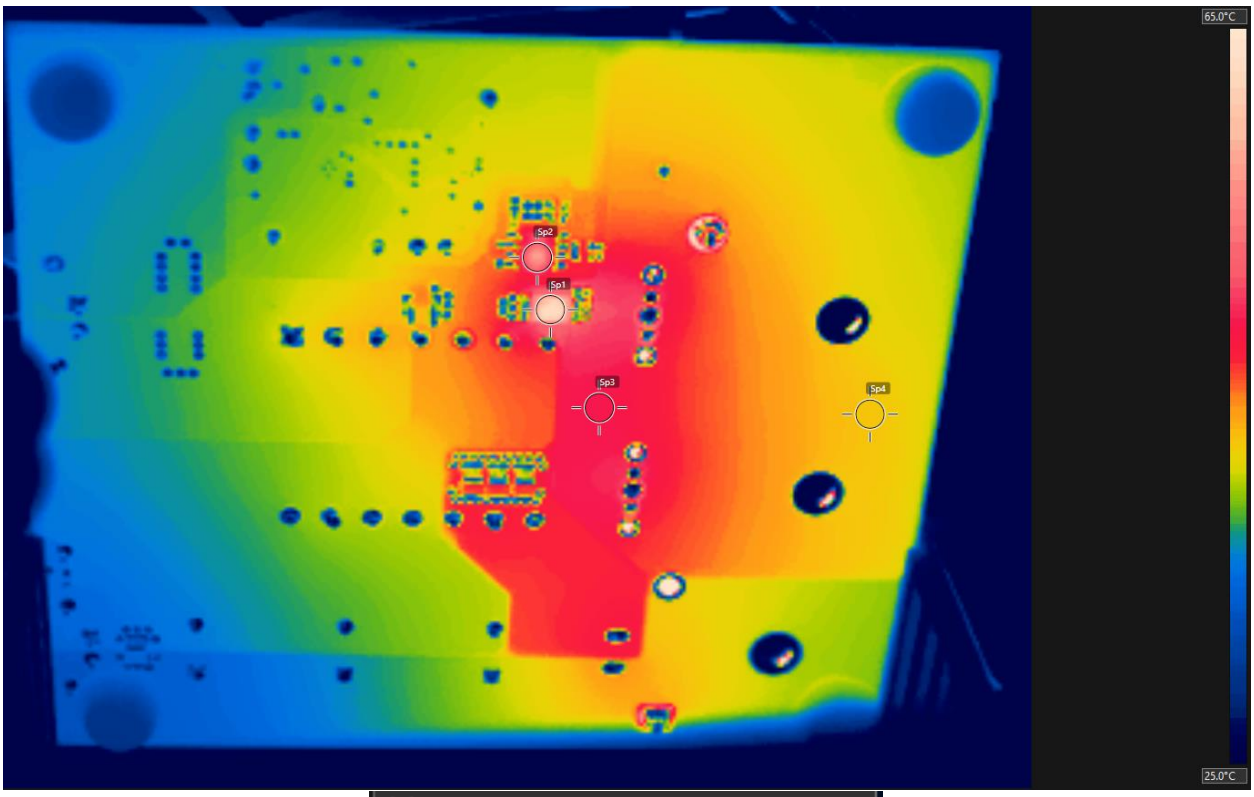


Measurements	
Sp1	76.2 °C
Sp2	63.2 °C
Sp3	55.4 °C
Sp4	45.5 °C

All thermal images show the operating temperature of the board with 40V input and 100V@2A output. The images were captured at room temperature after operating for 30 minutes and no air flow.



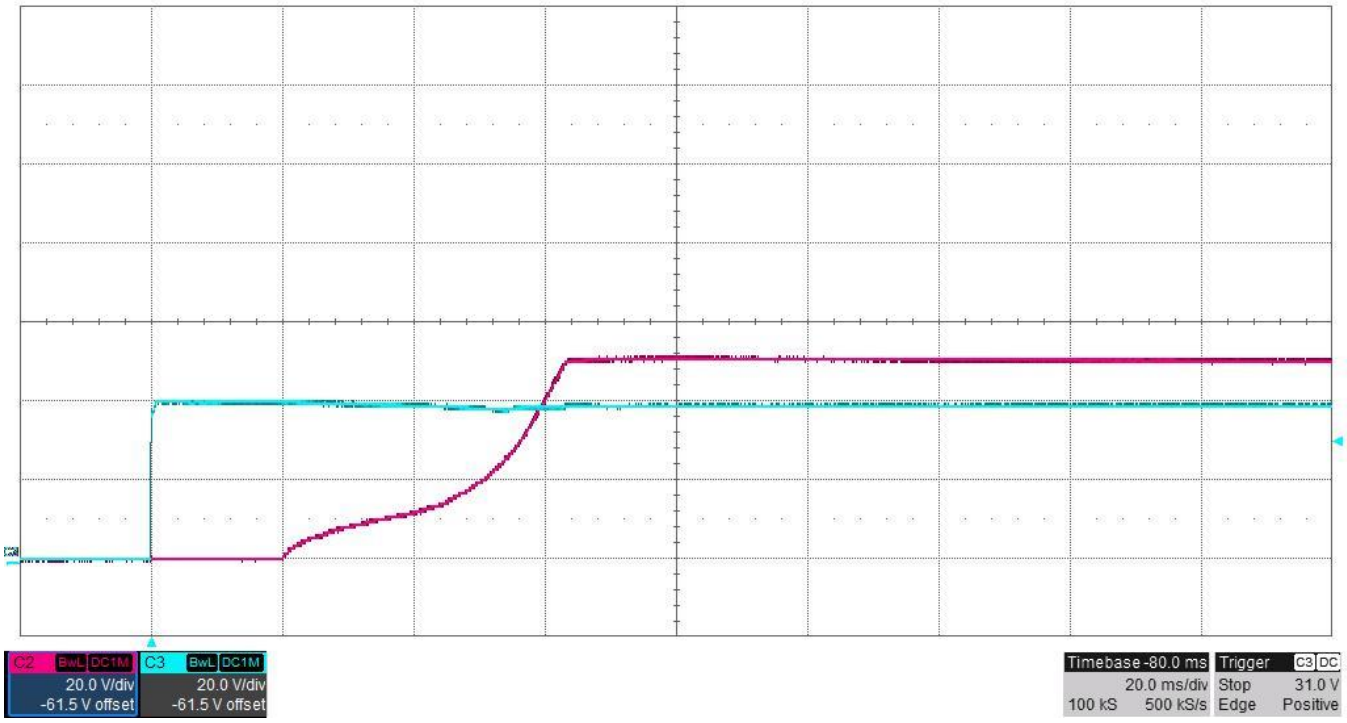
Measurements	
Sp1	85.6 °C
Sp2	77.2 °C
Sp3	56.3 °C
Sp4	43.3 °C



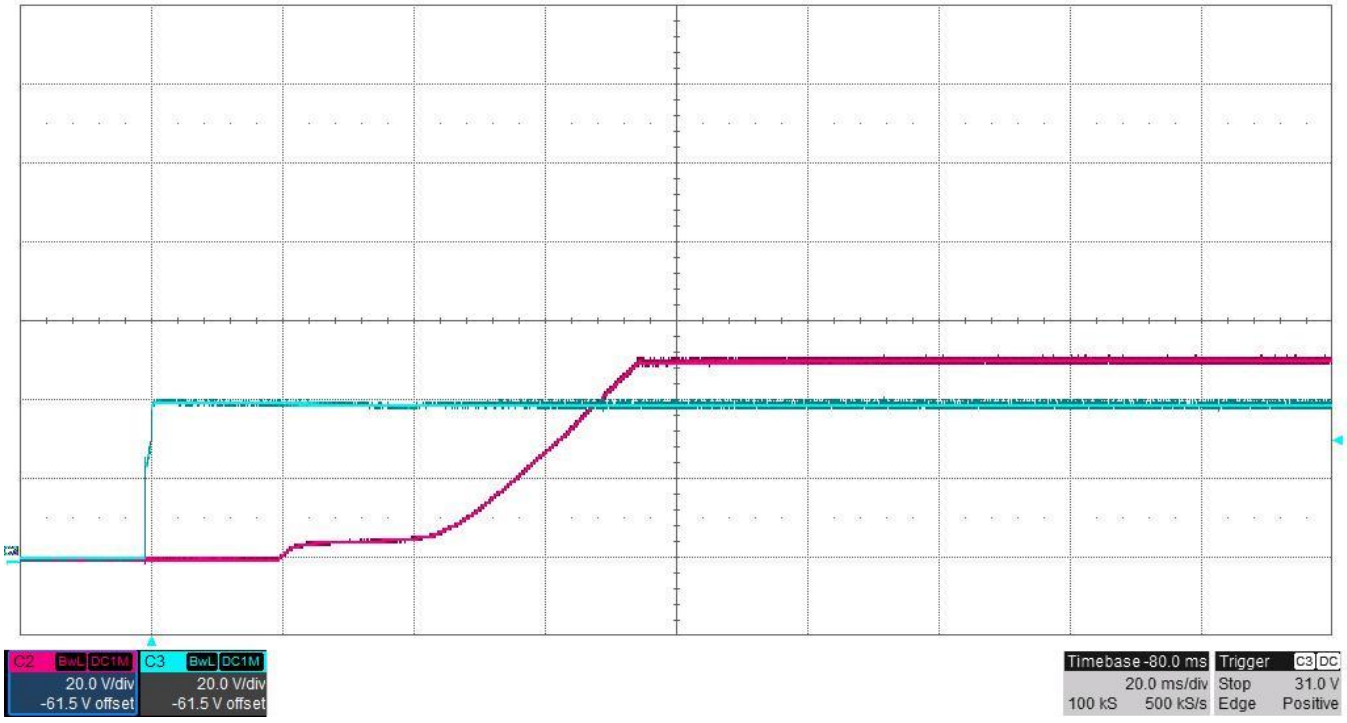
Measurements	
Sp1	63.4 °C
Sp2	58.1 °C
Sp3	50.2 °C
Sp4	44.1 °C

3 Waveforms

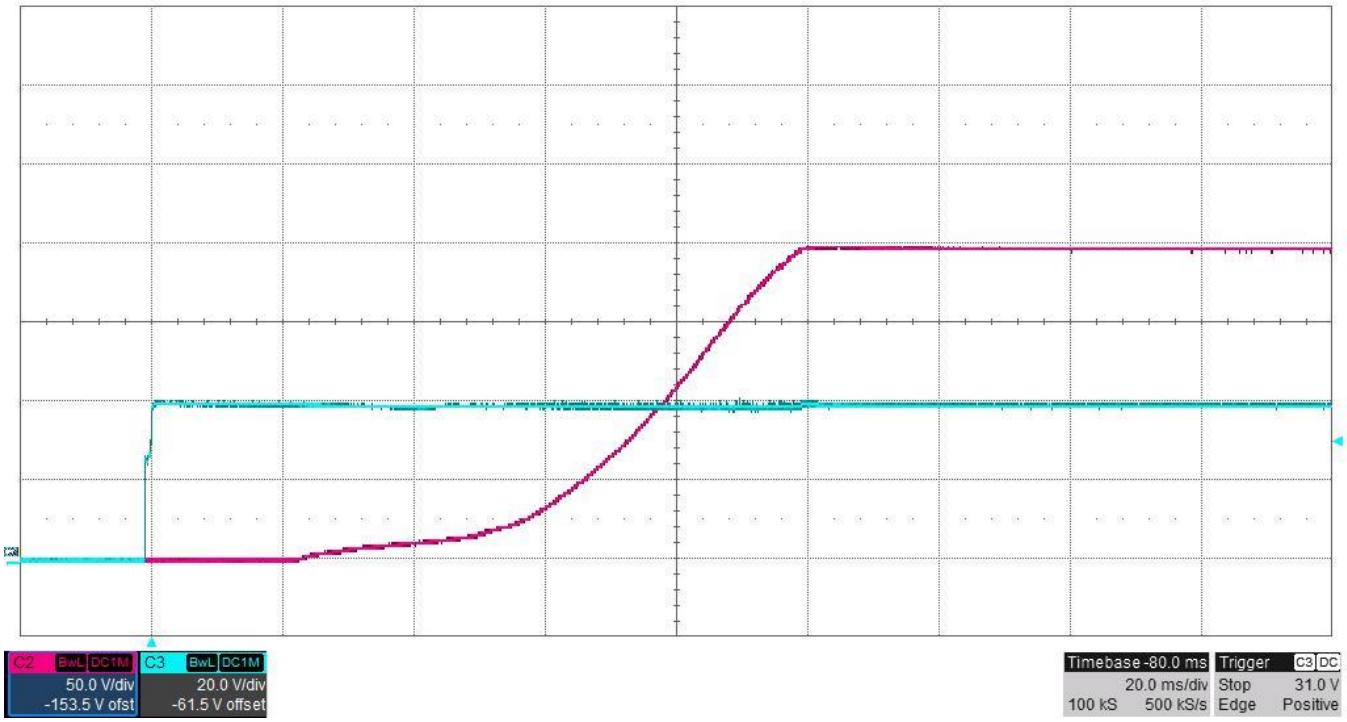
3.1 Startup Sequence



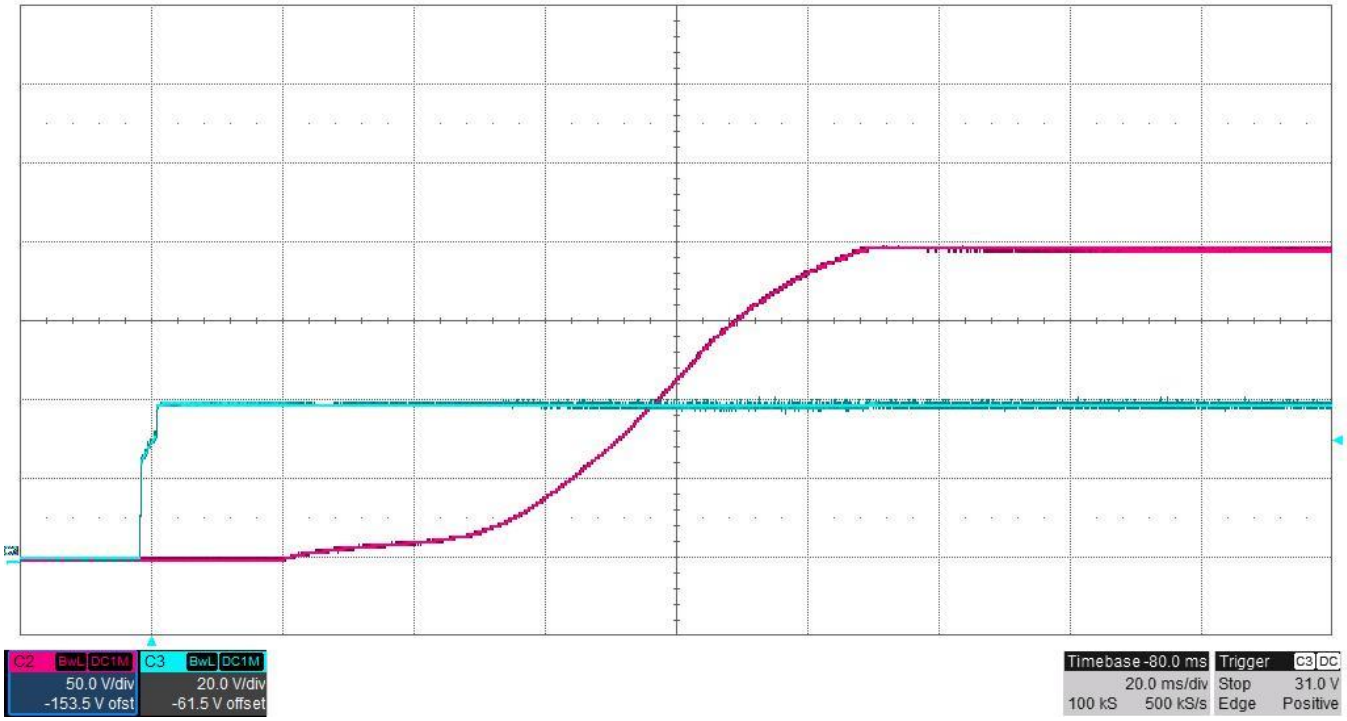
Start-up sequence with Vin applied, Vin = 40V (Blue), 50V @ 0A (Red)



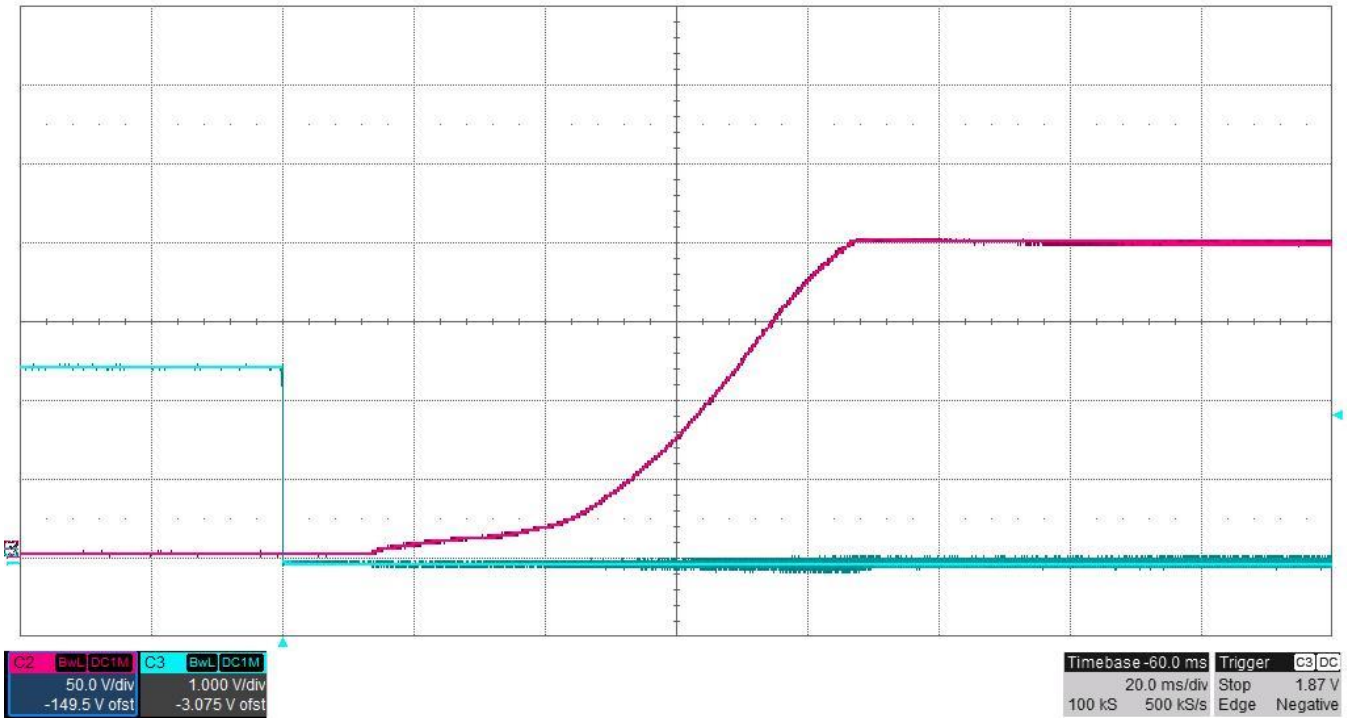
Start-up sequence with Vin applied, Vin = 40V (Blue), 50V @ 4A (Red)



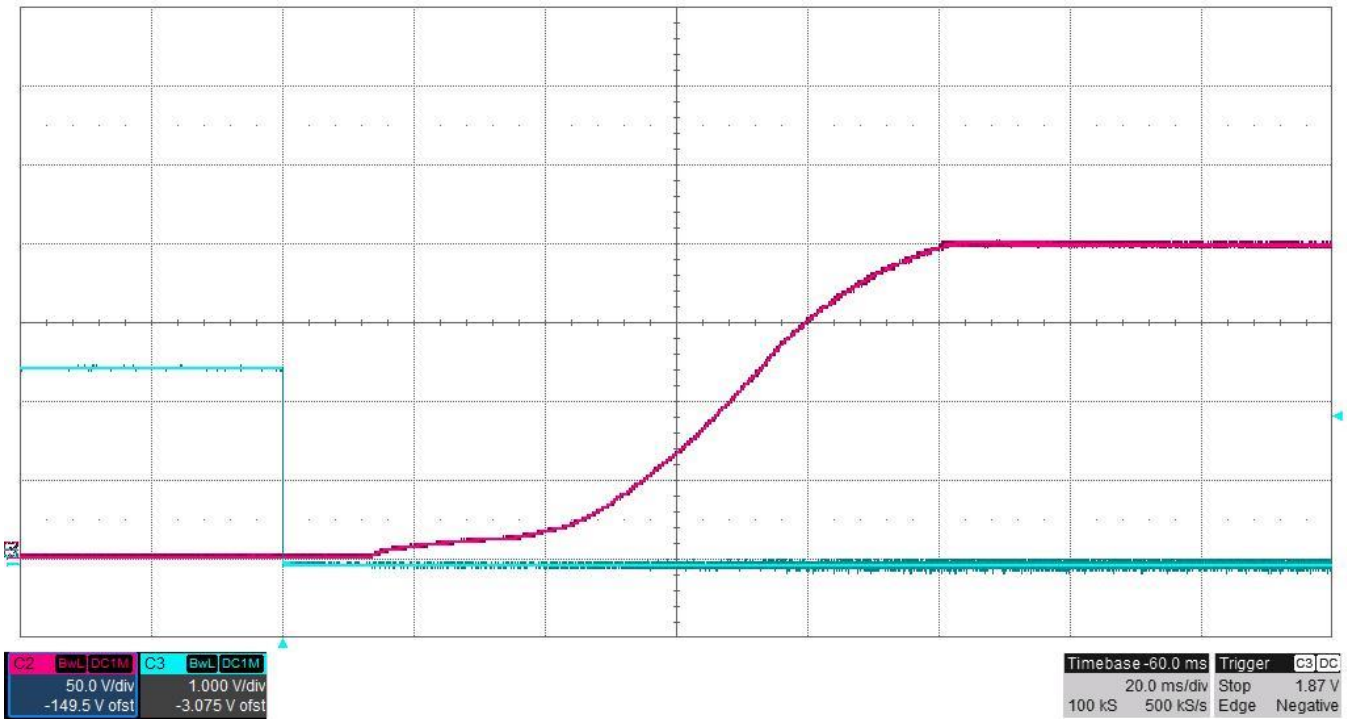
Start-up sequence with Vin applied, Vin = 40V (Blue), 200V @ 0A (Red)



Start-up sequence with Vin applied, Vin = 40V (Blue), 200V @ 1A (Red)

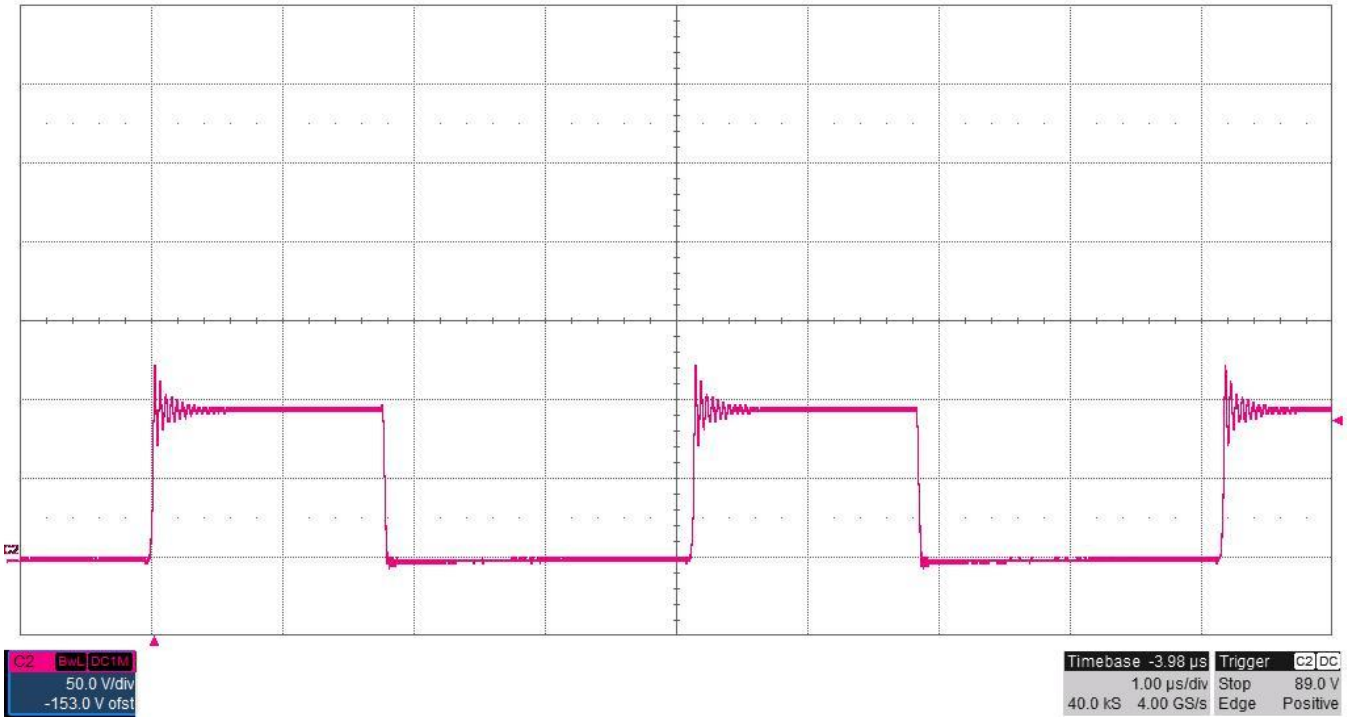


Start-up sequence with DISABLE input pulled low, DISABLE (Blue), 200V @ 0A (Red), Vin = 40V

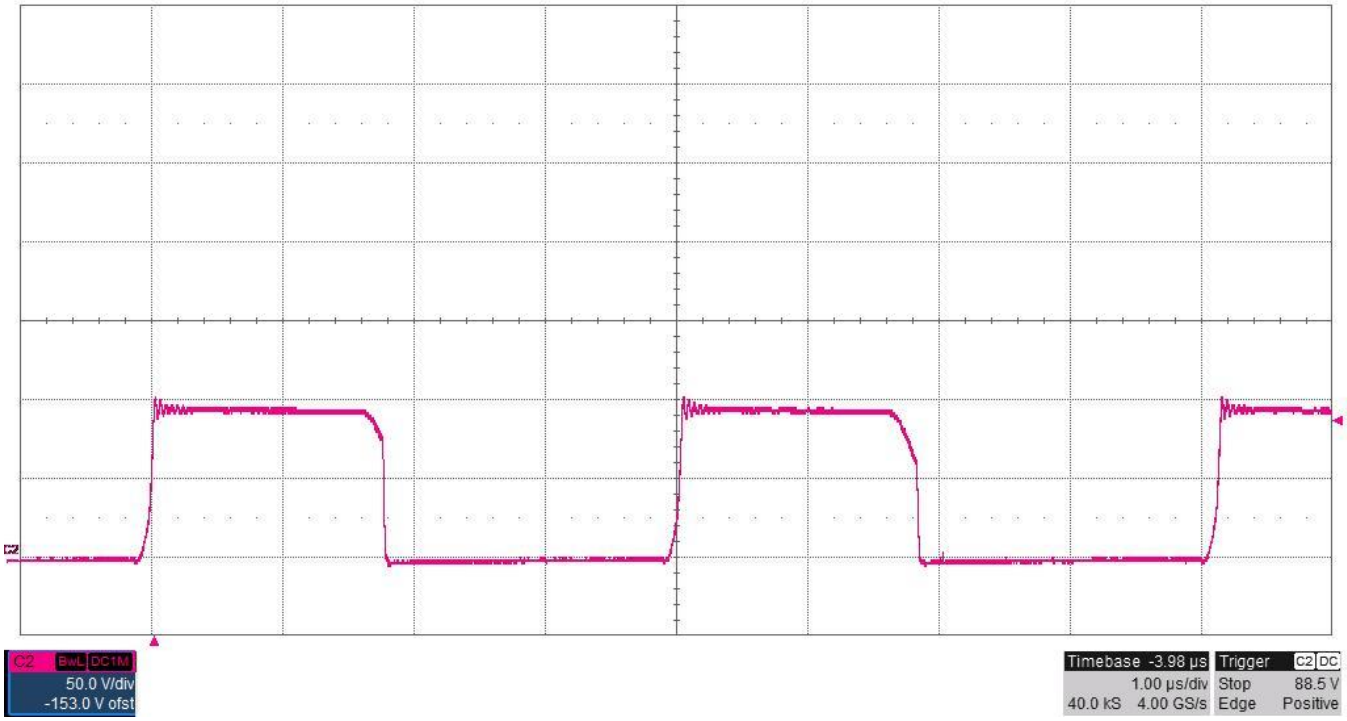


Start-up sequence with DISABLE input pulled low, DISABLE (Blue), 200V @ 1A (Red), Vin = 40V

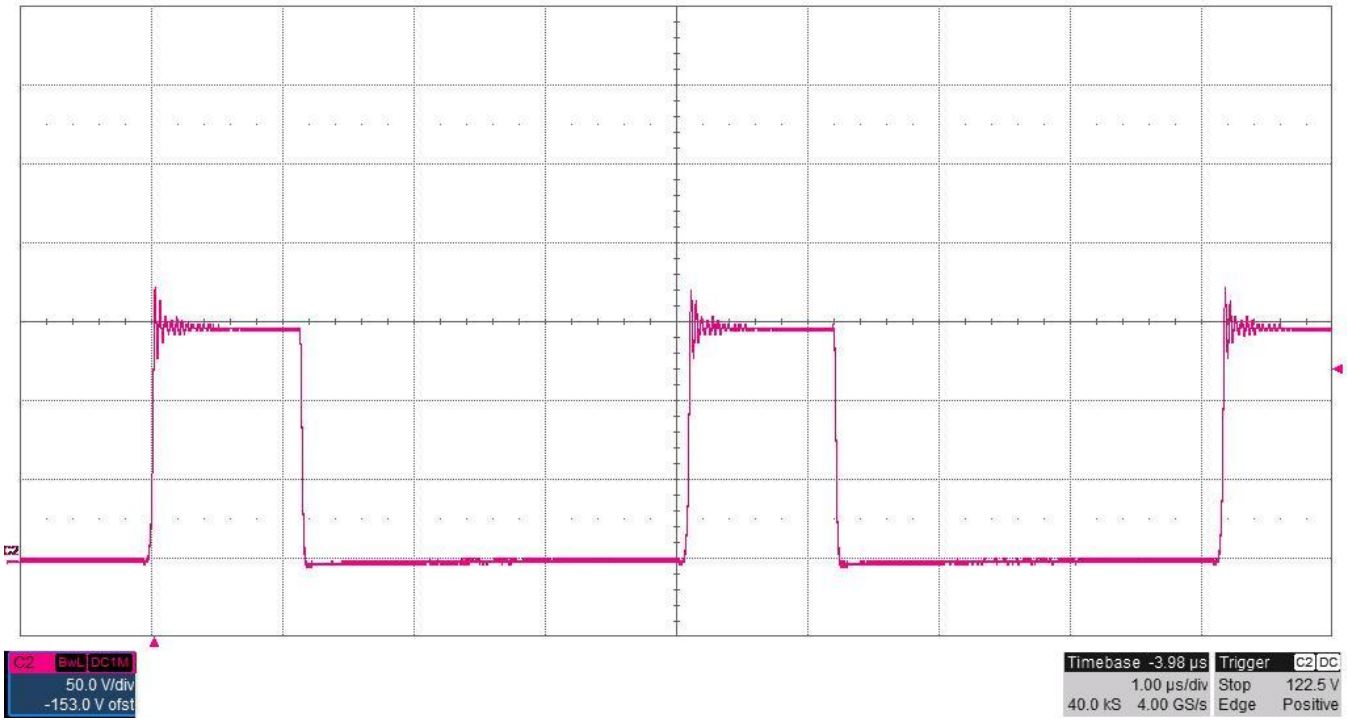
3.2 FET Switch Node



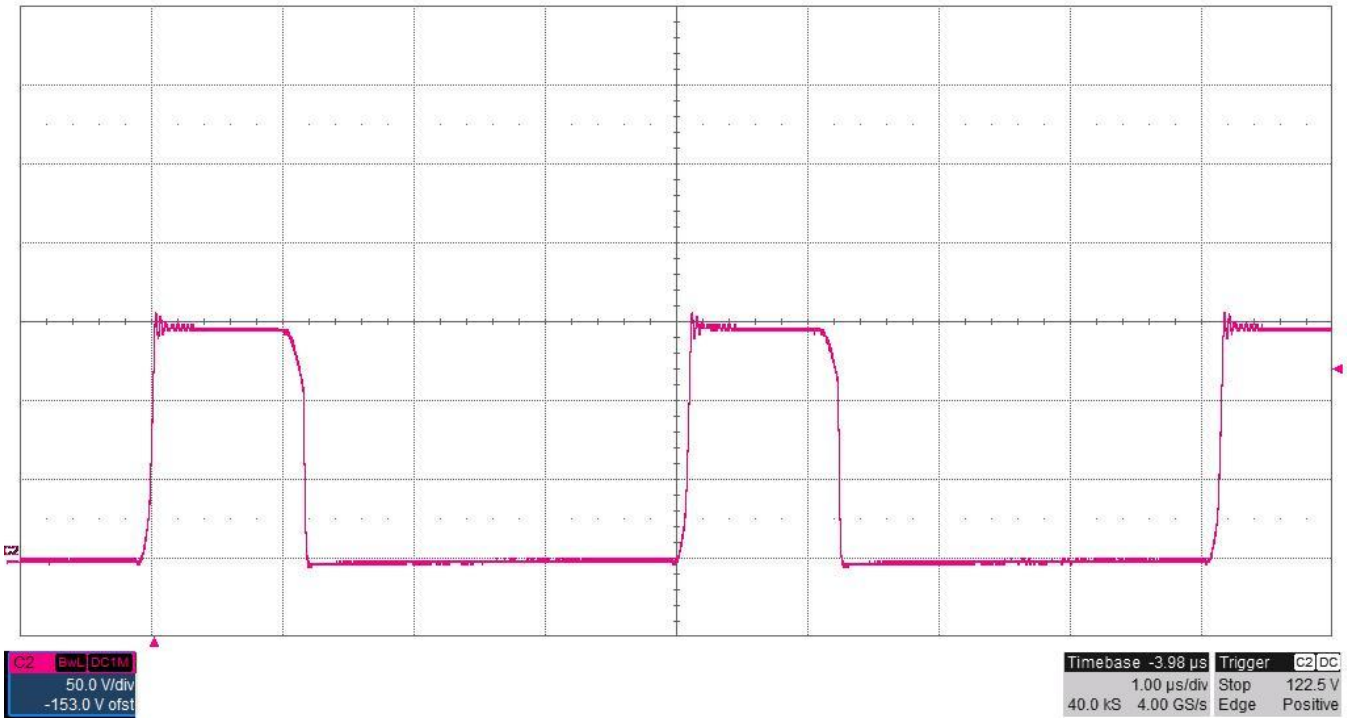
Switch node of FET with Vin = 40V, Vout = 50V@4A



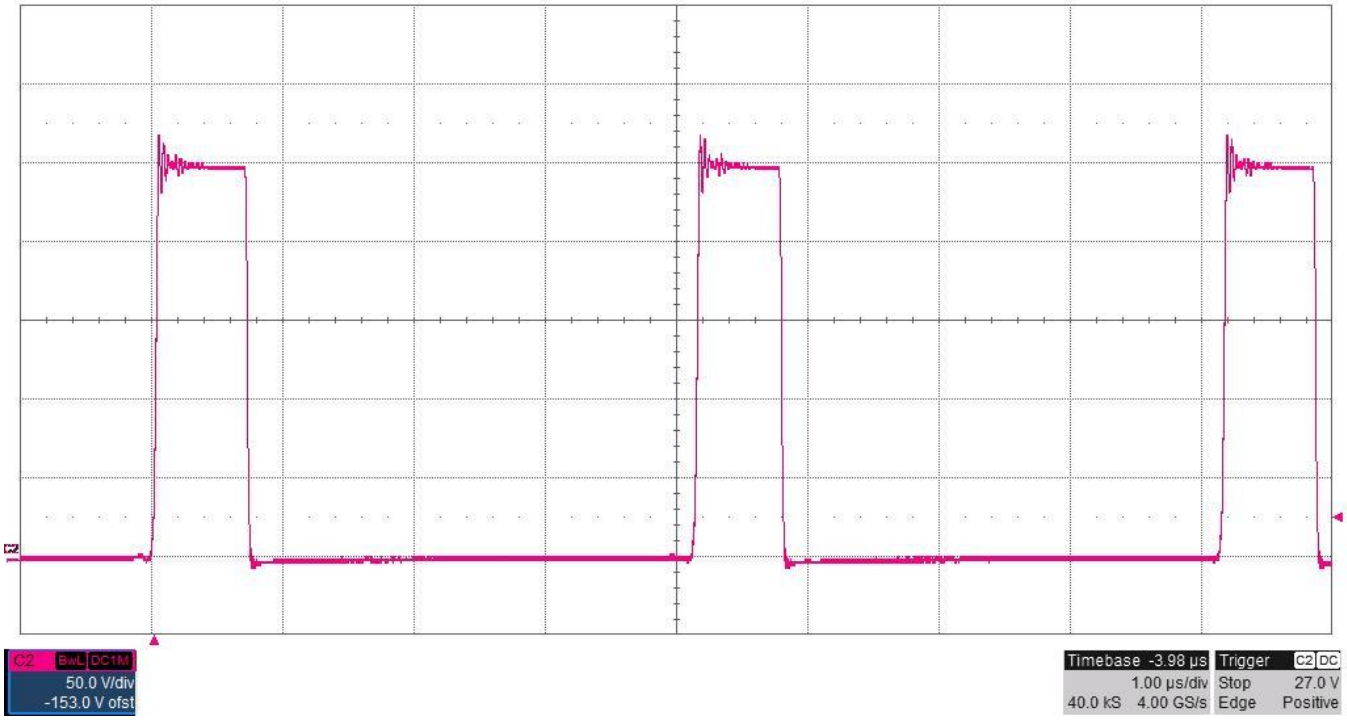
Switch node of FET with Vin = 40V, Vout = 50V@0.65A, DCM operation



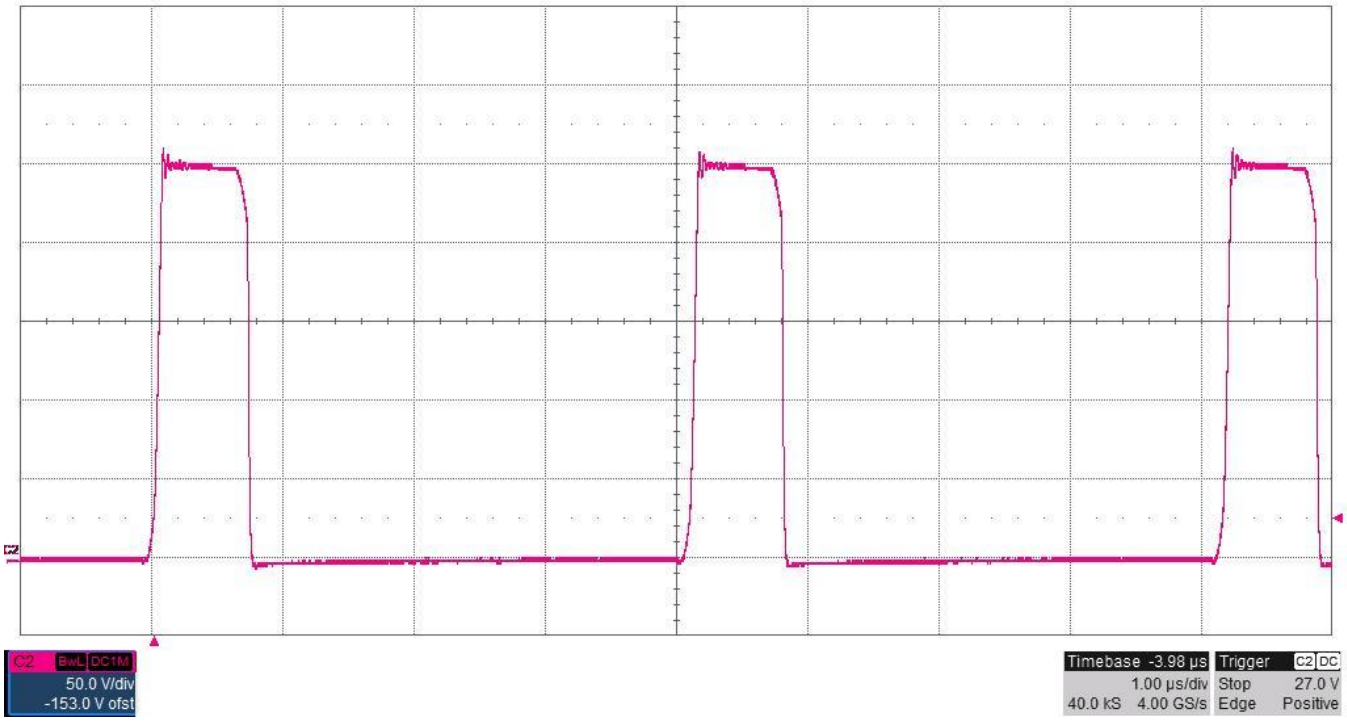
Switch node of FET with Vin = 40V, Vout = 100V@2A



Switch node of FET with Vin = 40V, Vout = 100V@0.50A, DCM operation

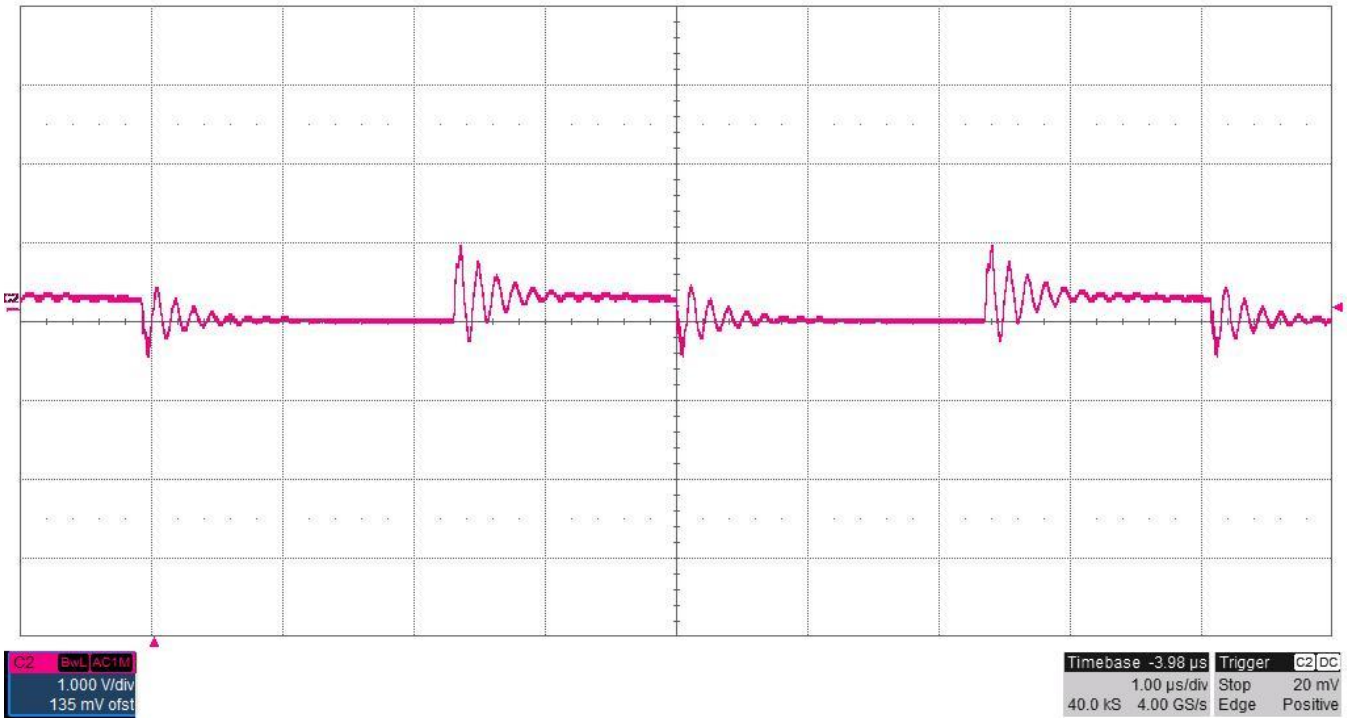


Switch node of FET with Vin = 40V, Vout = 200V@1A

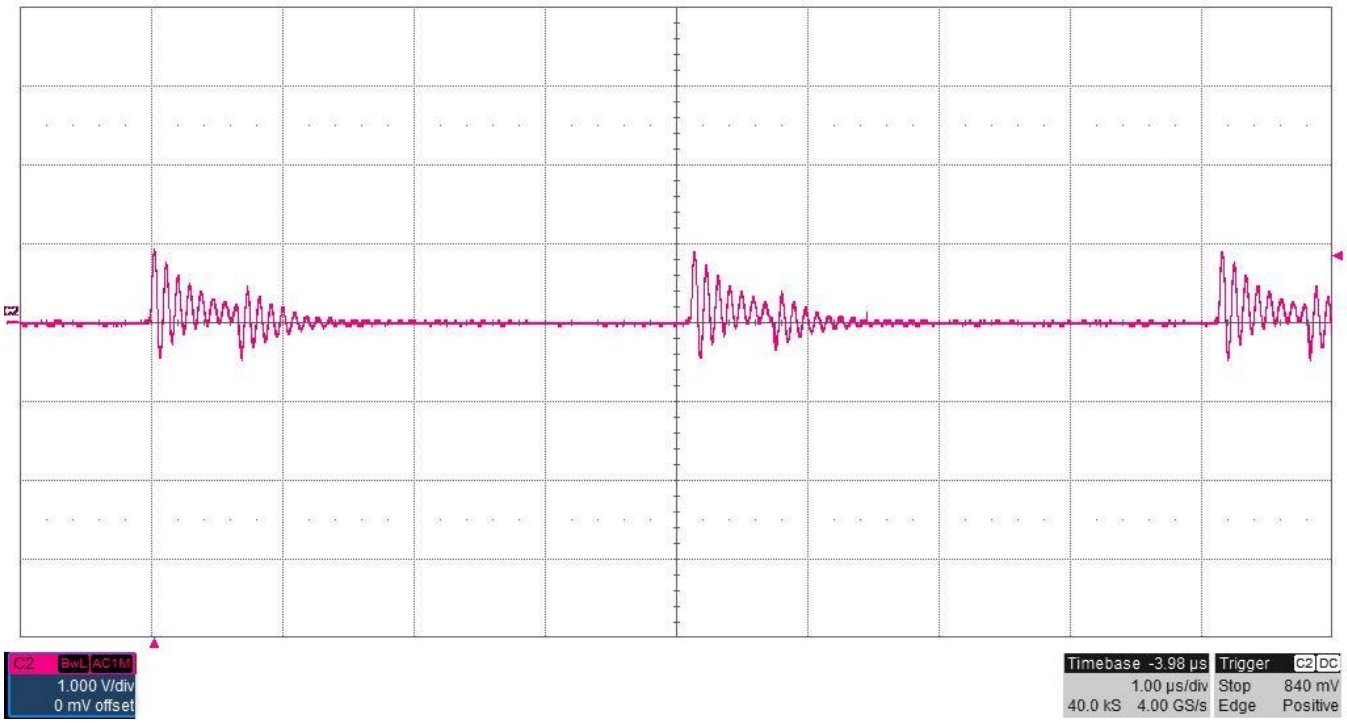


Switch node of FET with Vin = 40V, Vout = 200V@0.28A, DCM operation

3.3 Output Voltage Ripple

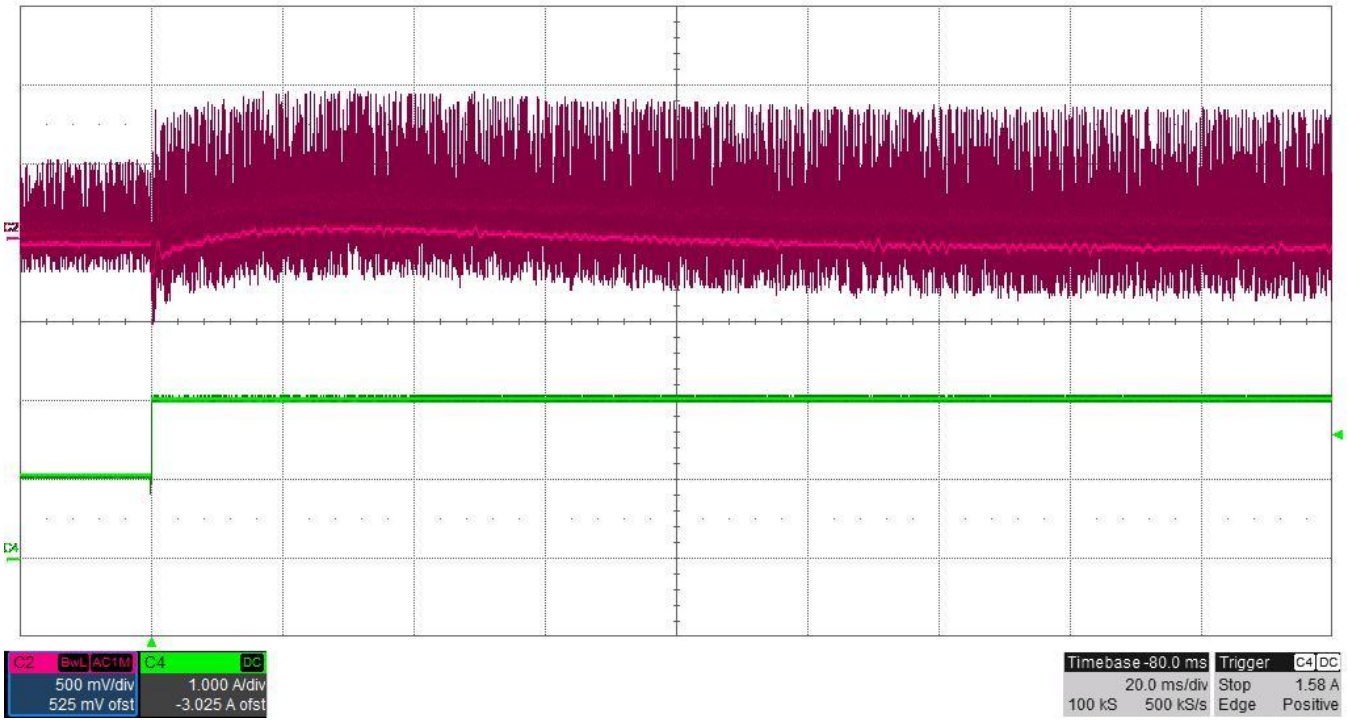


Output ripple voltage with Vin = 40V, Vout = 50V@4A, Bandwidth = 20MHz

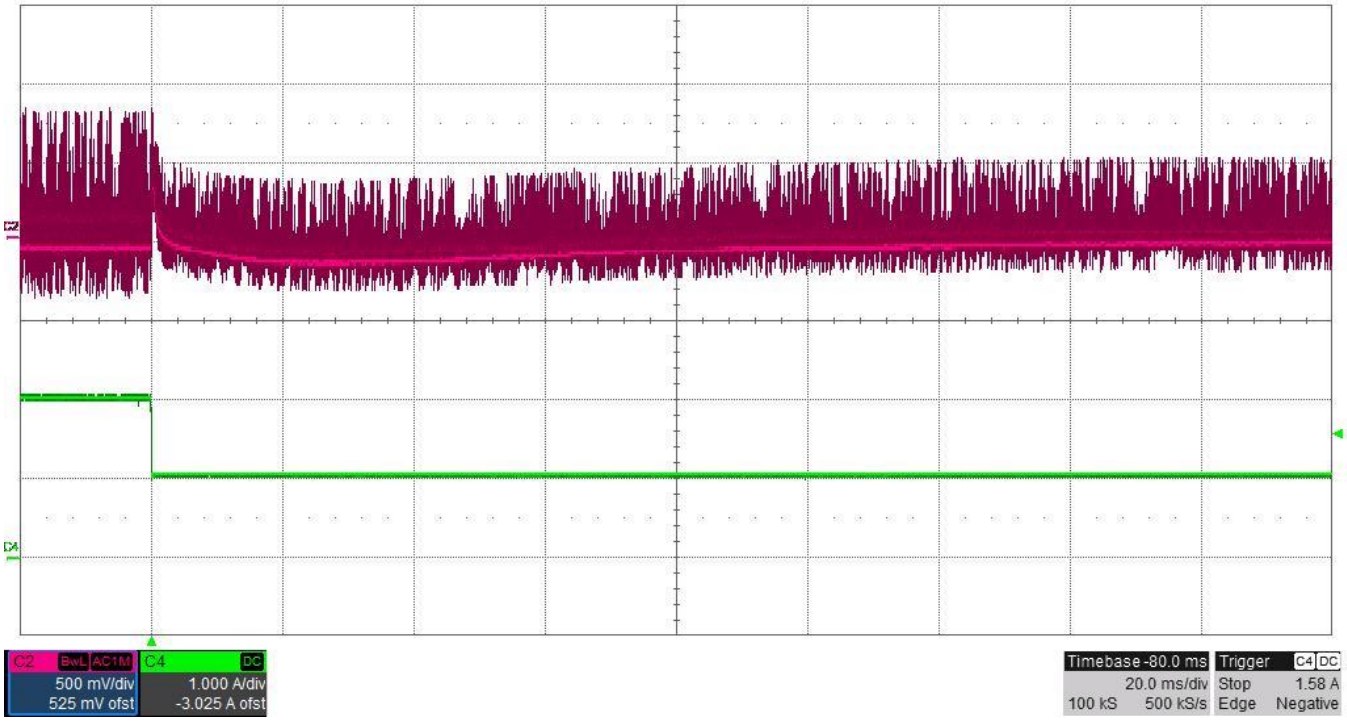


Output ripple voltage with Vin = 40V, Vout = 200V@1A, Bandwidth = 20MHz

3.4 Load Transients

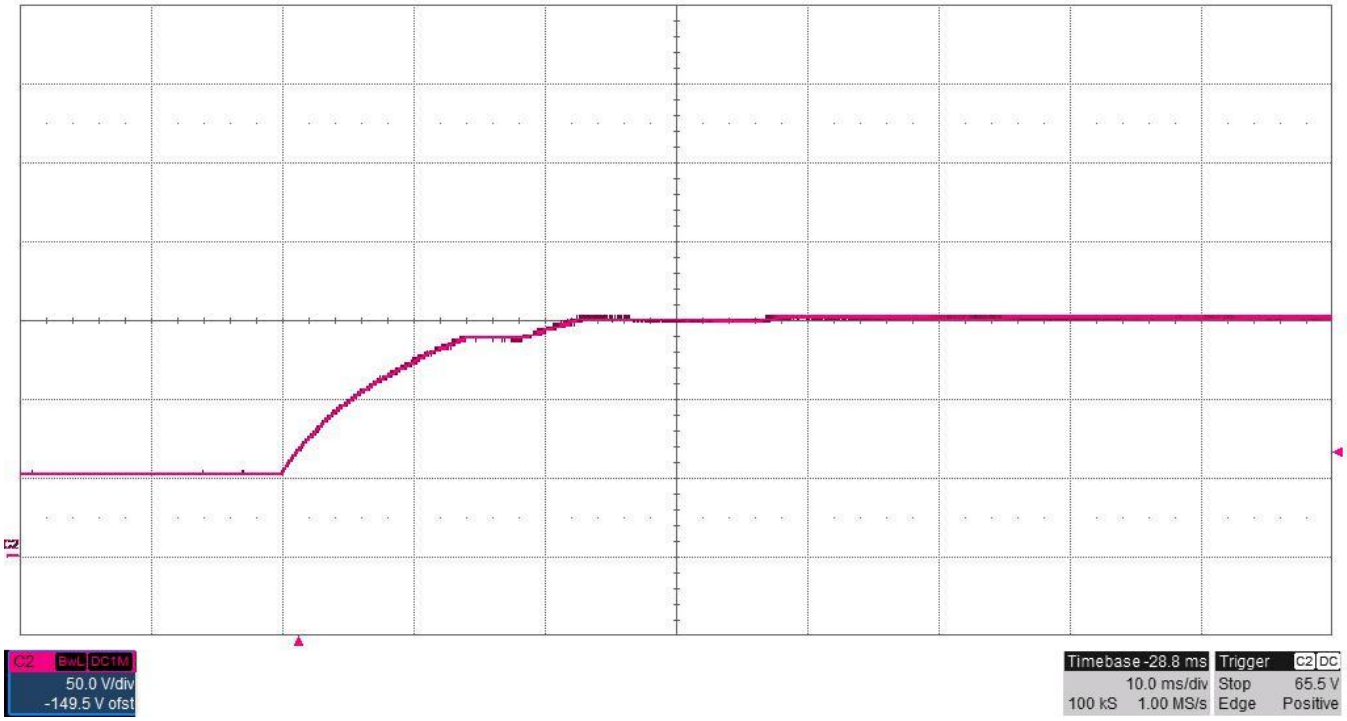


1A to 2A output load transient (Green) with the output set to 100V (Red, AC coupled), Vin = 40V

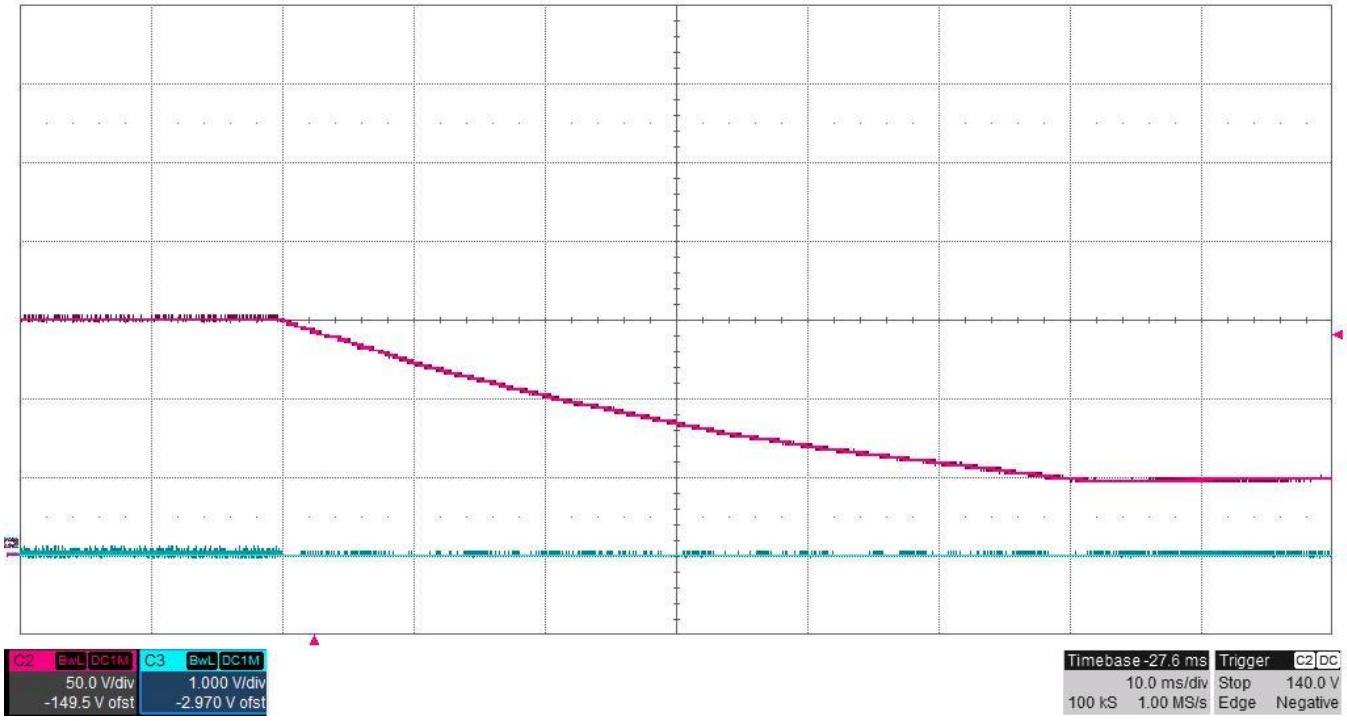


1A to 2A output load transient (Green) with the output set to 100V (Red, AC coupled), Vin = 40V

3.5 Vout change with PWM input



The output voltage is commanded to increase from 50V to 150V with by increasing the PWM input at J3 from 22% to 74% (PWM; 2.5V, freq = 100KHz). The output is loaded with a 112 ohm resistive load. Vin = 40V



The output voltage is commanded to decrease from 150V to 50V with by decreasing the PWM input at J3 from 74% to 22% (PWM; 2.5V, freq = 100KHz). The output is loaded with a 112 ohm resistive load. Vin = 40V

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