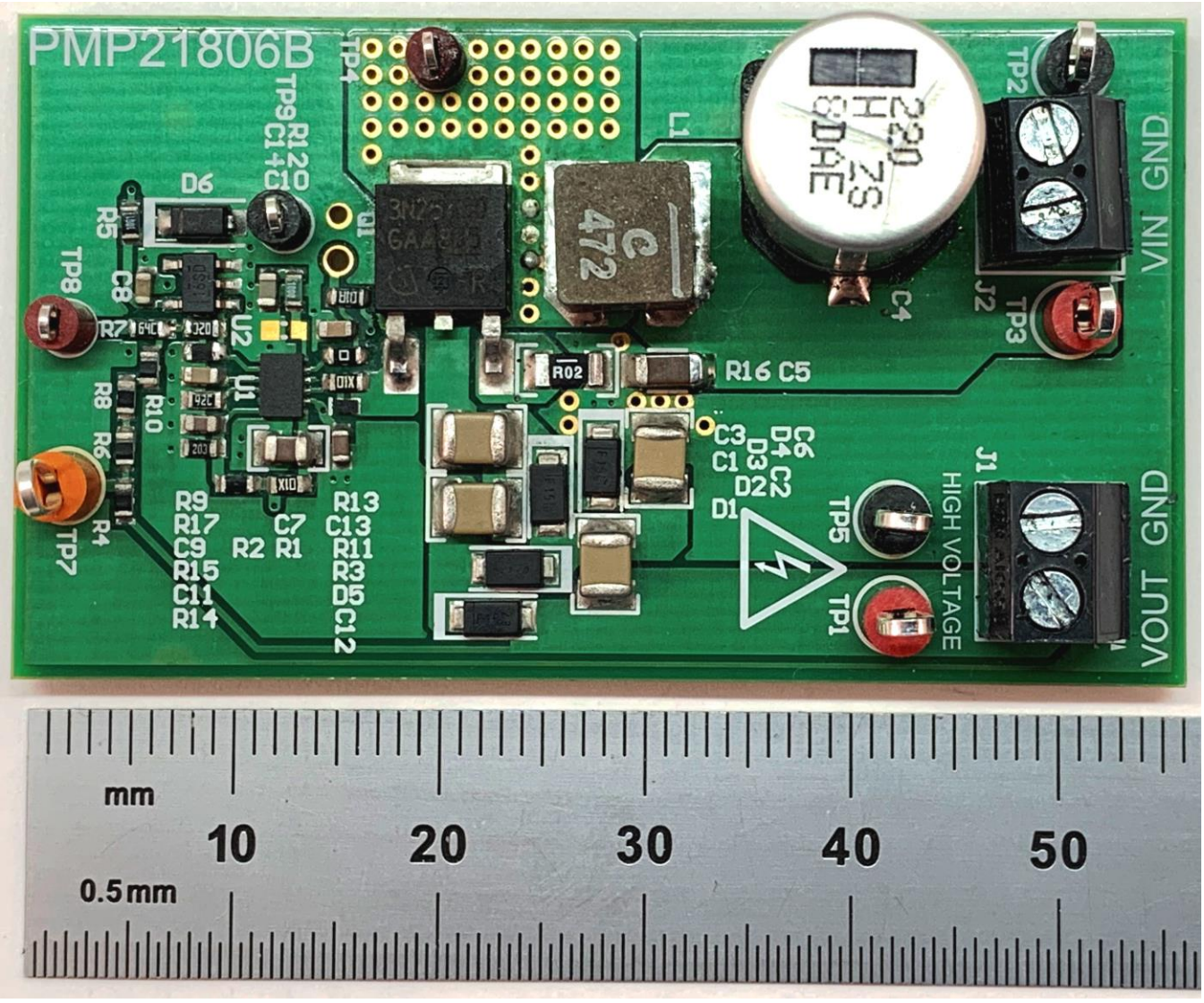
Test Report: PMP22155

High Voltage Inverting Buck-Boost Converter Reference Design for ADAS Applications

Description

This non-isolated design supplies an adjustable output voltage between -150V and -250V at 10mA for LIDAR applications. It operates over an automotive input voltage range of 6V - 40V and accepts a control voltage from 0V to 3V for output voltage adjustment. Utilizing a single inductor and operating in Discontinuous Conduction Mode (DCM), this converter offers a compact form factor and low cost.



1 Test Prerequisites

1.1 Voltage and Current Requirements

Table 1. Voltage and Current Requirements

PARAMETER	SPECIFICATIONS
Input voltage range	6V - 40V
Output voltage and current	-150V to -250V @ 10mA maximum
Control voltage range	0V to 3V
Switching frequency	250kHz
Isolation	No

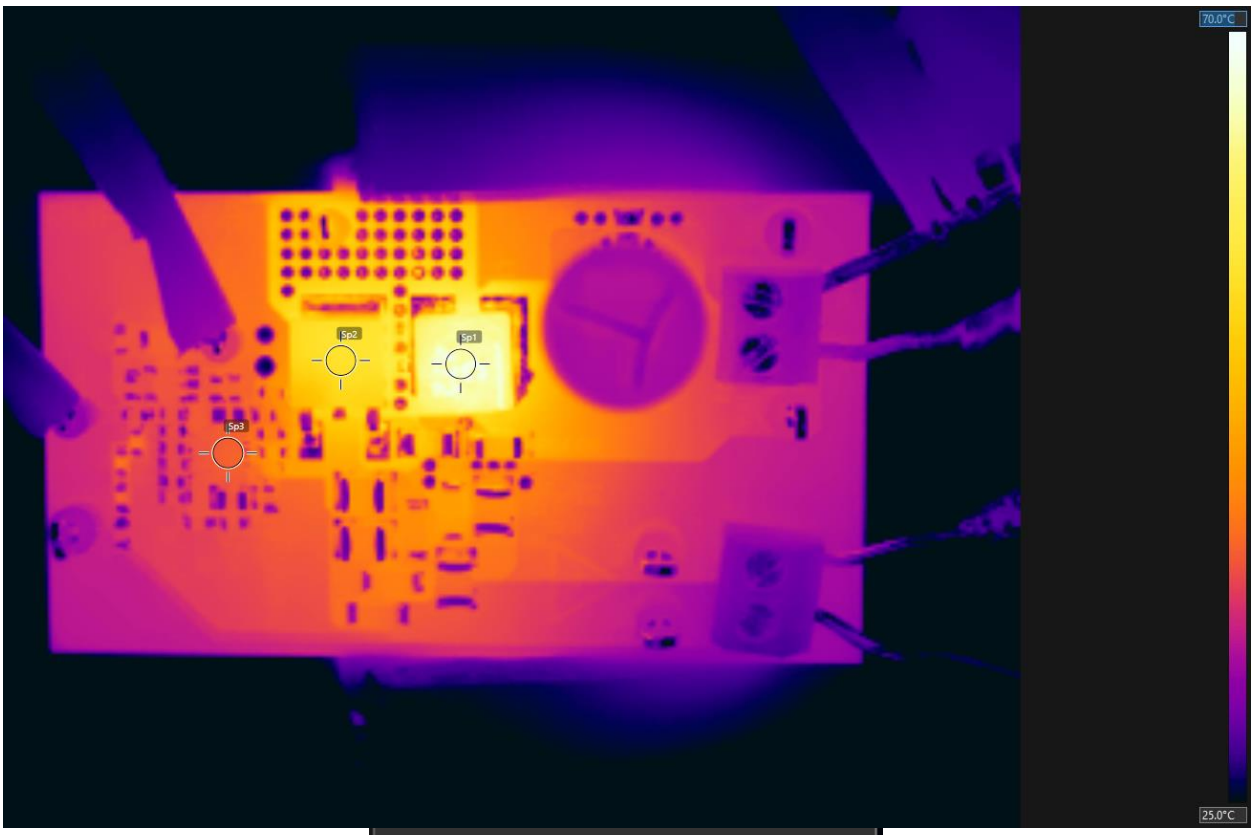
1.2 Required Equipment

- Resistive load (resistor decade box), 2.5W minimum
- Power supply, adjustable, 50V and 1A
- Power supply (for control), adjustable, 5V and 10mA
- Oscilloscope and probes
- Digital Multimeters
- Stability measurement device (Venable)

2 Testing and Results

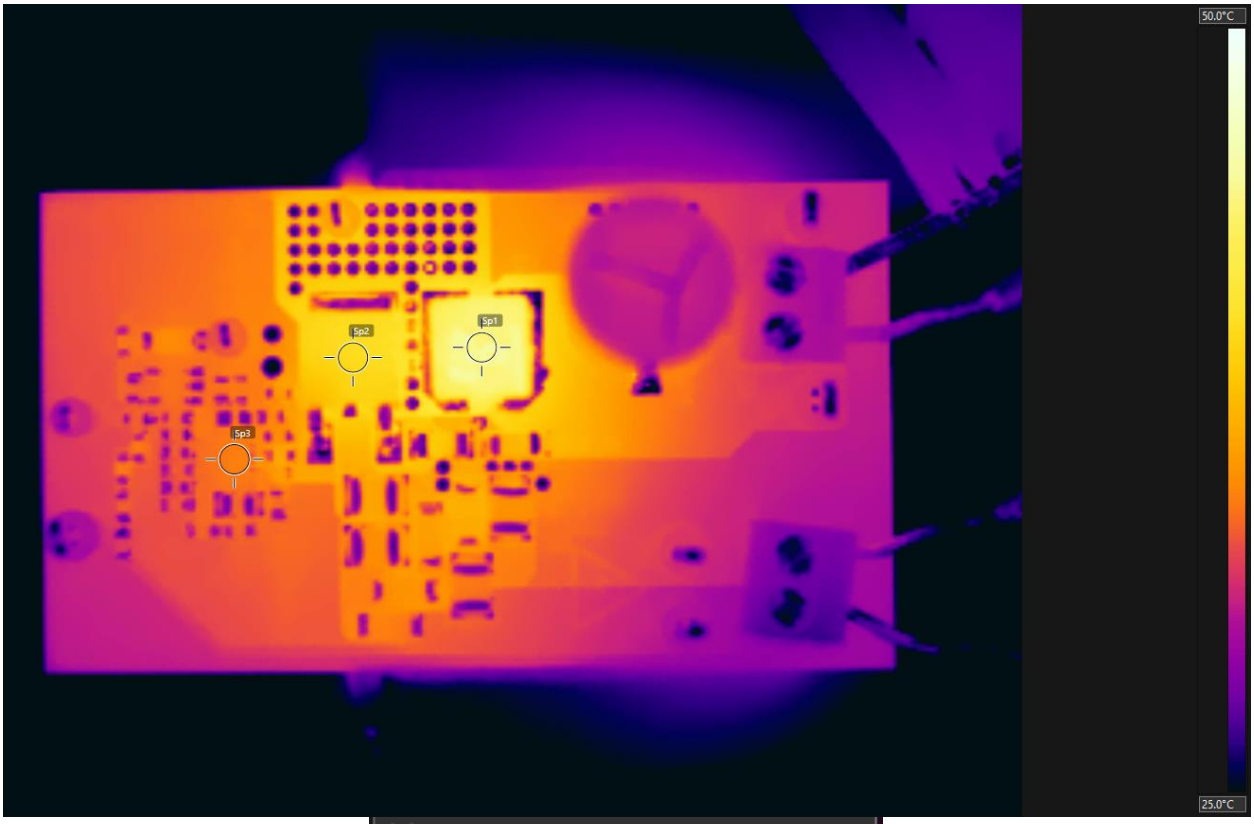
2.1 Thermal photos

This thermal image shows the operating temperature of the board with 12V input and the output voltage set to -250V @ 10mA loads at room temperature and no air flow.



Measurements	
Sp1	65.1 °C
Sp2	57.4 °C
Sp3	41.6 °C

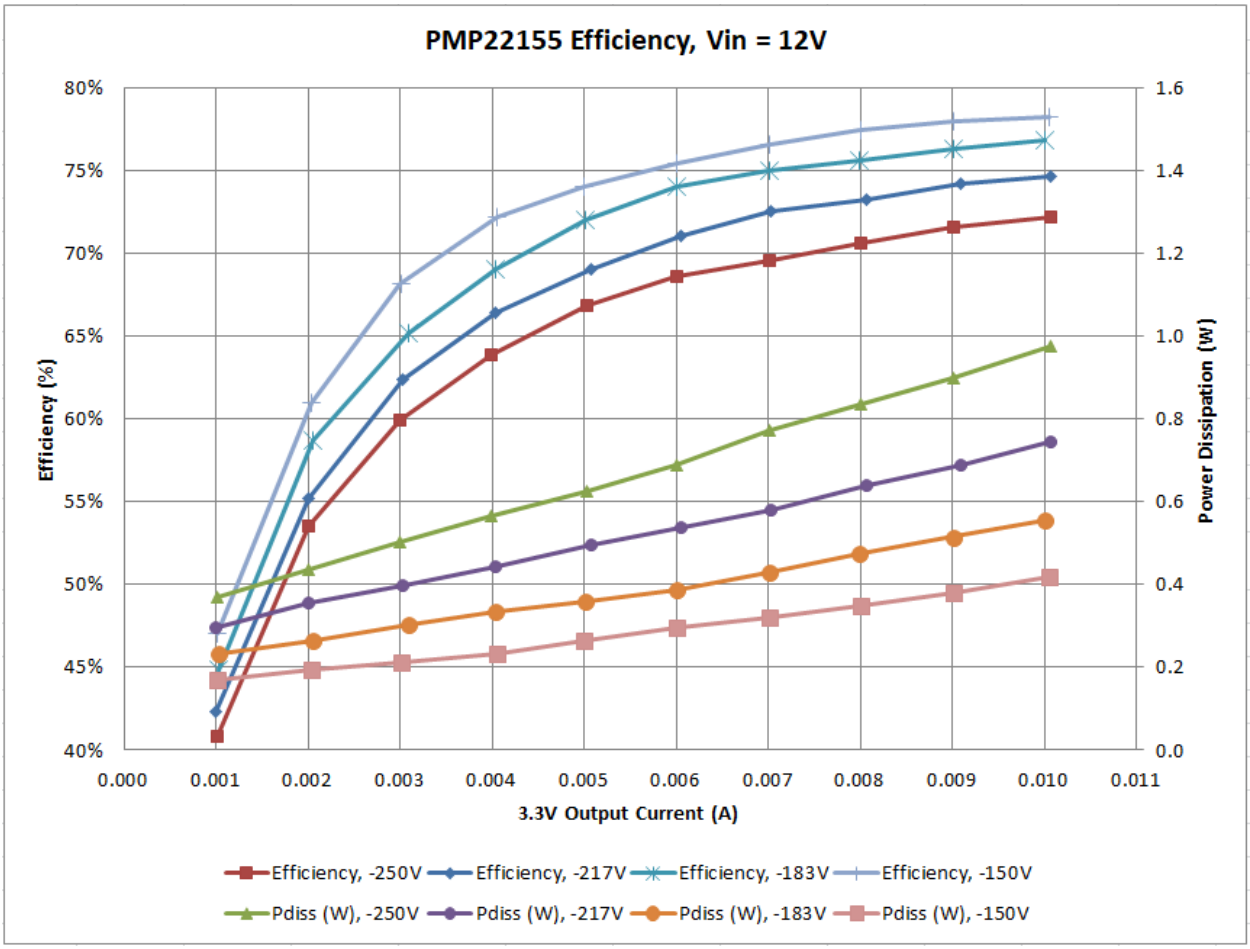
This thermal image shows the operating temperature of the board with 12V input and the output voltage set to -150V @ 10mA loads at room temperature and no air flow.



Measurements	
Sp1	45.1 °C
Sp2	40.8 °C
Sp3	35.3 °C

2.2 Efficiency and Power Dissipation Graphs

This graph displays the efficiency and power dissipation of the converter at 12V input. The control voltage was set to 0V, 1V, 2V and 3V to set the output to -150V, -183V, -217V and -250V, respectively.



2.2.1 Efficiency and Power Dissipation Data

Vcontrol = 3V

Vin	Iin	Vout	Iout	Po	Pin	Efficiency, -250V	Pdiss (W), -250V
12.0765	0.0517	-250.682	0.001017	0.255	0.624	40.9%	0.369
12.0217	0.0780	-250.681	0.002002	0.502	0.937	53.6%	0.435
12.1223	0.1034	-250.677	0.002995	0.751	1.253	59.9%	0.502
12.0703	0.1299	-250.680	0.003997	1.002	1.568	63.9%	0.566
12.0162	0.1571	-250.682	0.005032	1.261	1.887	66.8%	0.626
12.1137	0.1810	-250.686	0.005998	1.504	2.192	68.6%	0.688
12.1047	0.2091	-250.703	0.007018	1.759	2.531	69.5%	0.772
12.1000	0.2349	-250.702	0.008007	2.007	2.842	70.6%	0.835
12.0962	0.2610	-250.706	0.009007	2.258	3.157	71.5%	0.899
12.0919	0.2893	-250.714	0.010069	2.524	3.498	72.2%	0.974

Vcontrol = 2V

Vin	Iin	Vout	Iout1	Po	Pin	Efficiency, -217V	Pdiss (W), -217V
12.0457	0.0428	-217.220	0.001003	0.218	0.515	42.3%	0.297
12.0022	0.0658	-217.207	0.002007	0.436	0.790	55.2%	0.354
12.1085	0.0872	-217.197	0.003030	0.658	1.055	62.4%	0.397
12.0651	0.1095	-217.191	0.004036	0.877	1.321	66.4%	0.444
12.0197	0.1330	-217.187	0.005077	1.103	1.598	69.0%	0.496
12.1333	0.1525	-217.186	0.006048	1.314	1.850	71.0%	0.536
12.0909	0.1742	-217.190	0.007031	1.527	2.107	72.5%	0.580
12.0452	0.1987	-217.191	0.008071	1.753	2.393	73.3%	0.640
12.1040	0.2199	-217.191	0.009089	1.974	2.662	74.2%	0.688
12.1022	0.2421	-217.199	0.010061	2.185	2.930	74.6%	0.745

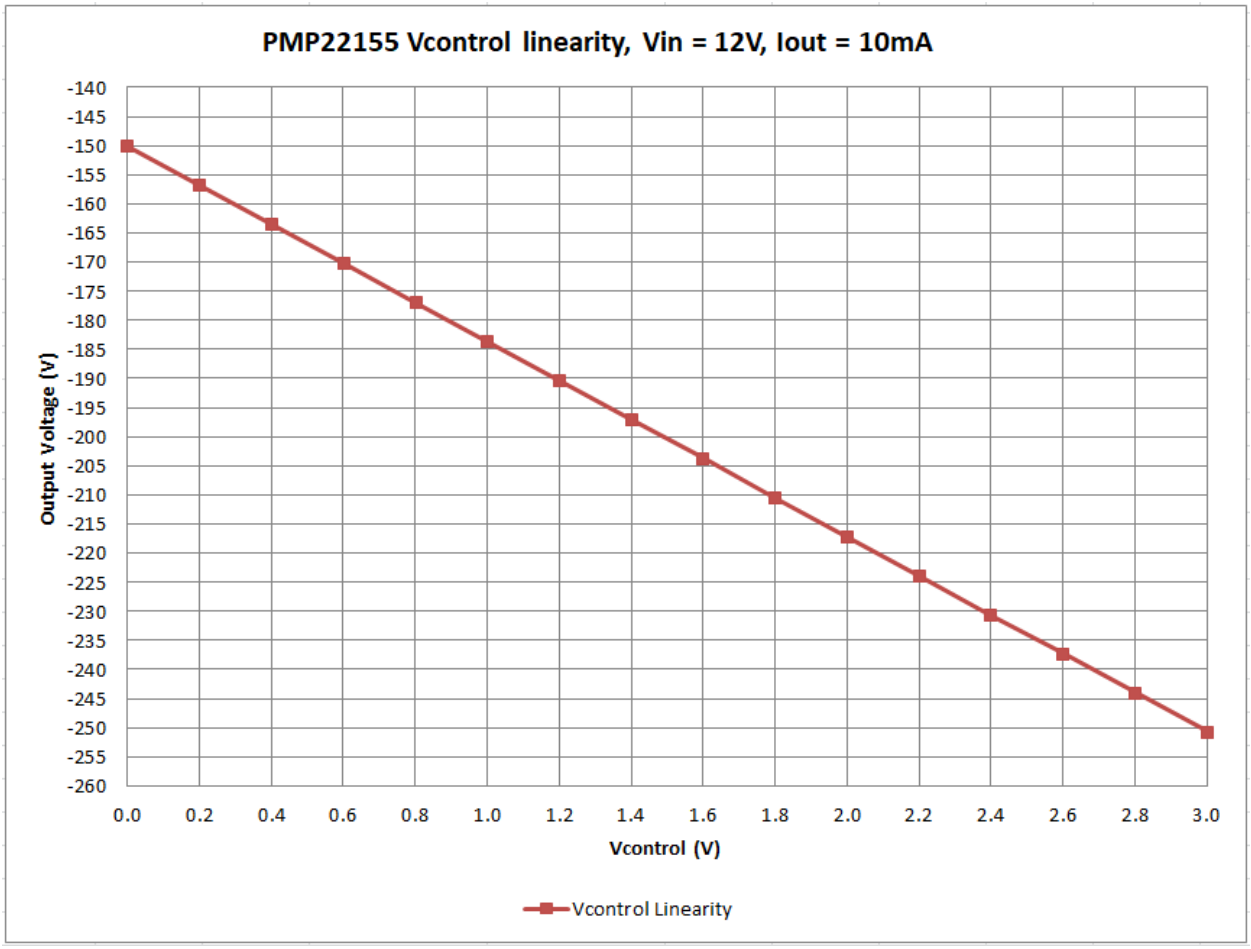
Vcontrol = 1V

Vin	Iin	Vout	Iout1	Po	Pin	Efficiency, -183V	Pdiss (W), -183V
12.1095	0.0347	-183.600	0.001026	0.188	0.420	44.9%	0.232
12.0738	0.0532	-183.588	0.002054	0.377	0.642	58.7%	0.265
12.0371	0.0722	-183.586	0.003085	0.566	0.870	65.1%	0.303
12.0044	0.0894	-183.583	0.004035	0.741	1.074	69.0%	0.333
12.1241	0.1055	-183.586	0.005013	0.920	1.279	72.0%	0.359
12.0900	0.1231	-183.587	0.006001	1.102	1.488	74.0%	0.387
12.0527	0.1423	-183.590	0.007006	1.286	1.715	75.0%	0.429
12.0154	0.1615	-183.594	0.007988	1.467	1.940	75.6%	0.474
12.0265	0.1804	-183.597	0.009012	1.655	2.169	76.3%	0.515
12.0948	0.1976	-183.599	0.010003	1.837	2.390	76.8%	0.554

Vcontrol = 0V

Vin	Iin	Vout	Iout1	Po	Pin	Efficiency, -150V	Pdiss (W), -150V
12.1763	0.0264	-150.032	0.001006	0.151	0.321	47.0%	0.170
12.1478	0.0412	-150.024	0.002033	0.305	0.500	61.0%	0.195
12.1214	0.0546	-150.023	0.003006	0.451	0.662	68.1%	0.211
12.0919	0.0696	-150.020	0.004051	0.608	0.842	72.2%	0.234
12.0638	0.0840	-150.019	0.005000	0.750	1.013	74.0%	0.263
12.0336	0.0993	-150.021	0.006006	0.901	1.195	75.4%	0.294
12.0037	0.1145	-150.022	0.007018	1.053	1.375	76.6%	0.322
12.1238	0.1278	-150.026	0.007998	1.200	1.550	77.4%	0.350
12.0921	0.1434	-150.027	0.009012	1.352	1.734	78.0%	0.382
12.0605	0.1598	-150.025	0.010050	1.508	1.927	78.2%	0.420

2.3 Vcontrol-to-output voltage linearity graph



This graph displays the measured output voltage when Vcontrol is varied between 0V to 3V. The converter was set to 12V input and the output was loaded to 10mA.

2.3.1 Vcontrol-to-output voltage linearity data

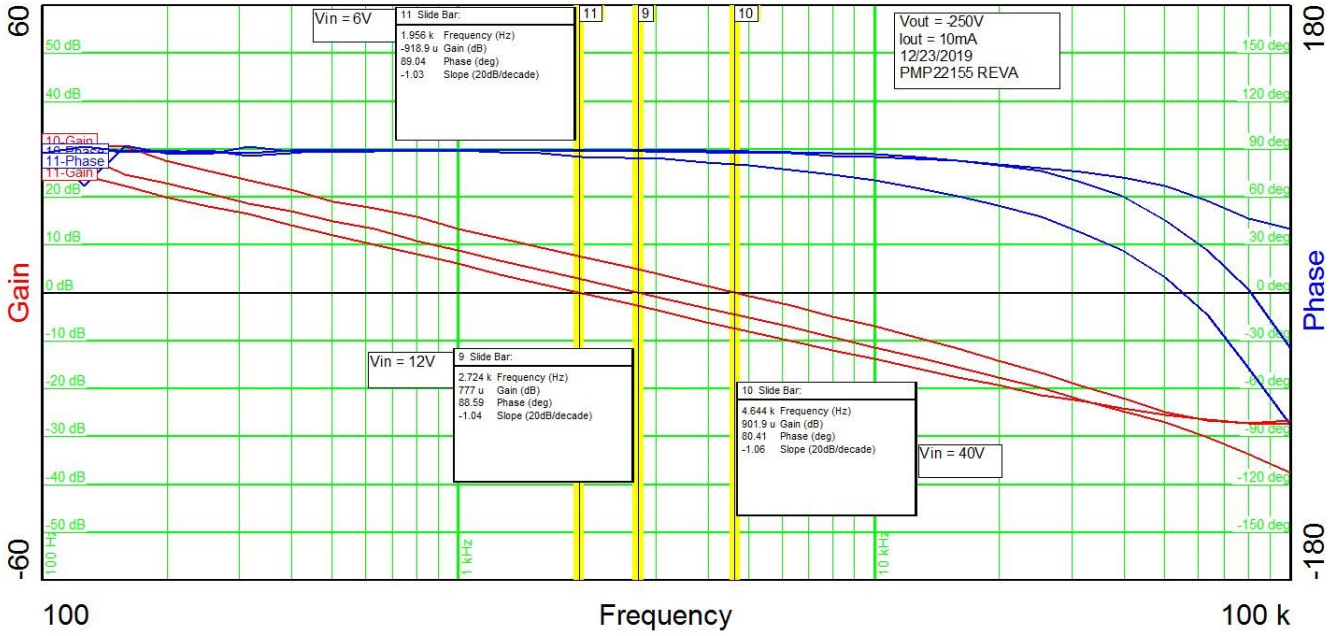
Vin=12V, Iout=10mA

Vcontrol	Vout
0.000	-150.03
0.200	-156.76
0.401	-163.49
0.601	-170.22
0.801	-176.92
0.999	-183.60
1.200	-190.32
1.400	-197.04
1.598	-203.70
1.801	-210.49
2.001	-217.20
2.200	-223.87
2.400	-230.59
2.600	-237.28
2.800	-243.99
3.000	-250.69

2.4 Loop Gain

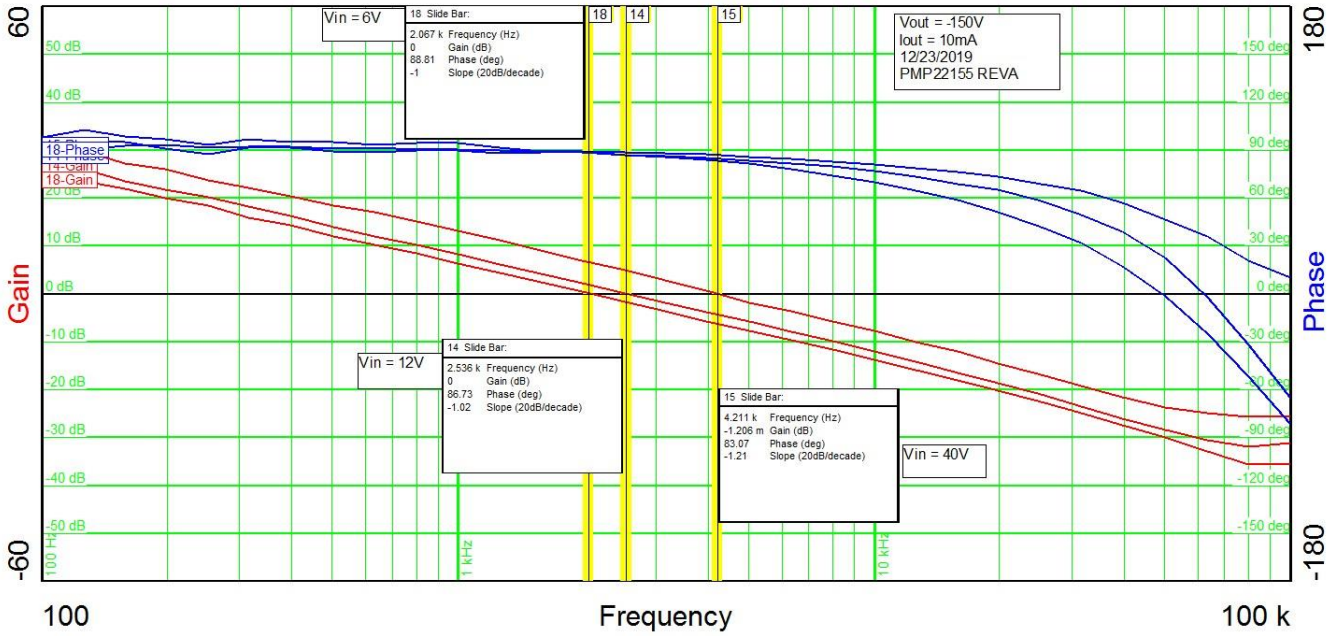
The plot below shows the converter's loop gain and phase margin when loaded to -250V @ 10mA.

Vin = 6V	Band Width = 1.96KHz	Phase Margin = 89.0 degrees
Vin = 12V	Band Width = 2.72KHz	Phase Margin = 88.6 degrees
Vin = 40V	Band Width = 4.64KHz	Phase Margin = 80.4 degrees



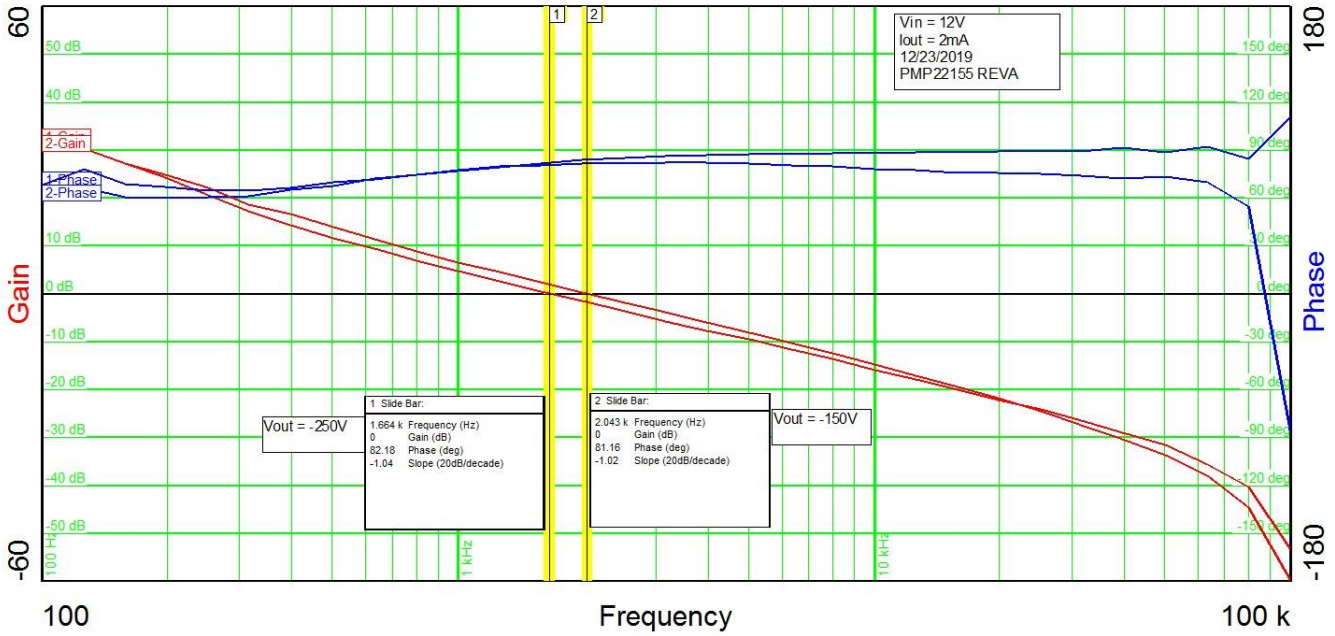
The plot below shows the converter's loop gain and phase margin when loaded to -150V @ 10mA.

Vin = 6V	Band Width = 2.07KHz	Phase Margin = 88.8 degrees
Vin = 12V	Band Width = 2.54KHz	Phase Margin = 86.7 degrees
Vin = 40V	Band Width = 4.21KHz	Phase Margin = 83.1 degrees



The plot below shows the converter's loop gain and phase margin when loaded to 2mA and Vin = 12V.

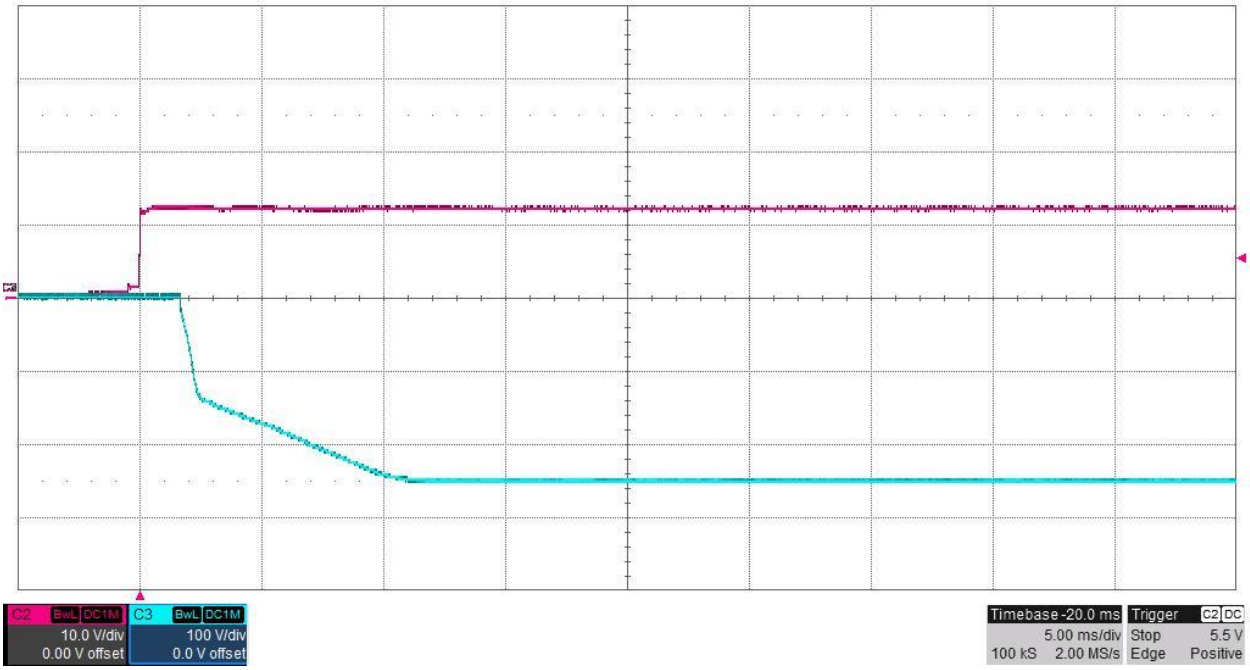
Vout = -250V	Band Width = 1.66KHz	Phase Margin = 82.2 degrees
Vout = -150V	Band Width = 2.04KHz	Phase Margin = 81.2 degrees



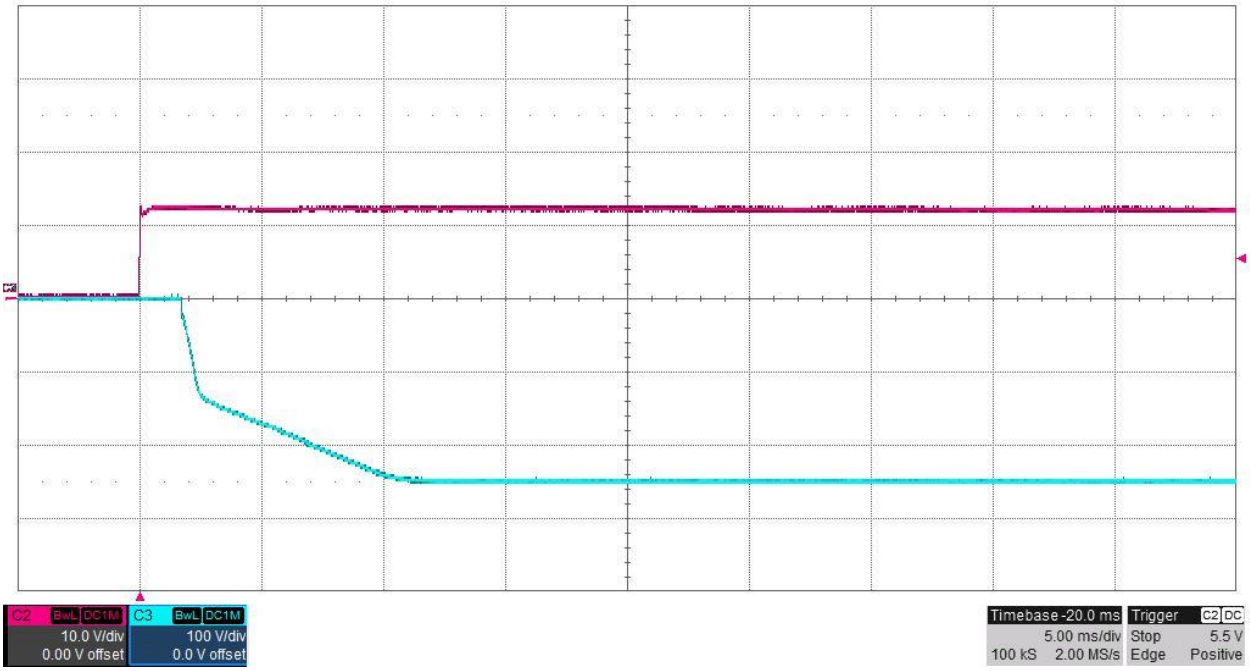
3 Waveforms

3.1 Startup

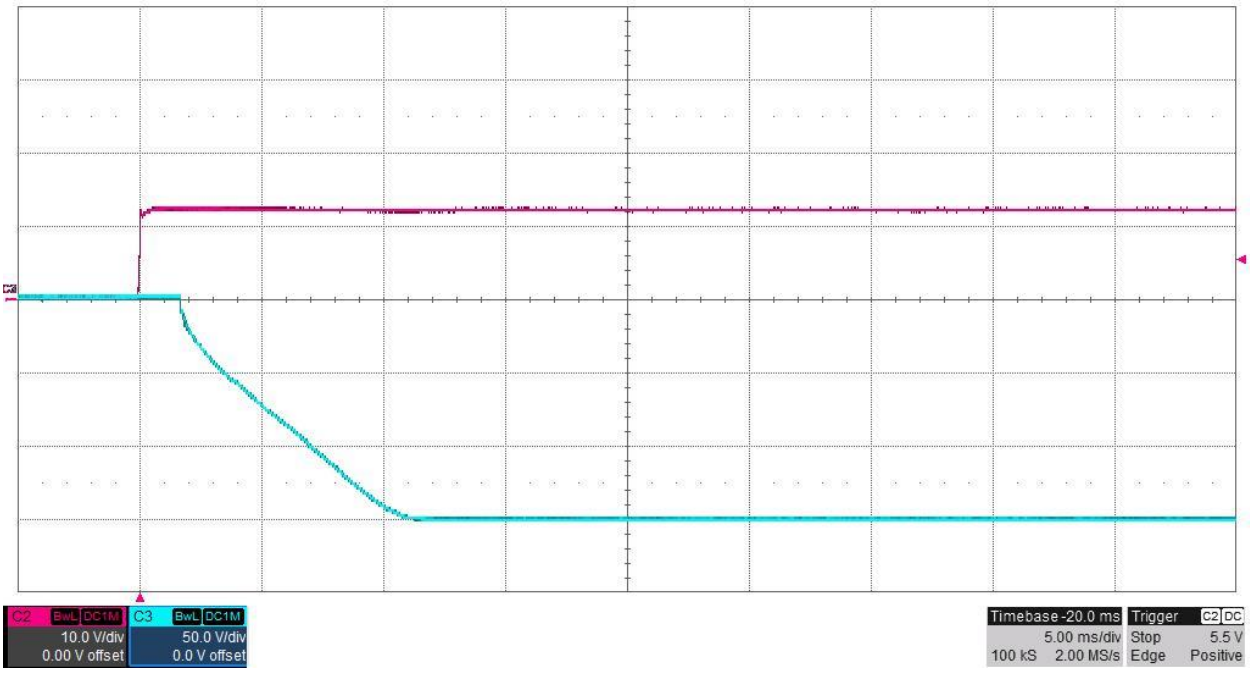
The photo below shows the output voltage startup waveform after the application of 12V input with the -250V output loaded to 0A. (VOUT: 100V/DIV, 5mS/DIV), (Vin: 10V/DIV)



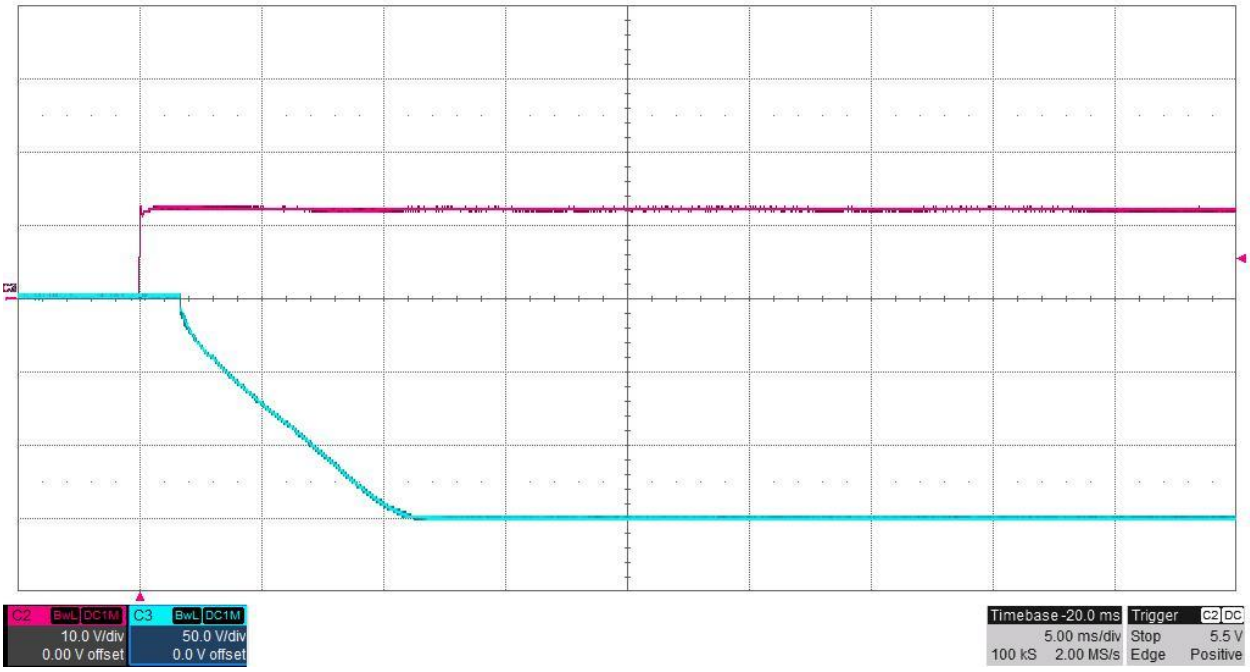
The photo below shows the output voltage startup waveform after the application of 12V input with the -250V output loaded to 10mA (25K ohm resistive load). (VOUT: 100V/DIV, 5mS/DIV), (Vin: 10V/DIV)



The photo below shows the output voltage startup waveform after the application of 12V input with the -150V output loaded to 0A. (VOUT: 50V/DIV, 5mS/DIV), (Vin: 10V/DIV)

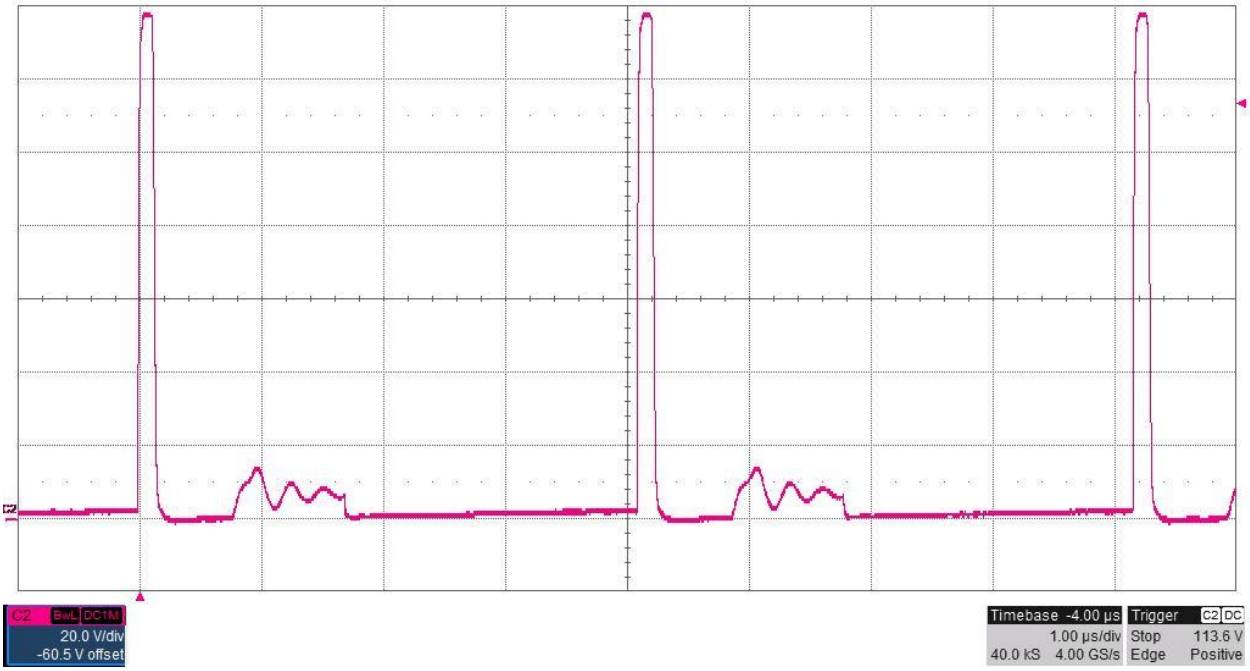


The photo below shows the output voltage startup waveform after the application of 12V input with the -150V output loaded to 10mA (15K ohm resistive load). (VOUT: 50V/DIV, 5mS/DIV), (Vin: 10V/DIV)

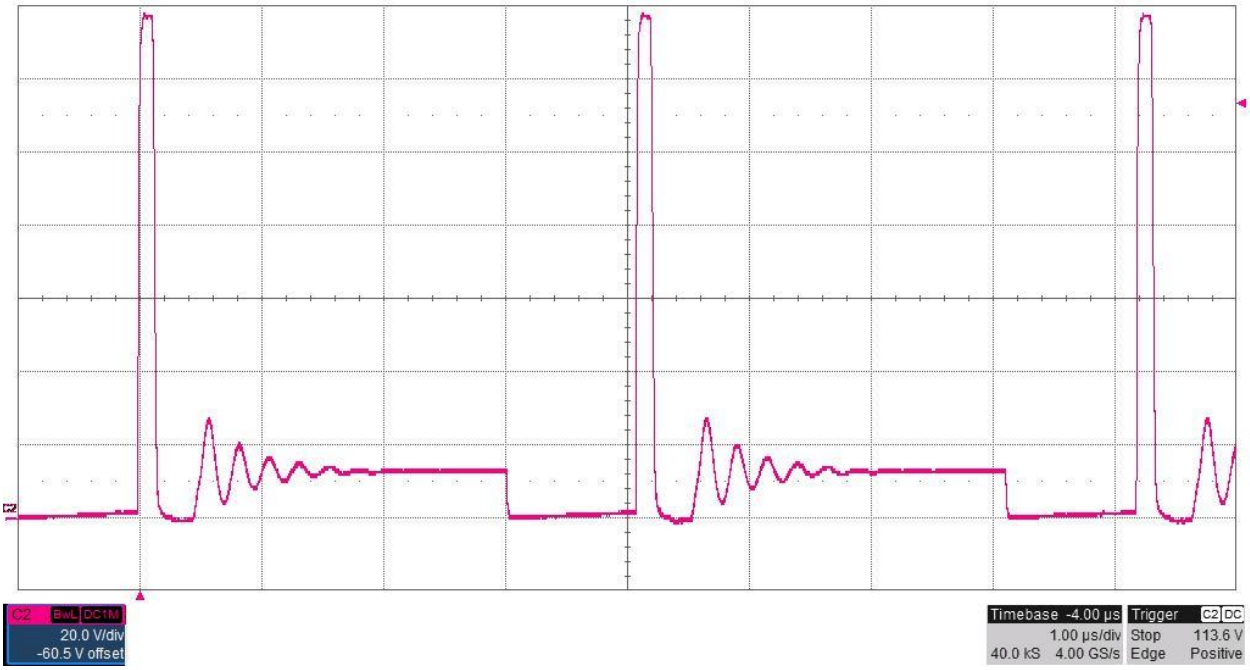


3.2 Switch Node

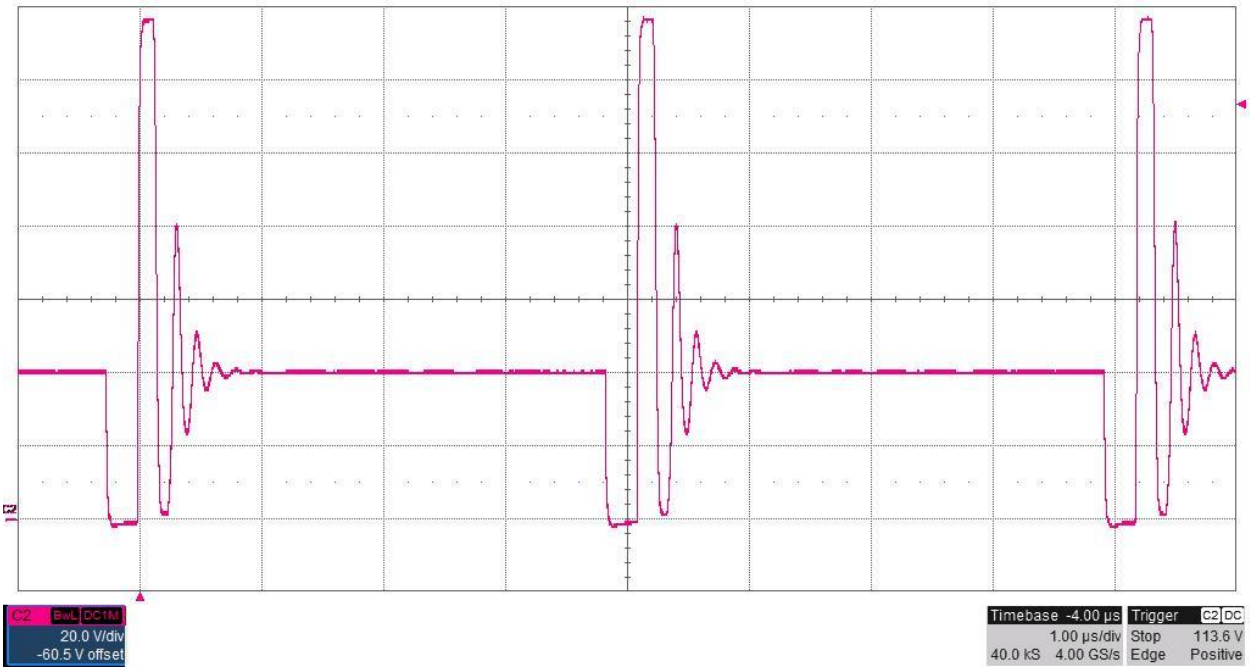
The photo below shows the FET switch node voltage at TP4. The input voltage is 6V and the -250V output is loaded to 10mA (25K ohm resistive load). (20V/DIV, 1uS/DIV)



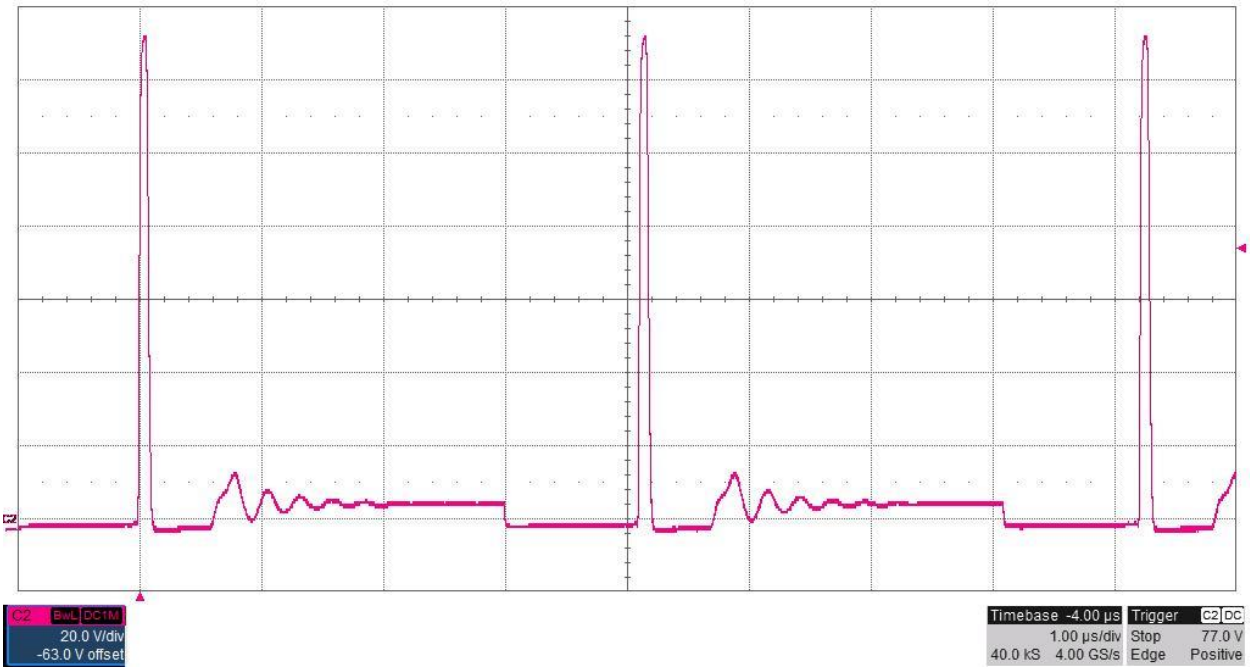
The photo below shows the FET switch node voltage at TP4. The input voltage is 12V and the -250V output is loaded to 10mA (25K ohm resistive load). (20V/DIV, 1uS/DIV)



The photo below shows the FET switch node voltage at TP4. The input voltage is 40V and the -250V output is loaded to 10mA (25K ohm resistive load). (20V/DIV, 1uS/DIV)

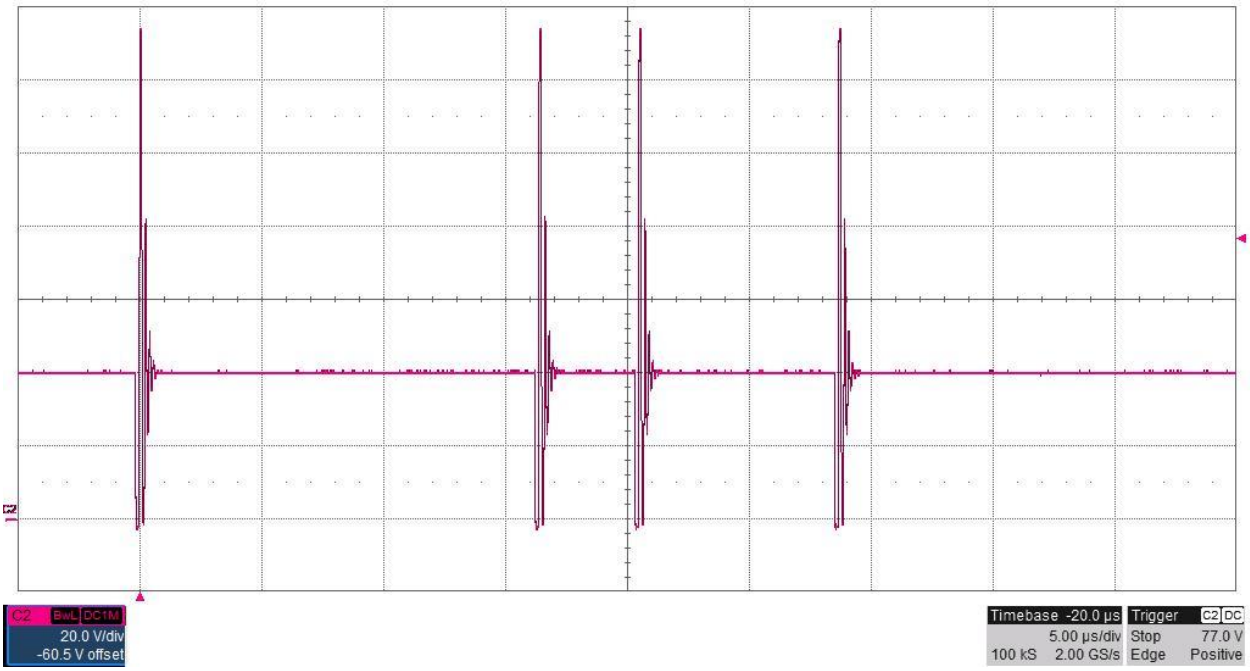


The photo below shows the FET switch node voltage at TP4. The input voltage is 6V and the -250V output is loaded to 1mA (250K ohm resistive load). (20V/DIV, 1uS/DIV)



The photo below shows the FET switch node voltage at TP4. The input voltage is 12V and the -250V output is loaded to 1mA (250K ohm resistive load). (20V/DIV, 1uS/DIV)

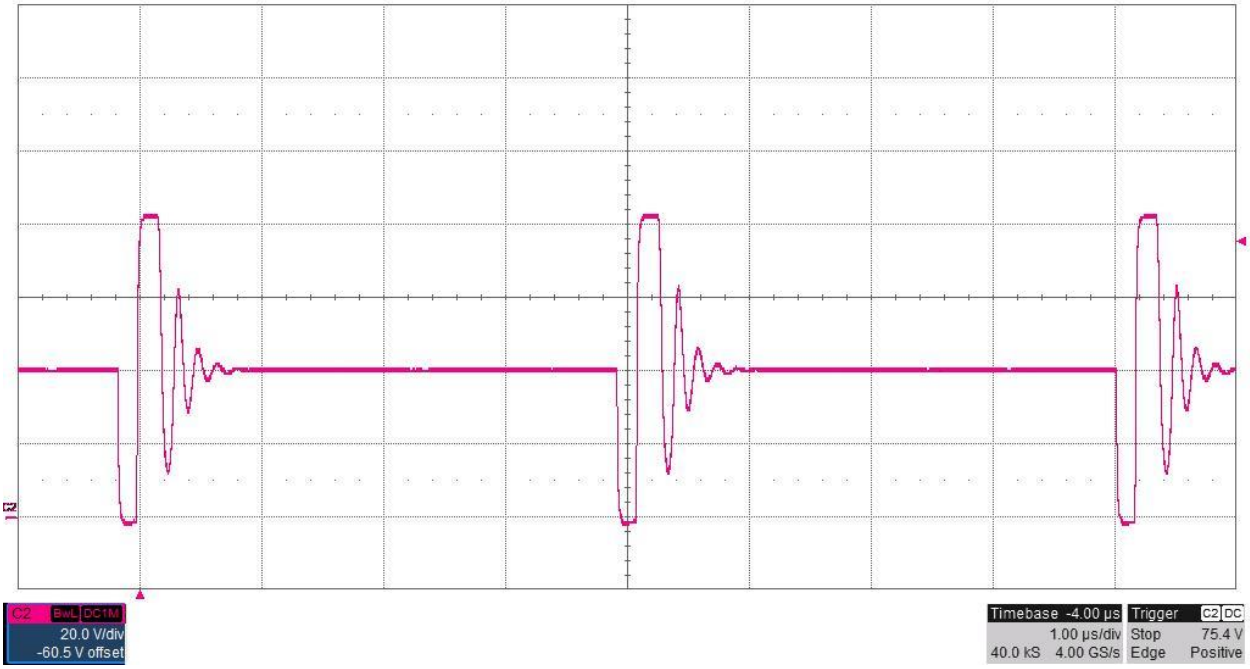
The photo below shows the FET switch node voltage at TP4. The input voltage is 40V and the -250V output is loaded to 1mA (250K ohm resistive load). Pulse skipping (20V/DIV, 5uS/DIV)



The photo below shows the FET switch node voltage at TP4. The input voltage is 6V and the -150V output is loaded to 10mA (15K ohm resistive load). (20V/DIV, 1uS/DIV)

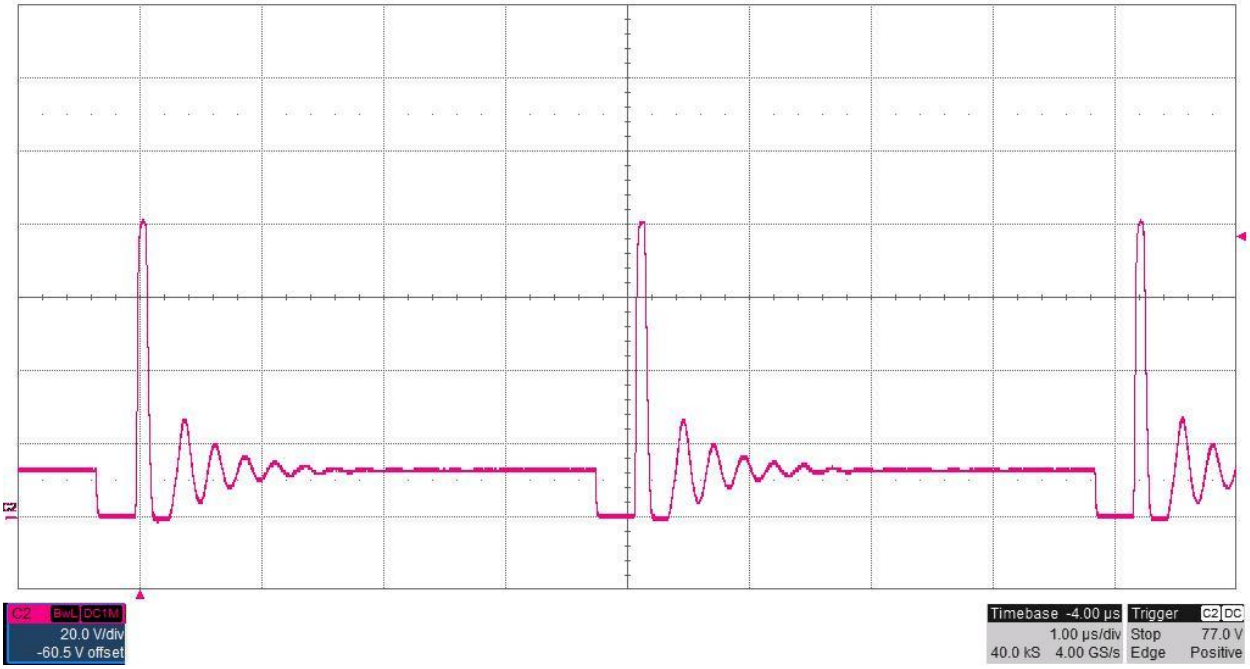
The photo below shows the FET switch node voltage at TP4. The input voltage is 12V and the -150V output is loaded to 10mA (15K ohm resistive load). (20V/DIV, 1uS/DIV)

The photo below shows the FET switch node voltage at TP4. The input voltage is 40V and the -150V output is loaded to 10mA (15K ohm resistive load). (20V/DIV, 1uS/DIV)

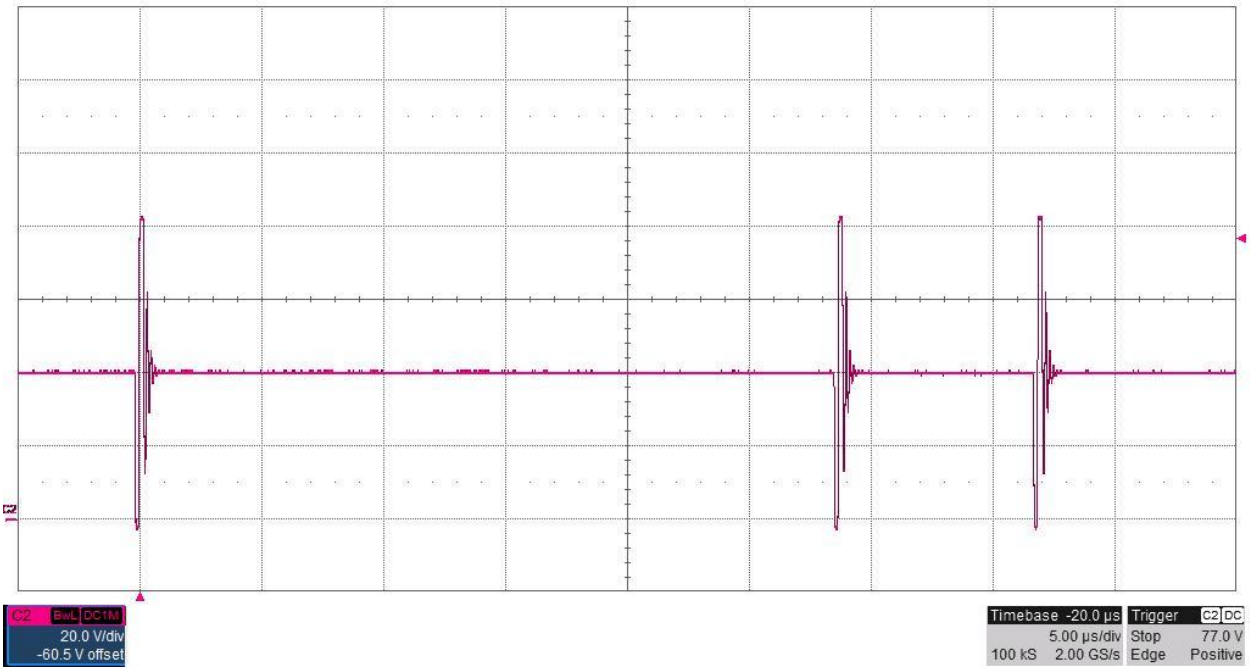


The photo below shows the FET switch node voltage at TP4. The input voltage is 6V and the -150V output is loaded to 1mA (150K ohm resistive load). (20V/DIV, 1uS/DIV)

The photo below shows the FET switch node voltage at TP4. The input voltage is 12V and the -150V output is loaded to 1mA (150K ohm resistive load). (20V/DIV, 1uS/DIV)

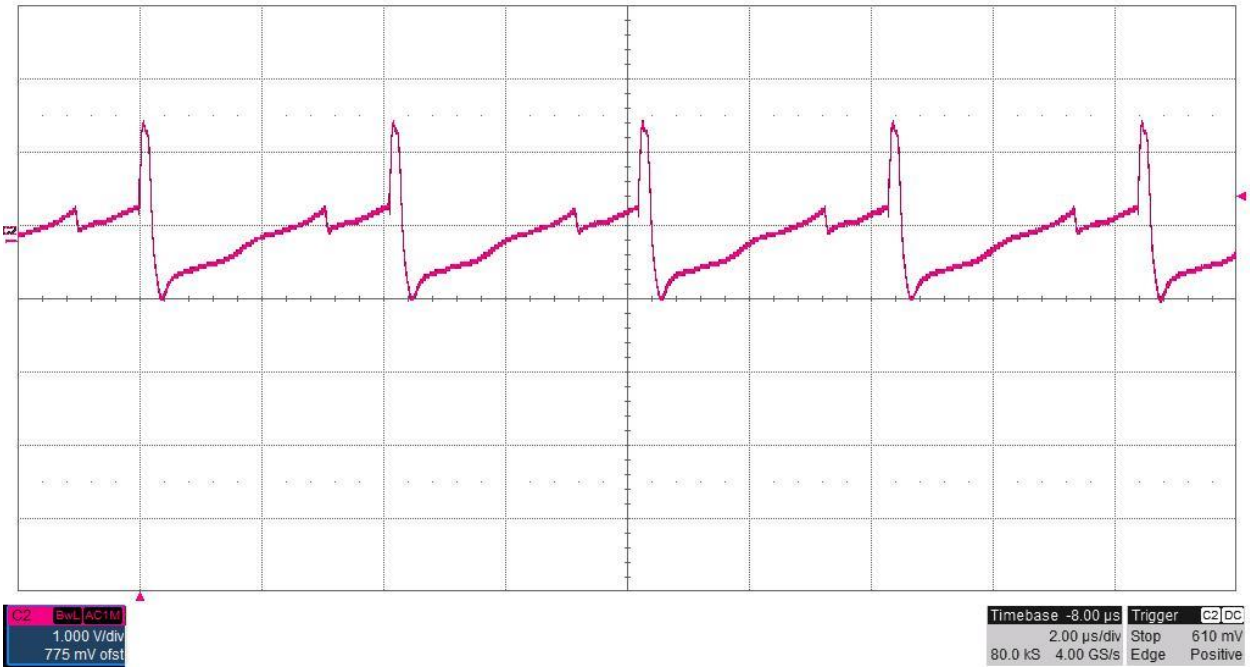


The photo below shows the FET switch node voltage at TP4. The input voltage is 40V and the -150V output is loaded to 1mA (150K ohm resistive load). Pulse skipping (20V/DIV, 5uS/DIV)

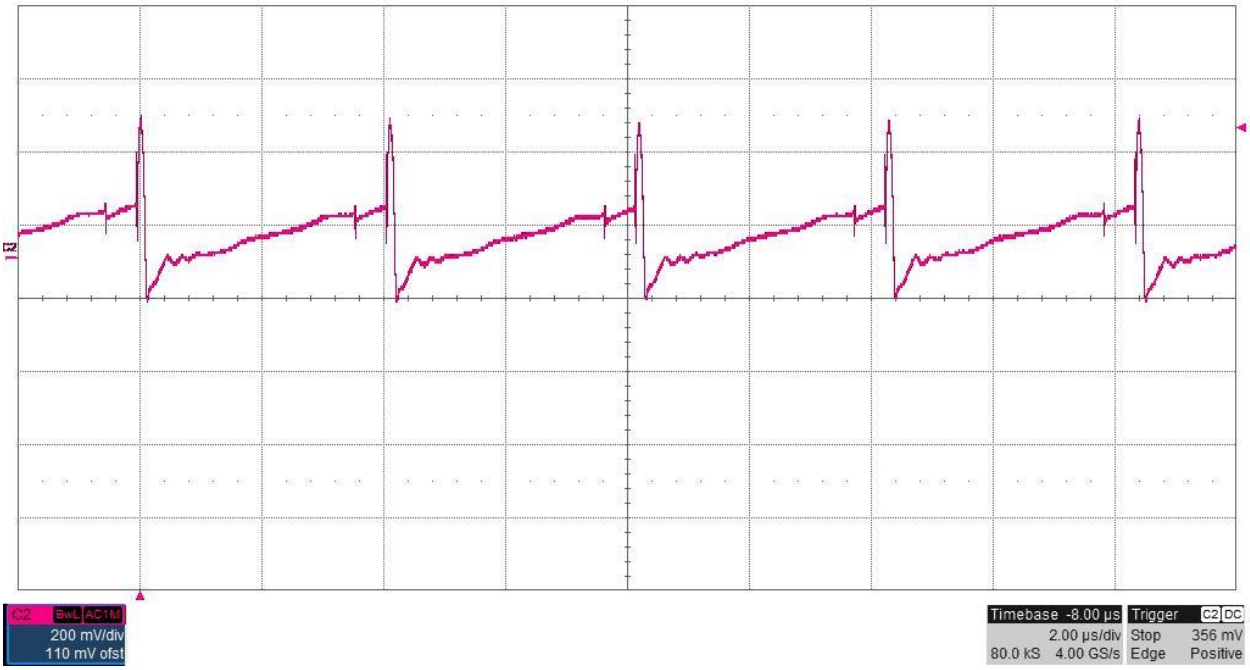


3.3 Output Voltage Ripple

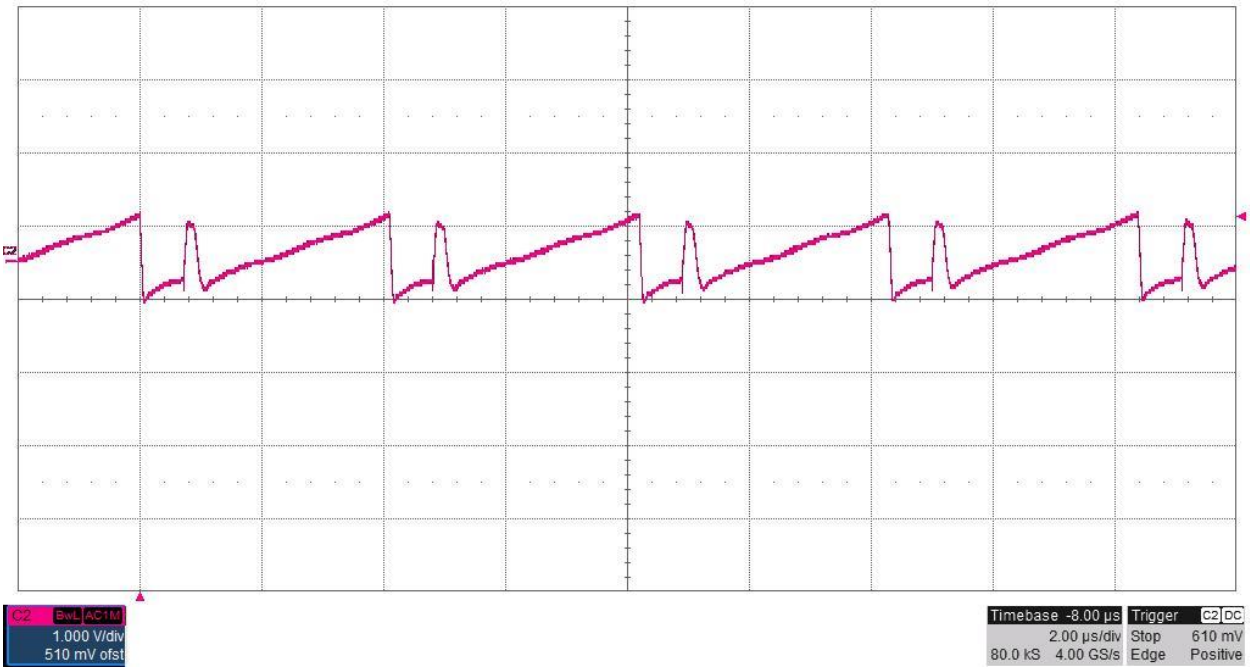
The output ripple voltage (AC coupled) is shown in the figure below. The input voltage is 12V and the -250V output is loaded to 10mA. (VOUT: 1V/DIV, 2uS/DIV)



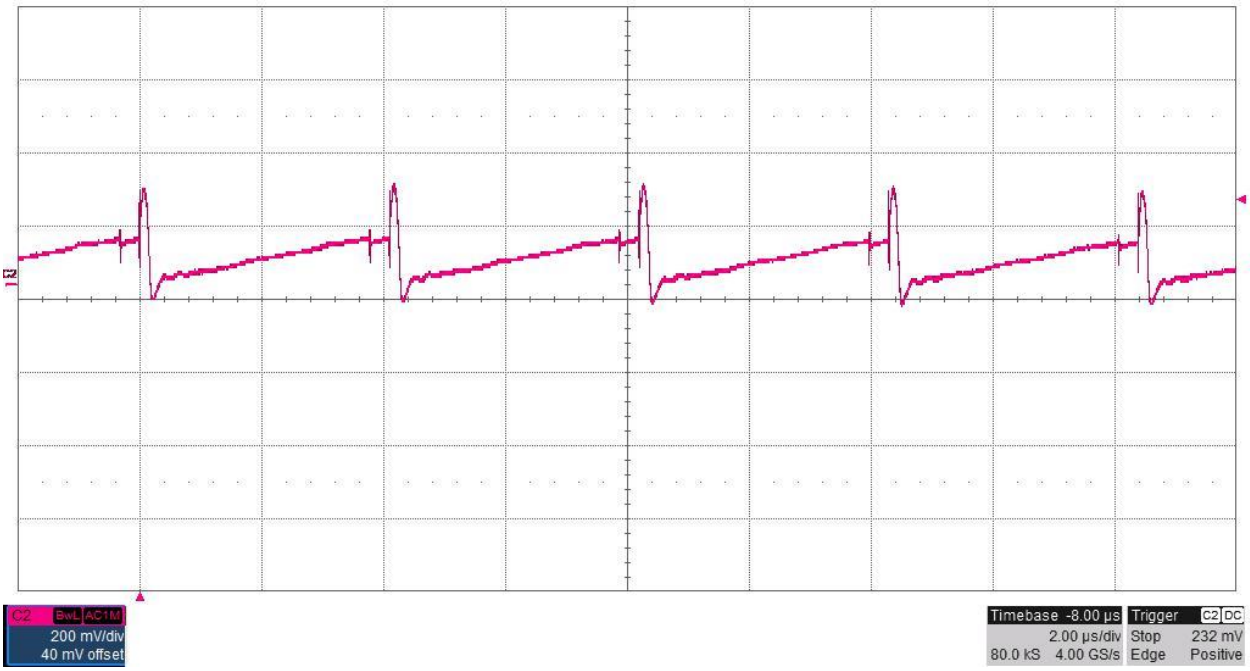
The output ripple voltage (AC coupled) is shown in the figure below. The input voltage is 12V and the -250V output is loaded to 1mA. (VOUT: 200mV/DIV, 2uS/DIV)



The output ripple voltage (AC coupled) is shown in the figure below. The input voltage is 12V and the -150V output is loaded to 10mA. (VOUT: 1V/DIV, 2uS/DIV)

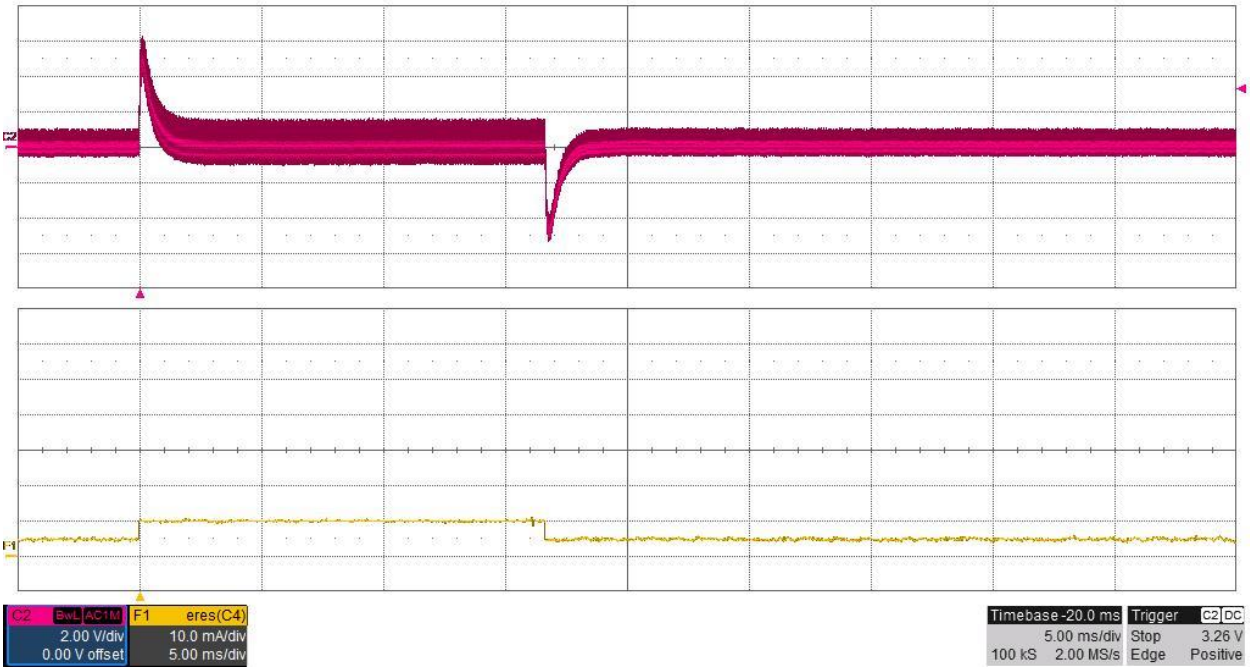


The output ripple voltage (AC coupled) is shown in the figure below. The input voltage is 12V and the -150V output is loaded to 1mA. (VOUT: 200mV/DIV, 2uS/DIV)

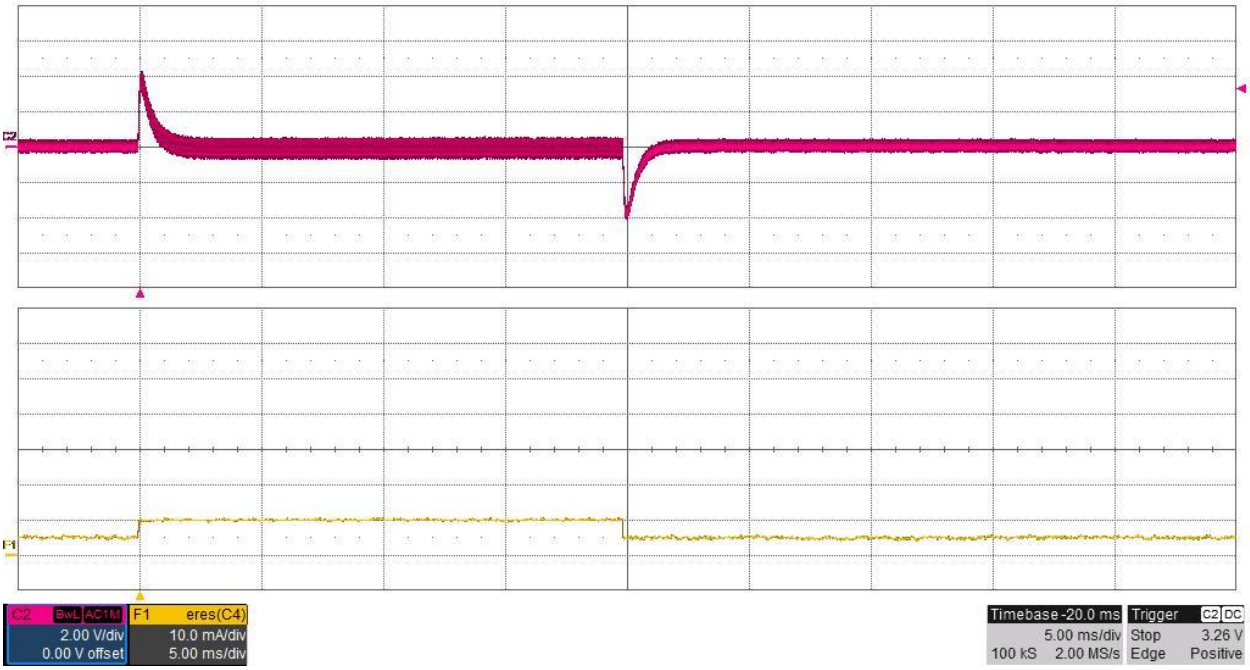


3.4 Load Transients

The photo below shows the -250V output voltage (AC coupled) when the load current is stepped between 5mA and 10mA. Vin = 12V. Current waveform digitally filtered to remove noise. (2V/DIV, 10mA/DIV, 5mS/DIV)

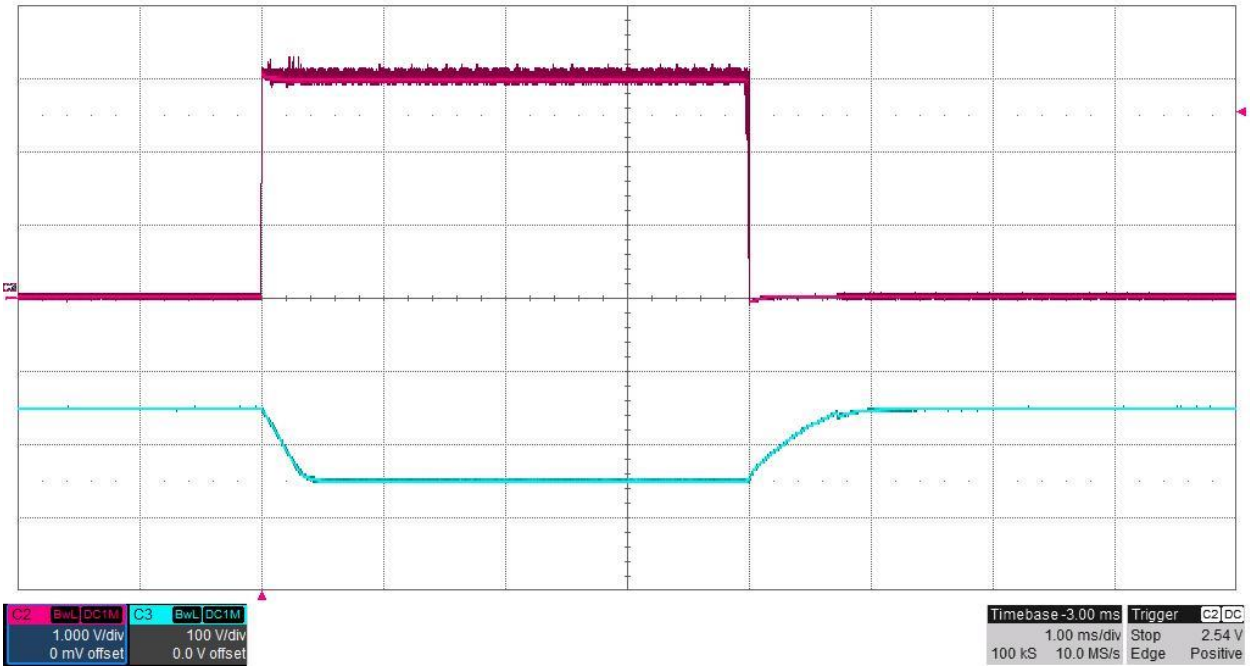


The photo below shows the -150V output voltage (AC coupled) when the load current is stepped between 5mA and 10mA. Vin = 12V. Current waveform digitally filtered to remove noise. (2V/DIV, 10mA/DIV, 5mS/DIV)



3.5 Vcontrol-to-output voltage response

The photo below shows the output voltage transition between -150V and -250V when the Vcontrol voltage is stepped between 0V and 3V. Vin = 12V and 25K ohm load resistor. (1V/DIV, 100V/DIV, 1mS/DIV)



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