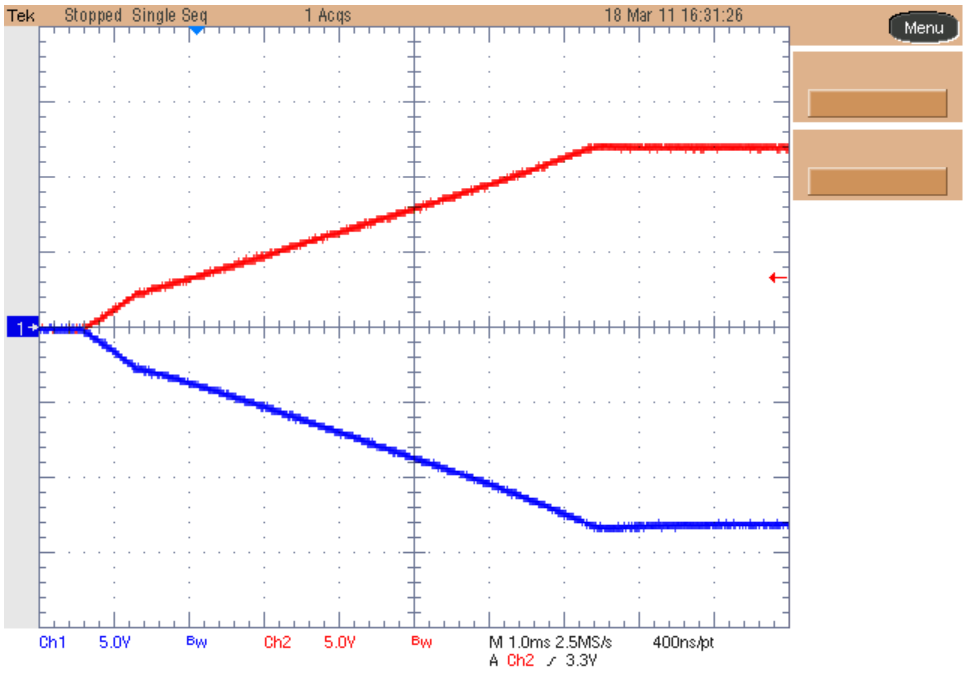
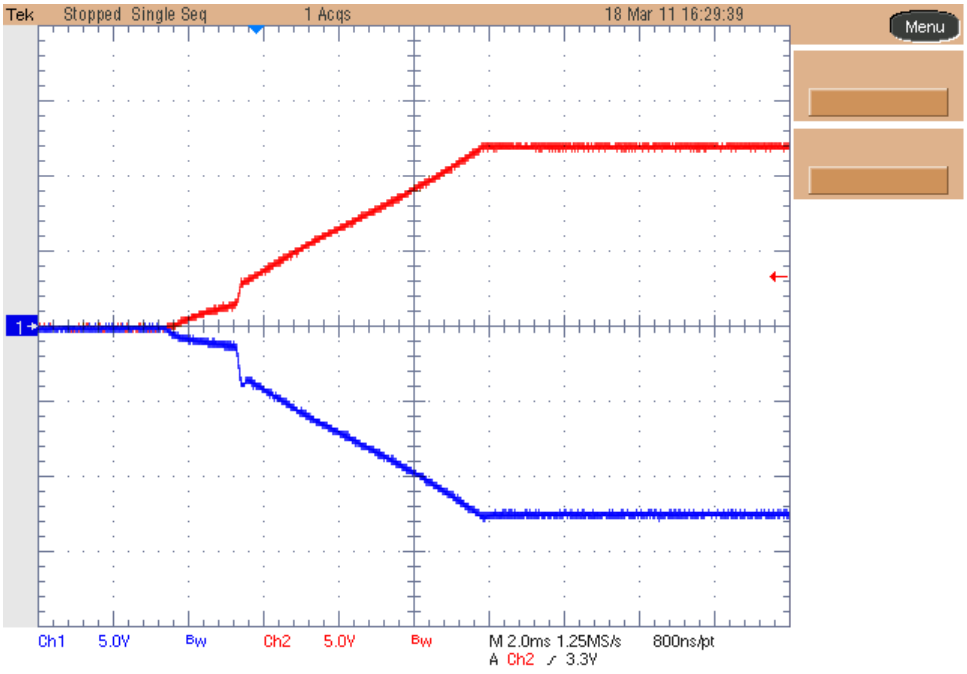
1 Startup

The +12Vout and the -12Vout startup behavior is shown in the pictures below. The input voltage has been set to 20V. Upper picture: no load, lower: full load on both outputs.

Channel 1 and 2: +12Vout and -12Vout (5V/div, 1ms/div, 20MHz BWL).

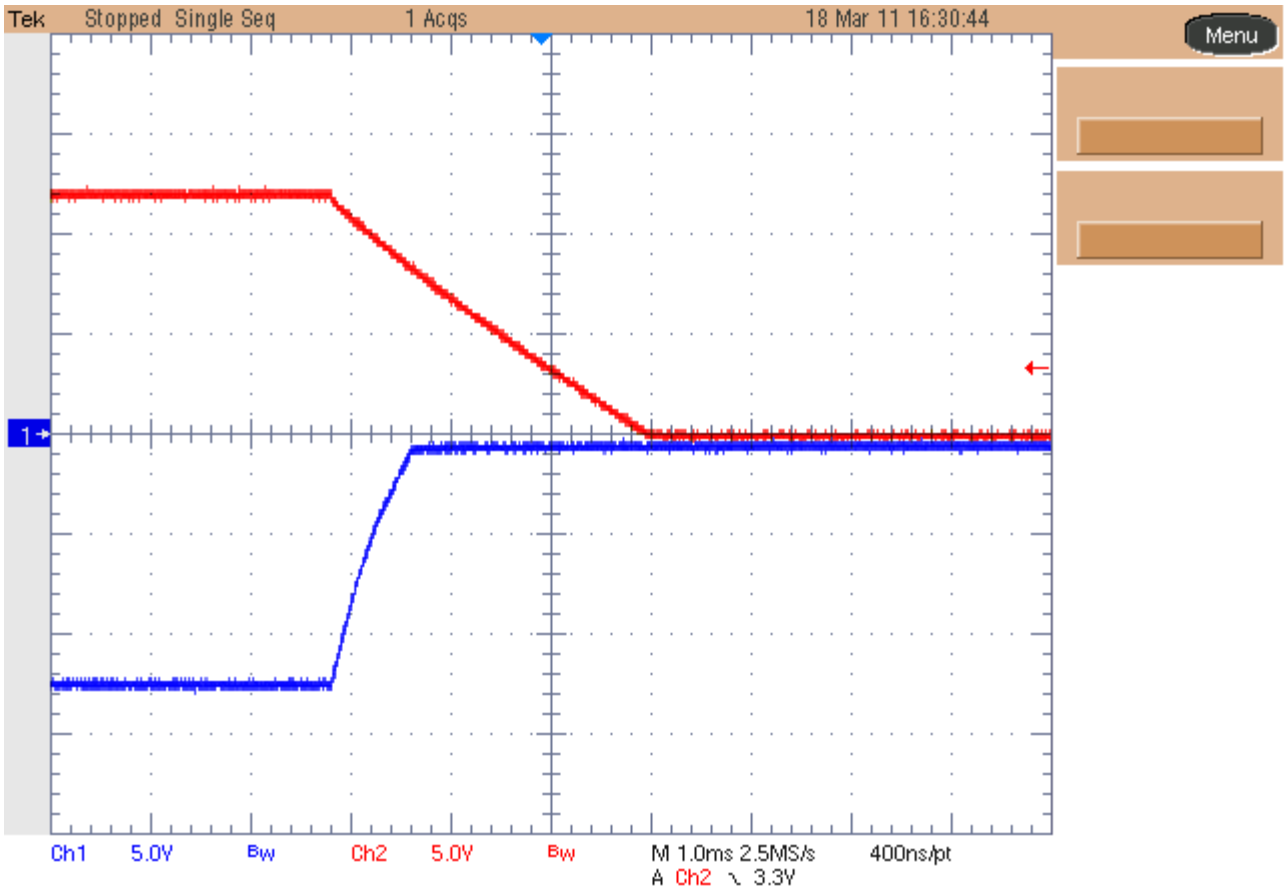




2 Shutdown

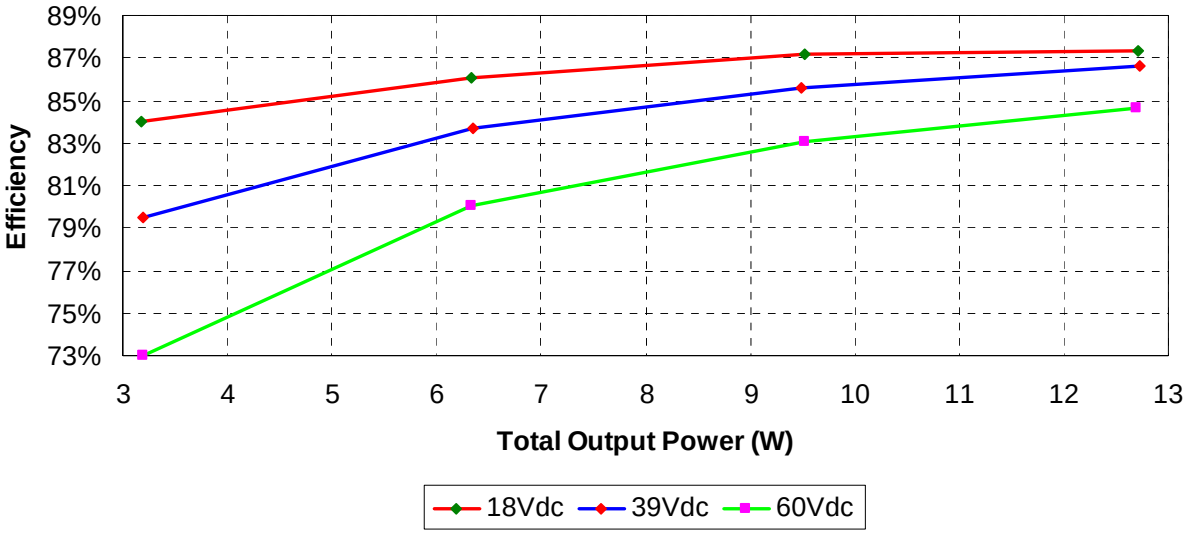
The +12Vout and the -12Vout behavior during shut down is shown in the picture below. The input voltage has been set to 20V and the load set to full load for both outputs.

Channel 1 and 2: +12Vout and -12Vout (5V/div, 1ms/div, 20MHz BWL).



3 Efficiency

The efficiency data is shown in the tables and graph below. The input voltage was set to 18V, 39V and 60V, while the load has been varied between 0, 25, 50, 75 and 100% of the nominal load at the same rate for both outputs.



Out 1: +12V		Out 2: -12V							
I (mA)	V (V)	I (-mA)	V (-V)	Pout (W)	Iin (mA)	Vin (V)	Pin (W)	Ploss (W)	Eff
0.0	11.99	0.0	12.61	0.00	15.7	17.99	0.282	0.28	0.00%
201.2	11.99	61.9	12.25	3.17	208.7	18.08	3.773	0.60	84.03%
400.7	11.99	124.5	12.27	6.33	409.0	17.99	7.358	1.03	86.06%
600.5	11.99	189.1	12.32	9.53	606.5	18.02	10.929	1.40	87.20%
800.2	11.99	250.9	12.39	12.70	807.8	18.01	14.548	1.85	87.32%

Out 1: +12V		Out 2: -12V							
I (mA)	V (V)	I (-mA)	V (-V)	Pout (W)	Iin (mA)	Vin (V)	Pin (W)	Ploss (W)	Eff
0.0	11.99	0.0	12.60	0.00	12.2	39.08	0.477	0.48	0.00%
201.5	11.99	63.8	12.25	3.20	103.0	39.04	4.021	0.82	79.52%
400.8	11.99	125.5	12.28	6.35	194.4	39.00	7.582	1.23	83.71%
600.5	11.99	186.6	12.31	9.50	284.5	39.00	11.096	1.60	85.59%
800.0	11.99	254.1	12.34	12.73	376.7	39.00	14.691	1.96	86.63%

Out 1: +12V		Out 2: -12V							
I (mA)	V (V)	I (-mA)	V (-V)	Pout (W)	Iin (mA)	Vin (V)	Pin (W)	Ploss (W)	Eff
0.0	11.99	0.0	12.68	0.00	10.3	60.1	0.619	0.62	0.00%
201.5	11.99	62.8	12.26	3.19	72.6	60.1	4.363	1.18	73.02%
400.9	11.99	124.8	12.28	6.34	131.8	60.1	7.921	1.58	80.03%
600.5	11.99	188.2	12.31	9.52	191.0	60.0	11.460	1.94	83.04%
800.0	11.99	250.9	12.34	12.69	249.9	60.0	14.994	2.31	84.62%

Output Voltage tracking between +12V and -12V:

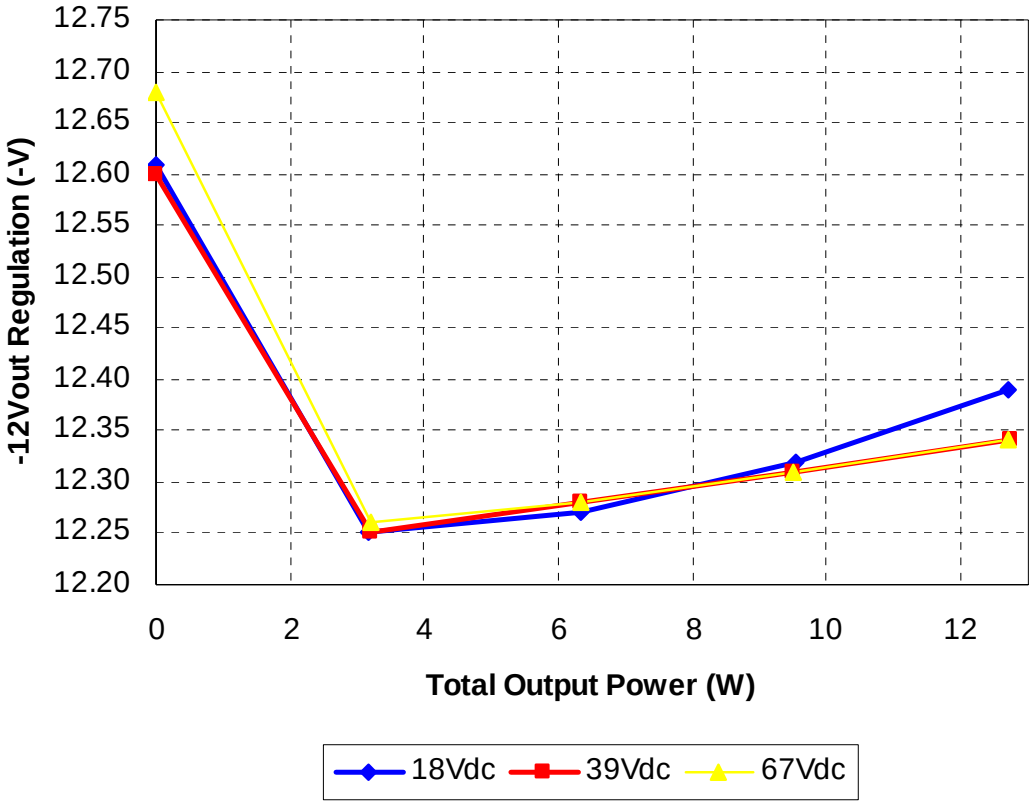
The table below shows which minimum load must be present on the outputs to keep into regulation the -12Vout. Since the regulation is done on the +12Vout, it will always be stable.

Out 1: +12V		Out 2: -12V	
I (mA)	V (V)	I (-mA)	V (-V)
21.2	11.99	261.0	11.58
21.2	11.99	0.0	12.85
800.0	11.99	0.0	14.45
800.0	11.99	26.4	13.30

When the +12Vout is loaded between 21.2mA and 800mA, the -12Vout is always lower than 14.45V, even if unloaded (the D5 zener is clamping). If the +12Vout is lightly loaded (21.2mA) and the -12Vout fully loaded (261mA) then the voltage drops down to 11.58V, which is still acceptable.
If the converter has zero load on the +12V, the -12V is able to deliver only few mA (~ 10mA) before losing regulation.

4 Output voltage regulation

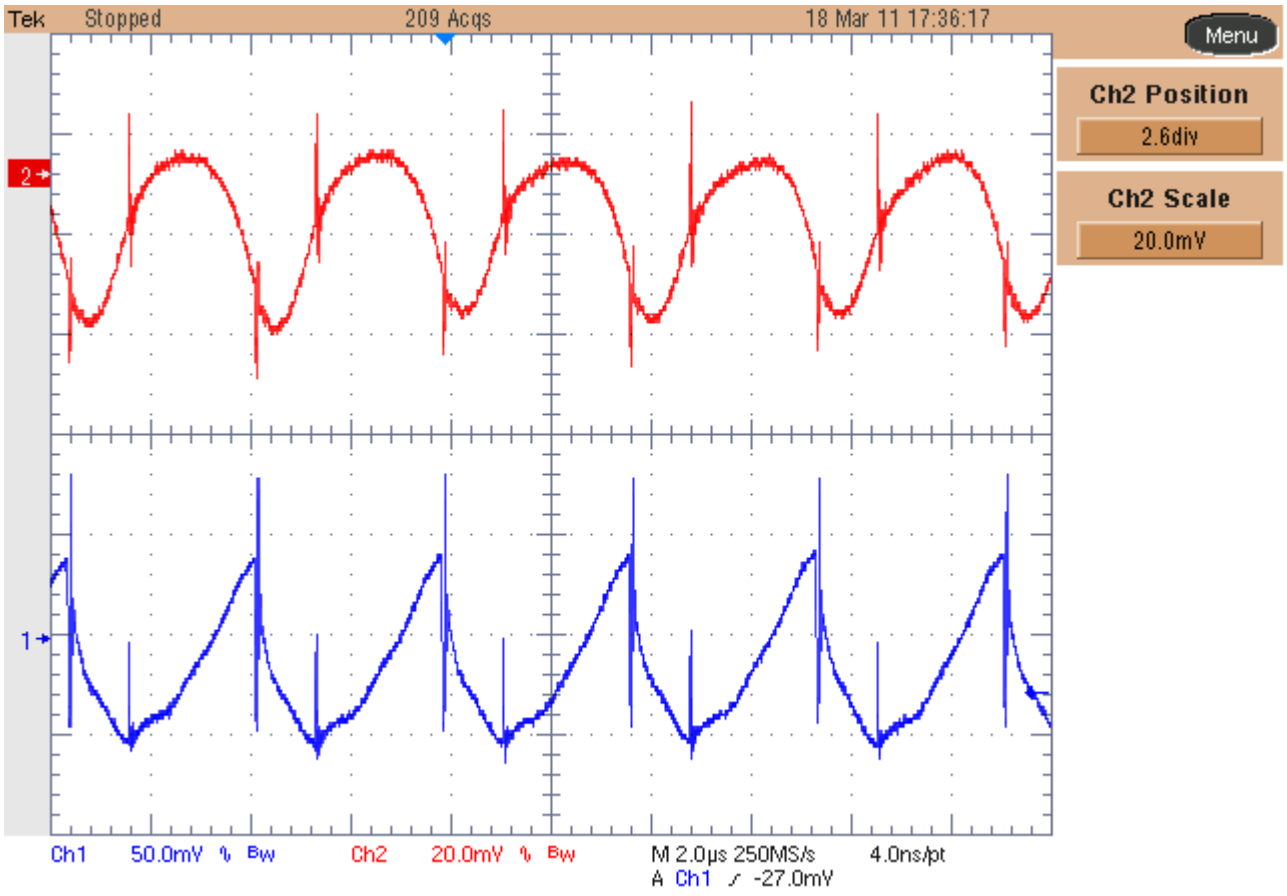
The -12Vout output voltage versus total output power is plotted below. Since the regulation is done on the +12Vout, it will always be stable, so it hasn't been plotted. The input voltage was set to 18V, 39V and 60V, while the load has been varied between 0, 25, 50, 75 and 100% of the nominal load at the same rate for both outputs.



5 Output ripple voltage

The output ripple voltages for both outputs are shown in the plot below. The input was set to 18Vin and the outputs both fully loaded.

Channel 2: +12V Output voltage (20 mV/div, 2us/div, AC coupling, 20MHz BWL)
Channel 1: -12V Output voltage (50 mV/div, AC coupling, 20MHz BWL).

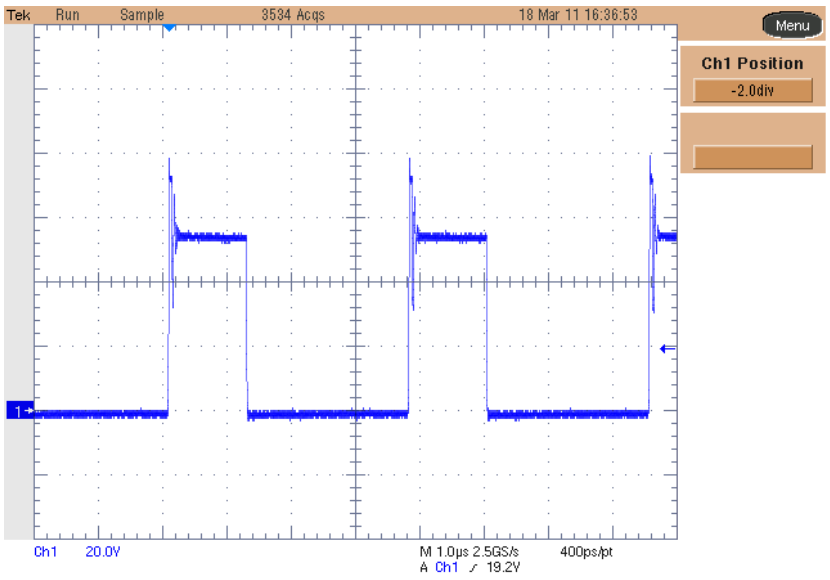


6 Switch-node

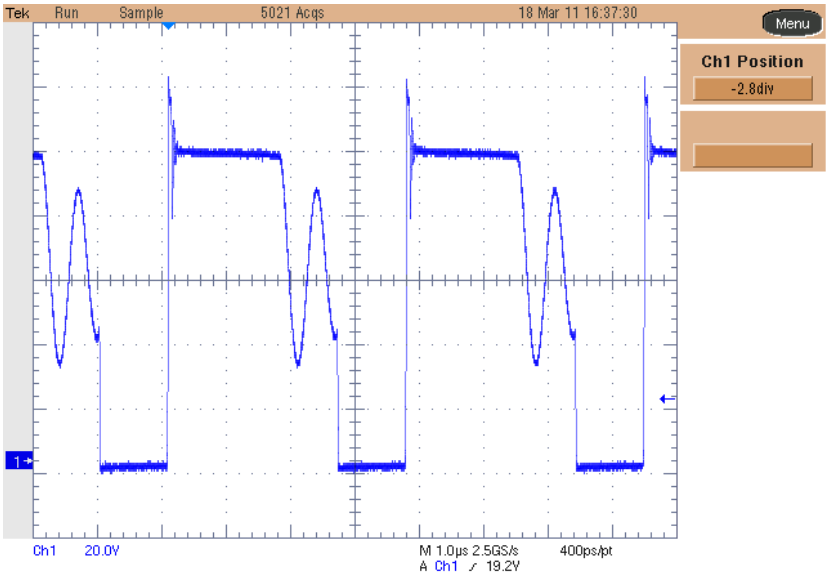
The images below show the switch-node waveform (drain of Q1). The input voltage was set to 18Vin and 60Vin respectively. A full load condition (on both outputs) and no load condition show the variation of the duty cycle. It never reaches zero because of the small clamping load made by D5, R24.

Channel 1: Q1 Vds voltage (20 V/div, 1us/div, No BWL).

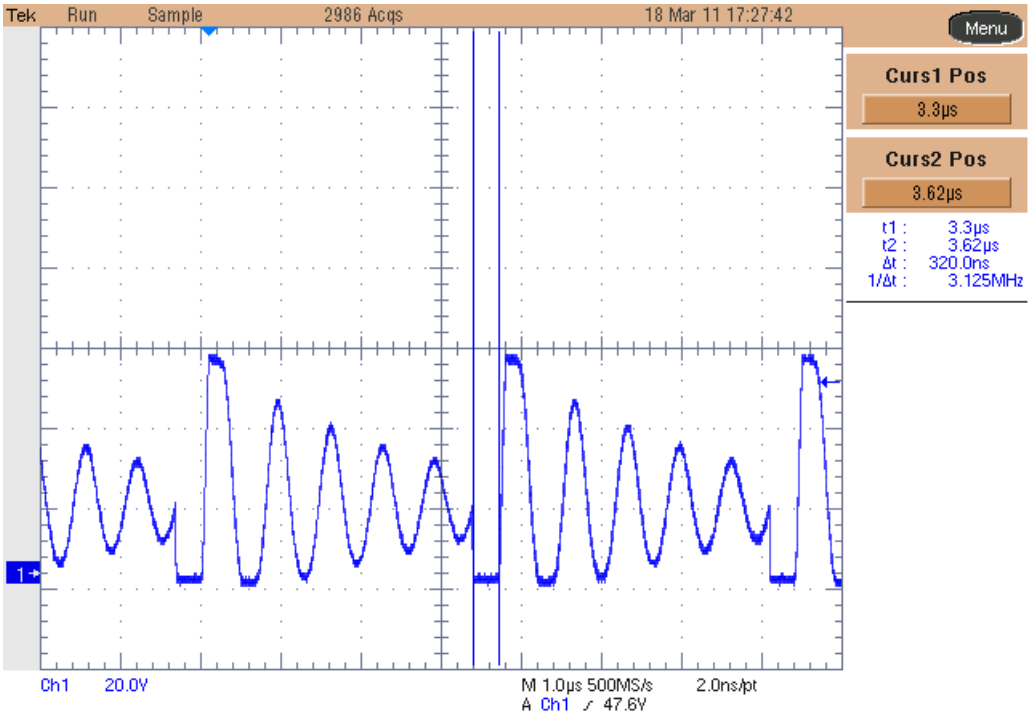
Full Load, 18Vin; Duty cycle: 68.5%



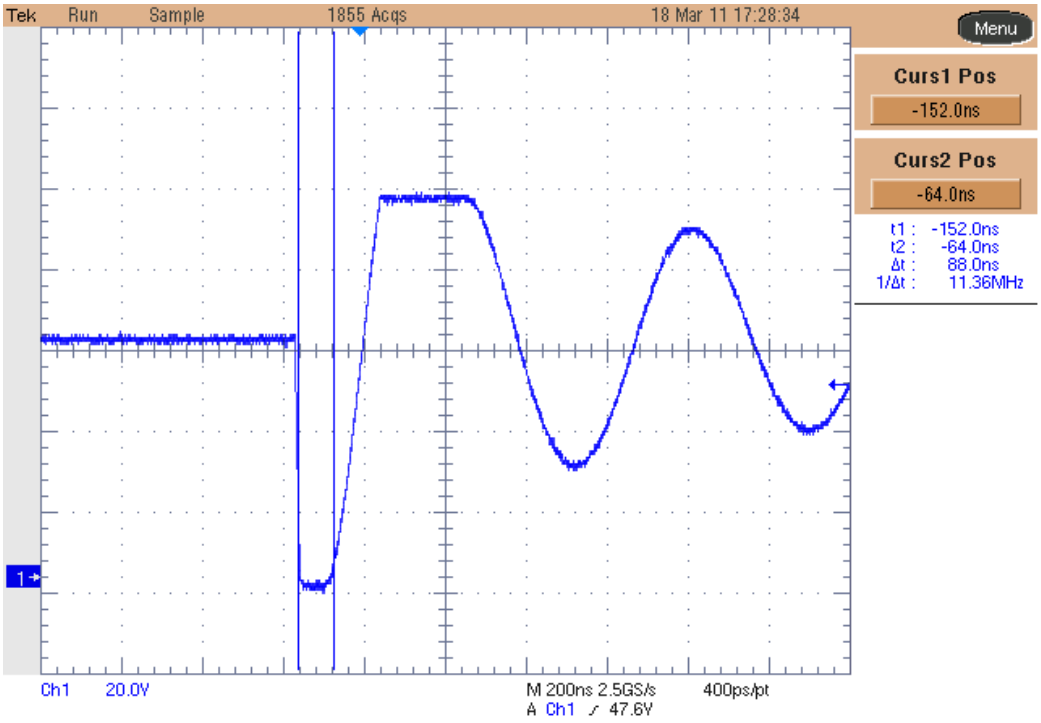
Full Load, 60Vin; Duty cycle: 28.23%



No Load, 18Vin; Ton = 320nsec



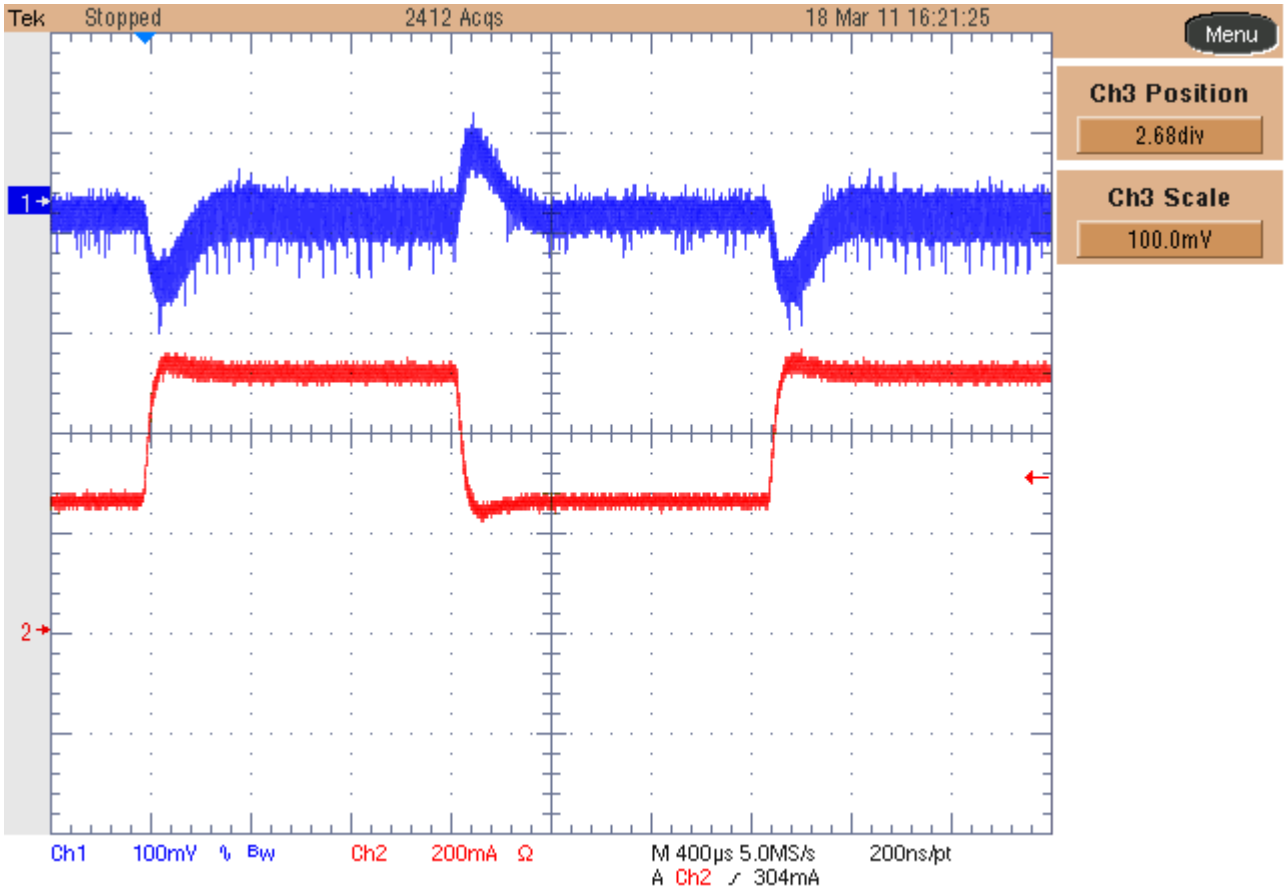
No Load, 60Vin; Ton = 88nsec



7 Transient response

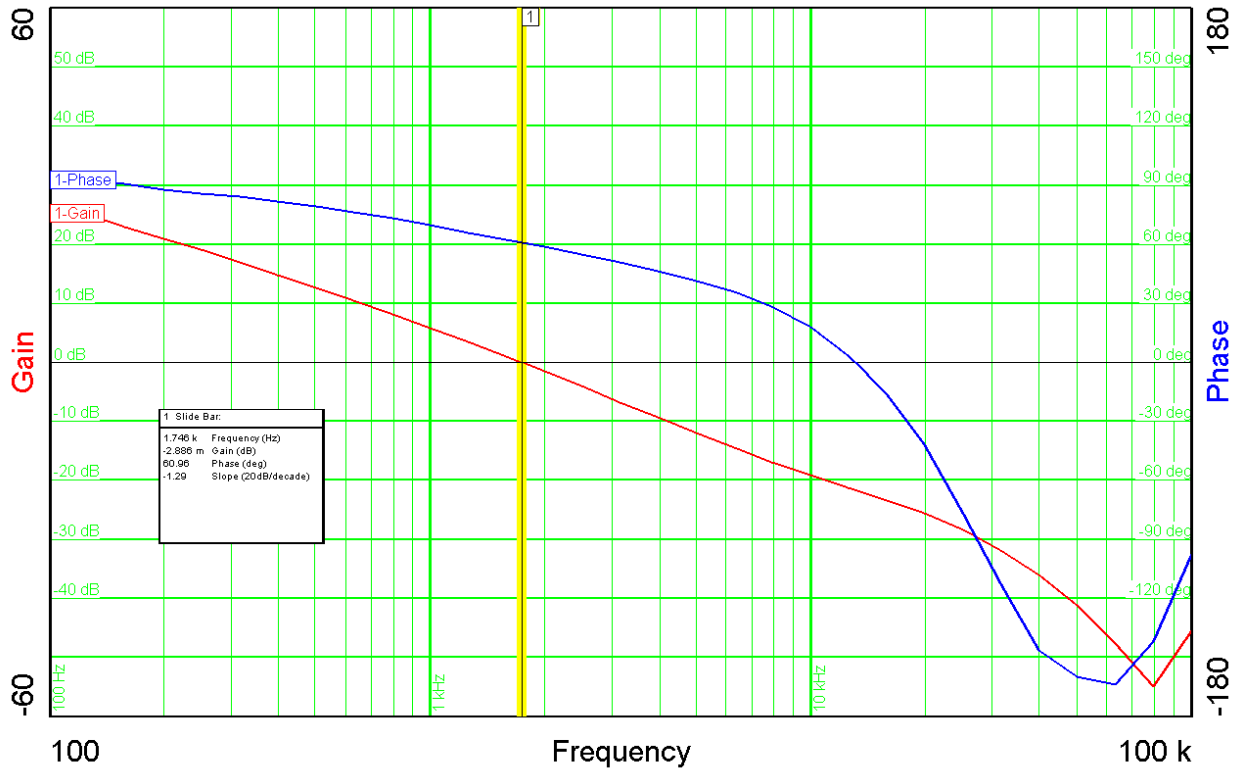
The image below shows the transient response of the +12Vout when the load was switched between 250mA and 500mA, and the -12V was loaded continuously with 250mA constant current load. The input voltage was set to 20V.

Channel 1: +12V output voltage (100 mV/div, AC coupling, 20 MHz BWL, 400us/div).
Channel 2: Output current (200 mA/div, DC coupling, No BWL).



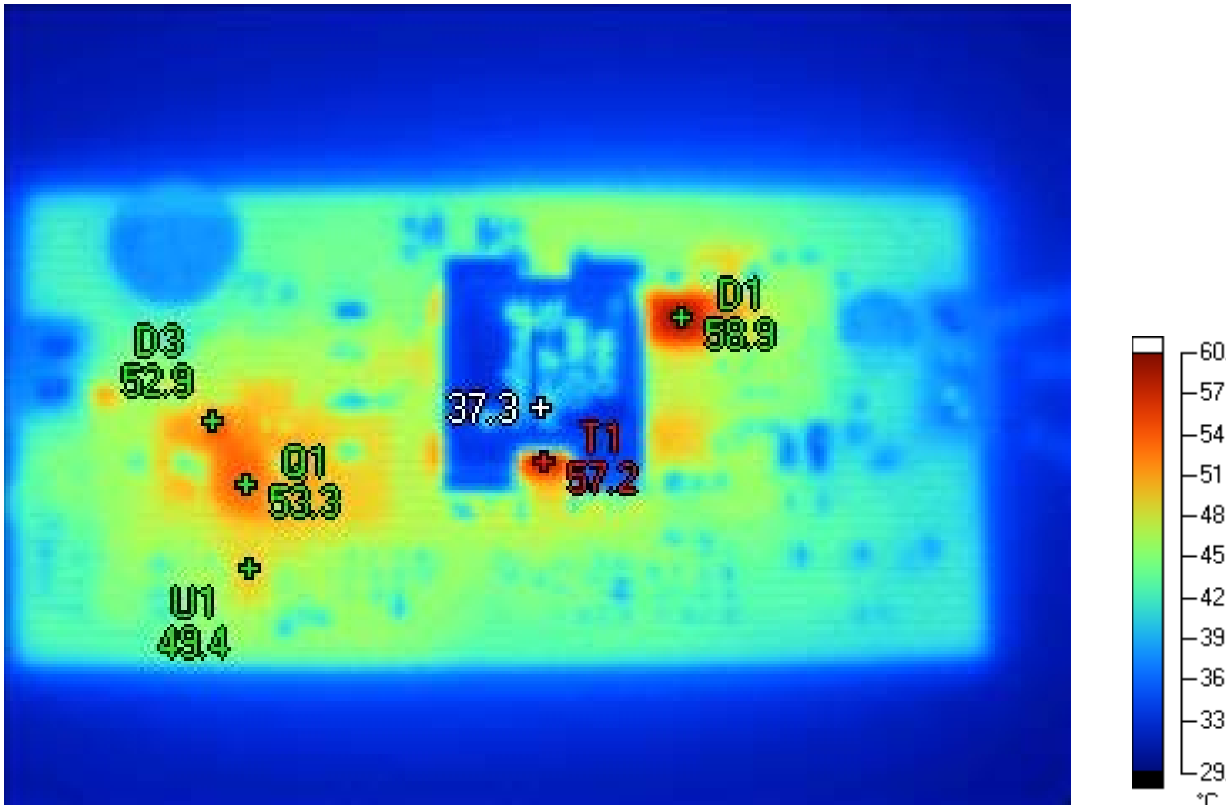
8 Loop Response

The image below shows the loop response of the converter measured with a 18Vdc input, and full load on both outputs. This is the worst case since the converter works, at this input voltage, in continuous conduction mode, thus generating a right half plane zero; this is the reason why we must keep low the crossover frequency.
The phase margin was 60.96 deg., the gain margin 21.62dB, and the crossover frequency was1.746KHz.



9 Thermal Image

The image below shows the thermal image taken from a **Fluke Ti40FT** Thermal camera. The input voltage was set to 39V and the power supply was fully loaded on both outputs; the ambient temperature was 23C and the measurement has been performed in still air conditions. The hottest spot was the diode D1 with 58.9C.



3/21/2011 12:44:30 PM

Image Info

Emissivity	0.95
Background	20.0 °C
Average Temperature	38.2 °C
Calibration Range	-20.0 °C to 100.0 °C
Camera Model	Ti40FT
Image Range	29.9 °C to 58.9 °C
Image Time	3/21/2011 12:44:30 PM
Lens Description	20mm/F0.8
Lens Serial #	40948-4409
Manufacturer	Fluke
Camera Serial Number	Ti40FT-070263

Markers

Label	Temperature	Emissivity	Background
Center Point	37.3 °C	0.95	20.0 °C
Q1	53.3 °C	0.95	20.0 °C
D3	52.9 °C	0.95	20.0 °C
U1	49.4 °C	0.95	20.0 °C
T1	57.2 °C	0.95	20.0 °C
D1	58.9 °C	0.95	20.0 °C

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