Test Data
For PMP10604
02/27/2015

Texas Instruments

Overview

The PMP10604 reference design is a 2-layer board 5V, 3A output power supply using LM53603 buck regulator for cluster unit in automotive applications. The LM53603 is a 3.5V to 36V input, 3A output capable, and 2.1 MHz fixed frequency buck regulator, specially designed for automotive applications. It has exceptionally low quiescent current (24μA typical at no load), and can transit to PFM from PWM to ensure high efficiency at light load. For this reference design, it has an input voltage range of 7.5V to 36V, covering the wide variation conditions of the 12V battery in automotive space. The reference board includes an input EMI filter section, and the layout is optimized for improved EMI performance on a 2-layers PCB. The board was tested under the automotive EMC standard, CISPR 25, and the conducted emissions were in compliance with the CISPR 25 Class 5 requirements.

Power Specification

Vin range:	7.5V – 36V
Output voltage:	5V
Output current:	3A max
Switching Frequency:	2.1 MHz in PWM mode

Reference Board

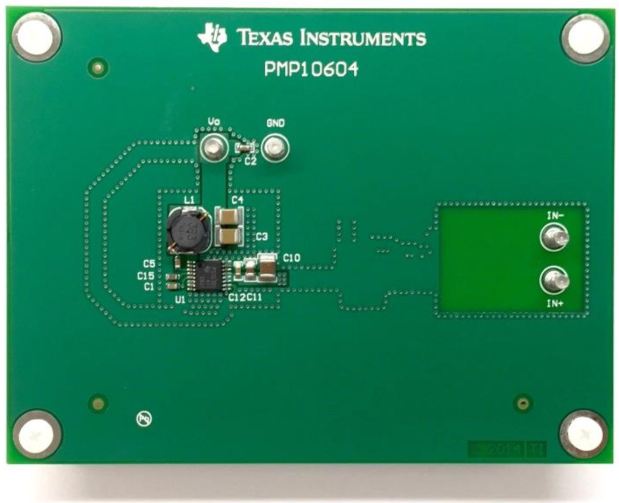

Figure 1 Reference board top view

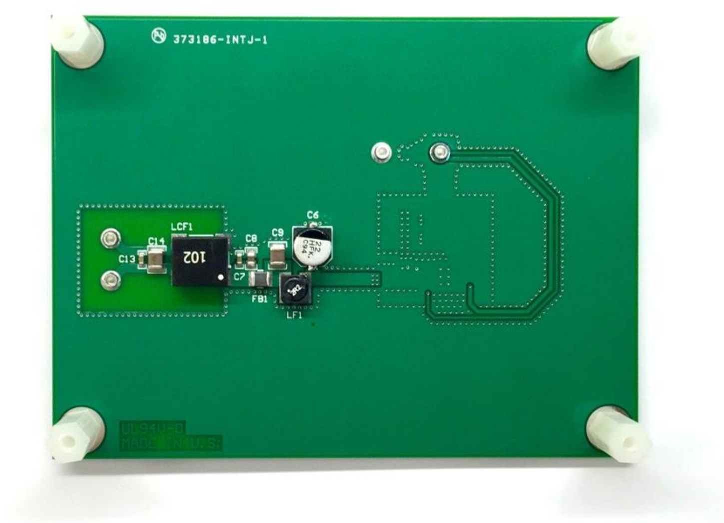

Figure 2 Reference board bottom view

The board size is 76 x 102 mm.

The component area is about 15x20 mm for the power converter, and about 10x35 mm for the input filter.

Efficiency

The efficiency measurement was taken at 7.5V, 12V, 24V and 36V inputs with load current sweep. The peak efficiency is 91% at 7.5V input and 1A out.

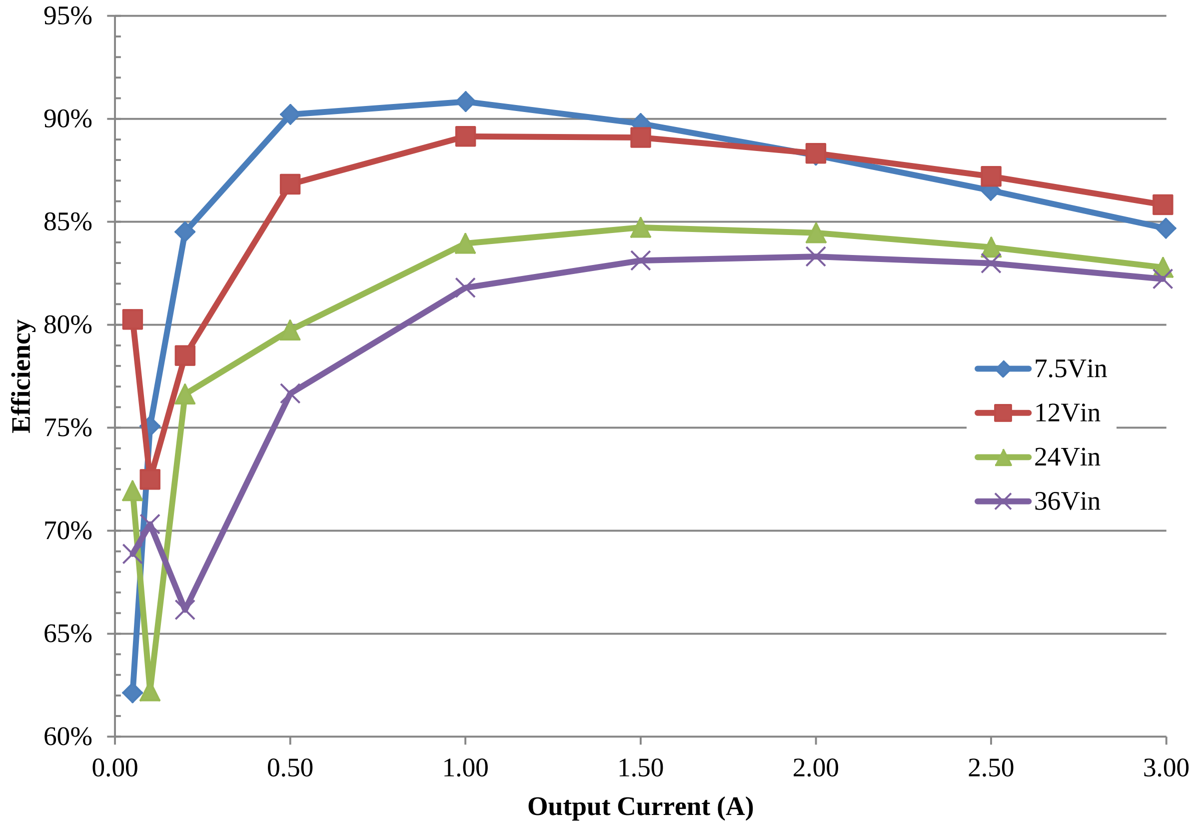

Figure 3 Power efficiency

Thermal

The thermal image was taken at 23°C room temperature, no air flow. The board was operating at 12V input, 3A output. The thermal performance can be further improved by using more layers and thicker copper.

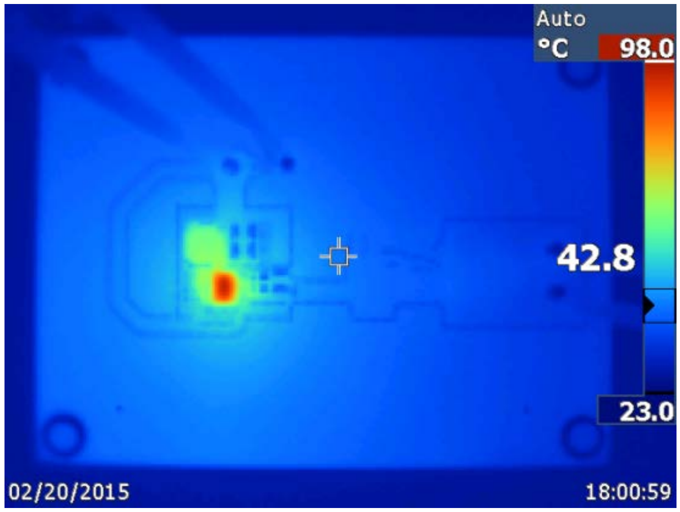

Figure 4 Thermal image from top view

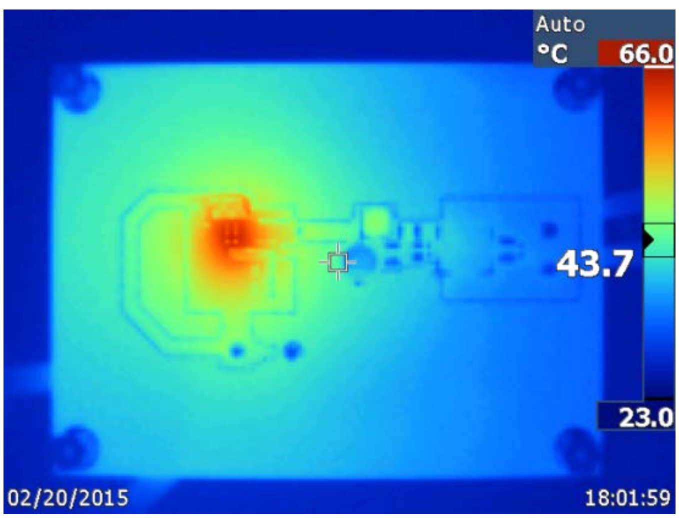

Figure 5 Thermal image from bottom view

Regulation

The overall variation on the 5V output is within 1.5%.

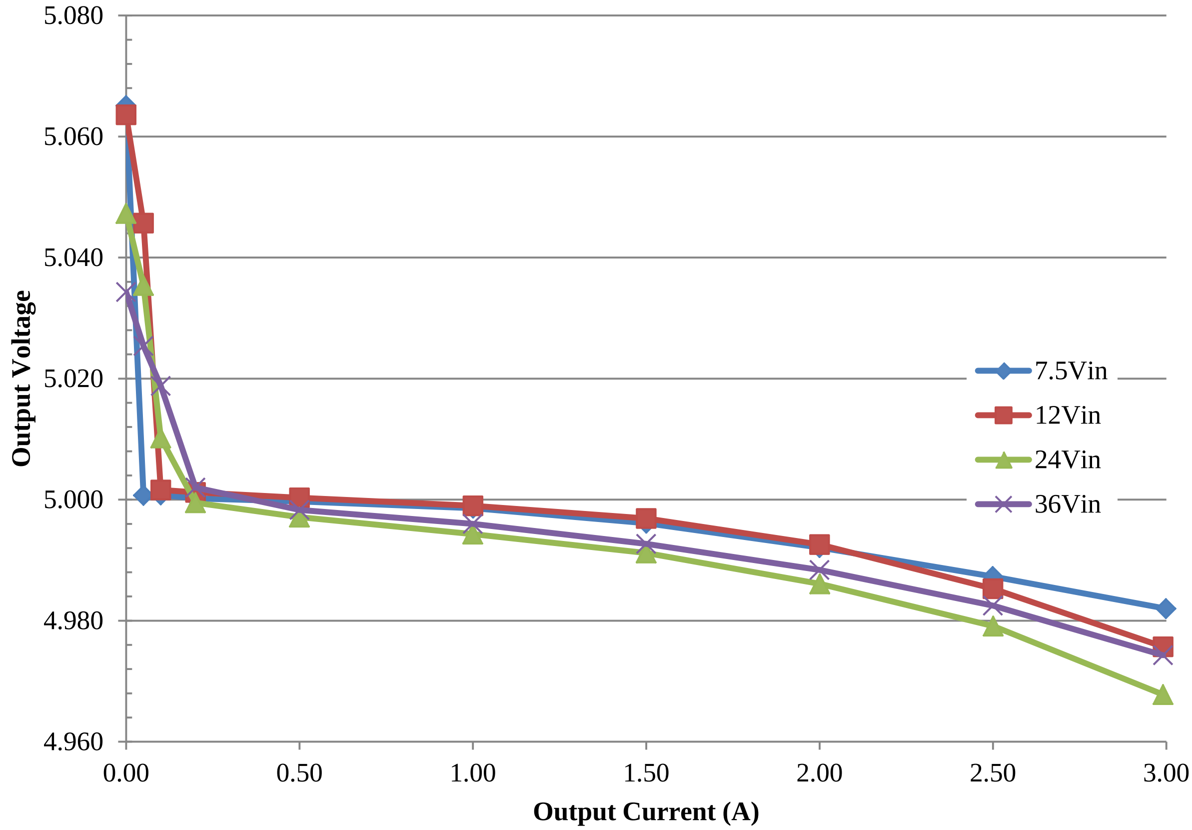

Figure 6 Output regulation

Supply Current at No Load

The input current was measured at no load condition. It can be seen that the power supply was drawing <75µA current, as the LM53603 operated in PFM.

Vin (V)	Iin (µA)	Vout (V)
7.501	71	5.065
12.002	54	5.064
24.002	43	5.047
36.001	44	5.034

Conducted EMI

The conducted emissions were tested under the CISPR 25 standards. The test setup is shown in Figure 7. A 13V input voltage was fed to the test board through two CISPR 25 compliant LISNs (Line Impedance Stabilization Networks), and three 5Ω resistors were soldered on the output terminals of the test board as a 3A load.

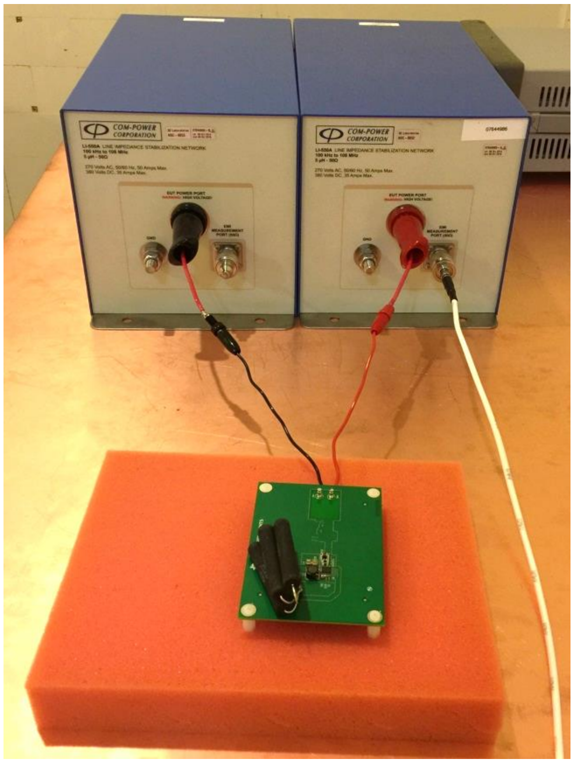

Figure 7 Conducted EMI Test Setup

On the reference board, the input EMI filter section (Figure 8) has a common mode filter stage and a differential mode filter stage. The common mode filter section is to further suppress the high frequency EMI noise (>30MHz). The conducted EMI was tested with and without the common mode filter. The test result shows that the reference board is compliance with CISPR 25 Class 5 with the common mode filter, and it can pass Class 4 marginally without the common mode filter. Note that all the other tests were done with the common mode filter.

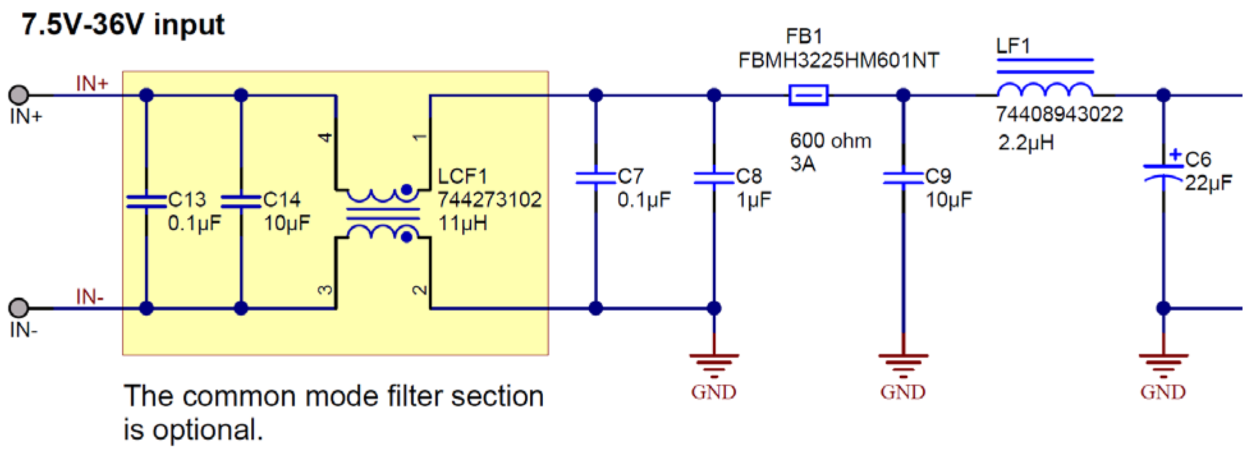

Figure 8 Input filter schematic

The frequency band examined spans from 150 kHz to 108 MHz covering the AM, FM radio bands, VHF band, and TV band specified in the CISPR 25. The scan results (Figure 9, Figure 10, Figure 11 and Figure 12) show the EMI noise using peak detector (yellow) and average detector (blue) in the spectrum analyzer. The limit lines in red are the Class 5 limits for conducted disturbances at different frequency bands specified in the standard, and the peak limits are the higher ones than the average limits. Figure 9 and Figure 10 are the test results with common mode filter, while Figure 11 and Figure 12 are the ones without common mode filter. It can be seen that they have similar performance at low frequency (<30MHz), but the test with common mode filter has lower EMI noise level in high frequency region (>30MHz). With common mode choke, the peak/average noise is lower than the corresponding peak/average limits in the scan results. Therefore, the power supply board is in compliance with the CISPR 25 Class 5 conducted emissions standard.

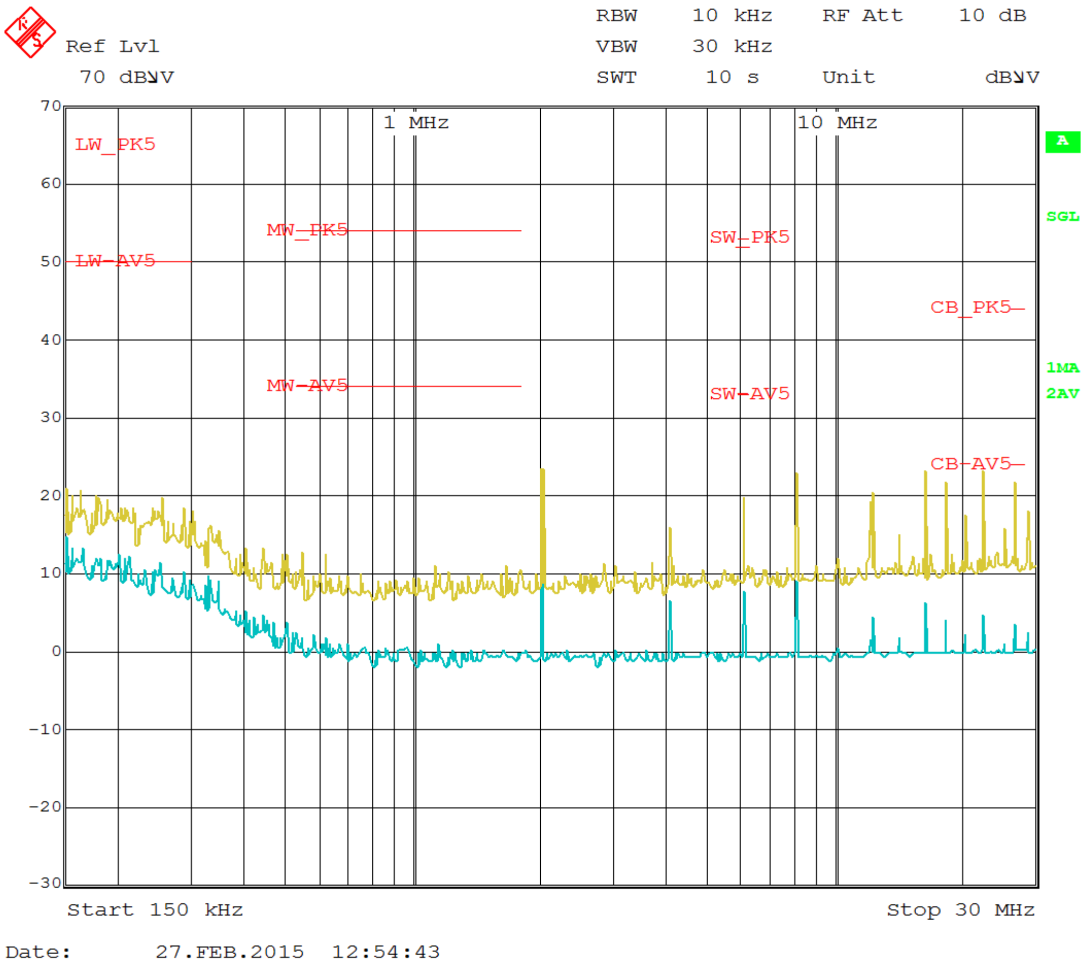

Figure 9 Conducted EMI scan, 150 kHz – 30 MHz, with common mode filter

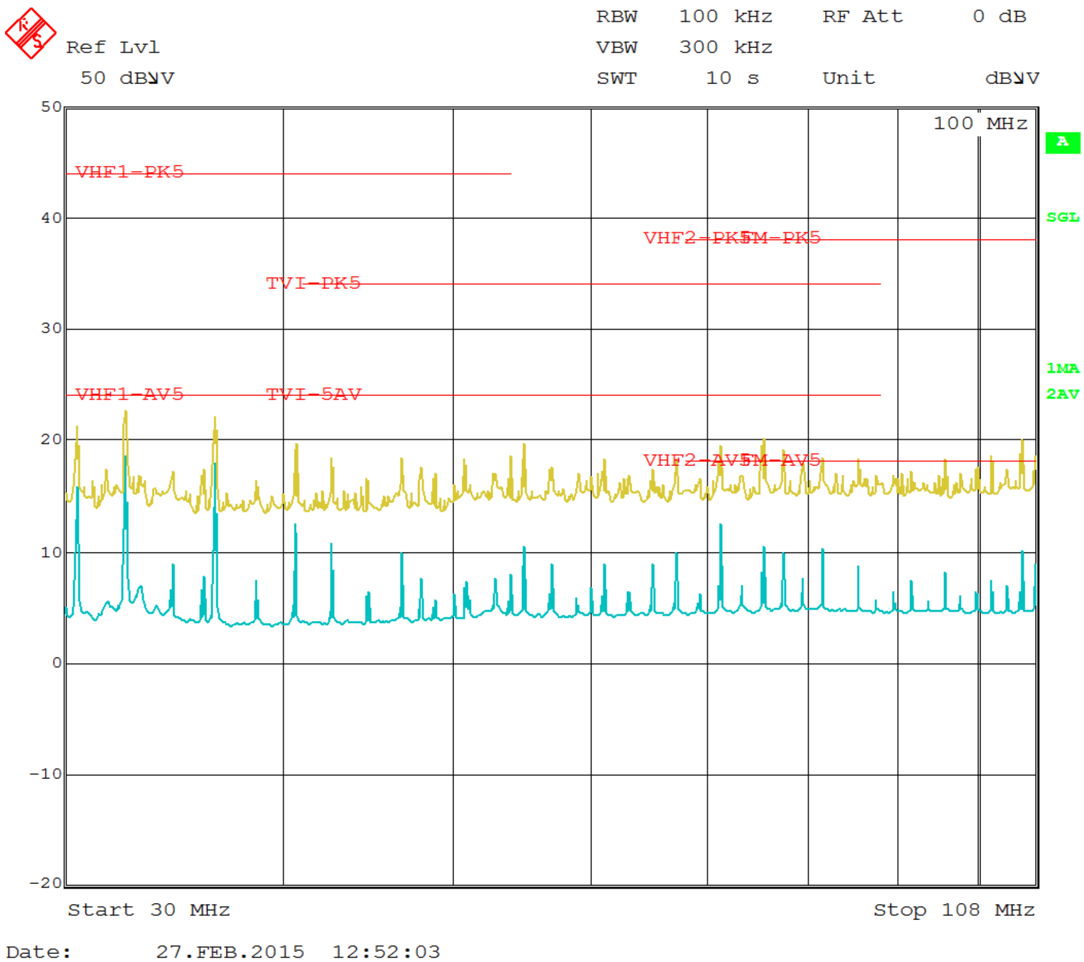

Figure 10 Conducted EMI scan, 30 MHz – 108 MHz, with common mode filter

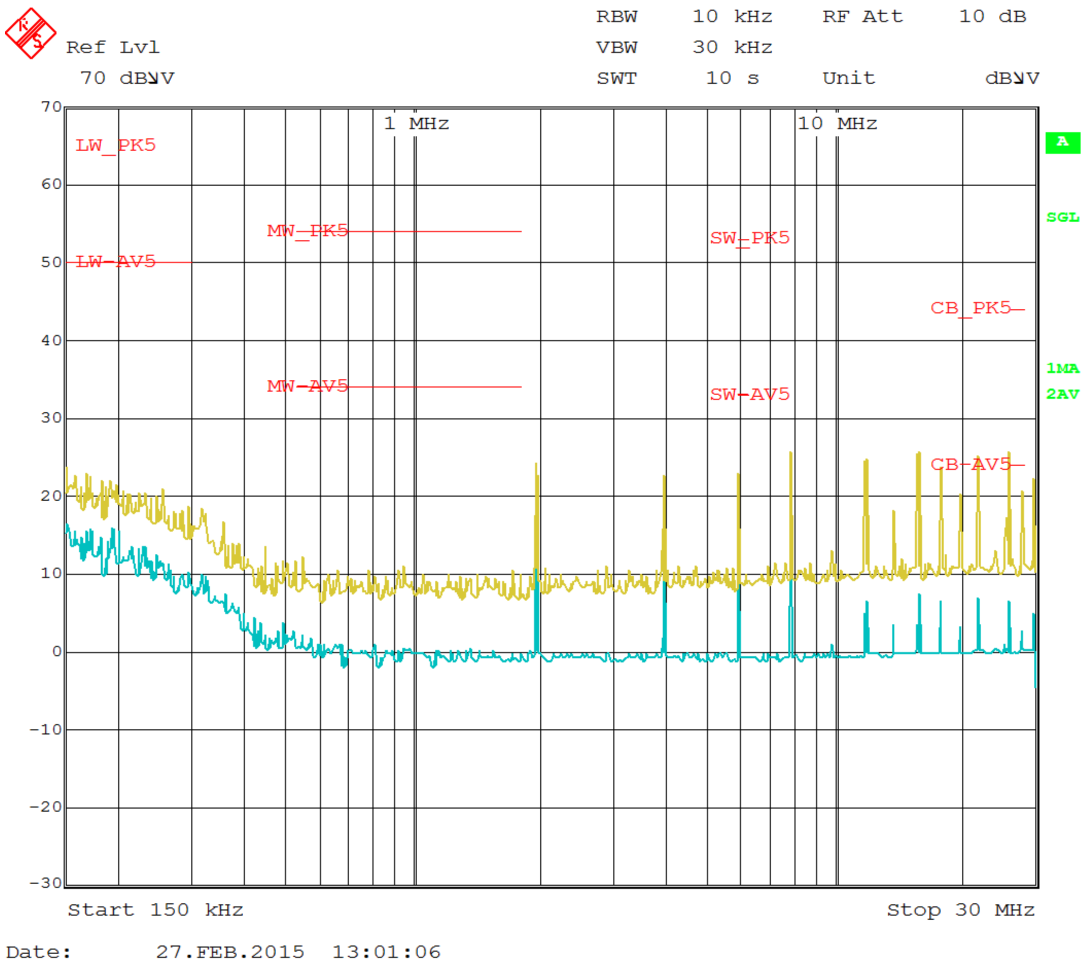

Figure 11 Conducted EMI scan, 150 kHz – 30 MHz, without common mode filter

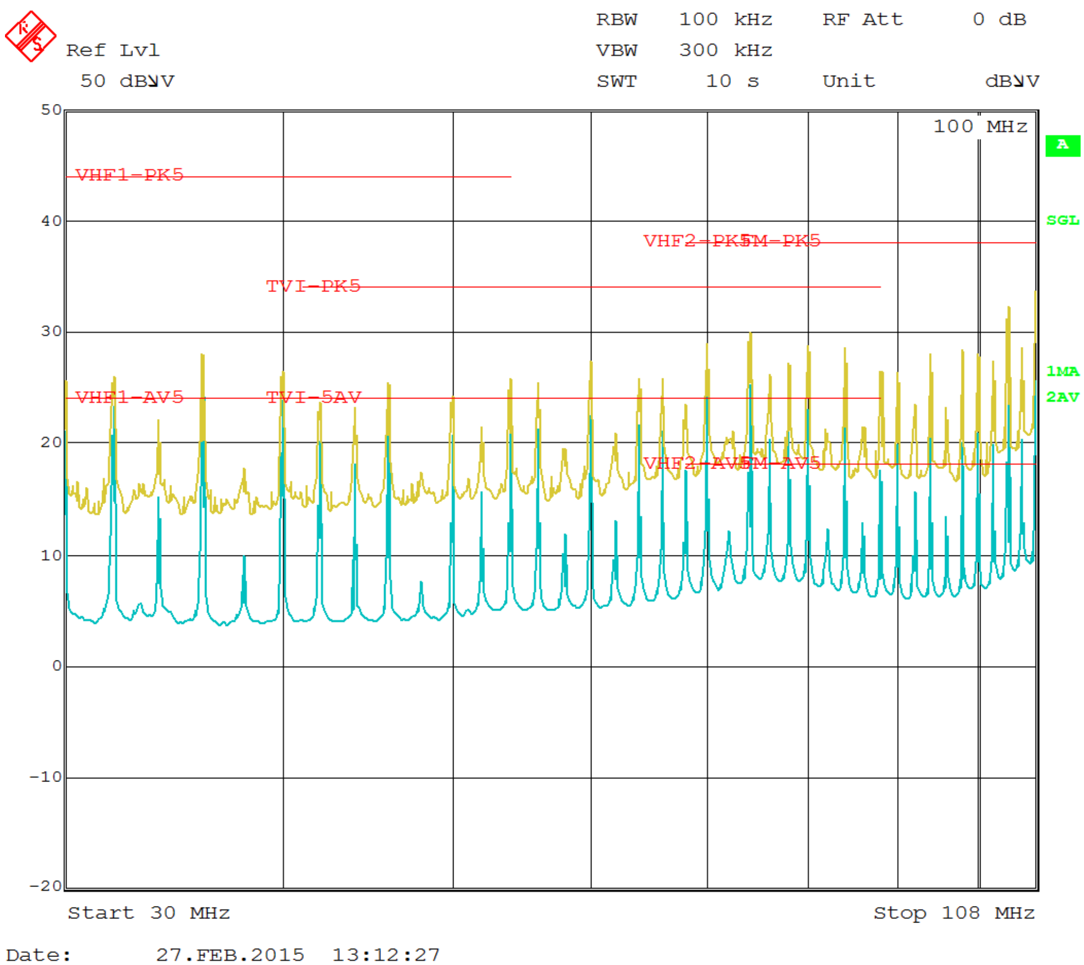

Figure 12 Conducted EMI scan, 30 MHz – 108 MHz, without common mode filter

Start Up

Ch1 (yellow) is the input voltage, and Ch2 (green) is the output voltage. It has about 2.5ms start-up time with full load or no load.

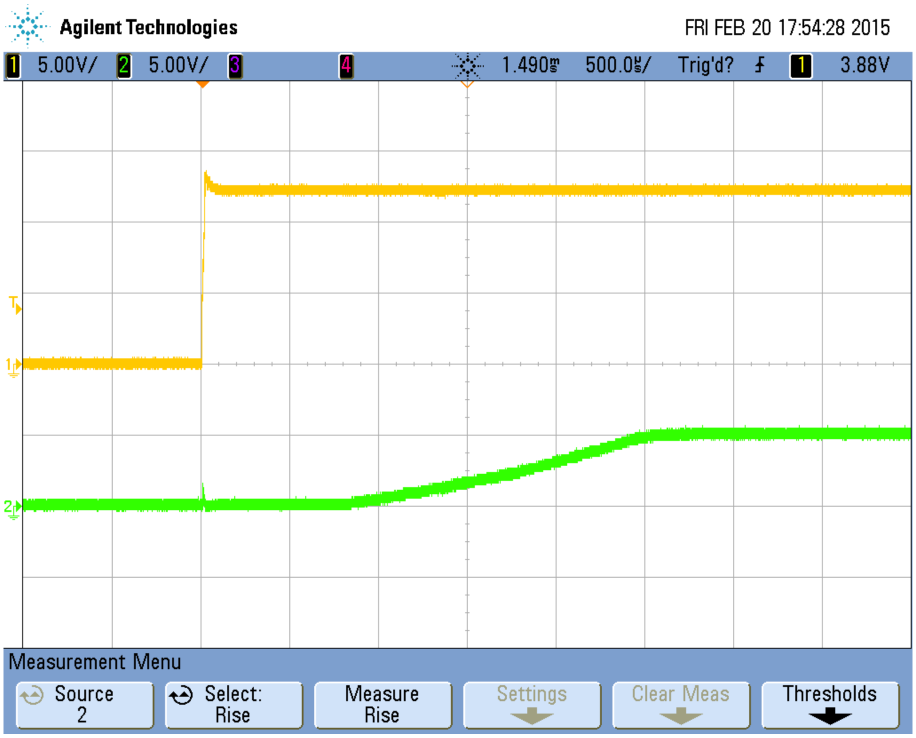

Figure 13 Start up into 3A load at 12Vin

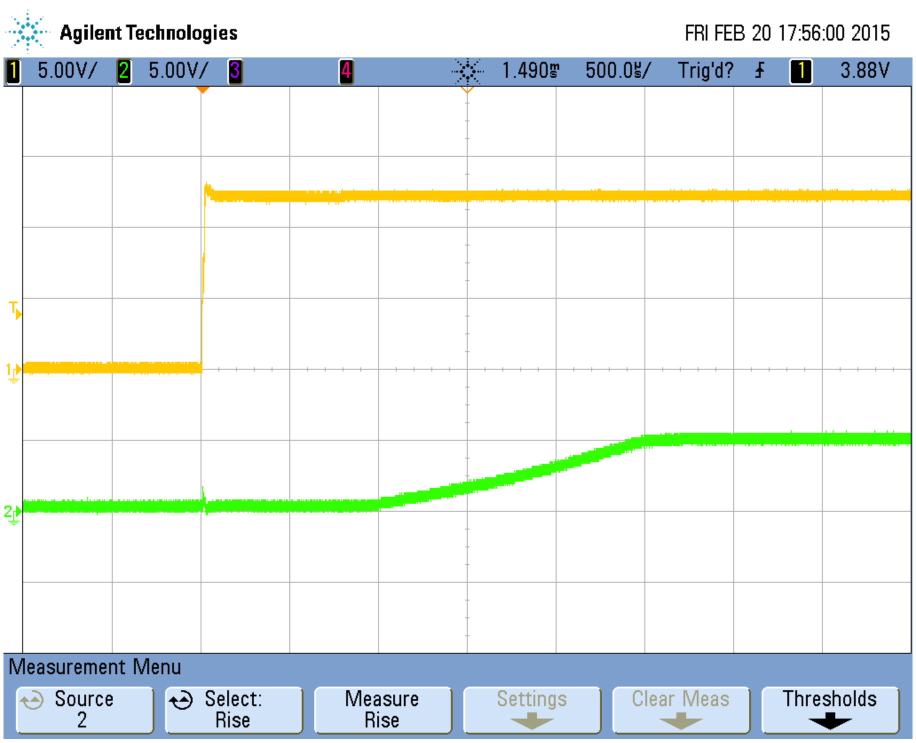

Figure 14 Start up into no load at 12Vin

Switching Waveforms

The switching waveforms show the operations in the PWM and PFM, and the switching frequency slows down at high input voltage in PWM as reaching minimum on-time. Ch1 (yellow) is the switch node voltage.

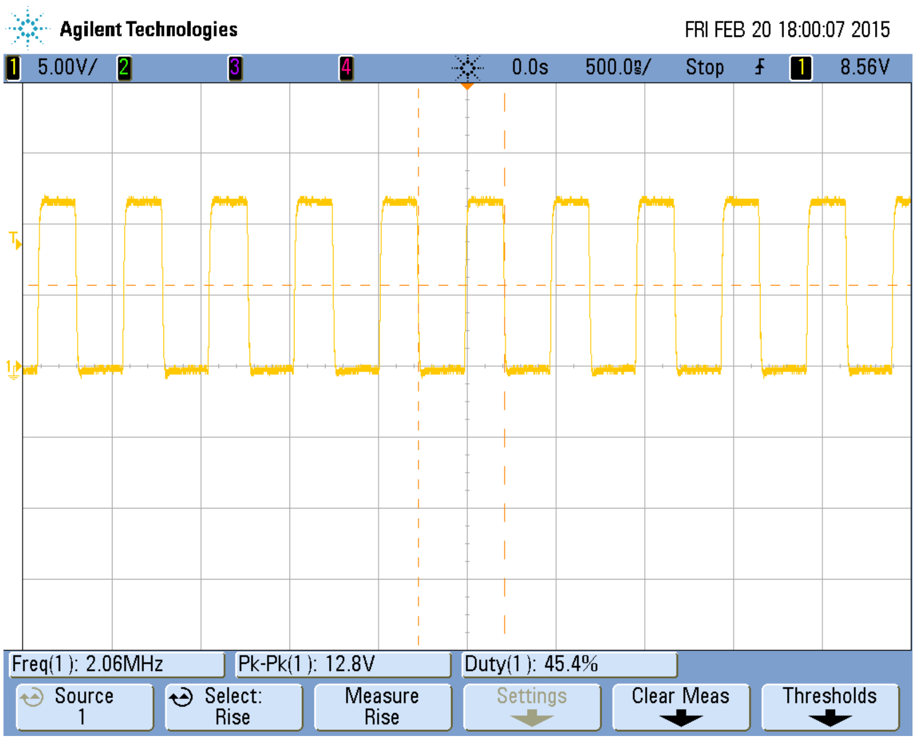

Figure 15 Switching waveform at 3A load, 12Vin, PWM

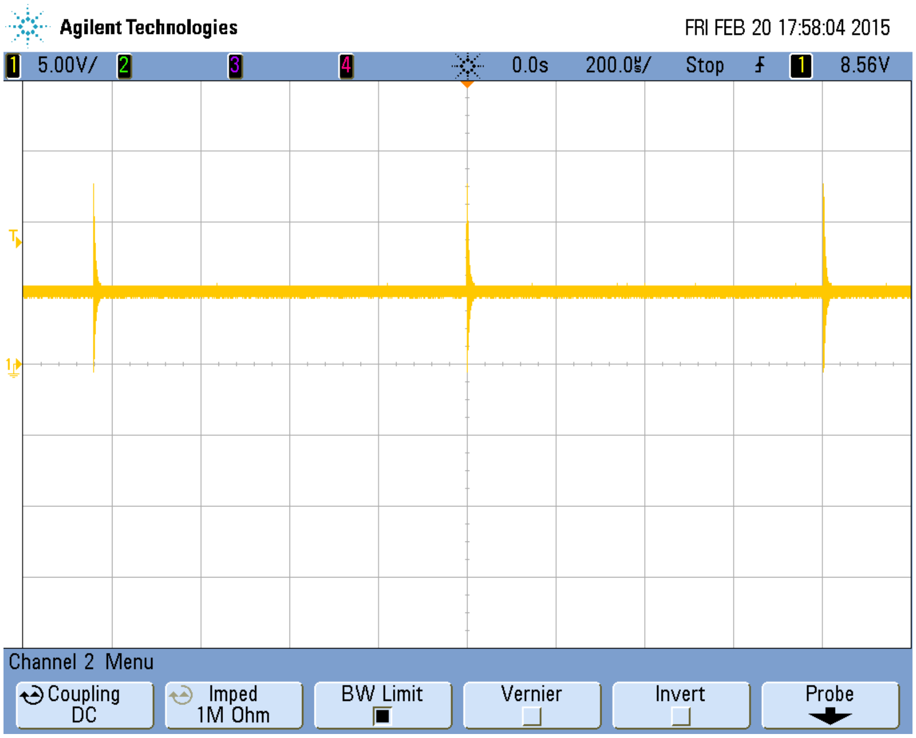

Figure 16 Switching waveform at no load, 12Vin, PFM

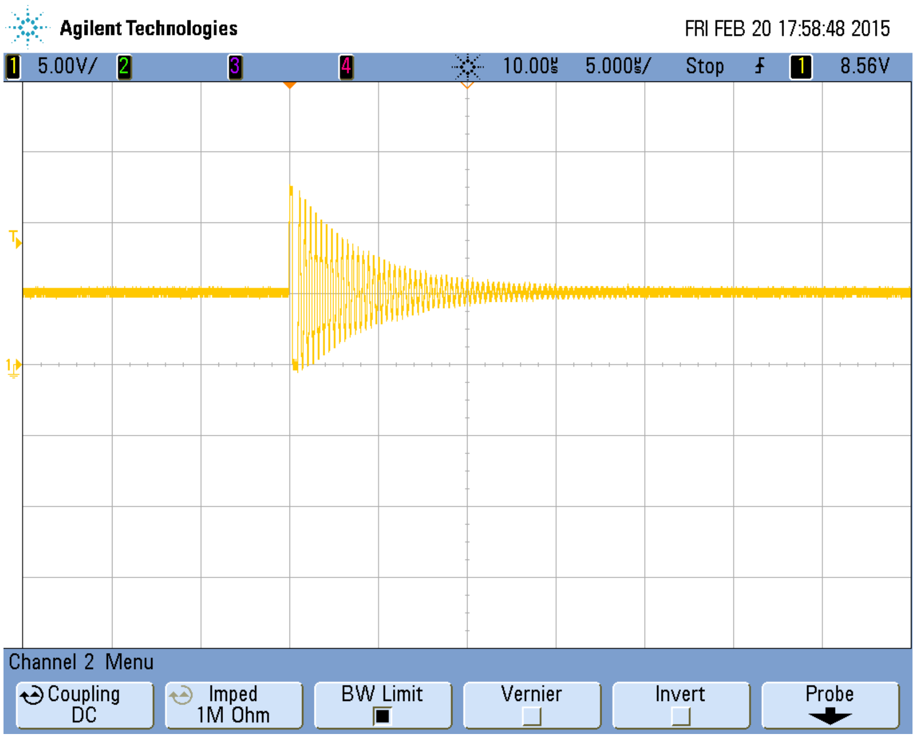

Figure 17 Zoom-in switching waveform at no load, 12Vin, PFM

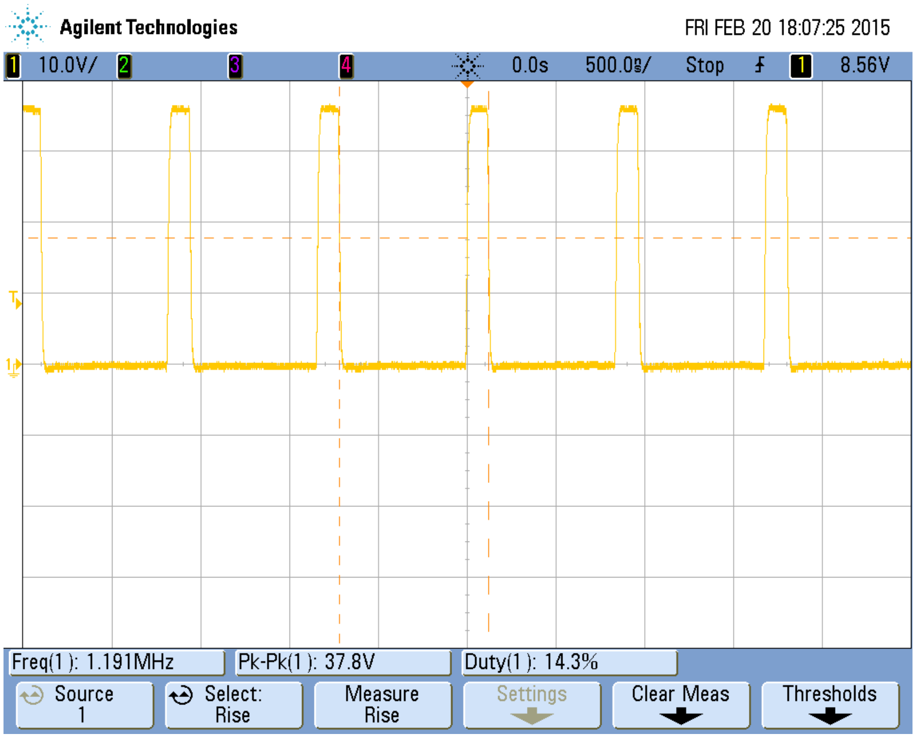

Figure 18 Switching waveform at 3A load, 36Vin, PWM, reduced Fsw

Load Transients

The load transient response was tested by applying load steps on the output at 12V input. Ch1 (yellow) is the output voltage in AC mode, and Ch4 (magenta) is the output current.

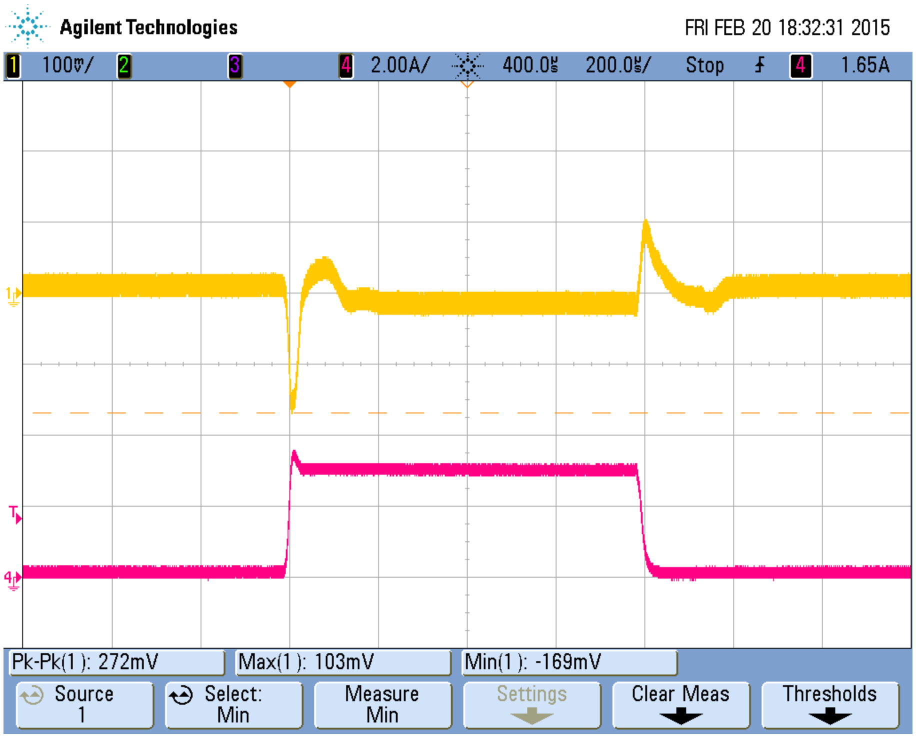

Figure 19 Output load transient 0A to 3A at 12Vin

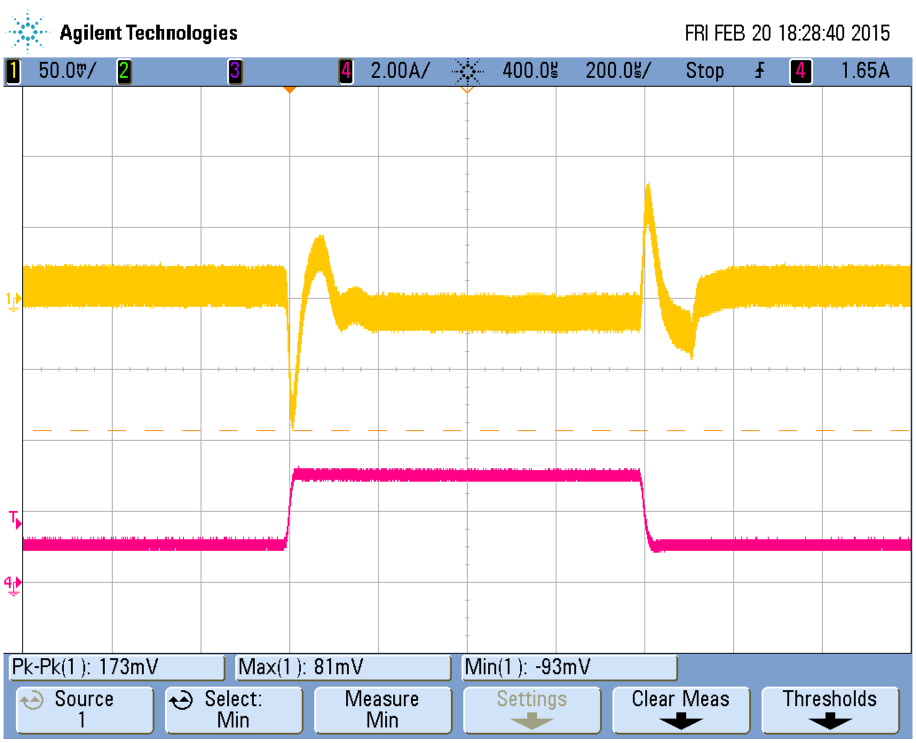

Figure 20 Output load transient 1A to 3A at 12Vin

Output Voltage Ripples

The output ripples were measured directly at the output capacitors. Ch1 (yellow) is the output voltage ripple in AC mode.

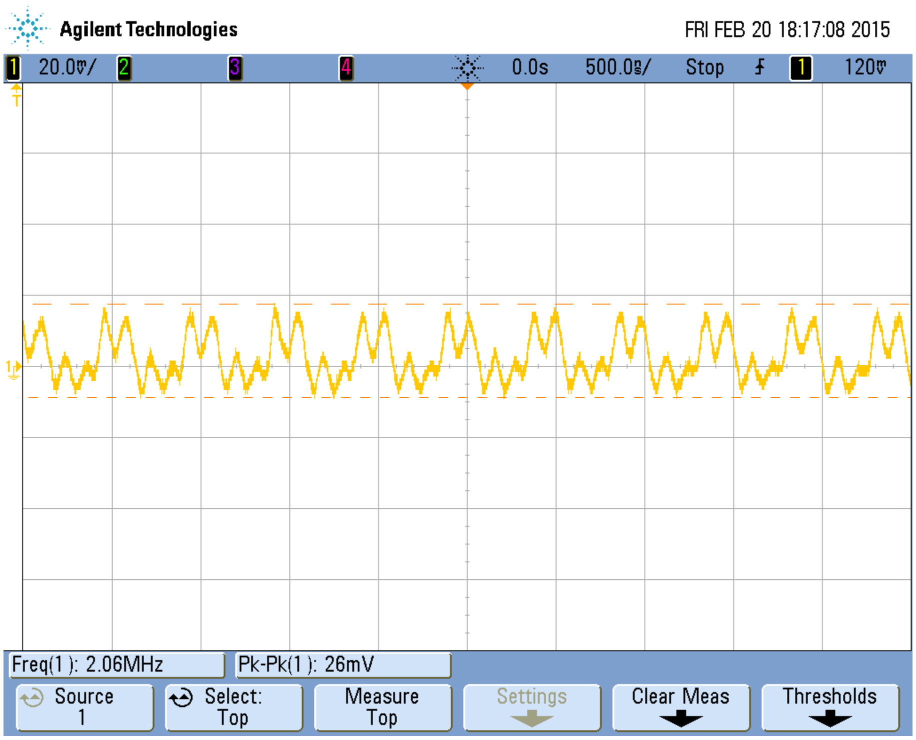

Figure 21 Output ripple at 3A load, 12Vin

Short Circuit Test

The short circuit test was performed by shorting the output rail to ground at 12V input, 3A load. Ch1 (yellow) is the output voltage, and Ch4 (magenta) is the output current.

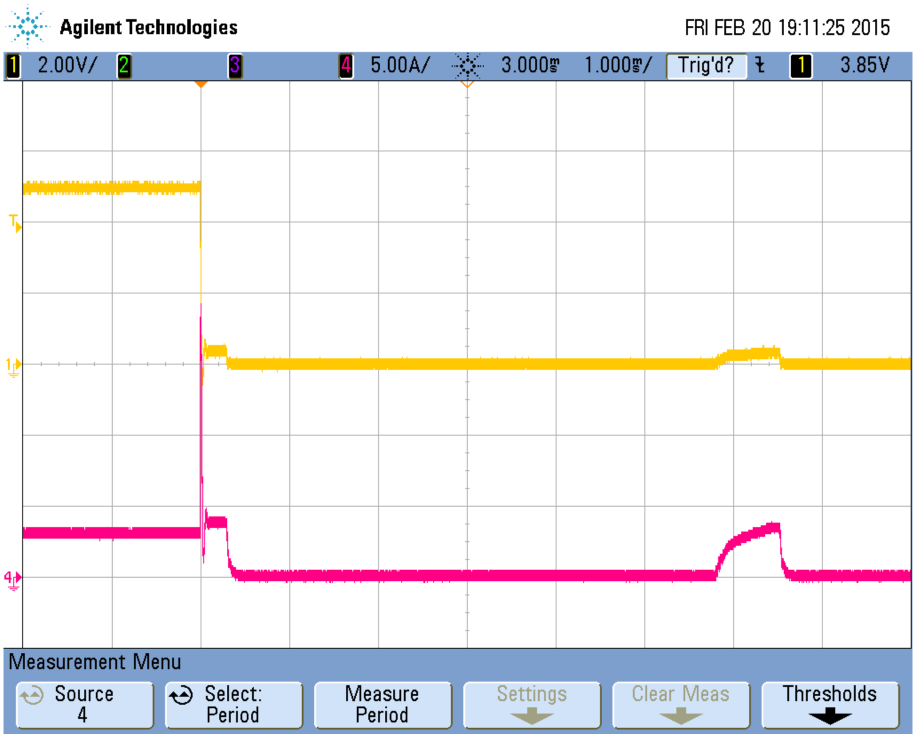

Figure 22 Short circuit transition at 12Vin

Figure 23 Stay in short circuit at 12Vin

Appendix: Efficiency and Regulation Test Data

Vin(V)	Iin(A)	Vout(V)	Iout(A)	Efficiency (%)
7.501	7.12E-05	5.065	0.000	0.0%
7.505	0.054	5.001	0.050	62.1%
7.501	0.089	5.001	0.100	75.1%
7.508	0.158	5.000	0.200	84.5%
7.496	0.370	5.000	0.501	90.2%
7.501	0.734	4.999	1.001	90.8%
7.507	1.112	4.996	1.500	89.8%
7.502	1.508	4.992	2.000	88.2%
7.506	1.919	4.987	2.499	86.5%
7.512	2.349	4.982	2.999	84.7%

Vin(V)	Iin(A)	Vout(V)	Iout(A)	Efficiency (%)
12.002	5.42E-05	5.064	0.000	0.0%
12.017	0.026	5.046	0.050	80.3%
12.046	0.057	5.002	0.100	72.5%
12.079	0.105	5.001	0.200	78.5%
12.036	0.239	5.000	0.500	86.8%
12.017	0.467	4.999	1.000	89.1%
11.992	0.702	4.997	1.500	89.1%
12.067	0.937	4.993	2.000	88.3%
12.000	1.191	4.985	2.500	87.2%
12.002	1.444	4.976	2.990	85.8%

Vin(V)	Iin(A)	Vout(V)	Iout(A)	Efficiency (%)
24.002	4.31E-05	5.047	0.000	0.0%
24.021	0.015	5.035	0.050	71.9%
24.016	0.034	5.010	0.100	62.2%
24.001	0.054	5.000	0.200	76.6%
24.033	0.130	4.997	0.500	79.7%
24.072	0.247	4.994	1.000	83.9%
24.008	0.368	4.991	1.500	84.7%
24.042	0.491	4.986	2.001	84.5%
24.075	0.617	4.979	2.501	83.8%
24.006	0.748	4.968	2.991	82.8%

Vin(V)	Iin(A)	Vout(V)	Iout(A)	Efficiency (%)
36.001	4.38E-05	5.034	0.000	0.0%
36.046	0.010	5.025	0.050	68.9%
35.992	0.020	5.019	0.100	70.3%
36.070	0.042	5.002	0.200	66.2%
36.000	0.091	4.998	0.500	76.7%
36.012	0.170	4.996	1.000	81.8%
36.070	0.250	4.993	1.500	83.1%
36.026	0.332	4.988	2.000	83.3%
36.002	0.417	4.983	2.500	83.0%
35.956	0.503	4.974	2.990	82.2%

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