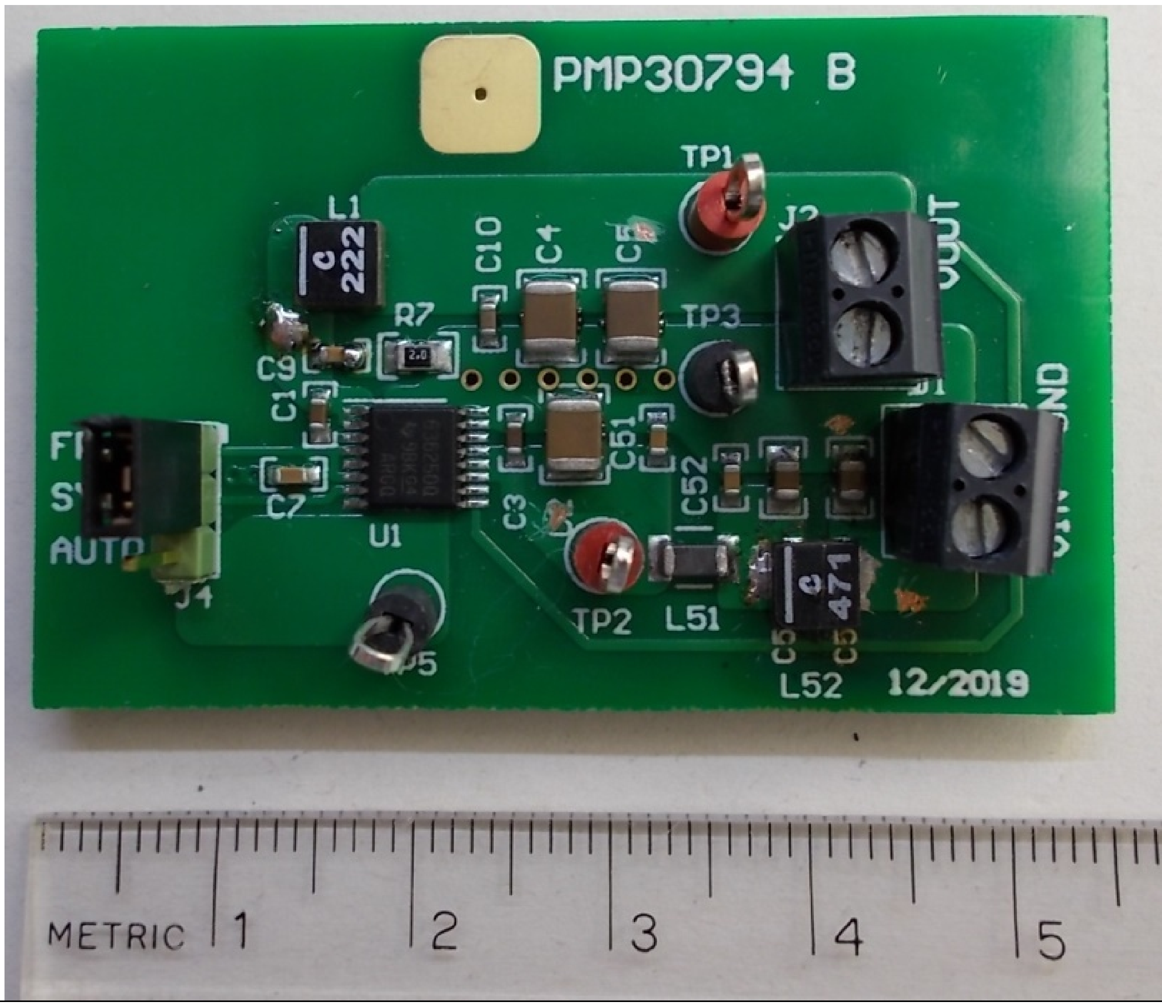
Test Report: PMP30794

2-MHz Synchronous 5-V Buck Reference Design

Description

Tiny automotive buck converter to support a 5-V rail by input voltage range 6.5-V up to 32-Vpk surge. Layout and design is optimized to pass CISPR-25. So design is equipped with a two stage input filter to minimize conducted emissions and a **solid ground plane** to attenuate radiated emissions in short wave range. Power stage capacitors are routed back-to-back to minimize parasitic inductances at forward and freewheeling loop. Highlight is cost effective two layers board, single side assembly – and keeping the solid ground plane to pass EMI.



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1 Test Prerequisites

1.1 Voltage and Current Requirements

Table 1. Voltage and Current Requirements

PARAMETER	SPECIFICATIONS
Input Voltage Range	6.5 V to 18 V
Output Voltage	5 V
Maximum Output Current	2.5 A
Switching Frequency	2 MHz

1.2 Considerations*

Unless otherwise indicated, a resistor was used as load, output current was adjusted to 2.5 A and input voltage was set to 12 V.
Due to availability ferrite bead 742792121 (300 Ω) was used.
Measured switching frequency is 2.1 MHz.

2 Testing and Results

2.1 Efficiency Graphs

The efficiencies are without input filter.

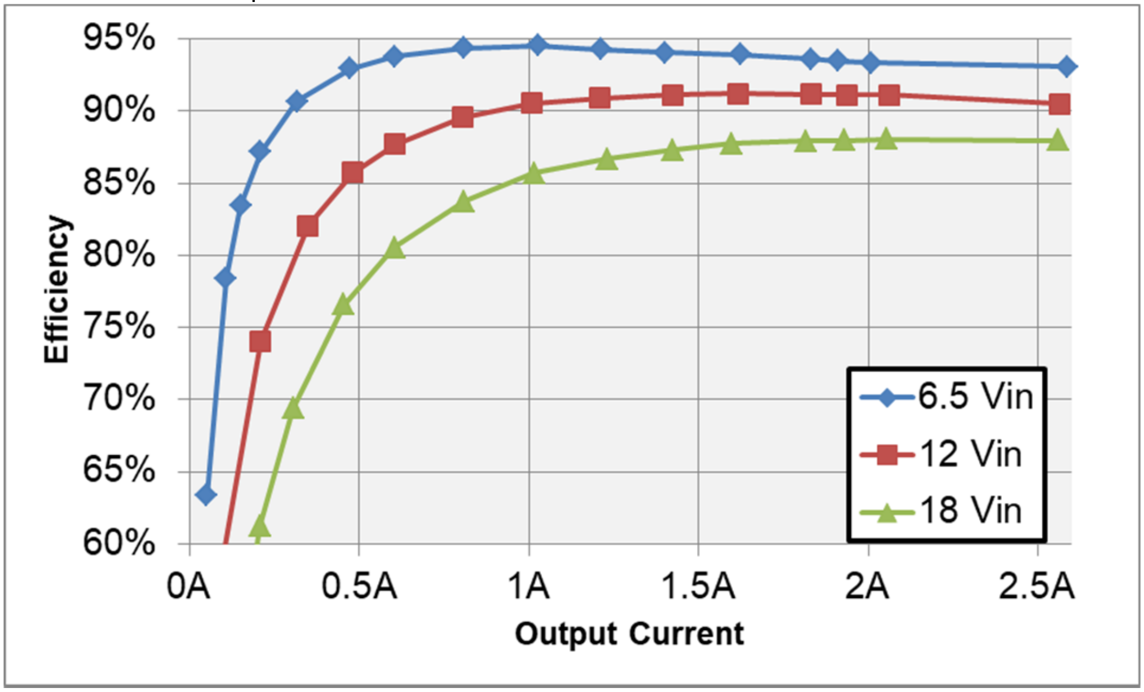


Figure 1 Efficiency vs Output Current

Figure 2 is a comparison of FPWM and AUTO mode.

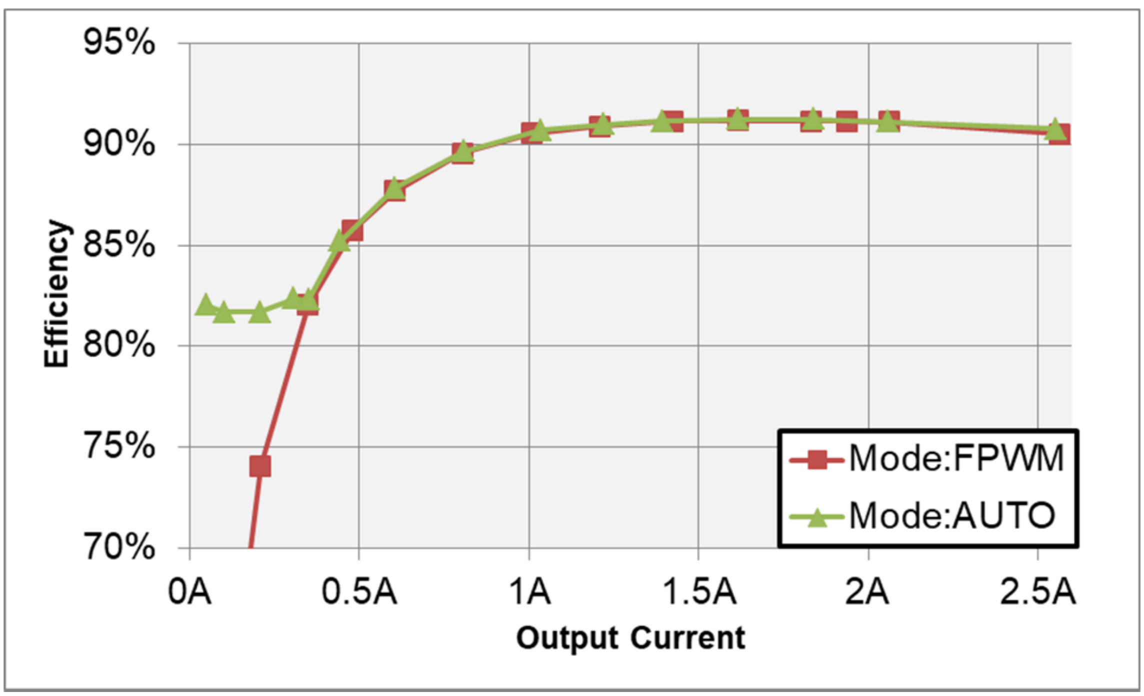


Figure 2 Efficiency @ 12 Vin vs Output Current (Mode Comparison)

See benefit of light load efficiency in AUTO mode !!!

2.2 Loss

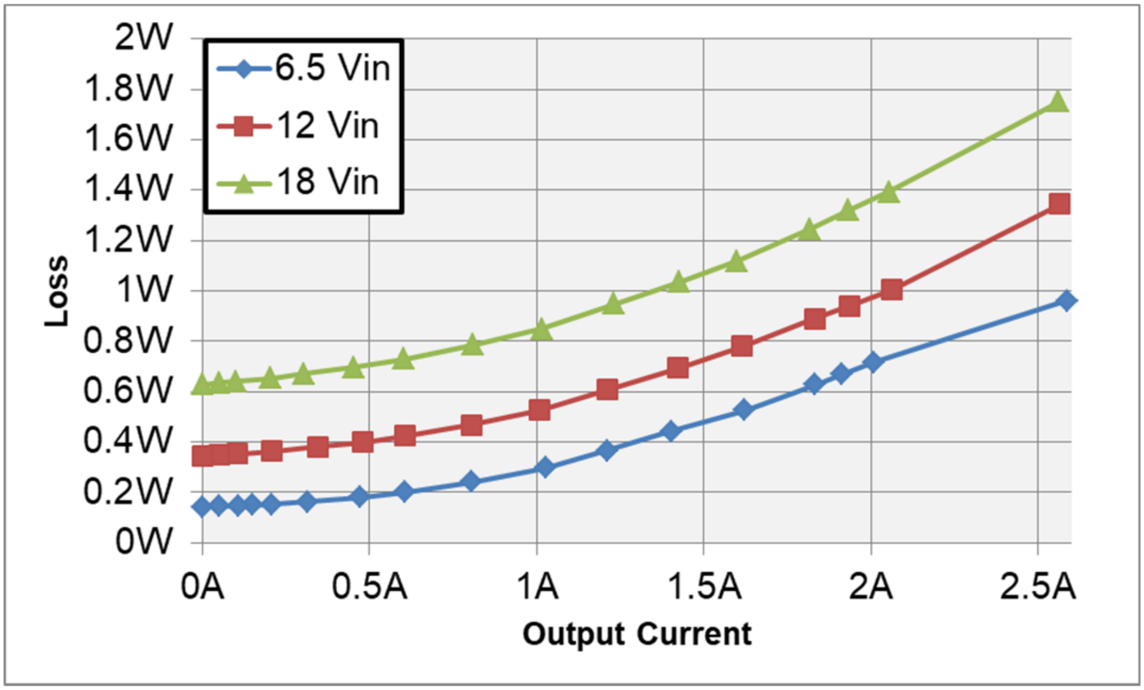


Figure 3 Loss (without input filter) vs Output Current

Figure 4 is a comparison of FPWM and AUTO mode.

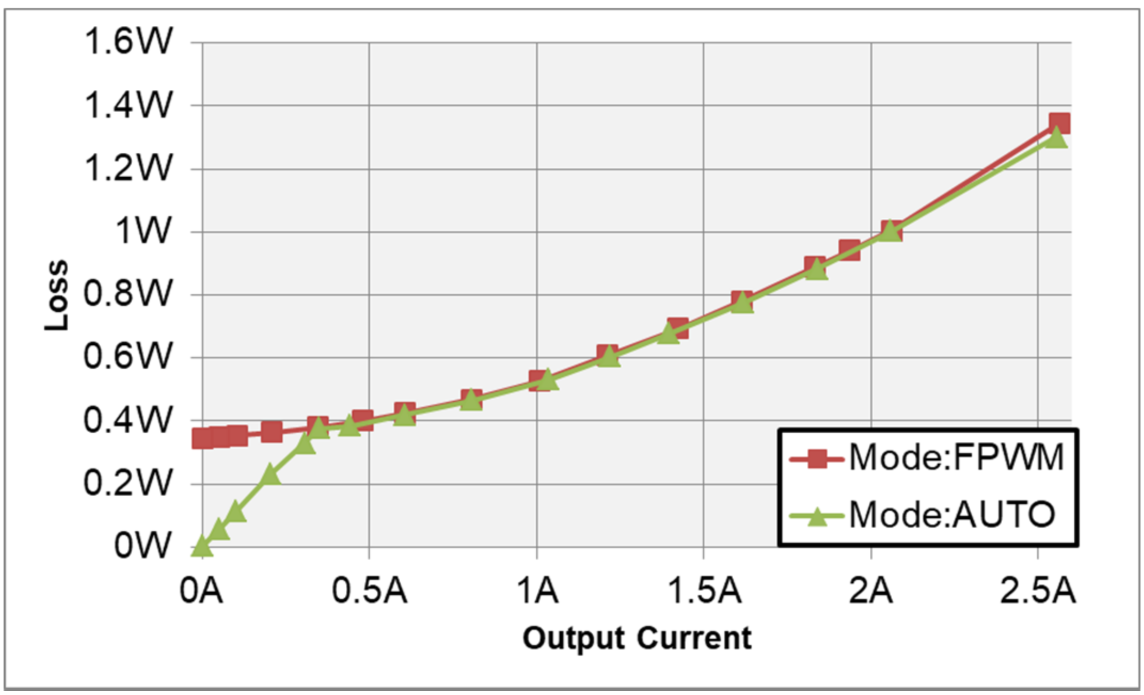


Figure 4 Loss @ 12 Vin vs Output Current (Mode Comparison)

2.3 Load Regulation

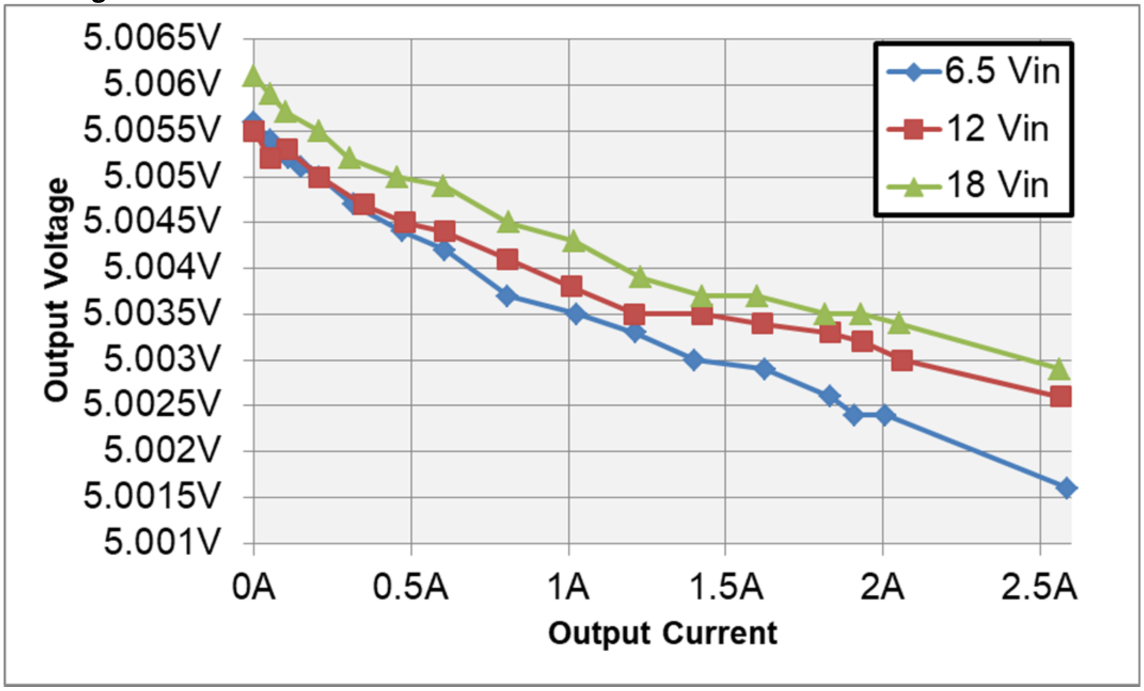


Figure 5 Output Voltage vs Output Current

Figure 6 is a comparison of FPWM and AUTO mode.

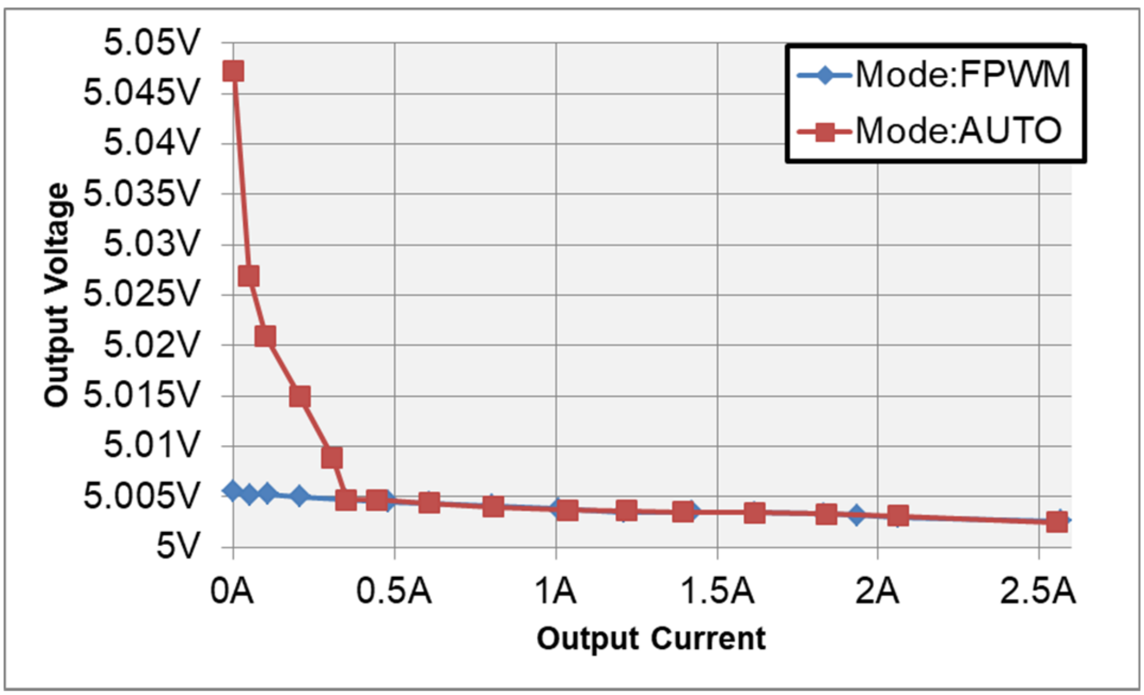


Figure 6 Output Voltage @ 12 Vin vs Output Current (Mode Comparison)

2.4 Line Regulation

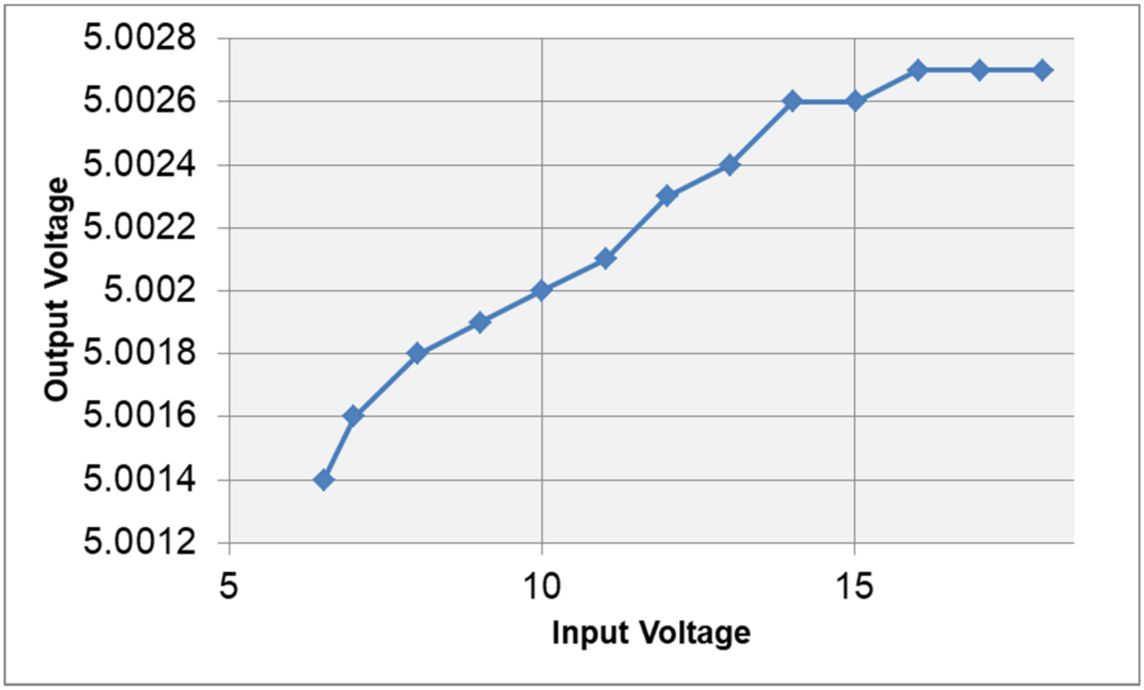


Figure 7 Output Voltage vs Input Voltage

With the same setup efficiencies and loss were calculated and the effect of the input filter is shown.

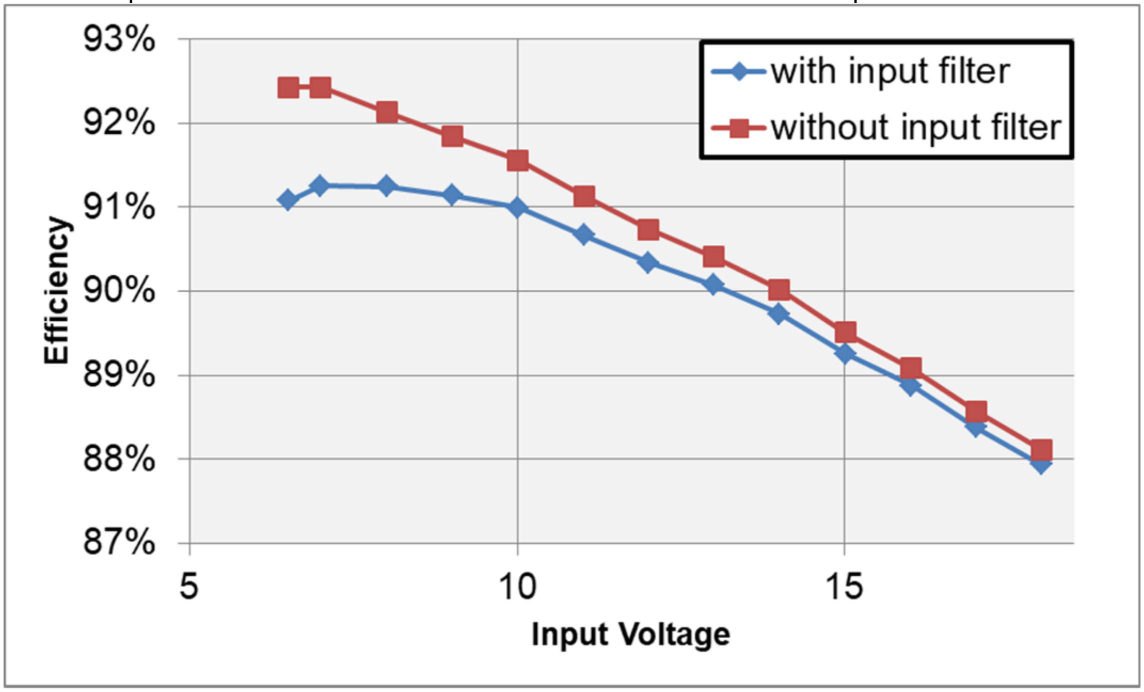


Figure 8 Efficiency vs Input Voltage

With the same setup efficiencies and loss were calculated and the effect of the input filter is shown.

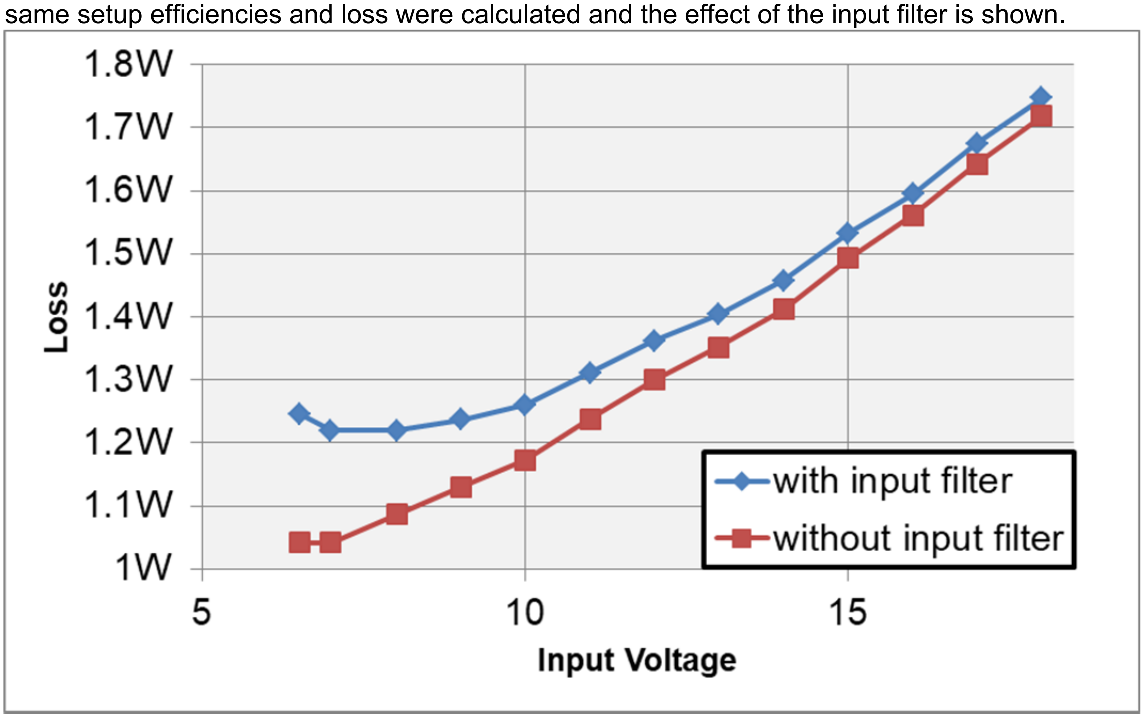
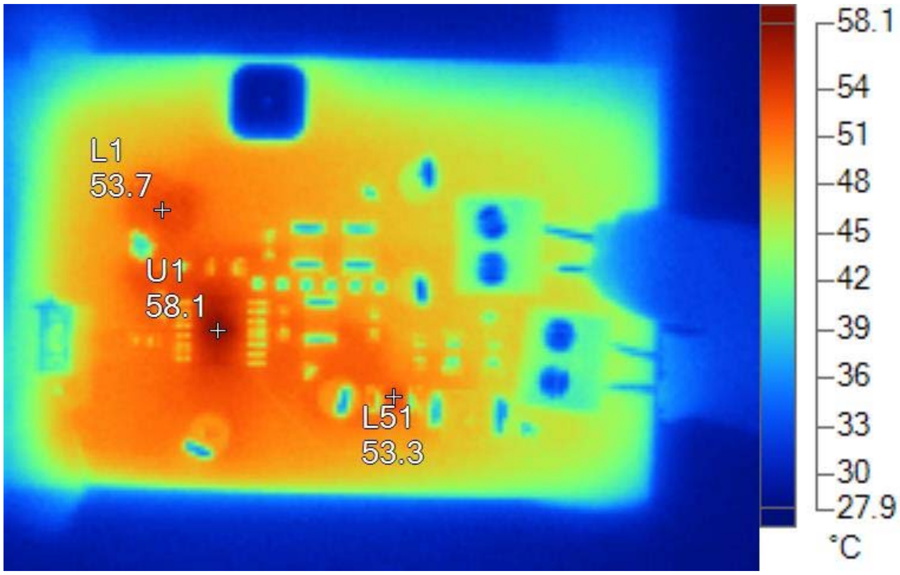


Figure 9 Loss vs Input Voltage

2.5 Thermal Images

The output current was adjusted to 2.5 A

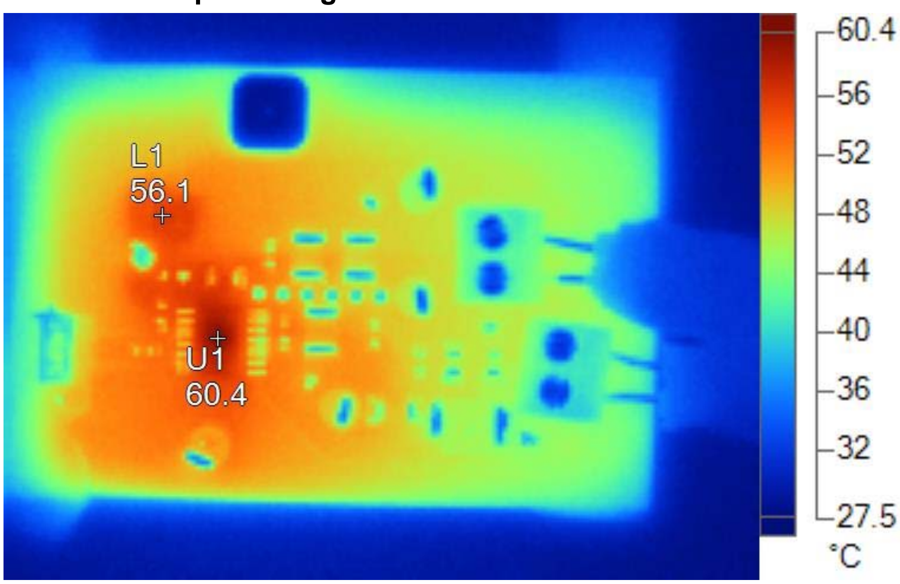
2.5.1 6.5 V Input Voltage



Name	Temperature
L1	53.7°C
L51	53.3°C
U1	58.1°C

Figure 10 IR @ 6.5 V Input Voltage

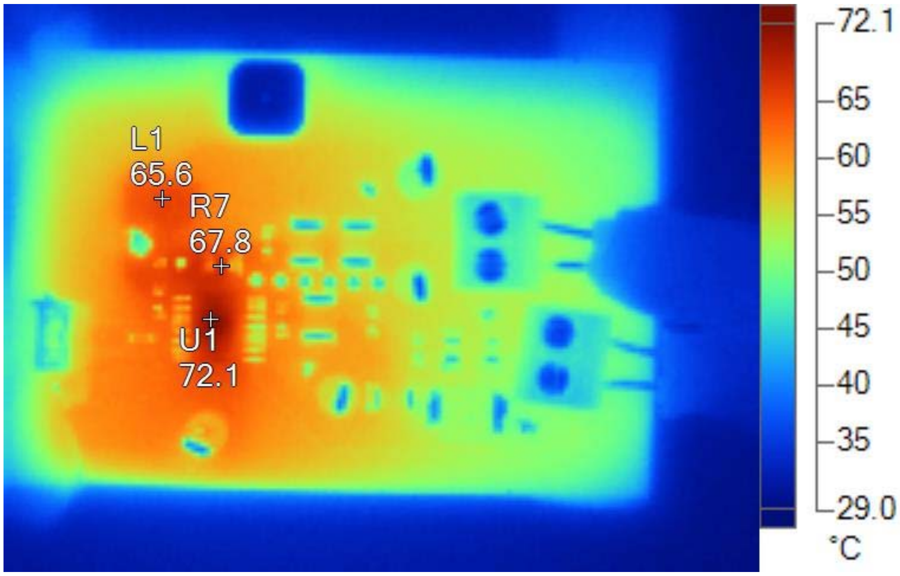
2.5.2 12 V Input Voltage



Name	Temperature
L1	56.1°C
U1	60.4°C

Figure 11 IR @ 12 V Input Voltage

2.5.3 18 V Input Voltage



Name	Temperature
U1	72.1°C
L1	65.6°C
R7	67.8°C

Figure 12 IR @ 18 V Input Voltage

2.6 Dimensions

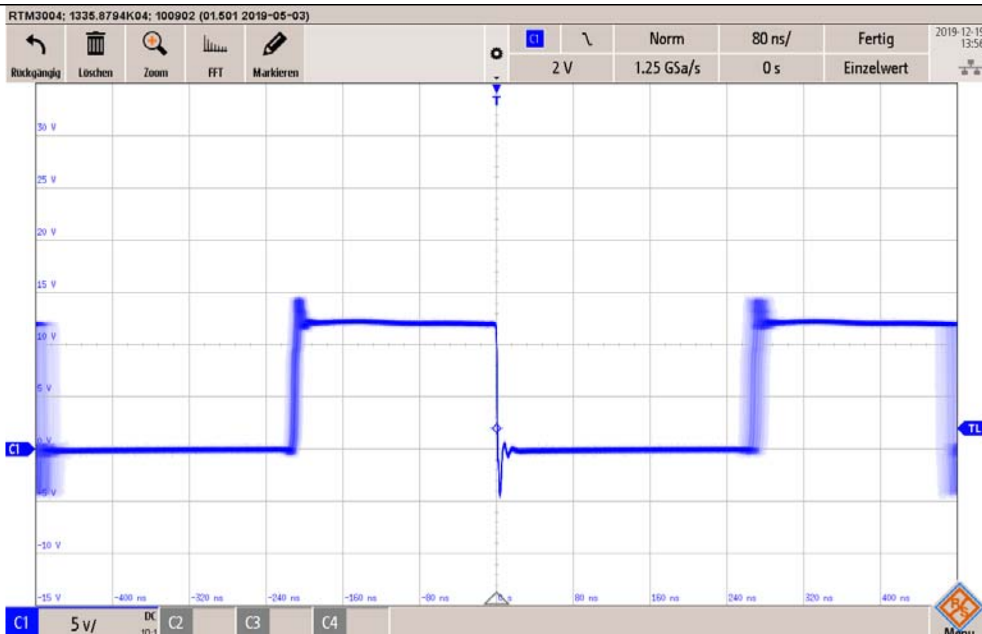
The board size is 53.3 mm to 34.3 mm.

3 Waveforms

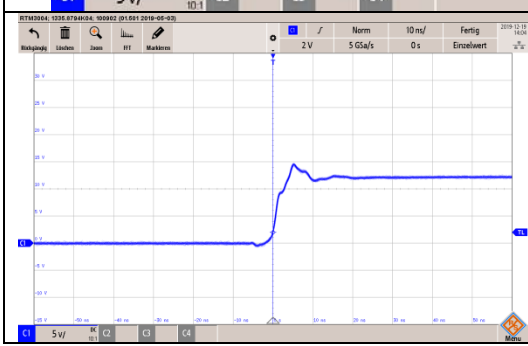
3.1 *Switching*

All switching waveforms were captured by 12 V input voltage

3.1.1 SW-GND



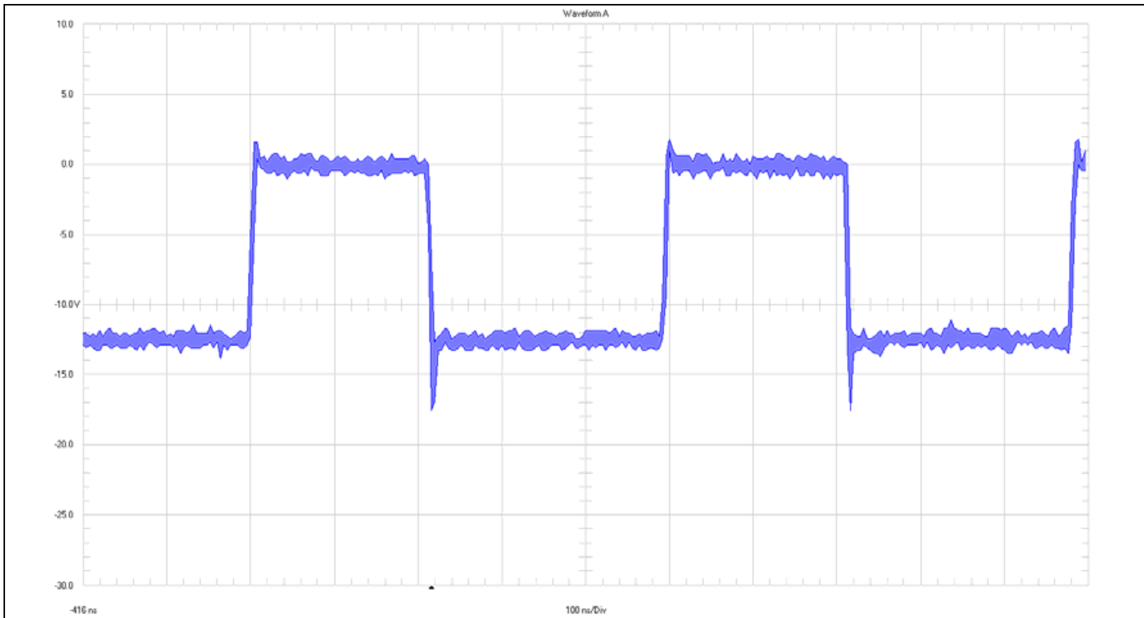
5 V /div
80 ns /div
full bw



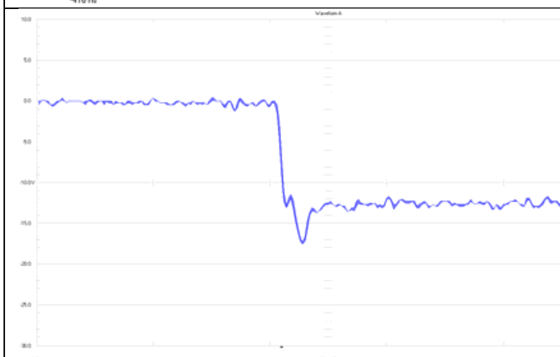
10 ns / div

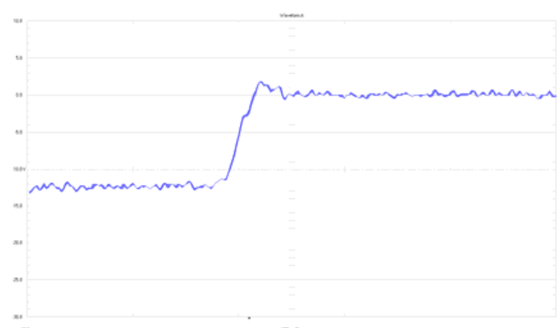
Figure 13 Switchnode to GND

3.1.2 SW to VIN



5 V /div
100 ns /div
full bw

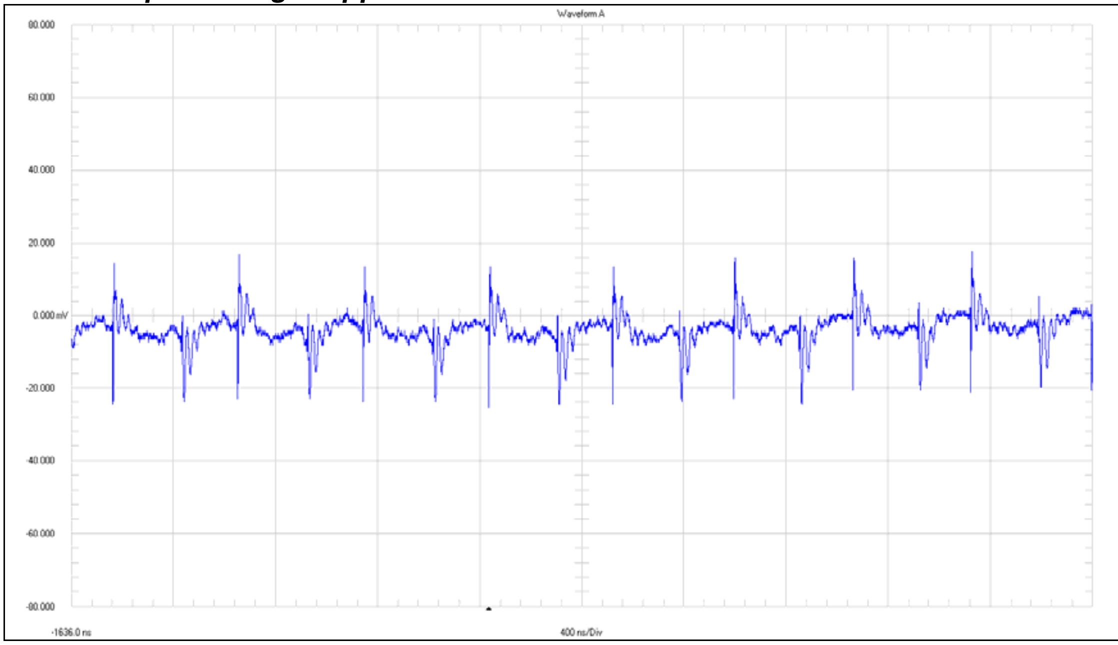




10 ns / major div

Figure 14 Switchnode to VIN

3.2 Output Voltage Ripple

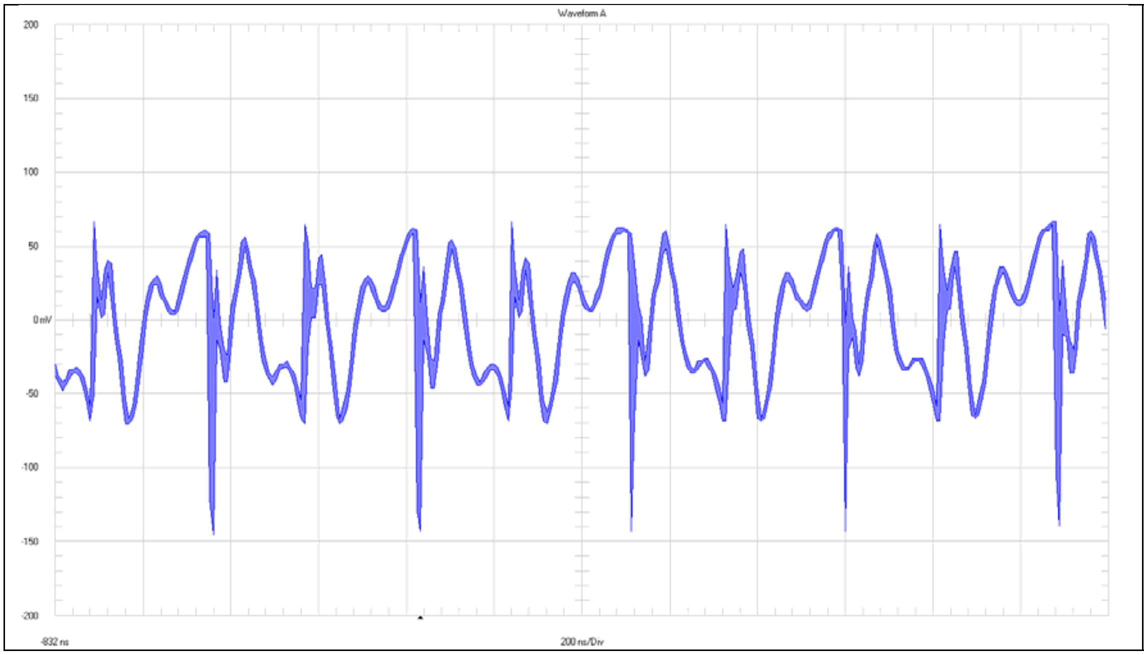


20mV / div
400 ns / div
20 MHz bw

Figure 15 Output Voltage Ripple

3.3 *Input Voltage Ripple*

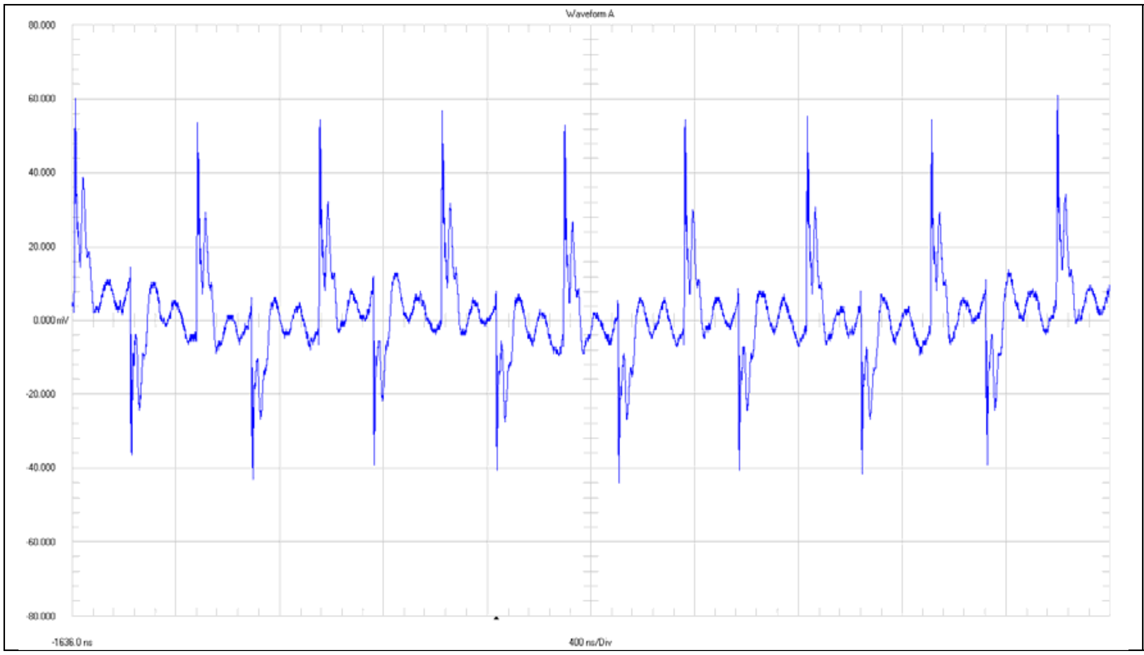
3.3.1 Power Stage Input to GND



100mV / div
200 ns / div
20 MHz bw

Figure 16 Input Voltage Ripple (Powerstage)

3.3.2 Between inductor and ferrite to GND

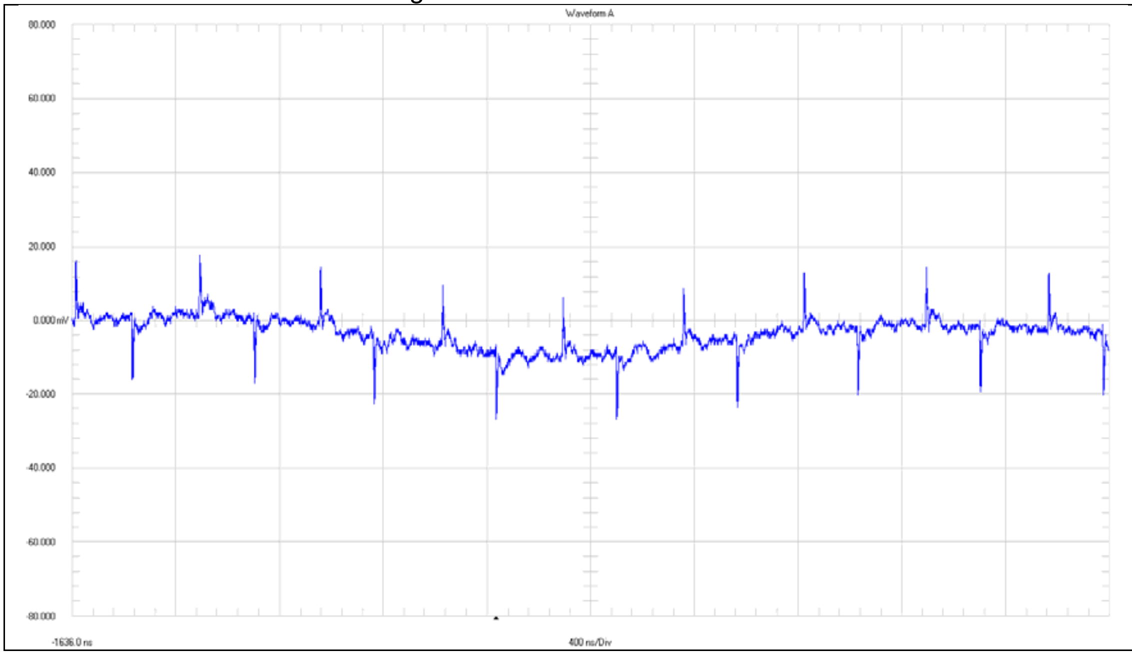


20mV / div
400 ns / div
20 MHz bw

Figure 17 Input Voltage Ripple (Ferrite)

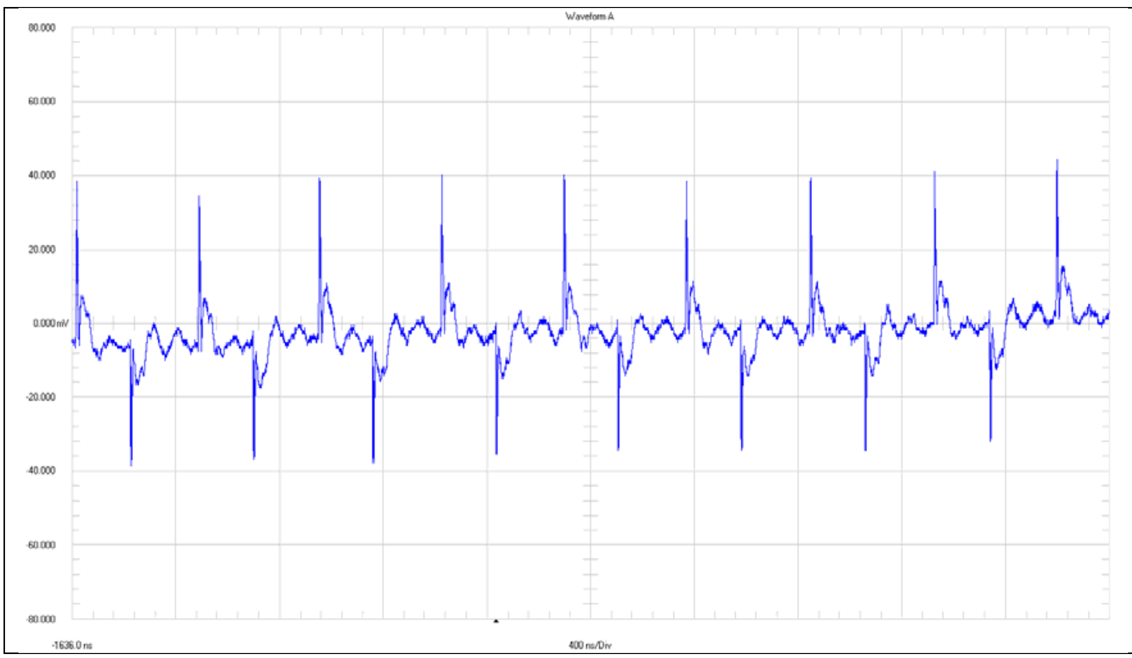
3.3.3 Voltage Input Ripple

The amplitude of the waveforms are strong dependent of the location from the GND contact. In Figure 18 the GND contact was near C54 In Figure 19 the GND contact was near C51.



20mV / div
400 ns / div
20 MHz bw

Figure 18 Input Voltage Ripple (Voltage Input)



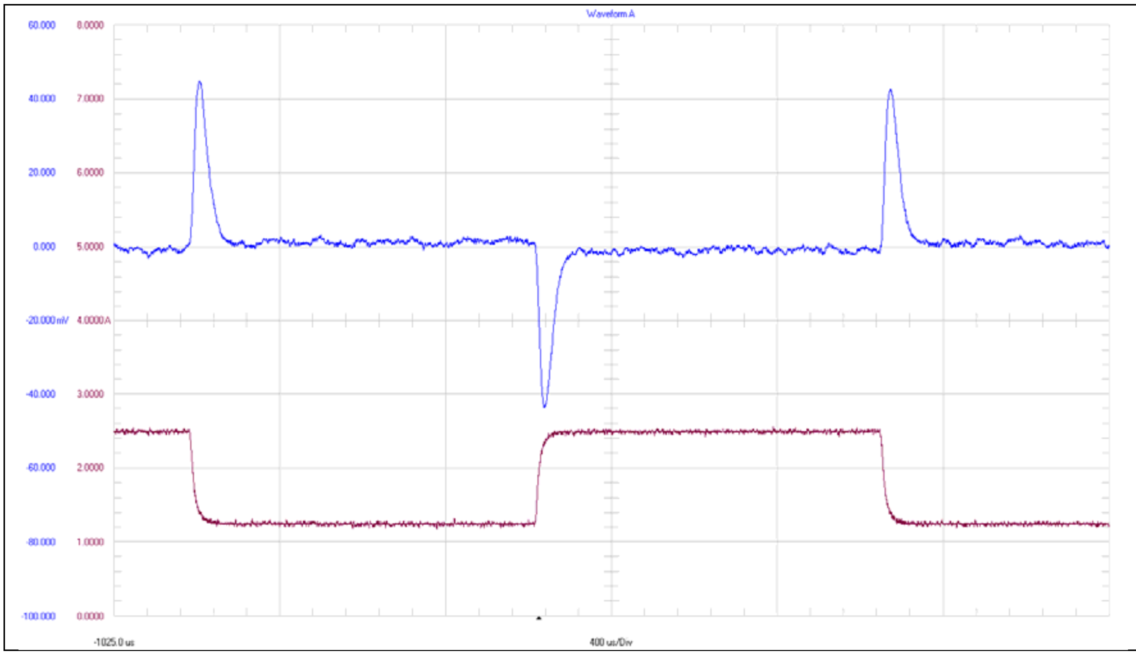
20mV / div
400 ns / div
20 MHz bw

Figure 19 Input Voltage Ripple (Voltage Input)

3.4 Load Transients

The electronic load (N3305A) switches between 1.25 A and 2 A with a frequency of 600 Hz,

3.4.1 6.5 V Input Voltage



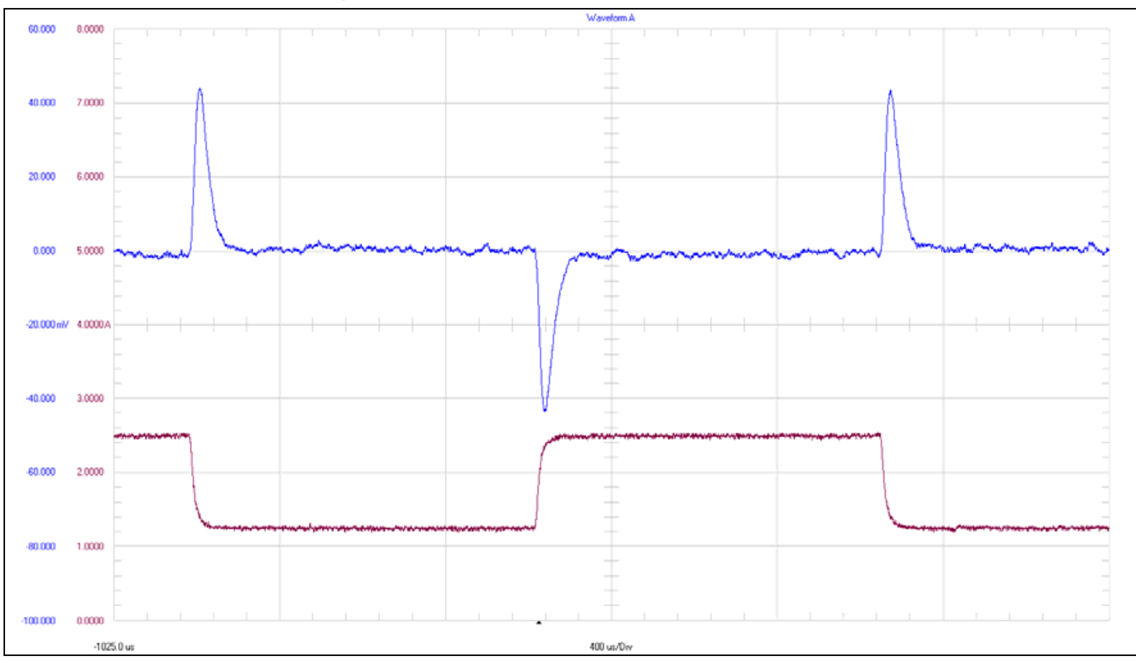
Ch1 Output Voltage => 20mV / div
10 kHz bw

Ch2 Output current => 1A / div
20 MHz bw

400 µs /div

Figure 20 Load Transient @ 6.5 Vin

3.4.2 12 V Input Voltage



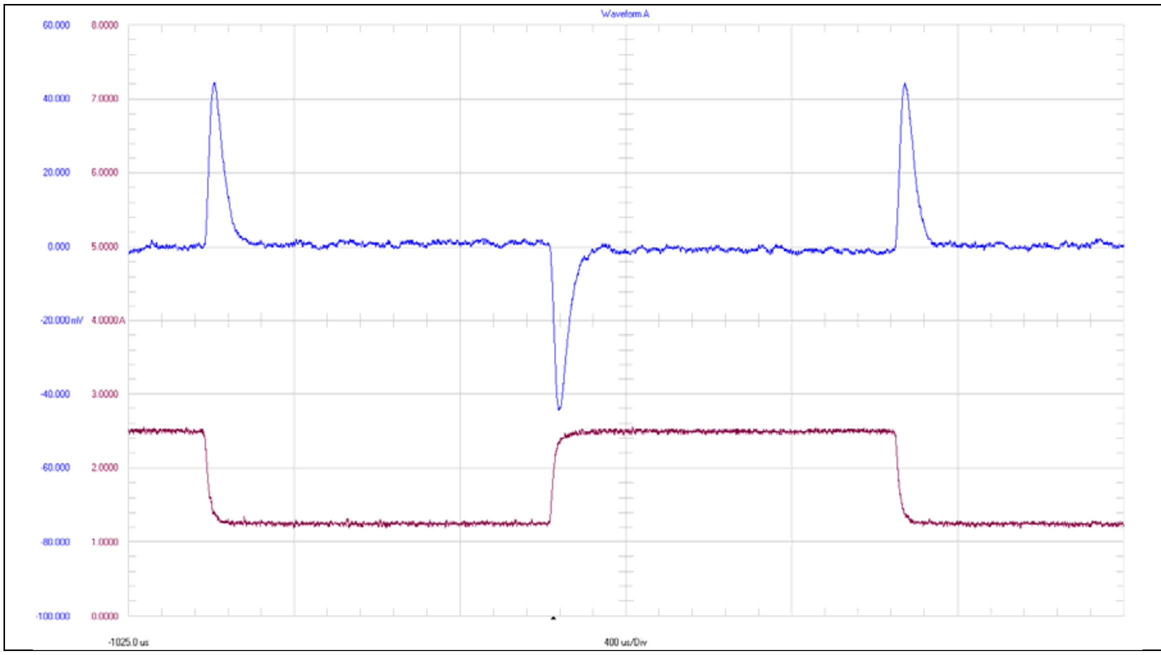
Ch1 Output Voltage => 20mV / div
10 kHz bw

Ch2 Output current => 1A / div
20 MHz bw

400 µs /div

Figure 21 Load Transient @ 12 Vin – deviation of Vout is <1% for a 50% transient (!)

3.4.3 18 V Input Voltage



Ch1 Output Voltage => 20mV / div
10 kHz bw

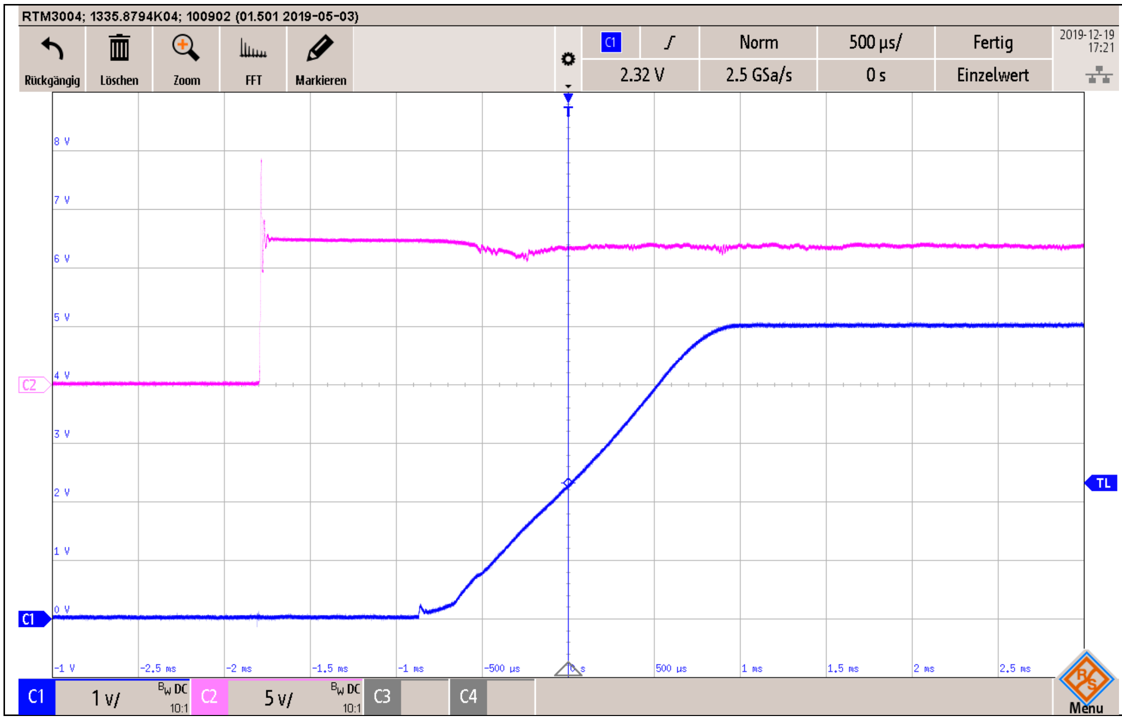
Ch2 Output current => 1A / div
20 MHz bw

400 µs /div

Figure 22 Load Transient @ 18 Vin

3.5 Start-up Sequence

Electronic load was connected to the output. Power supply was plugged in.



C2 Input voltage => 5 V /div

C1 Output voltage => 1 V / div

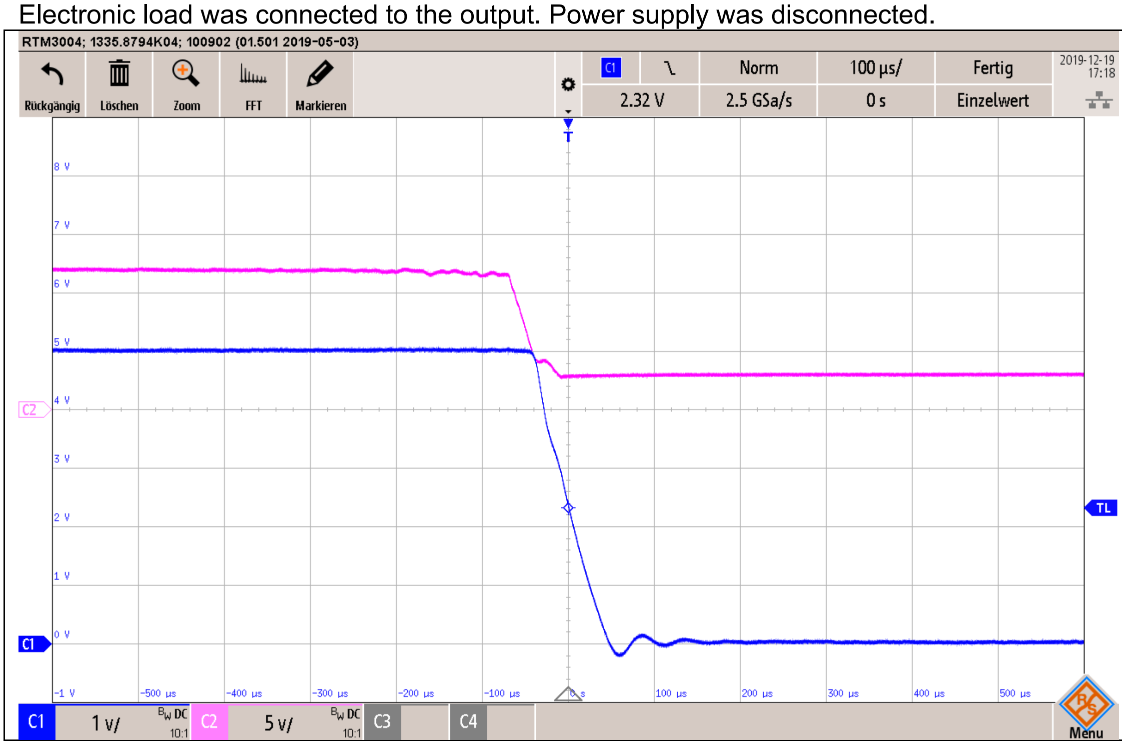
20 MHz bw

500µs / div

Figure 23 Start-up

3.6 Shut-down Sequence

Electronic load was connected to the output. Power supply was disconnected.



C2 Input voltage => 5 V /div

C1 Output voltage => 1 V / div

20 MHz bw

100µs / div

Figure 24 Shut-down

3.7 *Appendix Rev B1*

Circuit was modified to Rev B1 – added bootstrap resistor and increased RC damping at SW node.

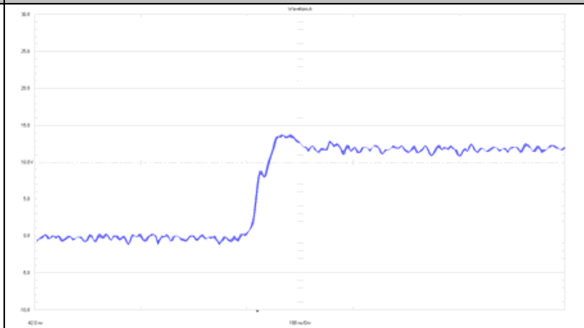
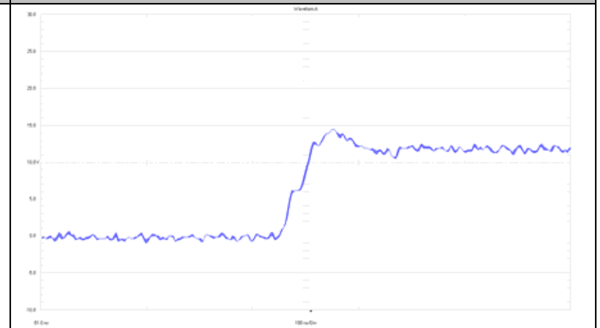
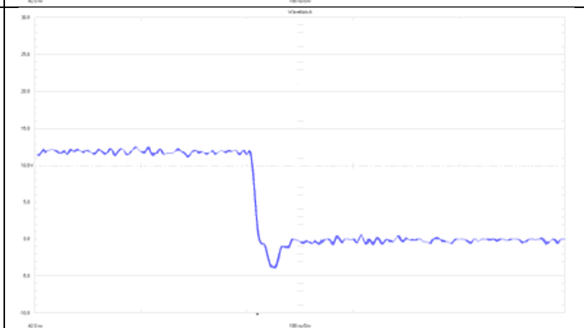
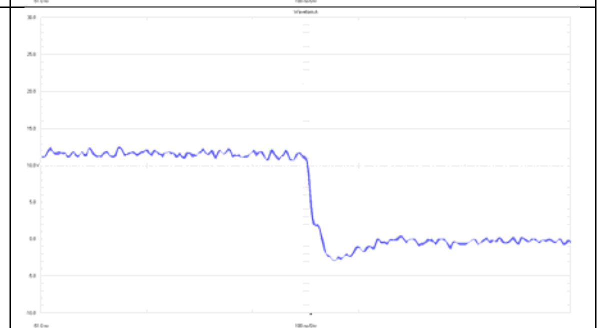
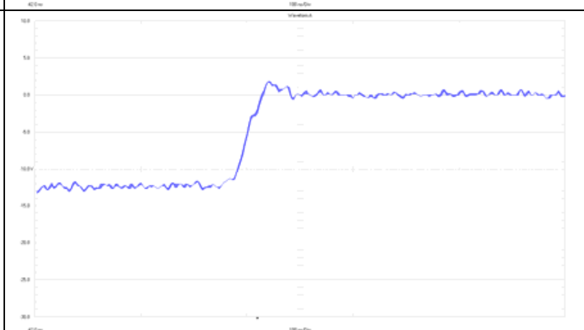
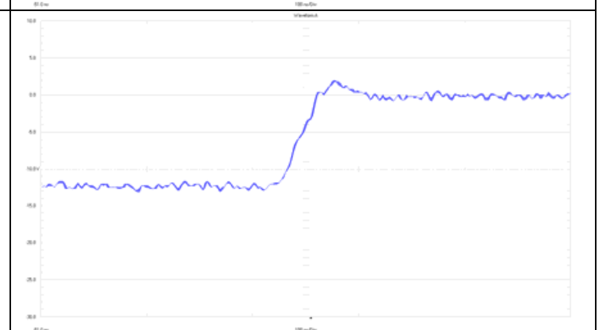
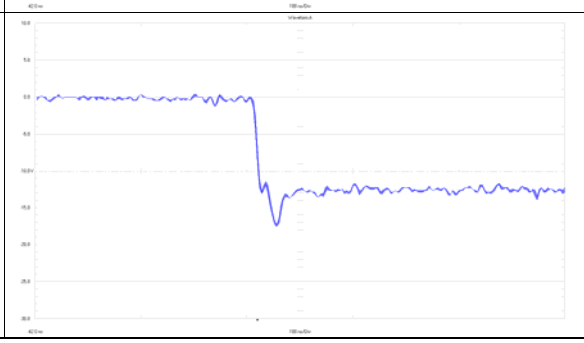
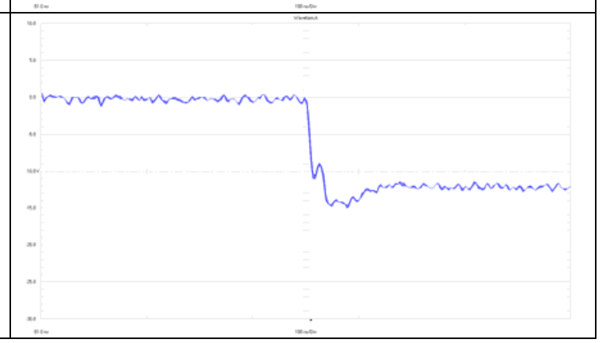
- 10 Ohm resistor was added to bootstrap capacitor C1 in series
- RC snubber, C9 was increased to 1 nF.

Figure 25 Modified Section

3.7.1 Efficiency comparison

Input Voltage	RevB	RevB1
6.5 V	93.0%	92.1%
12 V	90.5%	89.5%
18 V	88.0%	85.5%

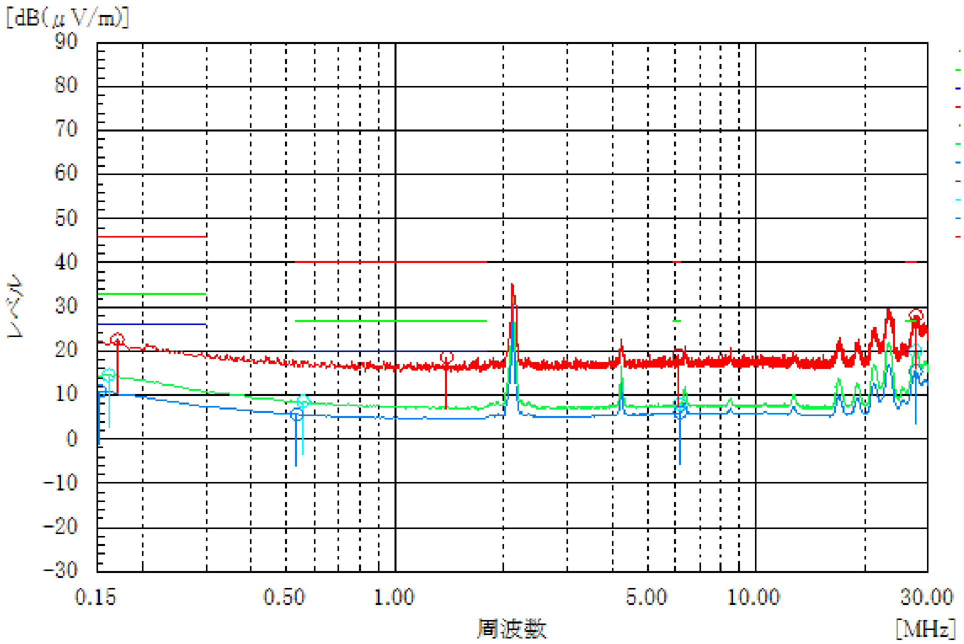
3.7.2 Switching waveforms (comparison)

	RevB	RevB1
SW-GND		
SW-GND		
SW-VIN		
SW-VIN		

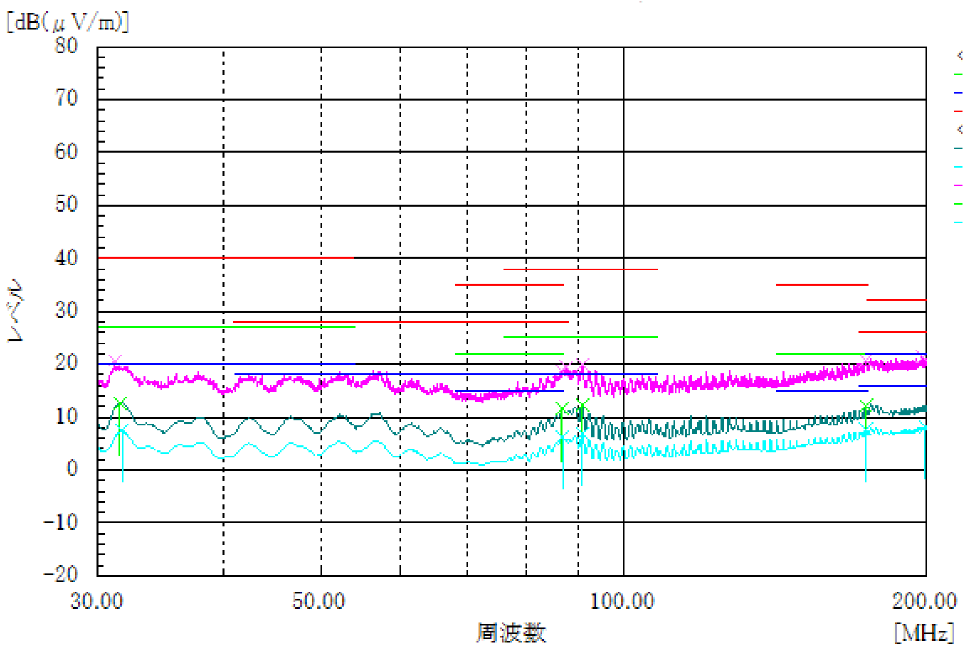
APPENDIX Rev B1 regarding CISPR 22

By using the CMC WE744273102 implemented at the ECU, adding a 10 Ohms resistor in series to bootstrap capacitor C1 and increased snubber cap C9 to 1nF this board passed CISPR 25 class 5 regarding radiated emissions:

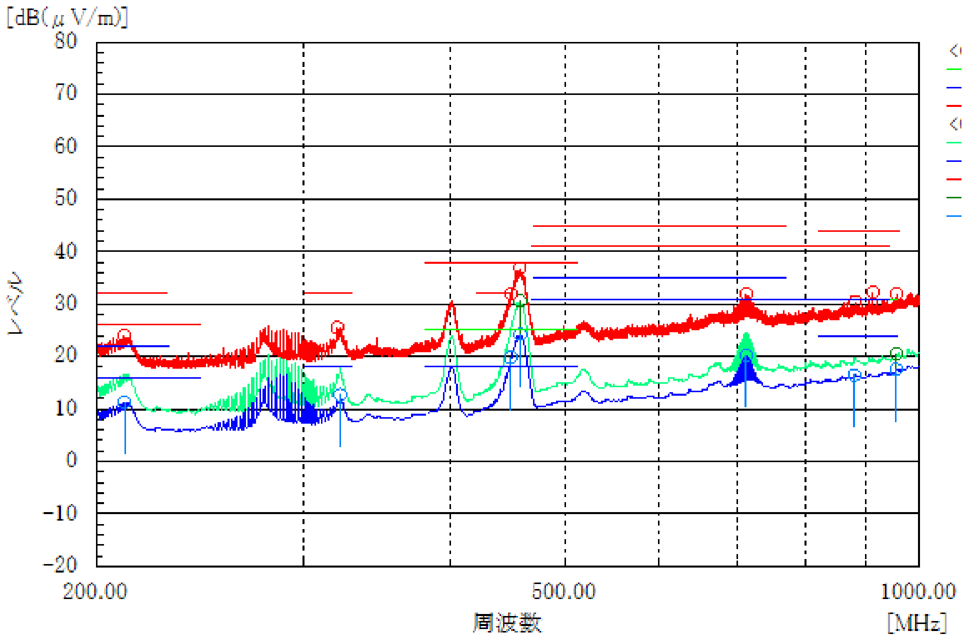
Limit(QP) **Limit(AV)** **Limit(PK)**



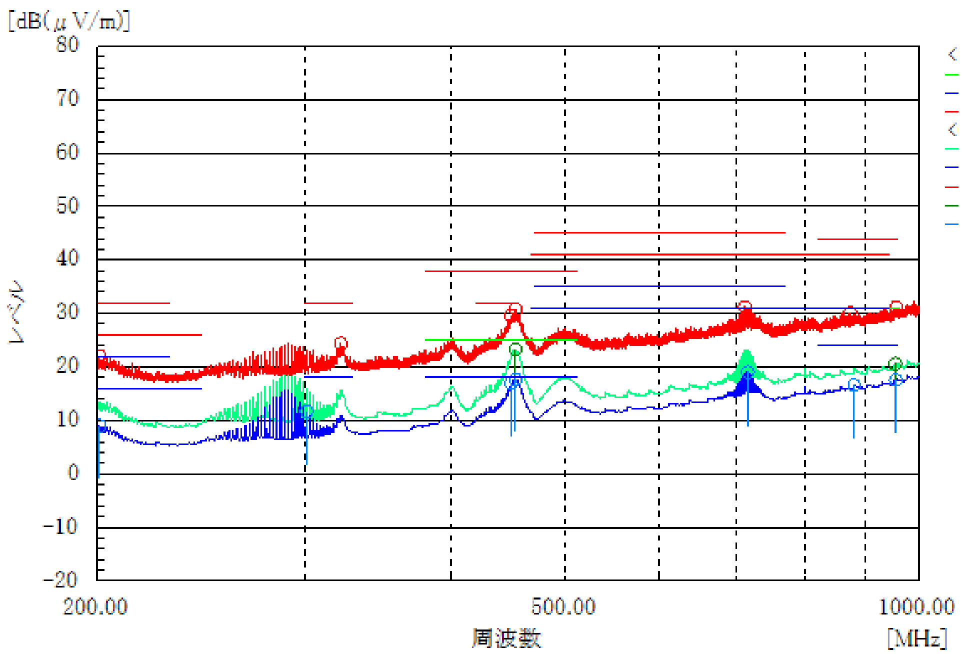
Rod antenna, LW to SW range



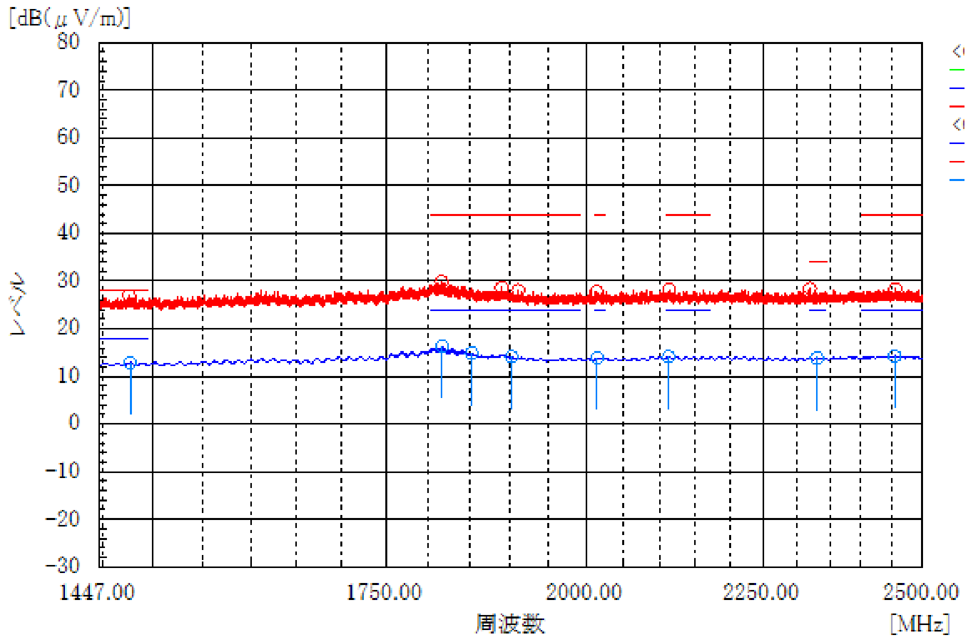
Biconical antenna, vertical polarization, SW to VHF range



Log periodic antenna, horizontal polarization, VHF to UHF range, **FAIL**



Log periodic antenna, horizontal polarization, VHF to UHF range, **using CMC here**, **PASSED**



Horn Antenna, UMTS / LTE band

Test Set Up: