TI Designs - TIDA-00746

17 W System Level power reference design for Automotive Infotainment Processor Power

Design Overview

TIDA-00746 is an off battery 17W system optimized (CISPR25 class5) SMPS design for powering automotive Infotainment processors typically used in telematics communications unit (TCUs), hybrid clusters, and automotive head units.

Design Resources

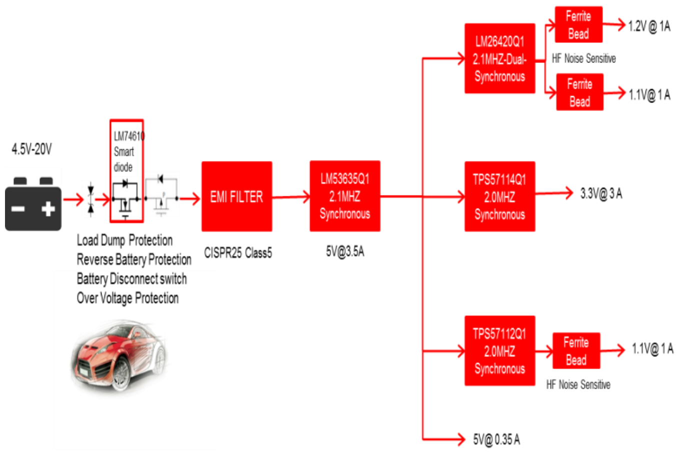
TIDA-00746	Design Folder
LM53635-Q1	Product Folder
LM26420-Q1	Product Folder
LM74610-Q1	Product Folder
TPS57114-Q1	Product Folder
TPS57112-Q1	Product Folder

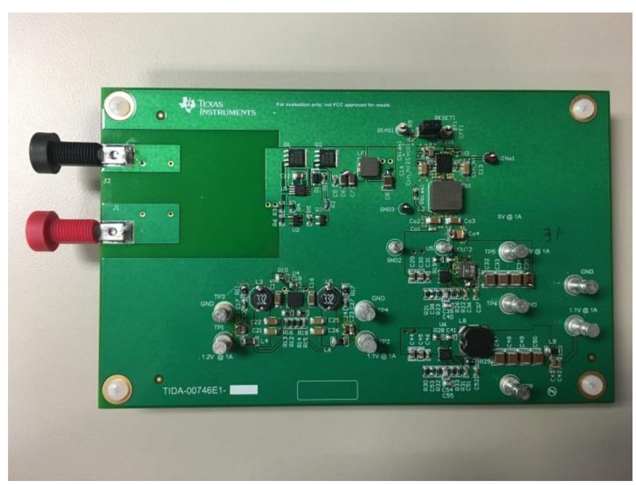
Design Features

- Wide-Vin front end power supply for 10-17W Automotive systems
- Off-Battery operation with reverse battery protection
- Series Fault protection FET with OVP at Input
- Passed CISPR25 Class 5 Conducted EMI test
- Switching frequency: Above AM band (>1.85 MHz) for all the Converters used.
- All AEC-Q100 qualified devices used
- Supports 5.5V to 30 V (20V OVP) wide Vin range.

Featured Applications

- SMPS for Automotive Infotainment Processors
- SMPS for Automotive ADAS Processors





Contents

1 System Description

TIDA-00746 is a 17W System optimized SMPS design for automotive Infotainment Processor Power which can be used in telematics communications unit, Hybrid Cluster, and Head Unit. The design has been tested for CISPR25 Class 5 conducted EMI limits and has easily passed the same.
All buck converter used in this design is switching above AM band (>1.85MHz)
The design is divided into four major blocks:

1. Front end Protection: In the design, we have implemented various protections such as against positive and negative pulses (ISO7630 Pulse 1, 2a, 3a/b) through TVS, reverse terminal protection through innovative Smart diode (LM74610) and also battery disconnect Switch with OVP protection (PFET).
2. EMI Filter: A common mode and a differential filter for Conducted EMI suppression.
3. Low EMI Front end DC/DC converter: LM53635-Q1 is used as Front end DC/DC converter which is automotive optimized, Low EMI, 2.1MHz, switching, synchronous 3.5A buck regulator. Apart from the Spread Spectrum option, the device comes in an automotive-qualified Hotrod QFN package with wettable flanks which reduces parasitic inductance and resistance while increasing efficiency, minimizing switch node ringing, and dramatically lowering electromagnetic interference (EMI).
4. Downstream POL Buck Converters (LM26420-Q1 (Integrated dual buck), TPS57114-Q1, and TPS57112-Q1): All POL switchers used in the design switch above AM band. For High Frequency noise sensitive rails, ferrite bead filter is used.

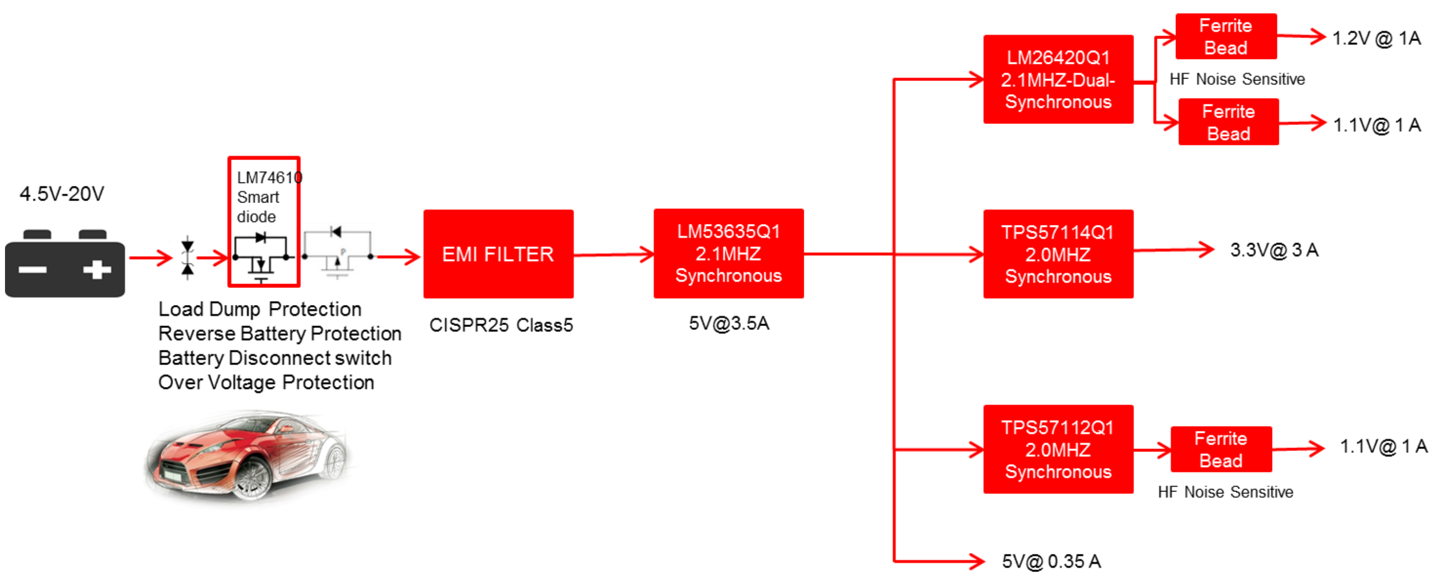


Figure 1: Block Diagram:-TIDA-00746

2 Key System Specifications

Vin Minimum	**5.5V**
Vin Maximum	**30V (OVP at 20V)**
Vin Nominal	**12V (automotive design)**
Vout 1	**5V**
Iout 1	**0.35A**
Vout 2	**3.3V**
Iout 2	**3 A**
Vout 3	**1.2V**
Iout 3	**1A**
Vout 4	**1.1V**
Iout 4	**1A**
Vout 5	**1.1V**
Iout 5	**1A**
Approximate Switching Frequency	**2.0MHz Approx(all the DC/DC converters)**
ISO Pulse test	**TVS diode used for protection**
EMI	**Passed CISPR25 Class 5 Limits**
Protection	**Input Overvoltage, Reverse polarity , Short Circuit protections at Outputs, Load Dump protection**

3 Highlighted Products

The following TI products are used in the design:

- **LM53635-Q1**
  - Synchronous Buck Converter
  - Qualified for Automotive Applications (AEC-Q100 Qualified)
  - Wide Operating Input Voltage: 3.55 V to 36 V (With Transient to 42 V)
  - Spread Spectrum Option Available –helps in EMI compliance
  - 2.1-MHz Fixed Switching Frequency –Avoids AM Band
  - Low Quiescent Current: 15 µA
  - –40°C to +150°C Junction Temperature Range
  - Shutdown Current: 1.8 µA
  - Adjustable, 3.3-V, or 5-V Output
  - Maximum Current Load: 2500 mA for LM53625-Q1, 3500 mA for LM53635-Q1
  - 4 mm × 5 mm, 0.5-mm Pitch VQFN Package With Wettable Flanks
  - Low EMI and Switch Noise

- **LM26420-Q1**
  - • Dual Synchronous Buck Converter
  - • LM26420-Q0: AEC-Q100 Grade 0 (Q0) Qualified Device Information (1) (TJ = –40°C to 150°C)
  - • Input Voltage Range of 3 V to 5.5
  - • Output Voltage Range of 0.8 V to 4.5 V
  - • 2-A Output Current per Regulator
  - • High Switching Frequency: 2.2 MHz
  - • Current Mode, PWM Operation
  - • Compliant with CISPR25 Class 5 Conducted Emissions

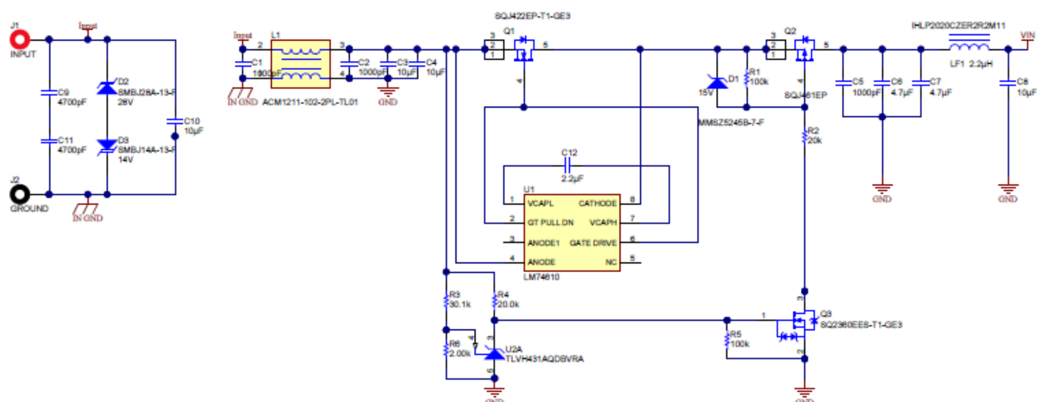
- **LM74610-Q1**.
  - • Zero IQ Reverse Polarity Protection Smart Diode Controller
  - • Qualified for Automotive Applications (AEC-Q100 Qualified)
  - • Maximum reverse voltage of 45 V
  - • Charge Pump Gate Driver for External N-Channel MOSFET
  - • Lower Power Dissipation than Schottky Diode/PFET Solutions
  - • Low Reverse Leakage Current
  - • Fast 2-µs Response to Reverse Polarity

- **TPS57114/2-Q1**
  - • Synchronous Buck Converter
  - • Qualified for Automotive Applications (AEC-Q100 Qualified)
  - • Input Voltage Range of 2.95 V to 6V
  - • 200-kHz to 2-MHz Switching Frequency
  - • Maximum Current Load: 2000 mA for TPS57112-Q1, 4000 mA for TPS57112-Q1

4 System Design

The SMPS has multiple protections at the front end of the design.

1. TVS are used in bidirectional way to clamp/filter high-voltage electrical fast transients and maintain operation through them (for positive going pulses). These pulses include clamped Load Dump (up to 38V) and other transients outlined in ISO 7637-2:2004.
2. Smart diode is implemented in the front end so that the system properly responds to a reverse battery polarity event and shut down appropriately.
3. There is a fault PFET switch which may be disconnected in the event of any fault. In this design OVP is implemented.
4. The EMI filter is included in the front end and the design is compliant with the stringent CISPR 25 Class 5 automotive EMI standard.



Further Normal operating frequency for all the synchronous Buck Converters (LM53635,LM26420 andLTPS57112/4) is 2.1 MHz allowing the use of small passive components2.1MHz is above the AM band, allowing significant saving in input filtering. These parts has a low unloaded current consumption eliminating the need for an external back-up LDO. The low shutdown current and high maximum operating voltage of the LM53635 also allows the elimination of an external load switch.

For Design Calculations and layout examples , Please refer to the datasheets of the devices used .

1. LM53635-Q1 datasheet (http://www.ti.com/product/lm53635-Q1)
2. LM26420-Q1 datasheet (http://www.ti.com/product/LM26420-q1)
3. LM74610-Q1 datasheet (http://www.ti.com/product/lm74610-q1)

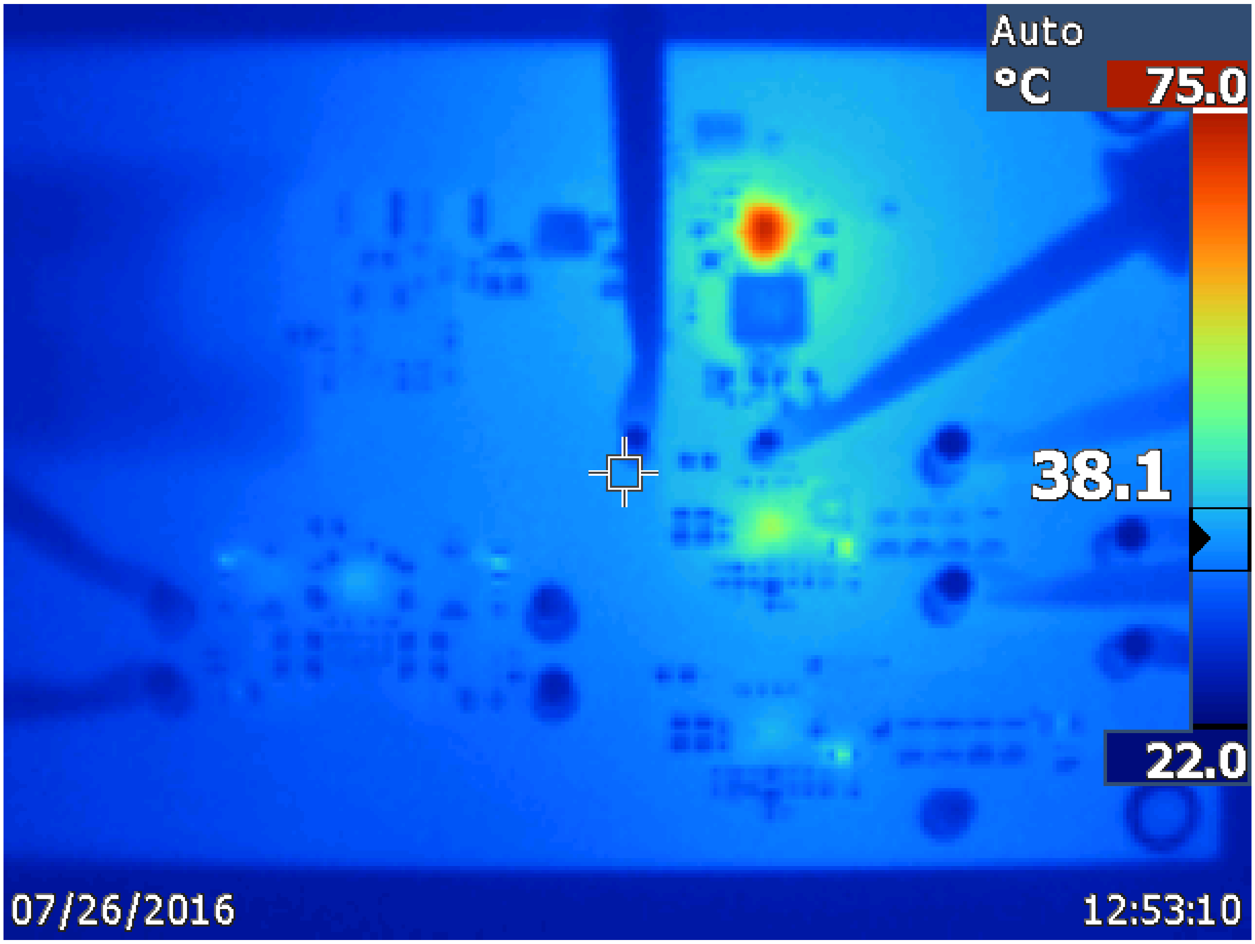
4. TPS57114-Q1 datasheet (http://www.ti.com/product/tps57114-q1)
5. TPS57112-Q1 datasheet (http://www.ti.com/product/TPS57112-q1

5 Test Results

The following diagrams show the results for various tests

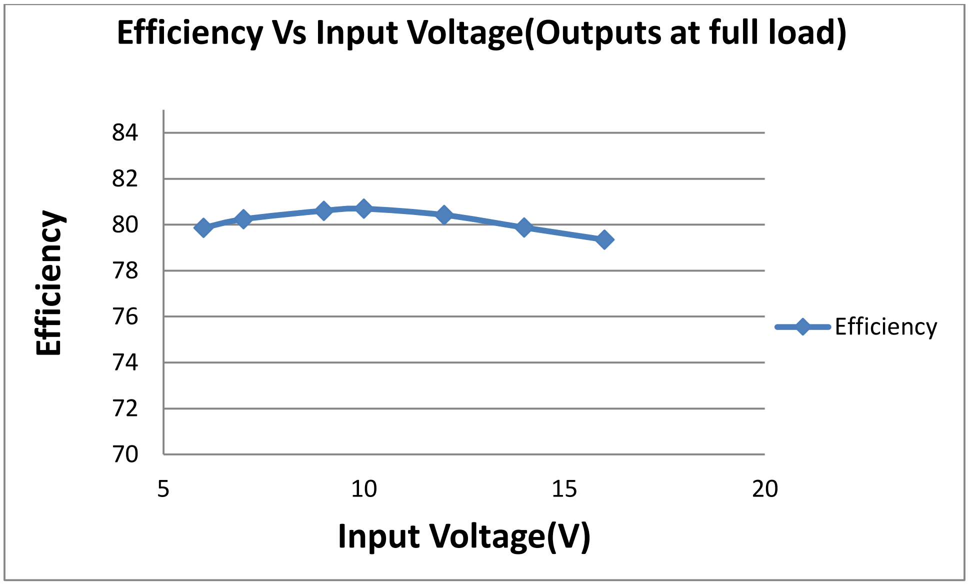
5.1 Thermal data

Setup: **IR thermal image taken at steady state with 12Vin and all the outputs at full load (no airflow)**



5.2 Efficiency data

5.2.1 Efficiency Chart – Input Voltage Vs Efficiency with outputs at full load



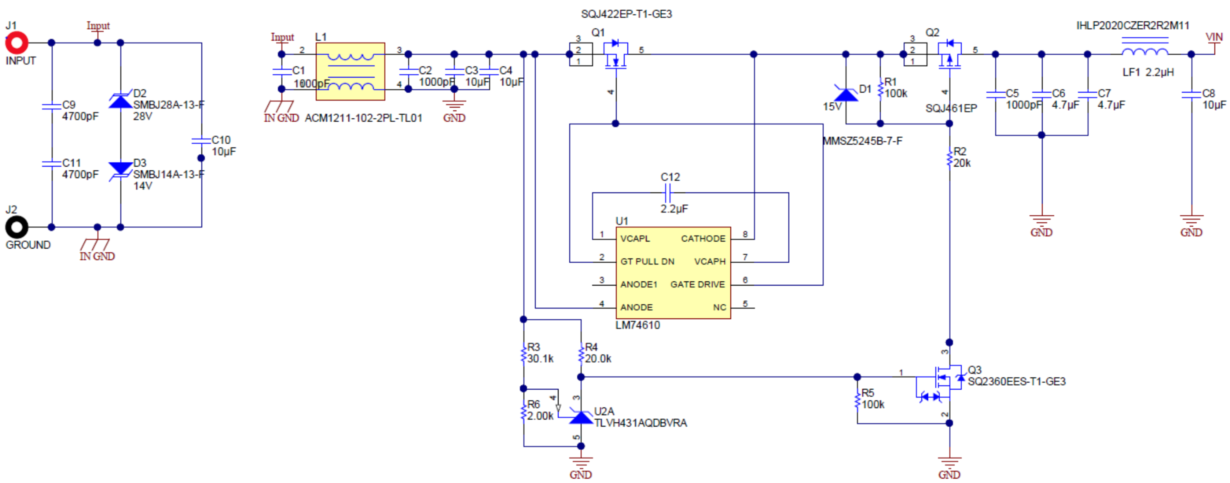
Efficiency Data

System's Efficiency Vs Input Voltage (Outputs at full load)

Vin(V)	Iin(A)	Vout (5V)	Iout (5V)	Vout (3.3V)	Iout (3.3V)	Vout (1.2V)	Iout (1.2V)	Vout (1.1V) (TPS)	Iout (1.1V) (TPS)	Pin(W)	Pout(W)	Efficiency (%)
6	3.031	4.956	0.5	3.278	3	1.158	1	1.055	1	18.186	14.525	79.869
7	2.584	4.929	0.501	3.278	3	1.156	1	1.055	1	18.088	14.514	80.241
9	2.001	4.931	0.501	3.278	3	1.158	1	1.055	1	18.009	14.517	80.609
10	1.799	4.931	0.501	3.278	3	1.158	1	1.055	1	17.99	14.517	80.694
12	1.504	4.931	0.501	3.278	3	1.156	1	1.055	1	18.048	14.515	80.424
14	1.298	4.928	0.501	3.278	3	1.158	1	1.055	1	18.172	14.515	79.875
16	1.143	4.924	0.501	3.278	3	1.156	1	1.055	1	18.288	14.511	79.347

6 Waveforms

6.1 Reverse Protection –Smart diode



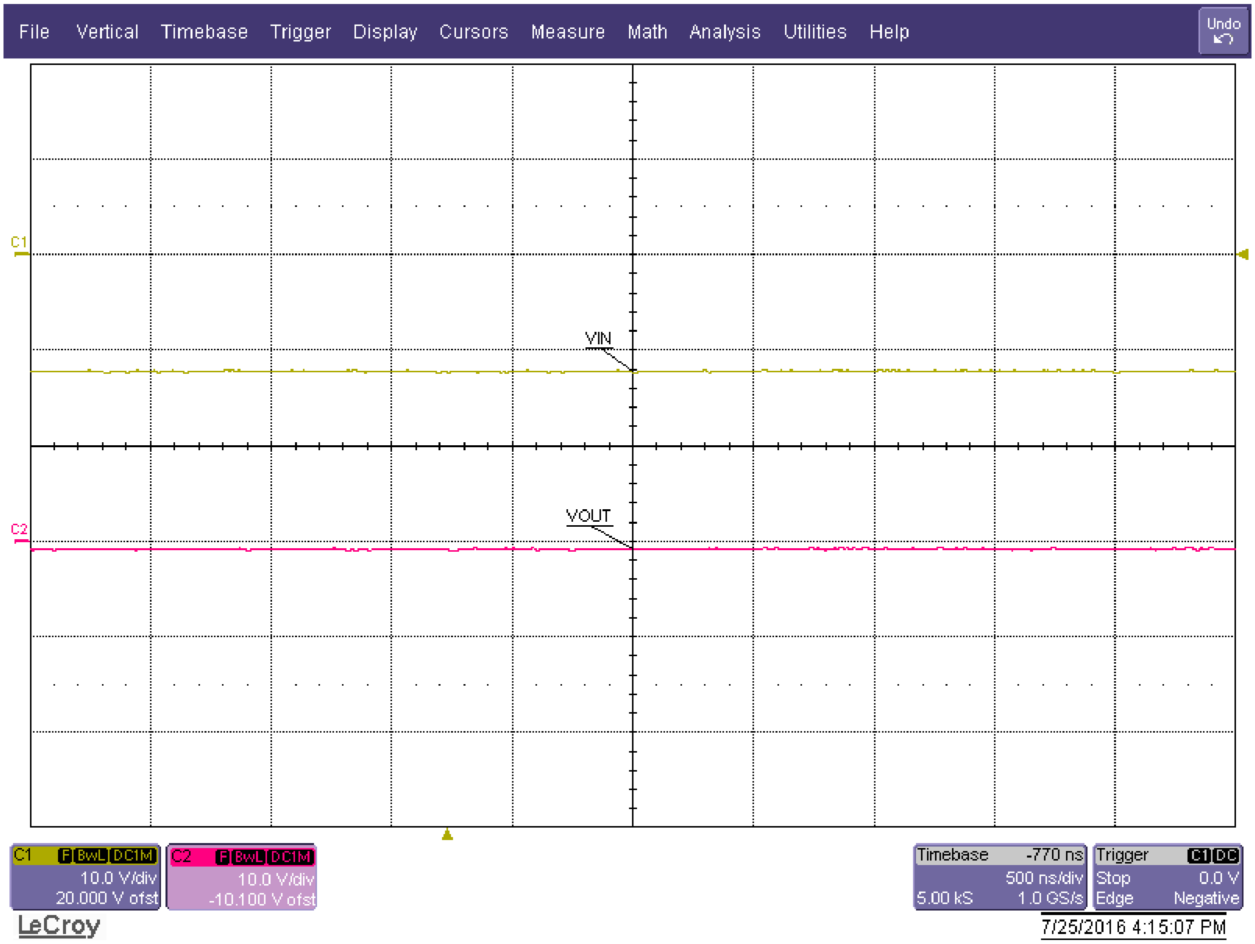


Fig: Continuous Reverse Voltage at Input: C1- Input(Input terminal for battery); C2- VIN(Input for DC/DC converter)

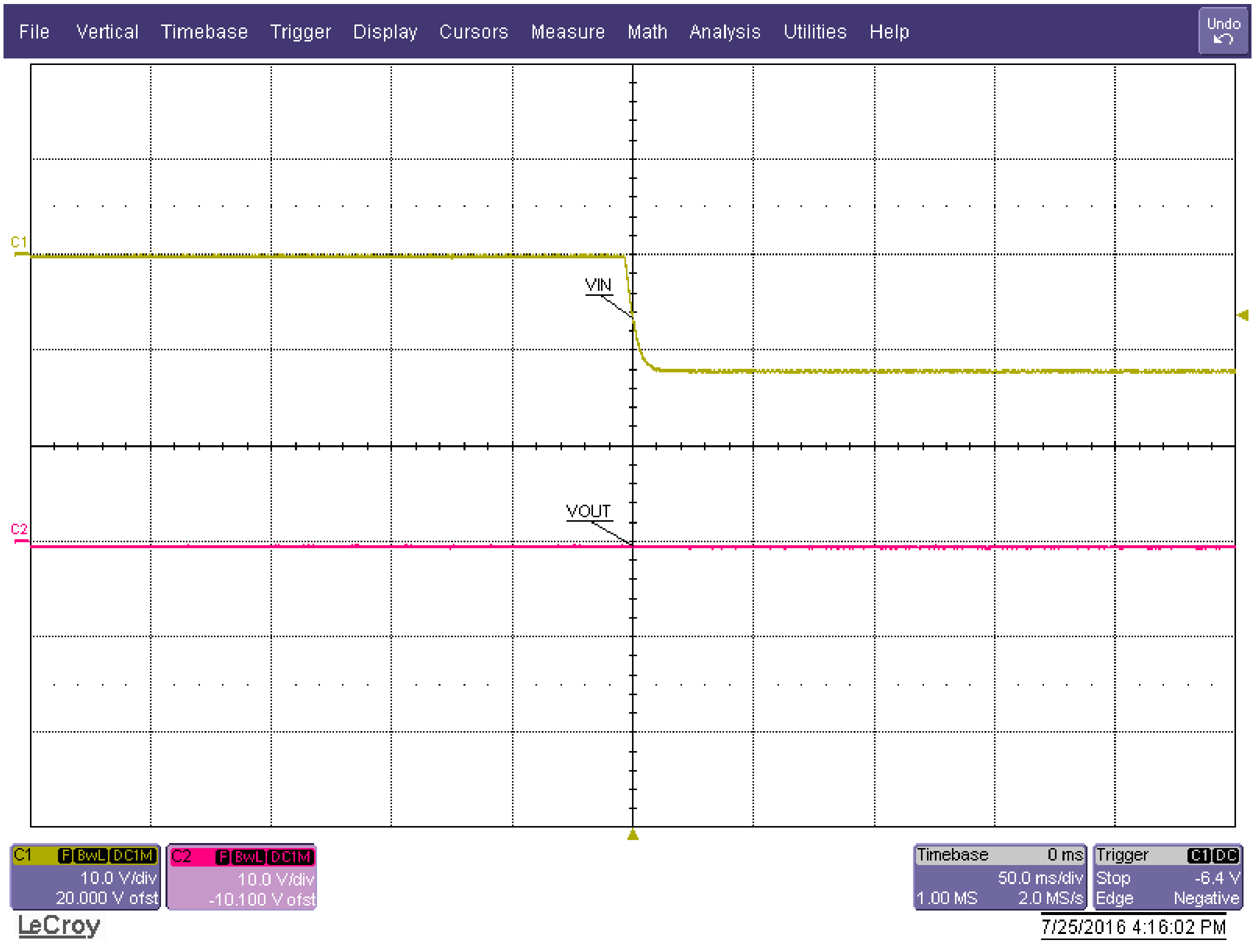
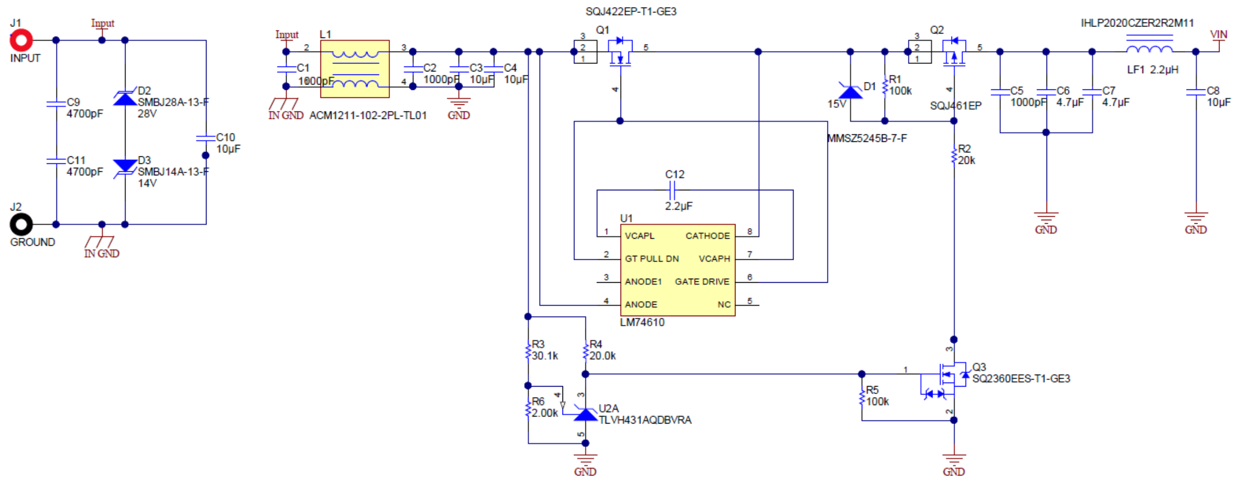


Fig: Transition to Reverse Voltage at Input: C1- Input(Input terminal for battery); C2- VIN(Input for DC/DC converter)

6.2 Input Overvoltage Protection – PFET Fault switch



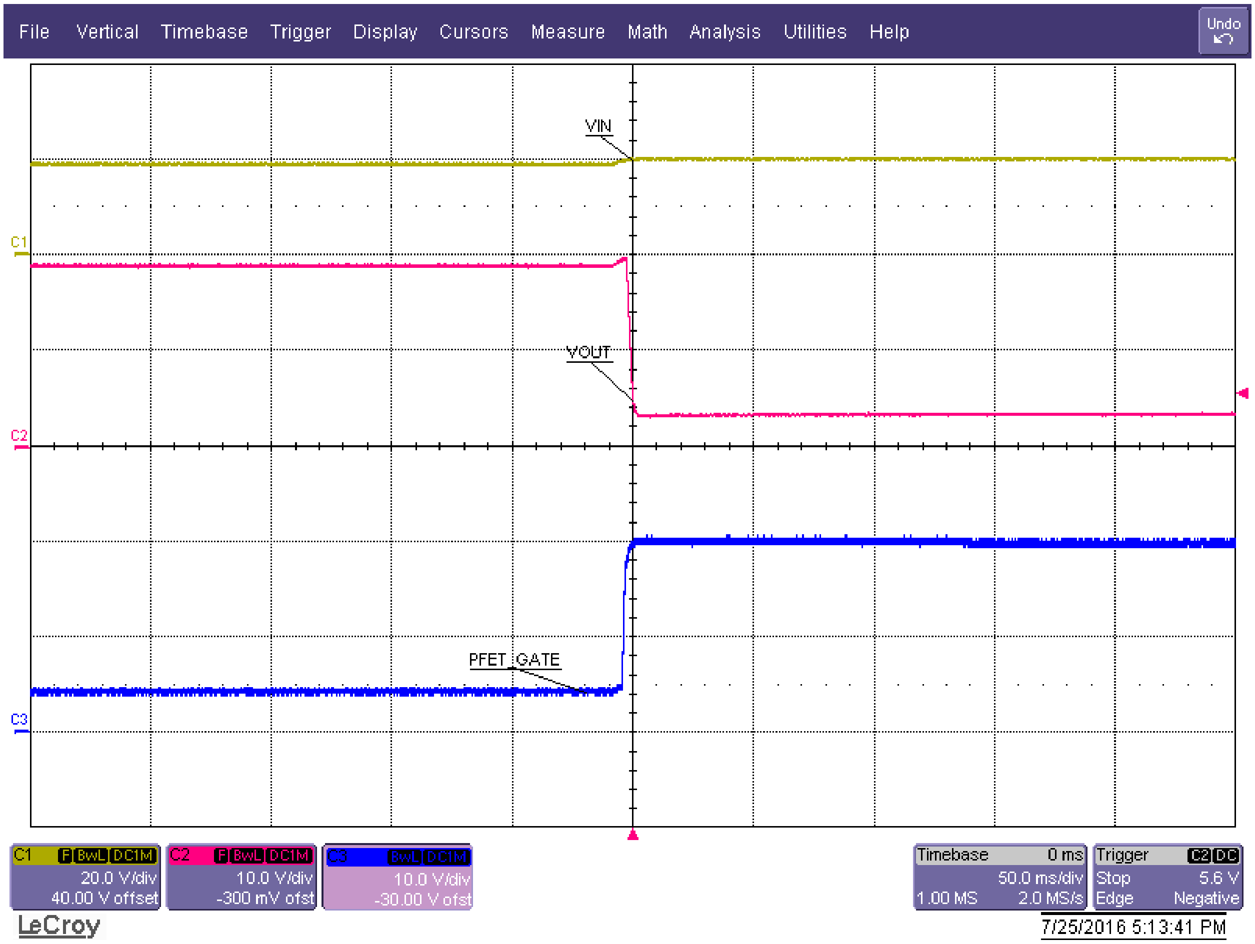


Fig: Transition to Overvoltage condition: C1- Input(Input terminal for battery); C2- VIN(Input for DC/DC converter); C3-Q2 PFET's gate

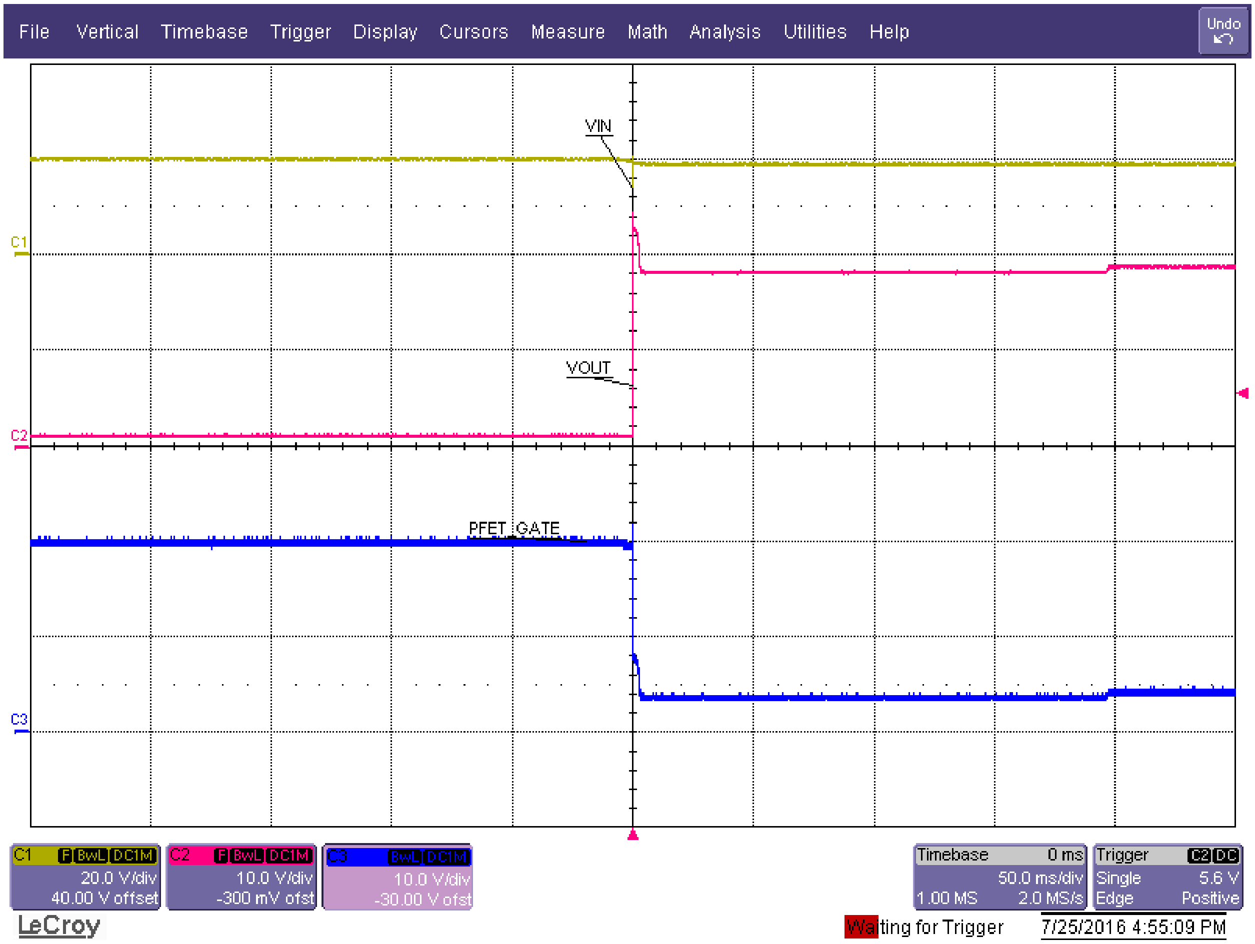


Fig: Transition From Overvoltage to normal condition: C1- Input(Input terminal for battery); C2- VIN(Input for DC/DC converter); C3-Q2 PFET's gate

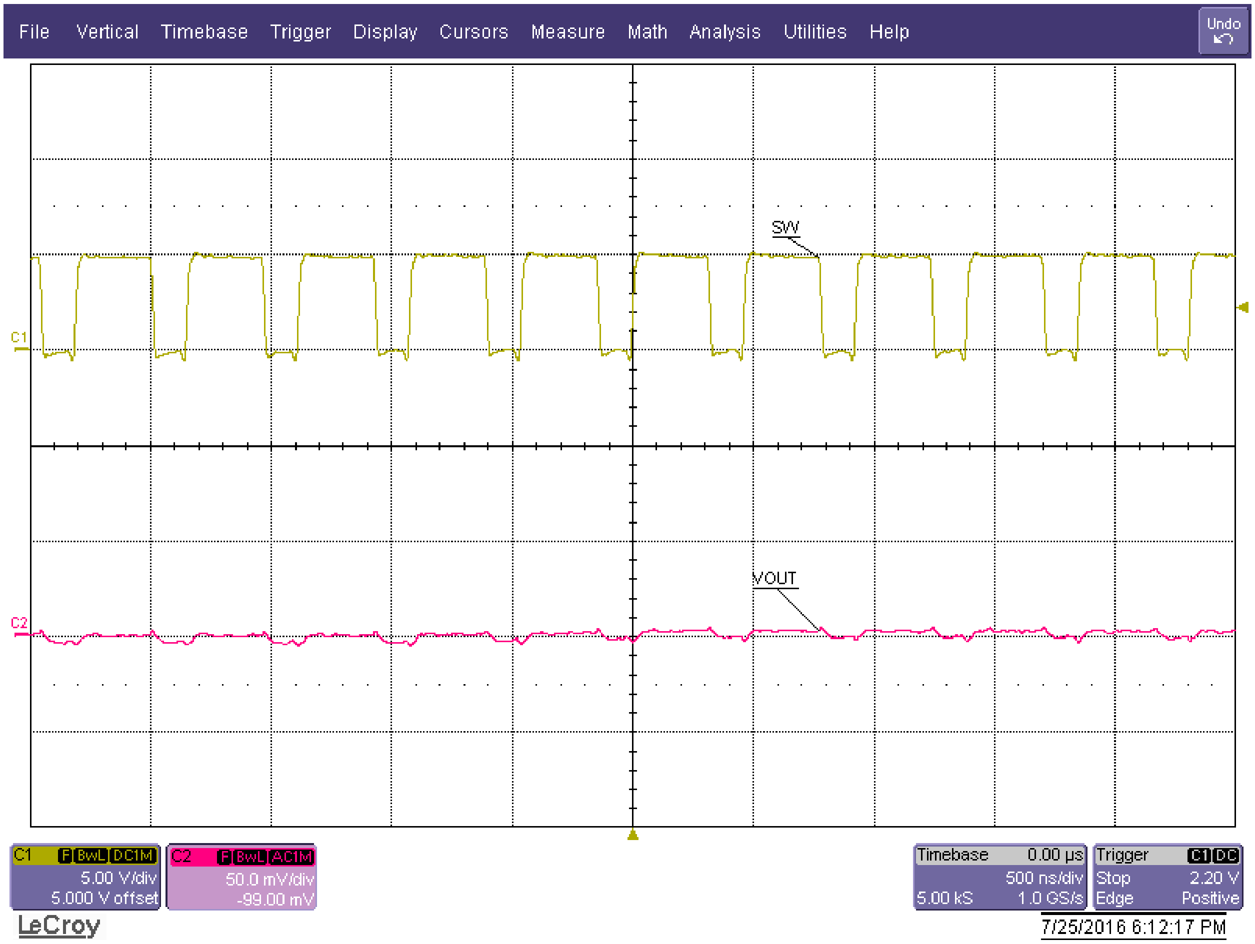
6.3 Output Voltage Ripple and Switch Node Voltage

6.3.1 LM53635-Q1's Output-5V

Switch Node Voltage and Output Voltage Ripple at 12 Vin and Full Load on all the outputs (Vripple < 50mVp-p)

Ch1-Switching Waveform
Ch2-Vout (AC Coupled)-5V

6.3.2 TPS57114-Q1's output – 3.3V



Switch Node Voltage and Output Voltage Ripple at 12 Vin and Full Load on all the outputs (Vripple < 50mVp-p)

Ch1-Switching Waveform
Ch2-Vout (AC Coupled)

6.3.3 TPS57112-Q1's output – 1.1V

Switch Node Voltage and Output Voltage Ripple at 12 Vin and Full Load on all the outputs (Vripple < 50mVp-p)

Ch1-Switching Waveform
Ch2-Vout (AC Coupled)

6.3.4 LM26420Q1's Dual output

6.3.4.1 LM26420Q1's output- 1.2V

Switch Node Voltage and Output Voltage Ripple at 12 Vin and Full Load on all the outputs (Vripple < 50mVp-p)

Ch1-Switching Waveform
Ch2-Vout (1.2V) (AC Coupled)

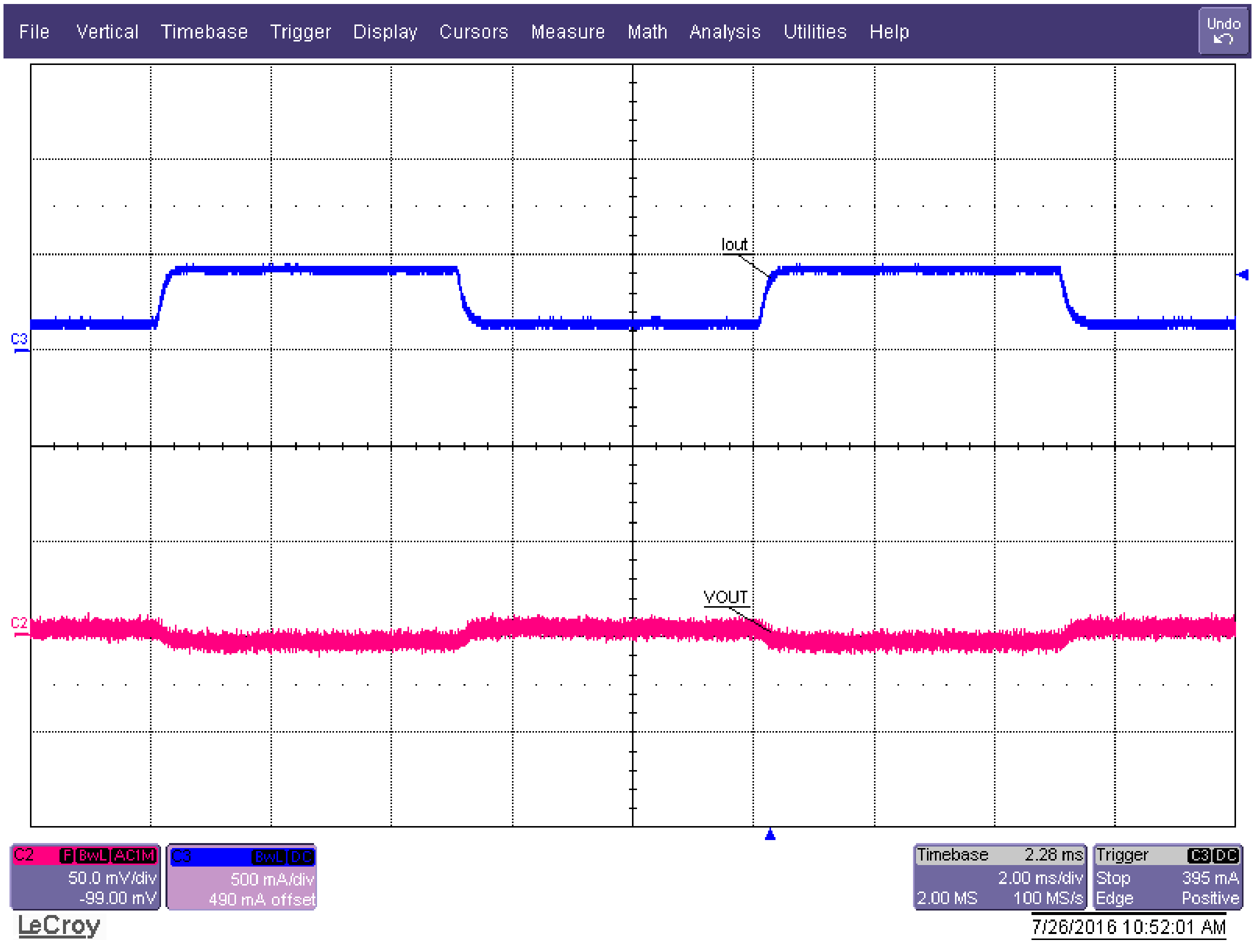
6.3.4.2 LM26420Q1's output- 1.1V

Switch Node Voltage and Output Voltage Ripple at 12 Vin and Full Load on all the outputs (Vripple < 50mVp-p)

Ch1-Switching Waveform
Ch2-Vout (1.1V) (AC Coupled)

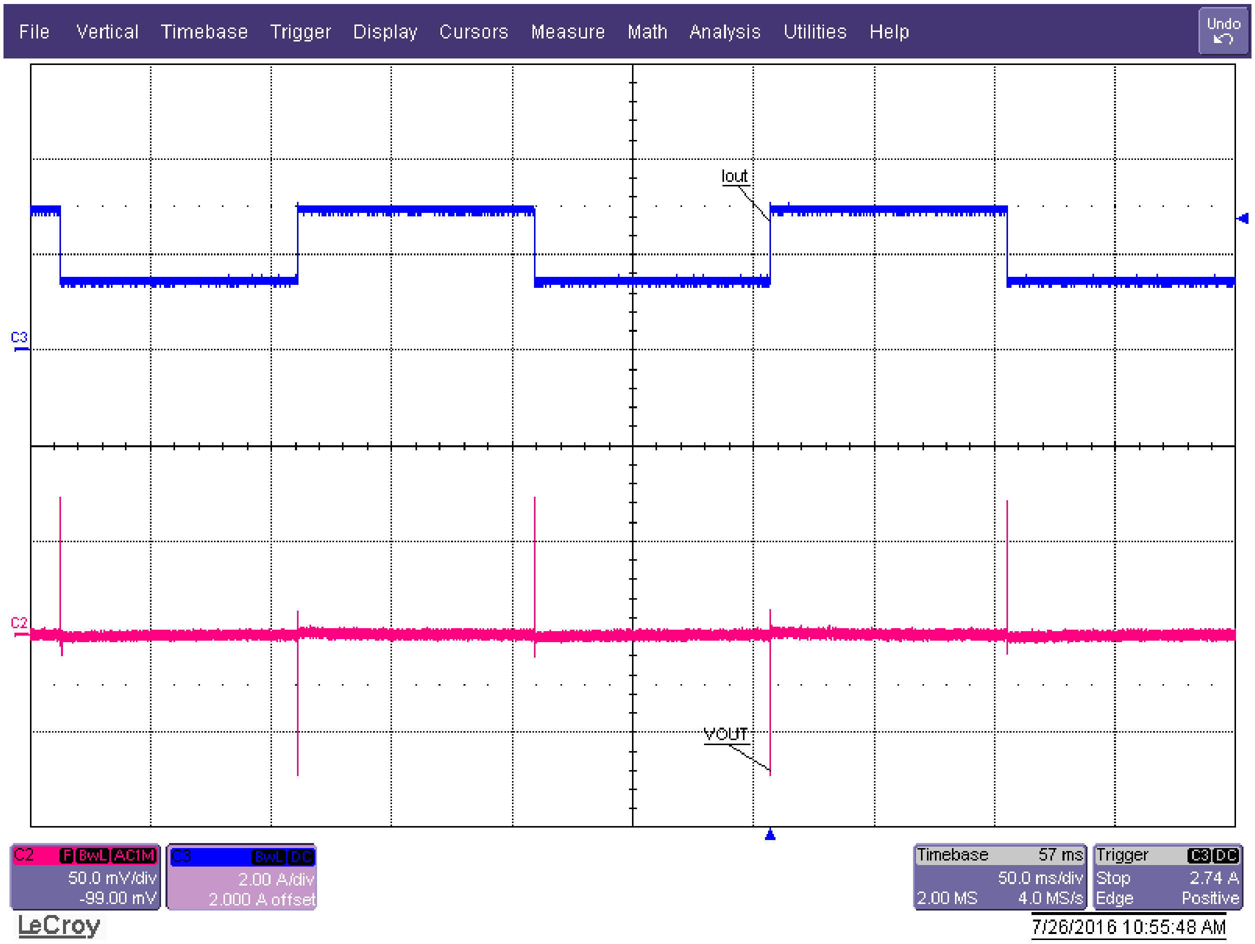
6.4 Load Transient Response

6.4.1 Load Transient Response - LM53635-Q1's output -5Vout



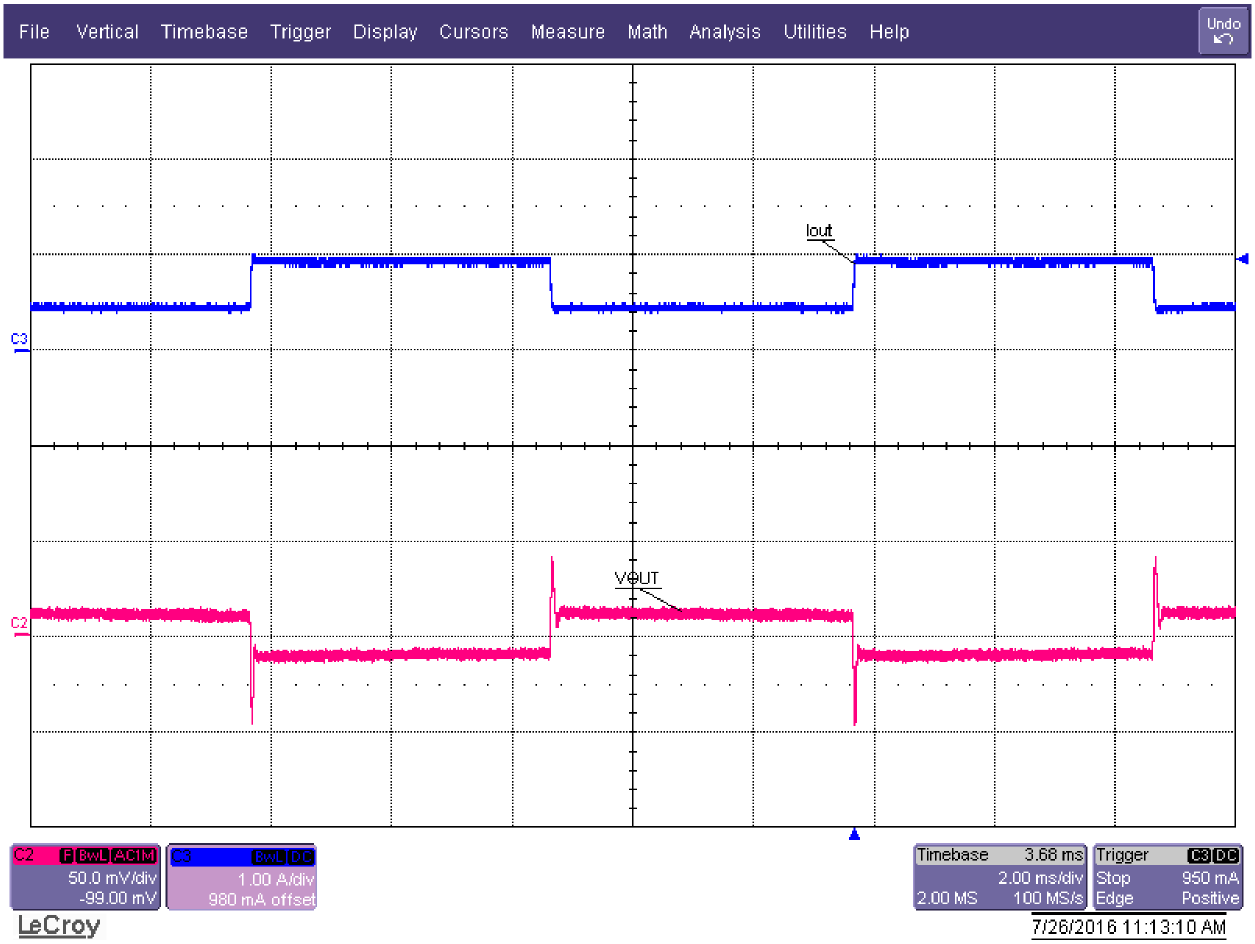
Load Transient Response at 12 Vin and 50%-to-100% Load Step on 5 V Output Vout2 (Full Load were connected to all other outputs)
Ch2 – Vout (AC coupled)
Ch3- Iout

6.4.2 Load Transient Response – TPS57114-Q1's output -3.3Vout



Load Transient Response at 12 Vin and 50%-to-100% Load Step on 3.3 V Output Vout2 (Full Load were connected to all other outputs)
Ch2 – Vout (AC coupled)
Ch3- Iout

6.4.3 Load Transient Response – TPS57112-Q1's output -1.1V



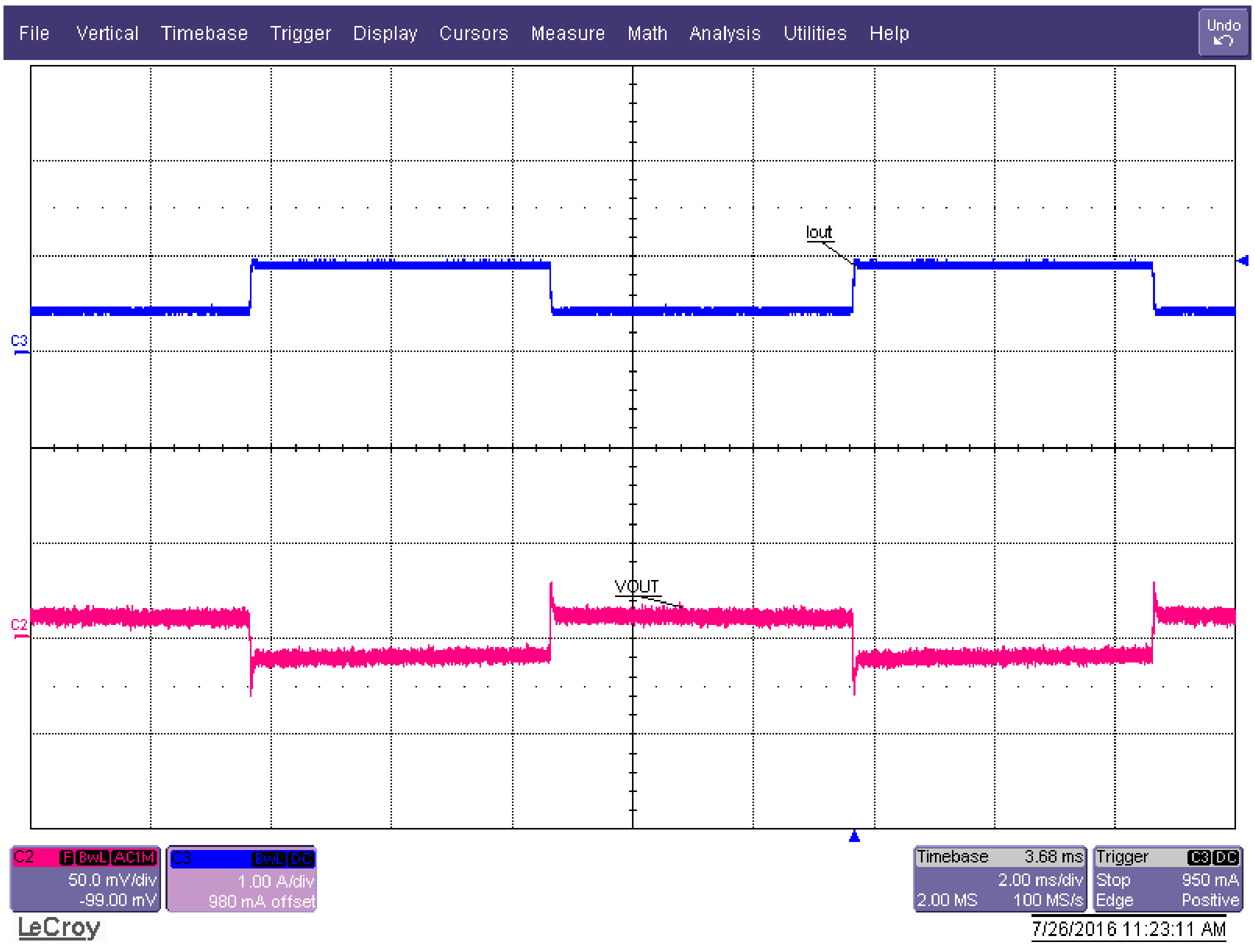
Load Transient Response at 12 Vin and 50%-to-100% Load Step on 1.1 V Output Vout2 (Full Load were connected to all other outputs)

Ch2 – Vout (AC coupled)

Ch3- Iout

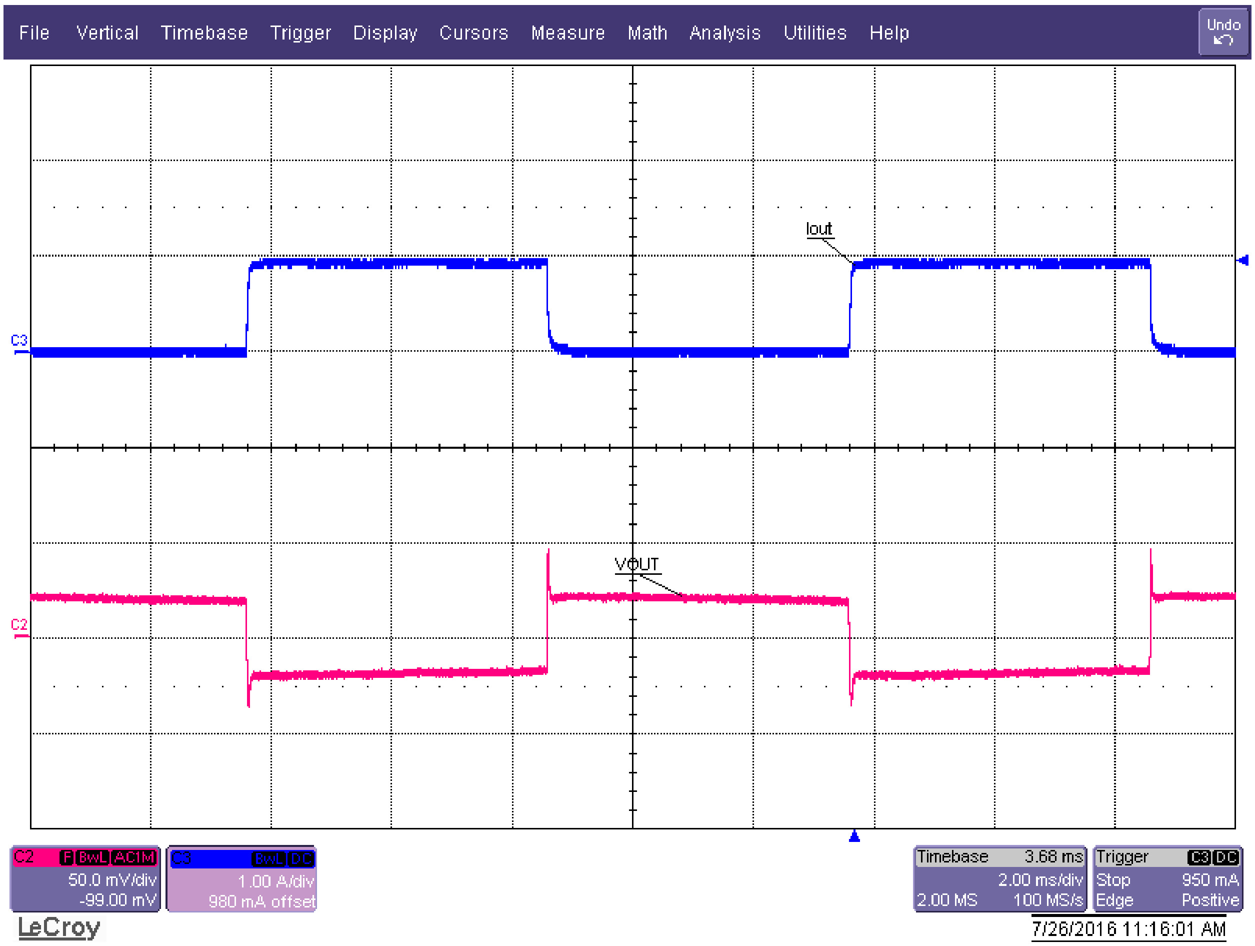
6.4.4 Load Transient Response – LM26420-Q1's dual outputs

6.4.4.1 Load Transient Response – LM26420-Q1's output – 1.2V



Load Transient Response at 12 Vin and 50%-to-100% Load Step on 1.2 V Output Vout2 (Full Load were connected to all other outputs)
Ch2 – Vout (AC coupled)
Ch3- Iout

6.4.4.2 Load Transient Response – LM26420-Q1's output – 1.1V

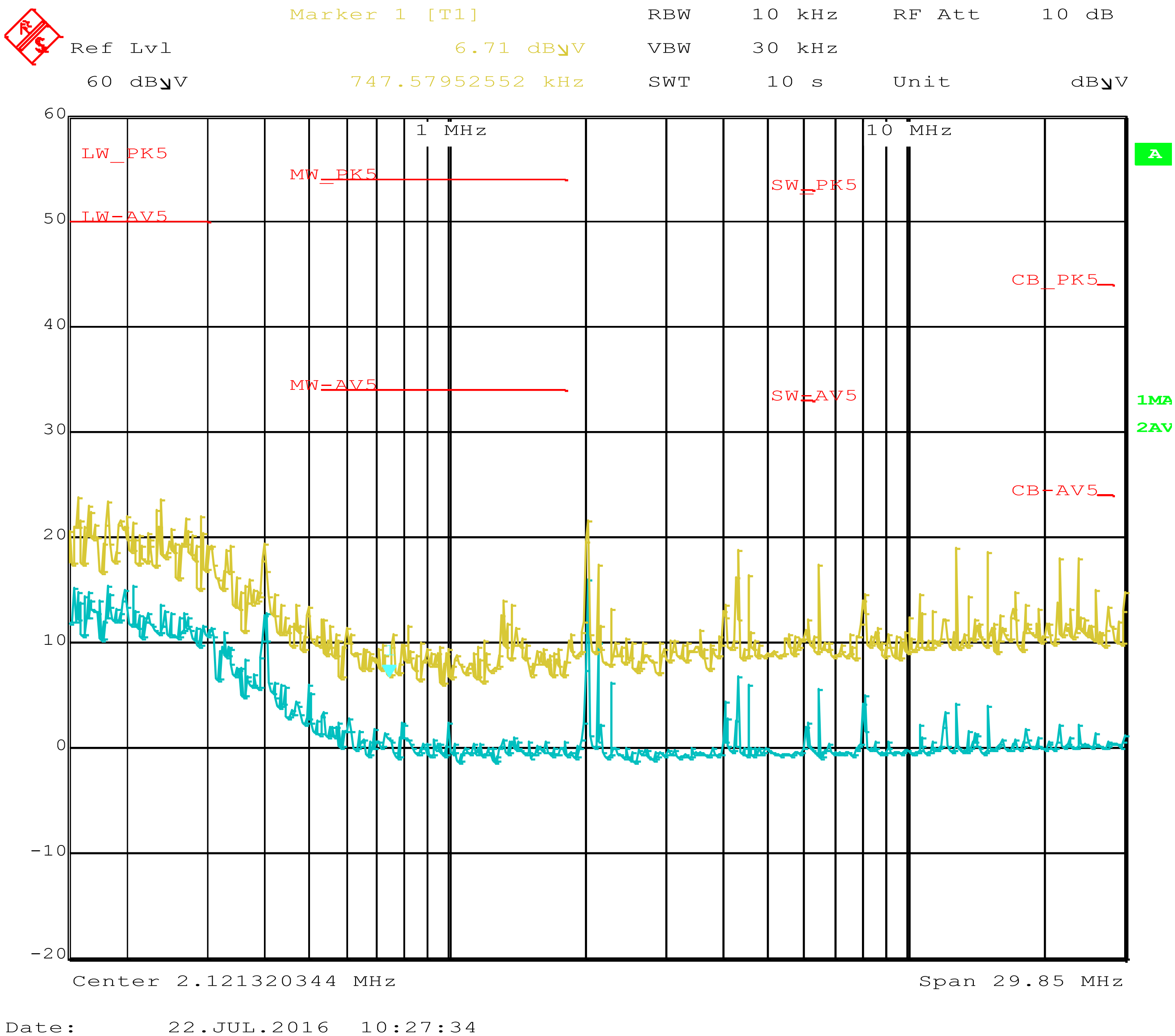


Load Transient Response at 12 Vin and 50%-to-100% Load Step on 1.1 V Output Vout2 (Full Load were connected to all other outputs)
Ch2 – Vout (AC coupled)
Ch3- Iout

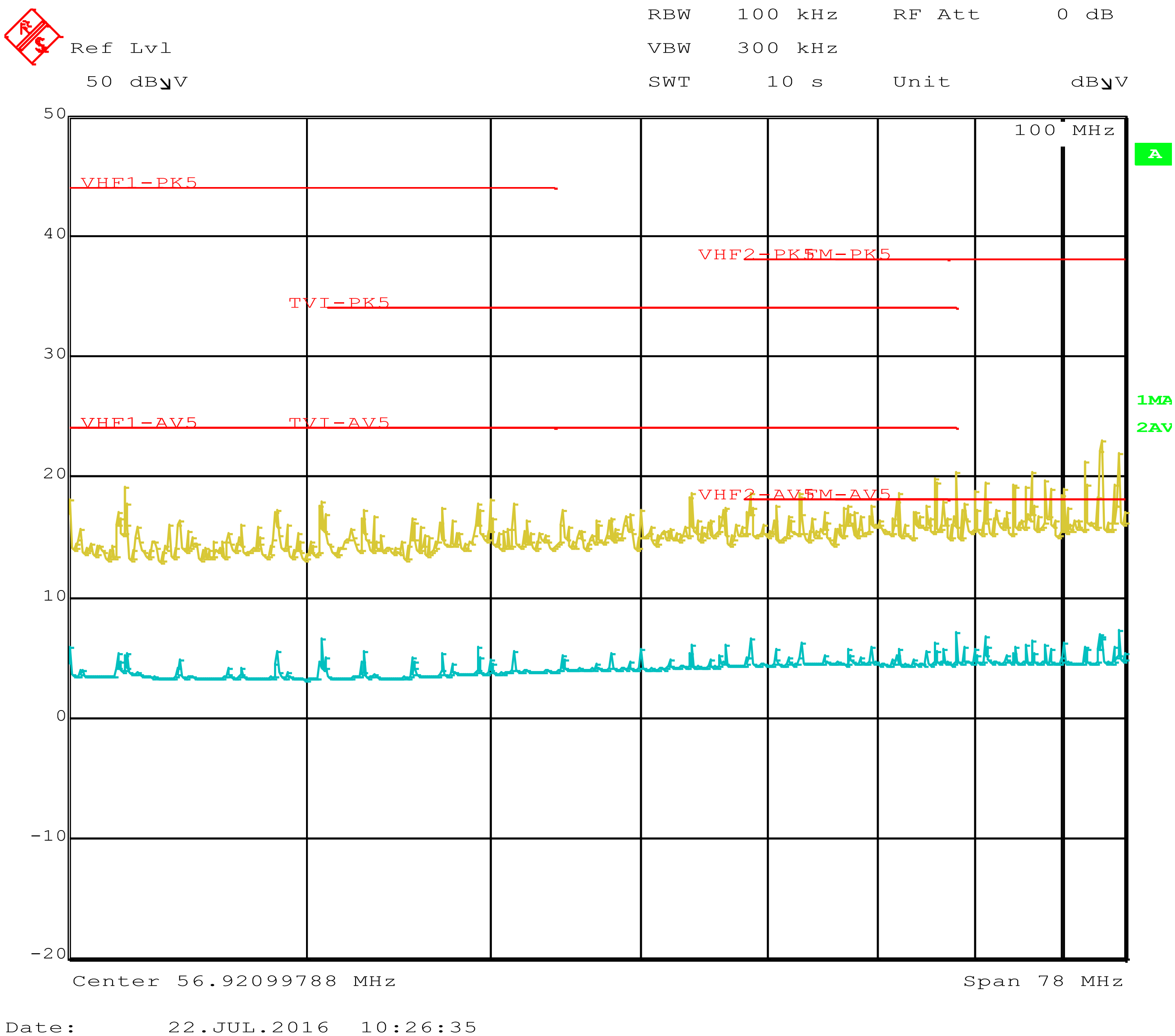
7 Conducted Emissions

The conducted emissions is tested followed the of CISPR 25 standards. 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 test results are shown in below two Figures. The first Figure show the test result using peak detector and Average detector measurement respectively up to 30MHz , and the last Figure show the test result using average detector and Peak Detector measurement from 30MHz to 108MHz. The limit lines shown in red are the Class 5 limits(up to 108MHz) for conducted disturbances specified in the CISPR 25; the yellow(Peak Detector measurement) and blue(Average detector measurement) traces is the test result. It can be seen that the power supply operates quietly and the noise is much below the stringent Class 5 limits overall.



Test result – Upto 30MHz Conducted Emission –Peak and Average Detection (All the DC/DC Switching with Full Load)



Test result –30MHz to 108MHz Conducted Emission –Peak and Average Detection (All the DC/DC Switching with Full Load)

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