Test Report: PMP23194

Three-Output Reference Design for Automotive ADAS Including Power for Main Processor And Cameras

Description

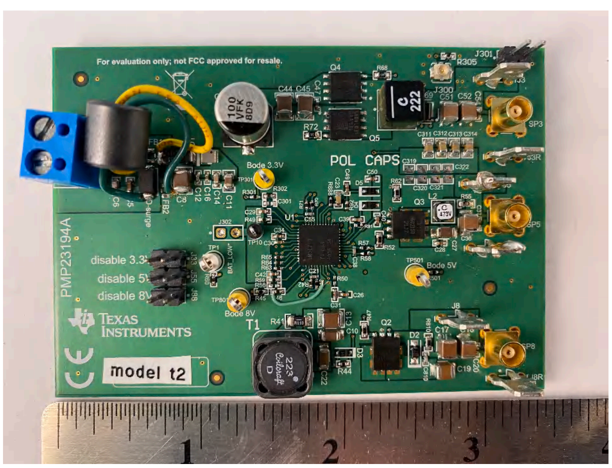
This reference design provides power for automotive advanced driver-assistance systems (ADAS) to power the cameras (8 V), controller area network CAN communications (5 V), and main processor (3.3 V). Operation is over the full automotive range including battery voltage surges to 34 V and dips to 6 V due to cold cranking. The design is low-noise to meet the stringent CISPR 25 Class 5 emissions requirements and includes an input filter. The board is designed for easy testing, providing jumpers to disable each output and an onboard dynamic load for the high-current 3.3-V output. The test report includes operational data on each output, and conducted emissions scans for the complete design against CISPR 25 Class 5.

Features

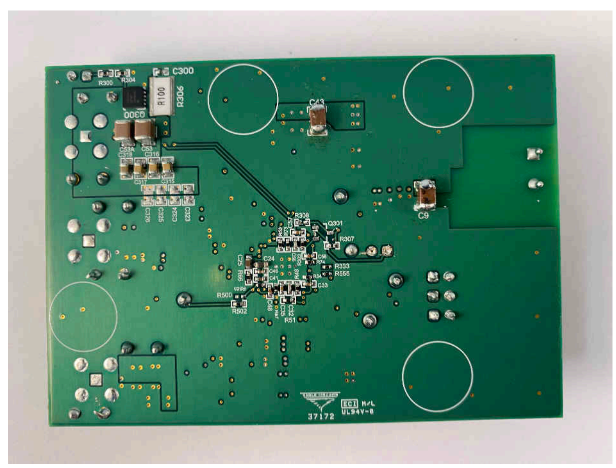
- Three output automotive ADAS power supplies using one controller
- Operation over the full automotive battery range including cold cranking and surges
- Provides power for main processor, CAN communications, and cameras
- Designed for low emissions and includes input filter to meet stringent CISPR 25 Class 5 requirements
- Tested for both performance and emissions against CISPR 25

Applications

- Driver monitoring
- Drive assist ECU
- Automotive thermal camera
- Camera module without processing



Board Photo (Top)



Board Photo (Bottom)

1 Test Prerequisites

This section provides the testing guide used in the detailed testing of the three-output power supply.

1.1 Power and Load Connections and Test Points

Table 1-1 describes power and load connections. Table 1-2 lists the test point descriptions and devices.

Table 1-1. Power and Load Connections

Connections	Description
J-BAT	V_{IN} to LM5127-Q1 three-output power supply 9-V to 18-V steady state main power input 2 × 1 5.08-mm terminal block
J8 and J8R	8-V, 600-mA SEPIC output, 2 × Keystone 1212-ST (0.187 in [4.75 mm] Quick-connect male solder connector non-insulated)
J5 and J5R	5-V, 120-mA buck output, 2 × Keystone 1212-ST
J3 and J3R	3.3-V, 6.7-A buck output, 2 × Keystone 1212-ST

Table 1-2. Test Points

Test Point	Description	Device
SP8	8-V output sense	MCX jack receptacle
TP801	Bode plot injection point for the 8-V loop	
TP1	Active low when any output active	
J55	Jumper to disable 5 V	TSW-102-07-G-S
J33	Jumper to disable 3.3 V	TSW-102-07-G-S
SP5	5-V output sense	MCX jack receptacle
TP501	Bode plot injection point for the 5-V loop	
SP3	3.3-V output sense	MCX jack receptacle
TP301	Bode plot injection point for the 3.3-V loop	
J300	Dynamic current monitor off the 3.3-V dynamic load	Receptacle, ultra miniature coaxial, male pin, 50-Ω, SMT
J301	Signal generator injection for the 3.3-V dynamic load	TSW-102-07-G-S
J302	Not used, was to change 3.3-V loop speed	

Figure 1-1 shows the test setup.

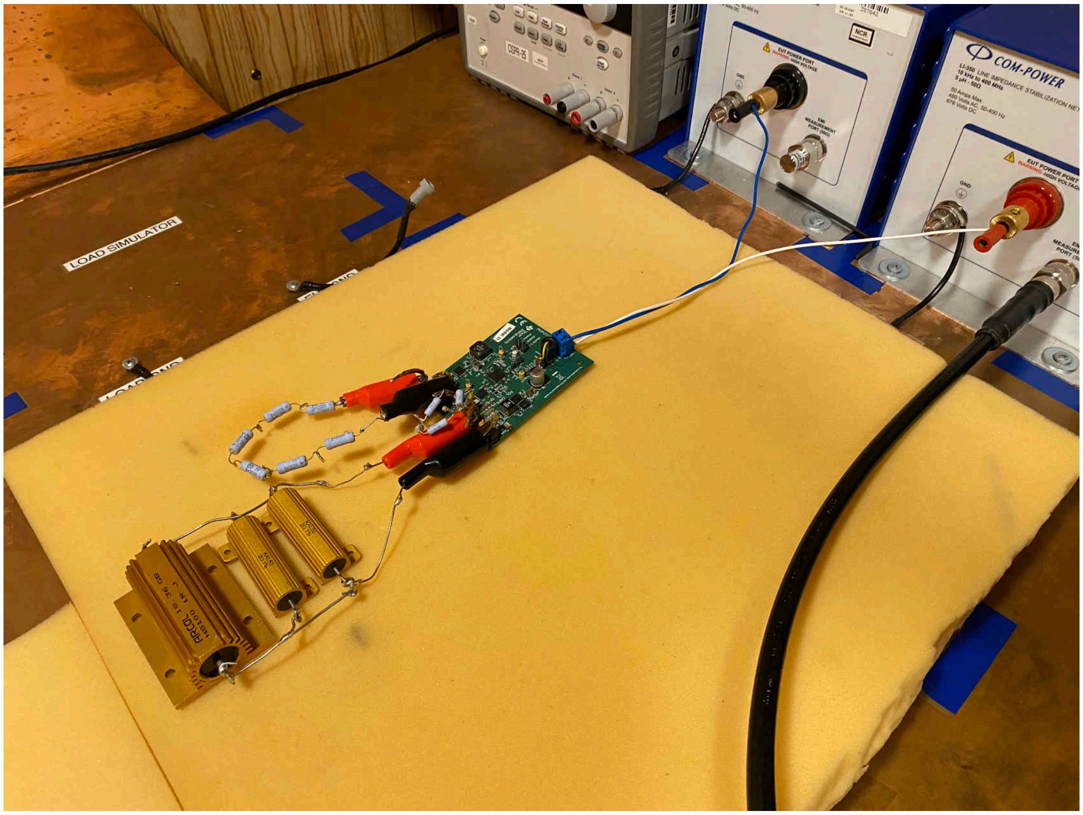


Figure 1-1. Test Setup for Conducted Emissions

1.2 Voltage and Current Requirements

Table 1-3. Requirements

Parameter	Specifications
Input Power	6-V to 18-V steady-state with surges to 42 V
8-V output	Load up to 600 mA
5-V output	Load up to 120 mA
3.3-V output	Load up to 6.7 A

1.3 Required Equipment

- V_{IN} power supply 6 V to 18 V, at least 5 A
- Resistive loads: Use actual resistors for conducted emissions testing
- Electronic load to step for efficiency graphs, and for dynamic load testing such as Kikusui PLZ334WL
- To connect onboard dynamic load for the 3.3-V output current sense, J300 to a BNC scope input: Taoglas CAB.011 (cable SMA jack) and Amphenol RF 095-850-250-024 [cable assembly coaxial BNC to SMA RG-316 DS 24.00 in (609.60 mm)]
- Signal generator with pulse mode such as Tektronix AFG3102
- Oscilloscope such as Tektronix MDO34 with TPP0500B 10 × voltage probes and 30-A TCP0030A current probe
- Digital multimeters such as Fluke 87iii or 87V
- For Bode plots: Vector Network Analyzer such as Bode 100 from OMICRON Lab
- Thermal camera such as FLIR E75
- Keysight 34970 data acquisition, switch unit along with calibrated 10-A and 1-A current shunts for efficiency measurements
- Automotive CISPR 25 conducted emissions setup with EMI receiver such as Rohde & Schwarz ESRP EMI test receiver

1.4 Considerations

When powering the board, the input voltage range must be 6 V to 18 V. All three outputs come up unless jumpers are placed on J88, J55, or J33 to disable the 8 V, 5 V, or 3.3 V, respectively. With each output loaded, switching frequency is approximately 440 kHz with dithering.

When testing for surges with input in the 18-V to 42-V range for more than a few seconds, use a fan blowing on the board.

1.5 Board Dimensions

3.4 in by 2.4 in

2 Testing and Results

2.1 Efficiency and Loss Graphs

Figure 2-1 through Figure 2-3 show the PMP23194 efficiency graphs for 3.3 V, 5 V and 8 V, respectively.

For the main 3.3 V with 22-W maximum output power, efficiency peaks at 95% at 10 V_{IN}, just over 93% for 14 V_{IN}, and about 91.5% for 18 V_{IN}. For the lowest power 5 V with 0.6-W maximum output power, efficiency is in the 70%–80% range at 14 V_{IN} and loading above 50% maximum load. For the 8 V with 4.8-W maximum output power, efficiency is in the 80%–86% range for loads at and above 2 W at all three input voltages tested.

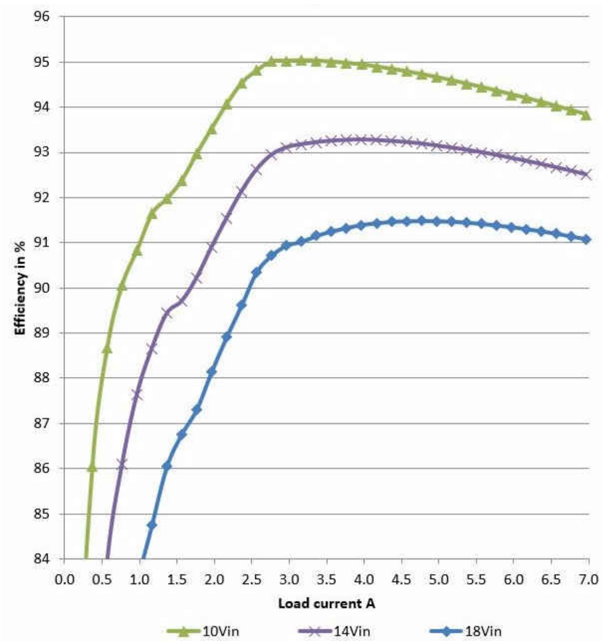


Figure 2-1. PMP23194 3.3-V DC/DC Converter Efficiency

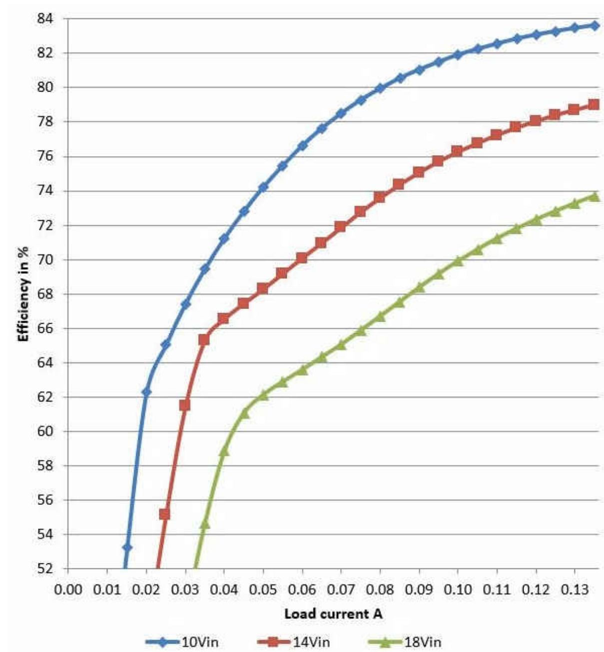


Figure 2-2. PMP23194 5-V DC/DC Converter Efficiency

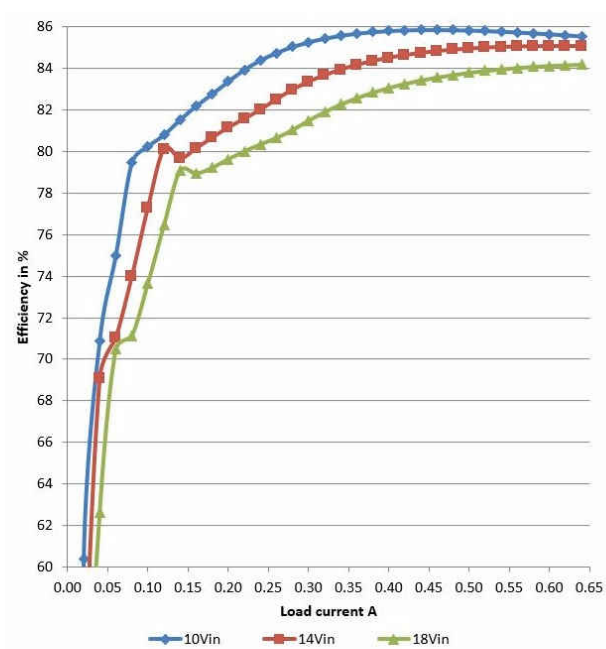


Figure 2-3. PMP23194 8-V DC/DC Converter Efficiency

Figure 2-4 through Figure 2-6 show the loss graphs for 3.3 V, 5 V and 8 V, respectively. These loss graphs for all three outputs are shown from no load thru maximum load at the same input voltages. Losses in input EMI filters are not included here.

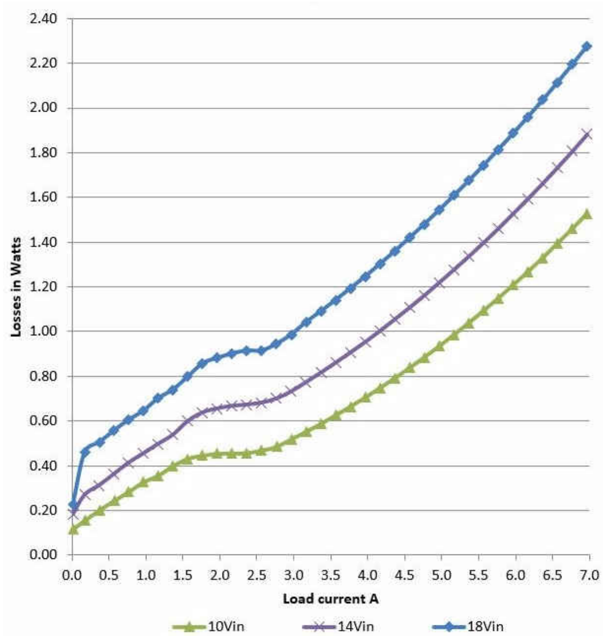


Figure 2-4. PMP23194 3.3-V DC/DC Converter Losses

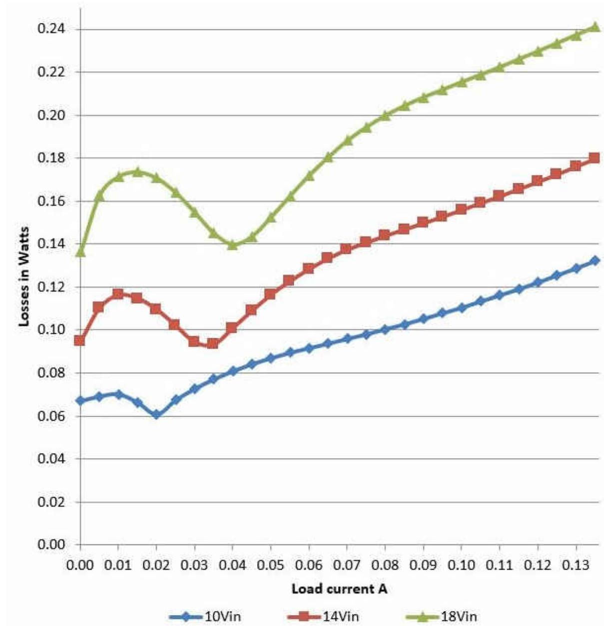


Figure 2-5. PMP23194 5-V DC/DC Converter Losses

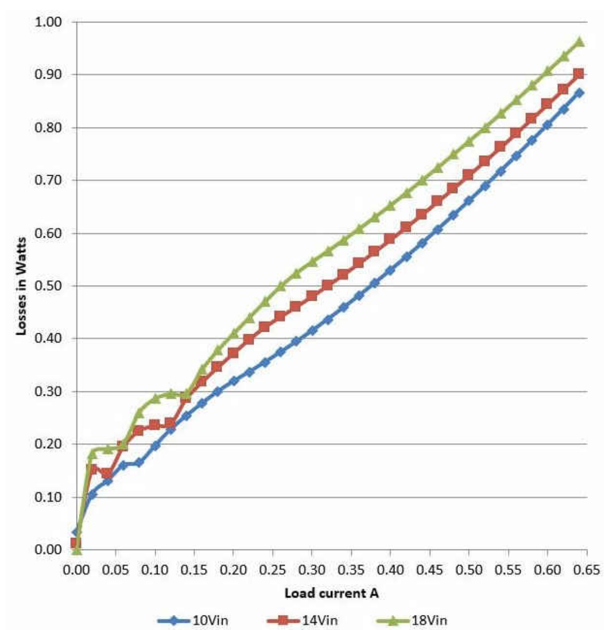


Figure 2-6. PMP23194 8-V DC/DC Converter Losses

2.2 Thermal Images

Figure 2-7 through Figure 2-10 show the worst-case thermal images. All outputs are loaded to their maximum; or 6.7 A off the 3.3 V, 120 mA off the 5 V, and 600 mA off the 8 V. Thermal images were taken at 10 V_{IN}, 14 V_{IN} and 18 V_{IN}. Ambient is room temperature or about 22°C, and there are no fans blowing on the boards.

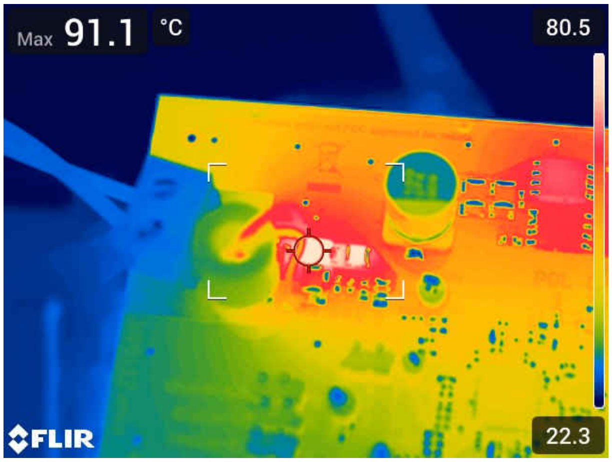


Figure 2-7. Input Reverse Protection Diode D1 Worst Case at 10 V_{IN}, 91°C

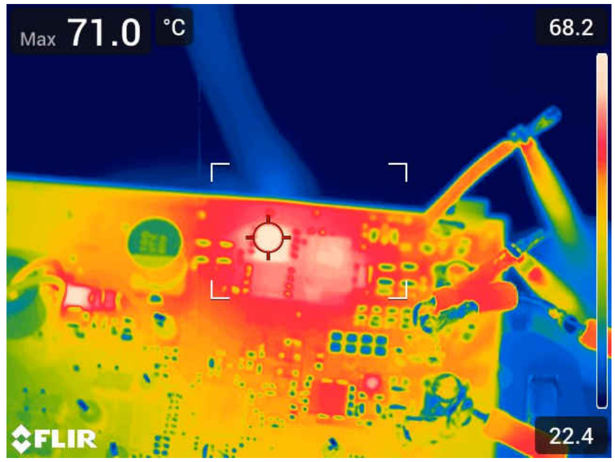


Figure 2-8. High-Side FET Q4 of the 3.3-V Buck Converter Worst Case at 18 V_{IN}, 71°C

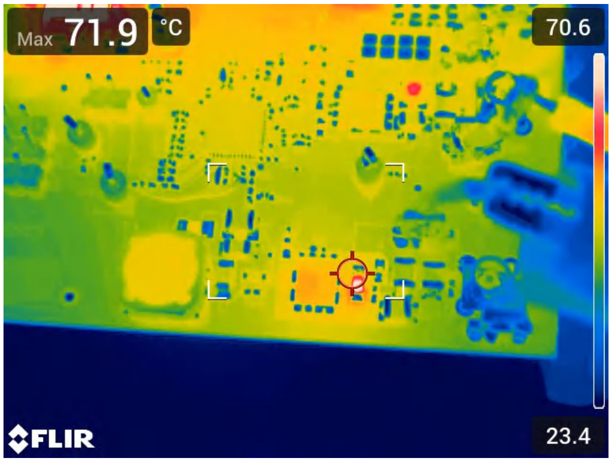


Figure 2-9. Output Rectifier of the 8-V SEPIC D2 Worst Case at 10 V_{IN}, 72°C

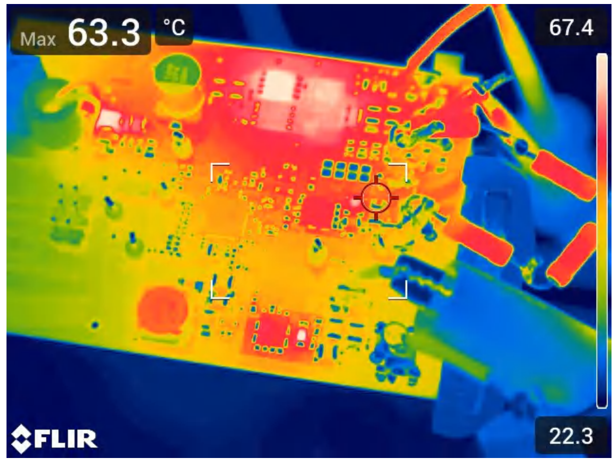
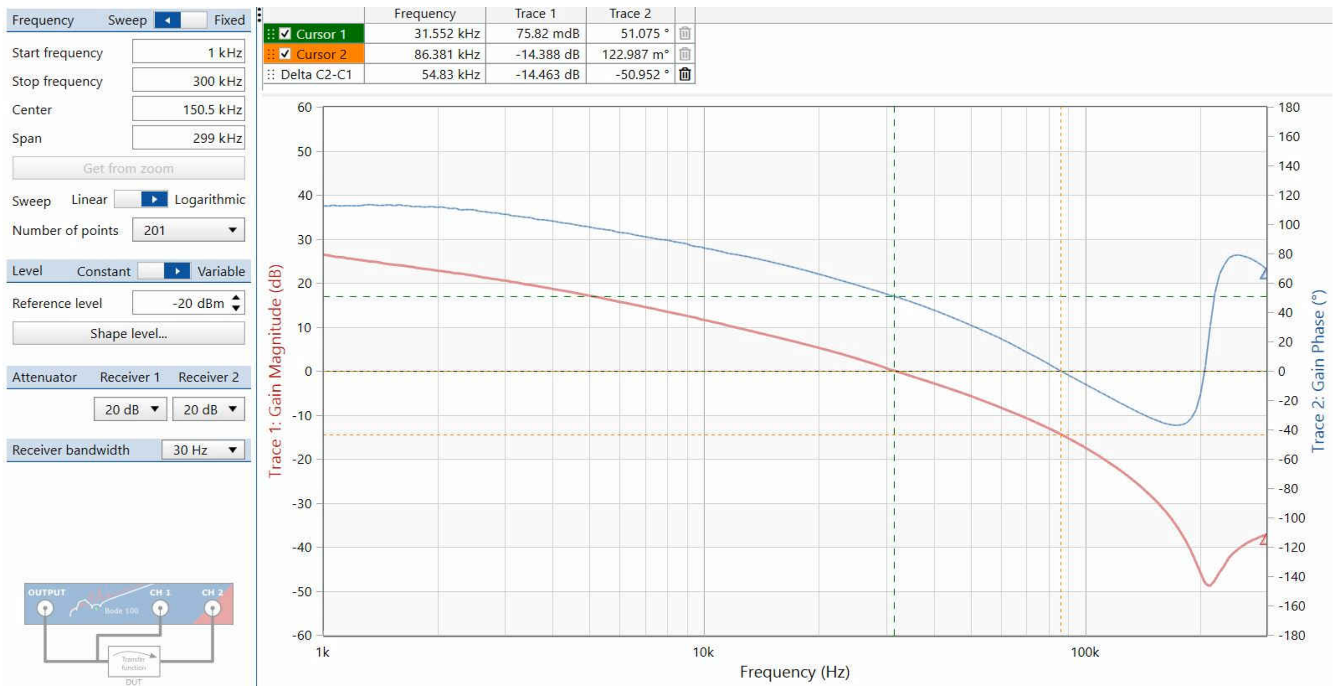


Figure 2-10. Main Inductor of the 5-V Buck L2 Worst Case at 18 V_{IN}, 63°C

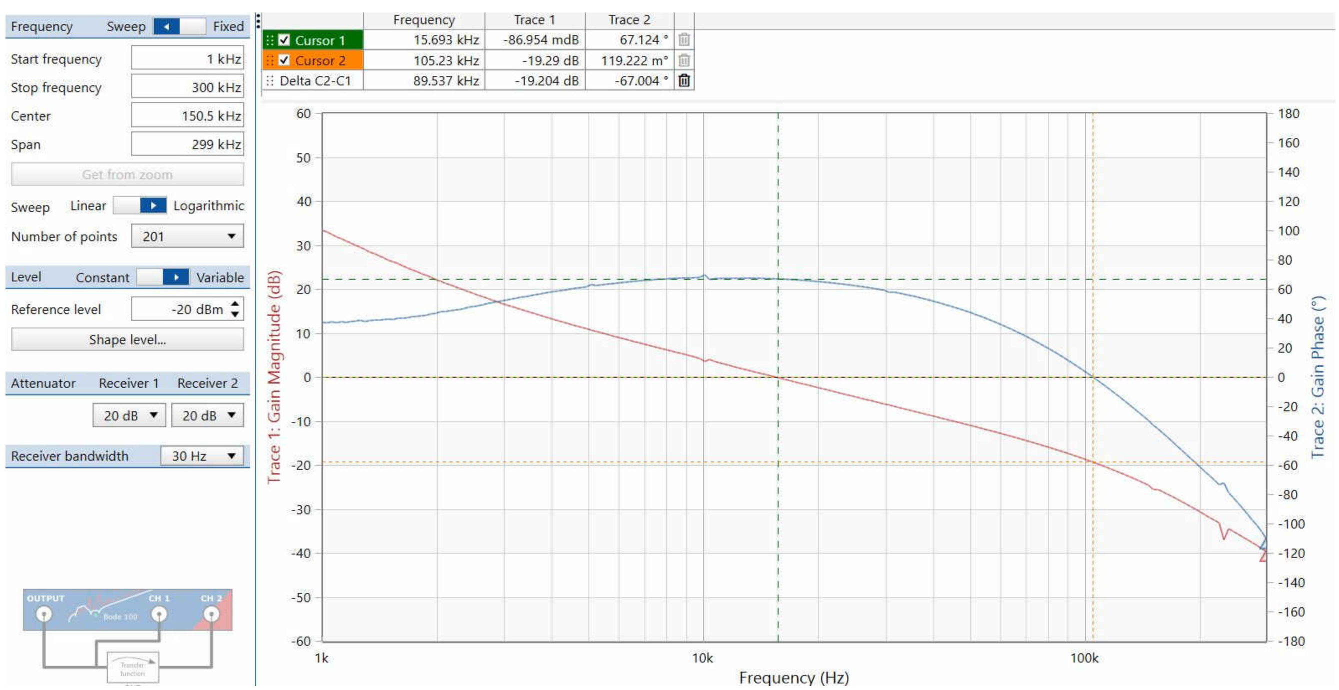
2.3 Bode Plots

Figure 2-11 through Figure 2-13 show the bode plots with 14 V_{IN} for 3.3-V, 5-V, and 8-V outputs respectively.



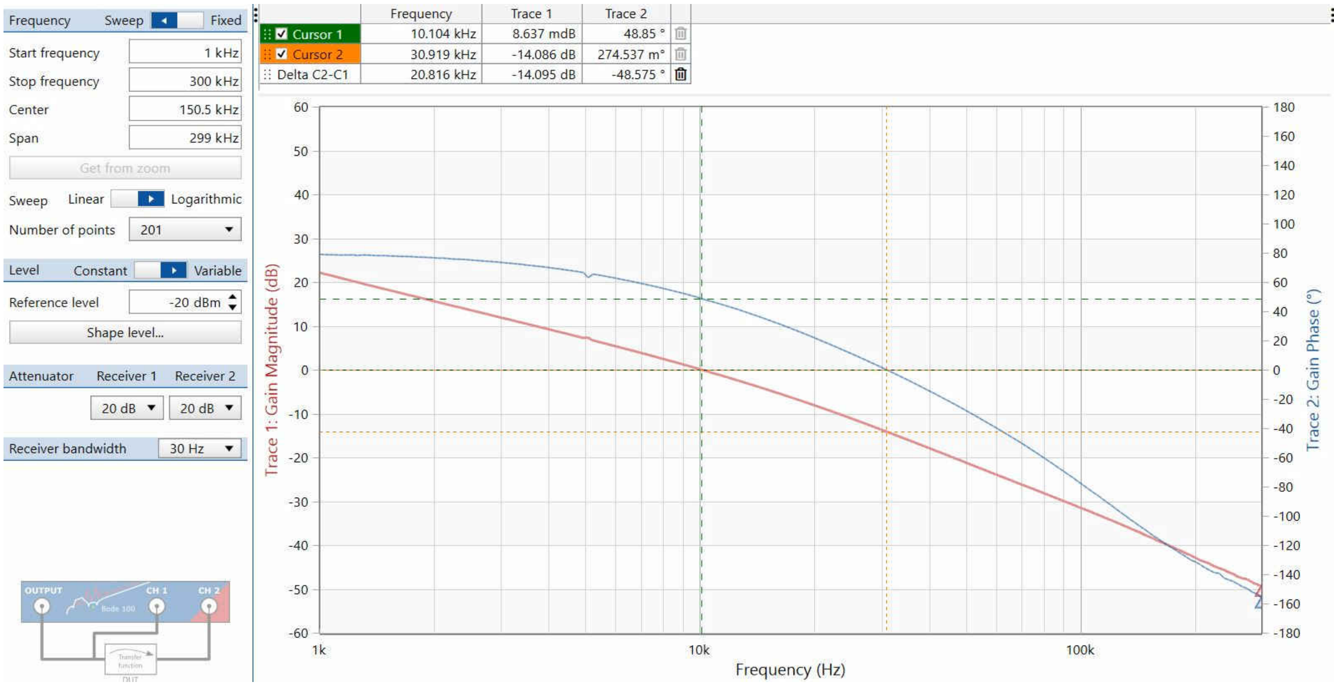
Crossover at 32 kHz with 51 degrees of phase margin, –180 degrees shift at 86 kHz with 14-dB gain margin

Figure 2-11. 3.3-V, 3-A Bode Plot off 14 V_{IN}



Crossover at 16 kHz with 67 degrees of phase margin, –180 degrees shift at 105 kHz with 19-dB gain margin

Figure 2-12. 5-V, 120-mA Bode Plot off 14 V_{IN}



Crossover at 10 kHz with 49 degrees of phase margin, –180 degrees shift at 31 kHz with 14-dB gain margin

Figure 2-13. 8-V, 600-mA Bode Plot off 14 V_{IN}

2.4 Conducted Emissions vs CISPR Class 5

See the test setup for conducted emissions in Figure 1-1. Conducted EMI scans over the full 150-kHz to 108-MHz range are shown in the following figures. All three PMP23194 models were tested with near maximum loading on all three outputs. Each scan shows the maximum peak detection trace, quasi-peak detection trace, and CISPR average detection trace. Limit lines shown are for CISPR 25 Class 5 peak, quasi-peak and average limits. Worst cases were around 70 MHz for both quasi-peak and average with less than 1-dB margin, and for maximum peak with 4- to 5-dB margin. All three models scanned show passing Class 5 and very similar results. The worst-case average and quasi-peak results varied less than 0.5 dB. The following scans are models t1, t2, and t3 respectively.

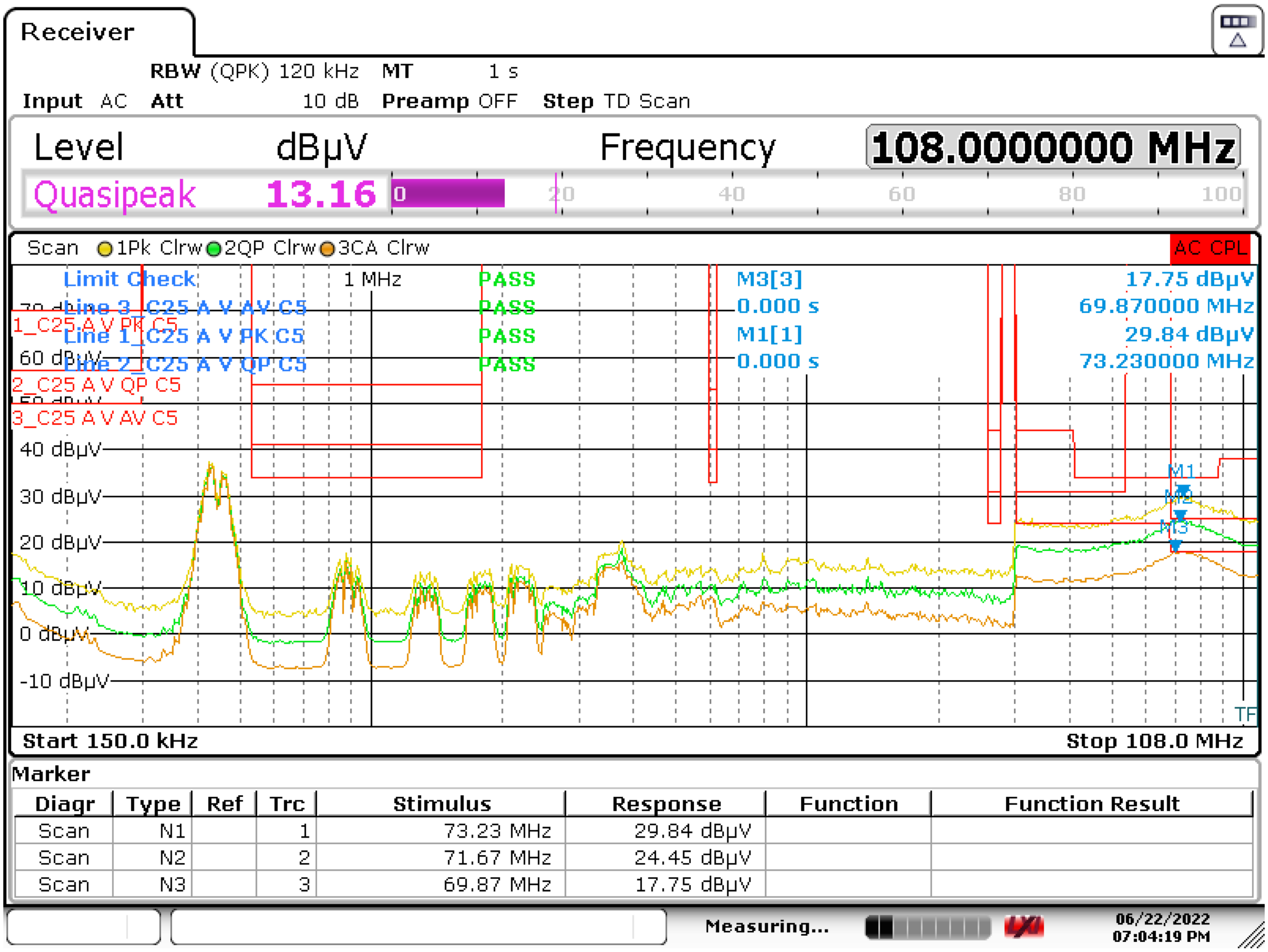


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Figure 2-14. Model t1 Conducted Emissions

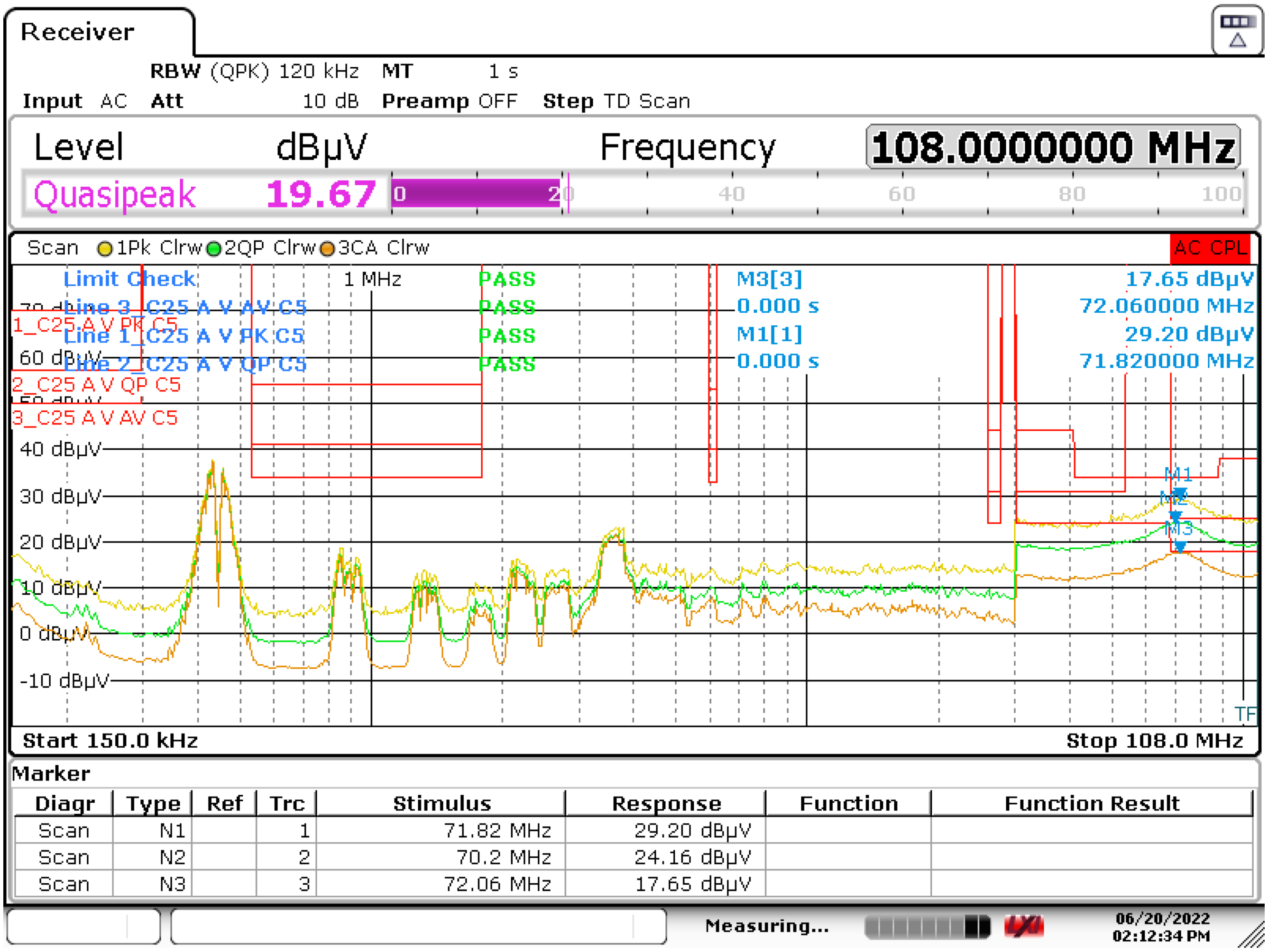

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Figure 2-15. Model t2 Conducted Emissions

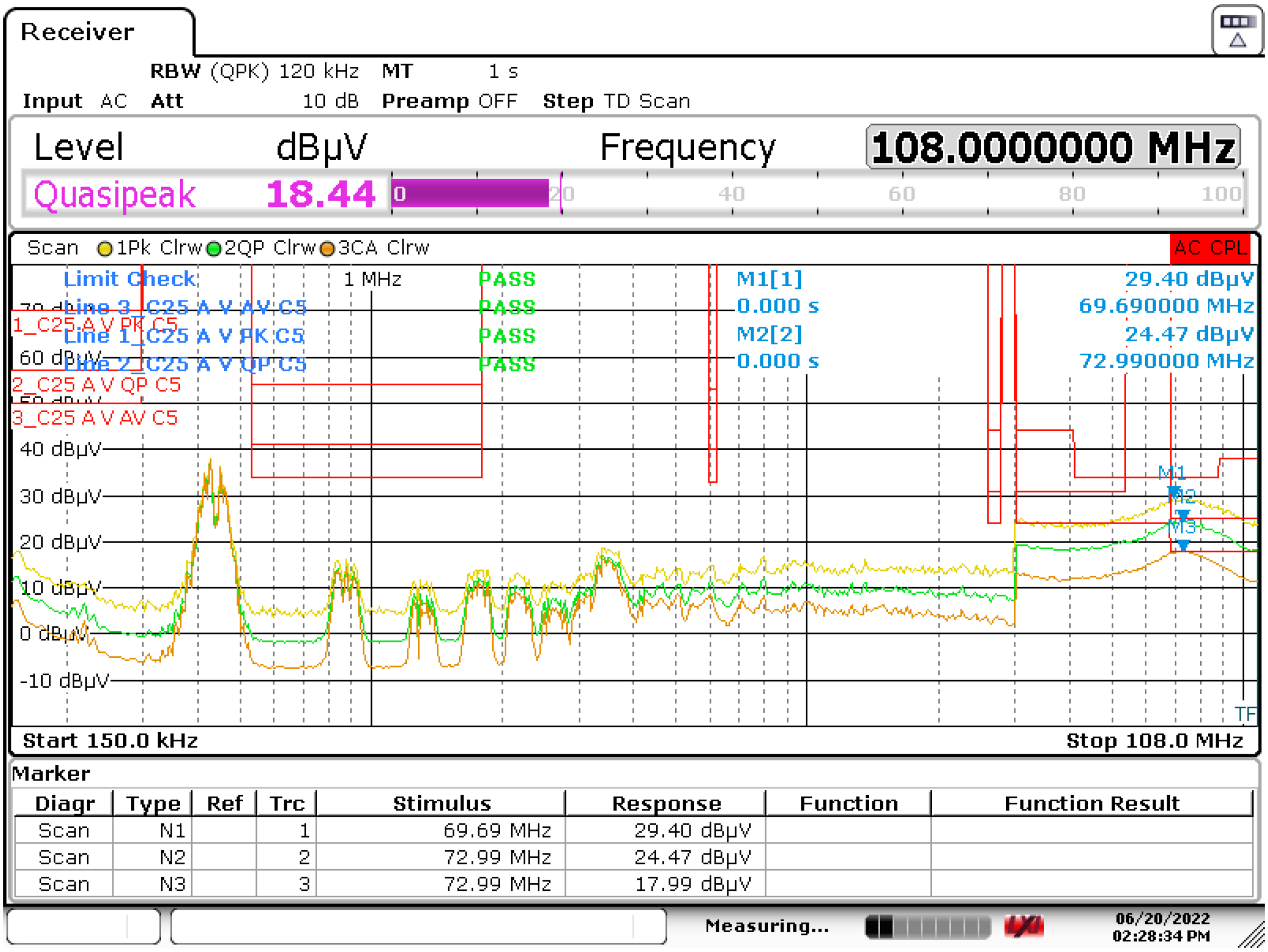

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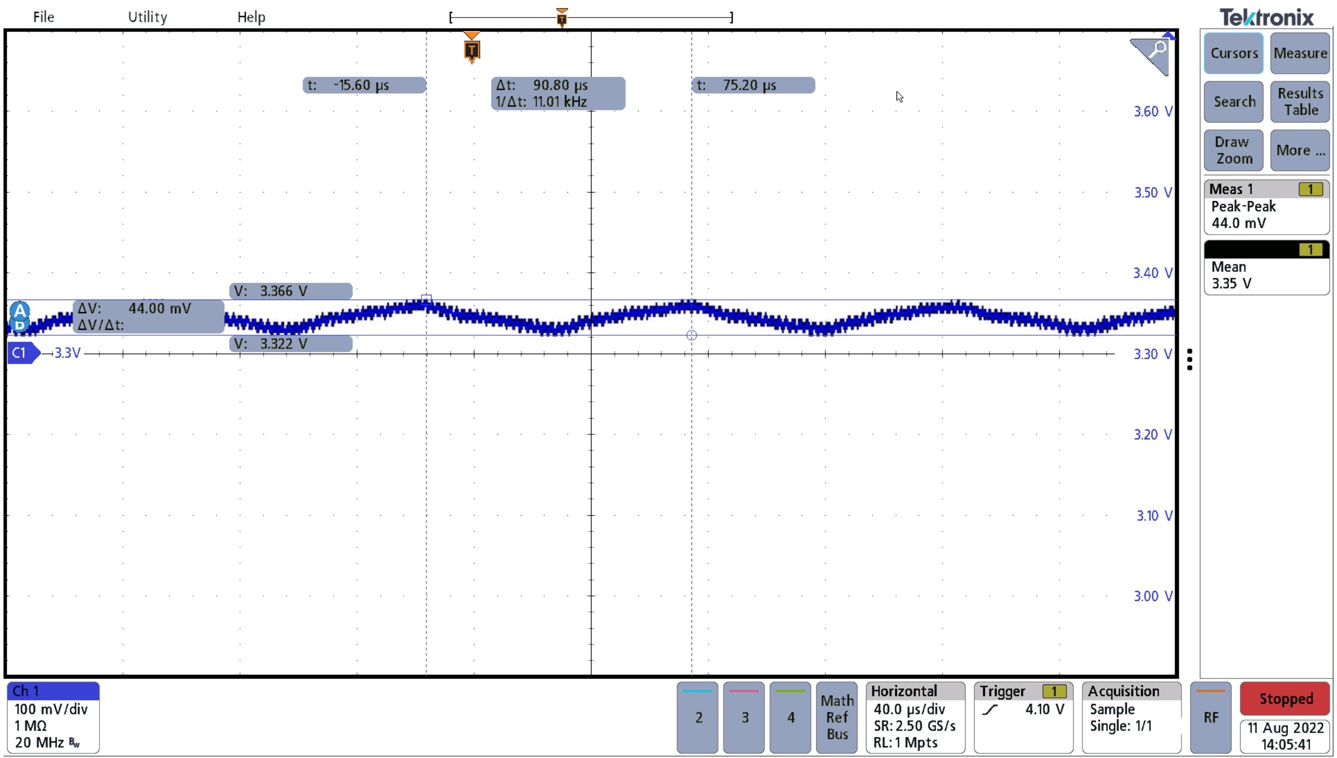
Figure 2-16. Model t3 Conducted Emissions

3 Waveforms

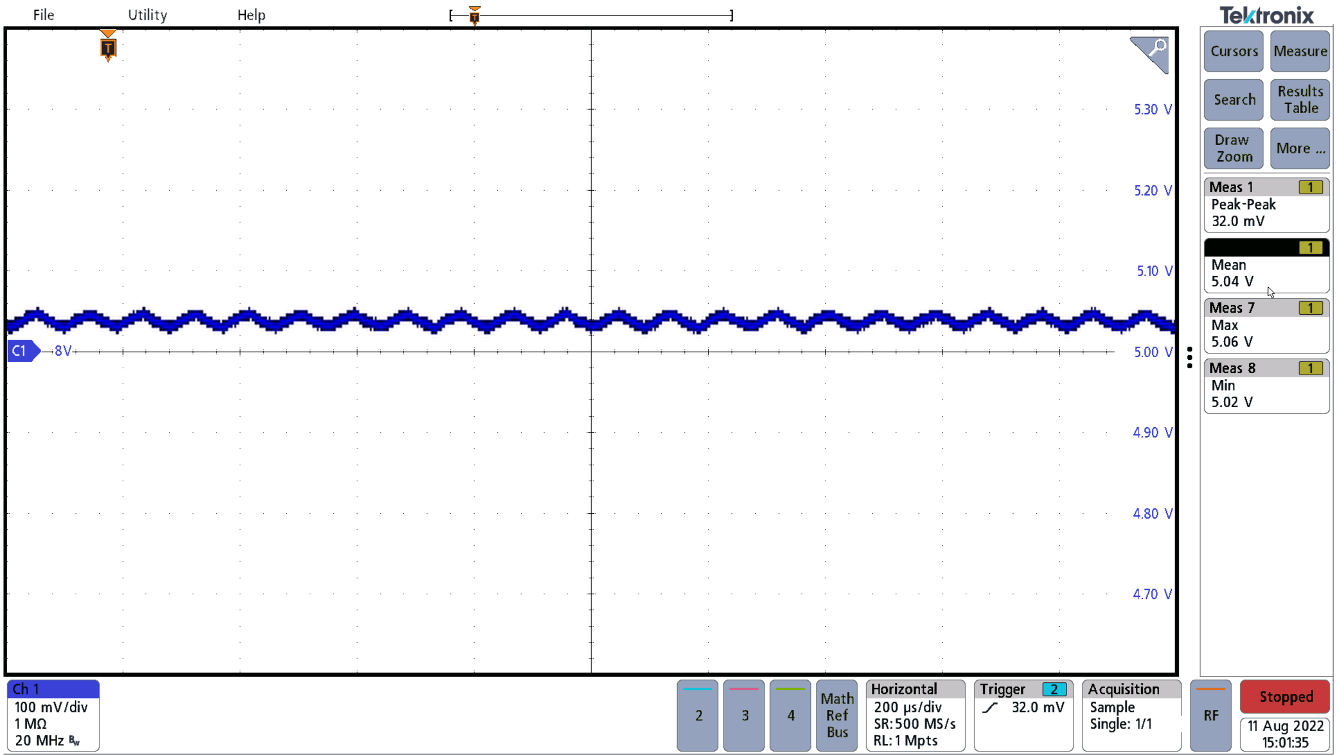
3.1 Output Voltage Ripple

Figure 3-1 through Figure 3-3 show the output voltage ripple waveforms with switching frequency dithering turned on. Ripple is from the 11-kHz dithering of the main 440-kHz switching frequency dominated the overall output ripple for all three outputs.



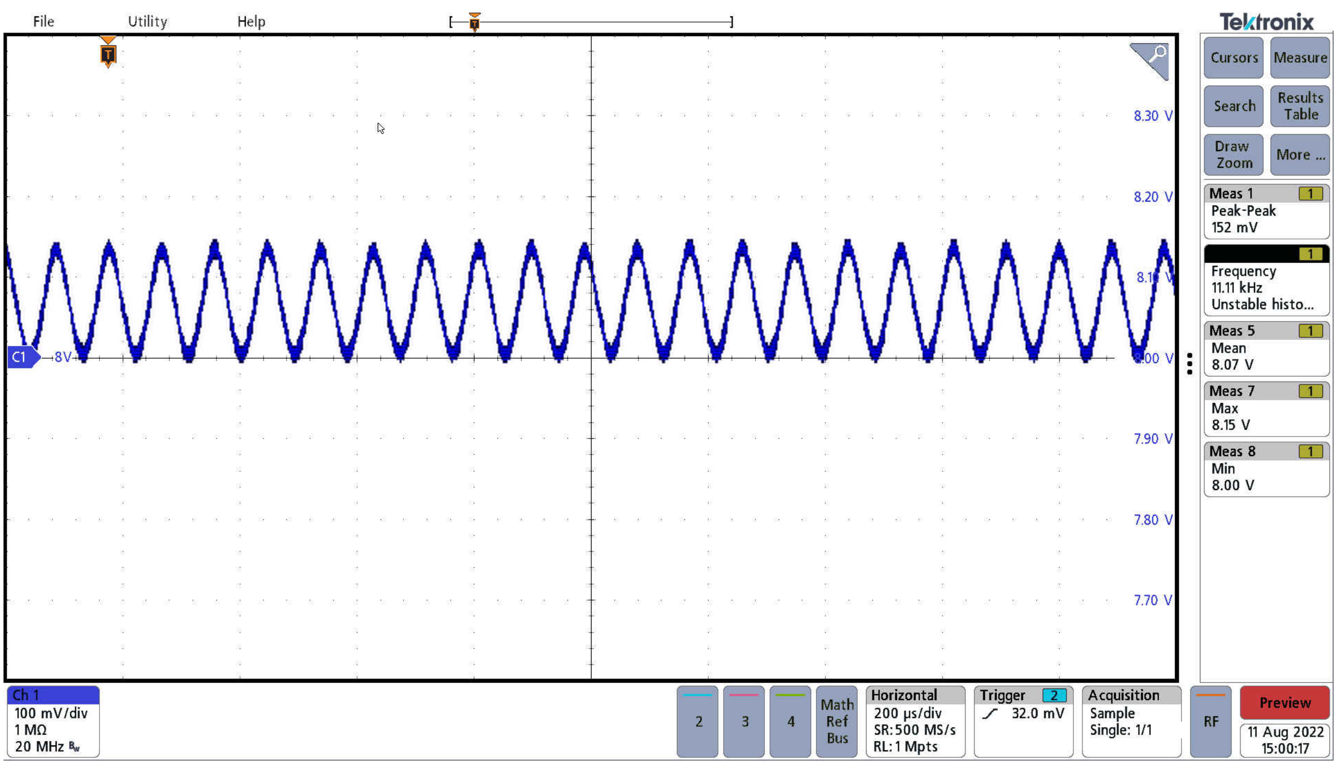
40 mV peak to peak

Figure 3-1. Output Voltage Ripple 3.3 V, 6.7 A off 14 V_{IN}



40 mV peak to peak

Figure 3-2. Output Voltage Ripple 5 V, 120 mA off 14 V_{IN}

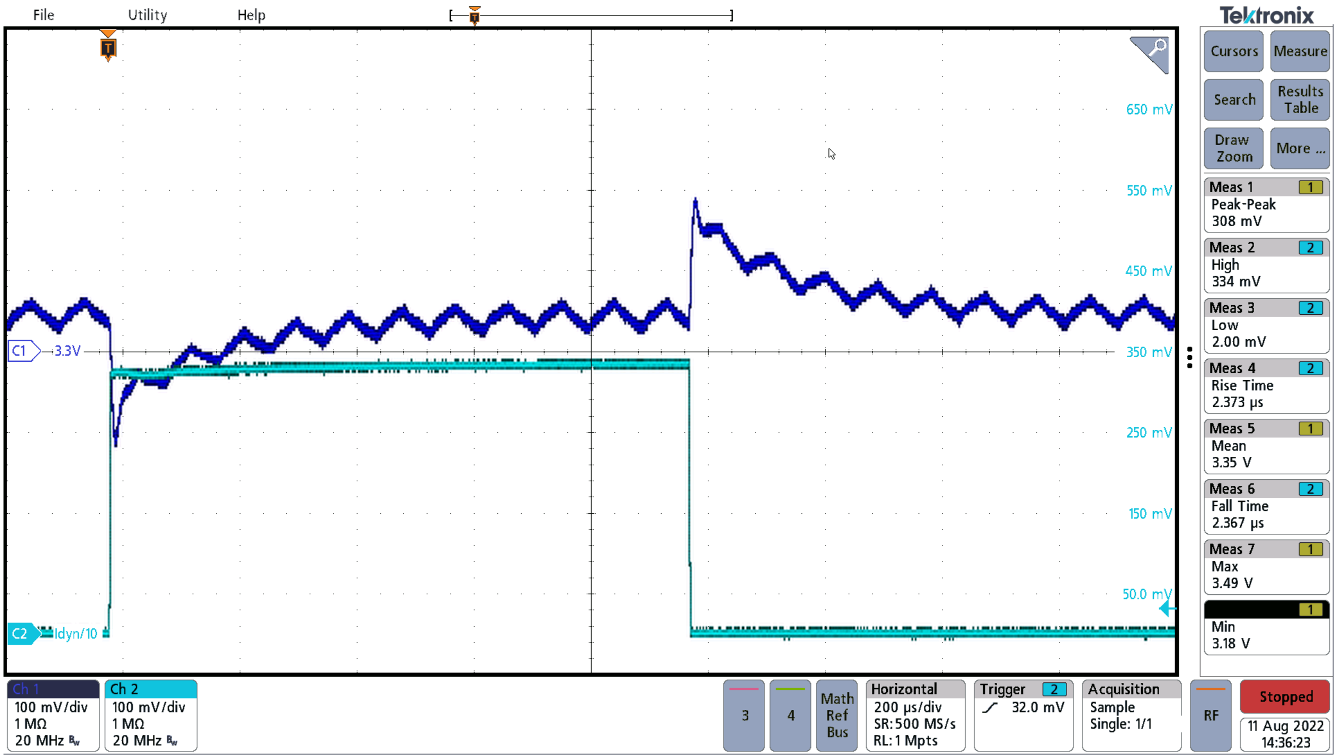


150 mV peak to peak

Figure 3-3. Output Voltage Ripple 8 V, 600 mA off 14 V_{IN}

3.2 Load Transients

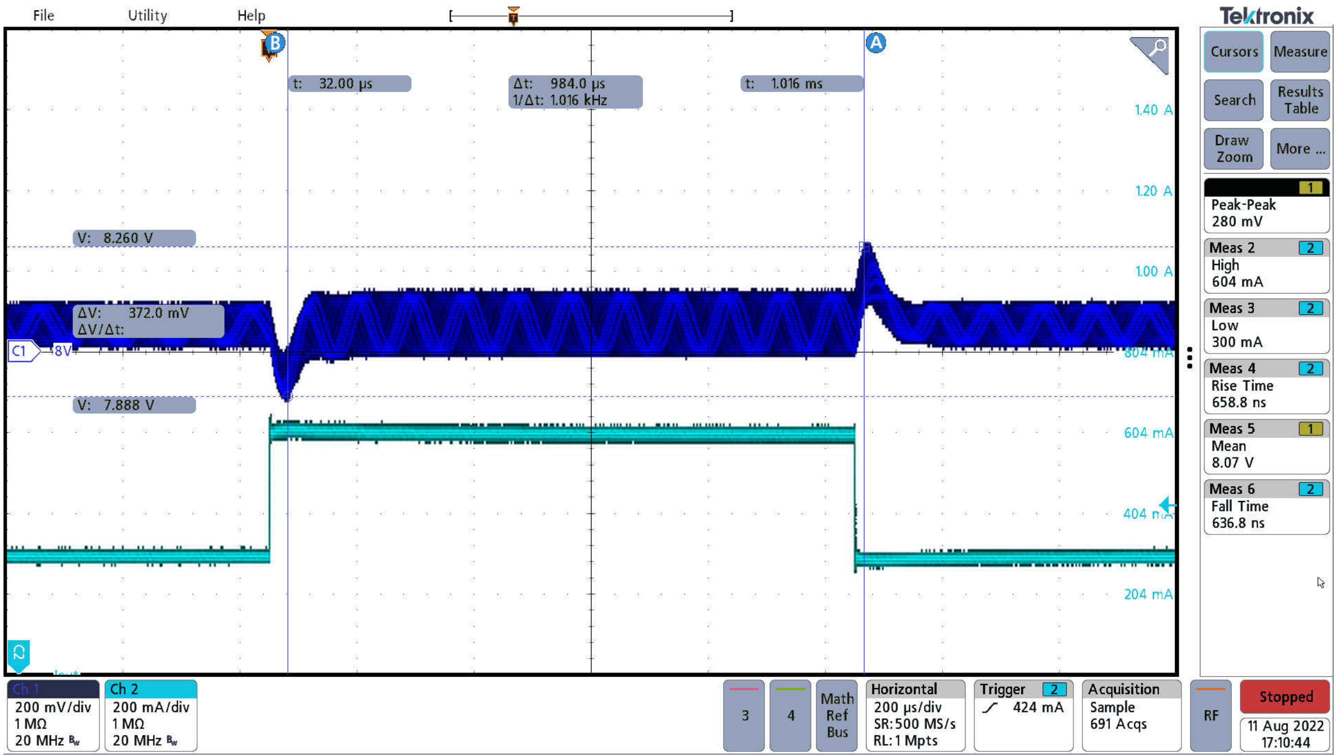
Figure 3-4 shows the load transient waveform at 8 V. The waveform was taken at 14 V_{IN} with the load going from 3 A to 6.35 A and back to 3 A. The onboard dynamic load (J301 and Q300) was driven by Tektronix AFG3102.



Output undershoot and overshoot each about 150 mV (purple trace). Dynamic current measured at J300 across a 100-mΩ shunt R306 on the PMP23194 board (blue trace).

Figure 3-4. Load Transient 3.3 V

Figure 3-5 shows the load transient waveform at 8 V. The waveform was taken at 14 V_{IN} with the load going from 300 mA to 600 mA and back to 300 mA. Dynamic load inside the Kikusui PLZ334WA was used.

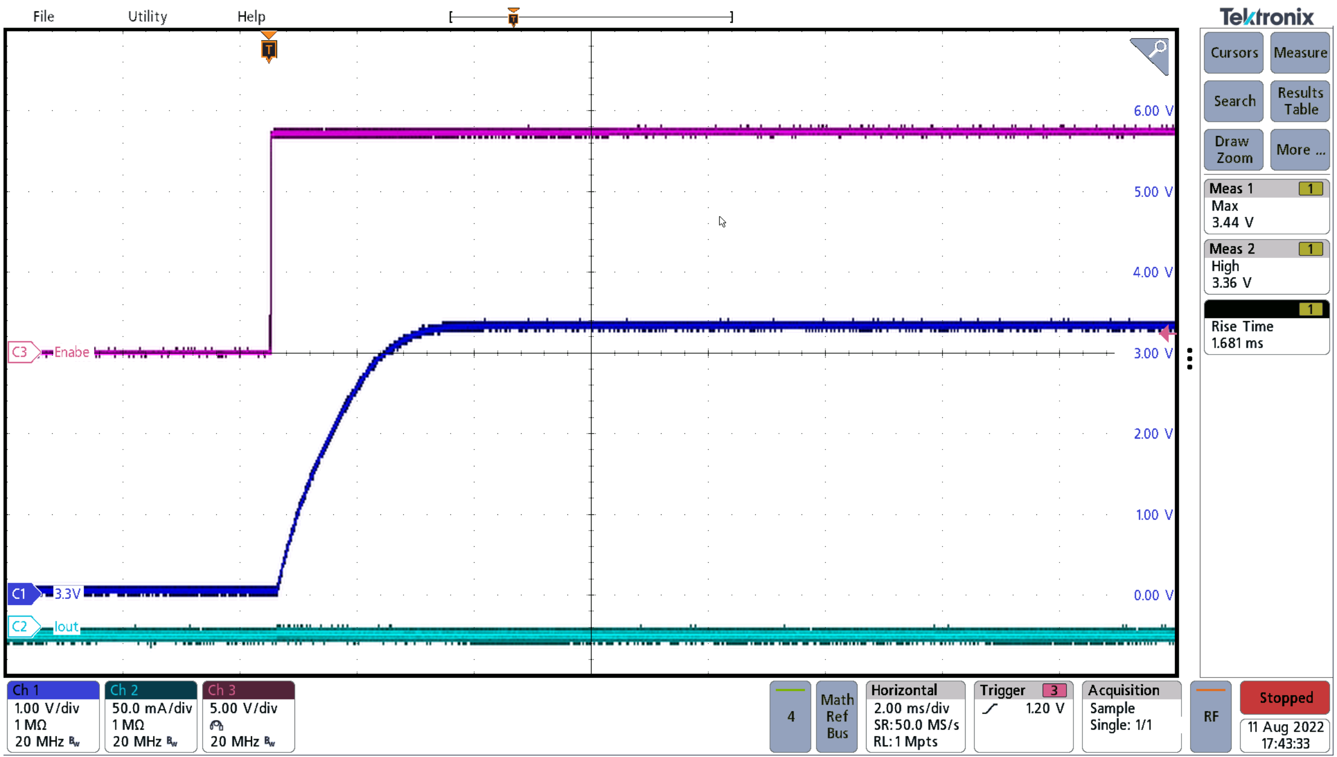


Undershoot and overshoot are each about 120 mV (dark blue trace). Dynamic current was measured with clip-on current probe (blue trace).

Figure 3-5. Load Transient 8 V

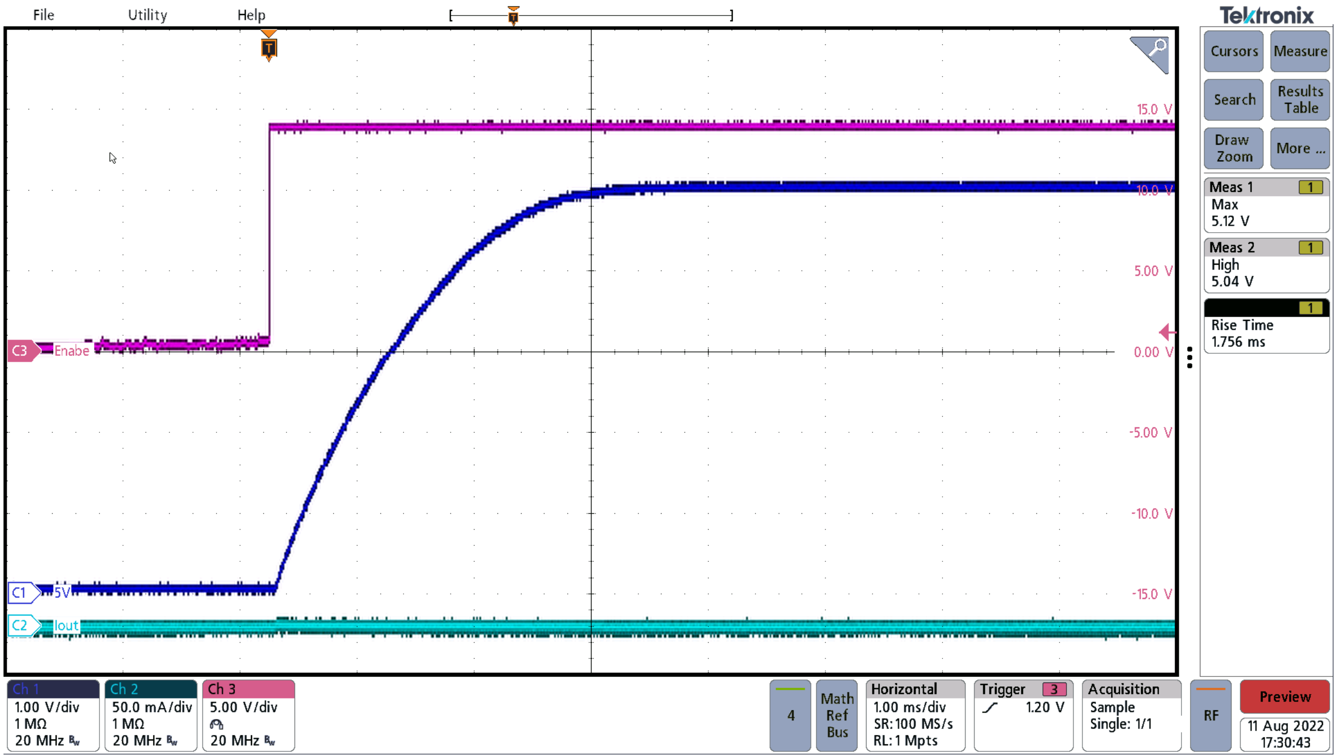
3.3 Start-Up of Each Independently-Controlled Output

Start-up behavior is shown in the following figures.



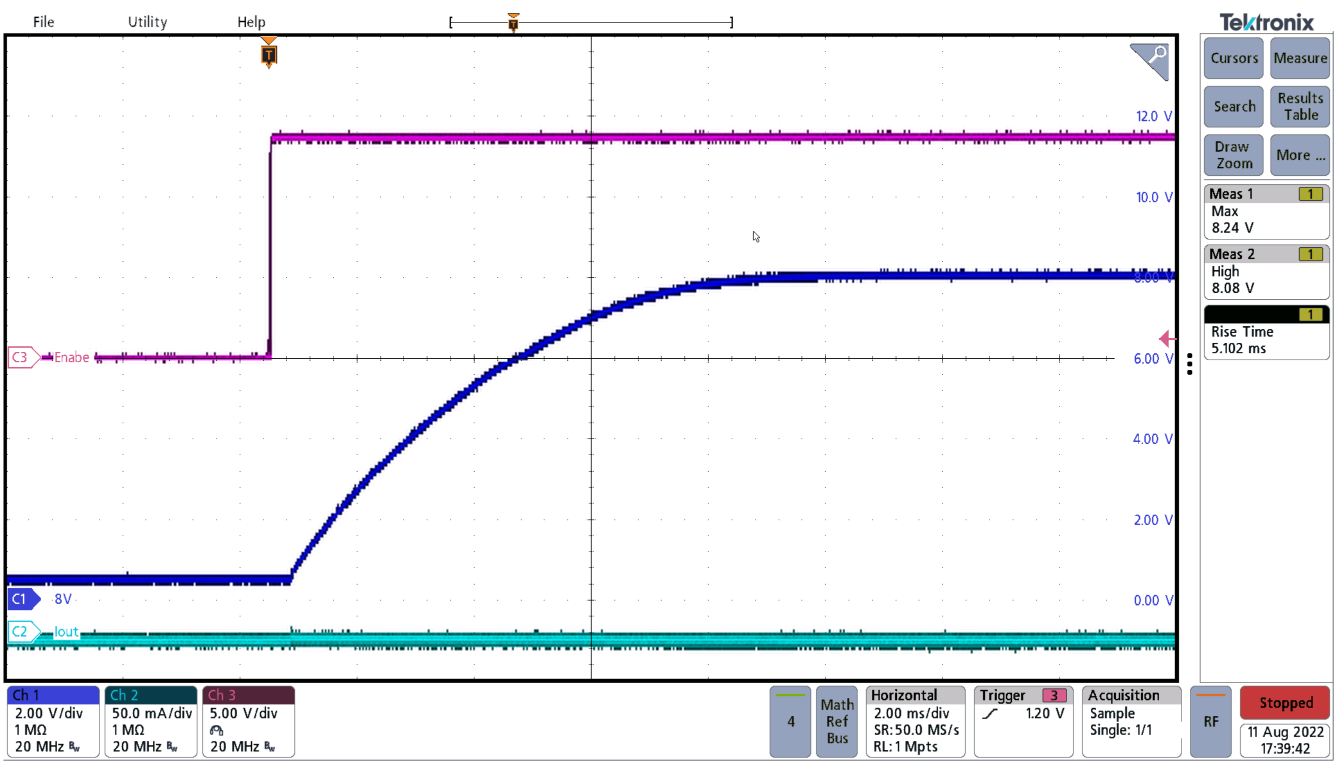
Enable going high: Red trace is the enable signal, the dark blue trace is V_{OUT}, and the light blue trace is the load current. Smooth V_{OUT} rise in under 2.5 ms with no overshoot seen.

Figure 3-6. Start-Up 3.3-V No-Load Off 14 V_{IN} From 3.3 V



Enable going high: Enable going high: the red trace is the enable signal, the dark blue trace is V_{OUT}, and the light blue trace is the load current. Smooth 5 V_{OUT} rise in under 3 ms with no overshoot seen.

Figure 3-7. Start-Up 5-V No-Load off 14 V_{IN} From 5 V



Enable going high: Enable going high: the red trace is the enable signal, the dark blue trace is V_{OUT}, and the light blue trace is the load current. Smooth 8 V_{OUT} rise in under 10 ms with no overshoot seen.

Figure 3-8. Start-Up 8-V No-Load off 14 V_{IN} From 8 V