Test Report: PMP22951

54-V, 3-kW, Phase-Shifted Full Bridge With Active Clamp Reference Design

Description

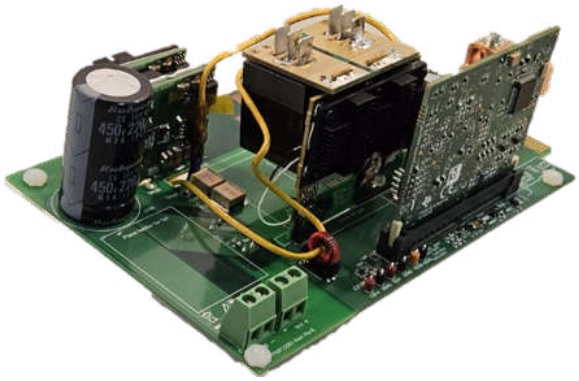
This reference design is an all-GaN based, 3-kW, phase-shifted full-bridge converter. This design employs an active clamp on the secondary side to minimize the voltage stress on the synchronous rectifier MOSFETs enabling the use of lower-voltage-rating MOSFETs that possess better figure-of-merit (FoM). The design uses 30-mΩ TI GaN on the primary side and 100 V, 1.8-mΩ GaN for the synchronous rectifiers. PSFB control is realized using TMS320F280049C real-time MCU. The phase-shifted full-bridge (PSFB) converter operates at 140-kHz switching frequency and achieves a peak efficiency of 97.45% with 385-V input.

Features

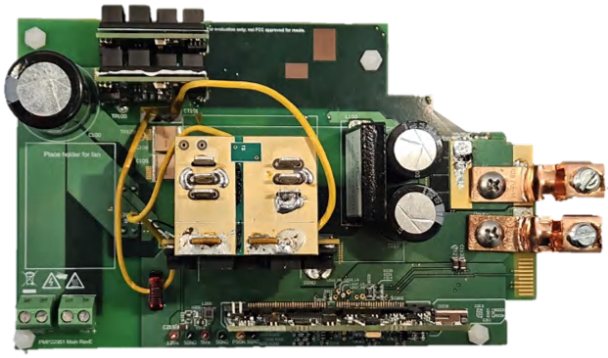
- Peak efficiency of 97.45% at 385-V input
- Active clamp for minimizing voltage stress on synchronous rectifiers enabling the use of better FoM devices
- All-GaN design

Application

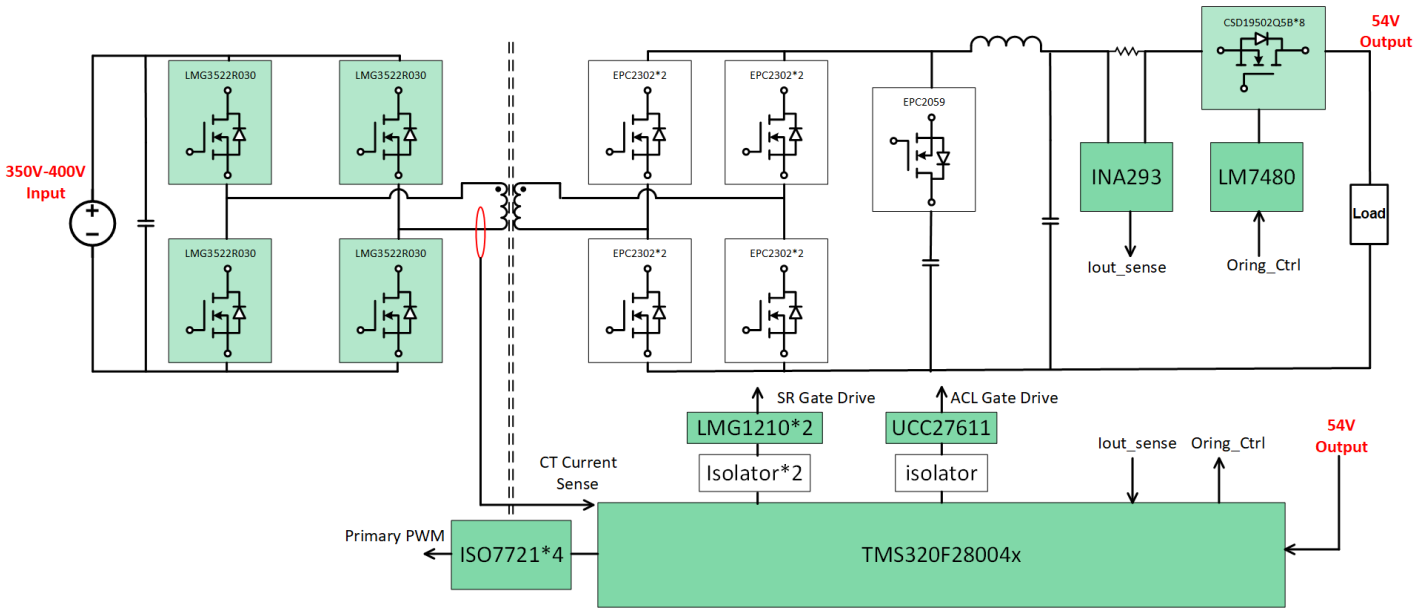
- Rack and server PSU with 48-V output
- Merchant telecom rectifiers



Board Isometric View



Board Top View



PSFB With Active Clamp Block Diagram

1 Performance Specification

Table 1-1. PMP22951 Specifications

Parameter	Specifications	Units
Input Voltage	350 – 400	VDC
Output Voltage	54	VDC
Output Current (max)	56	A
Output Power	3	kW
Switching Frequency	140	kHz

2 Testing and Results

2.1 Efficiency Graph

The parameters of Figure 2-1 are taken under the following conditions:

- Switching frequency: 140 kHz
- Primary side GaN turn-on slew rate: 20 V/ns
- Output voltage: 54 V
- Dead-time range: 640 ns to 80 ns, auto-adjusted in code based on operating point
- Auxiliary bias not included
- Output current shunt resistors and ORing FETs are shorted
- Input voltage, input current, and output voltage are measured using Fluke 83-V digital multimeters
- Output current measured using a 1.997713-mΩ calibrated shunt resistor + Agilent 34401A 6-digit digital multimeter
- PFB0412EN-E fan used to provide forced air across PSFB power stage

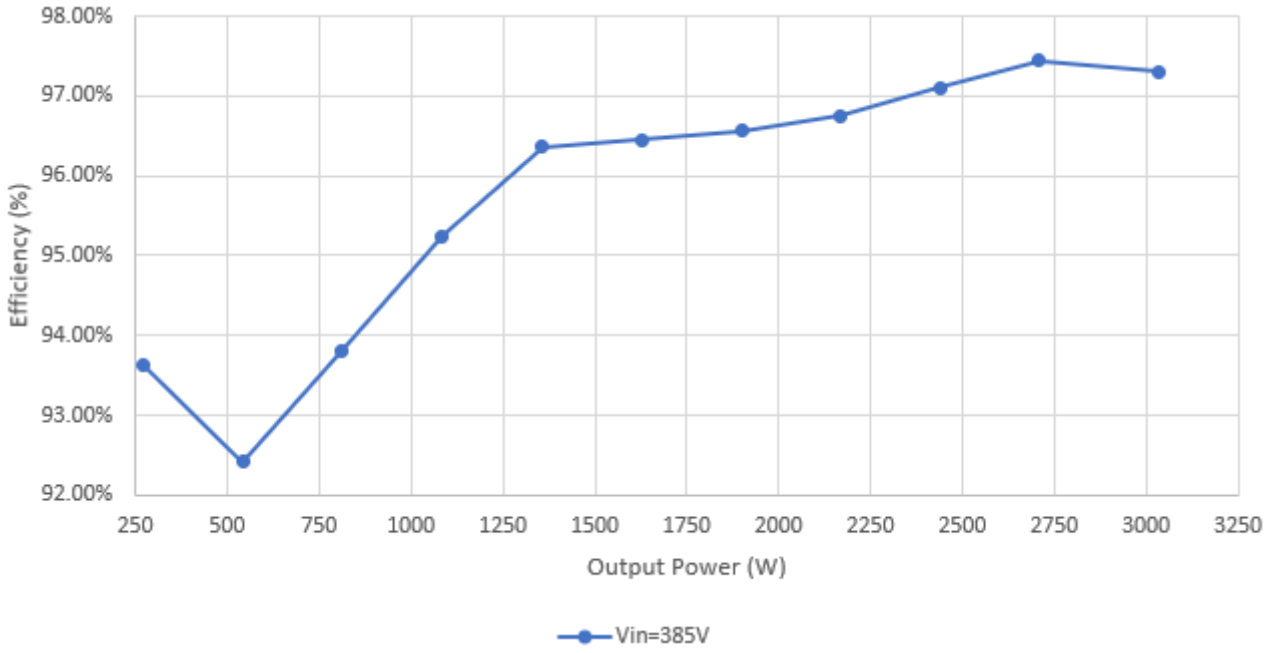


Figure 2-1. Efficiency Graph

2.2 Efficiency Data

Table 2-1 summarizes the efficiency data at 385-V input.

Table 2-1. 385-VDC Input Efficiency

Input Voltage (V)	Input Current (A)	Input Power (W)	Output Voltage (V)	Output Current (A)	Output Power (W)	Efficiency (%)
385.0	0.753	289.905	54.30	4.998	271.403	93.62
384.8	1.526	587.205	54.31	9.992	542.689	92.42
384.7	2.249	865.190	54.14	14.991	811.593	93.81
384.6	2.963	1139.570	54.30	19.987	1085.313	95.24
384.5	3.661	1407.655	54.29	24.985	1356.439	96.36
384.4	4.389	1687.132	54.27	29.984	1627.247	96.45
384.3	5.115	1965.695	54.26	34.982	1898.096	96.56
384.2	5.836	2242.191	54.26	39.980	2169.299	96.75
384.1	6.537	2510.862	54.21	44.977	2438.227	97.11
384.0	7.240	2780.160	54.21	49.977	2709.261	97.45
383.9	8.120	3117.268	54.19	55.976	3033.340	97.31

2.3 Thermal Images

The parameters of Table 2-2 and Figure 2-2 are taken under the following conditions:

- Input: 385 VDC
- Output: 54-V, 56-A load
- Switching frequency: 140 kHz
- Primary GaN turn-on slew rate: 20 V/ns
- Dead-time: 80 ns at 3-kW load
- PFB0412EN-E fan used to provide forced air across PSFB power stage

Table 2-2 summarizes the peak temperature of the major components within the PSFB power stage

Table 2-2. Power Stage Component Temperatures

Component	Temperature (°C)
Primary GaN daughter cards	38.5
Transformer	65.2
SR daughter card	48.8
Output inductor	46.8

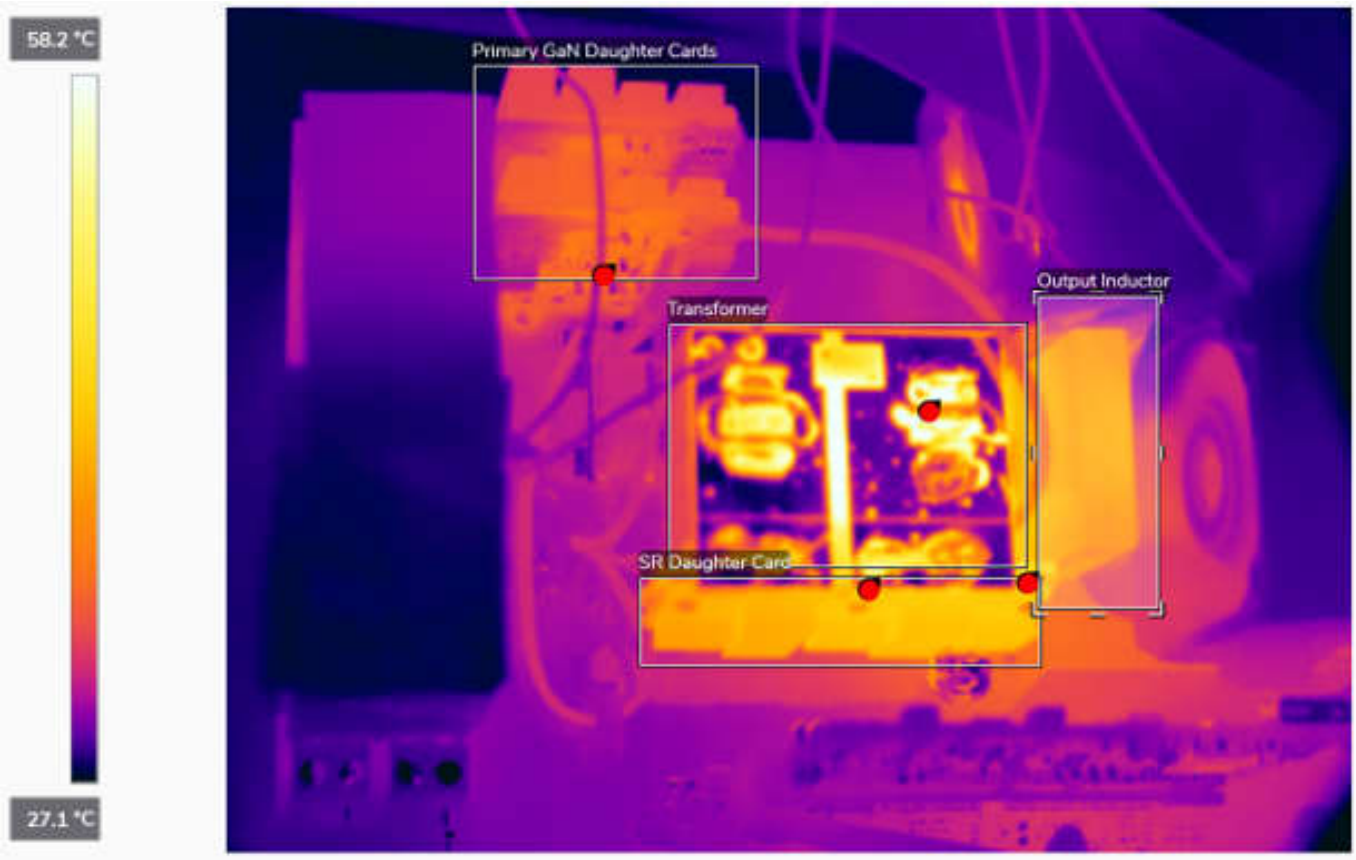


Figure 2-2. 3-kW Thermal Image

3 Waveforms

3.1 Start-Up

Figure 3-1 illustrates the start-up behavior of the PMP22951 with a 2-A load.

C1 = Secondary Winding Voltage, C2 = Output Voltage, C3 = Leg1 Low-Side PWM

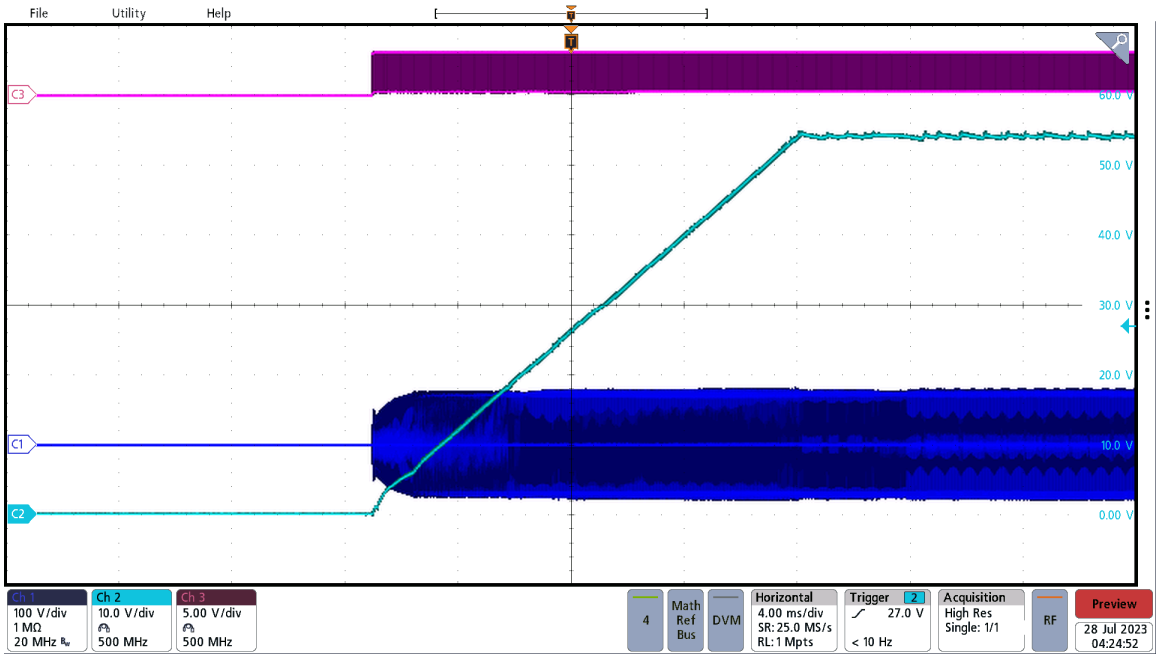


Figure 3-1. 385-V Input, 54-V Output Start-Up

3.2 Load Transients

The waveforms illustrated in Figure 3-2 and Figure 3-3 represent the transient response of PMP22951 for a 3-A to 31-A load step. The test is conducted according to M-CRPS version 1.00, release candidate 4, table 7-5. 1 mF is connected across the output terminals. The load current slew rate is 1 A/µs.

C1 = Load Current, C2 = V_{OUT}, AC coupled, C4 = Secondary Winding Voltage

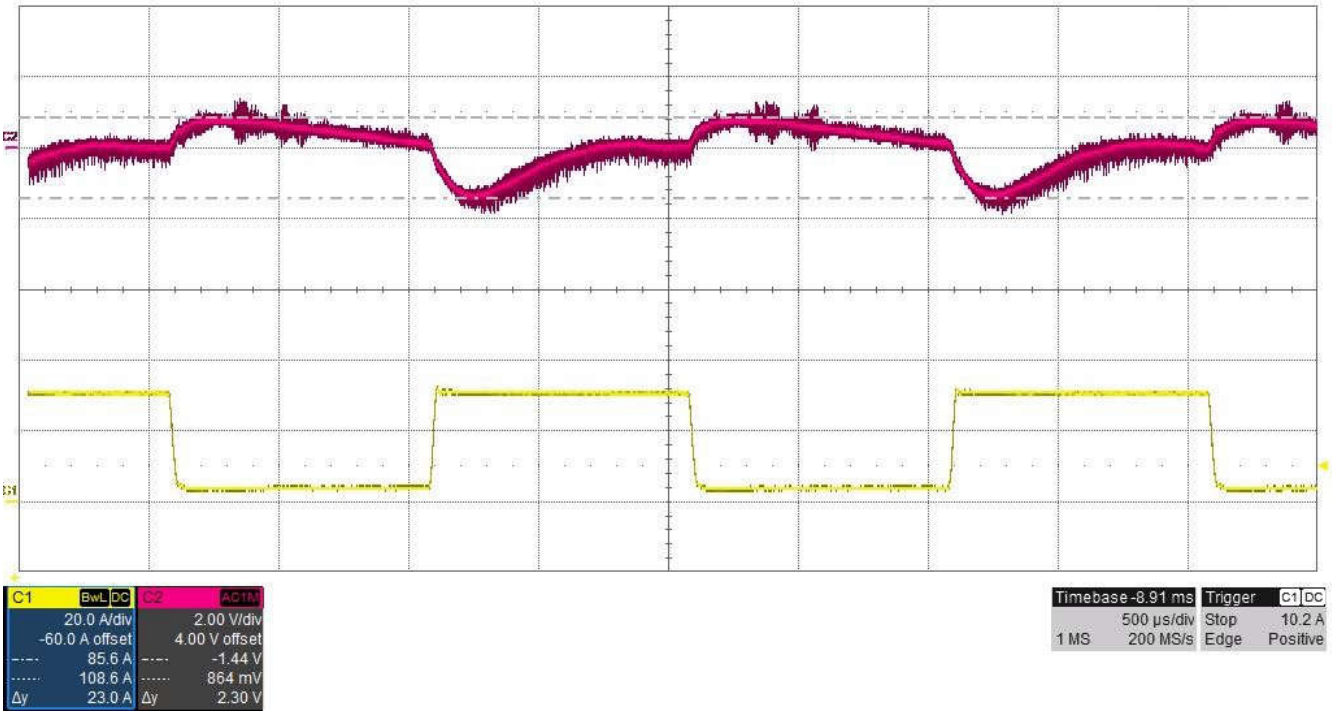


Figure 3-2. PMP22951 Transient Response for a 3-A to 31-A Load Step

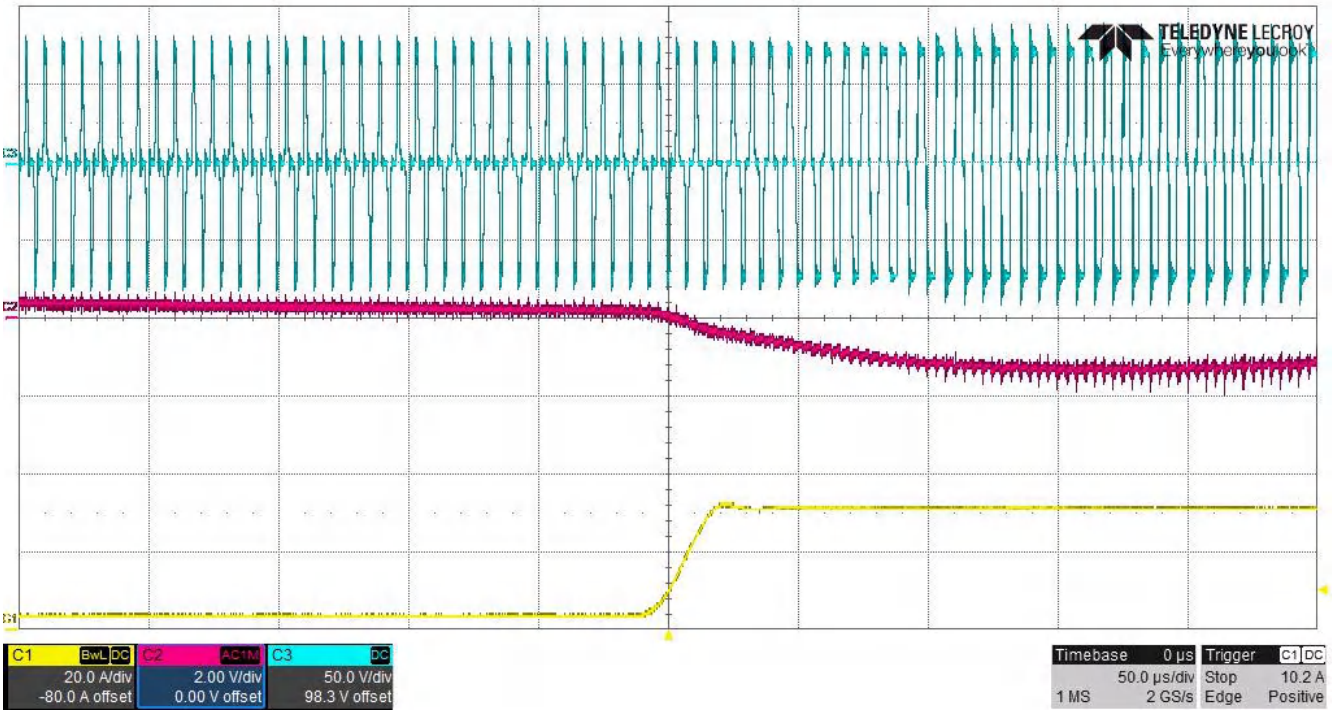


Figure 3-3. PMP22951 Transient Response for a 3-A to 31-A Load Step (Zoomed-In View)

3.3 Steady-State Waveforms

The following waveforms illustrate the steady-state waveforms of the PSFB converter with constant-current loads from 10 A to 56 A.

C1 = Secondary Winding Voltage, C2 = Leg1 Low-Side PWM, C4 = Transformer Primary Current

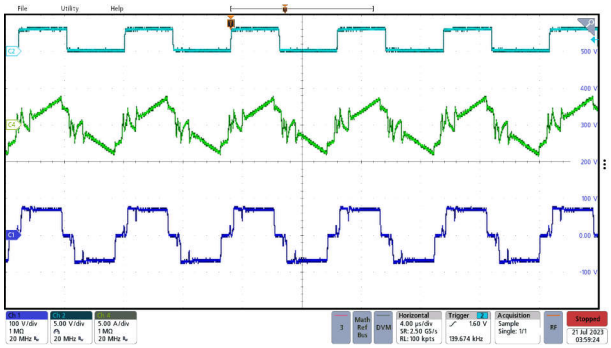


Figure 3-4. 10-A Load

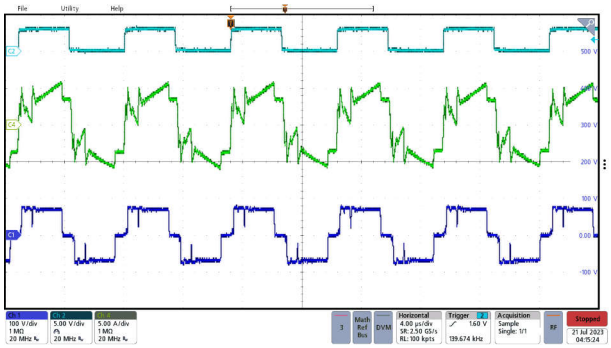


Figure 3-5. 20-A Load

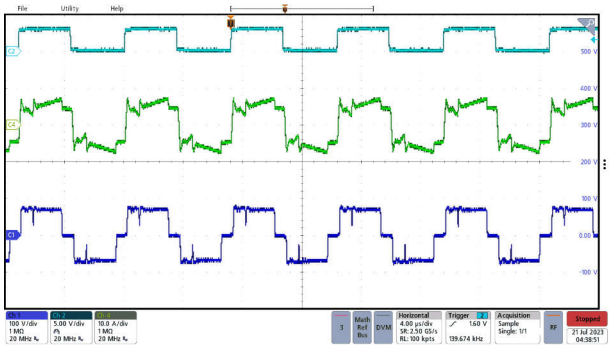


Figure 3-6. 30-A Load

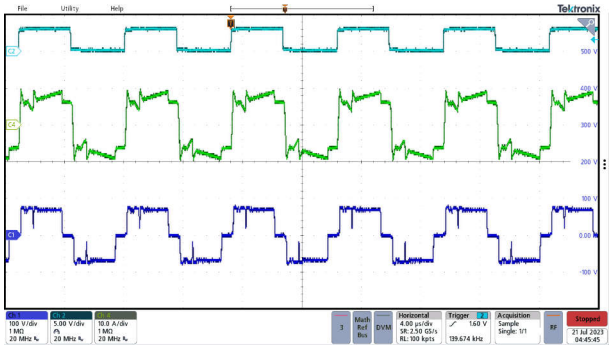


Figure 3-7. 40-A Load

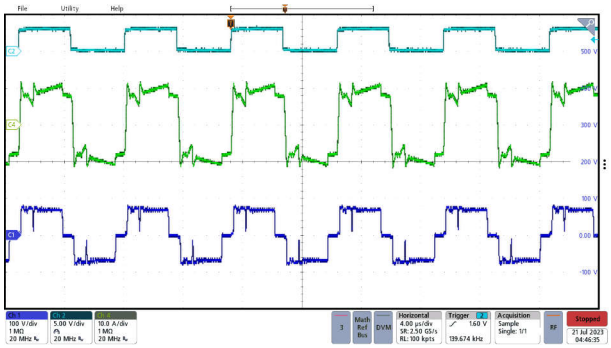


Figure 3-8. 50-A Load

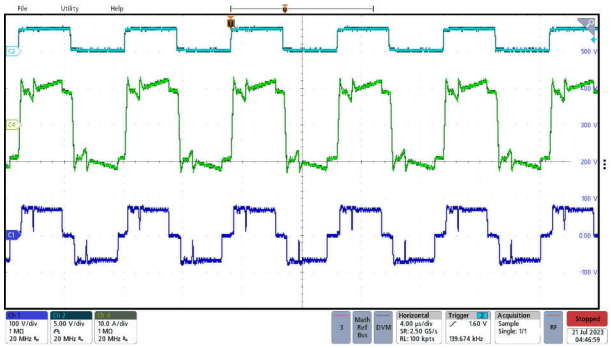


Figure 3-9. 56-A Load

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