EVLONE140W - 140 W USB PD 3.1 EPR reference design based on ST-ONEHP

Introduction

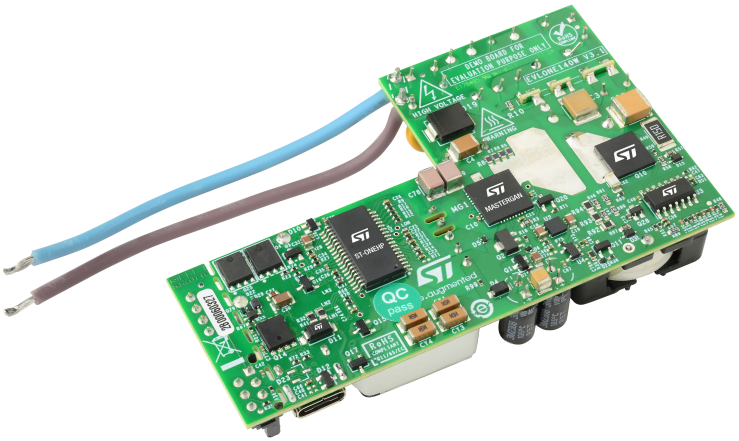
This document reports the functional, thermal, and efficiency measurement results for the EVLONE140W TMPFC + Active-Clamping Flyback(ACF) AC–DC converter reference design for the USB PD 3.1 adaptor. This reference design meets CoC Tier 2 and DoE Level 6 efficiency requirements with peak efficiency of 94.4%.

This reference design adopts an integrated GaN based solution and TMPFC + ACF control.

The main devices used in this reference design are:

- ST-ONEHP: ZVS non-complementary ACF controller with synchronous rectification and USB PD 3.1 EPR and AVS interface.
- MASTERGAN1: High power density 600 V half-bridge driver with two enhancement mode GaN HEMT
- L6563S: Transition mode (TM) PFC controller
- STL36N60M6: N-channel 600 V, 91 mΩ typ., 25 A MDmesh™ M6 power MOSFET in a PowerFLAT 8x8 HV package.

Figure 1. EVLONE140W board



1 Main characteristics

The main features of the EVLONE140W board are listed below:

- Input voltage: AC (90 V_{AC} ÷ 250 V_{AC}) with (47 ÷ 63 Hz) frequency range
- Maximum output power: 140 W
- Five fixed PDOs: 5 V@3.75 A, 9 V@3.75 A, 15 V@3.75 A, 20 V@5 A, 28 V@5 A
- One APDO (AVS): (15 V ÷ 28 V) @5 A
- Dimensions: 95 mm (L) * 56 mm (W) * 24 mm (H)
- Efficiency: Meets CoC Tier 2 and DoE Level 6 efficiency requirements, full load efficiency 93.4% at 115 V_{AC}, and 94.1% at 230 V_{AC}
- Transition mode (TM) PFC and Active-Clamping Flyback controller
- Integrated GaN IC MASTERGAN1 leads to compact, simplified PCB layout and bill of material reduction
- Protections: brown-out, overcurrent protection, overtemperature protection, overvoltage protection, undervoltage protection, x-cap discharge.

2 Schematic diagram

Figure 2. **EVLONE140W ACF section schematic (main board)**

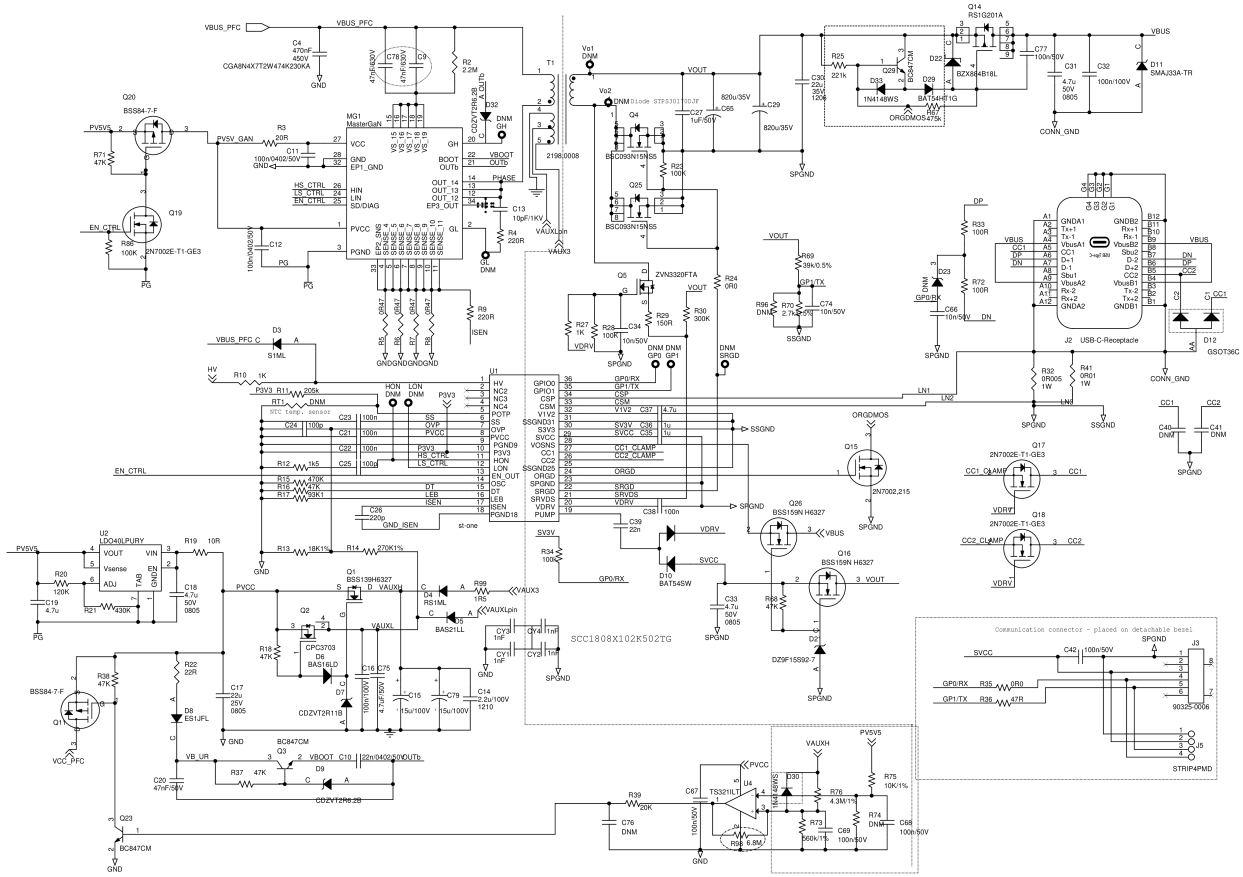


Figure 3. **EVLONE140W input and PFC sections schematic (main board)**

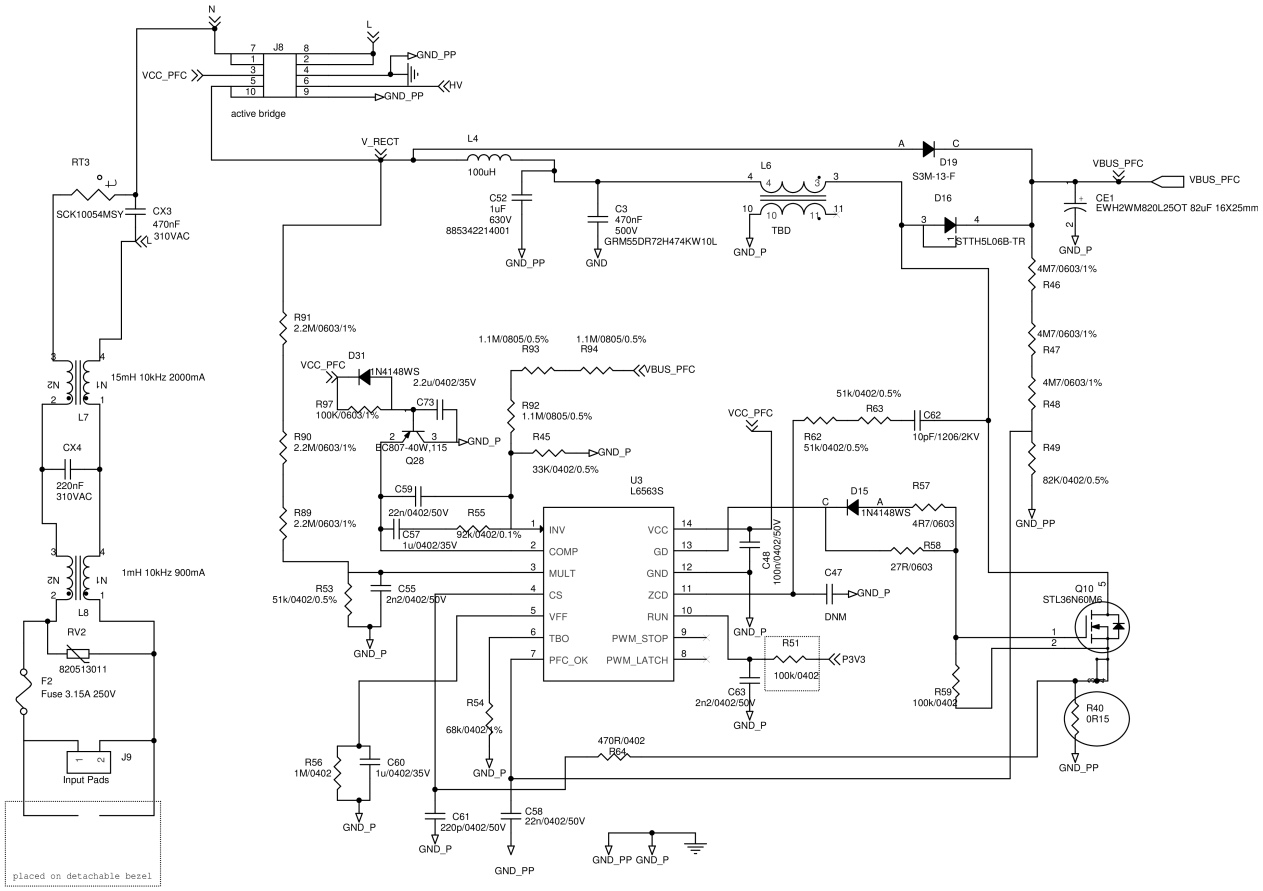
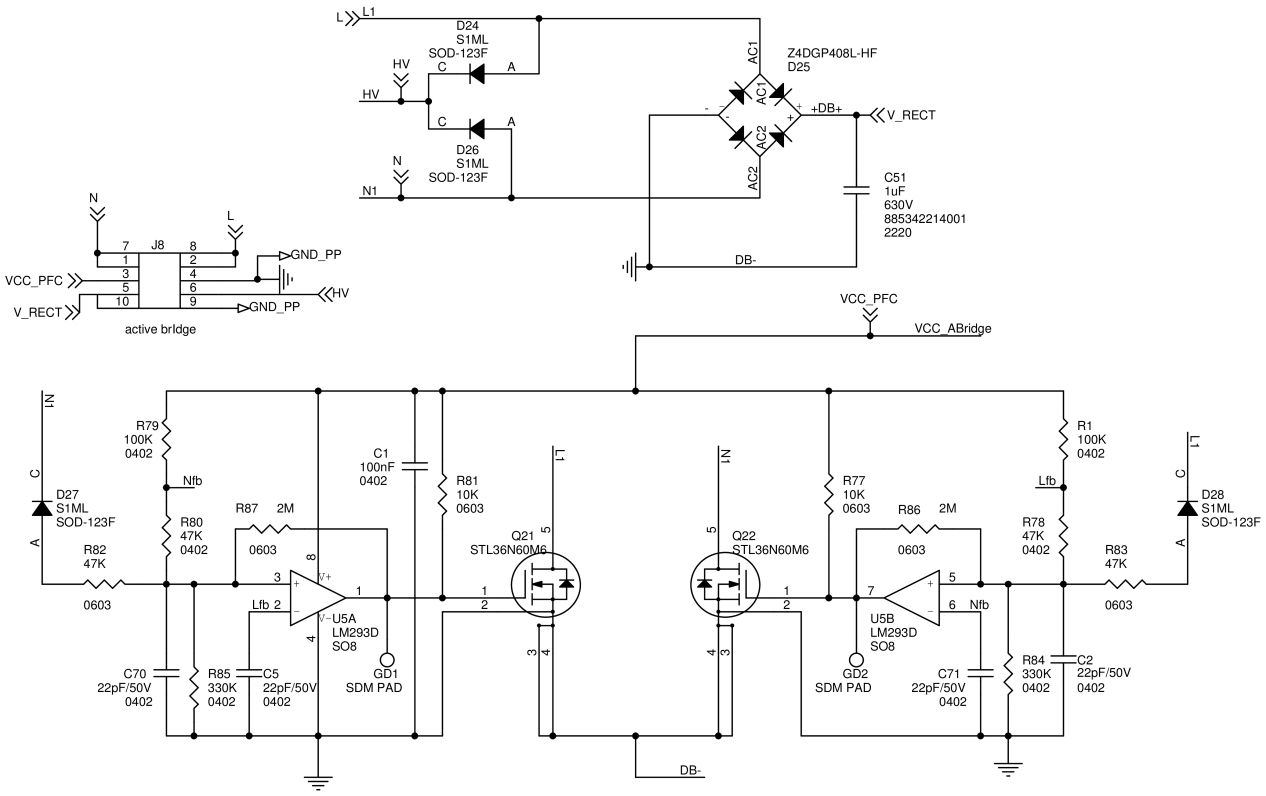


Figure 4. **EVLONE140W active bridge section schematic (daughterboard)**



3 Specifications

Table 1. EVLONE140W electrical specifications

Symbol	Parameter	Test conditions	Min.	Nom.	Max.	Unit
Input parameters						
V_{IN}	Input line voltage		90	115 / 230	250	Vrms
f_{LINE}	Input line frequency		47	50 / 60	63	Hz
P_{STBY}	No load input power	VIN = 115 V_{RMS} & 230 V_{RMS}			104	mW
Output parameters						
Vout	Output voltage	VIN = 90 V_{RMS}~250 V_{RMS} IOUT = 0A~3A/5A		5, 9, 15, 20, 28		V
V_{ripple}	Output voltage ripple	Peak-to-peak value with 20MHz bandwidth			161	mV
I_{out}	Output current		0	3.75 @5V,9V,15V 5 @20V,28V		A
P_{out}	Continuous output power		0		140	W
η_{ave}	4-point average efficiency 25%, 50%,75% and 100% load	At 115 VAC / 28V output and measured after load switch		92.43		%
η_{ave}	4-point average efficiency 25%, 50%,75% and 100% load	At 230 VAC / 28V output and measured after load switch		92.58		%

4 Startup

The startup phase of the device is shown in the following figures at 90 V_{AC}/50 Hz, 115 V_{AC}/60 Hz, 230 V_{AC}/50 Hz, and 250 V_{AC}/60 Hz under no load and full load conditions. The output voltage is 5 V.

The output voltage starts increasing after a short delay from the presence of the input voltage (< 200 ms). There are not considerable oscillations in the output waveforms.

From Figure 5 to Figure 8:

- Light green = I_{OUT} - 1 A/div
- Blue = V_{OUT} - 2 V/div
- Red = P_{VCC} - 10 V/div
- Orange = HV -100 V/div

Figure 5. Startup at 90 V_{AC}, V_{OUT} 5 V, no load

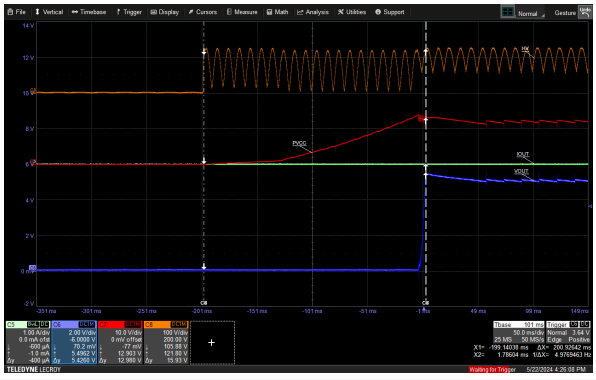


Figure 6. Startup at 90 V_{AC}, V_{OUT} 5 V, load 3 A

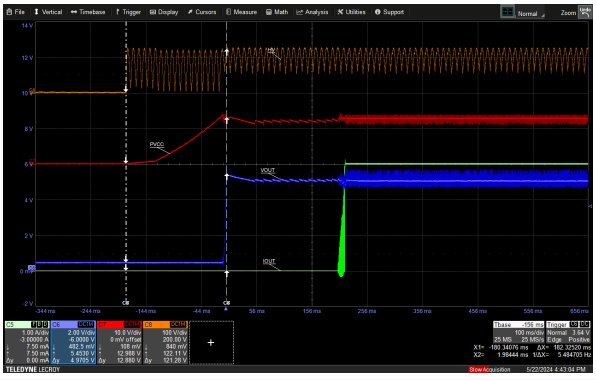


Figure 7. Startup at 115 V_{AC}, V_{OUT} 5 V, no load

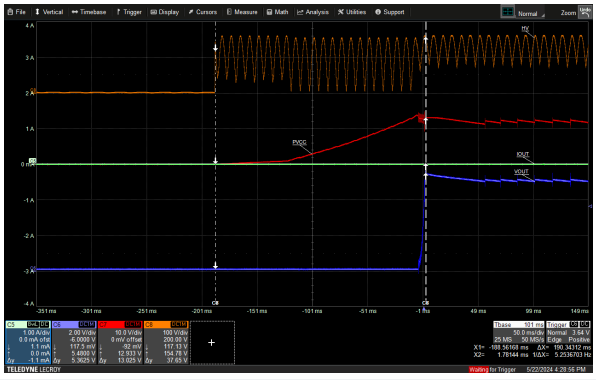
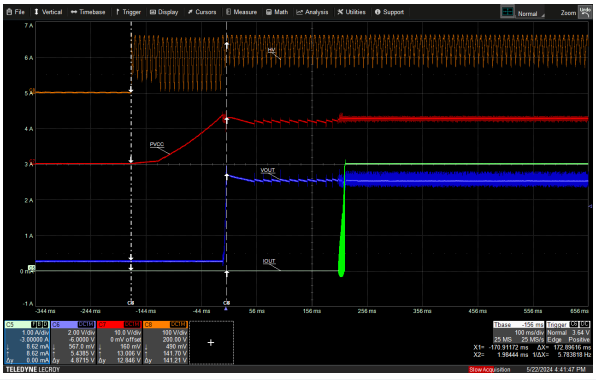


Figure 8. Startup at 115 V_{AC}, V_{OUT} 5 V, load 3 A



From Figure 9 to Figure 12:

- Light green = I_{OUT} - 1 A/div
- Blue = V_{OUT} - 2 V/div
- Red = P_{VCC} - 10 V/div
- Orange = HV - 200 V/div

Figure 9. Startup at 230 V_{AC}, V_{OUT} 5 V, no load

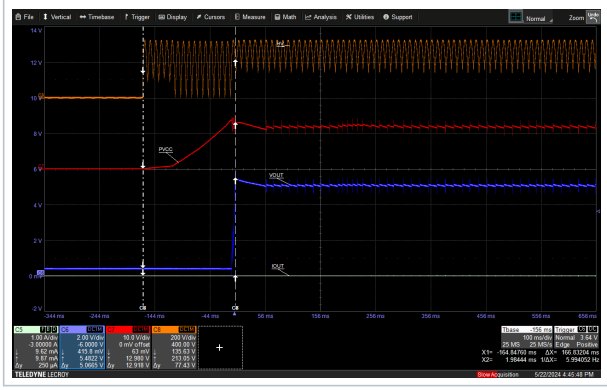


Figure 10. Startup at 230 V_{AC}, V_{OUT} 5 V, load 3 A

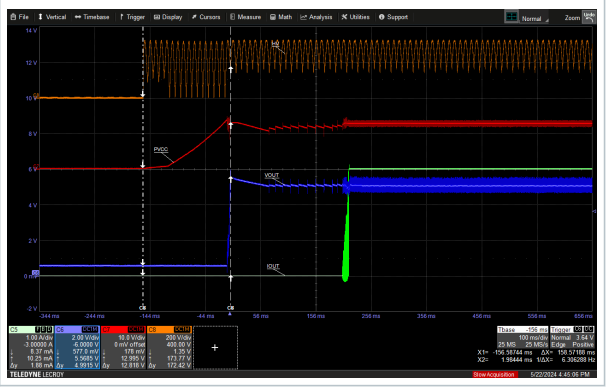


Figure 11. Startup at 250 V_{AC}, V_{OUT} 5 V, no load

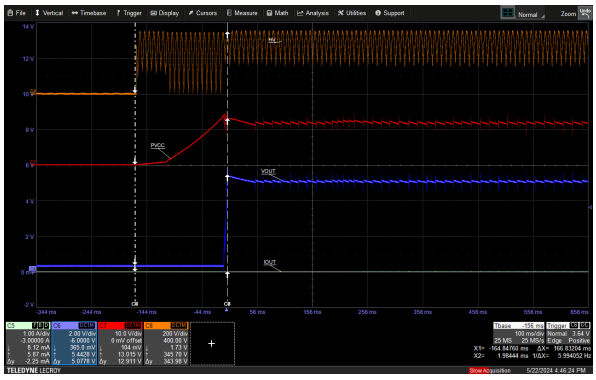
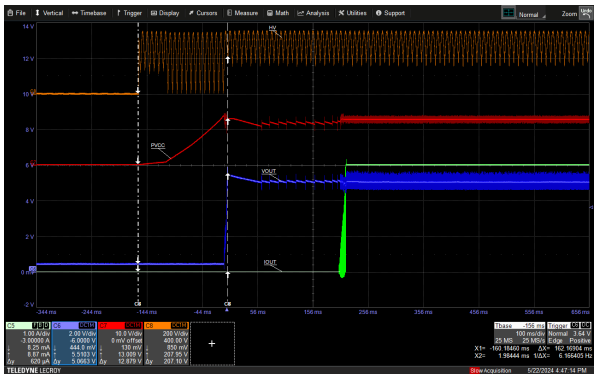


Figure 12. Startup at 250 V_{AC}, V_{OUT} 5 V, load 3 A



5 Output voltage regulation for dynamic load variation

The following figures show the load transient response waveforms of the active clamp flyback converter when subjected to repetitive dynamic load transitions from zero to full load at 115 V_{AC}/60 Hz and 230 V_{AC}/50 Hz. The transition period is 100 ms (except for 28 V output, for which it is 2 sec) with a 50% duty cycle and a slew rate of 3.2 mA/µs.

There are no abnormal oscillations in the output voltage and the overshoot and undershoot are acceptable.

From Figure 13 to Figure 26:

- Light blue = V_{BUS} 500 mV/div
- Light green = I_{OUT} 1 A/div

Figure 13. Dynamic load from 0% to 25% of 3.75 A, out 5 V, V_{IN}=115 V_{AC}

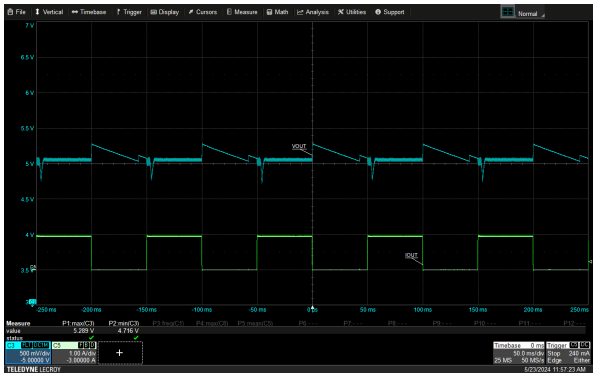


Figure 14. Dynamic load from 0% to 25% of 3.75 A, out 5 V, V_{IN}=230 V_{AC}

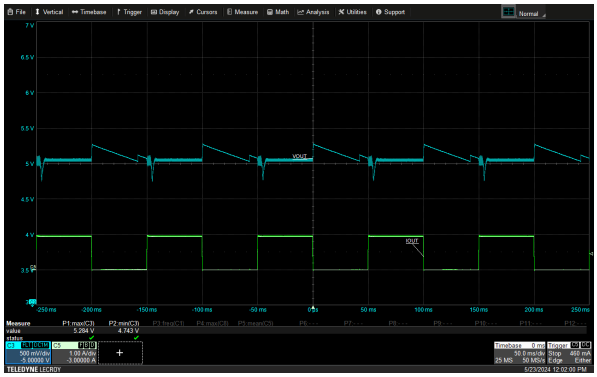


Figure 15. Dynamic load from 25% to 50% of 3.75 A, out 5 V, V_{IN}=115 V_{AC}

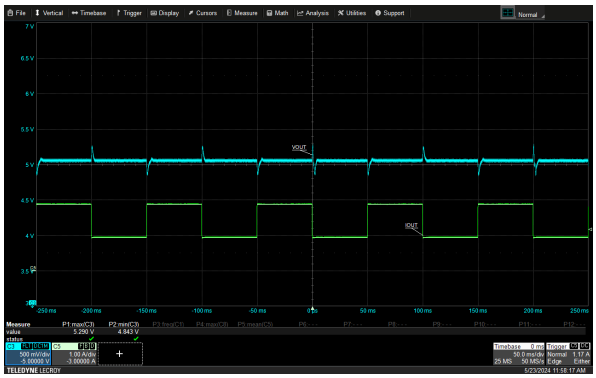


Figure 16. Dynamic load from 25% to 50% of 3.75 A, out 5 V, V_{IN}=230 V_{AC}

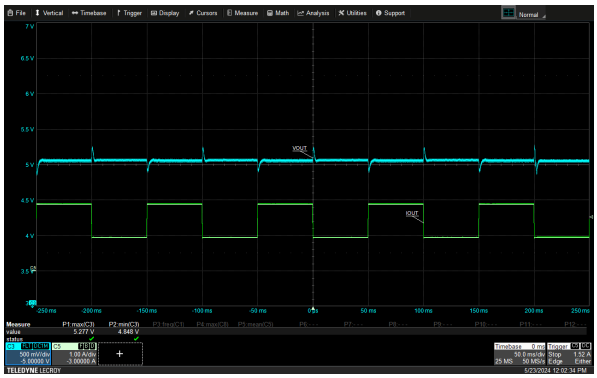


Figure 17. Dynamic load from 50% to 75% of 3.75 A, out 5 V, V_{IN}=115 V_{AC}

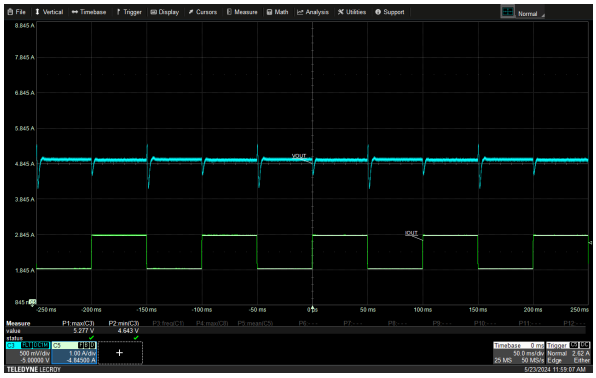


Figure 18. Dynamic load from 50% to 75% of 3.75 A, out 5 V, V_{IN}=230 V_{AC}

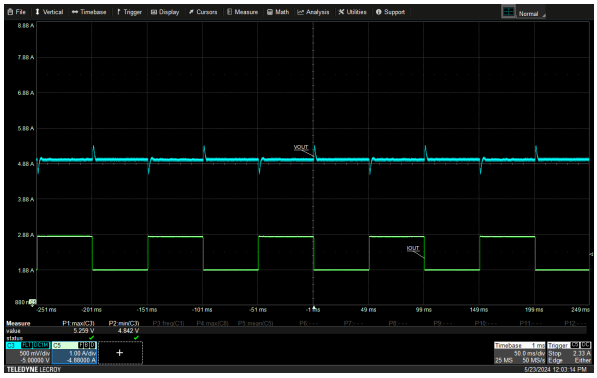


Figure 19. Dynamic load from 75% to 100% of 3.75 A, out 5 V, V_{IN}=115 V_{AC}

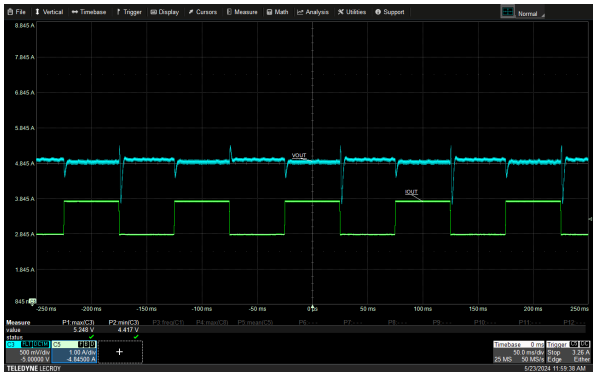


Figure 20. Dynamic load from 75% to 100% of 3.75 A, out 5 V, V_{IN}=230 V_{AC}

Figure 21. Dynamic load from 0 A to 3.75 A, out 5 V, V_{IN}=115 V_{AC}

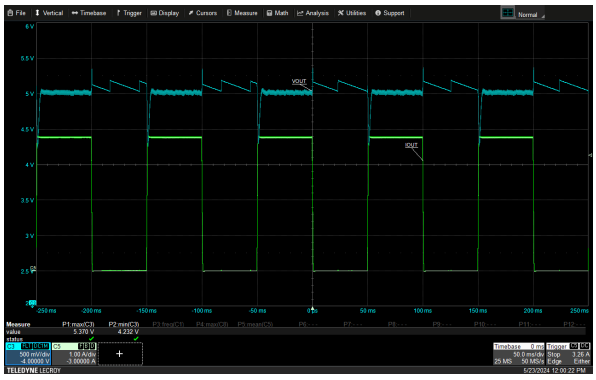


Figure 22. Dynamic load from 0 A to 3.75 A, out 5 V, V_{IN}=230 V_{AC}

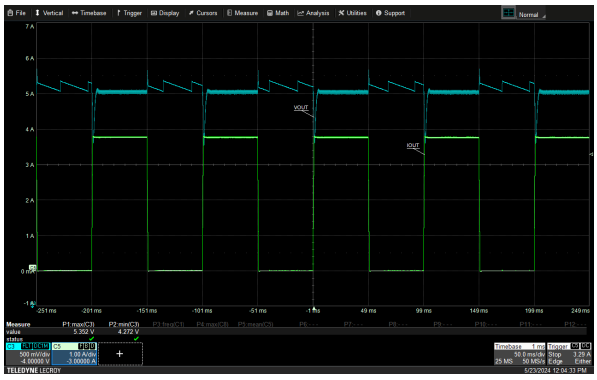


Figure 23. Dynamic load from 0 A to 3.75 A, out 9 V, V_{IN}=115 V_{AC}

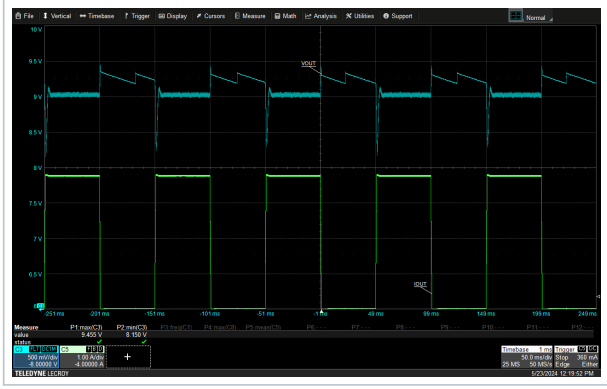


Figure 24. Dynamic load from 0 A to 3.75 A, out 9 V, V_{IN}=230 V_{AC}

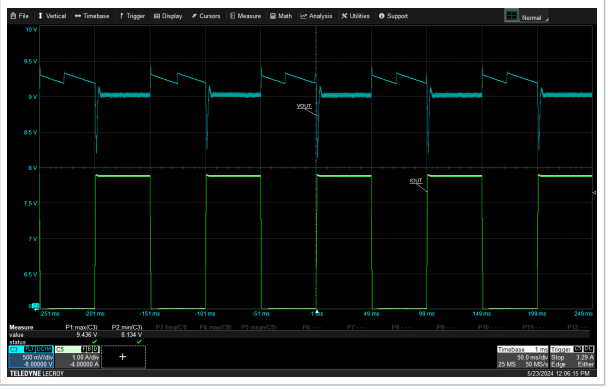


Figure 25. Dynamic load from 0 A to 3.75 A, out 15 V, V_{IN}=115 V_{AC}

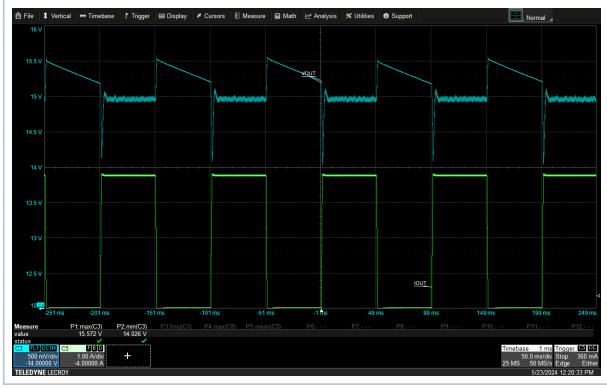
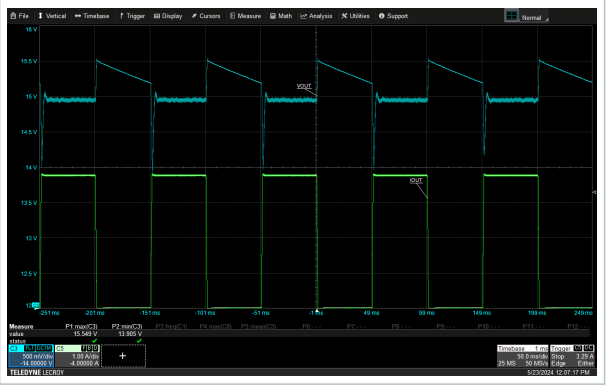


Figure 26. Dynamic load from 0 A to 3.75 A, out 15 V, V_{IN}=230 V_{AC}



From Figure 27 to Figure 30:

- Light blue = V_{BUS} 500 mV/div
- Light green = I_{OUT} 2 A/div

Figure 27. Dynamic load from 0 A to 5 A, out 20 V, V_{IN}=115 V_{AC}

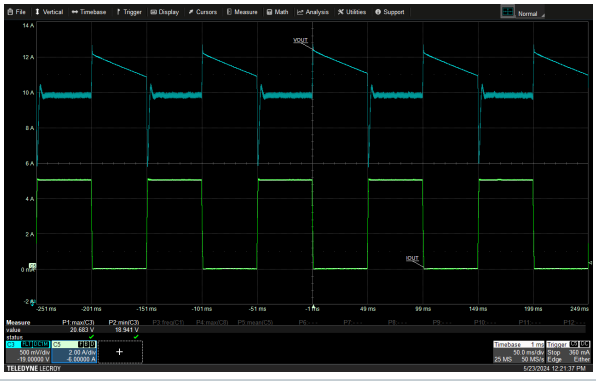


Figure 28. Dynamic load from 0 A to 5 A, out 20 V, V_{IN}=230 V_{AC}

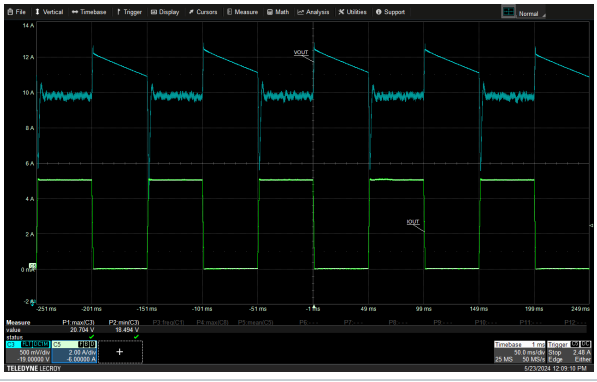


Figure 29. Dynamic load from 0 A to 5 A, out 28 V, V_{IN}=115 V_{AC}

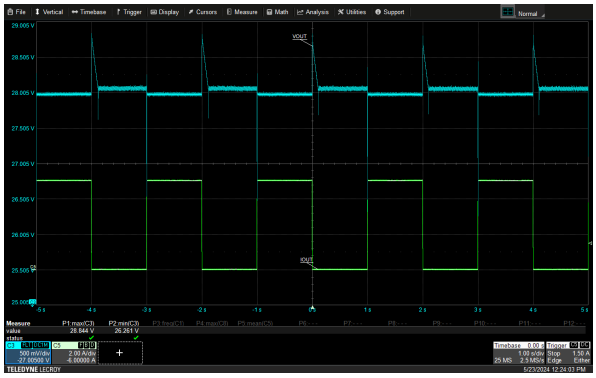
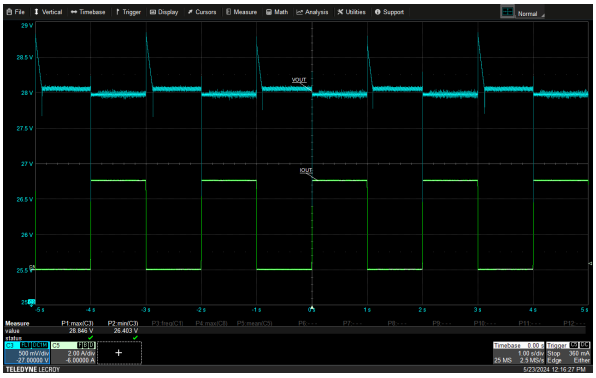


Figure 30. Dynamic load from 0 A to 5 A, out 28 V, V_{IN}=230 V_{AC}



6 Line transient

The following figures show the output voltage at line transient from 115 V_{AC}/60 Hz to 230 V_{AC}/60 Hz and vice versa.

In figures Figure 31 and Figure 32:

- Orange = HV pin 50 V/div
- Blue = V_{BUS} 2 V/div

Figure 31. Line transient from 115 V_{AC} to 230 V_{AC}

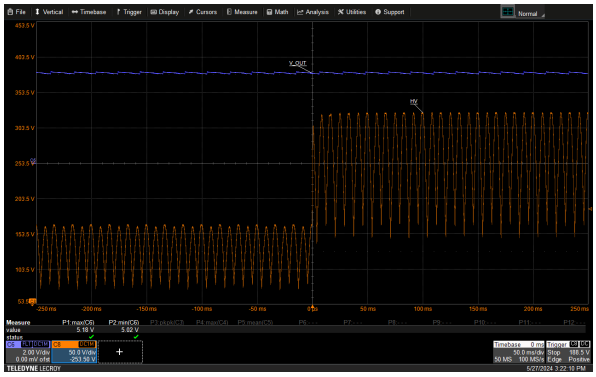
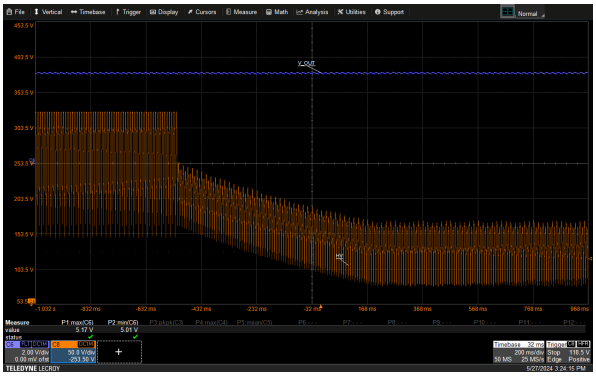


Figure 32. Line transient from 230 V_{AC} to 115 V_{AC}



7 Output voltage ripple

The output voltage ripple has been measured through an oscilloscope at different output voltages with two different loads (0 A and maximum available current). To set the different output voltages, a sink tool has been used. The different loads have been set using a DC active load.

Tests have been performed at two input voltages:

- 115 V_{AC}/60 Hz
- 230 V_{AC}/50 Hz

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From Figure 33 to Figure 52:

- Light blue = V_{BUS} 100 mV/div

Figure 33. Ripple at 115 V_{AC}, out 5 V, 0 A load

- Ripple = 130.70 mV_{pp}

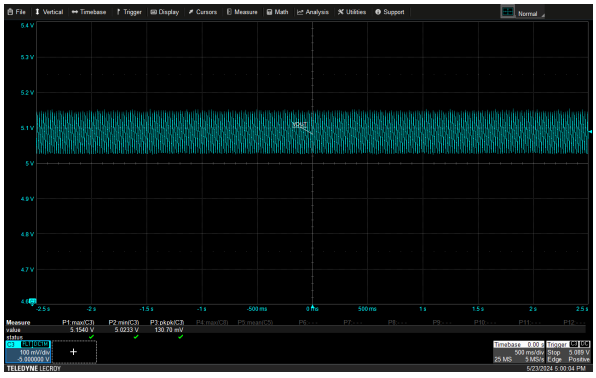


Figure 34. Ripple at 230 V_{AC}, out 5 V, 0 A load

- Ripple = 136.70 mV_{pp}

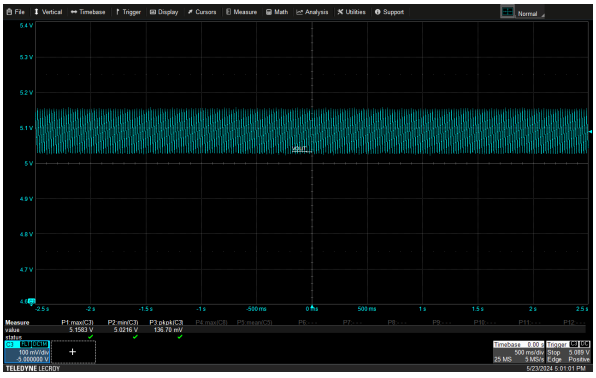


Figure 35. Ripple at 115 V_{AC}, out 5 V, 3.75 A load

- Ripple = 57.51 mV_{pp}

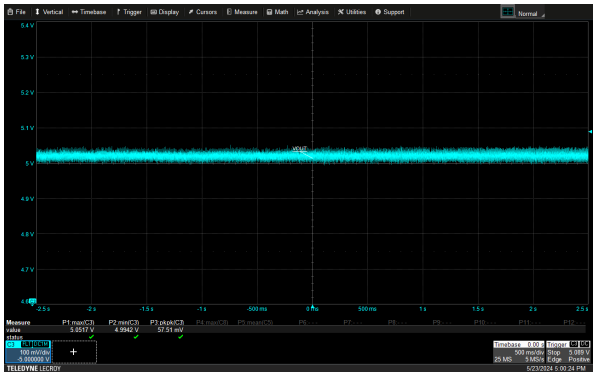


Figure 36. Ripple at 230 V_{AC}, out 5 V, 3.75 A load

- Ripple = 43.74 mV_{pp}

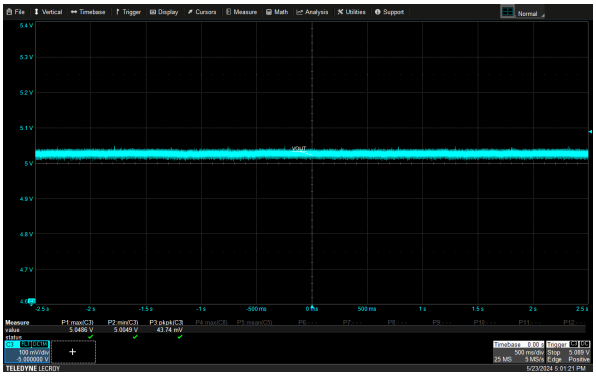


Figure 37. Ripple at 115 V_{AC}, out 9 V, 0 A load

- Ripple = 120.96 mV_{pp}

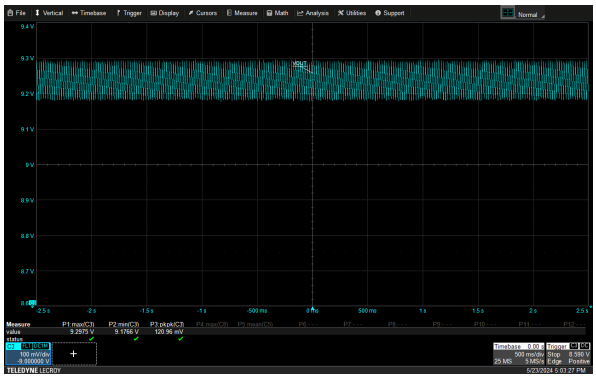


Figure 38. Ripple at 230 V_{AC}, out 9 V, 0 A load

- Ripple = 133.36 mV_{pp}

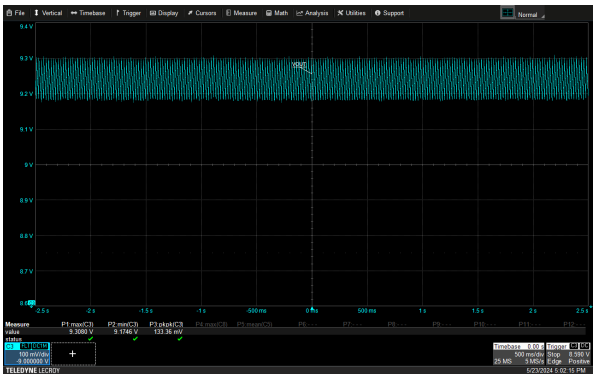


Figure 39. Ripple at 115 V_{AC}, out 9 V, 3.75 A load

- Ripple = 54.85 mV_{pp}

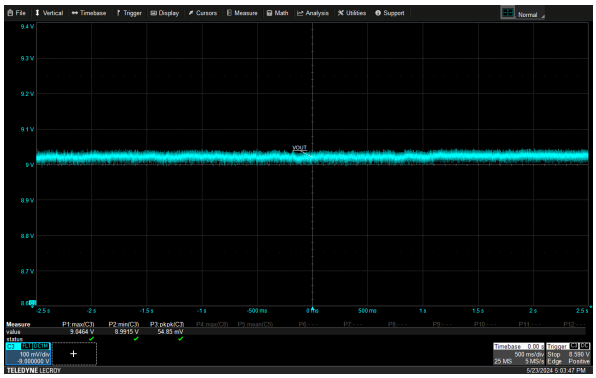


Figure 40. Ripple at 230 V_{AC}, out 9 V, 3.75 A load

- Ripple = 42.75 mV_{pp}

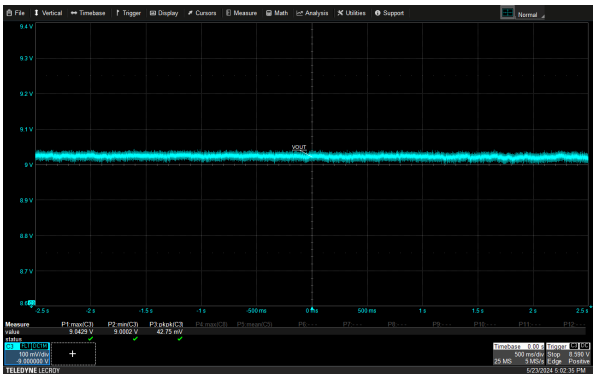


Figure 41. Ripple at 115 V_{AC}, out 15 V, 0 A load

- Ripple = 145.35 mV_{pp}

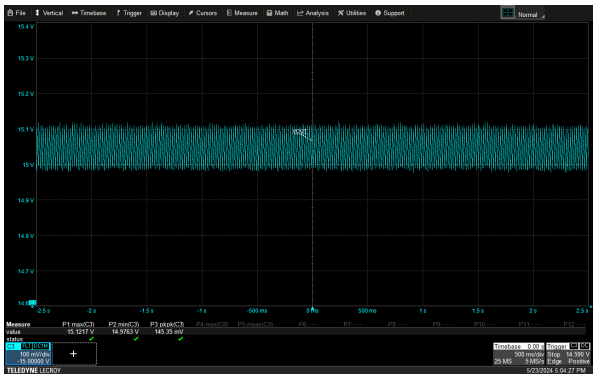


Figure 42. Ripple at 230 V_{AC}, out 15 V, 0 A load

- Ripple = 160.68 mV_{pp}

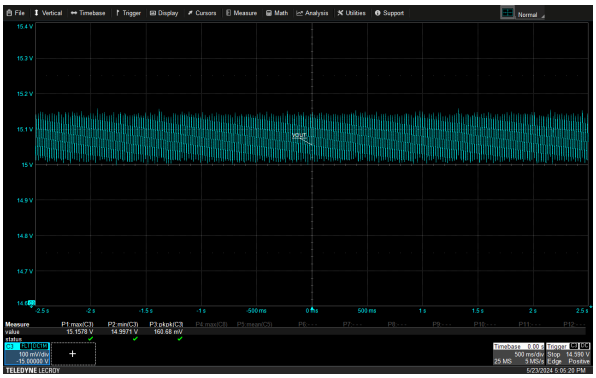


Figure 43. Ripple at 115 V_{AC}, out 15 V, 3.75 A load

- Ripple = 80.44 mV_{pp}

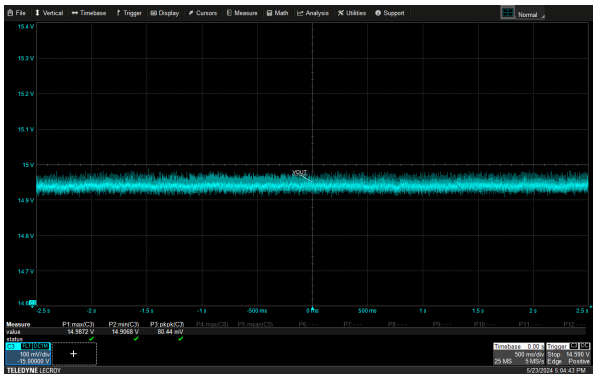


Figure 44. Ripple at 230 V_{AC}, out 15 V, 3.75 A load

- Ripple = 68.64 mV_{pp}

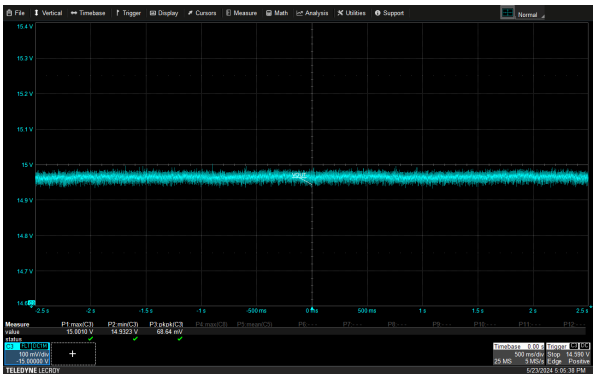


Figure 45. Ripple at 115 V_{AC}, out 20 V, 0 A load

- Ripple = 97.94 mV_{pp}

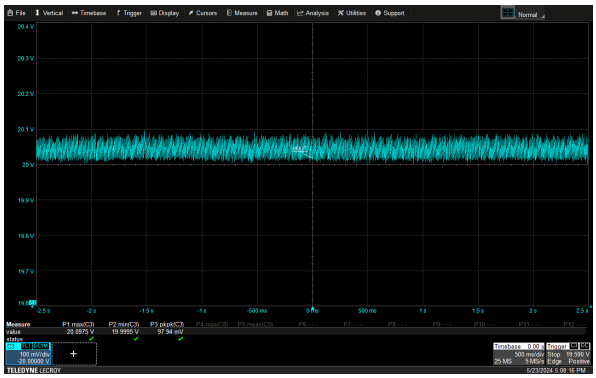


Figure 46. Ripple at 230 V_{AC}, out 20 V, 0 A load

- Ripple = 97.99 mV_{pp}

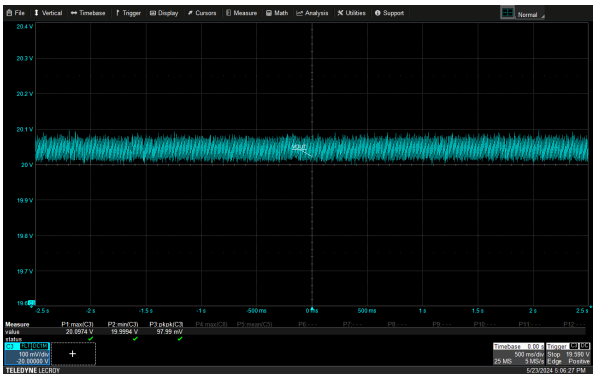


Figure 47. Ripple at 115 V_{AC}, out 20 V, 5 A load

- Ripple = 74.25 mV_{pp}

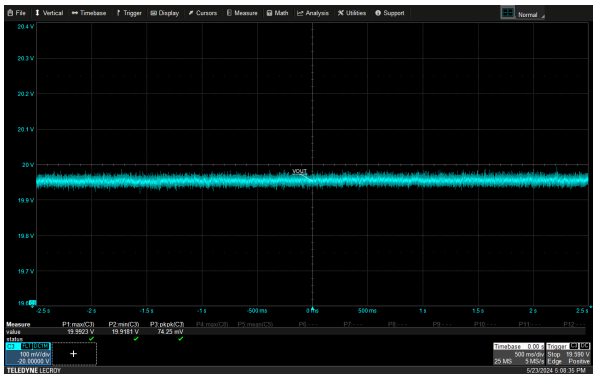


Figure 48. Ripple at 230 V_{AC}, out 20 V, 5 A load

- Ripple = 131.35 mV_{pp}

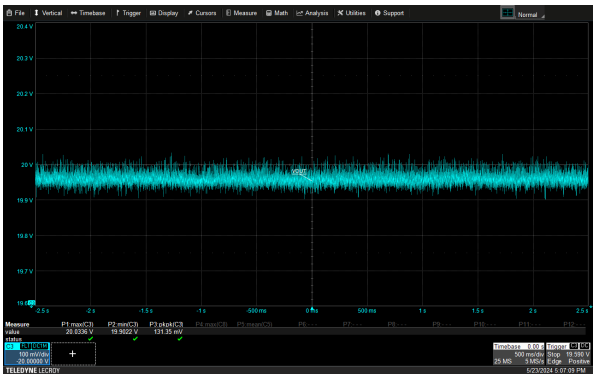


Figure 49. Ripple at 115 V_{AC}, out 28 V, 0 A load

- Ripple = 95.49 mV_{pp}

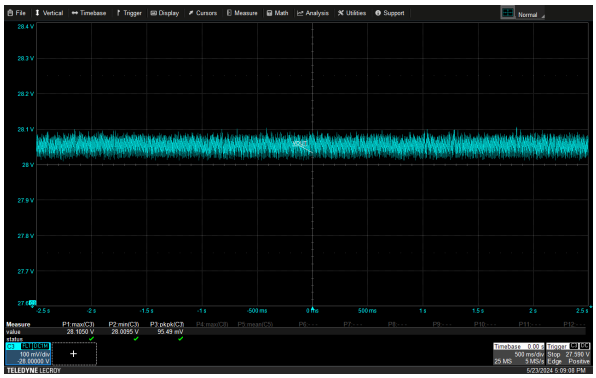


Figure 50. Ripple at 230 V_{AC}, out 28 V, 0 A load

- Ripple = 106.46 mV_{pp}

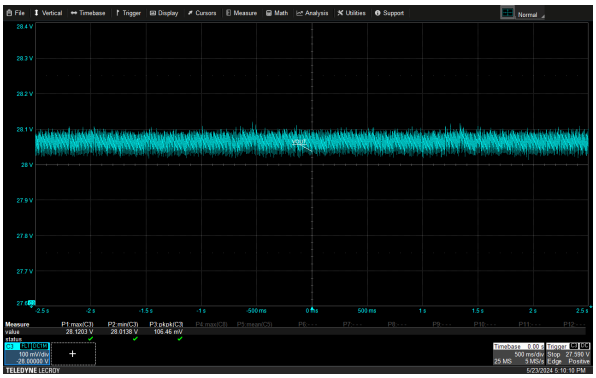


Figure 51. Ripple at 115 V_{AC}, out 28 V, 5 A load

- Ripple = 77.20 mV_{pp}

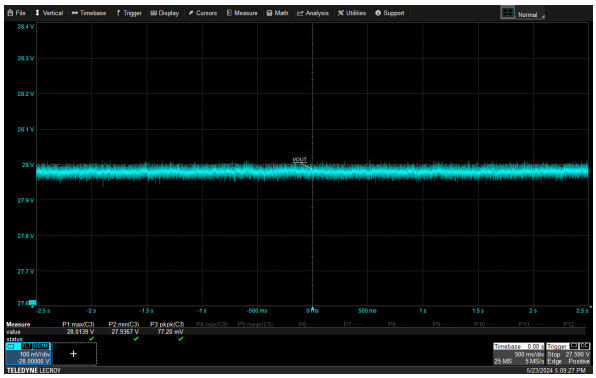
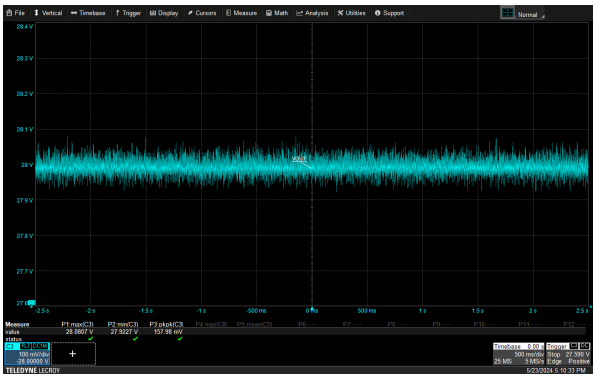


Figure 52. Ripple at 230 V_{AC}, out 28 V, 5 A load

- Ripple = 157.98 mV_{pp}



8 Voltage transitions across all profiles

The following images show all the output voltage transitions acquired through an oscilloscope and using PDO profiles.

All the transitions respect USB PD requirements (transitions time <275 ms in SPR case and <700 ms in EPR case, maximum voltage in addition to the new voltage value during the transition time max. ±500 mV).

All the tests have been performed at two different input voltages:

- 115 V_{AC}/60 Hz
- 230 V_{AC}/50 Hz

From Figure 53 to Figure 60:

- Light blue = V_{BUS} 1 V/div

Figure 53. Voltage transition from 5 V to 9 V at 115 V_{AC} - no load

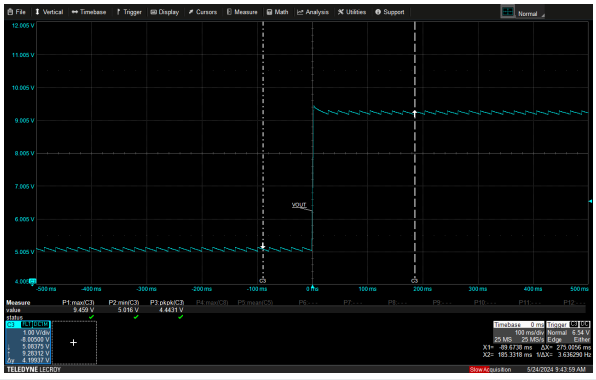


Figure 54. Voltage transition from 5 V to 9 V at 230 V_{AC} - no load

Figure 55. Voltage transition from 5 V to 9 V at 115 V_{AC} - 3.75 A load

Figure 56. Voltage transition from 5 V to 9 V at 230 V_{AC} - 3.75 A load

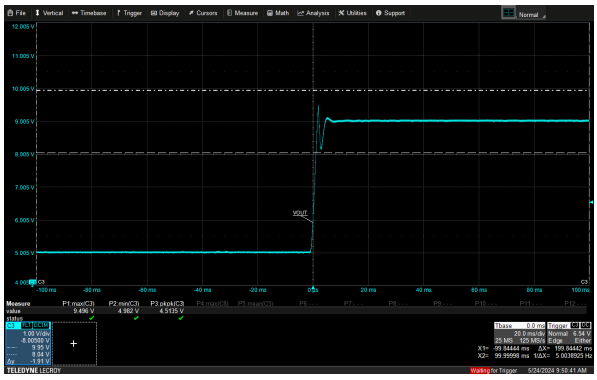


Figure 57. Voltage transition from 9 V to 5 V at 115 V_{AC} - no load

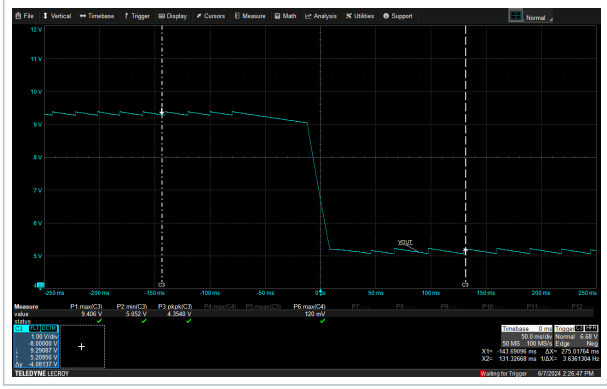


Figure 58. Voltage transition from 9 V to 5 V at 230 V_{AC} - no load

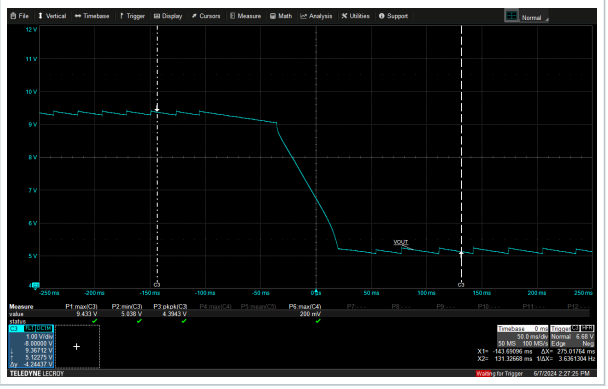


Figure 59. Voltage transition from 9 V to 5 V at 115 V_{AC} - 3.75 A load

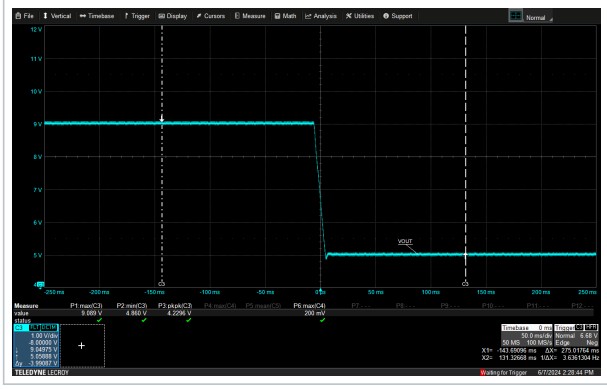


Figure 60. Voltage transition from 9 V to 5 V at 230 V_{AC} - 3.75 A load

From Figure 61 to Figure 68:

- Light blue = V_{BUS} 2 V/div

Figure 61. Voltage transition from 5 V to 15 V at 115 V_{AC} - no load

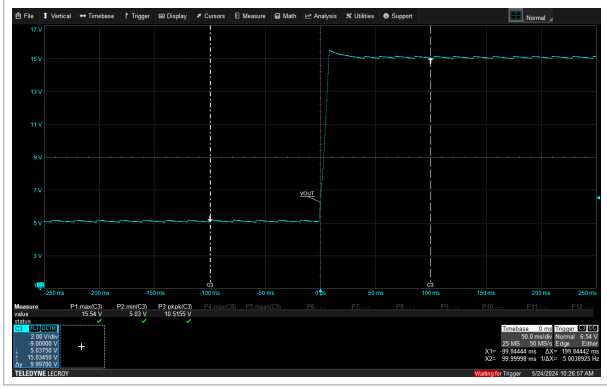


Figure 62. Voltage transition from 5 V to 15 V at 230 V_{AC} - no load

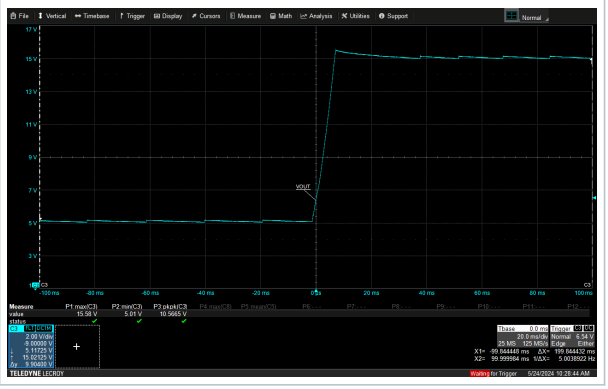


Figure 63. Voltage transition from 5 V to 15 V at 115 V_{AC} - 3.75 A load

Figure 64. Voltage transition from 5 V to 15 V at 230 V_{AC} - 3.75 A load

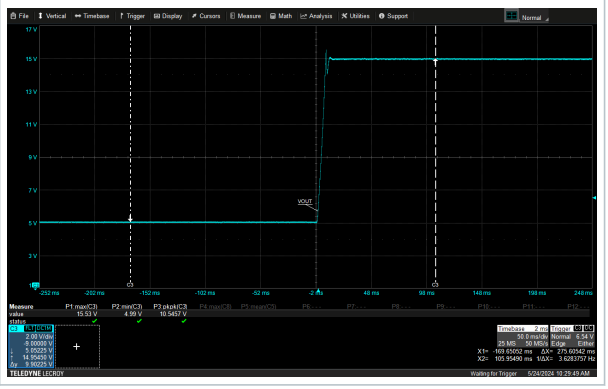


Figure 65. Voltage transition from 15 V to 5 V at 115 V_{AC} - no load

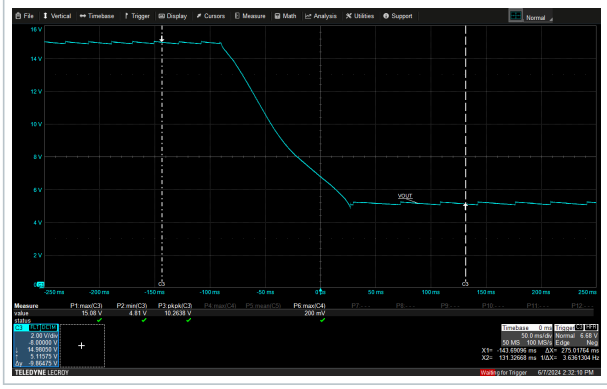


Figure 66. Voltage transition from 15 V to 5 V at 230 V_{AC} - no load

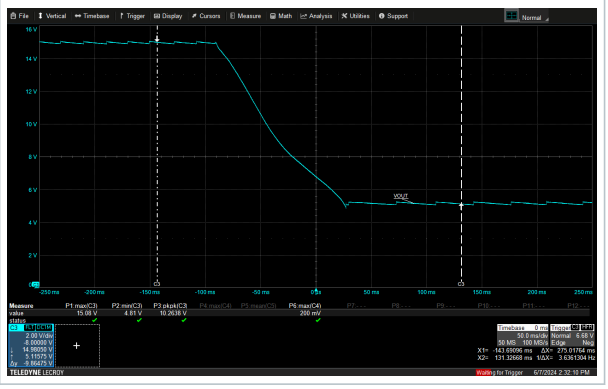


Figure 67. Voltage transition from 15 V to 5 V at 115 V_{AC} - 3.75 A load

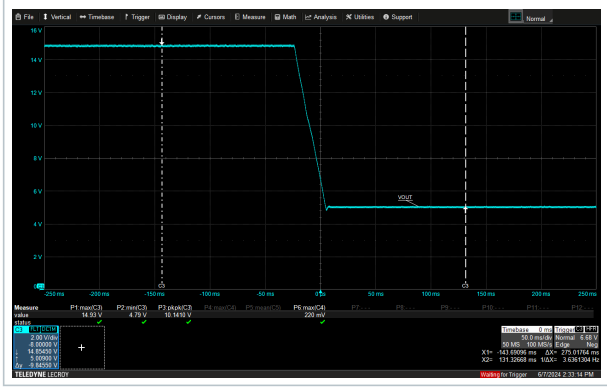
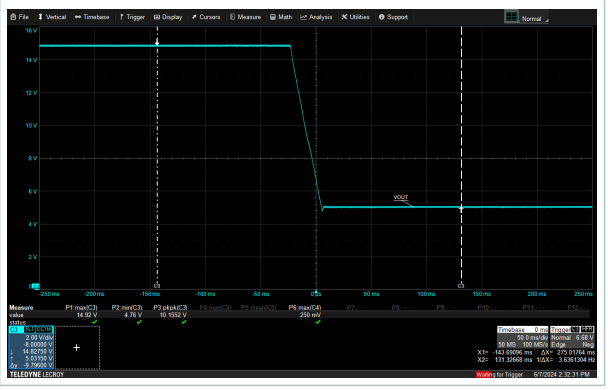


Figure 68. Voltage transition from 15 V to 5 V at 230 V_{AC} - 3.75 A load



From Figure 69 to Figure 84:

- Light blue = V_{BUS} 5 V/div

Figure 69. Voltage transition from 5 V to 20 V at 115 V_{AC} - no load

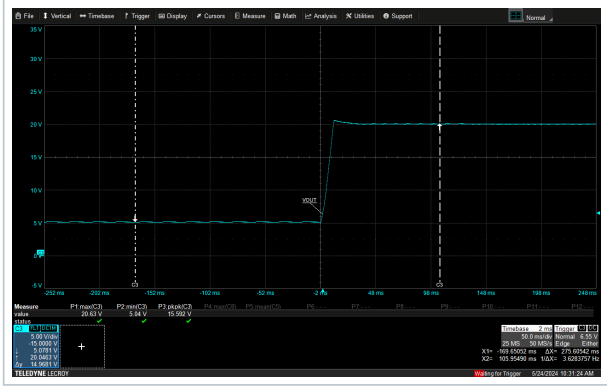


Figure 70. Voltage transition from 5 V to 20 V at 230 V_{AC} - no load

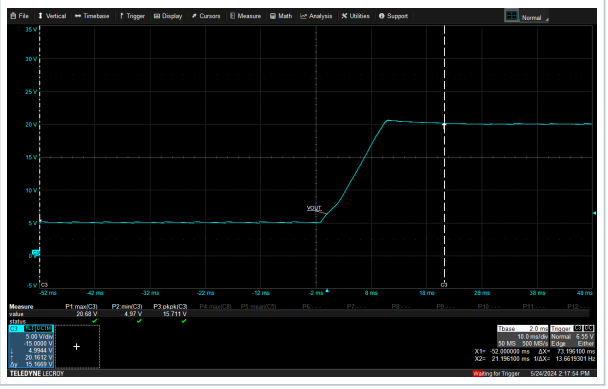


Figure 71. Voltage transition from 5 V to 20 V at 115 V_{AC} - 3.75 A load

Figure 72. Voltage transition from 5 V to 20 V at 230 V_{AC} - 3.75 A load

Figure 73. Voltage transition from 20 V to 5 V at 115 V_{AC} - no load

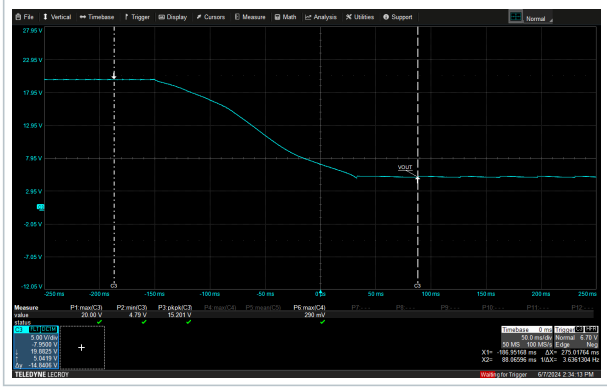


Figure 74. Voltage transition from 20 V to 5 V at 230 V_{AC} - no load

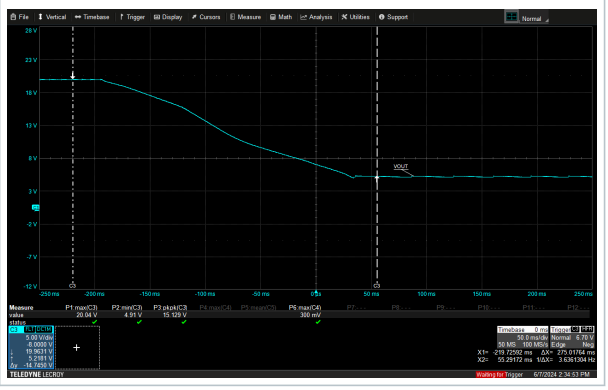


Figure 75. Voltage transition from 20 V to 5 V at 115 V_{AC} - 3.75 A load

Figure 76. Voltage transition from 20 V to 5 V at 230 V_{AC} - 3.75 A load

Figure 77. Voltage transition from 5 V to 28 V at 115 V_{AC} - no load

Figure 78. Voltage transition from 5 V to 28 V at 230 V_{AC} - no load

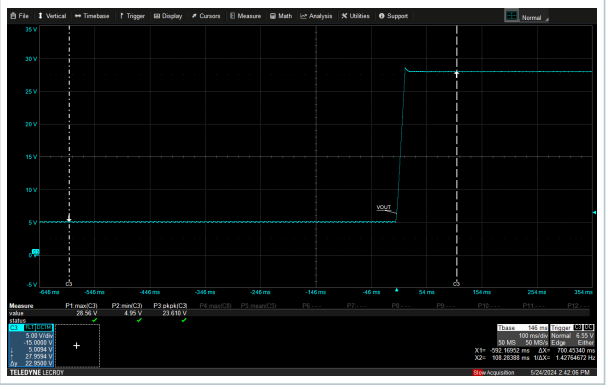


Figure 79. Voltage transition from 5 V to 28 V at 115 V_{AC} - 3.75 A load

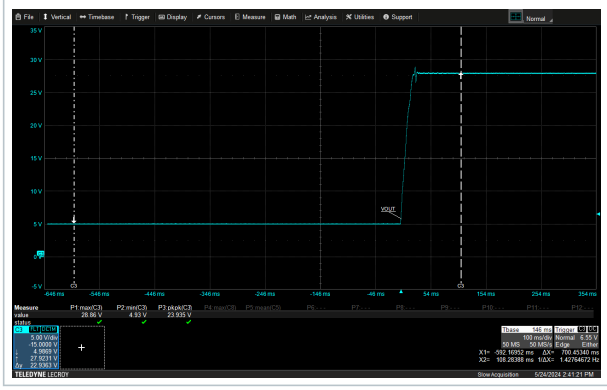


Figure 80. Voltage transition from 5 V to 28 V at 230 V_{AC} - 3.75 A load

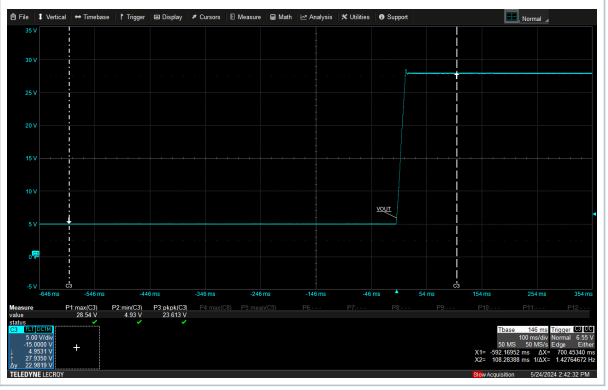


Figure 81. Voltage transition from 28 V to 5 V at 115 V_{AC} - no load

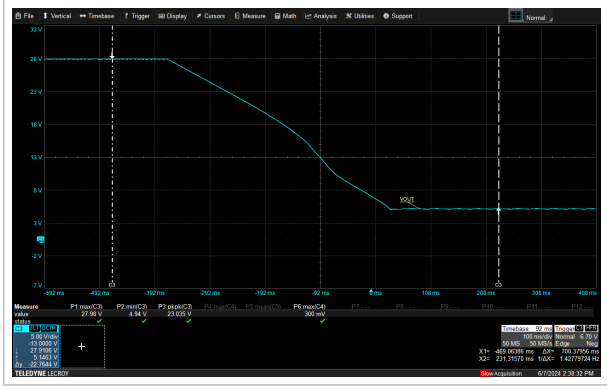


Figure 82. Voltage transition from 28 V to 5 V at 230 V_{AC} - no load

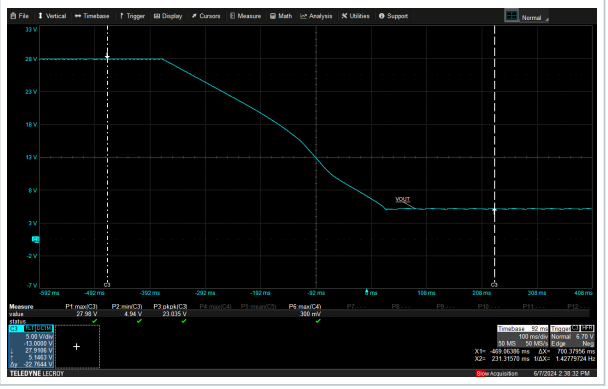


Figure 83. Voltage transition from 28 V to 5 V at 115 V_{AC} - 3.75 A load

Figure 84. Voltage transition from 28 V to 5 V at 230 V_{AC} - 3.75 A load

From Figure 85 to Figure 92:

- Light blue = V_{BUS} 1 V/div

Figure 85. Voltage transition from 9 V to 15 V at 115 V_{AC} - no load

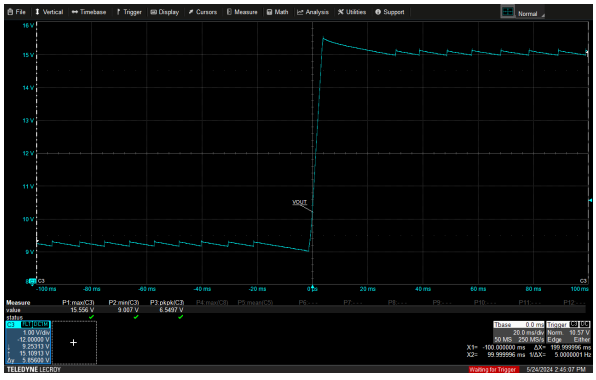


Figure 86. Voltage transition from 9 V to 15 V at 230 V_{AC} - no load

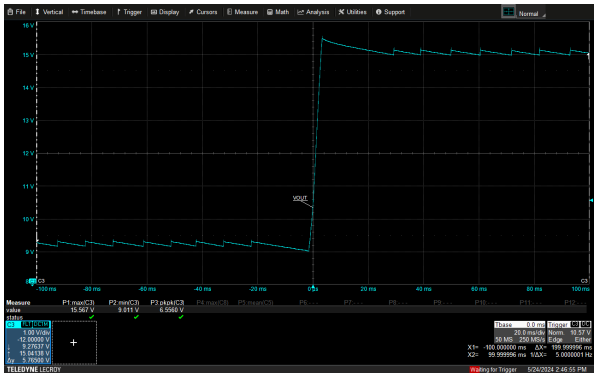


Figure 87. Voltage transition from 9 V to 15 V at 115 V_{AC} - 3.75 A load

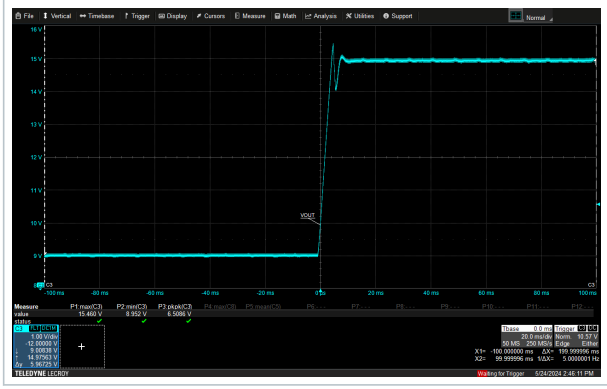


Figure 88. Voltage transition from 9 V to 15 V at 230 V_{AC} - 3.75 A load

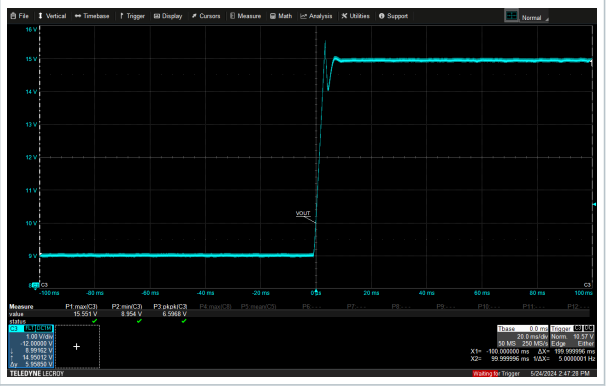


Figure 89. Voltage transition from 15 V to 9 V at 115 V_{AC} - no load

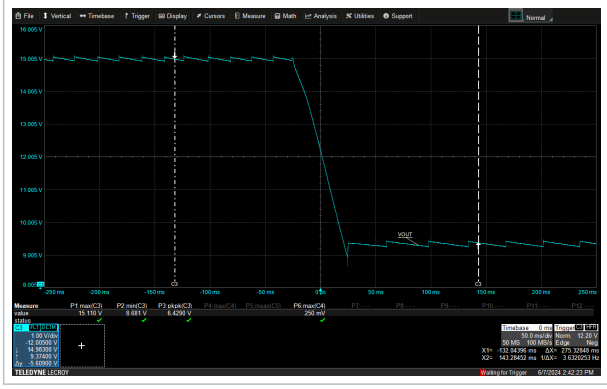


Figure 90. Voltage transition from 15 V to 9 V at 230 V_{AC} - no load

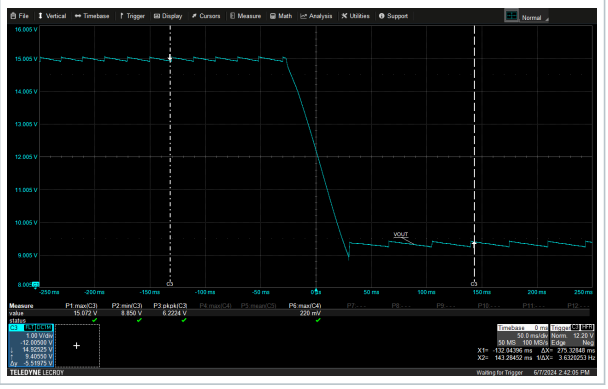


Figure 91. Voltage transition from 15 V to 9 V at 115 V_{AC} - 3.75 A load

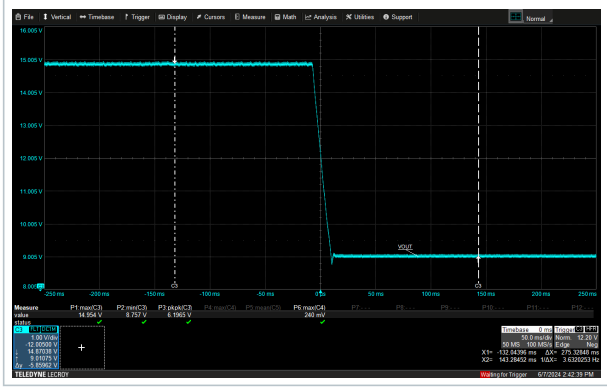
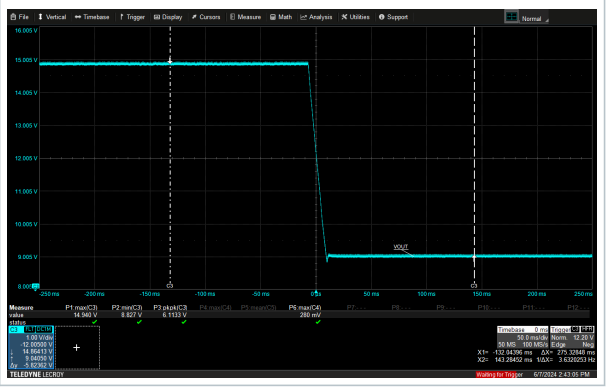


Figure 92. Voltage transition from 15 V to 9 V at 230 V_{AC} - 3.75 A load



From Figure 93 to Figure 100:

- Light blue = V_{BUS} 2 V/div

Figure 93. Voltage transition from 9 V to 20 V at 115 V_{AC} - no load

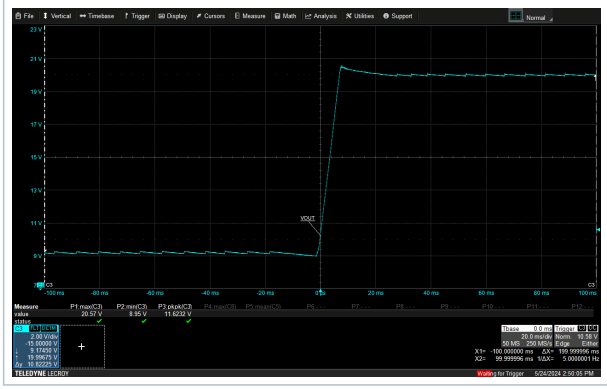


Figure 94. Voltage transition from 9 V to 20 V at 230 V_{AC} - no load

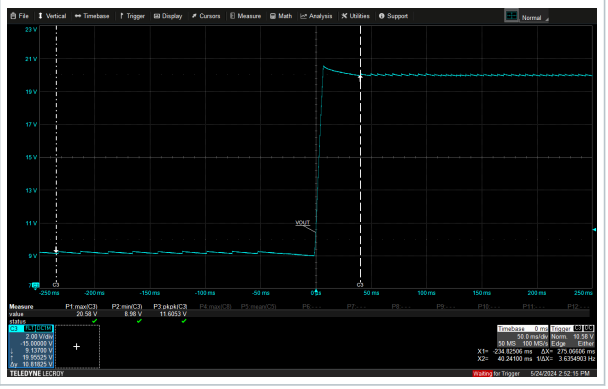


Figure 95. Voltage transition from 9 V to 20 V at 115 V_{AC} - 3.75 A load

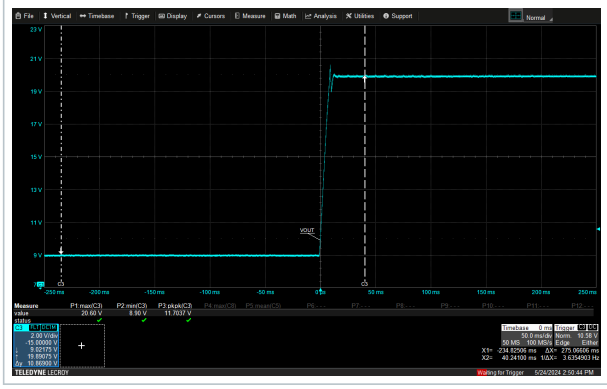


Figure 96. Voltage transition from 9 V to 20 V at 230 V_{AC} - 3.75 A load

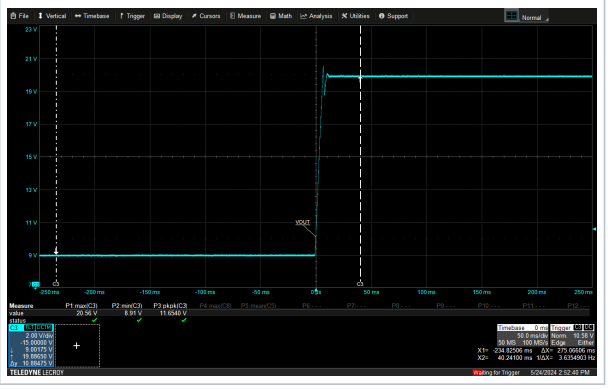


Figure 97. Voltage transition from 20 V to 9 V at 115 V_{AC} - no load

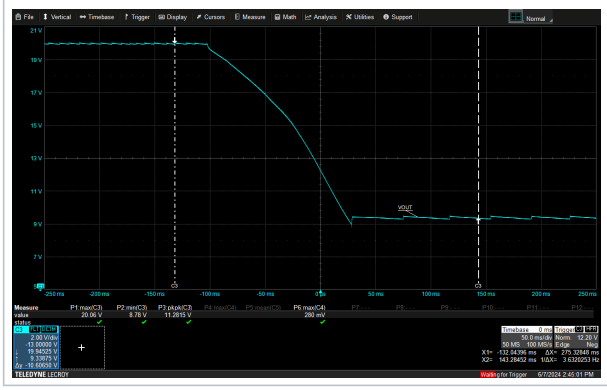


Figure 98. Voltage transition from 20 V to 9 V at 230 V_{AC} - no load

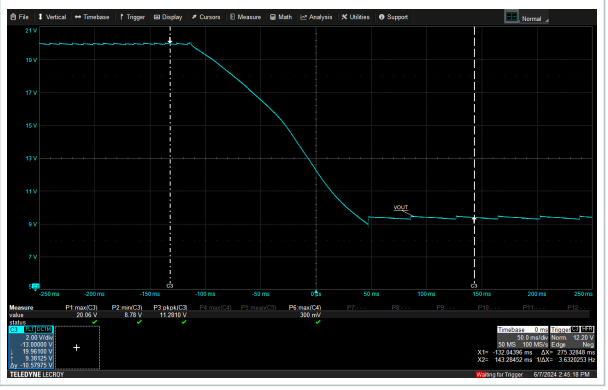


Figure 99. Voltage transition from 20 V to 9 V at 115 V_{AC} - 3.75 A load

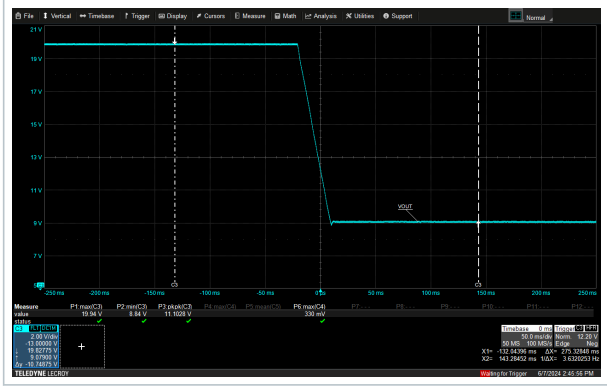
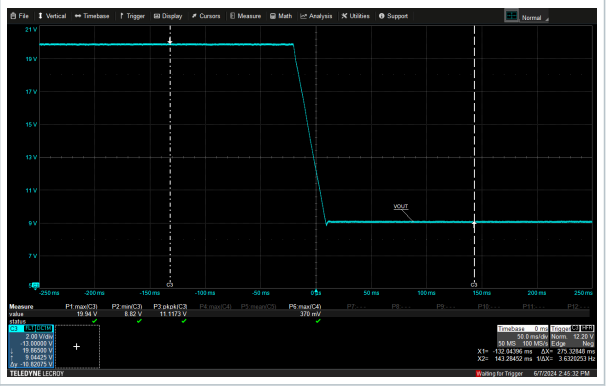


Figure 100. Voltage transition from 20 V to 9 V at 230 V_{AC} - 3.75 A load



From Figure 101 to Figure 108:

- Light blue = V_{BUS} 5 V/div

Figure 101. Voltage transition from 9 V to 28 V at 115 V_{AC} - no load

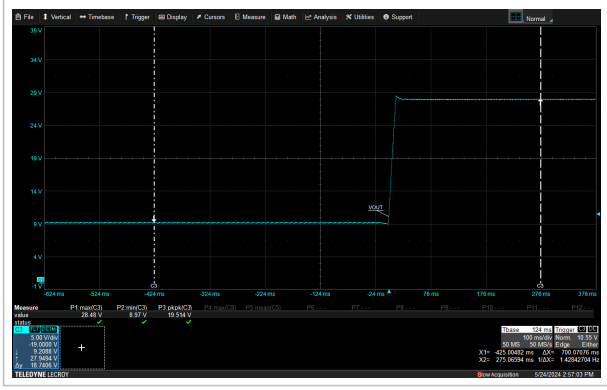


Figure 102. Voltage transition from 9 V to 28 V at 230 V_{AC} - no load

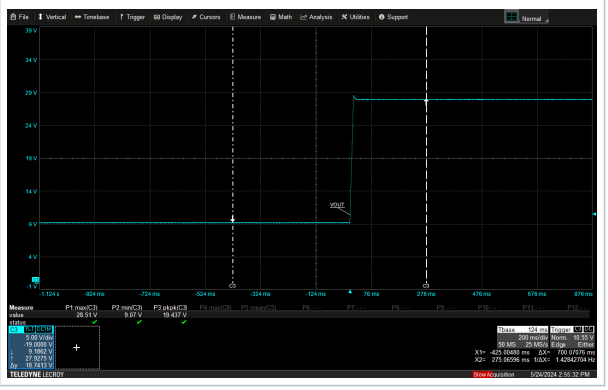


Figure 103. Voltage transition from 9 V to 28 V at 115 V_{AC} - 3.75 A load

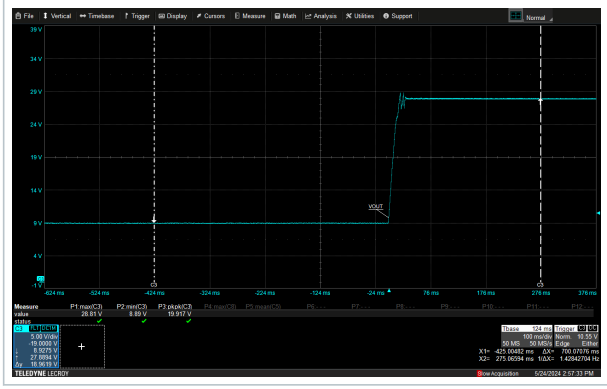


Figure 104. Voltage transition from 9 V to 28 V at 230 V_{AC} - 3.75 A load

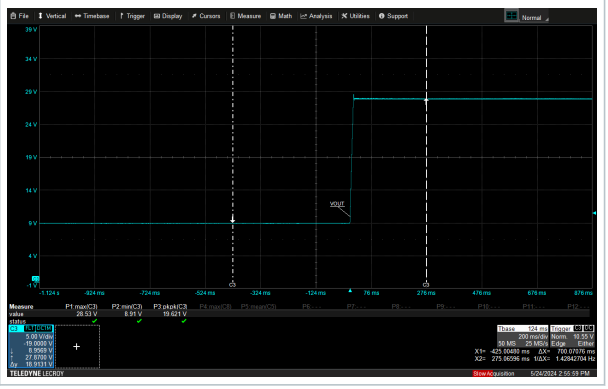


Figure 105. Voltage transition from 28 V to 9 V at 115 V_{AC} - no load

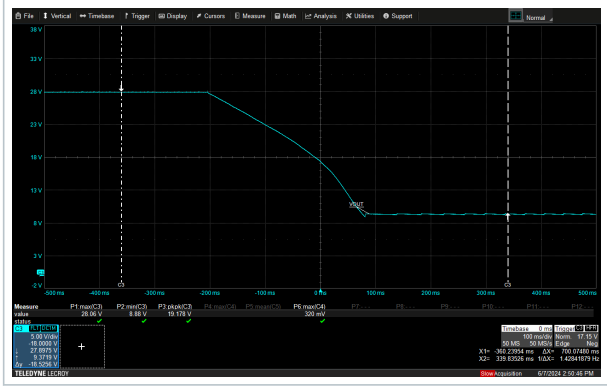


Figure 106. Voltage transition from 28 V to 9 V at 230 V_{AC} - no load

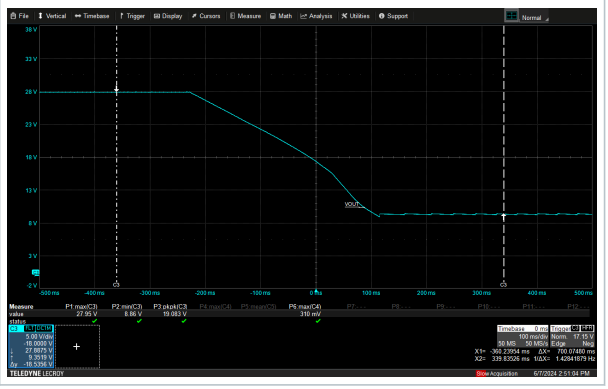


Figure 107. Voltage transition from 28 V to 9 V at 115 V_{AC} - 3.75 A load

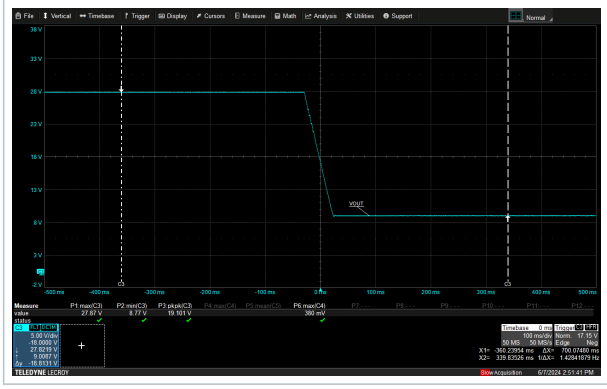
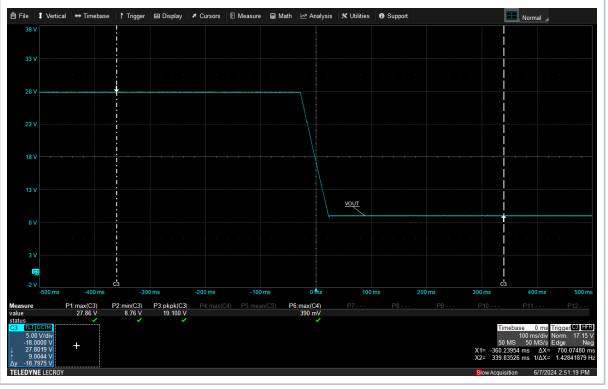


Figure 108. Voltage transition from 28 V to 9 V at 230 V_{AC} - 3.75 A load



From Figure 109 to Figure 116:

- Light blue = V_{BUS} 1 V/div

Figure 109. Voltage transition from 15 V to 20 V at 115 V_{AC} - no load

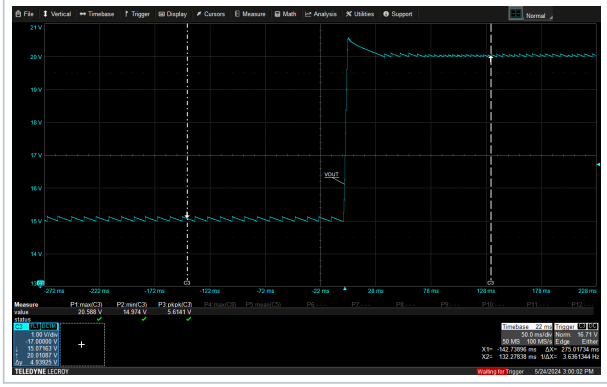


Figure 110. Voltage transition from 15 V to 20 V at 230 V_{AC} - no load

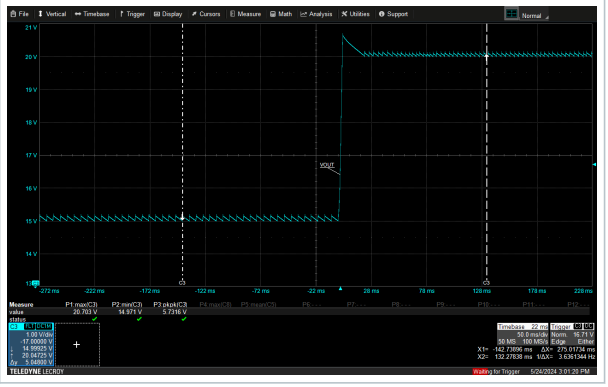


Figure 111. Voltage transition from 15 V to 20 V at 115 V_{AC} - 3.75 A load

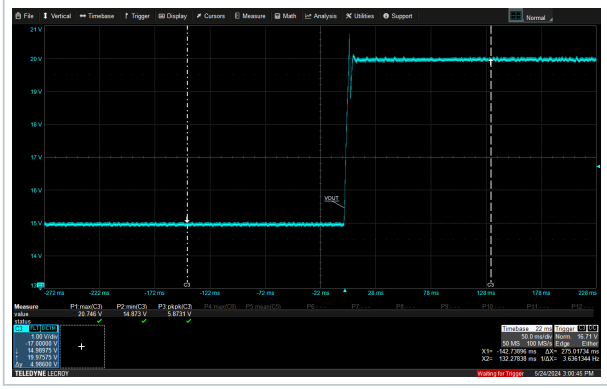


Figure 112. Voltage transition from 15 V to 20 V at 230 V_{AC} - 3.75 A load

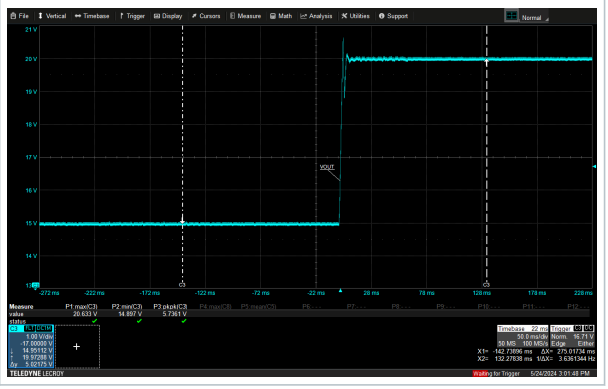


Figure 113. Voltage transition from 20 V to 15 V at 115 V_{AC} - no load

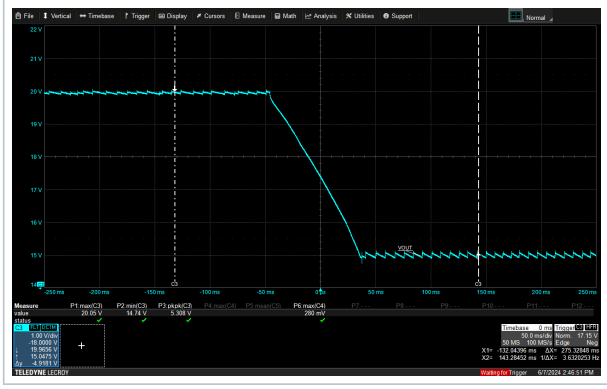


Figure 114. Voltage transition from 20 V to 15 V at 230 V_{AC} - no load

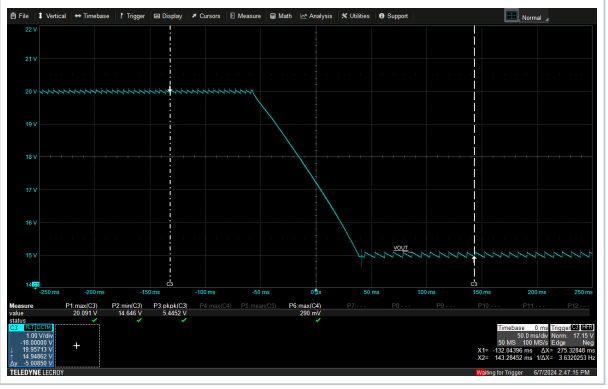


Figure 115. Voltage transition from 20 V to 15 V at 115 V_{AC} - 3.75 A load

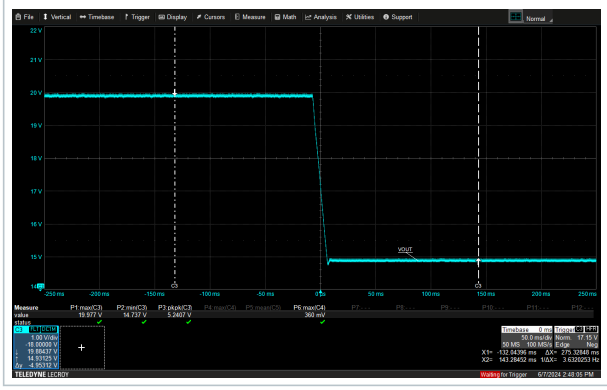
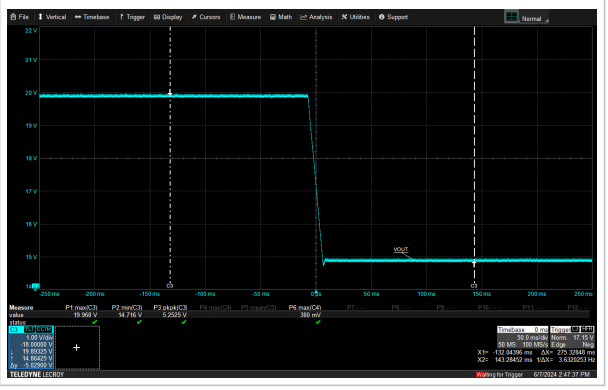


Figure 116. Voltage transition from 20 V to 15 V at 230 V_{AC} - 3.75 A load



From Figure 117 to Figure 132:

- Light blue = V_{BUS} 2 V/div

Figure 117. Voltage transition from 15 V to 28 V at 115 V_{AC} - no load

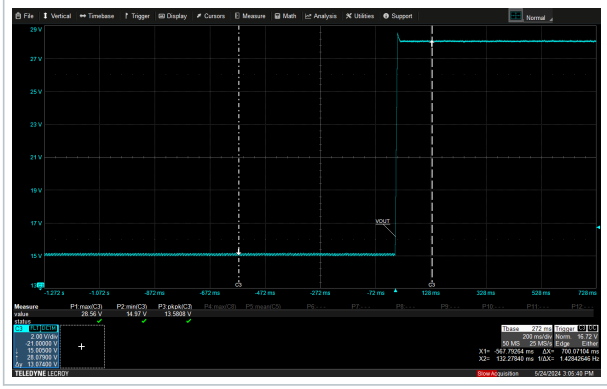


Figure 118. Voltage transition from 15 V to 28 V at 230 V_{AC} - no load

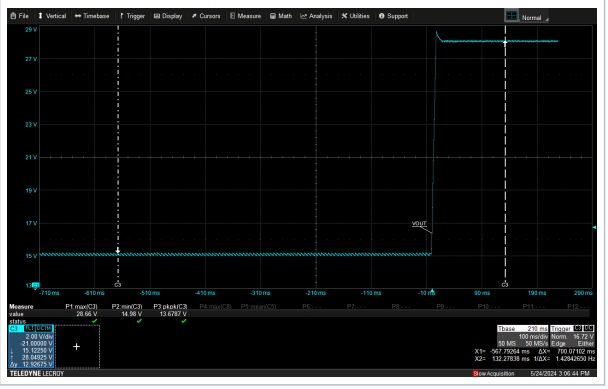


Figure 119. Voltage transition from 15 V to 28 V at 115 V_{AC} - 3.75 A load

Figure 120. Voltage transition from 15 V to 28 V at 230 V_{AC} - 3.75 A load

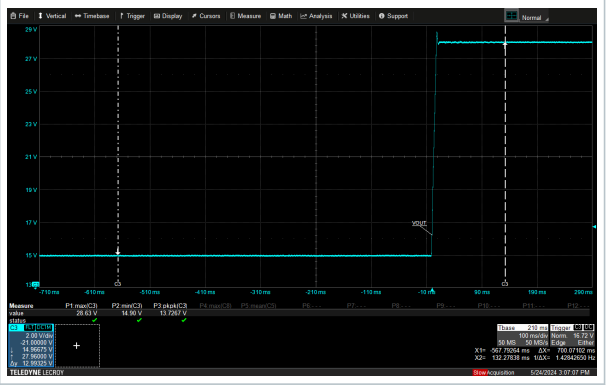


Figure 121. Voltage transition from 28 V to 15 V at 115 V_{AC} - no load

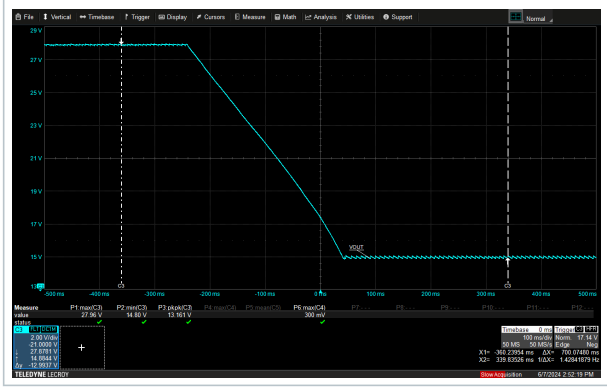


Figure 122. Voltage transition from 28 V to 15 V at 230 V_{AC} - no load

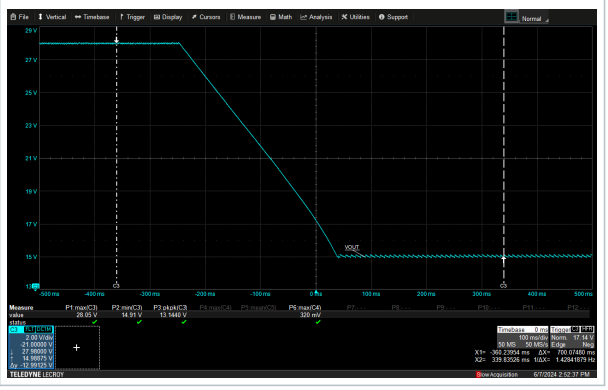


Figure 123. Voltage transition from 28 V to 15 V at 115 V_{AC} - 3.75 load

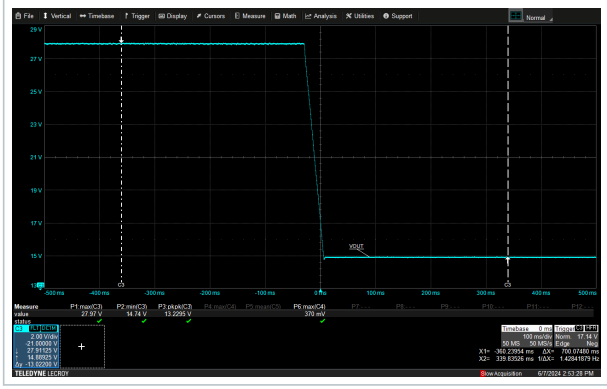


Figure 124. Voltage transition from 28 V to 15 V at 230 V_{AC} - 3.75 load

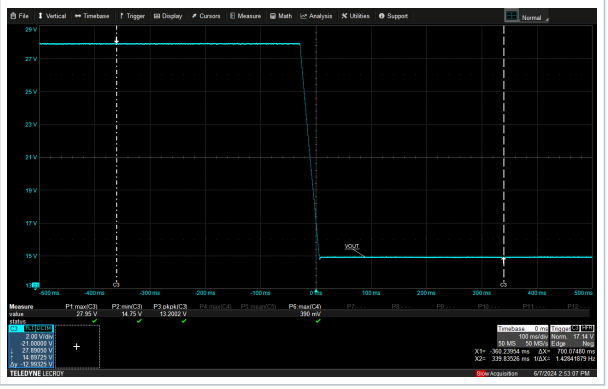


Figure 125. Voltage transition from 20 V to 28 V at 115 V_{AC} - no load

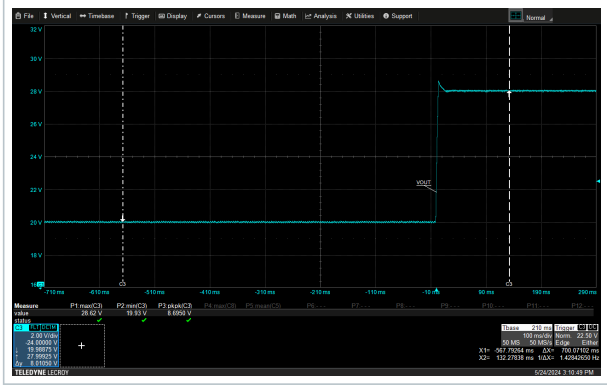


Figure 126. Voltage transition from 20 V to 28 V at 230 V_{AC} - no load

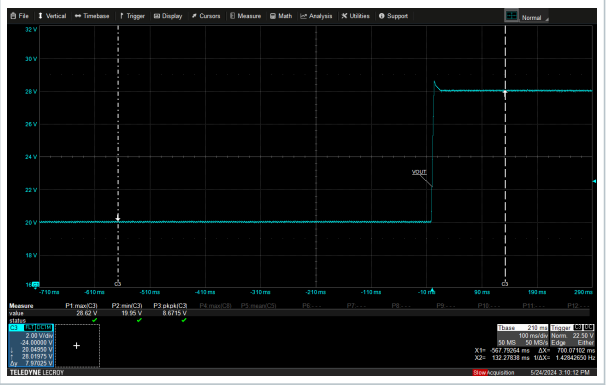


Figure 127. Voltage transition from 20 V to 28 V at 115 V_{AC} - 3.75 A load

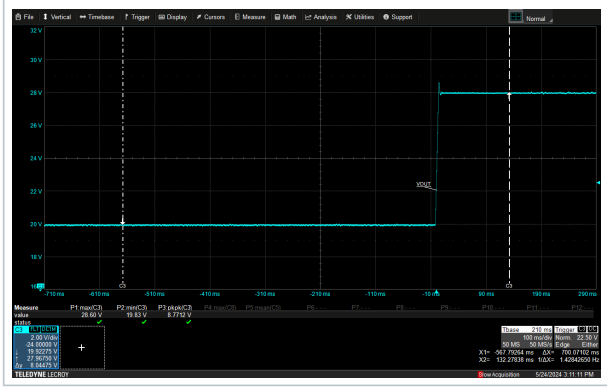


Figure 128. Voltage transition from 20 V to 28 V at 230 V_{AC} - 3.75 A load

Figure 129. Voltage transition from 28 V to 20 V at 115 V_{AC} - no load

Figure 130. Voltage transition from 28 V to 20 V at 230 V_{AC} - no load

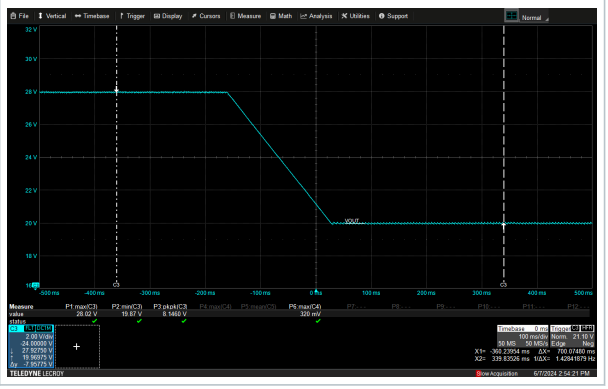


Figure 131. Voltage transition from 28 V to 20 V at 115 V_{AC} - 3.75 A load

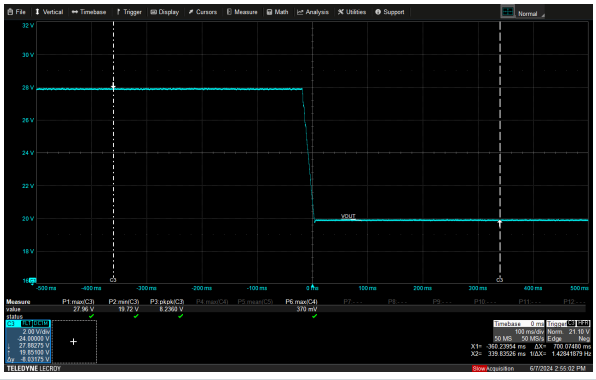
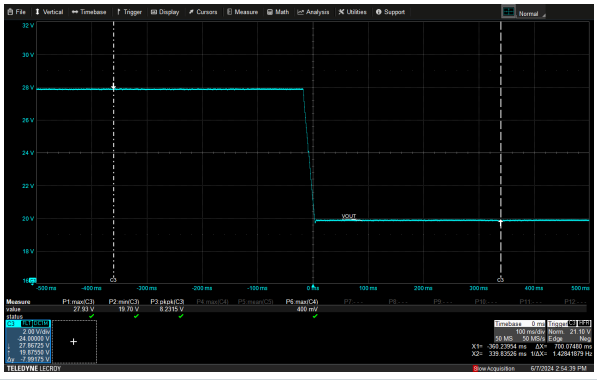


Figure 132. Voltage transition from 28 V to 20 V at 230 V_{AC} - 3.75 A load



9 Voltage stress on the main power MOSFET

The following images show the voltage phase on the primary side and the current sense pin voltage. The measurements have been performed with 90 V_{AC}/50 Hz and 250 V_{AC}/60 Hz input voltages under full load condition. Different output voltages have been selected (5V-PDO, 9V-PDO, 15V-PDO, 20V-PDO, and 28V-PDO).

Figure 133. Primary side phase waveform with 5 V output at 90 V_{AC} - 3.75 A load

- Blue = V_{ISEN} 200 mV/div
- Green = V_{PHASE} 50 V/div
- $V_{PHASEmax}$ = 169.1 V

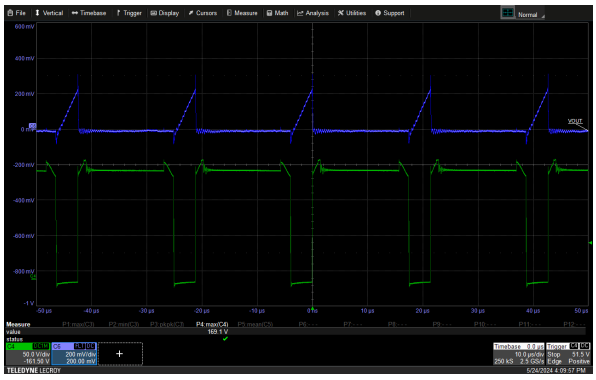


Figure 134. Primary side phase waveform with 5 V output at 250 V_{AC} - 3.75 A load

- Blue = V_{ISEN} 200 mV/div
- Green = V_{PHASE} 100 V/div
- $V_{PHASEmax}$ = 396 V

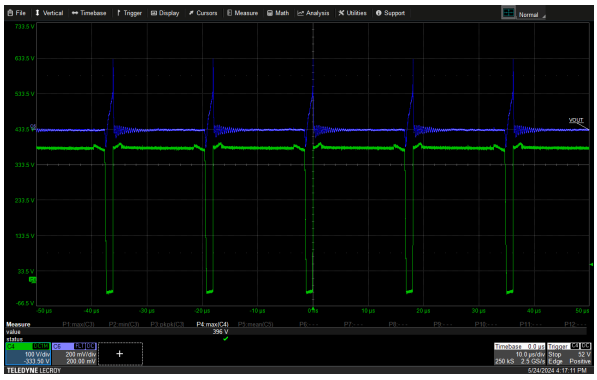


Figure 135. Primary side phase waveform with 9 V output at 90 V_{AC} - 3.75 A load

- Blue = V_{ISEN} 200 mV/div
- Green = V_{PHASE} 50 V/div
- $V_{PHASEmax}$ = 170.5 V

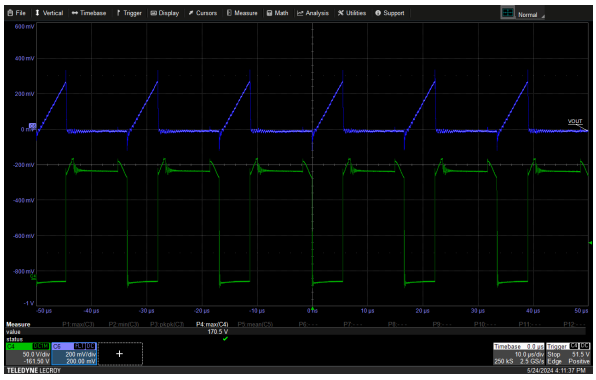


Figure 136. Primary side phase waveform with 9 V output at 250 V_{AC} - 3.75 A load

- Blue = V_{ISEN} 500 mV/div
- Green = V_{PHASE} 200 V/div
- $V_{PHASEmax}$ = 420.9 V

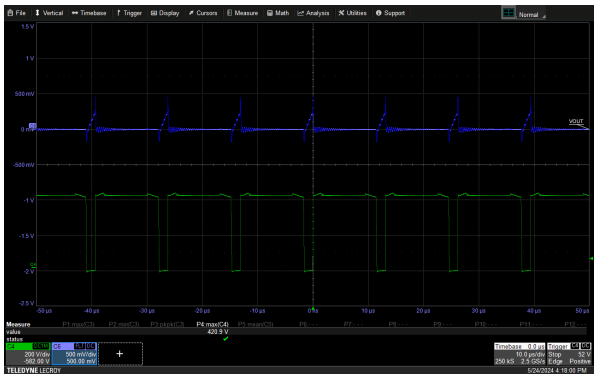


Figure 137. Primary side phase waveform with 15 V output at 90 V_{AC} - 3.75 A load

- Blue = V_{ISEN} 200 mV/div
- Green = V_{PHASE} 50 V/div
- $V_{PHASEmax}$ = 225.9 V

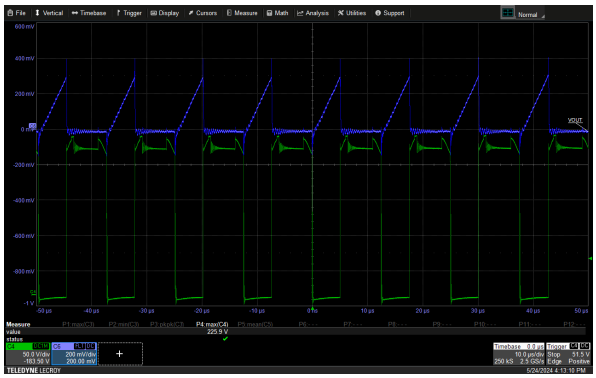


Figure 138. Primary side phase waveform with 15 V output at 250 V_{AC} - 3.75 A load

- Blue = V_{ISEN} 500 mV/div
- Green = V_{PHASE} 200 V/div
- $V_{PHASEmax}$ = 462 V

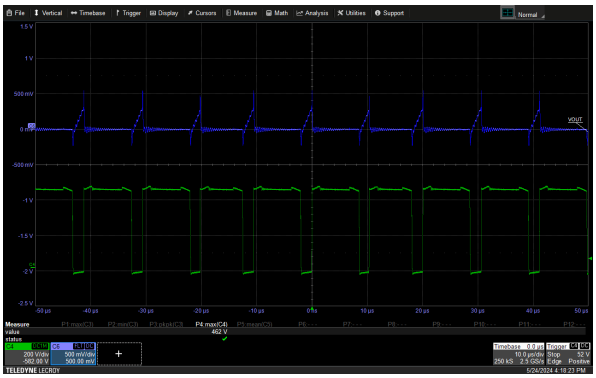


Figure 139. Primary side phase waveform with 20 V output at 90 V_{AC} - 5 A load

- Blue = V_{ISEN} 500 mV/div
- Green = V_{PHASE} 200 V/div
- $V_{PHASEmax}$ = 438 V

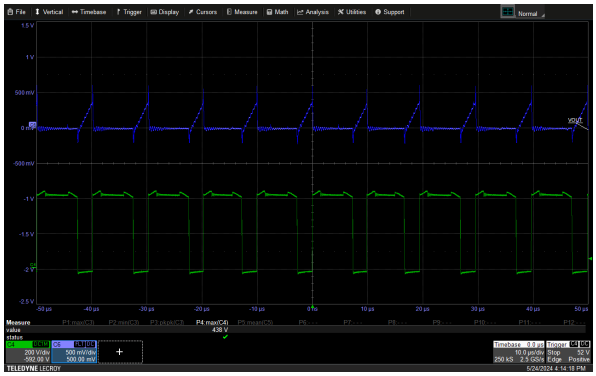


Figure 140. Primary side phase waveform with 20 V output at 250 V_{AC} - 5 A load

- Blue = V_{ISEN} 500 mV/div
- Green = V_{PHASE} 200 V/div
- $V_{PHASEmax}$ = 510 V

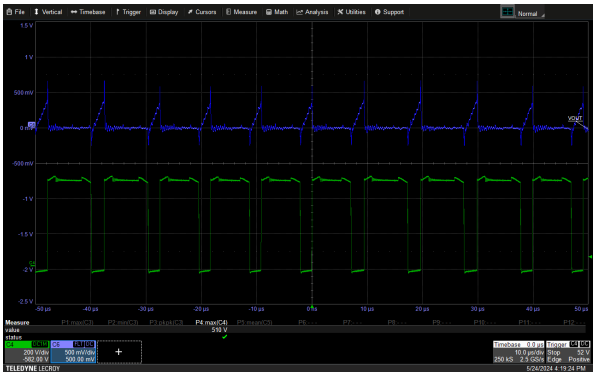


Figure 141. Primary side phase waveform with 28 V output at 90 V_{AC} - 5 A load

- Blue = V_{ISEN} 500 mV/div
- Green = V_{PHASE} 200 V/div
- $V_{PHASEmax}$ = 484 V

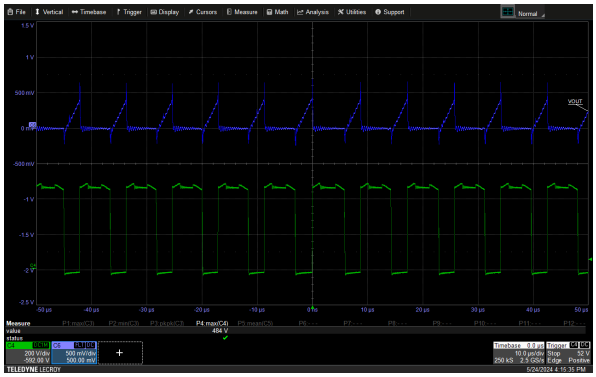
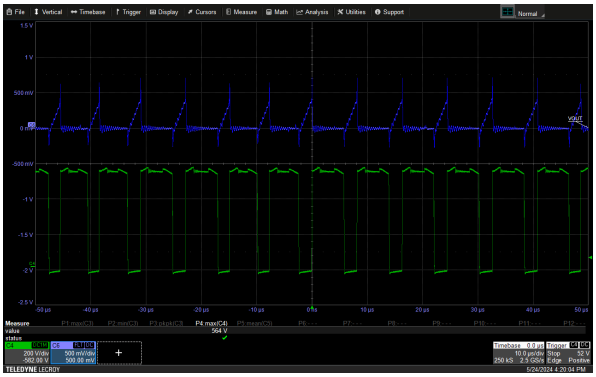


Figure 142. Primary side phase waveform with 28 V output at 250 V_{AC} - 5 A load

- Blue = V_{ISEN} 500 mV/div
- Green = V_{PHASE} 200 V/div
- $V_{PHASEmax}$ = 564 V



10 AVS voltage transitions

The EVLONE140W is designed to provide AVS profiles to control the output voltage. The test below shows an AVS voltage transition from 15 V to 28 V with 100 mV steps.

In Figure 143 and Figure 144:

- Blue = V_{BUS} 2 V/div

Figure 143. AVS voltage transition from 15 V to 28 V at 230 V_{AC} - 1 A load

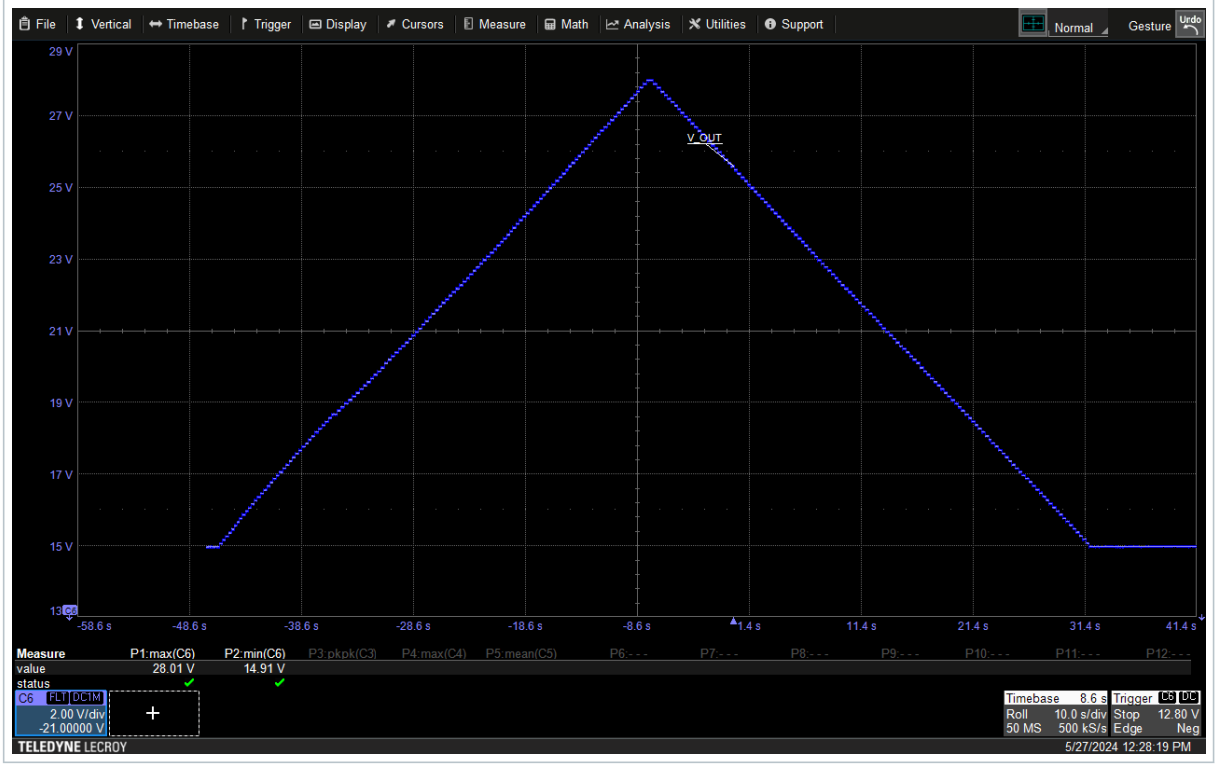
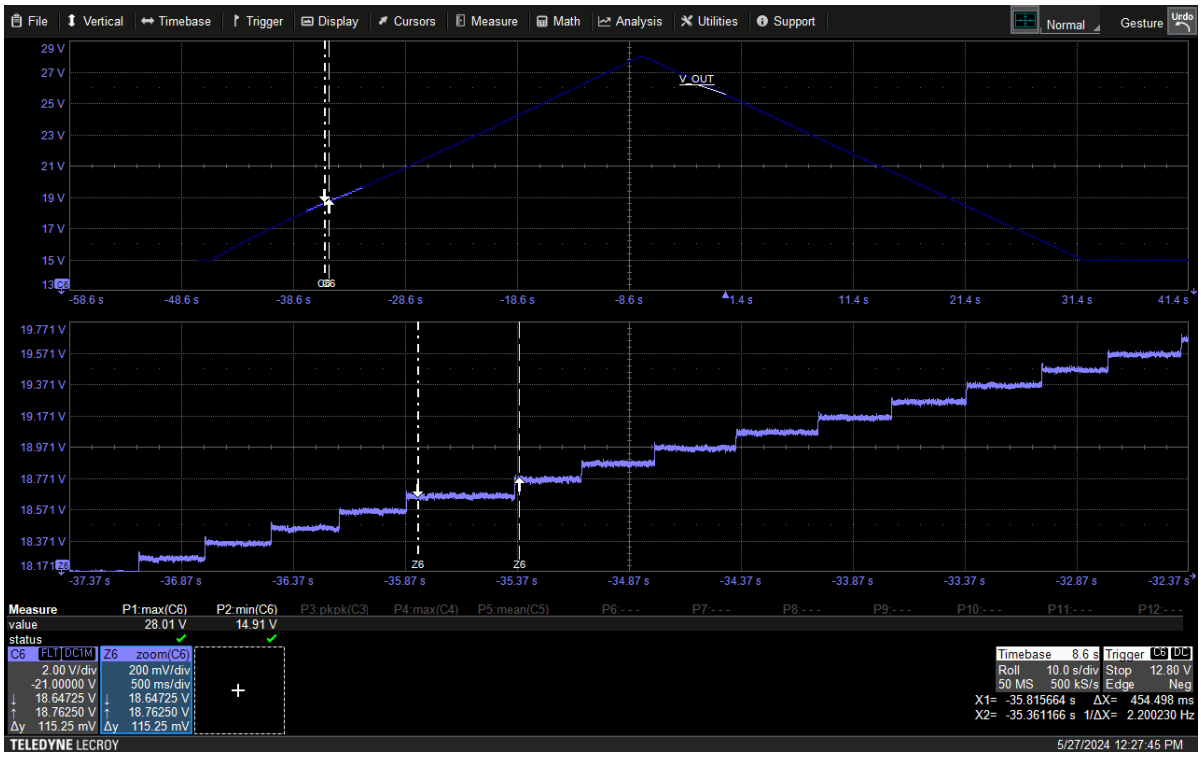


Figure 144. **AVS voltage transition from 15 V to 28 V at 230 V_{AC} - 1 A load (zoom on voltage steps)**



11 Operating modes

The following figures show the operation modes of the device under different conditions. The test has been performed with 230 V_{AC}/50 Hz input voltage and setting two different outputs:

- 5 V at 3.75 A load
- 20 V at 5 A load

To change the mode of operation, the maximum load has been slowly decreased until the minimum load value (0 A), and vice versa. Starting from maximum load it is possible to observe the CCM/DCM mode, then decreasing the load the system enters in valley skipping mode, and finally at very low load the device is in burst mode, and the reverse when the load is increased. The following waveforms show the primary side phase at the different operation modes. From Figure 145 to Figure 150:

- Blue = V_PHASE 100 V/div

Figure 145. CCM/DCM operation mode at 230 V_{AC} with 5 V output, full load

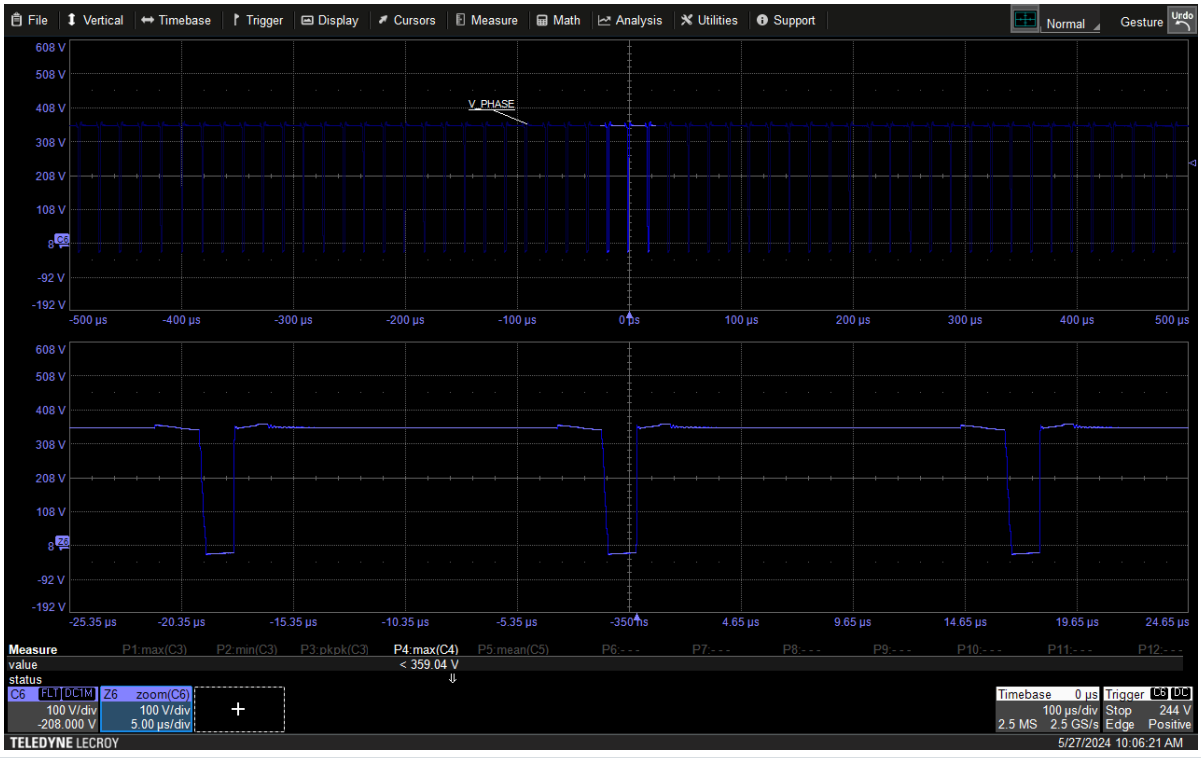


Figure 146. **Valley skipping operation mode at 230 V_{AC} with 5 V output, medium load**

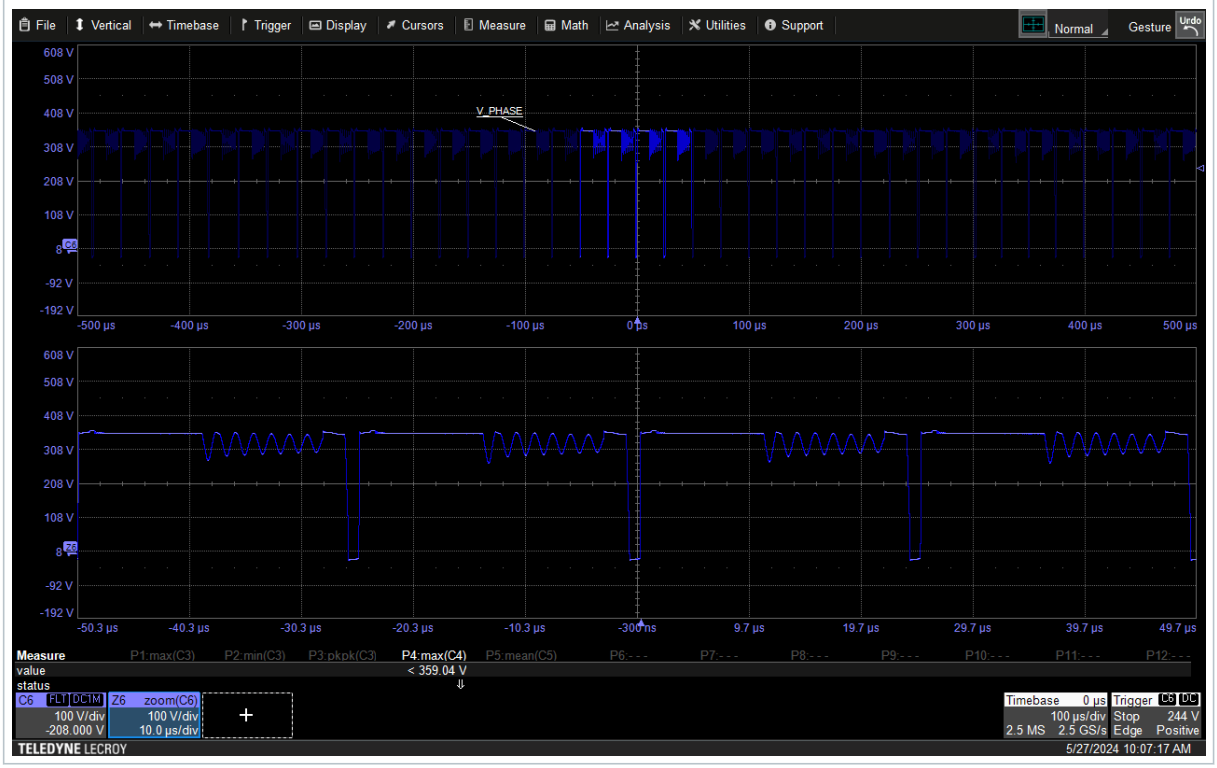


Figure 147. **Burst operation mode at 230 V_{AC} with 5 V output, low load**

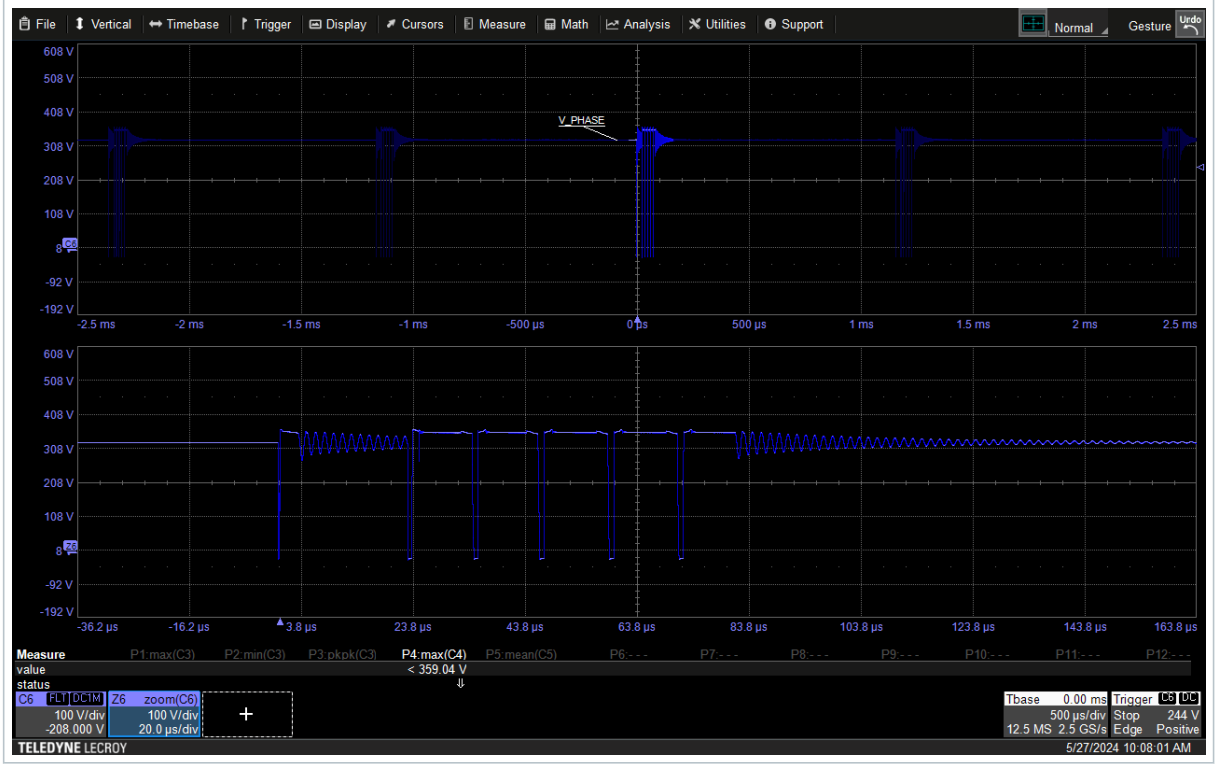


Figure 148. CCM/DCM operation mode at 230 V_{AC} with 20 V output, full load

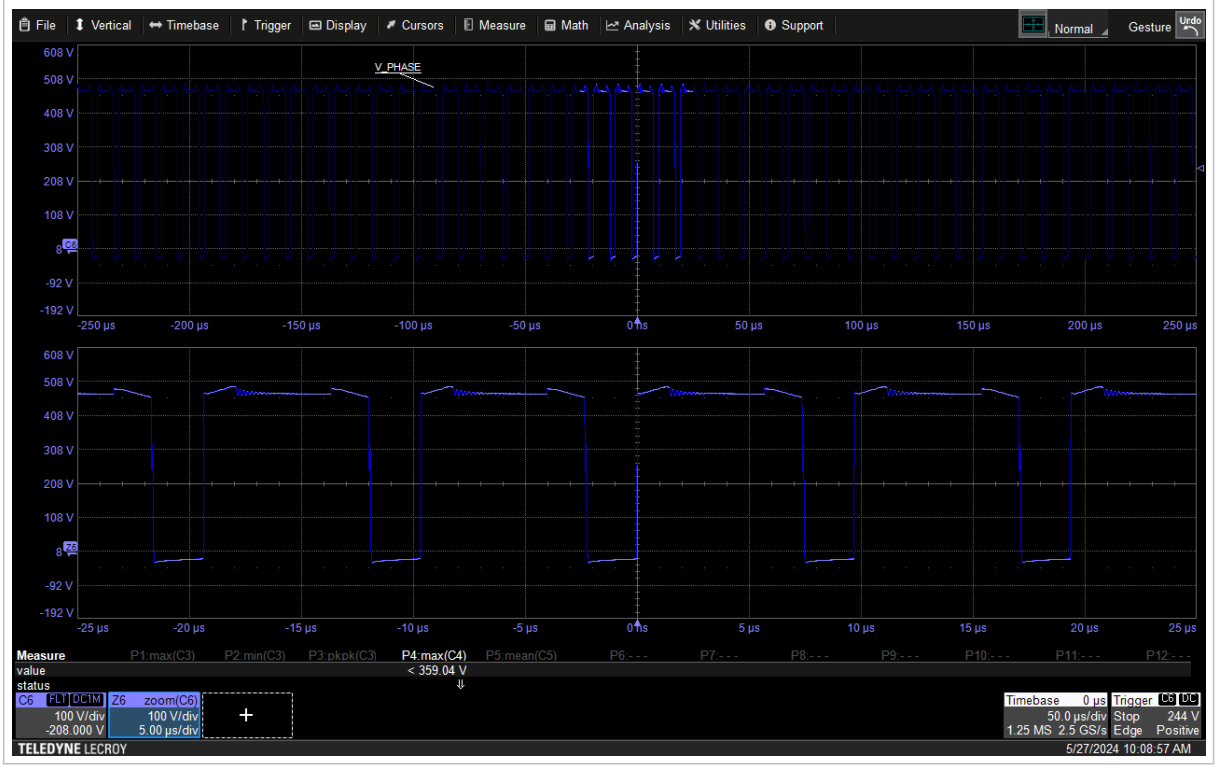


Figure 149. Valley skipping operation mode at 230 V_{AC} with 20 V output, medium load

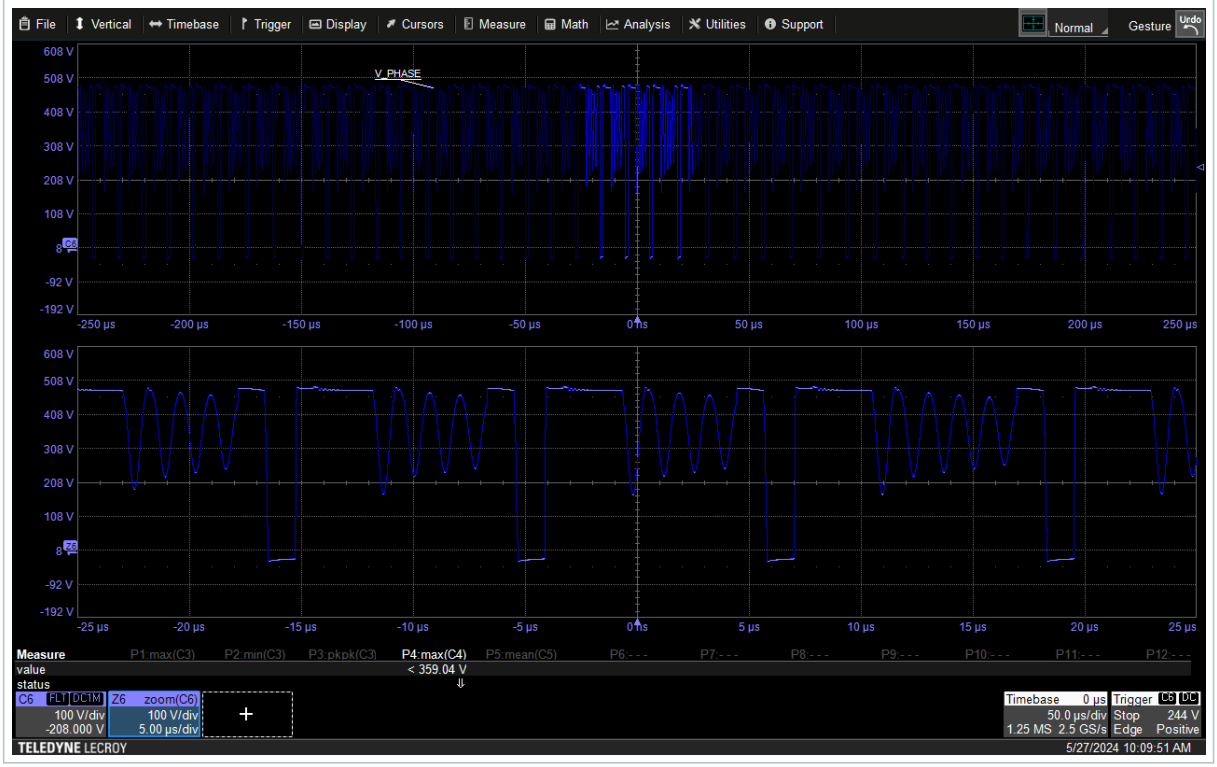
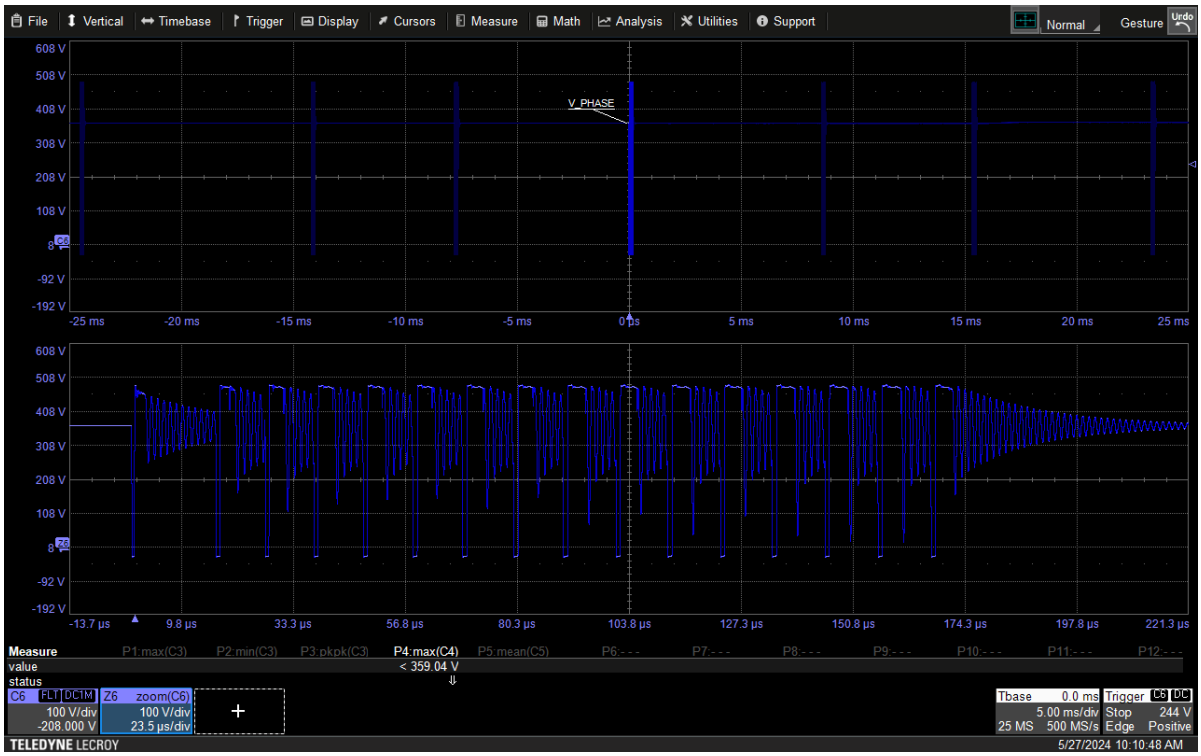


Figure 150. Burst operation mode at 230 V_{AC} with 20 V output, low load



12 Protections

12.1 Overcurrent protection on secondary side

To implement the overcurrent protection tests on the secondary side, an extra current load is requested. The test is performed for all the PDO profiles. The V_{BUS} shuts down when the output current load exceeds the maximum PDO current value by 5.5%. The test has been performed with 115 V_{AC}/60 Hz and 230 V_{AC}/50 Hz input voltages. From Figure 151 to Figure 154:

- Light green = I_{OUT} 200 mA/div
- Blue = V_{BUS} 2 V/div

Figure 151. Overcurrent protection with 5 V output at 115 V_{AC}

Figure 152. Overcurrent protection with 5 V output at 230 V_{AC}

Figure 153. Overcurrent protection with 9 V output at 115 V_{AC}

Figure 154. Overcurrent protection with 9 V output at 230 V_{AC}

From Figure 155 to Figure 160:

- Light green = I_{OUT} 200 mA/div
- Blue = V_{BUS} 5 V/div

Figure 155. Overcurrent protection with 15 V output at 115 V_{AC}

Figure 156. Overcurrent protection with 15 V output at 230 V_{AC}

Figure 157. Overcurrent protection with 20 V output at 115 V_{AC}

Figure 158. Overcurrent protection with 20 V output at 230 V_{AC}

Figure 159. Overcurrent protection with 28 V output at 115 V_{AC}

Figure 160. Overcurrent protection with 28 V output at 230 V_{AC}

12.2 OC1 protection on primary side

To test this kind of protection, a function waveform generator is connected to the ISEN pin through a diode. A DC offset is set to trigger the OC1 level protection. When the voltage on the current sense pin bypasses the $V_{IPKCLAMP}$ threshold (equal to 525 mV), LON is turned off after the blanking time is expired.

In Figure 161:

- Yellow = HON 5 V/div
- Pink = LON 5 V/div
- Light green = V_{ISEN} 200 mV/div
- Blue = V_{BUS} 5 V/div

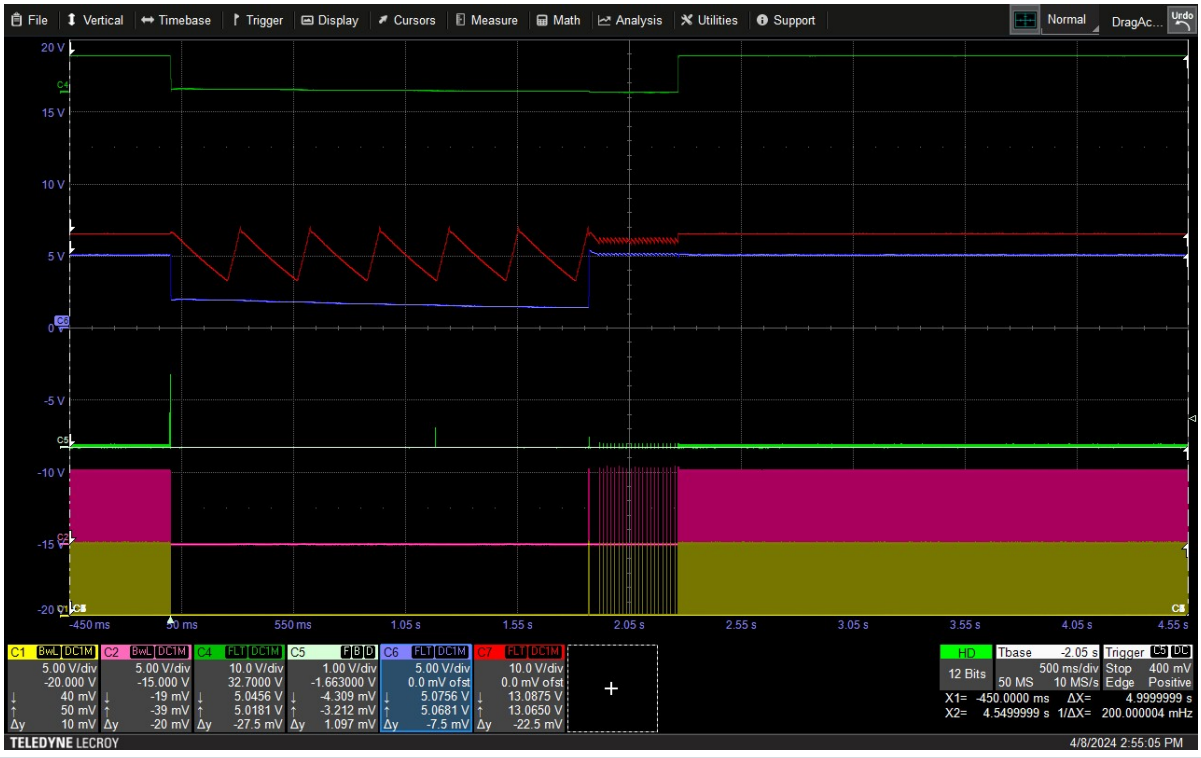
Figure 161. OC1 protection on primary side – 5 V output – 0.5 A load – 90 V_{AC} input

12.3 OC2 protection on primary side

To test this kind of protection, a function waveform generator is connected to the ISEN pin through a diode. A DC offset is set to trigger the OC2 level protection. When the voltage on the current sense pin bypasses the V_{OCTH} (equal to 900 mV), the device goes into auto-restart mode. In Figure 162:

- Yellow = HON 5 V/div
- Pink = LON 5 V/div
- Green = V_{BUS} 10 V/div
- Light green = V_{ISEN} 1 V/div
- Blue = V_{OUT} 5 V/div
- Red = P_{VCC} 10 V/div

Figure 162. OC2 protection on primary side – 5 V output – 1 A load – 90 V_{AC} input

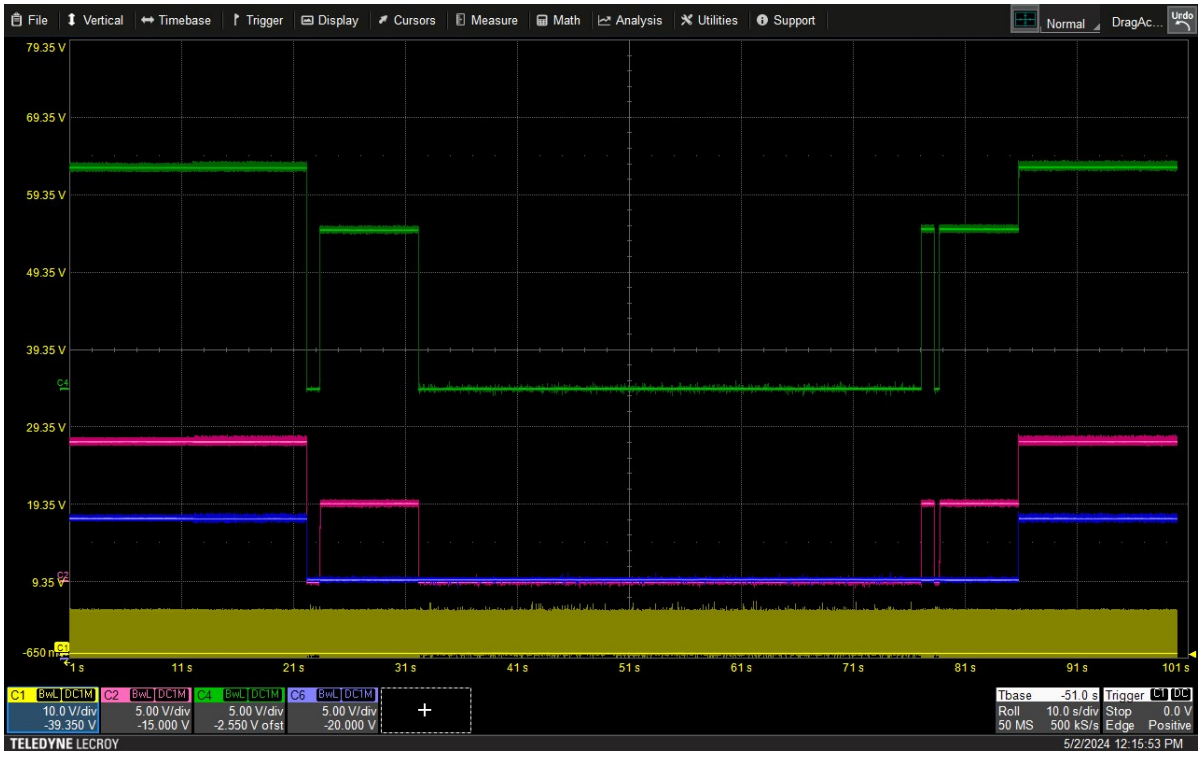


12.4 OTP protection on secondary side

To check the correct behavior of the OTP protection on the secondary side, the board is heated and when watching the trend of V_{BUS}, it is possible to observe that ST-ONE enters in WTP (V_{BUS}=5 V) and then V_{BUS} is turned off when the OTP level is triggered. After turning off the heat source, it is possible to understand from V_{BUS} that ST-ONEHP returns in WTP and then to its normal behavior (V_{BUS}=9 V). In Figure 163:

- Yellow = LON 10 V/div
- Pink = V_{BUS} 5 V/div
- Green = ORGD 5 V/div
- Blue = V_{OUT} 5 V/div

Figure 163. OTP protection on secondary side – 9 V output – 0.4 A load – 115 V_{AC} input



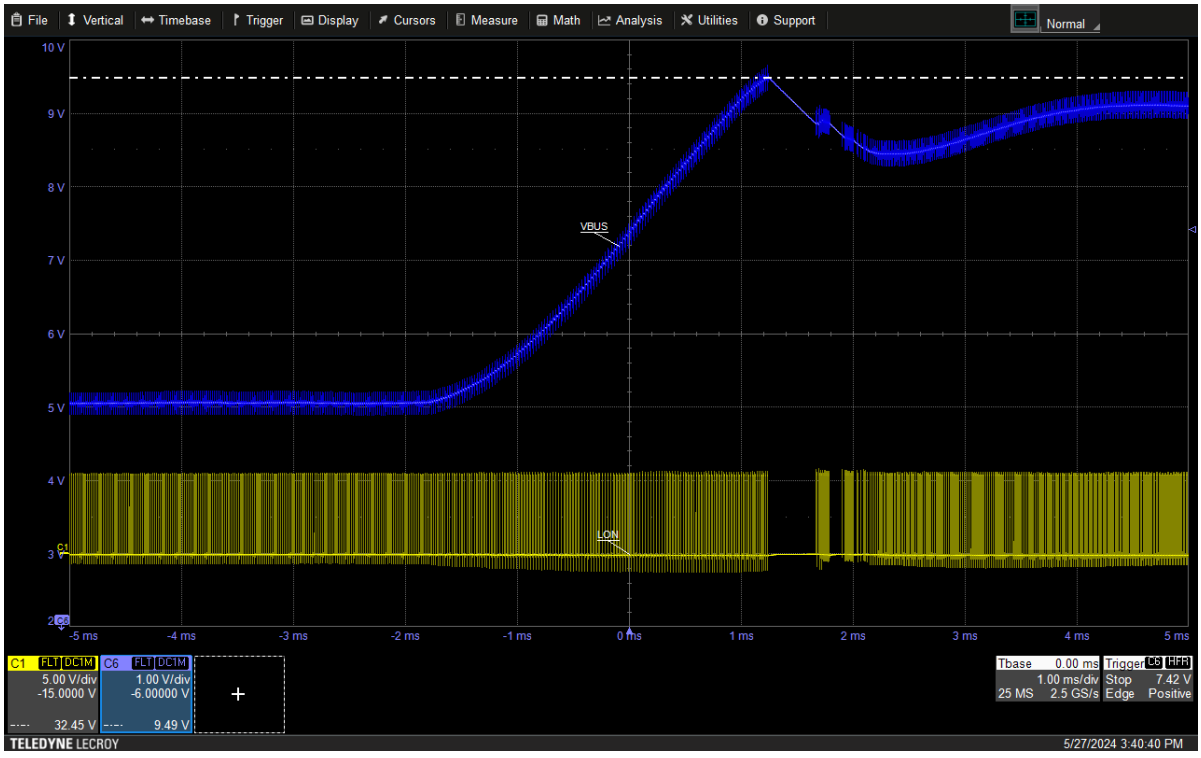
12.5 OVP protection on secondary side

To test the OVP protection on the secondary side, an output voltage transition has been performed. The transition is from 5 V to 9 V output, 115 V_{AC} input and 2.5 A load. Once the output voltage reaches the secondary OVP threshold, the device enters burst mode and waits for the voltage to drop under safe condition.

In Figure 164:

- Yellow = LON 5 V/div
- Blue = V_{BUS} 1 V/div

Figure 164. OVP protection on secondary side – output transition from 5 V to 9 V at 115 V_{AC} and 2.5 A load

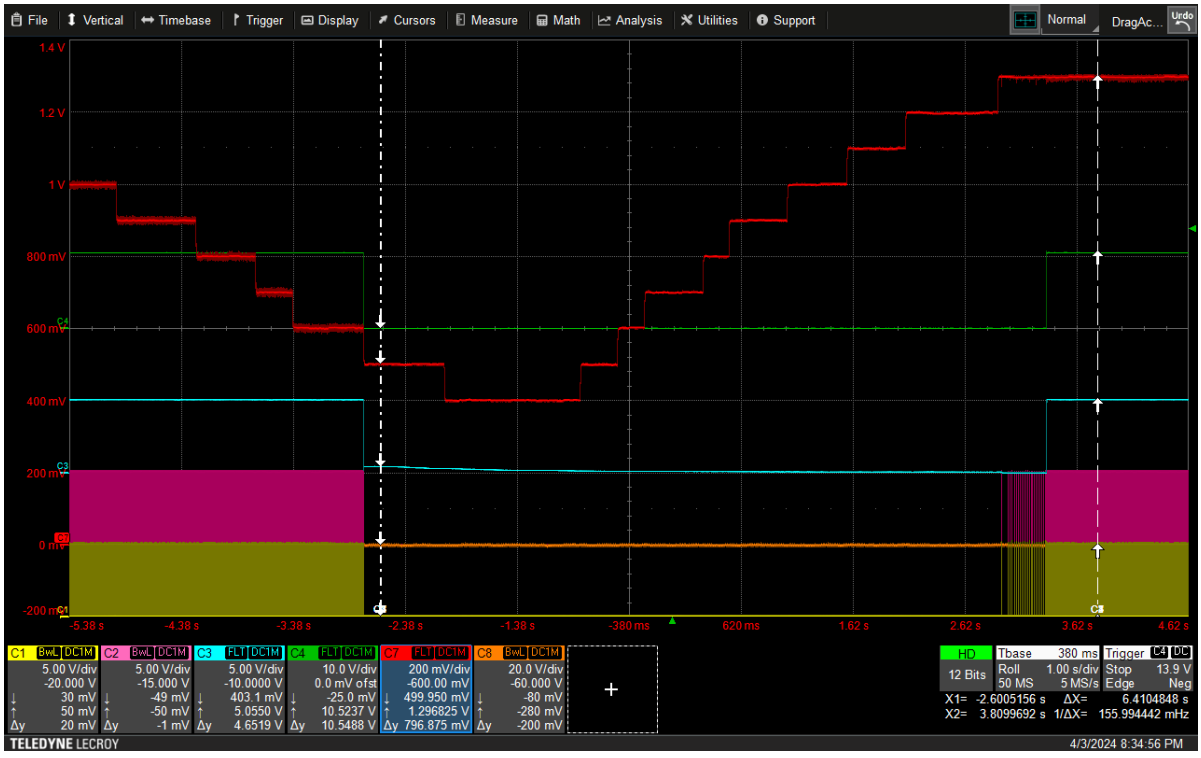


12.6 OTP protection on primary side

To check the OTP protection on the primary side, a voltage generator is attached to the POTP pin. In this way it is possible to trigger the protection without heating. When the voltage on the POTP pin is decreased and bypasses the V_{POVTH} (equal to 600 mV) threshold, the VBUS and LON are turned off. Then, when the voltage is increased and bypasses the 1.24 V threshold, the fault condition is cleared. In Figure 165:

- Yellow = LON 5 V/div
- Pink = HON 5 V/div
- Light blue = V_{BUS} 5 V/div
- Green = ORGD 10 V/div
- Red = V_{POTP} 200 mV/div

Figure 165. OTP protection on primary side – 5 V output – 1 A load – 90 V_{AC} input



13 Efficiency measurements

In this section the efficiencies of all the PDO profiles are reported. An automatic test setup has been used to perform this test. The output voltage has been measured at the board end (on top of capacitor C31), while the current is measured from the DC active load. The input power has been captured using a digital power meter, while the output power has been calculated as the product between V_{OUT} and I_{OUT}. Below are the steps to follow for the measurements:

1. Turn on the board at 5 V output - 90 V_{AC} - 10% load
2. Wait 10 seconds
3. Measure the efficiency for 5 times (one second between each measurement) and calculate the mean value
4. Repeat step 3 for each load value
5. Repeat steps 3 and 4 for 115 V_{AC} input and then for 230 V_{AC} and 250 V_{AC}
6. Repeat steps 1, 2, 3, 4, and 5 for output voltage 9 V and then for 15 V, 20 V, and 28 V

Table 2 to Table 5 show the results for different input voltages and with output load at 100%, 75%, 50%, 25%, and 10%.

Table 2. **Efficiency at 90 V_{AC}**

VIN [V_{AC}]	Output load [%]	V_{OUT} [V]	I_{OUT} [A]	P_{OUT} [W]	P_{IN} [W]	η [%]
90 V_{AC}/50 Hz	**5V output**					
	10%	5.063	0.373	1.89	2.144	88
	25%	5.027	0.928	4.66	5.12	91.1
	50%	4.998	1.874	9.37	10.25	91.4
	75%	4.957	2.804	13.90	15.31	90.8
	100%	4.901	3.750	18.38	20.504	89.6
	Average (100, 75, 50, 25 %) = 90.73					
	9V output					
	10%	9.054	0.372	3.36	3.79	88.8
	25%	9.028	0.927	8.37	9.11	91.9
	50%	8.994	1.872	16.84	18.232	92.4
	75%	8.950	2.802	25.08	27.272	92.0
	100%	8.899	3.748	33.36	36.56	91.2
	Average (100, 75, 50, 25 %) = 91.88					
	15V output					
	10%	15.025	0.372	5.58	6.138	91.0
	25%	15.002	0.927	13.90	14.996	92.7
	50%	14.962	1.871	28.00	30.152	92.8
	75%	14.923	2.801	41.81	45.25	92.4
	100%	14.874	3.746	55.72	60.876	91.5
	Average (100, 75, 50, 25 %) = 92.35					
	20V output					
	10%	20.037	0.490	9.82	12.108	81.1
	25%	20.008	1.241	24.82	27.69	89.6
	50%	19.960	2.486	49.62	53.722	92.4
	75%	19.906	3.746	74.57	80.196	93.0
	100%	19.843	4.991	99.04	106.924	92.6
	Average (100, 75, 50, 25 %) = 91.90					
	28V output					
	10%	28.064	0.490	13.75	16.51	83.3
	25%	28.042	1.239	34.75	38.432	90.4
	50%	28.001	2.485	69.57	75.104	92.6
	75%	27.942	3.745	104.64	112.402	93.1
	100%	27.887	4.990	139.16	150.408	92.5
	Average (100, 75, 50, 25 %) = 92.15					

Table 3. **Efficiency at 115 V_{AC}**

VIN [V_{AC}]	Output load [%]	V_{OUT} [V]	I_{OUT} [A]	P_{OUT} [W]	P_{IN} [W]	η [%]
115 V_{AC}/60 Hz	**5V output**					
	10%	5.065	0.372	1.89	2.15	87.7
	25%	5.033	0.928	4.67	5.11	91.4
	50%	5.001	1.874	9.37	10.21	91.8
	75%	4.959	2.805	13.91	15.232	91.3
	100%	4.906	3.749	18.39	20.376	90.3
	Average (100, 75, 50, 25 %) = 91.2					
	9V output					
	10%	9.061	0.372	3.37	3.79	89.0
	25%	9.035	0.928	8.38	9.07	92.4
	50%	9.001	1.873	16.86	18.138	92.9
	75%	8.961	2.802	25.11	27.086	92.7
	100%	8.909	3.748	33.39	36.238	92.1
	Average (100, 75, 50, 25 %) = 92.53					
	15V output					
	10%	15.041	0.370	5.57	6.124	90.9
	25%	15.017	0.927	13.91	14.93	93.2
	50%	14.977	1.873	28.04	29.948	93.6
	75%	14.933	2.802	41.85	44.822	93.4
	100%	14.893	3.747	55.80	60.008	93.0
	Average (100, 75, 50, 25 %) = 93.30					
	20V output					
	10%	20.047	0.491	9.84	12.14	81.1
	25%	20.016	1.240	24.83	27.988	88.7
	50%	19.965	2.486	49.62	53.812	92.2
	75%	19.911	3.746	74.59	80.004	93.2
	100%	19.846	4.991	99.05	106.406	93.1
	Average (100, 75, 50, 25 %) = 91.80					
	28V output					
	10%	28.086	0.489	13.73	16.904	81.2
	25%	28.056	1.240	34.78	38.666	89.9
	50%	28.014	2.484	69.59	74.996	92.8
	75%	27.954	3.743	104.64	111.786	93.6
	100%	27.893	4.990	139.19	149.044	93.4
	Average (100, 75, 50, 25 %) = 92.43					

Table 4. **Efficiency at 230 V_{AC}**

VIN [V_{AC}]	Output load [%]	V_{OUT} [V]	I_{OUT} [A]	P_{OUT} [W]	P_{IN} [W]	η [%]
230 V_{AC}/50 Hz	**5V output**					
	10%	5.033	0.373	1.88	2.208	84.9
	25%	5.031	0.929	4.67	5.14	90.9
	50%	4.999	1.874	9.37	10.214	91.7
	75%	4.963	2.805	13.92	15.244	91.3
	100%	4.924	3.750	18.46	20.306	90.9
	Average (100, 75, 50, 25 %) = 91.20					
	9V output					
	10%	9.059	0.372	3.37	3.864	87.1
	25%	9.035	0.927	8.38	9.08	92.3
	50%	9.001	1.873	16.86	18.062	93.3
	75%	8.962	2.802	25.11	26.864	93.5
	100%	8.906	3.748	33.38	35.84	93.1
	Average (100, 75, 50, 25 %) = 93.05					
	15V output					
	10%	15.040	0.369	5.56	6.178	89.9
	25%	15.017	0.926	13.90	14.884	93.4
	50%	14.973	1.871	28.01	29.762	94.1
	75%	14.934	2.801	41.83	44.318	94.4
	100%	14.893	3.747	55.8	59.148	94.3
	Average (100, 75, 50, 25 %) = 94.05					
	20V output					
	10%	20.039	0.491	9.83	11.32	86.8
	25%	20.009	1.241	24.82	27.598	90.0
	50%	19.955	2.485	49.59	53.882	92.0
	75%	19.891	3.745	74.50	80.384	92.7
	100%	19.837	4.992	99.02	106.164	93.3
	Average (100, 75, 50, 25 %) = 92.00					
	28V output					
	10%	28.104	0.488	13.71	16.316	84.0
	25%	28.075	1.238	34.76	38.474	90.3
	50%	28.016	2.483	69.57	75.594	92.0
	75%	27.962	3.743	104.67	111.508	93.9
	100%	27.901	4.989	139.20	147.93	94.1
	Average (100, 75, 50, 25 %) = 92.58					

Table 5. **Efficiency at 250 V_{AC}**

VIN [V_{AC}]	Output load [%]	V_{OUT} [V]	I_{OUT} [A]	P_{OUT} [W]	P_{IN} [W]	η [%]
250 V_{AC}/60 Hz	**5V output**					
	10%	5.038	0.372	1.87	2.228	84.1
	25%	5.033	0.928	4.67	5.164	90.5
	50%	5.000	1.875	9.38	10.258	91.4
	75%	4.964	2.804	13.92	15.312	90.9
	100%	4.926	2.804	18.47	20.364	90.7
	Average (100, 75, 50, 25 %) = 90.88					
	9V output					
	10%	9.065	0.372	3.38	3.88	87.0
	25%	9.039	0.928	8.38	9.092	92.2
	50%	9.007	1.872	16.86	18.09	93.2
	75%	8.965	2.804	25.13	26.89	93.5
	100%	8.912	3.749	33.41	35.852	93.2
	Average (100, 75, 50, 25 %) = 93.03					
	15V output					
	10%	15.045	0.370	5.57	6.204	89.8
	25%	15.018	0.926	13.90	14.918	93.2
	50%	14.978	1.870	28.01	29.8	94.0
	75%	14.934	2.801	41.84	44.318	94.4
	100%	14.895	3.746	55.80	59.162	94.3
	Average (100, 75, 50, 25 %) = 93.98					
	20V output					
	10%	20.059	0.490	9.82	11.444	85.8
	25%	20.027	1.239	24.82	27.506	90.2
	50%	19.972	2.484	49.62	53.53	92.7
	75%	19.913	3.745	74.58	80.618	92.5
	100%	19.857	4.991	99.11	106.412	93.1
	Average (100, 75, 50, 25 %) = 92.13					
	28V output					
	10%	28.117	0.488	13.71	15.718	87.2
	25%	28.082	1.238	34.77	38.176	91.1
	50%	28.027	2.483	69.59	75.756	91.9
	75%	27.966	3.743	104.69	111.644	93.8
	100%	27.907	4.988	139.18	148.178	93.9
	Average (100, 75, 50, 25 %) = 92.68					

Table 6 shows the results of EVLONE140W no load consumption at 115 V_{AC} and 230 V_{AC}. The consumption has been measured 5 minutes after the power on and without a type C wire connected to the type C output port:

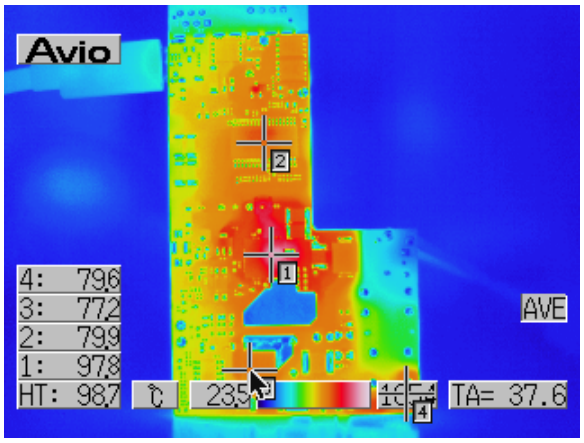
Table 6. **Consumption at no load without wire**

5 V output - no load - no wire	
115 V_{AC} / 60 Hz	**230 V_{AC} / 50 Hz**
Pin [mW]	Pin [mW]
54.622	103.74

14 Thermal measurements

A thermal analysis of the board has been performed with an infrared thermal imaging camera. The test was performed with the output voltage set to 28 V under full load condition. The test has been performed at 115 V_{AC} and 230 V_{AC}. Figure 166 to Figure 169 show the thermal results after 30 minutes from turning on the board.

Figure 166. Thermal image at 115 V_{AC} – bottom view



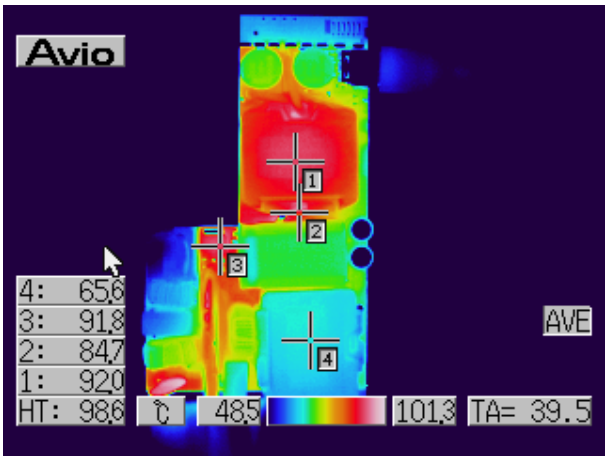
MasterGaN = 97.8 °C

ST-ONEHP = 79.9 °C

PFC MOS = 77.2 °C

NTC thermistor = 79.6 °C

Figure 167. Thermal image at 115 V_{AC} – top view



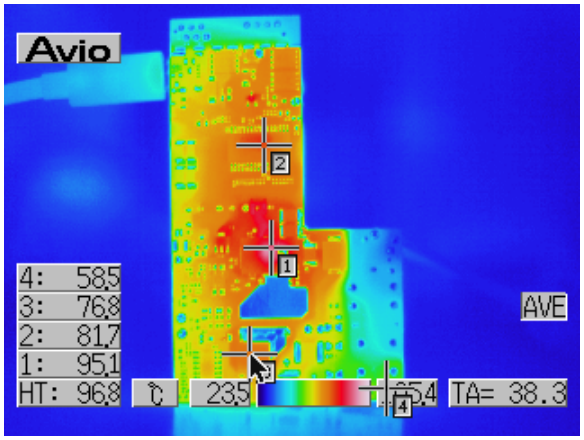
Transformer core = 92.0 °C

Transformer winding = 84.7 °C

PFC diode = 91.8 °C

PFC choke core = 65.6 °C

Figure 168. Thermal image at 230 V_{AC} – bottom view



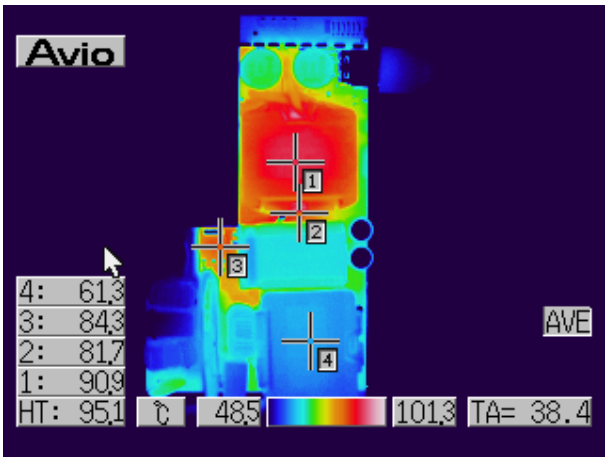
MasterGaN = 95.1 °C

ST-ONEHP = 81.7 °C

PFC MOS = 76.8 °C

NTC thermistor = 58.5 °C

Figure 169. Thermal image at 230 V_{AC} – top view



Transformer core = 90.9 °C

Transformer winding = 81.7 °C

PFC diode = 84.3 °C

PFC choke core = 61.3 °C

15 Bill of materials

Table 7. **EVLONE140W main board - Bill of materials**

Item	Q.ty	Reference	Value	Description	Manuf. Code	Manufacturer
1	1	C3	470nF	SMD Multilayer Ceramic Cap.	GRM55DR72H474KW10L	Murata
2	1	C4	470nF	SMD Multilayer Ceramic Cap.	CGA8N4X7T2W474K230KA	TDK
3	2	C9, C78	47nF/630V	SMD Multilayer Ceramic Cap.	C4532NP02J473J320KA	TDK
4	3	C10, C58, C59	22n/0402/50V	SMD Multilayer Ceramic Cap.	C1005X7R1H223K050BE	TDK
5	2	C11, C12	100n/0402/50V	SMD Multilayer Ceramic Cap. Automotive	GCM155R71H104KE02J	Murata
6	1	C13	10pF/1KV	SMD Multilayer Ceramic Cap.	CC1206JKNPOCBN100	Yageo
7	1	C14	2.2u/100V	SMD Multilayer Ceramic Cap.	885012209071	Würth Elektronik
8	2	C15, C79	15u/100V	Radial Electrolytic Cap. D.6.3mm - Pitch 2.5mm - h.11mm	100ZL15MEFC6.3X11	RUBYCON
9	2	C16, C32	100n/100V	SMD Multilayer Ceramic Cap.	885012206120	Würth Elektronik
10	1	C17	22u	SMD Multilayer Ceramic Cap.	GRT21BR61E226ME13L	Murata
11	4	C18, C19, C31, C33	4.7u	SMD Multilayer Ceramic Cap. Automotive	CGA4J1X7R1H475K125AC	TDK
12	1	C20	47nF/50V	SMD Multilayer Ceramic Cap.	C1608X7R1H473K080AA	TDK
13	4	C21, C22, C23, C38	100n	SMD Multilayer Ceramic Cap. Automotive	GCM155R71H104KE02J	Murata
14	2	C24, C25	100p	SMD Multilayer Ceramic Cap. Automotive	GCM1555C1H101JA16D	Murata
15	1	C26	220p	SMD Multilayer Ceramic Cap.	GRM155R71H221JA01D	Murata
16	1	C27	1uF/50V	SMD Multilayer Ceramic Cap.	CC0603KRX7R9BB105	Yageo
17	2	C29, C65	820u/35V	SMD Electrolytic Cap. Automotive		
18	1	C30	22u	SMD Multilayer Ceramic Cap.	C3216X5R1V226M160AC	TDK
19	3	C34, C66, C74	10n/50V	SMD Multilayer Ceramic Cap.	GCM155R71H103KA55	Murata
20	2	C35, C36	1u	SMD Multilayer Ceramic Cap.	C1005X5R1V105K050BC	TDK
21	1	C37	4.7u	SMD Multilayer Ceramic Cap.	GRM155D81A475ME15D	Murata

Item	Q.ty	Reference	Value	Description	Manuf. Code	Manufacturer
22	1	C39	22n	SMD Multilayer Ceramic Cap.	C1005X7R1E223K050BB	TDK
23	4	C40, C41, C47, C76	DNM	SMD Multilayer Ceramic Cap.		
24	4	C42, C67, C68, C69	100n/50V	SMD Multilayer Ceramic Cap. Automotive	GCM155R71H104KE02J	Murata
25	1	C77	47n/50V	SMD Multilayer Ceramic Cap.	GRM155R71H473KE14D	Murata
26	1	C48	100n/0402/50V	SMD Multilayer Ceramic Cap. Automotive	GCM155R71H104KE02J	Murata
27	1	C52	1uF	SMD Multilayer Ceramic Cap.	885342214001	Würth Elektronik
28	2	C55, C63	2n2/0402/50V	SMD Multilayer Ceramic Cap. Automotive	GCM155R71H222KA37D	Murata
29	2	C57, C60	1u/0402/35V	SMD Multilayer Ceramic Cap.	C1005X5R1V105K050BC	TDK
30	1	C61	220p/0402/50V	SMD Multilayer Ceramic Cap.	C0402C221J5GACTU	KEMET
31	1	C62	10pF/1206/2KV	SMD Multilayer Ceramic Cap.	CC1206JKNPODBN100	Yageo
32	1	C73	2.2u/0402/35V	SMD Multilayer Ceramic Cap.	C1005X5R1V225K050BC	TDK
33	1	C75	4.7uF/50V	SMD Multilayer Ceramic Cap.	C2012X7R1H475K125AC	TDK
34	1	CE1	EWH2WM820L25OT 82uF 16X25mm	Cap Pol Radial (Electrolytic); 7.50mm C X 16.00mm Dia X 31.50mm H body	EWH2WM820L25OT	AISHI
35	1	CX1	220nF	Radial Polypropylene Metall. Cap.	890334025027CS	Würth Elektronik
36	1	CX2	470nF	Radial Polypropylene Metall. Cap.	890334026020	Würth Elektronik
37	4	CY1, CY2, CY3, CY4	1nF	SMD Multilayer Ceramic Cap.	SCC1808X102K502TG	Holy Stone Enterprise
38	1	D3	S1ML	SMD Diode	S1ML R3G	Taiwan Semi
39	1	D4	RS1ML	Diode SMD SOD-123F, DO-219AB	RS1ML R3G	Taiwan Semiconductor
40	1	D5	BAS21LL	High-voltage Switching Diode	BAS21LLYL	Nexperia
41	1	D6	BAS16LD	SMD Fast Switching Rectifier	BAS16LD	NXP
42	1	D7	CDZVT2R11B	Zener Diodes	CDZVT2R11B	ROHM Semiconductor
43	1	D8	ES1JFL	SMD Diode	ES1JFL	On Semiconductor
44	2	D9, D32	CDZVT2R6.2B	Zener Diodes	CDZVT2R6.2B	ROHM Semiconductor

Item	Q.ty	Reference	Value	Description	Manuf. Code	Manufacturer
45	1	D10	BAT54SW	SMD Schottky Rectifiers Array	BAT54SWFILM	STMicroelectronics
46	1	D11	SMAJ33A-TR	SMD Transient Voltage Rectifier	SMAJ33A-TR	STMicroelectronics
47	1	D12	GSOT36C	SMD Two-Line ESD Protection in SOT-23	GSOT36C-E3-08	VISHAY
48	1	D15	1N4148WS	Diode SMD SOD-323F, SC-90	1N4148WS	ON SEMICONDUCTOR
49	1	D16	STTH5L06B-TR	Diode GEN PURP 600V 5A DPAK	STTH5L06B-TR	STMicroelectronics
50	1	D19	S3M-13-F	High-voltage Switching Diode	S3M-13-F	Diodes
51	1	D21	DZ9F15S92-7	Zener Diodes	DZ9F15S92-7	Diodes
52	1	D22	BZX884B18L	SMD Zener Diode	BZX884B18L-HG3-08	VISHAY
53	1	D23	DNM	Zener Diode 15V 250MW SOT23		
54	1	D29	BAT54HT1G	SMD Schottky Rectifier	BAT54HT1G	ON SEMICONDUCTOR
55	3	D30, D31, D33	1N4148WS	Diode SMD SOD-323F, SC-90	1N4148WS	ON SEMICONDUCTOR
56	1	F1	Fuse 3.15A 250V	Fuses with Leads (Through Hole) 2.5A 250V SS-5F-RADIAL FA FUSE	39213150000	Littelfuse
57	4	GH, GL, GP0, GP1	DNM	PTH Test Point Pad. Ignore.		
58	5	HON, LON, SRGD, VO1, VO2	DNM	SMD Test Point Pad. Ignore!		
59	1	J1	Input pads	Plated Holes for cable. Ignore.		
60	1	J2	USB Type-C®-Receptacle	Conn SMD USB3.1 Type C, SMD, receptacle, right angle	2012670005	MOLEX
61	1	J3	90325-0006	Conn Flat Male 6 pins, straight, Pitch 1.27mm	90325-0006	MOLEX
62	1	J5	STRIP4PMD	Male Strip 4 pins pitch 2.54 180°	61300411121	Würth Elektronik
63	1	J7	Active bridge	CONN HEADER .100 DUAL STR 6POS		
64	1	L1	1mH 10kHz 900mA	Common-mode Choke		
65	1	L4	100uH	WE-FI Leaded Toroidal Line Choke		
66	1	L5	15mH 10kHz 2000mA	Common-mode Choke		
67	1	L6	250uH	PFC choke - 250uH - 100kHz - 140W	ATQ27	Allied Components International

Item	Q.ty	Reference	Value	Description	Manuf. Code	Manufacturer
68	3	LN1, LN2, LN3	LINK	PCB LINK. IGNORE!		
69	1	MG1	MasterGaN	High power density half-bridge 650V GaN with embedded driver	MASTERGAN1	STMicroelectronics
70	1	Q1	BSS139H6327	SMD N-ch MOSFET	BSS139H6327XTSA1	Infineon Technologies
71	1	Q2	CPC3703	SMD N-ch MOSFET	CPC3703CTR	IXYS
72	3	Q3, Q23, Q29	BC847CM	SMD NPN Transistor General Purpose	BC847CM,315	Nexperia USA Inc.
73	2	Q4, Q25	BSC093N15NS5	N-channel 60 V, 2 mO typ., 120 A STripFET F7	BSC093N15NS5ATMA1	Infineon Technologies
74	1	Q5	ZVN3320FTA	SMD N-ch MOSFET	ZVN3320FTA	Diodes Incorporated
75	1	Q10	STL36N60M6	SMD N-ch Power MOSFET	STL36N60M6	STMicroelectronics
76	2	Q11, Q20	BSS84-7-F	MOSFET P-CH 150V 0.53A SOT23-3	BSS84-7-F	Diodes
77	1	Q14	RS1G201A	SMD Pch -40V -78A Power MOSFET	RS1G201ATTB1	ROHM
78	1	Q15	2N7002,215	MOSFET 60V 240mA 0.35W 3.0ohm @ 10V	2N7002,215	NEXPERIA
79	2	Q16, Q26	BSS159N H6327	MOSFET N-CH 100V 0.17A SOT-23	BSS159N H6327	Infineon Technologies
80	3	Q17, Q18, Q19	2N7002E-T1-GE3	MOSFET 60V 240mA 0.35W 3.0ohm @ 10V	2N7002E-T1-GE3	Vishay Semiconductors
81	1	Q28	BC807-40W,115	TRANS PNP 40V 0.2A SOT323	BC807-40W,115	NEXPERIA
82	1	R2	2.2M	SMD Resistor Automotive	AC0805FR-072M2L	Yageo
83	1	R3	20R	SMD Resistor	RC0603FR-0720RL	Yageo
84	2	R4, R9	220R	SMD Resistor	RC0402FR-07220RL	Yageo
85	4	R5, R6, R7, R8	0R47	SMD Resistor Automotive	SR731JTTDR470F	KOA Speer
86	1	R10	1K	SMD Resistor	RC0603FR-071KL	Yageo
87	1	R11	205k	SMD Resistor	RC0402FR-07205KL	Yageo
88	1	R12	1k5	SMD Resistor	RC0402FR-071K5L	Yageo
89	1	R13	18K1%	SMD Resistor	RC0402FR-0718KL	Yageo
90	1	R14	270K1%	SMD Resistor	RC0402FR-07270KL	Yageo
91	1	R15	470K	SMD Resistor	RC0402FR-07470KL	Yageo
92	6	R16, R18, R37, R38, R68, R71	47K	SMD Resistor	RC0402FR-0747KL	Yageo

Item	Q.ty	Reference	Value	Description	Manuf. Code	Manufacturer
93	1	R17	93K1	SMD Resistor	RT0402FRE0793K1L	Yageo
94	1	R19	10R	SMD Resistor	CRCW040210R0JNED	Vishay
95	1	R20	120K	SMD Resistor	RC0402FR-07120KL	Yageo
96	1	R21	430K	SMD Resistor	RC0402FR-07430KL	Yageo
97	1	R22	22R	SMD Resistor	RC0805FR-7W22RL	Yageo
98	4	R23, R28, R34, R86	100K	SMD Resistor	RC0402FR-07100KL	Yageo
99	2	R24, R35	0R0	SMD Resistor	RMCF0402ZT0R00	Stackpole Electronics
100	1	R25	221k	SMD Resistor	RC0402FR-07221KL	Yageo
101	1	R27	1K	SMD Resistor	RC0402JR-071KL	Yageo
102	1	R29	150R	SMD Resistor Automotive	CRCW0402150RFKED	VISHAY
103	1	R30	300K	SMD Resistor	RC0402FR-07300KL	Yageo
104	1	R32	0R005	SMD Very High Power, Low Value Resistor	WSLP08055L000FEA18	VISHAY
105	2	R33, R72	100R	SMD Resistor	RC0402FR-07100RL	Yageo
106	1	R36	47R	SMD Resistor	RC0402FR-0747RL	Yageo
107	1	R39	20K	SMD Resistor Automotive	CRCW060320K0FKEA	VISHAY
108	1	R40	0R15	SMD Resistor Automotive	PT2512FK-7W0R15L	Yageo
109	1	R41	0R01	SMD Current Sense Resistor	WSLP0805R0100FEA18	VISHAY
110	1	R45	33K/0402/0.5%	SMD Resistor Automotive	ERA-2AED333X	PANASONIC
111	3	R46, R47, R48	4M7/0603/1%	SMD Current Sense Resistor	RC0603FR-074M7L	Yageo
112	1	R49	82K/0402/0.5%	SMD Resistor	RT0402DRE0782KL	Yageo
113	2	R51, R59	100k/0402	SMD Resistor	RC0402FR-07100KL	Yageo
114	3	R53, R62, R63	51k/0402/0.5%	SMD Resistor Automotive	ERA-2AED513X	PANASONIC
115	1	R54	68k/0402/1%	SMD Resistor	RC0402FR-0768KL	Yageo
116	1	R55	92k/0402/0.1%	SMD Resistor	RT0402BRD0792KL	Yageo
117	1	R56	1M/0402	SMD Resistor Automotive	ERJ-2RKF1004X	PANASONIC
118	1	R57	4R7/0603	SMD Resistor	RMCF0603FT4R70	Stackpole Electronics
119	1	R58	27R/0603	SMD Resistor	RMCF0603FT27R0	Stackpole Electronics
120	1	R64	470R/0402	SMD Resistor	RC0402JR-13470RL	Yageo
121	1	R67	475k	SMD Resistor Automotive	ERJ-2RKF4753X	PANASONIC
122	1	R69	39k/0.5%	SMD Resistor Automotive	ERA-2AED393X	PANASONIC
123	1	R70	2.7k/0.5%	SMD Resistor Automotive	RNCF0402DTE2K70	Stackpole Electronics
124	1	R73	560k/1%	SMD Resistor	RC0402FR-13560KL	Yageo
125	2	R74, R96	DNM	SMD Resistor	MCR01MZPJ000	ROHM

Item	Q.ty	Reference	Value	Description	Manuf. Code	Manufacturer
126	1	R75	10K/1%	SMD Resistor Automotive	ERJ2RKF1002X	PANASONIC
127	1	R76	4.3M/1%	SMD Resistor Automotive	CRCW04024M30FKED	VISHAY
128	3	R89, R90, R91	2.2M/0603/1%	SMD Resistor	RC0603FR-072M2L	Yageo
129	3	R92, R93, R94	1.1M/0805/0.5%	SMD Resistor Automotive	RN73R2ATTD1104D25	KOA Speer
130	1	R97	100K/0603/1%	SMD Resistor	CRG0603F100K	TE Connectivity
131	1	R98	6.8M	SMD Resistor Automotive	CRCW04026M80FKED	VISHAY
132 (1)	1	R99	1R5	SMD Resistor	RC0402FR-071R5L	Yageo
133	1	RT1	DNM	SMD Thermistor NTC	NCP15WM474J03RC	Murata
134	1	RT2	SCK10054MSY	Thermistor NTC 1OHM 2600K	SCK10054MSY	Thinking Electronics Industrial Co.
135	1	RV1	820513011	VARISTOR 470V 2.5KA DISC 10mm	820513011	Würth Elektronik
136	1	T1	215uH	Switch Mode Transformer 140W - 120kHz - 215uH	ATQ27	Allied Components International
137	1	U1	ST-ONEHP	STMicroelectronics Fully integrated controller for smart chargers	ST-ONEHP	STMicroelectronics
138	1	U2	LDO40LPURY	SMD 400mA, 38V low-dropout regulator	LDO40LPURY	STMicroelectronics
139	1	U3	L6563S	IC PFC CTRLR TRANSITION	L6563S	STMicroelectronics
140	1	U4	TS321ILT	SMD Low-power single operational amplifier	TS321ILT	STMicroelectronics

1. *In case the board does not turn on or if it shuts down during normal operation, check this resistor first. If it is broken, substitute it with the parallel of two 3 Ω resistors.*

Table 8. **Active Bridge daughterboard - Bill of materials**

Item	Q.ty	Reference	Value	Description	Package	Manuf. Code	Manufacturer
1	1	C1	100nF	SMD Multilayer Ceramic Cap. Automotive	0402	GCM155R71H104KE02J	Murata
2	4	C2, C5, C70, C71	22pF/50V	SMD Multilayer Ceramic Cap.	0402	CC0402JRNPO9BN220	Yageo
3	1	C51	1uF	SMD Multilayer Ceramic Cap.	2220	885342214001	Würth Elektronik
4	4	D24, D26, D27, D28	S1ML	SMD Rectifier	SOD-123F	S1ML	Taiwan Semiconductor
5	1	D25	Z4DGP408L-HF	SMD Bridge Rectifier	Z4-D	Z4DGP408L-HF	Comchip Technology
6	2	GD1,GD2	SDM PAD	PCB test point_SMD - Only SMD pad			
7	1	J8	DNM	CONN HEADER .100 DUAL STR 6POS			
8	2	Q21, Q22	STL36N60M6	SMD N-ch Power MOSFET	PowerFLAT8x8	STL36N60M6	STMicroelectronics
9	2	R1, R79	100K	SMD Resistor	0402	RC0402FR-07100KL	Yageo
10	2	R77, R81	10K	SMD Resistor	0603	RC0603FR-0710KL	Yageo
11	2	R78, R80	47K	SMD Resistor	0402	RC0402FR-0747KL	Yageo
12	2	R82, R83	47K	SMD Resistor	0603	RC0603FR-0747KL	Yageo
13	2	R84, R85	330K	SMD Resistor	0402	WR04X3303FTL	WALSIN
14	2	R86, R87	2M	SMD Resistor	0603	RC0603FR-072ML	Yageo
15	1	U5	LM293D	SMD Low-power, dual-voltage comparators	SO-8	LM293DT	STMicroelectronics

Revision history

Table 9. **Document revision history**

Date	Version	Changes
02-Aug-2024	1	Initial release.

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