Design **V**erification **T**est:

TDK Lambda DRF-960-24-1
Unit Rev 4.1
11-05-500437-1

1 Revision History

No.	Date	Changes / Notes	Editor
1.0	23.03.2016		FJ Möers
2.0	01.07.2016		FJ Möers
2.1	11.10.2016	Additional measurements	FJ Möers
3.0	20.10.2016	Rev. Level 3.0 of the unit	FJ Möers
4.0	18.12.2016	Rev. Level 4.0 of the unit	FJ Möers
4.1	17.05.2017	Rev. Level 4.1 of the unit	FJ Möers

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3 Characteristics

The Design Verification Test based on the specification „DRF960-24-1 Specification 260209 Rev5“.

3.1 Steady state data

3.1.1 Regulation

3.1.1.1 Line and load

Condition: Vout = 24V   Ta = 25°C

Iout / Vin	180VAC	230VAC	277VAC	Line regulation	
0%	24,118	24,118	24,118	0mV	0%
50%	24,098	24,098	24,099	1mV	0,004%
100%	24,066	24,066	24,067	1mV	0,004%
Load regulation	52mV	52mV	51mV		
	0,22%	0,22%	0,22%		

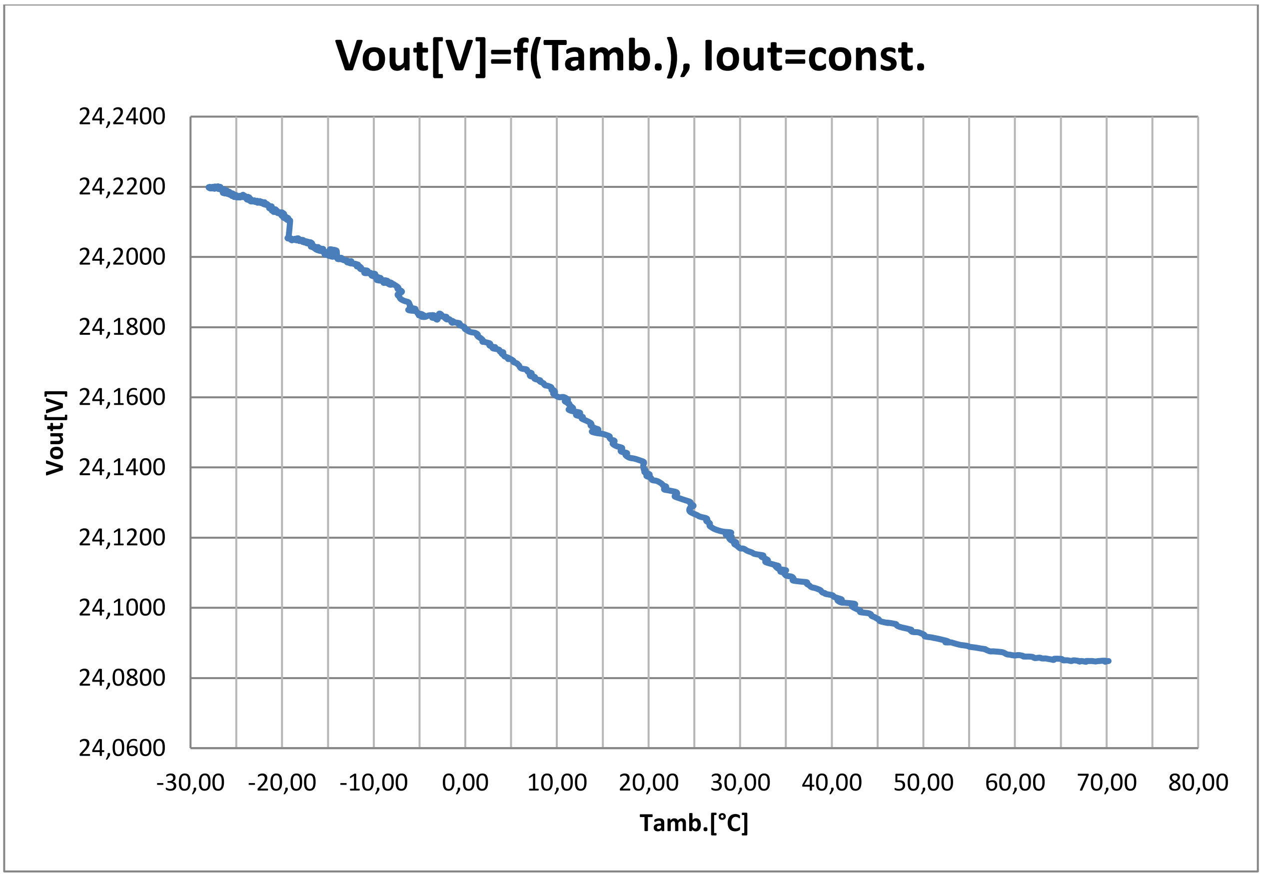
Condition: Vout = 28V   Ta = 25°C

Iout / Vin	180VAC	230VAC	277VAC	Line regulation	
0%	28,062	28,062	28,063	1mV	0,004%
50%	28,049	28,049	28,050	1mV	0,004%
100%	28,032	28,032	28,033	1mV	0,004%
Load regulation	30mV	30mV	30mV		
	0,11%	0,11%	0,11%		

3.1.1.2 Temperature drift

Condition: Vout = 24V Iout = 30A Ta = -25°C…..+70°C

The measurement was done with a cold start at -25°C. Then the ambient temperature was increased up to +70°C.



	Vout
-25°C	24,2173V
+70°C	24,0848V
ΔVout	0,1325V
Temperature Coefficient	0,0058%/K

The measured temperature drift is lower as the specified value of 0,02%/K.

Result: Pass

3.1.1.3 Start up voltage and Drop out voltage

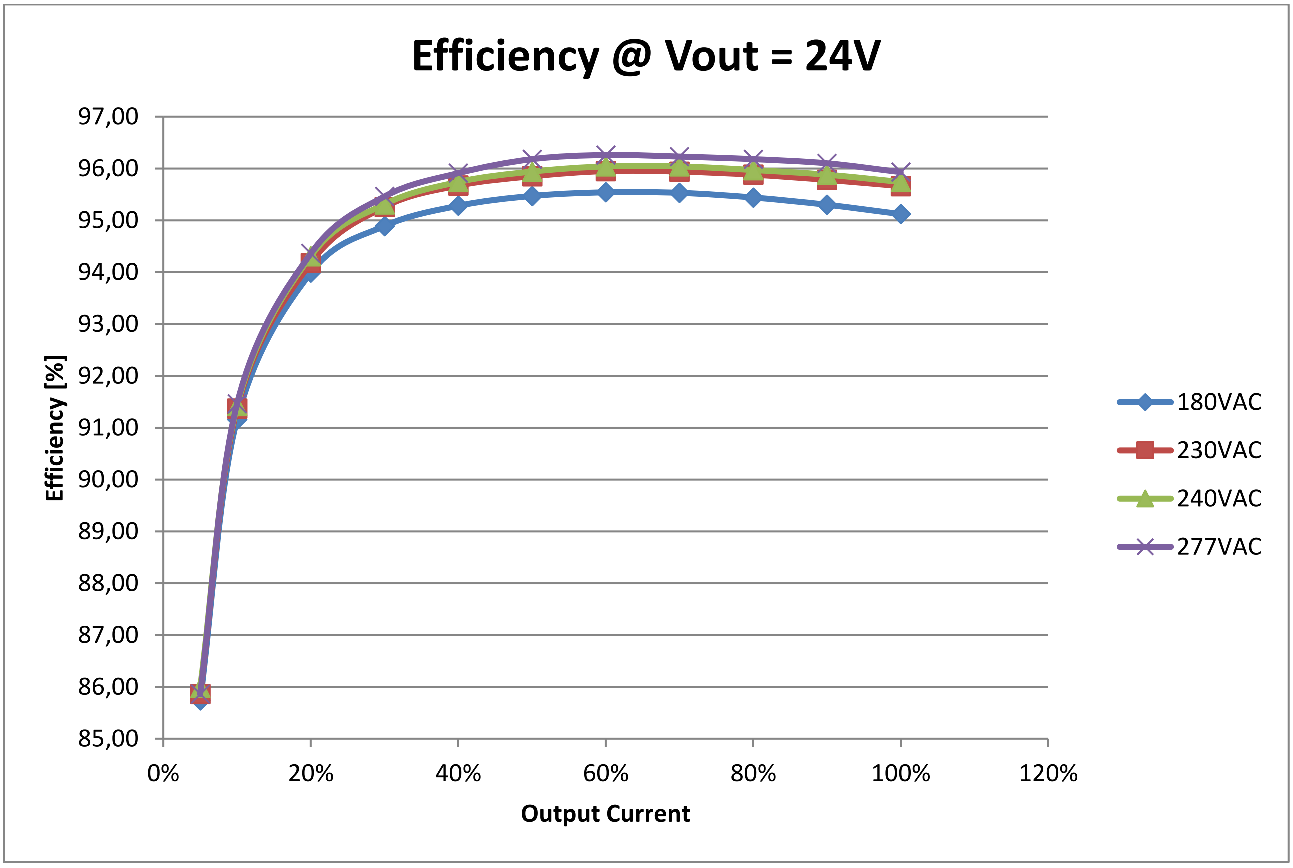
Condition: Vout = 24V Iout = 40A Ta = 25°C

Line Input	With isolation transformer	With an AC Source
Start up voltage (Vin)	174,5VAC	172,2VAC
Drop out voltage (Vin)	156,2VAC	156,7VAC

3.1.2 Efficiency vs. Output current

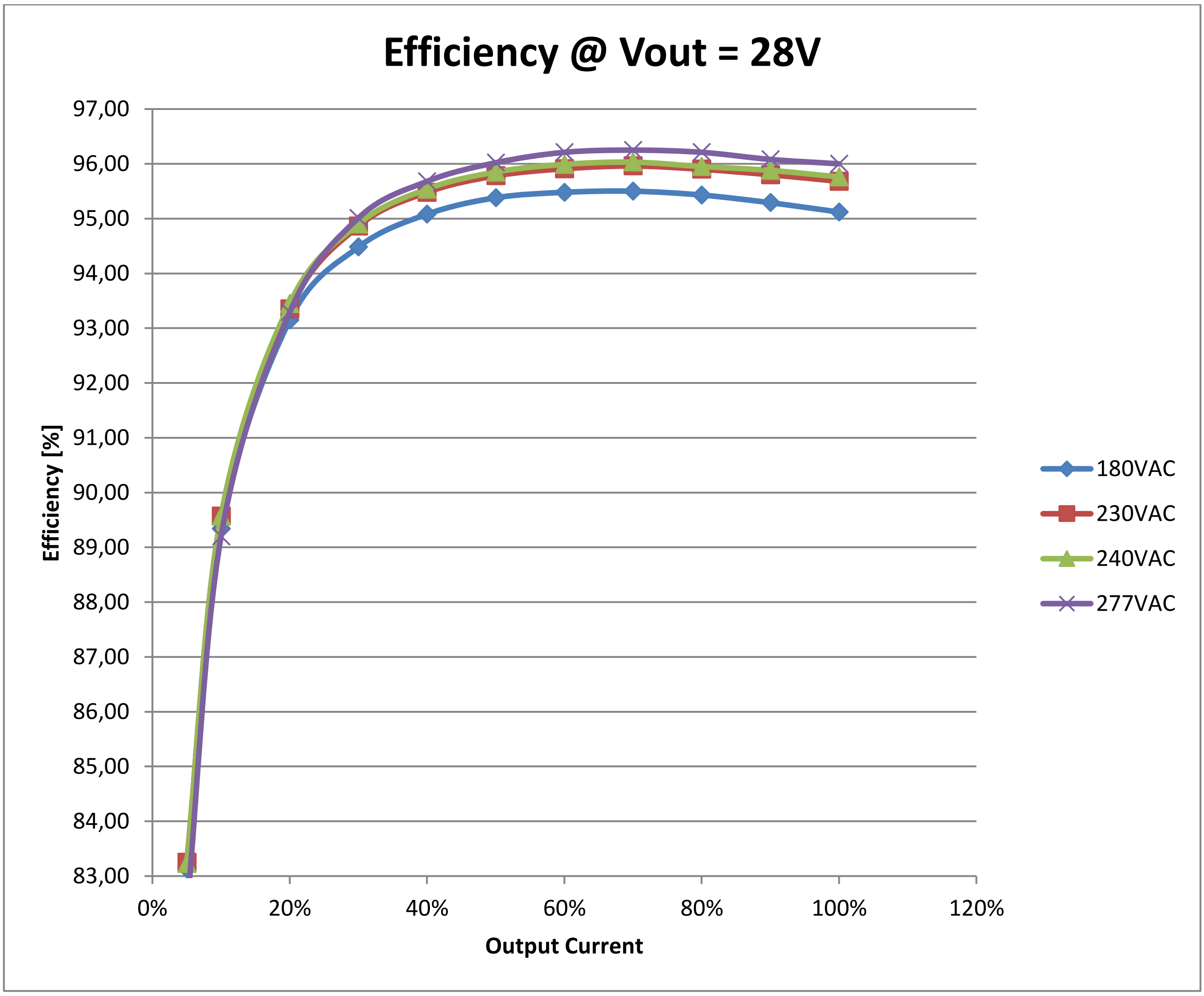
Condition: Vout = 24V Ta = 25°C

Iout / Vin	180VAC	230VAC	240VAC	277VAC	Iout [A]
5%	85,74	85,86	85,98	85,86	2,00
10%	91,16	91,37	91,42	91,46	4,00
20%	93,99	94,18	94,31	94,36	8,00
30%	94,89	95,26	95,31	95,46	12,00
40%	95,28	95,67	95,74	95,91	16,00
50%	95,47	95,85	95,94	96,18	20,00
60%	95,54	95,95	96,04	96,26	24,00
70%	95,53	95,94	96,04	96,23	28,00
80%	95,44	95,88	95,97	96,18	32,00
90%	95,30	95,78	95,88	96,10	36,00
100%	95,12	95,66	95,74	95,93	40,00



Condition: Vout = 28V Ta = 25°C

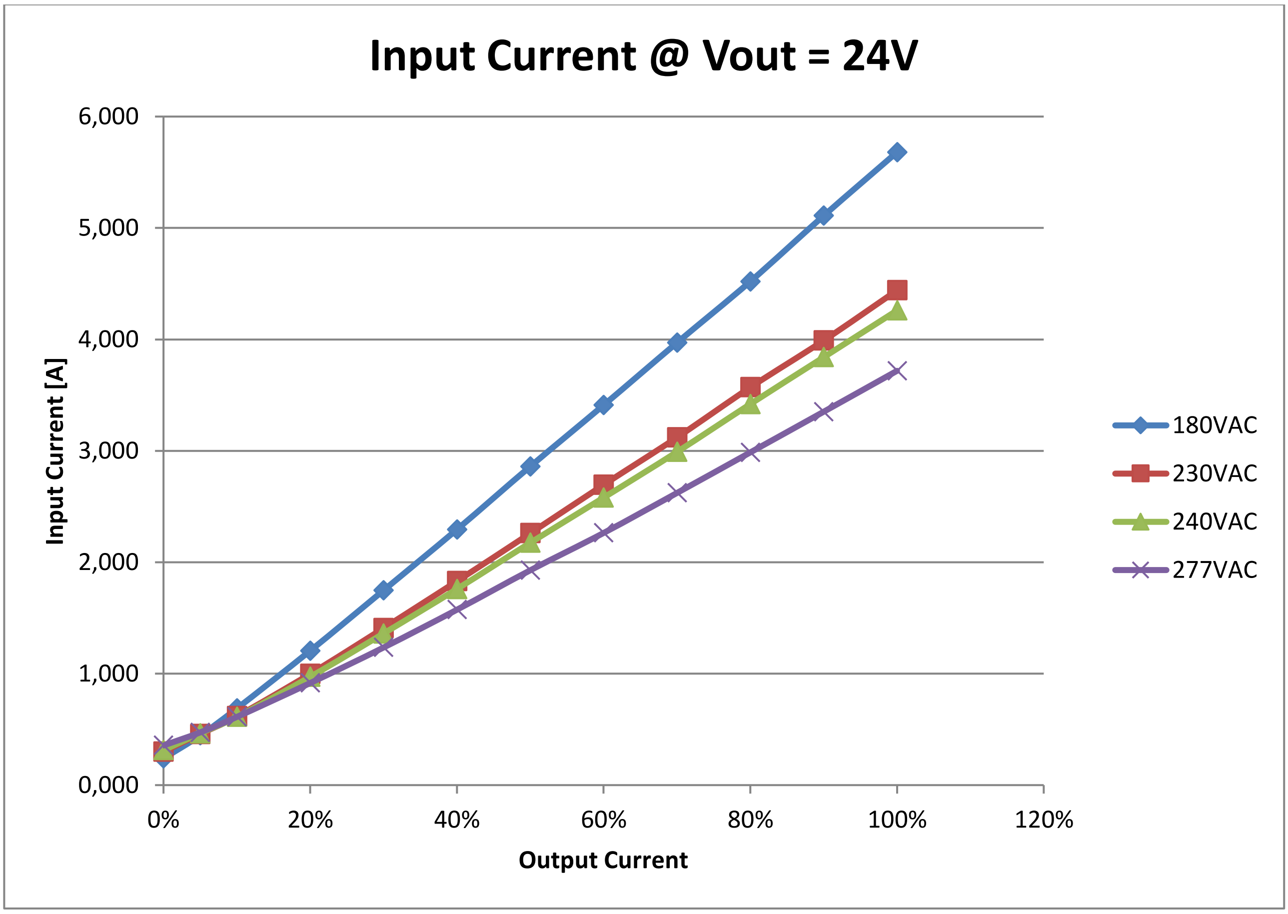
Iout / Vin	180VAC	230VAC	240VAC	277VAC	Iout [A]
5%	83,13	83,25	83,23	82,34	1,71
10%	89,34	89,57	89,57	89,20	3,43
20%	93,15	93,35	93,45	93,29	6,86
30%	94,48	94,86	94,90	95,01	10,29
40%	95,08	95,48	95,54	95,68	13,71
50%	95,38	95,78	95,85	96,02	17,14
60%	95,48	95,91	95,99	96,21	20,57
70%	95,50	95,96	96,03	96,25	24,00
80%	95,43	95,90	95,95	96,21	27,43
90%	95,29	95,80	95,88	96,08	30,86
100%	95,12	95,68	95,76	96,00	34,29



3.1.3 Input current vs. Output current

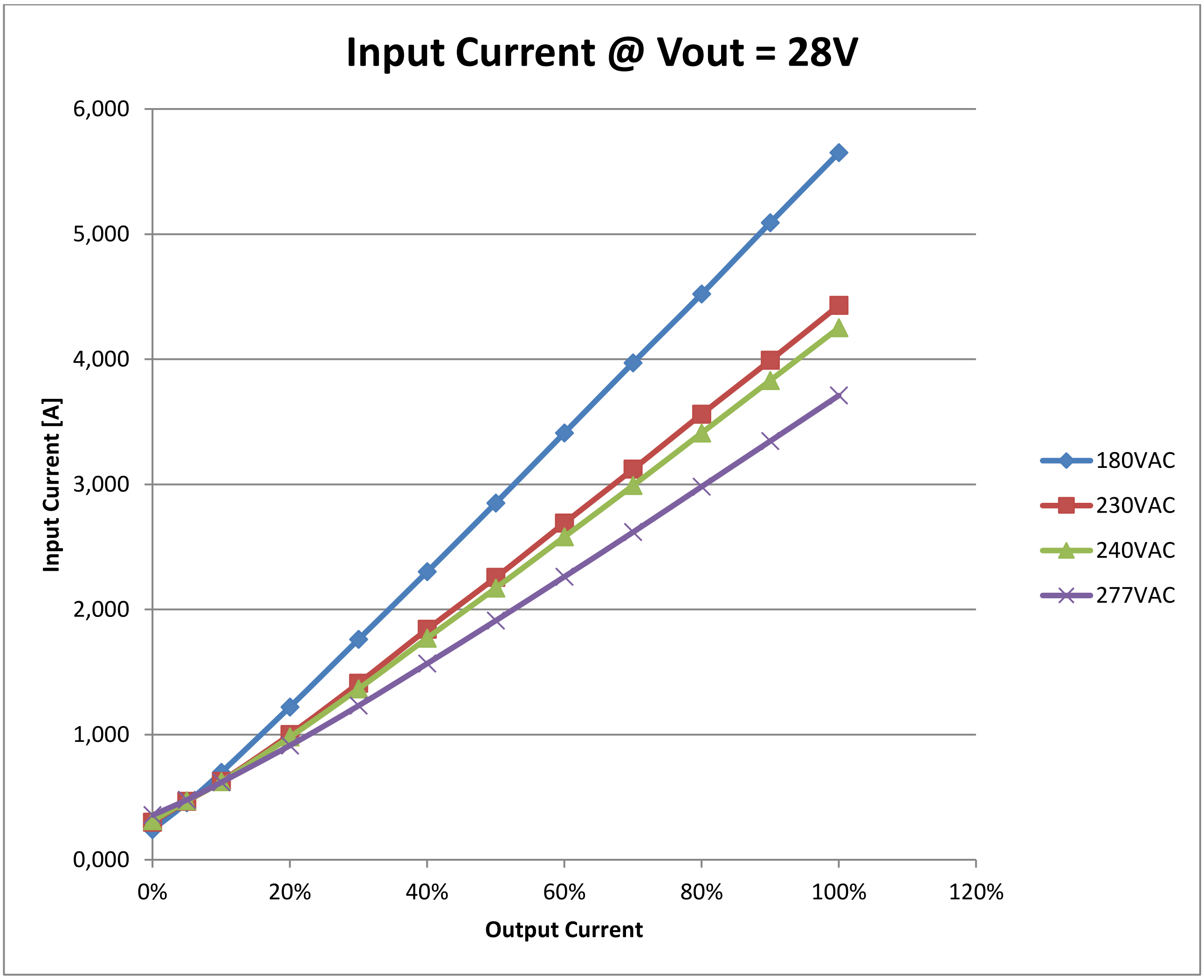
Condition: Vout = 24V Ta = 25°C

Iout / Vin	180VAC	230VAC	240VAC	277VAC	Iout [A]
0%	0,240	0,300	0,313	0,356	0,000
5%	0,445	0,459	0,465	0,473	2,000
10%	0,688	0,618	0,612	0,612	4,000
20%	1,206	0,998	0,972	0,916	8,000
30%	1,748	1,409	1,361	1,235	12,000
40%	2,294	1,830	1,760	1,574	16,000
50%	2,860	2,260	2,175	1,928	20,000
60%	3,410	2,695	2,580	2,263	24,000
70%	3,970	3,120	2,990	2,622	28,000
80%	4,520	3,570	3,420	2,986	32,000
90%	5,110	3,990	3,840	3,351	36,000
100%	5,680	4,440	4,260	3,718	40,000



Condition: Vout = 28V   Ta = 25°C

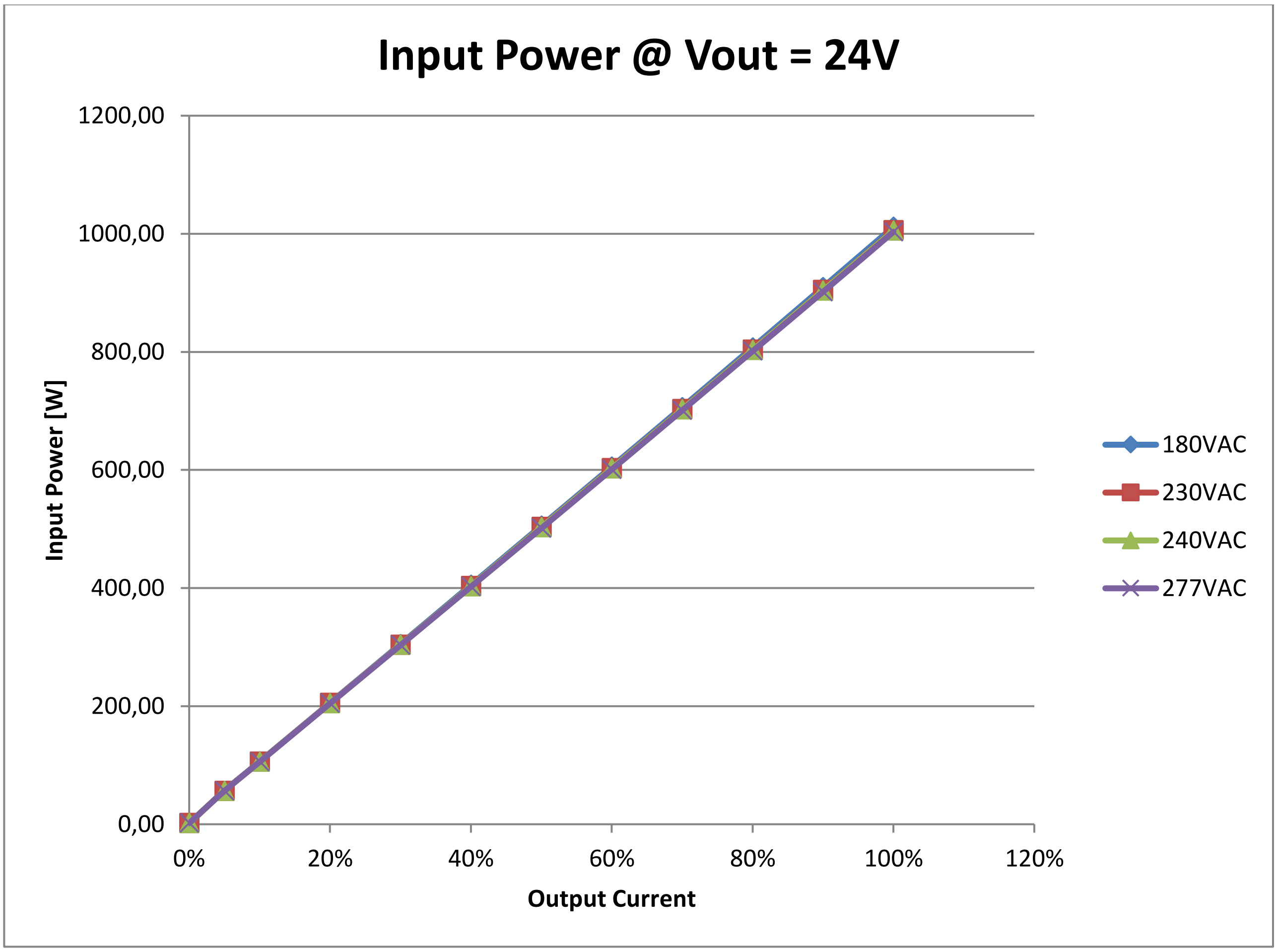
Iout / Vin	180VAC	230VAC	240VAC	277VAC	Iout [A]
0%	0,240	0,300	0,310	0,356	0,00
5%	0,455	0,466	0,470	0,478	1,71
10%	0,697	0,626	0,622	0,618	3,43
20%	1,220	1,000	0,980	0,912	6,86
30%	1,760	1,410	1,365	1,230	10,29
40%	2,300	1,840	1,770	1,567	13,71
50%	2,850	2,255	2,170	1,910	17,14
60%	3,410	2,690	2,580	2,261	20,57
70%	3,970	3,120	2,990	2,617	24,00
80%	4,520	3,560	3,410	2,981	27,43
90%	5,090	3,990	3,830	3,345	30,86
100%	5,650	4,430	4,250	3,710	34,29



3.1.4 Input power vs. Output current

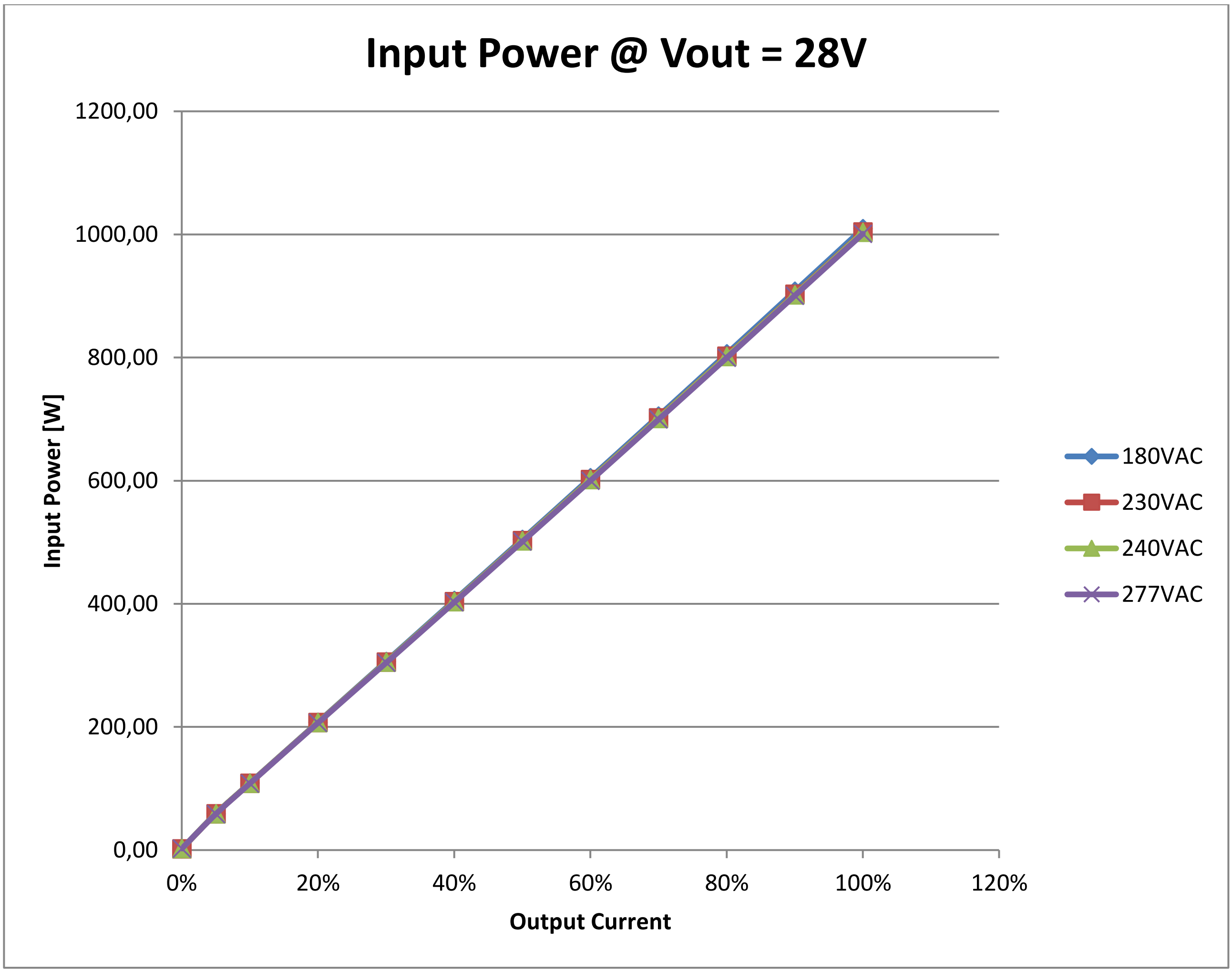
Condition: Vout = 24V Ta = 25°C

Iout / Vin	180VAC	230VAC	240VAC	277VAC	Iout [A]
0%	1,88	1,76	1,83	1,77	0,00
5%	56,51	56,49	56,44	56,24	2,00
10%	106,14	105,92	105,90	105,64	4,00
20%	205,48	205,09	204,85	204,60	8,00
30%	305,05	303,88	303,75	303,20	12,00
40%	405,27	403,12	403,05	402,20	16,00
50%	505,40	503,20	502,90	501,20	20,00
60%	605,70	603,00	602,50	600,80	24,00
70%	706,20	703,00	702,40	700,90	28,00
80%	807,60	803,60	803,00	801,20	32,00
90%	909,50	904,50	903,90	901,70	36,00
100%	1011,80	1006,00	1005,20	1003,30	40,00



Condition: Vout = 28V Ta = 25°C

Iout / Vin	180VAC	230VAC	240VAC	277VAC	Iout [A]
0%	1,92	1,82	2,11	2,33	0,00
5%	58,93	58,87	58,95	58,45	1,71
10%	108,95	108,64	108,60	108,15	3,43
20%	207,70	207,26	207,10	206,57	6,86
30%	306,50	305,30	305,15	304,10	10,29
40%	405,48	403,70	403,50	402,30	13,71
50%	504,70	502,70	502,30	501,00	17,14
60%	604,70	602,00	601,60	599,90	20,57
70%	705,00	701,80	701,20	699,40	24,00
80%	806,00	802,10	801,60	799,50	27,43
90%	907,70	902,80	901,90	900,50	30,86
100%	1009,60	1004,00	1003,20	1001,10	34,29



3.1.5 Input power at no load and stand-by mode (Control OFF)

Condition: Vout = 24V   Ta = 25°C

Vin	Input power [W] @ 24V	
[VAC]	Iout: 0%	Control OFF
180	1,88	0,54
230	1,76	0,70
240	1,83	0,77
277	1,77	0,75

Condition: Vout = 28V   Ta = 25°C

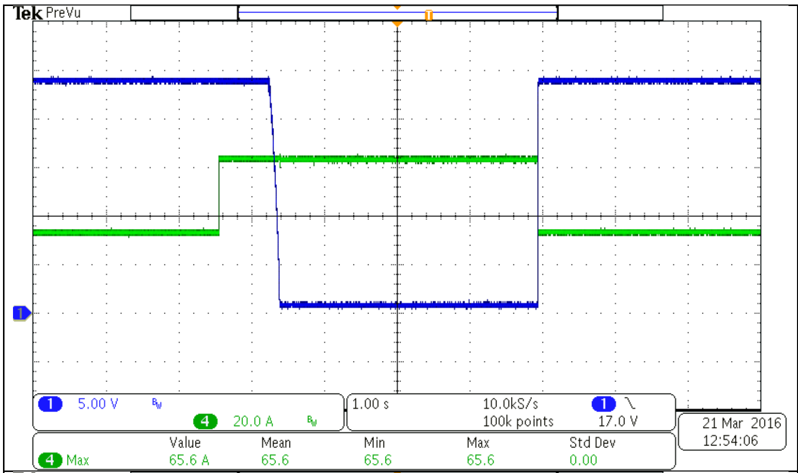
Vin	Input power [W] @ 28V	
[VAC]	Iout: 0%	Control OFF
180	1,92	0,54
230	1,82	0,70
240	2,11	0,77
277	2,33	0,75

3.2 Over current protection (OCP) characteristics

Measurement condition: Vin=230Vac, Ta=25°C

Description of the overcurrent characteristics: The unit works with two different current protection circuits.

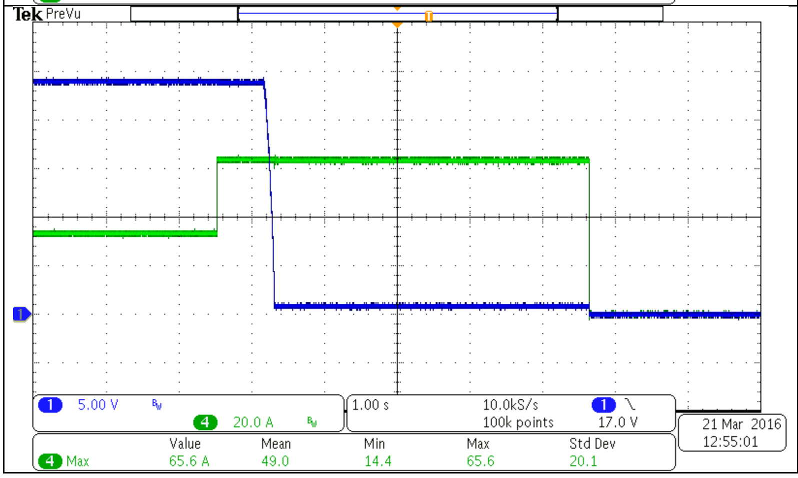
1. At output currents >105% the unit will shutdown after a time ≥ 4 seconds (manual reset or re-power on required).
2. At output currents >150% the unit goes into constant current limitation. This function works for a time of minimum 4 seconds with auto recovery. After a time ≥ 4 seconds the circuit will shutdown the output (manual reset or re-power on required).



Picture 1. Over current characteristics @ 24Vdc
Load >150%, 4,4sec
Constant current – auto recovery

Channel 1: V_{out}
Channel 4: I_{out}

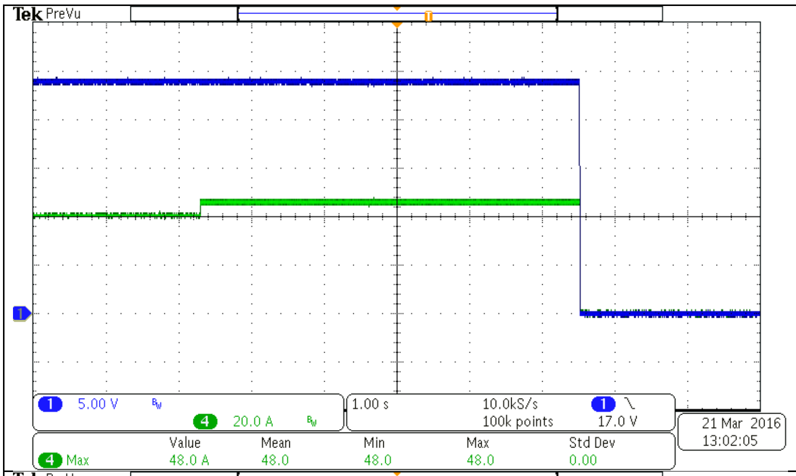
Result: pass



Picture 2. Over current characteristics @ 24Vdc
Load >150%, > 5sec
Constant current – latch off

Channel 1: V_{out}
Channel 4: I_{out}

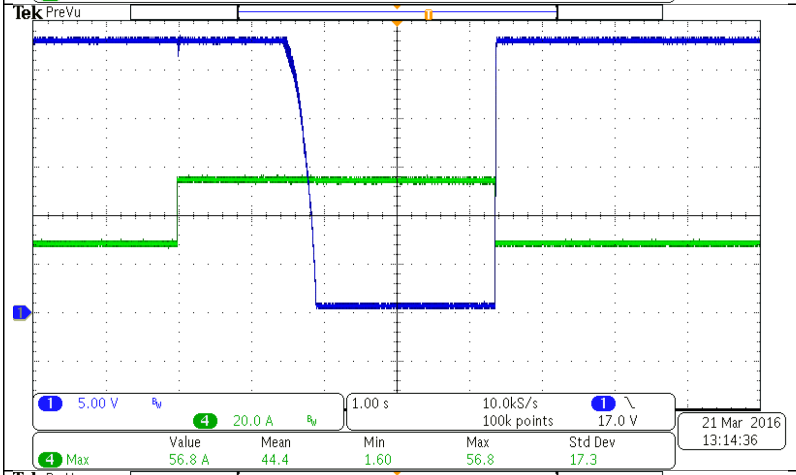
Result: pass



Picture 3. Over current characteristics
@ 24Vdc
Load >105% (≈46A), > 5sec
Constant current – latch off

Channel 1: V_{out}
Channel 4: I_{out}

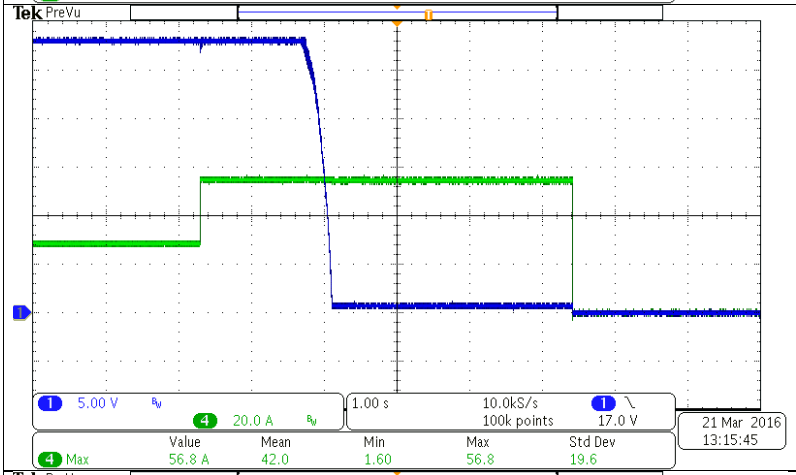
Result: **pass**



Picture 4. Over current characteristics
@ 28Vdc
Load >150%, 4,4sec
Constant current – auto recovery

Channel 1: V_{out}
Channel 4: I_{out}

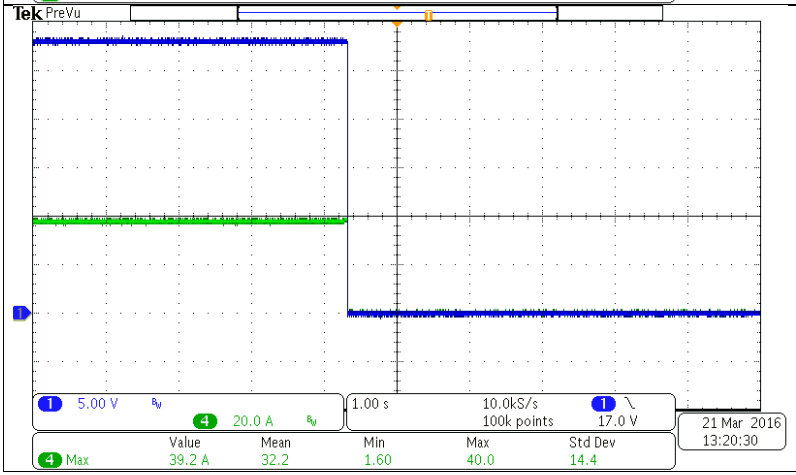
Result: **pass**



Picture 5. Over current characteristics
@ 28Vdc
Load >150%, > 5sec
Constant current – latch off

Channel 1: V_{out}
Channel 4: I_{out}

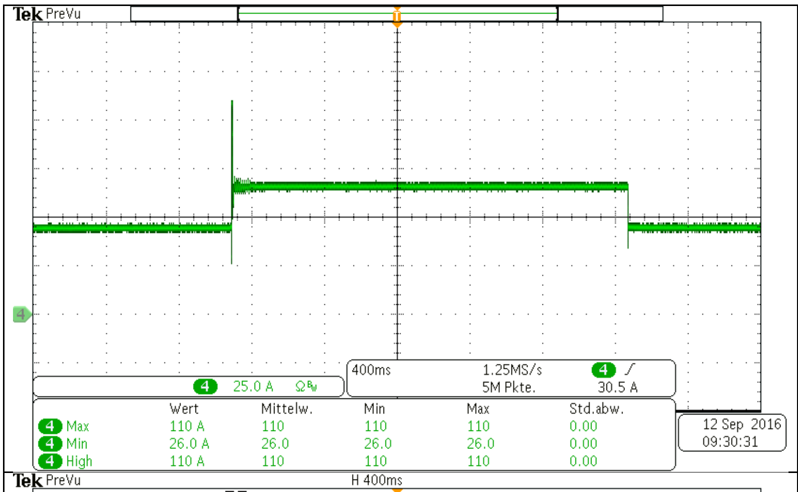
Result: **pass**



Picture 6. Over current characteristics
@ 28Vdc
Load >105% (≈37A), > 5sec
Constant current – latch off

Channel 1: V_{out}
Channel 4: I_{out}

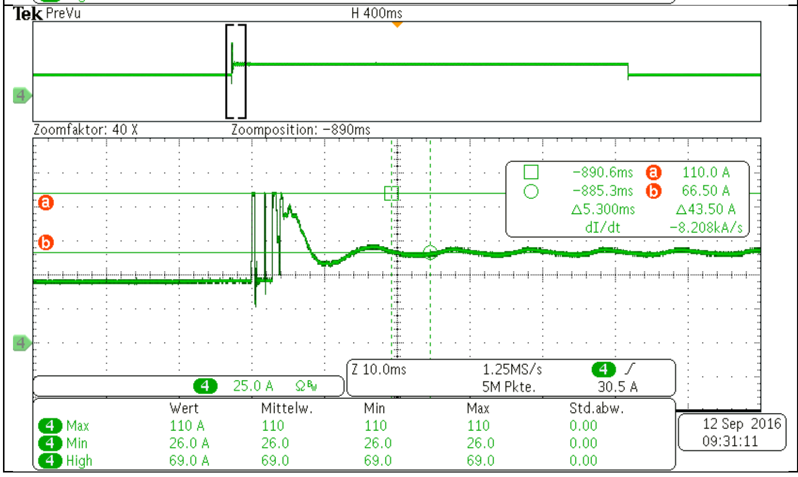
Result: **pass**



Picture 7. Over current characteristics
@ 24Vdc
Load= short circuit, = 2sec

Channel 4: I_{out}

Result: pass



Picture 8. Same measurement as picture above
@ 24Vdc
Load= short circuit, = 2sec

Channel 4: I_{out}

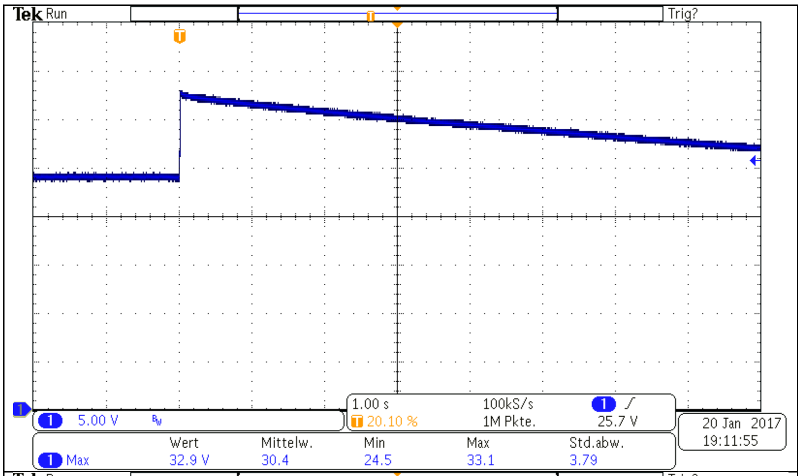
Max. short circuit current = 110A

Result: pass

3.3 Over voltage protection (OVP) characteristics

The setting for the OVP trip point is 32,7V. With tolerances the OVP range is 31,8V…..33,7V.

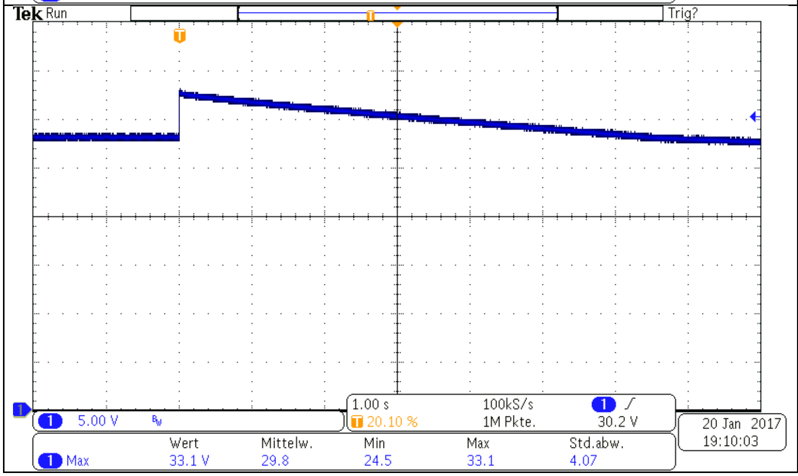
Measurement condition: Vin=230Vac, Ta=25°C



Picture 9. Over voltage characteristics @ 24Vdc
Load 0%
latch off characteristics

Channel 1: V_{out}

Result: pass



Picture 10. Over voltage characteristics @ 28Vdc
Load 0%
latch off characteristics

Channel 1: V_{out}

Result: pass

3.4 Over Temperature Protection (OTP)

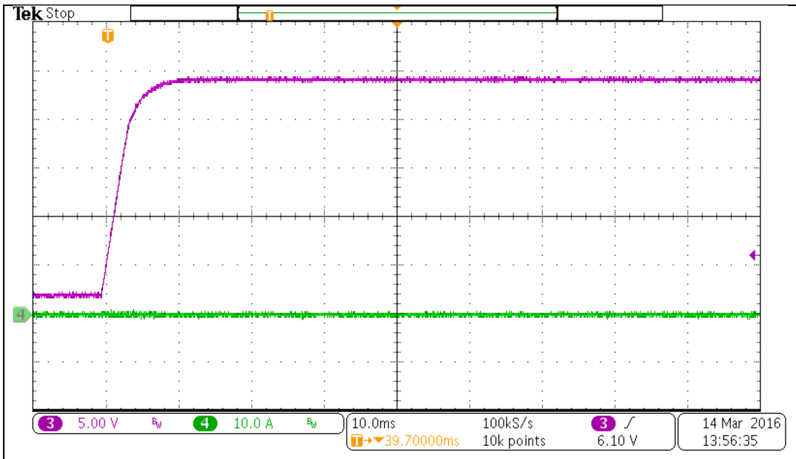
Measurement of the OTP trip point.

In the case of an OTP shut down the unit required a manual reset or re-power on.

Shut Down at Tamb			
Vout	Iout	Pout	Tamb.
24V	40A	960W	57°C
24V	30A	720W	75°C

3.5 Output rise characteristics

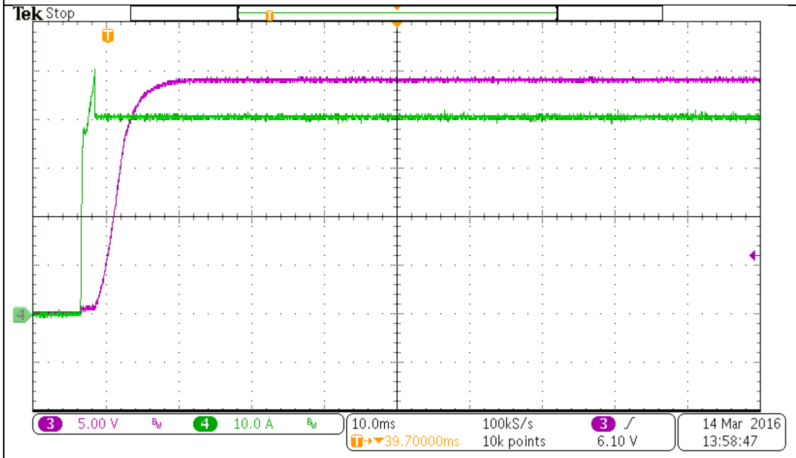
Measurement condition: Ta=25°C



Picture 11. Output rise characteristics
@ 180Vac, 24Vdc / 0% load

Channel 3: V_{out}
Channel 4: I_{out}

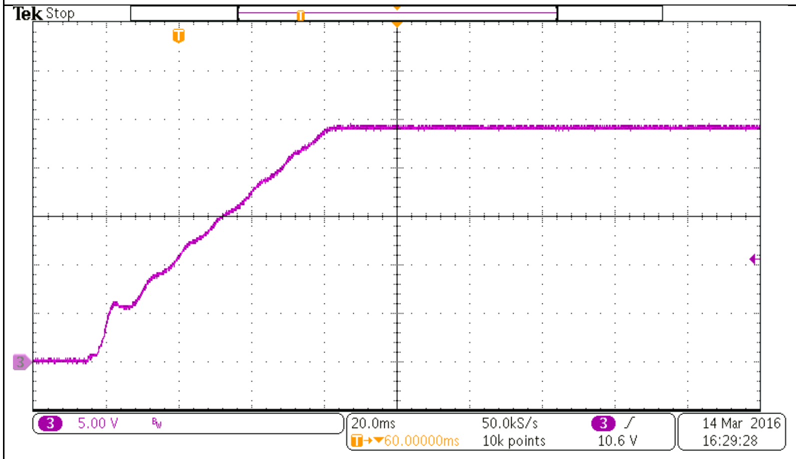
Result: pass



Picture 12. Output rise characteristics
@ 180Vac, 24Vdc / 100% load

Channel 3: V_{out}
Channel 4: I_{out}

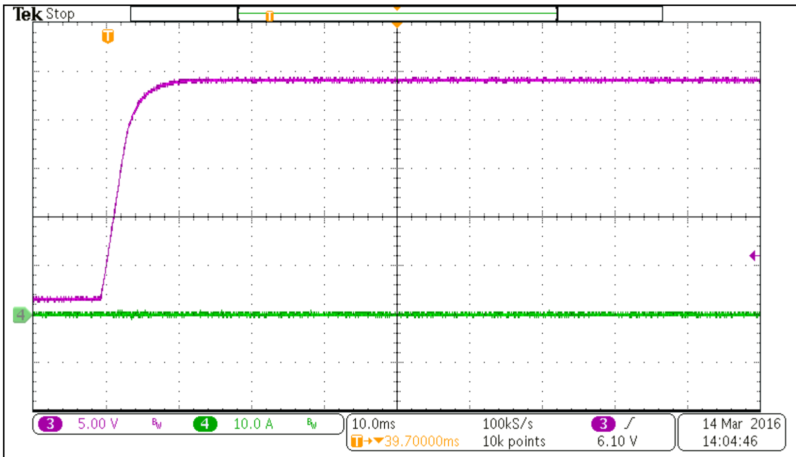
Result: pass



Picture 13. Output rise characteristics
@ 180Vac, 24Vdc / 100% load and 69000µF

Channel 3: V_{out}
Channel 4: I_{out}

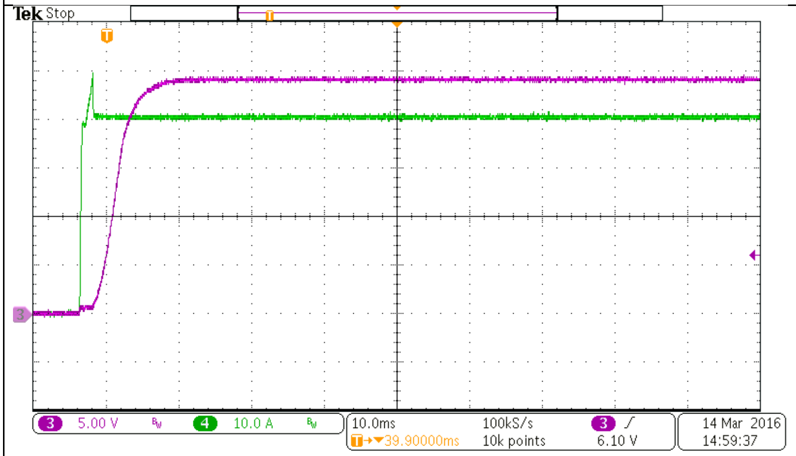
Result: pass



Picture 14. Output rise characteristics @ 230Vac, 24Vdc / 0% load

Channel 3: V_{out}
Channel 4: I_{out}

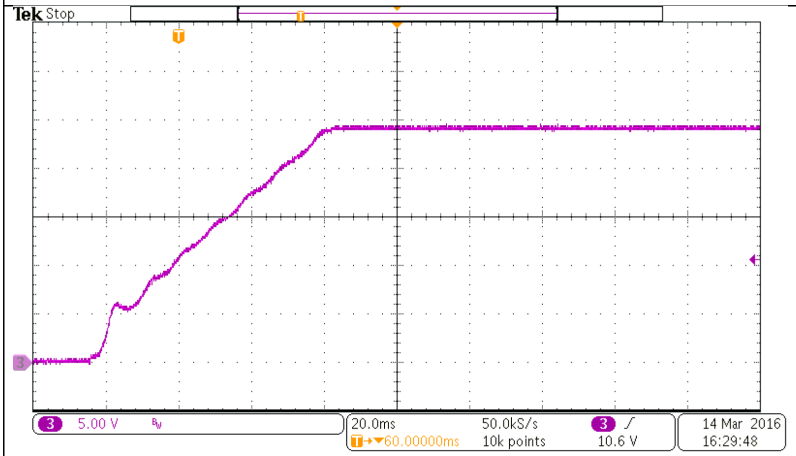
Result: pass



Picture 15. Output rise characteristics @ 230Vac, 24Vdc / 100% load

Channel 3: V_{out}
Channel 4: I_{out}

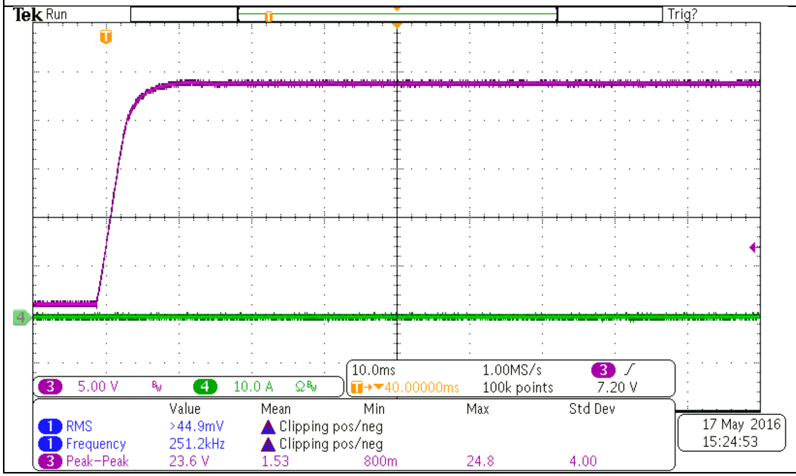
Result: pass



Picture 16. Output rise characteristics @ 230Vac, 24Vdc / 100% load and 69000µF

Channel 3: V_{out}
Channel 4: I_{out}

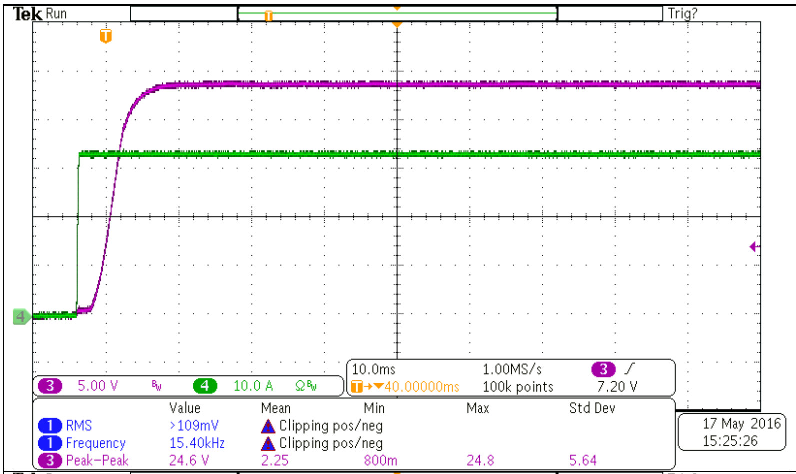
Result: pass



Picture 17. Output rise characteristics @ 277Vac, 24Vdc / 0% load

Channel 3: V_{out}
Channel 4: I_{out}

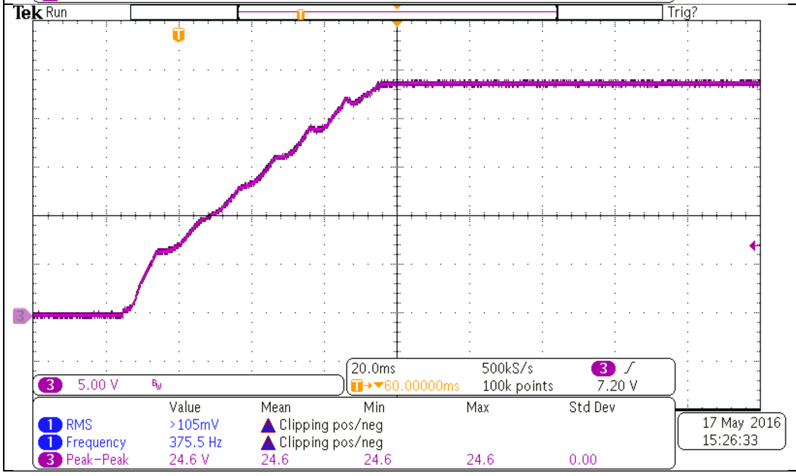
Result: pass



Picture 18. Output rise characteristics @ 277Vac, 24Vdc / 100% load

Channel 3: V_{out}
Channel 4: I_{out}

Result: pass



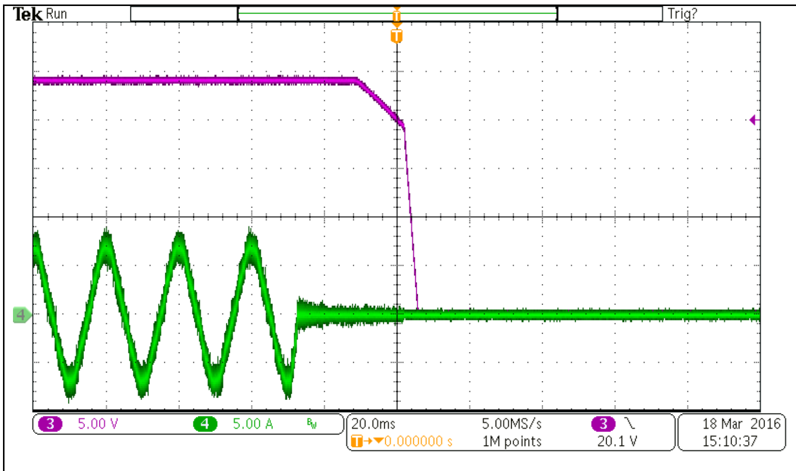
Picture 19. Output rise characteristics @ 277Vac, 24Vdc / 100% load and 69000µF

Channel 3: V_{out}
Channel 4: I_{out}

Result: pass

3.6 Output fall characteristics

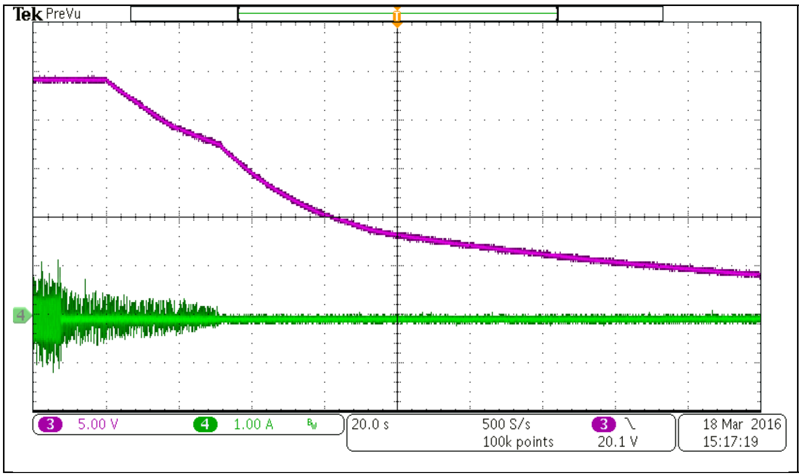
Measurement condition: Vin=230Vac, Ta=25°C



Picture 20. Output fall characteristics @ 230Vac, 24Vdc / 100% load

Channel 3: V_{out}
Channel 4: I_{in}

Result: pass



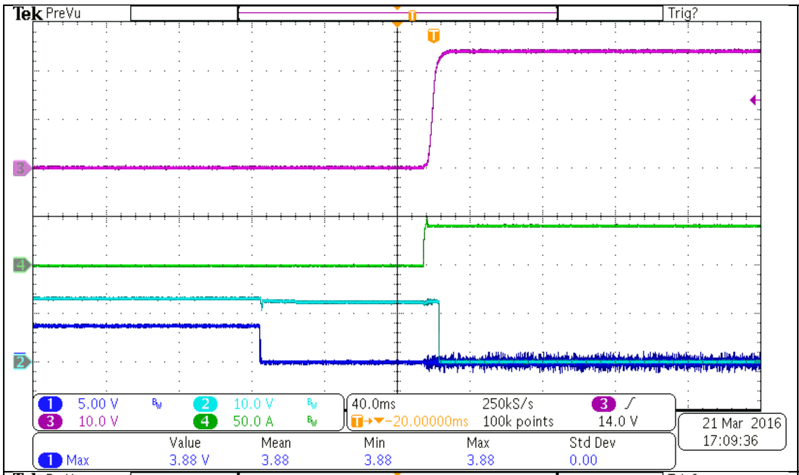
Picture 21. Output fall characteristics @ 230Vac, 24Vdc / 0% load

Channel 3: V_{out}
Channel 4: I_{in}

Result: pass

3.7 Output rise, fall characteristics with ON/OFF Control

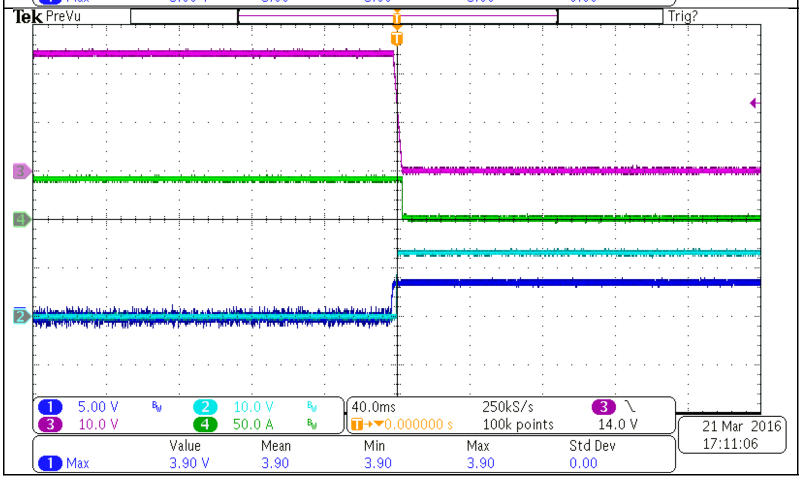
Measurement condition: Vin=230Vac, Ta=25°C



Picture 22. Output rise characteristics with ON/OFF control @ 230Vac, 24Vdc / 100% load

Channel 1: ON/OFF control signal
Channel 2: DC_ok signal
Channel 3: V_{out}
Channel 4: I_{out}

Result: pass

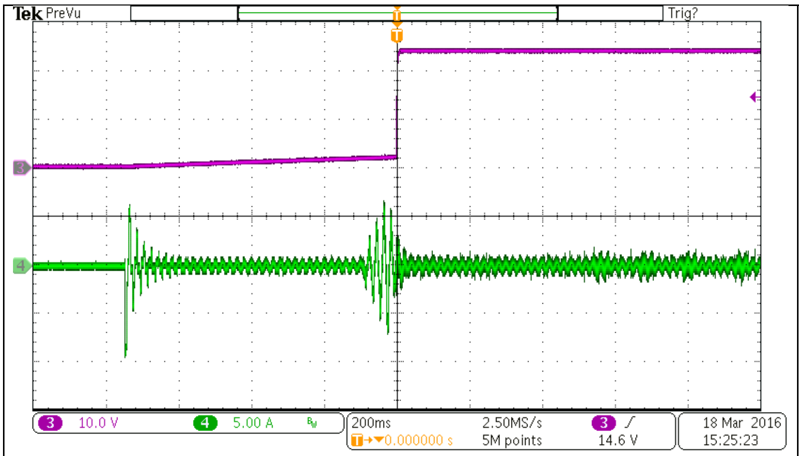


Picture 23. Output fall characteristics with ON/OFF control @ 230Vac, 24Vdc / 100% load

Channel 1: ON/OFF control signal
Channel 2: DC_ok signal
Channel 3: V_{out}
Channel 4: I_{out}

Result: pass

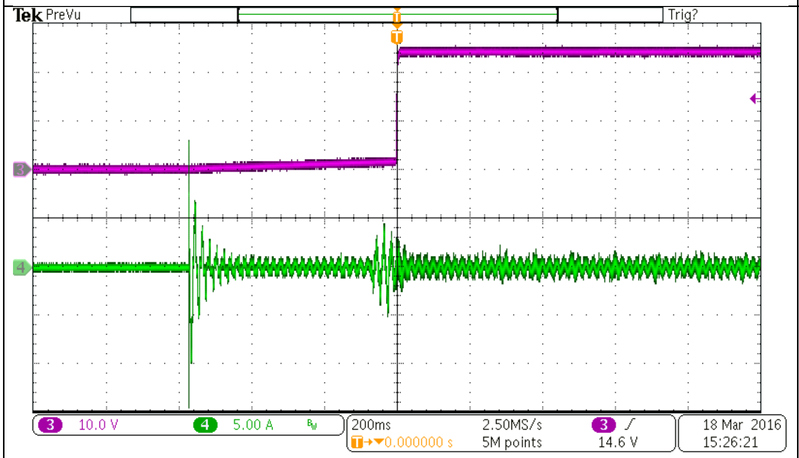
3.8 Start up time



Picture 24. Start up time @ 180Vac, 24Vdc / 0% load

Channel 3: V_{out}
Channel 4: I_{in}

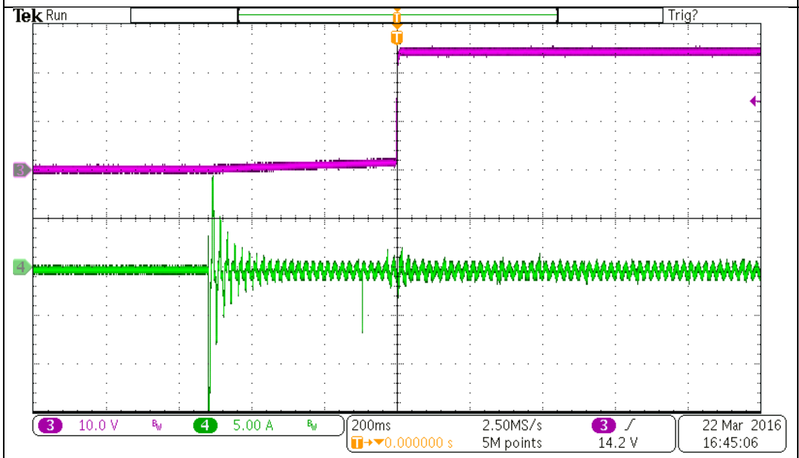
Result: pass



Picture 25. Start up time @ 230Vac, 24Vdc / 0% load

Channel 3: V_{out}
Channel 4: I_{in}

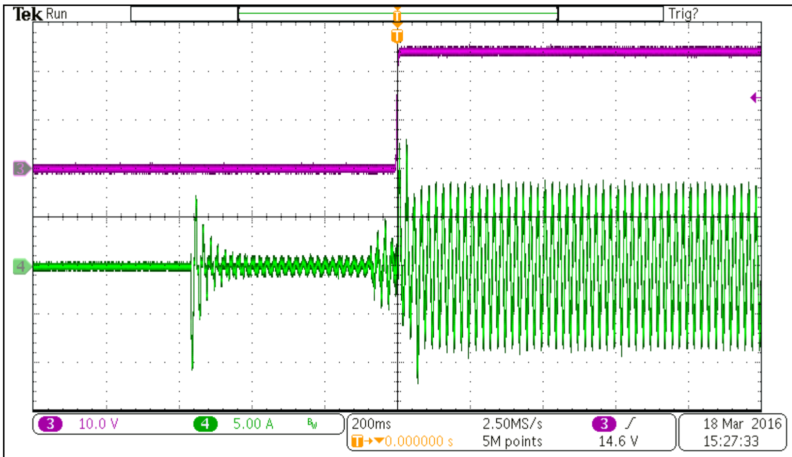
Result: pass



Picture 26. Start up time @ 277Vac, 24Vdc / 0% load

Channel 3: V_{out}
Channel 4: I_{in}

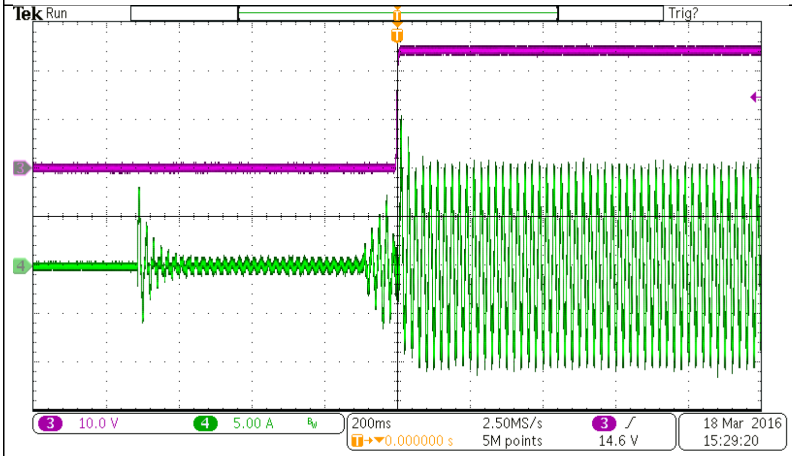
Result: pass



Picture 27. Start up time @ 180Vac, 24Vdc / 100% load

Channel 3: V_{out}
Channel 4: I_{in}

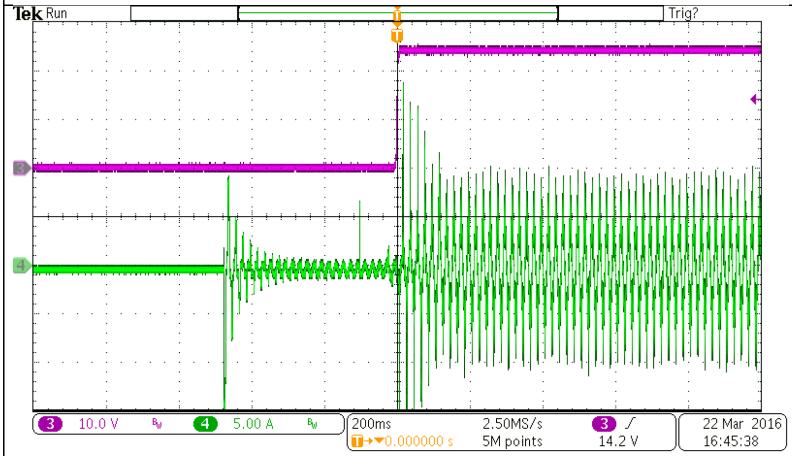
Result: pass



Picture 28. Start up time @ 230Vac, 24Vdc / 100% load

Channel 3: V_{out}
Channel 4: I_{in}

Result: pass



Picture 29. Start up time @ 277Vac, 24Vdc / 100% load

Channel 3: V_{out}
Channel 4: I_{in}

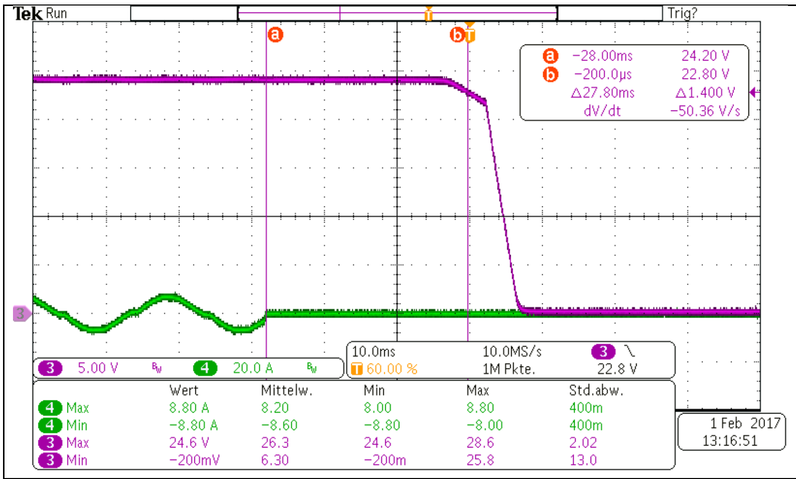
Result: pass

3.9 Hold up time characteristics

Hold up time: >10ms (specified)

The time is measured between the turn off of the input voltage and the point when the output voltage is dropped to 95%.

Measurement condition: Vin=230Vac, Ta=25°C



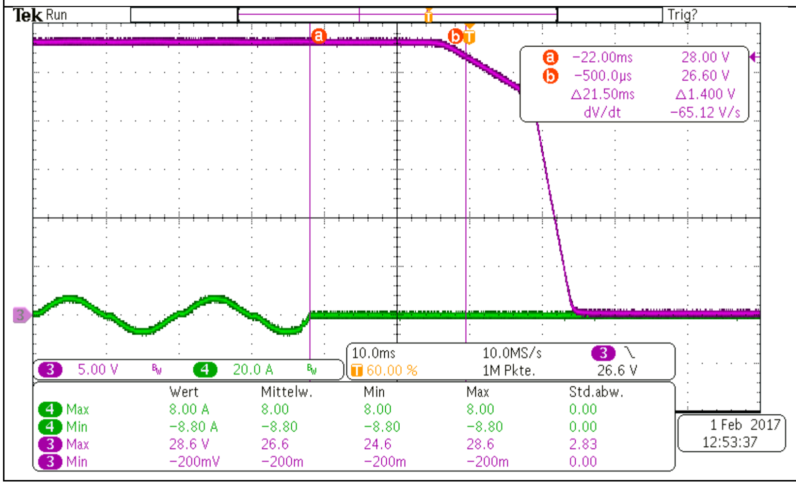
Picture 30. Hold up time @ 24Vdc / 100% load

Channel 3: Vout
Channel 4: Iout

V_{out}=24V

$V_{outholdup}$=V_{out}x95%=22,8V

Result: pass



Picture 31. Hold up time @ 28Vdc / 100% load

Channel 3: Vout
Channel 4: Iout

V_{out}=28V

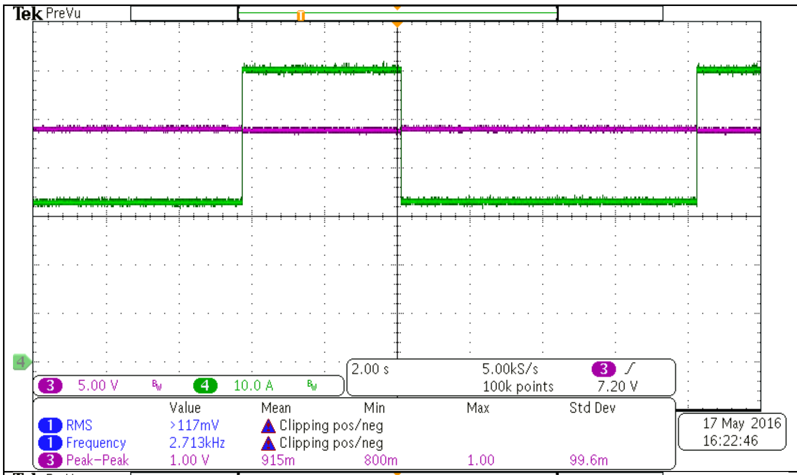
$V_{outholdup}$=V_{out}x95%=26,6V

Result: pass

3.10 Peak power characteristics

Measurement condition: Ta=25°C

Peak power 150% of rated power for 4 seconds, max. duty cycle <=0,35, $P_{out\_max\_rms}$=960W

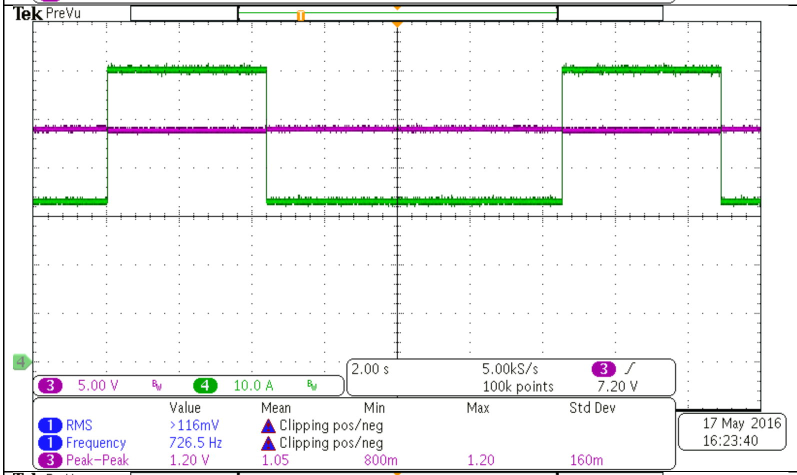


Picture 32. Peak power characteristics @ 180Vac, 24Vdc

Load: 80%/8sec. to 150%/4,4sec

Channel 1: V_{out}
Channel 4: I_{out}

Result: pass

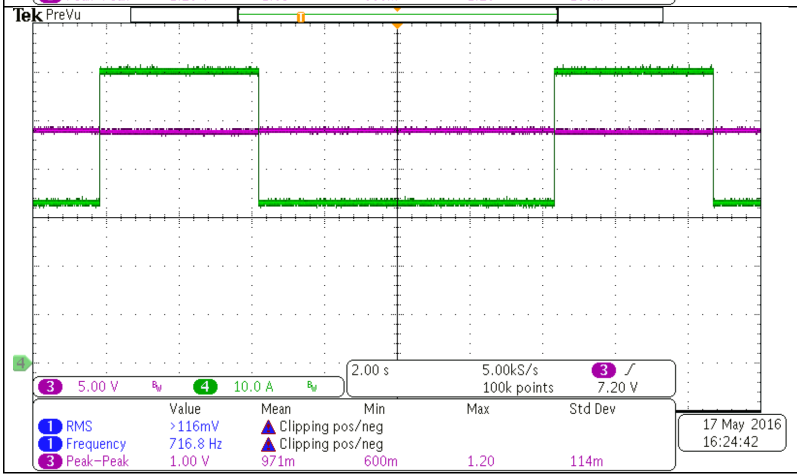


Picture 33. Peak power characteristics @ 230Vac, 24Vdc

Load: 80%/8sec. to 150%/4,4sec

Channel 1: V_{out}
Channel 4: I_{out}

Result: pass

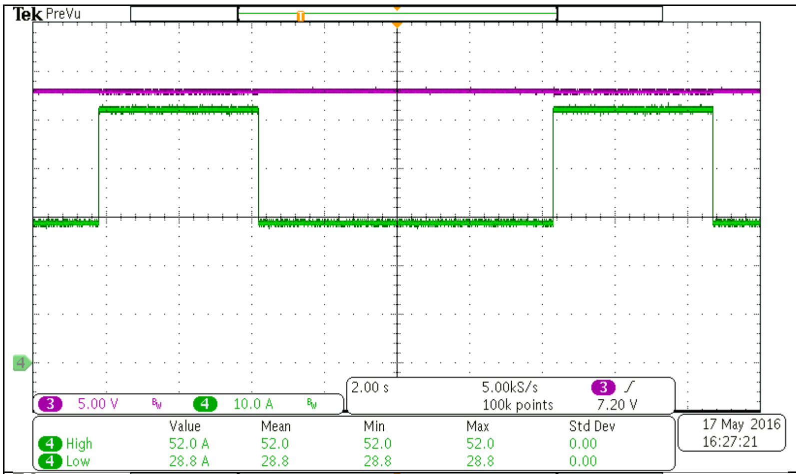


Picture 34. Peak power characteristics @ 277Vac, 24Vdc

Load: 80%/8sec. to 150%/4,4sec

Channel 1: V_{out}
Channel 4: I_{out}

Result: pass

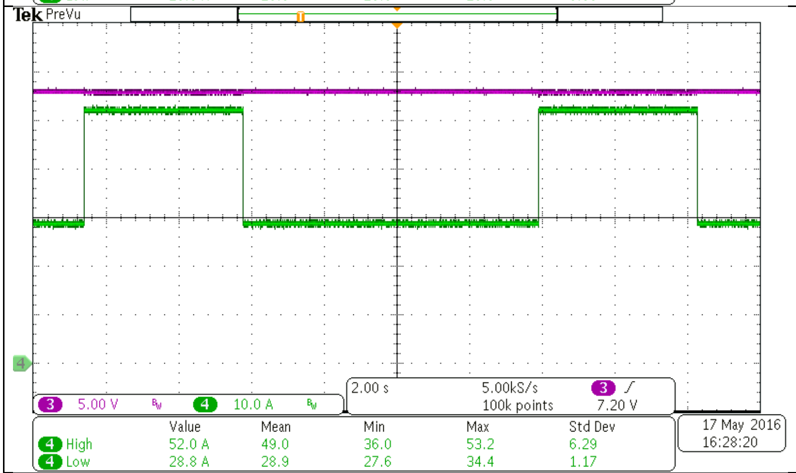


Picture 35. Peak power characteristics @ 180Vac, 28Vdc

Load: 80%/8sec. to 150%/4,4sec

Channel 1: V_{out}
Channel 4: I_{out}

Result: pass

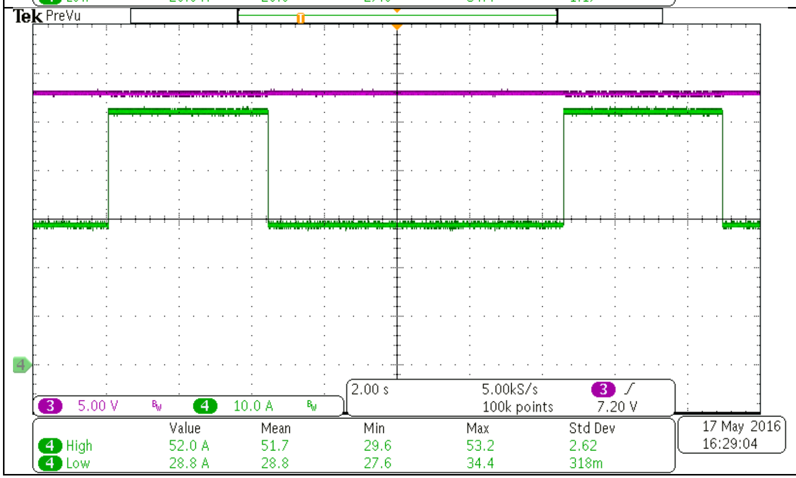


Picture 36. Peak power characteristics @ 230Vac, 28Vdc

Load: 80%/8sec. to 150%/4,4sec

Channel 1: V_{out}
Channel 4: I_{out}

Result: pass



Picture 37. Peak power characteristics @ 277Vac, 28Vdc

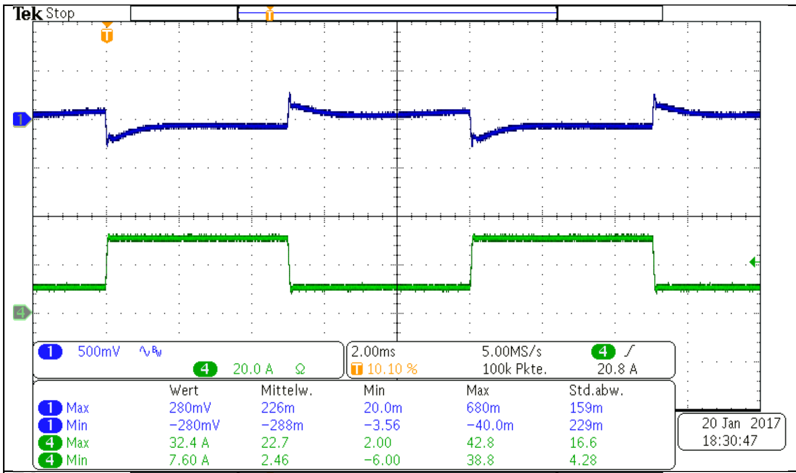
Load: 80%/8sec. to 150%/4,4sec

Channel 1: V_{out}
Channel 4: I_{out}

Result: pass

3.11 Dynamic load response characteristics

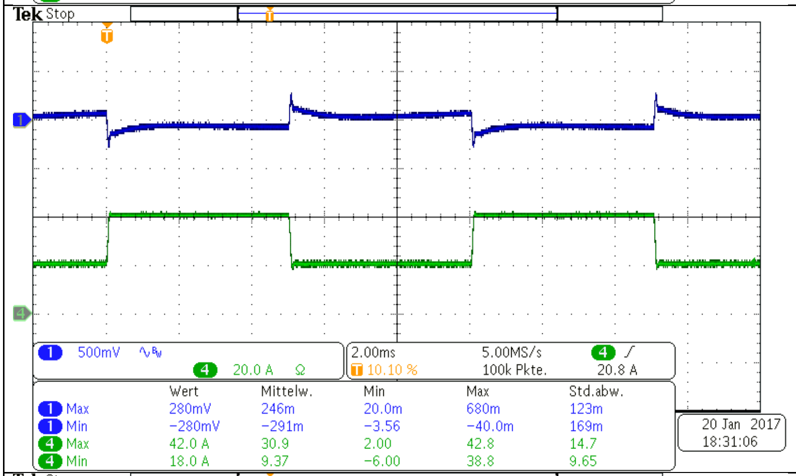
Measurement condition: Vin=230Vac, Ta=25°C, di/dt=1A/µs



Picture 38. Transient response @ 24Vdc load step 25% -> 75% 100Hz

Channel 1: Vout
Channel 4: Iout

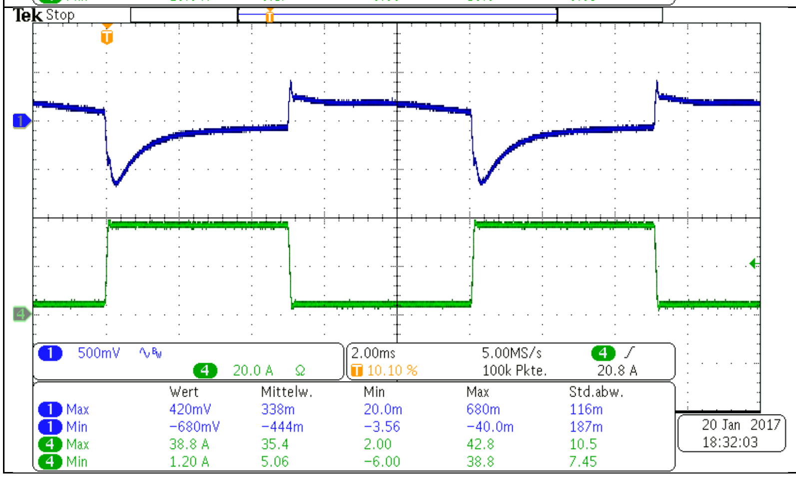
Result: pass



Picture 39. Transient response @ 24Vdc load step 50% -> 100% 100Hz

Channel 1: Vout
Channel 4: Iout

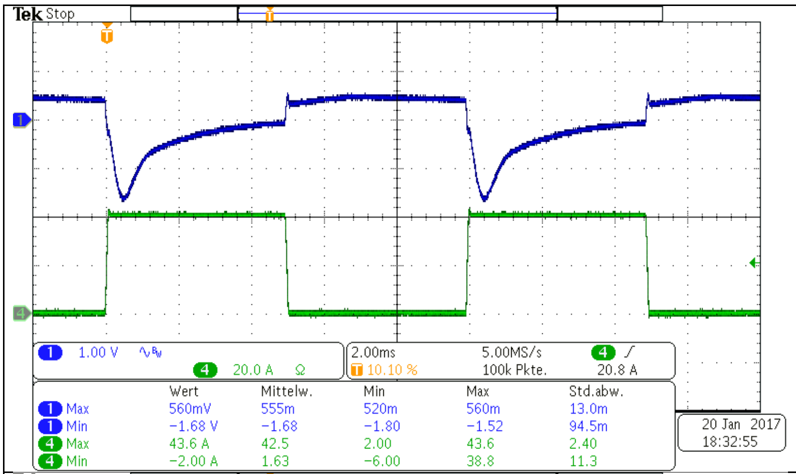
Result: pass



Picture 40. Transient response @ 24Vdc load step 10% -> 90% 100Hz

Channel 1: Vout
Channel 4: Iout

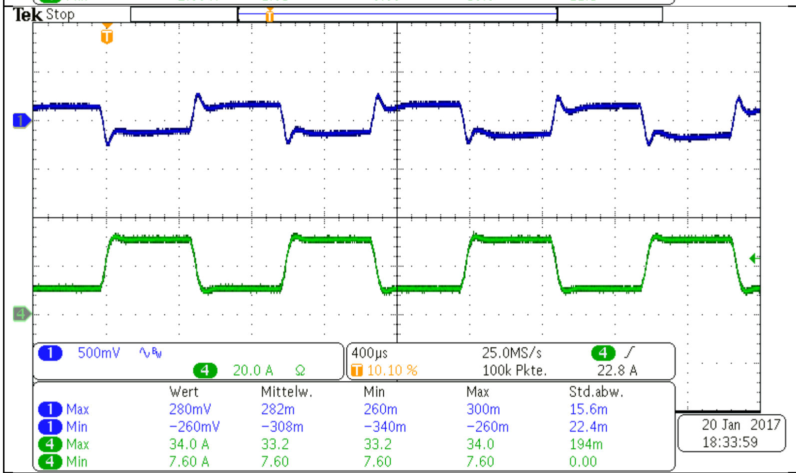
Result: pass



Picture 41. Transient response @ 24Vdc
load step 0% -> 100% 100Hz

Channel 1: Vout
Channel 4: Iout

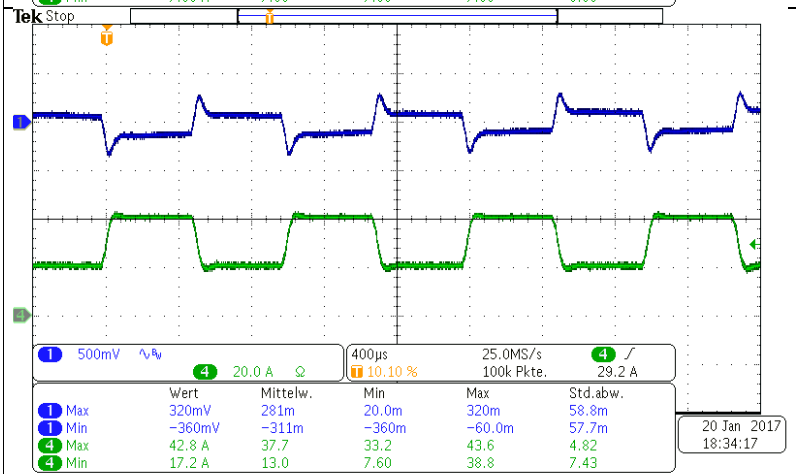
Result: pass



Picture 42. Transient response @ 24Vdc
load step 25% -> 75% 1kHz

Channel 1: Vout
Channel 4: Iout

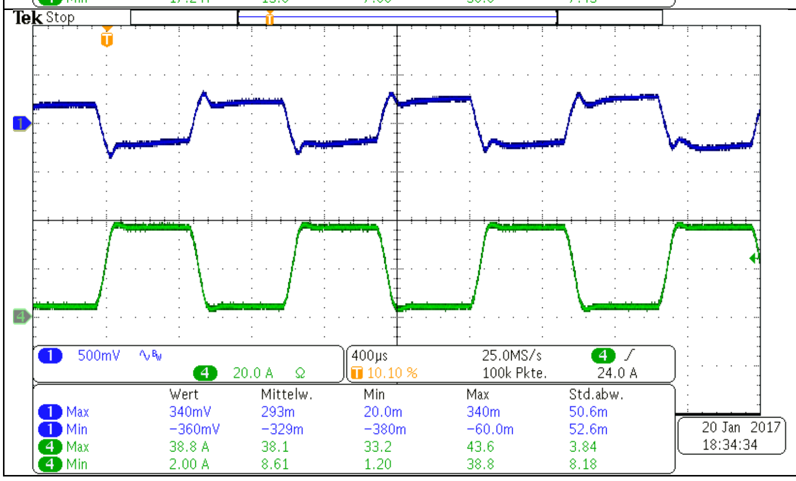
Result: pass



Picture 43. Transient response @ 24Vdc
load step 50% -> 100% 1kHz

Channel 1: Vout
Channel 4: Iout

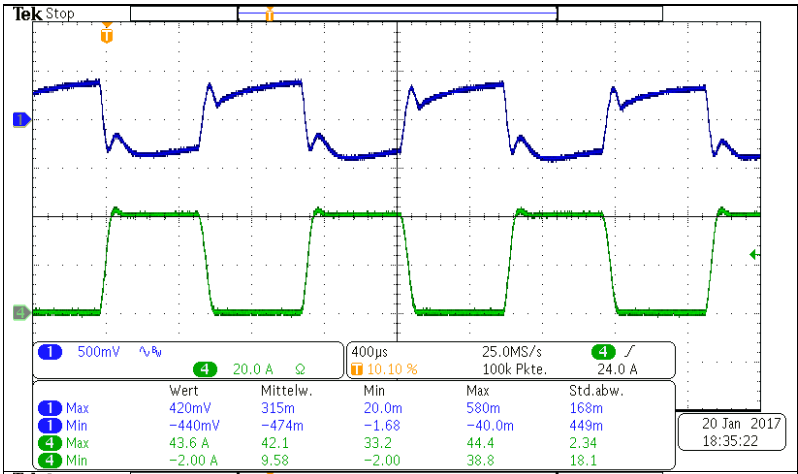
Result: pass



Picture 44. Transient response @ 24Vdc
load step 10% -> 90% 1kHz

Channel 1: Vout
Channel 4: Iout

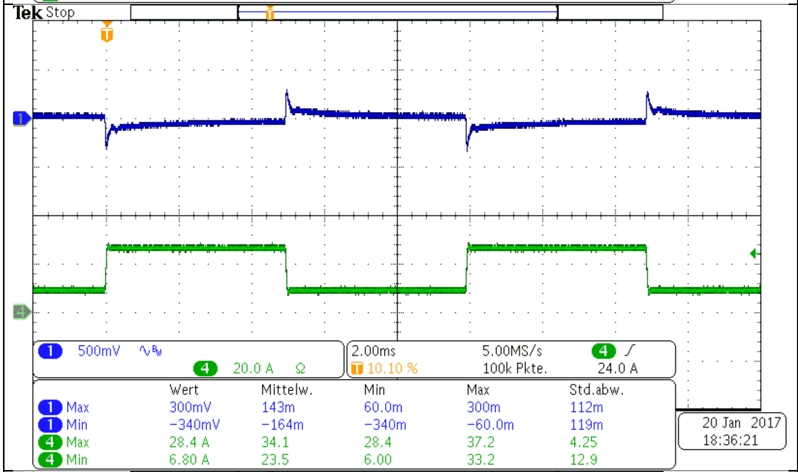
Result: pass



Picture 45. Transient response @ 24Vdc
load step 0% -> 100% 1kHz

Channel 1: Vout
Channel 4: Iout

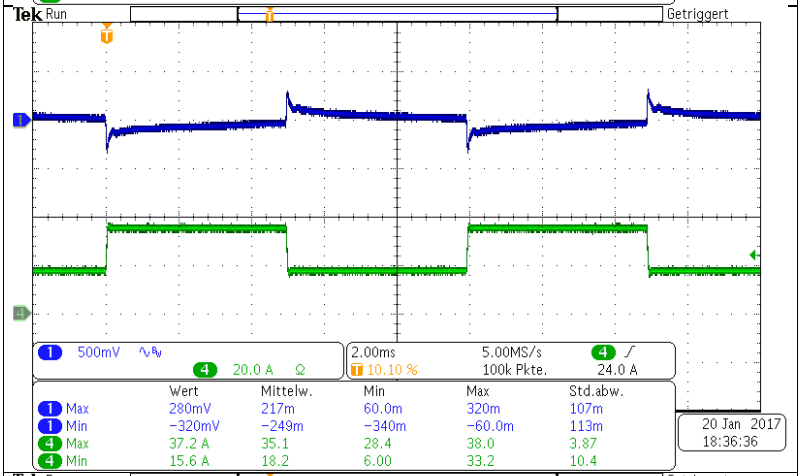
Result: pass



Picture 46. Transient response @ 28Vdc
load step 25% -> 75% 100Hz

Channel 1: Vout
Channel 4: Iout

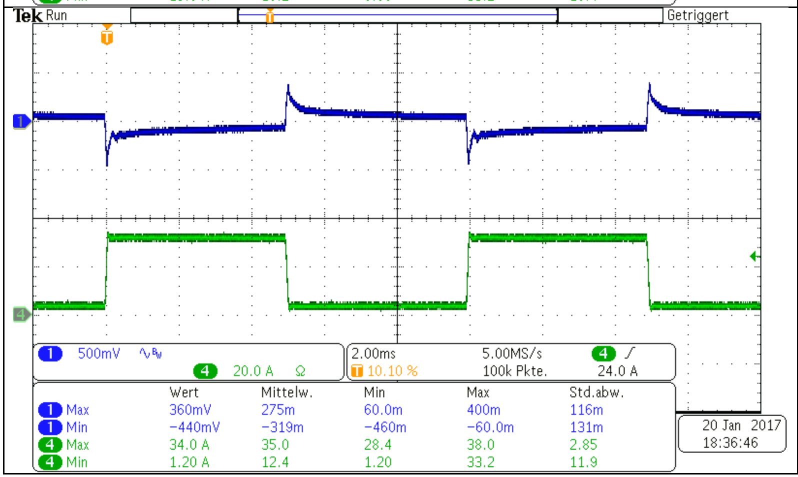
Result: pass



Picture 47. Transient response @ 28Vdc
load step 50% -> 100% 100Hz

Channel 1: Vout
Channel 4: Iout

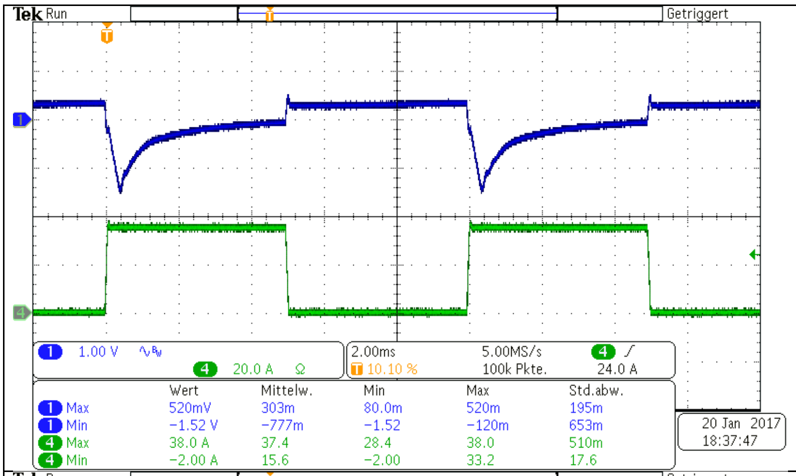
Result: pass



Picture 48. Transient response @ 28Vdc
load step 10% -> 90% 100Hz

Channel 1: Vout
Channel 4: Iout

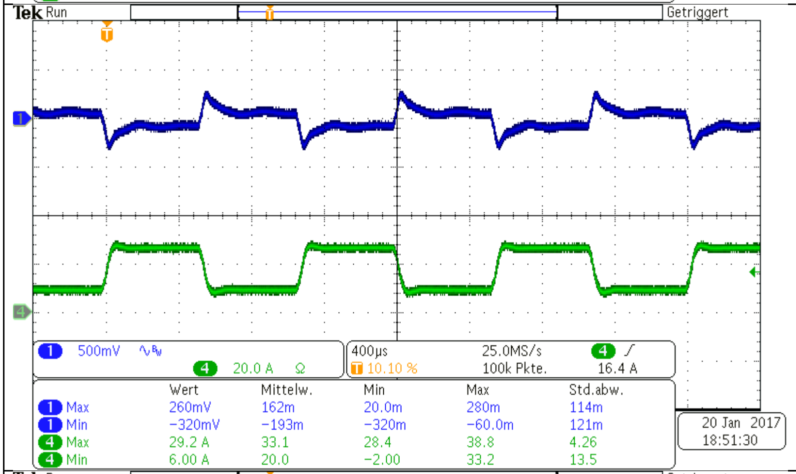
Result: pass



Picture 49. Transient response @ 28Vdc
load step 0% -> 100% 100Hz

Channel 1: Vout
Channel 4: Iout

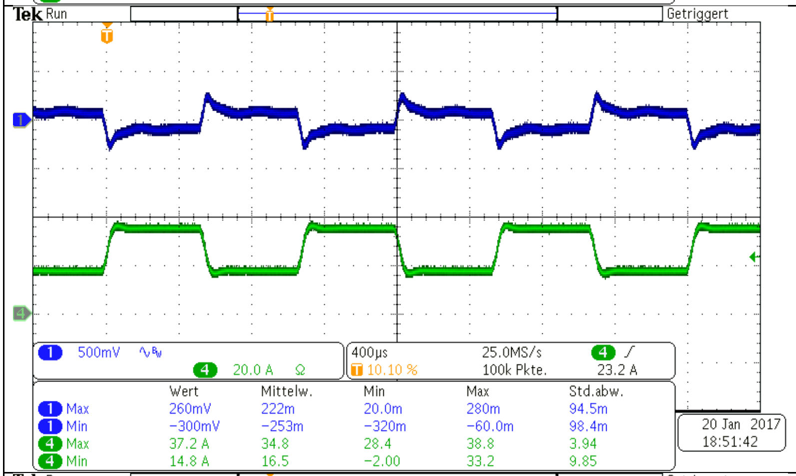
Result: pass



Picture 50. Transient response @ 28Vdc
load step 25% -> 75% 1kHz

Channel 1: Vout
Channel 4: Iout

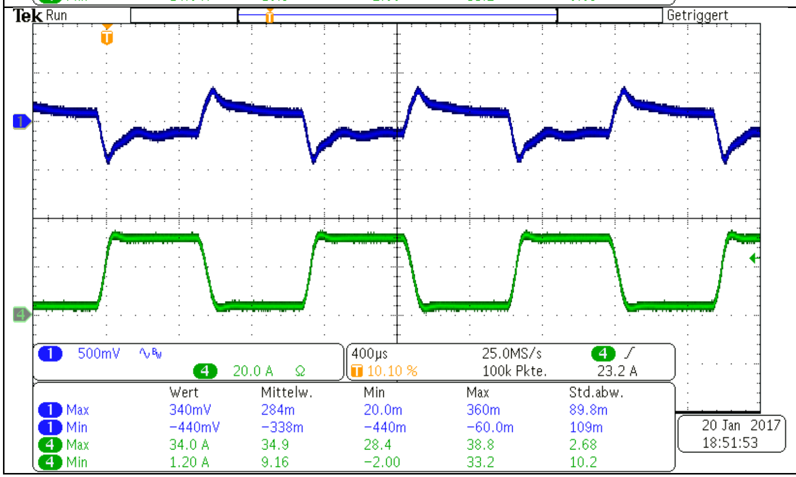
Result: pass



Picture 51. Transient response @ 28Vdc
load step 50% -> 100% 1kHz

Channel 1: Vout
Channel 4: Iout

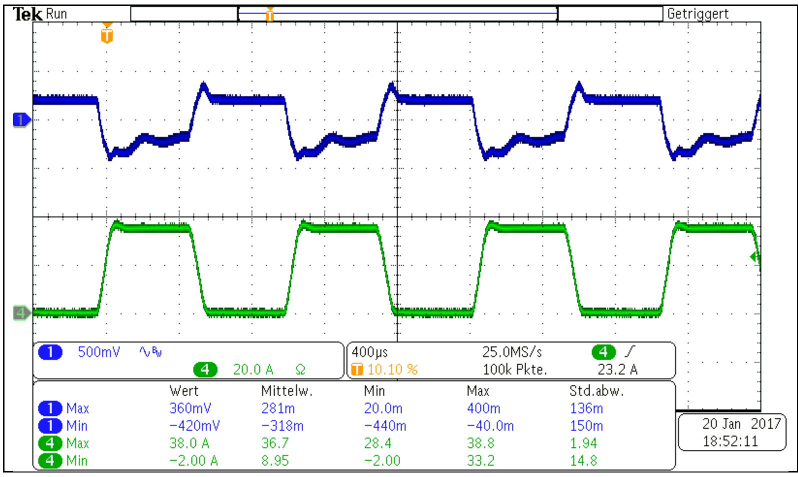
Result: pass



Picture 52. Transient response @ 28Vdc
load step 10% -> 90% 1kHz

Channel 1: Vout
Channel 4: Iout

Result: pass



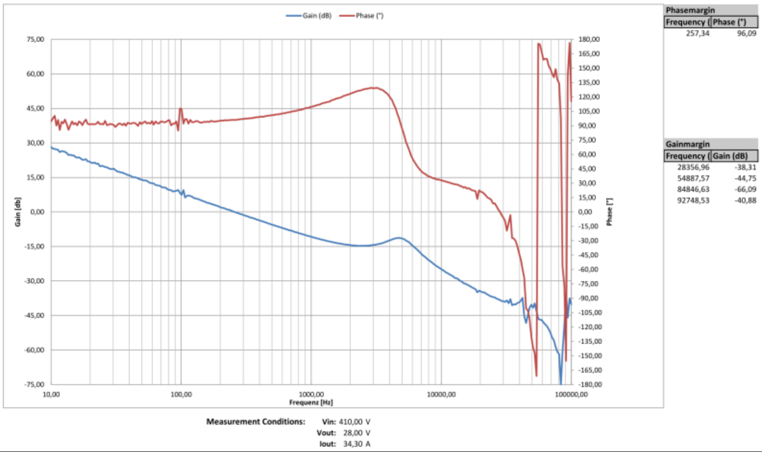
Picture 53. Transient response @ 28Vdc
load step 0% -> 100%   1kHz

Channel 1: Vout
Channel 4: Iout

Result: pass

3.12 Frequency Response Analysis

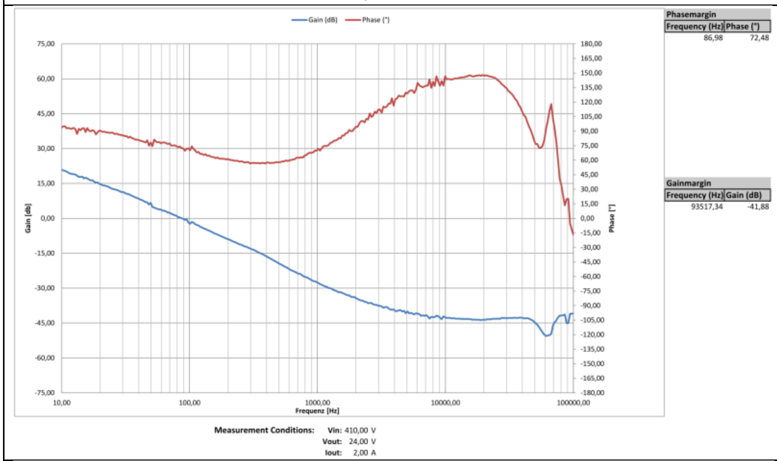
The Frequency Response of the DC/DC stage was measured with a frequency response analyser from N4L (Typ: PSM3750).



Picture 54. Frequency Response Analysis
@ Vin = 410Vdc (PFC operating)
Vout = 28Vdc
Iout = 34,3A

Recommended:
gain margin: about 10dB
phase margin: < 45 degrees

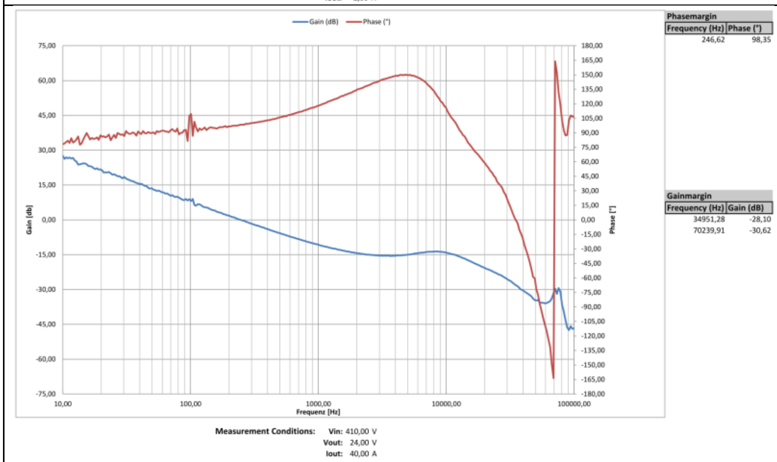
Result: **pass**



Picture 55. Frequency Response Analysis
@ Vin = 410Vdc (PFC operating)
Vout = 24Vdc
Iout = 2A

Recommended:
gain margin: about 10dB
phase margin: < 45 degrees

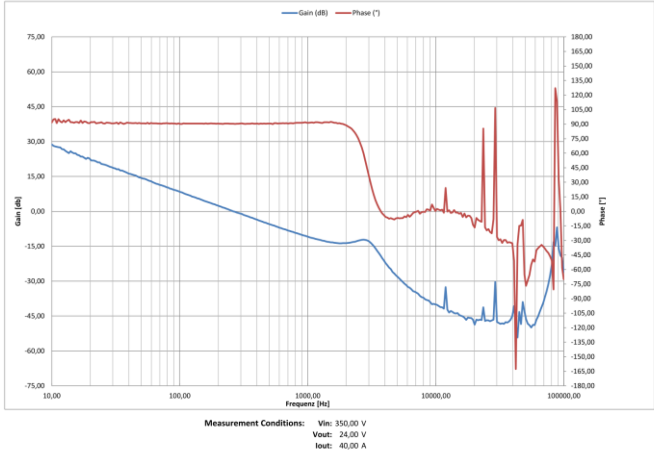
Result: **pass**



Picture 56. Frequency Response Analysis
@ Vin = 410Vdc (PFC operating)
Vout = 24Vdc
Iout = 40A

Recommended:
gain margin: about 10dB
phase margin: < 45 degrees

Result: **pass**



Phasemargin

Frequency (Hz)	Phase (°)
262,49	90,46

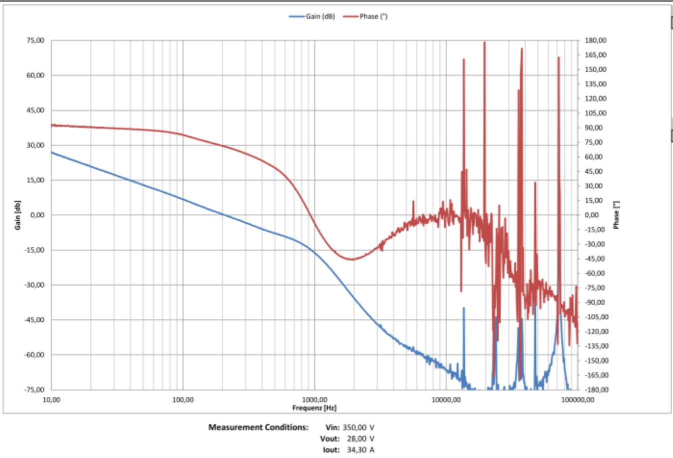
Gainmargin

Frequency (Hz)	Gain (dB)
3720,43	-19,20
7154,84	-35,14
7336,74	-35,59
8316,52	-37,84
11413,49	-41,57
11605,65	-41,30
12315,13	-42,12
12409,89	-42,54
12855,94	-43,26
13698,69	-43,45
14160,85	-43,83
22893,94	-46,13
24144,31	-46,14
28366,70	-45,41
29921,54	-44,12
84210,17	-13,78
94165,76	-19,01

Picture 57. Frequency Response Analysis
@ Vin = 340Vdc (DC power supply, Hold Up simulation)
Vout = 24Vdc
Iout = 40A

Recommended:
gain margin: about 10dB
phase margin: < 45 degrees

Result: pass



Phasemargin

Frequency (Hz)	Phase (°)
208,30	70,60

Gainmargin

Frequency (Hz)	Gain (dB)
929,97	-14,71
5614,24	-57,62
5674,19	-57,49
6656,99	-59,64
6668,30	-59,72
7575,17	-61,80
7607,43	-61,99
8826,91	-64,81
9255,04	-64,91
9393,93	-65,55
9750,78	-65,75
9893,02	-65,95
9980,99	-66,40
10104,39	-66,86

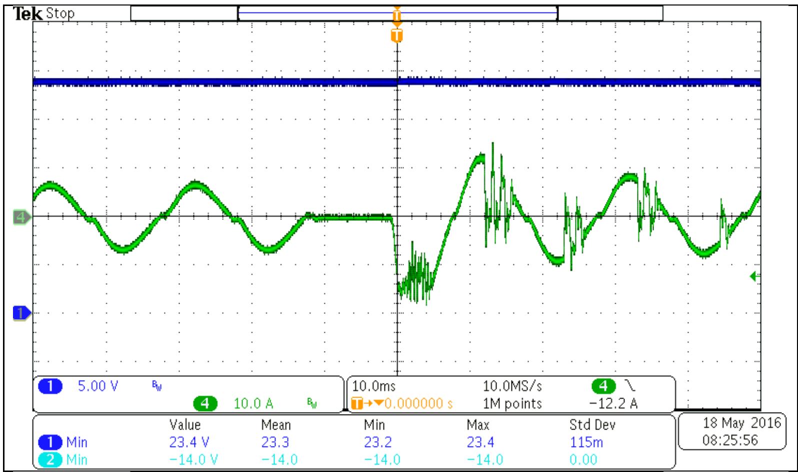
Picture 58. Frequency Response Analysis
@ Vin = 340Vdc (DC power supply, Hold Up simulation)
Vout = 28Vdc
Iout = 34,3A

Recommended:
gain margin: about 10dB
phase margin: < 45 degrees

Result: pass

3.13 Response to brown out characteristics

To check the stability of the outputs while various lengths of input interruptions are applied.

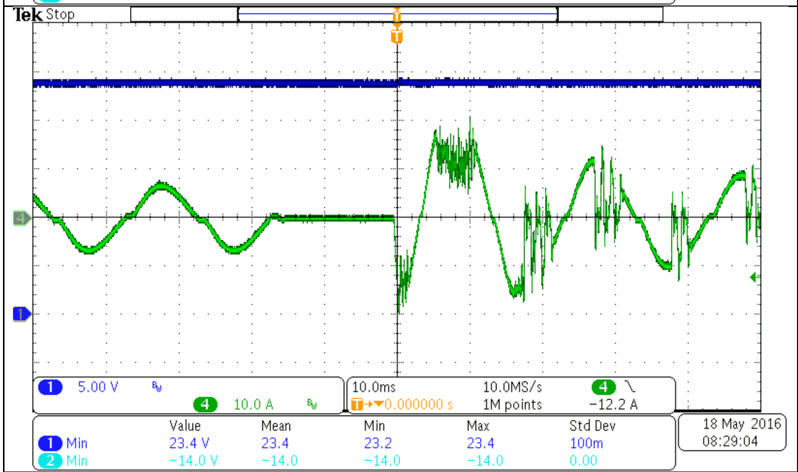


Picture 59. Brown out response @ 240Vac / 24Vdc / 100% load

Interruption time: 10ms

Channel 1: Vout
Channel 2: PG Signal
Channel 4: Iin

Result: pass

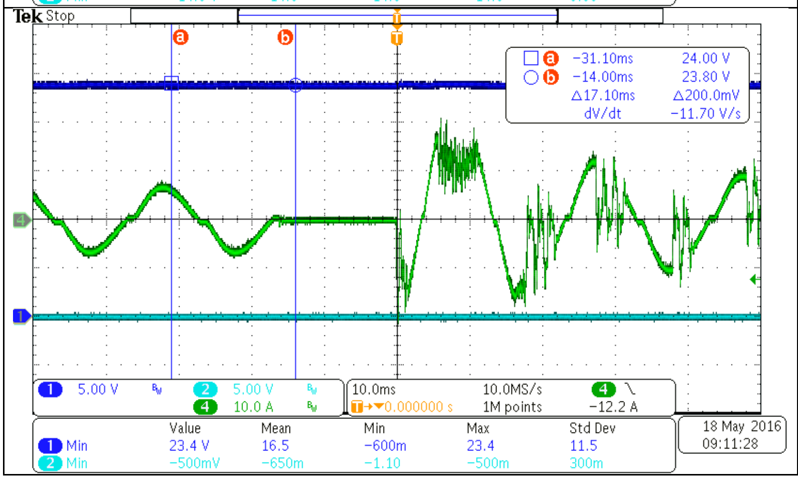


Picture 60. Brown out response @ 240Vac / 24Vdc / 100% load

Interruption time: 15ms

Channel 1: Vout
Channel 2: PG Signal
Channel 4: Iin

Result: pass

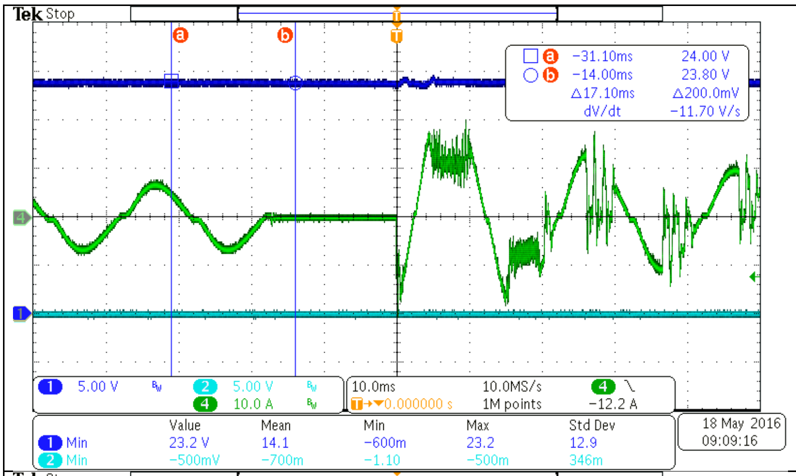


Picture 61. Brown out response @ 240Vac / 24Vdc / 100% load

Interruption time: 16ms

Channel 1: Vout
Channel 2: PG Signal
Channel 4: Iin

Result: pass

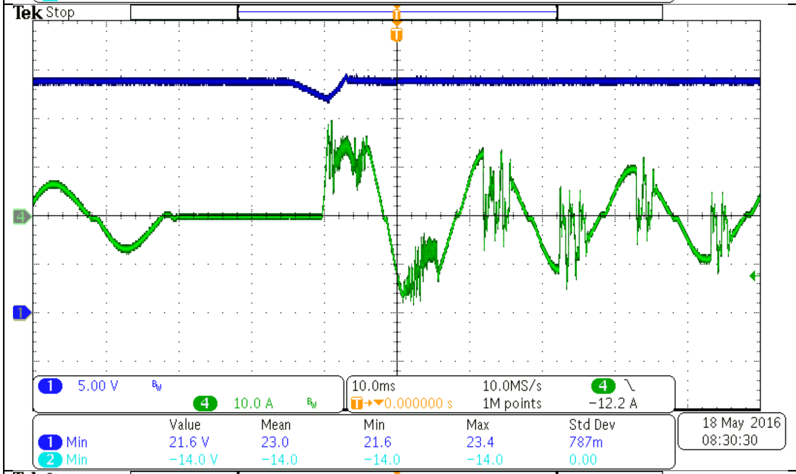


Picture 62. Brown out response @ 240Vac / 24Vdc / 100% load

Interruption time: 17ms

Channel 1: Vout
Channel 2: PG Signal
Channel 4: Iin

Result: pass

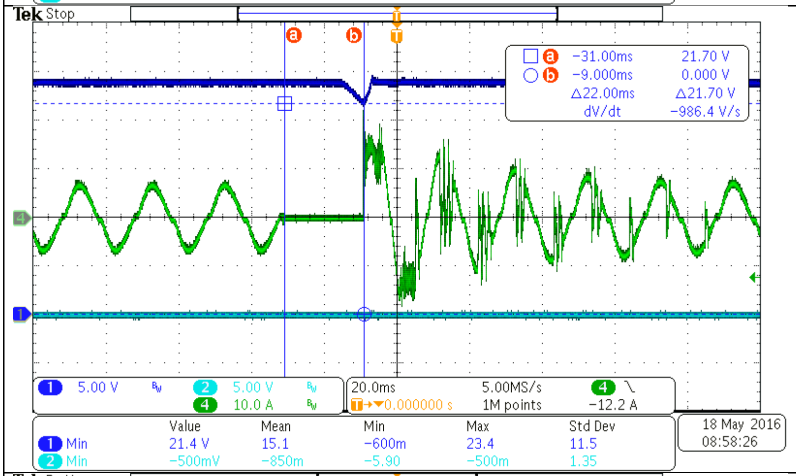


Picture 63. Brown out response @ 240Vac / 24Vdc / 100% load

Interruption time: 20ms

Channel 1: Vout
Channel 2: PG Signal
Channel 4: Iin

Result: pass

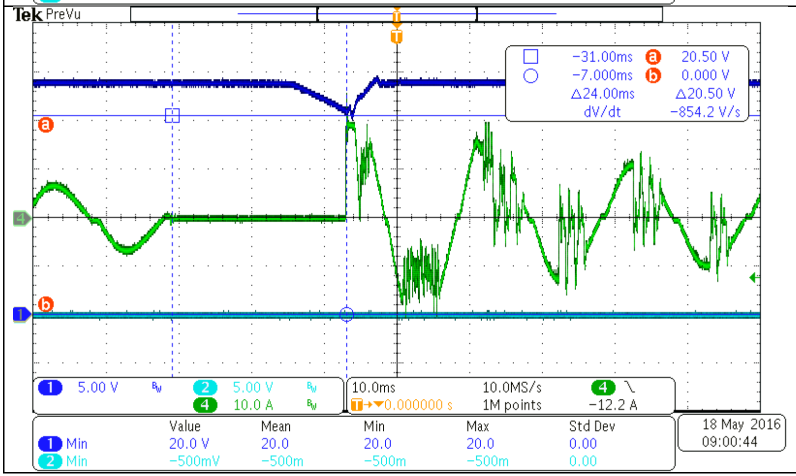


Picture 64. Brown out response @ 240Vac / 24Vdc / 100% load

Interruption time: 22ms

Channel 1: Vout
Channel 2: PG Signal
Channel 4: Iin

Result: pass

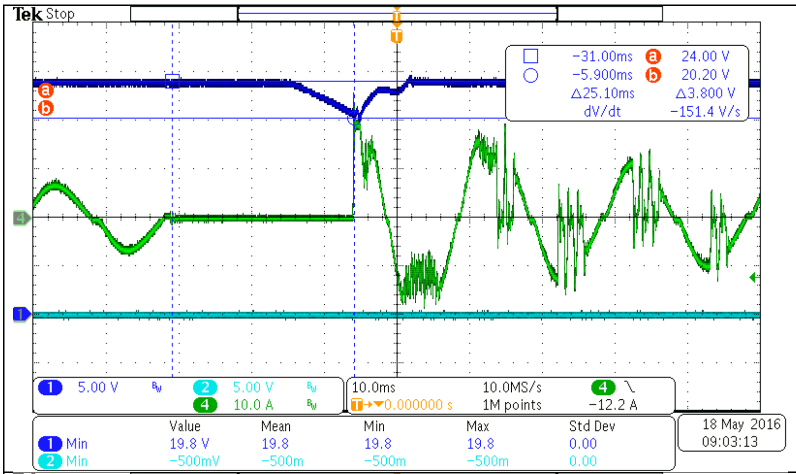


Picture 65. Brown out response @ 240Vac / 24Vdc / 100% load

Interruption time: 24ms

Channel 1: Vout
Channel 2: PG Signal
Channel 4: Iin

Result: pass

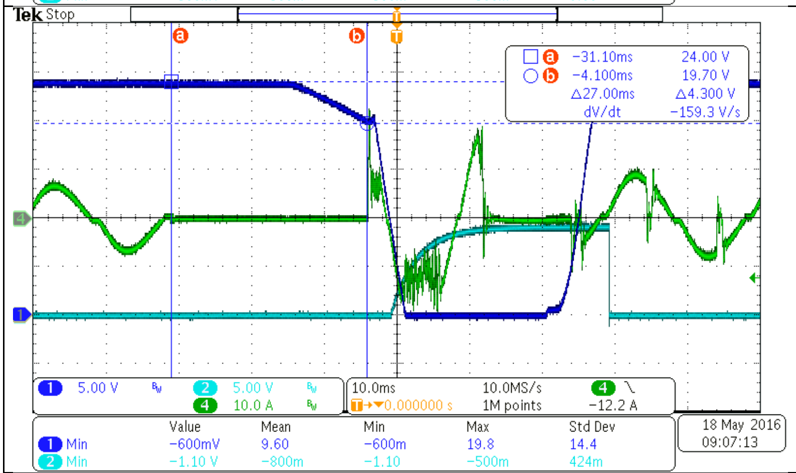


Picture 66. Brown out response @ 240Vac / 24Vdc / 100% load

Interruption time: 25ms

Channel 1: Vout
Channel 2: PG Signal
Channel 4: Iin

Result: pass

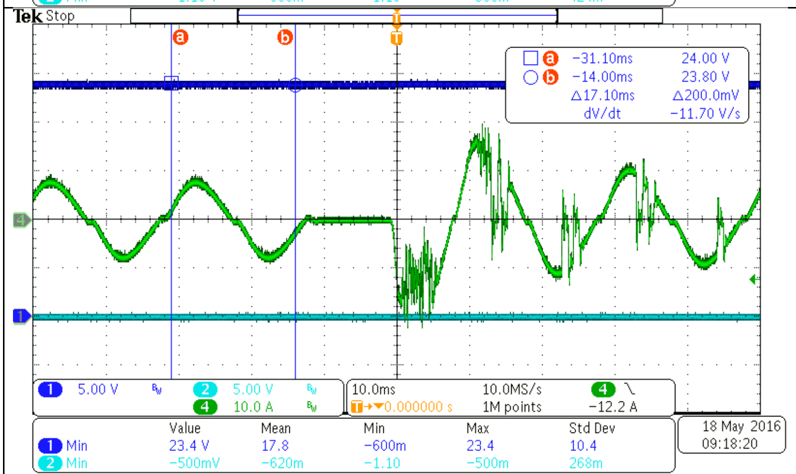


Picture 67. Brown out response @ 240Vac / 24Vdc / 100% load

Interruption time: 27ms

Channel 1: Vout
Channel 2: PG Signal
Channel 4: Iin

Result: pass

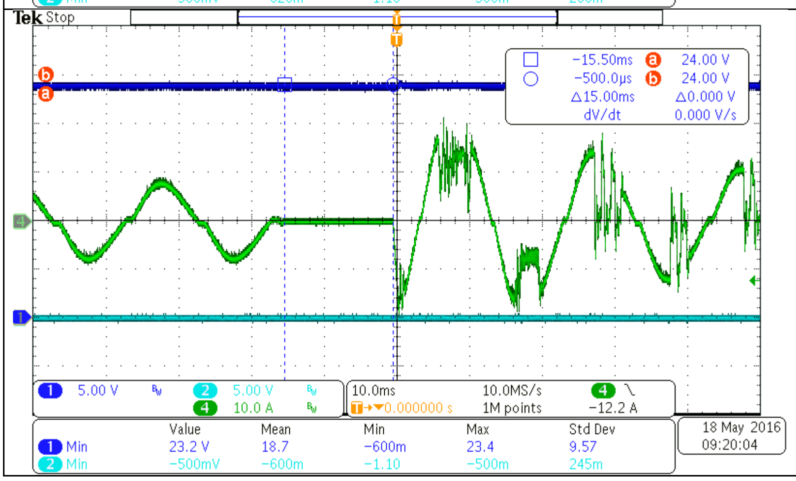


Picture 68. Brown out response @ 200Vac / 24Vdc / 100% load

Interruption time: 10ms

Channel 1: Vout
Channel 2: PG Signal
Channel 4: Iin

Result: pass

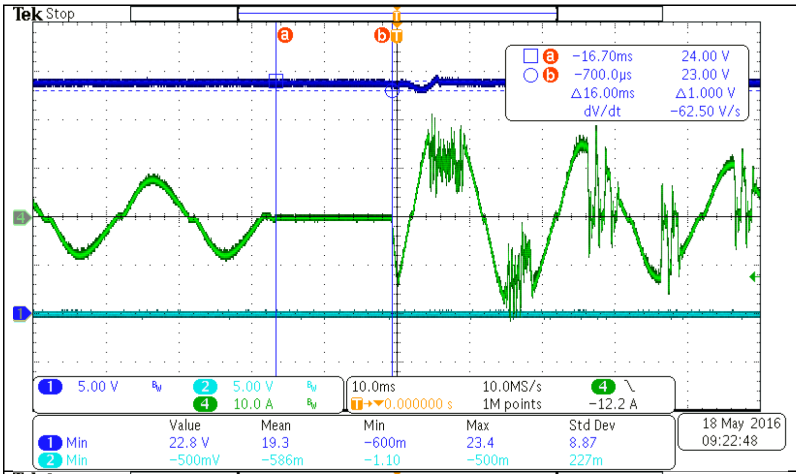
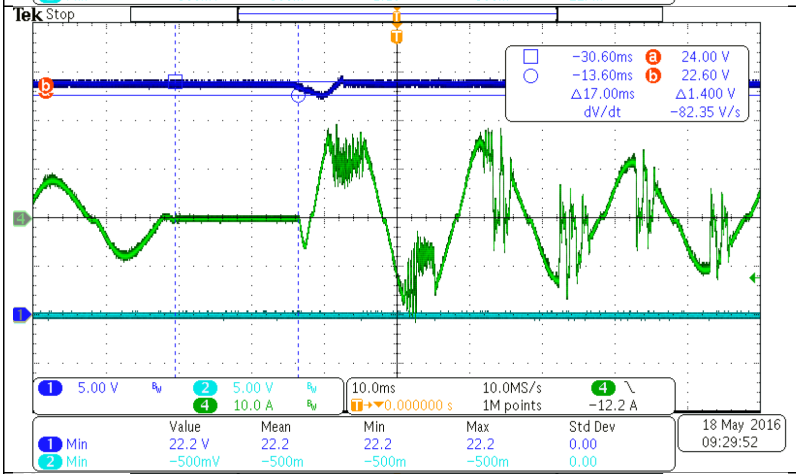
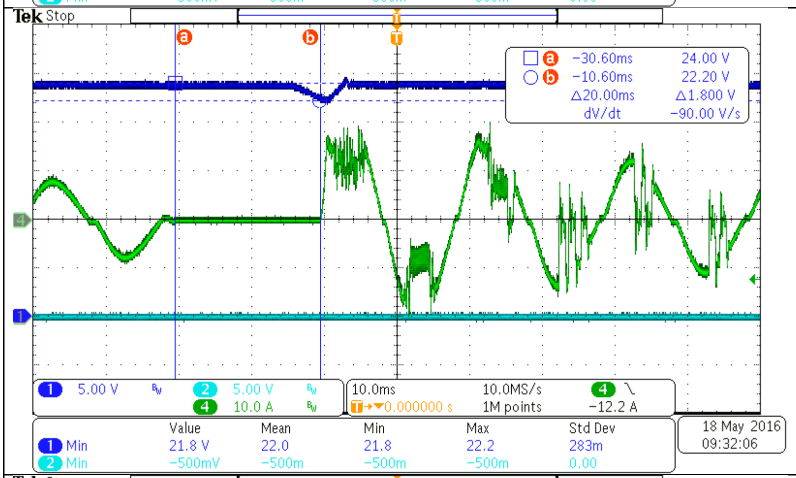
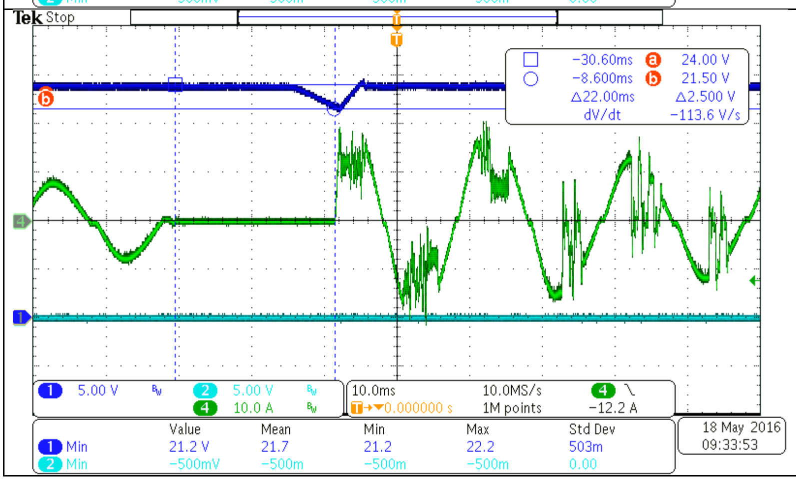


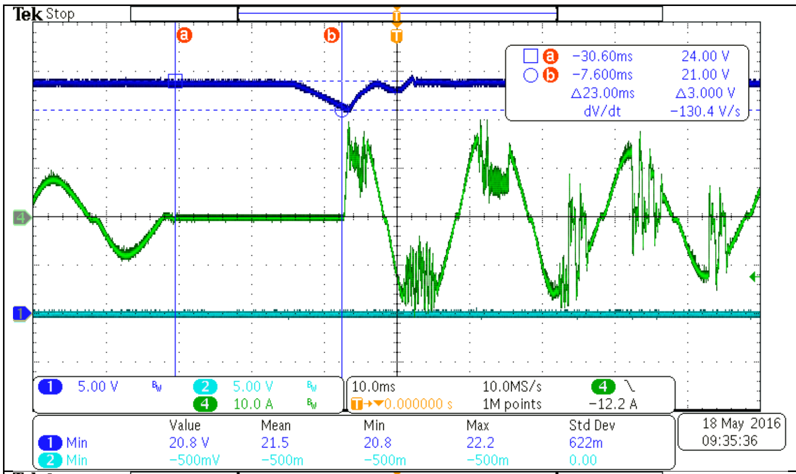
Picture 69. Brown out response @ 200Vac / 24Vdc / 100% load

Interruption time: 15ms

Channel 1: Vout
Channel 2: PG Signal
Channel 4: Iin

Result: pass

	**Picture 70. Brown out response @ 200Vac / 24Vdc / 100% load** Interruption time: 16ms Channel 1: Vout Channel 2: PG Signal Channel 4: Iin **Result: pass**
	**Picture 71. Brown out response @ 200Vac / 24Vdc / 100% load** Interruption time: 17ms Channel 1: Vout Channel 2: PG Signal Channel 4: Iin **Result: pass**
	**Picture 72. Brown out response @ 200Vac / 24Vdc / 100% load** Interruption time: 20ms Channel 1: Vout Channel 2: PG Signal Channel 4: Iin **Result: pass**
	**Picture 73. Brown out response @ 200Vac / 24Vdc / 100% load** Interruption time: 22ms Channel 1: Vout Channel 2: PG Signal Channel 4: Iin **Result: pass**

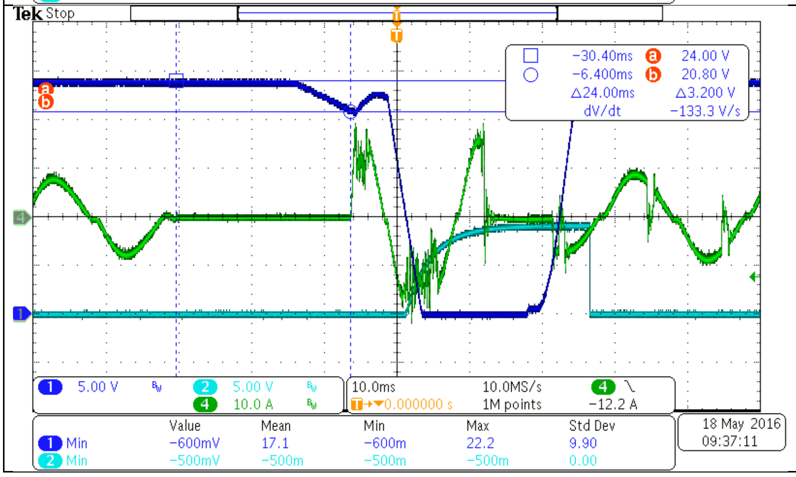


Picture 74. Brown out response @ 200Vac / 24Vdc / 100% load

Interruption time: 23ms

Channel 1: Vout
Channel 2: PG Signal
Channel 4: Iin

Result: pass



Picture 75. Brown out response @ 200Vac / 24Vdc / 100% load

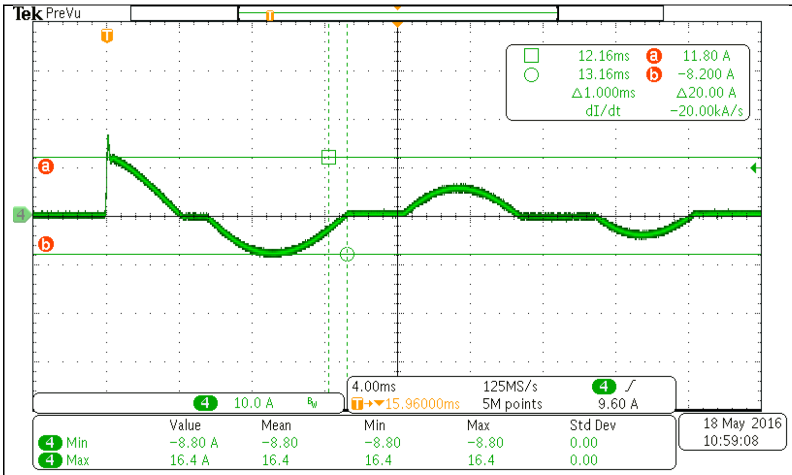
Interruption time: 24ms

Channel 1: Vout
Channel 2: PG Signal
Channel 4: Iin

Result: pass

3.14 Inrush current waveform

The input voltage was switched on at 90° phase lag to get the maximum inrush current.



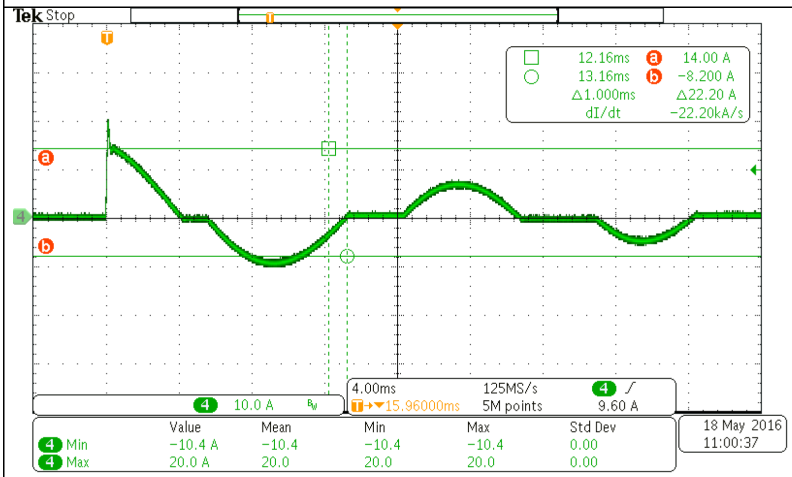
Picture 76. Inrush current @ 180Vac, 24Vdc / 100% load

Channel 4: I_{in}

$I_{in\text{-}max.}$ = 11,8A

Specified: <20A @ 240Vac

Result: pass



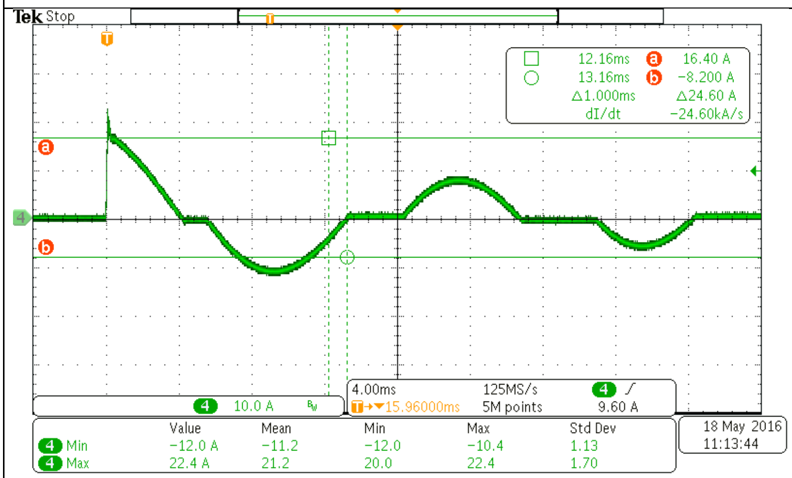
Picture 77. Inrush current @ 240Vac, 24Vdc / 100% load

Channel 4: I_{in}

$I_{in\text{-}max.}$ = 14A

Specified: <20A @ 240Vac

Result: pass



Picture 78. Inrush current @ 277Vac, 24Vdc / 100% load

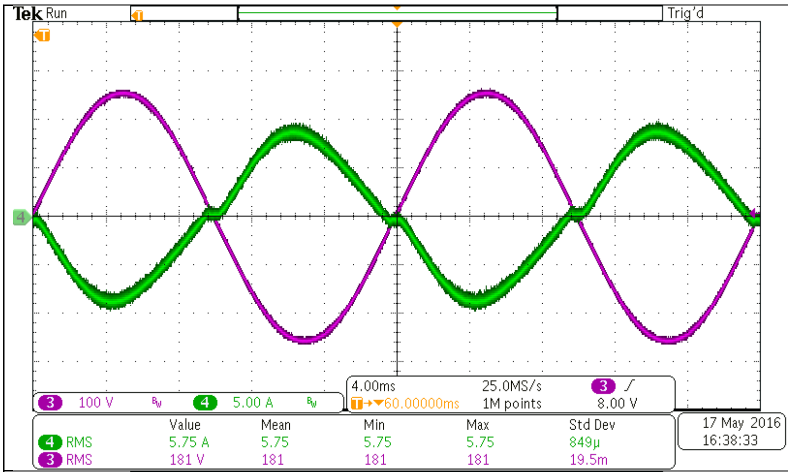
Channel 4: I_{in}

$I_{in\text{-}max.}$ = 16,4A

Specified: <20A @ 240Vac

Result: pass

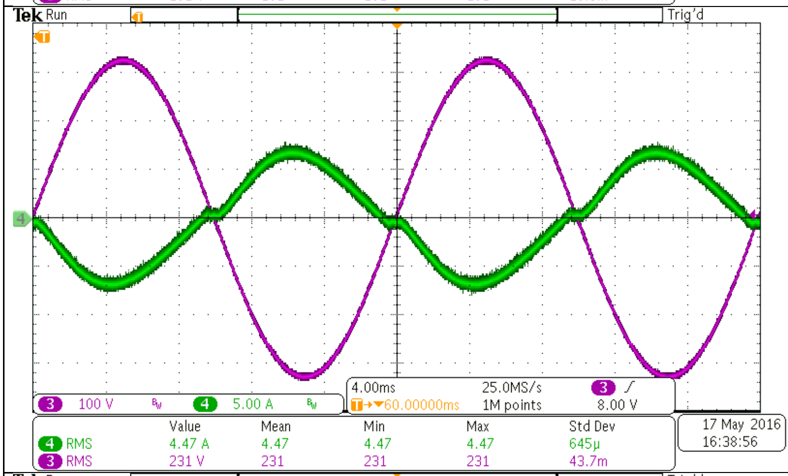
3.15 Input current waveform



Picture 79. Input current waveform @ 180Vac, 24Vdc / 100% load

Channel 3: V_{in}
Channel 4: I_{in}

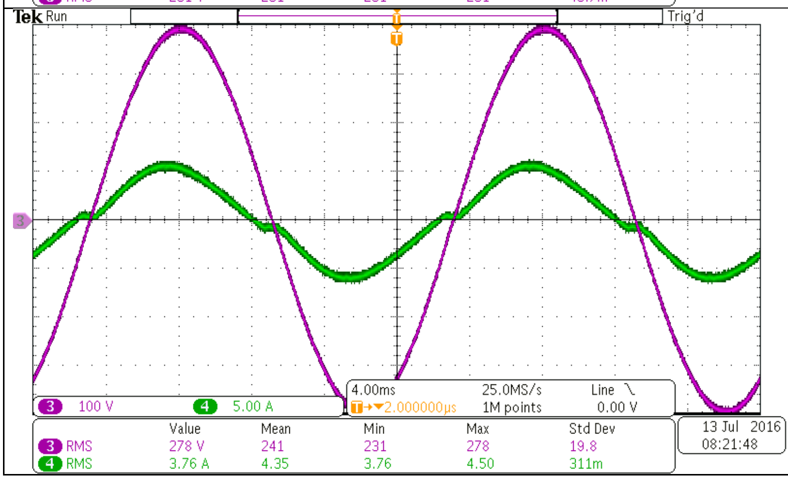
Result: pass



Picture 80. Input current waveform @ 230Vac, 24Vdc / 100% load

Channel 3: V_{in}
Channel 4: I_{in}

Result: pass



Picture 81. Input current waveform @ 277Vac, 24Vdc / 100% load

Channel 3: V_{in}
Channel 4: I_{in}

Result: pass

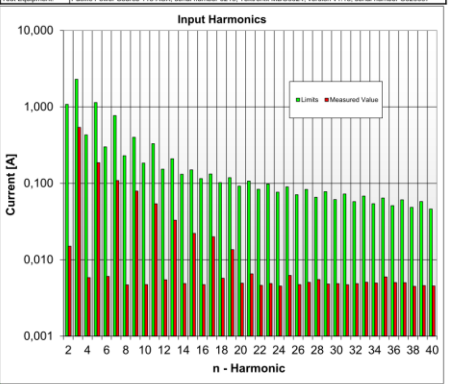
3.16 Input current harmonics

Input current harmonics according to EN6100-3-2 – Class A

Testreport: Input Current Harmonics According to: EN61000-3-2 - Class A

Unit:	TDK Lambda DRF960-24-1 Rev.4.1	Operating condition:	24V = 40A / 200VAC/50Hz
P/N: / Sno.:	11-05-437000-1	Operator:	FJM
Date:	04.01.2017	Test Equipment:	Pacific Power Source 118-ACX, serial number 0215, Tektronix MDO3024, version v1.18, serial number C020657

Harmonics			Current	
n	odd	even	Limit	measured
2	1,080		1,080	0,015032
3		2,300	2,300	0,539523
4	0,430		0,430	0,005835
5		1,140	1,140	0,185968
6	0,300		0,300	0,006049
7		0,770	0,770	0,108467
8	0,230		0,230	0,004689
9		0,400	0,400	0,079142
10	0,184		0,184	0,004721
11		0,330	0,330	0,053879
12	0,153		0,153	0,005455
13		0,210	0,210	0,032893
14	0,131		0,131	0,004886
15		0,150	0,150	0,022103
16	0,115		0,115	0,004717
17		0,132	0,132	0,01995
18	0,102		0,102	0,005732
19		0,118	0,118	0,013569
20	0,092		0,092	0,004927
21		0,107	0,107	0,006547
22	0,084		0,084	0,004614
23		0,098	0,098	0,004876
24	0,077		0,077	0,004524
25		0,090	0,090	0,00623
26	0,071		0,071	0,004721
27		0,083	0,083	0,005053
28	0,066		0,066	0,005504
29		0,078	0,078	0,004805
30	0,061		0,061	0,004864
31		0,073	0,073	0,004697
32	0,058		0,058	0,004862
33		0,068	0,068	0,005078
34	0,054		0,054	0,004945
35		0,064	0,064	0,005973
36	0,051		0,051	0,005026
37		0,061	0,061	0,005001
38	0,048		0,048	0,004488
39		0,058	0,058	0,004583
40	0,046		0,046	0,004539



Power Factor: 0,986

Test Result: OK

04.01.2017 (Date:) FJM (Sign:)

THD-F 11,46%
RMS 5.200717 A
Overall Pass
Frequency (measured) 49.997246 Hz

Picture 82. Input Current Harmonics

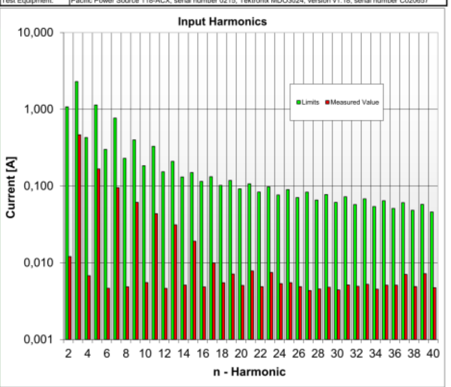
@ 200Vac, 50Hz, 24Vdc / 100% load

Result: pass

Testreport: Input Current Harmonics According to: EN61000-3-2 - Class A

Unit:	TDK Lambda DRF960-24-1 Rev.4.1	Operating condition:	24V = 40A / 240VAC/50Hz
P/N: / Sno.:	11-05-437000-1	Operator:	FJM
Date:	04.01.2017	Test Equipment:	Pacific Power Source 118-ACX, serial number 0215, Tektronix MDO3024, version v1.18, serial number C020657

Harmonics			Current	
n	odd	even	Limit	measured
2	1,080		1,080	0,012044
3		2,300	2,300	0,465447
4	0,430		0,430	0,006769
5		1,140	1,140	0,167048
6	0,300		0,300	0,004659
7		0,770	0,770	0,095109
8	0,230		0,230	0,004858
9		0,400	0,400	0,061286
10	0,184		0,184	0,005519
11		0,330	0,330	0,043578
12	0,153		0,153	0,004645
13		0,210	0,210	0,031253
14	0,131		0,131	0,005128
15		0,150	0,150	0,019122
16	0,115		0,115	0,004848
17		0,132	0,132	0,009933
18	0,102		0,102	0,005488
19		0,118	0,118	0,007129
20	0,092		0,092	0,005064
21		0,107	0,107	0,00784
22	0,084		0,084	0,004889
23		0,098	0,098	0,007478
24	0,077		0,077	0,005356
25		0,090	0,090	0,005514
26	0,071		0,071	0,004891
27		0,083	0,083	0,004351
28	0,066		0,066	0,004559
29		0,078	0,078	0,0048
30	0,061		0,061	0,00443
31		0,073	0,073	0,005144
32	0,058		0,058	0,004945
33		0,068	0,068	0,005238
34	0,054		0,054	0,004529
35		0,064	0,064	0,005104
36	0,051		0,051	0,005109
37		0,061	0,061	0,007046
38	0,048		0,048	0,004906
39		0,058	0,058	0,007209
40	0,046		0,046	0,004733



Power Factor: 0,981

Test Result: OK

04.01.2017 (Date:) FJM (Sign:)

THD-F 12,03%
RMS 4.291134 A
Overall Pass
Frequency (measured) 49.998880 Hz

Picture 83. Input Current Harmonics

@ 240Vac, 50Hz, 24Vdc / 100% load

Result: pass

3.17 Touch Current (UL/EN/IEC 60950)

3.17.1 according to the standard

EUT: TDK-Lambda DRF960-24-1		Inspector:	F.J. Möers
Rev.: 4.1		Date:	24.02.2017
S/No: DRF00002H047		Input Voltage:	277Vac
P/N: 11-05-500437-1		Frequency:	63 Hz

Polarity (p1)	Switch **e**	Switch **s**	Polarity (p2)	Voltage U_2 [mV] see Figure D.1	Figure	Touch Current [mA] U2/RB (500Ω)
N - L/PE	open	PE-Connection	--------	467,46	5 A	0,9349
L - N/PE	open	PE-Connection	--------	456,00	5 A	0,9120
N - L/PE	open	chassis/housing [1)]	--------		5 A	0,0000
L - N/PE	open	chassis/housing [1)]	--------		5 A	0,0000
N - L/PE	closed	secondary	+ OUT 1	8,06	5 A	0,0161
N - L/PE	closed	secondary	- OUT 1	8,13	5 A	0,0163
L - N/PE	closed	secondary	+ OUT 1	7,94	5 A	0,0159
L - N/PE	closed	secondary	- OUT 1	8,00	5 A	0,0160

[1)] Only for protection class II units

Input Voltage measured with: Instrument: Oscilloscope Tektronix MDO3024 S/N: C020657
Voltage U2 measured with: Instrument: Touch Current Measurement Box S/N:

The EUT (☒ pass) (☐ fail) the requirements according to EN/IEC 60950.

3.17.2 according to customer specification

Customer specified: Touch Current < 1mA @ 240Vac/60Hz

EUT: TDK-Lambda DRF960-24-1
Rev.: 4.1
S/No: DRF00002H047
P/N: 11-05-500437-1

Inspector: F.J. Möers
Date: 24.02.2017
Input Voltage: 240Vac
Frequency: 60 Hz

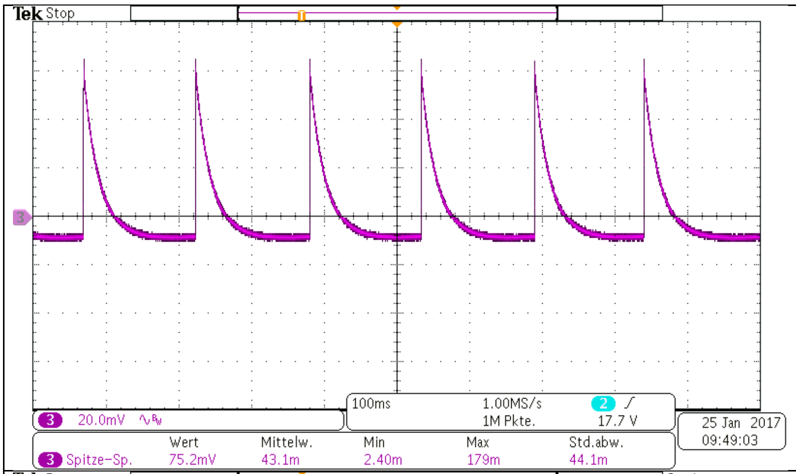
Polarity (p1)	Switch **e**	Switch **s**	Polarity (p2)	Voltage U_2 [mV] see Figure D.1	Figure	Touch Current [mA] U2/RB (500Ω)
N - L/PE	open	PE-Connection	--------	373,00	5 A	0,7460
L - N/PE	open	PE-Connection	--------	371,00	5 A	0,7420
N - L/PE	open	chassis/housing [1)]	--------		5 A	0,0000
L - N/PE	open	chassis/housing [1)]	--------		5 A	0,0000
N - L/PE	closed	secondary	+ OUT 1	6,83	5 A	0,0137
N - L/PE	closed	secondary	- OUT 1	6,91	5 A	0,0138
L - N/PE	closed	secondary	+ OUT 1	6,98	5 A	0,0140
L - N/PE	closed	secondary	- OUT 1	7,00	5 A	0,0140

[1)] Only for protection class II units

Input Voltage measured with: Instrument: Oscilloscope Tektronix MDO3024 S/N: C020657
Voltage U2 measured with: Instrument: Touch Current Measurement Box S/N:

The EUT (☒ pass) (☐ fail) the requirements according to the customer specification.

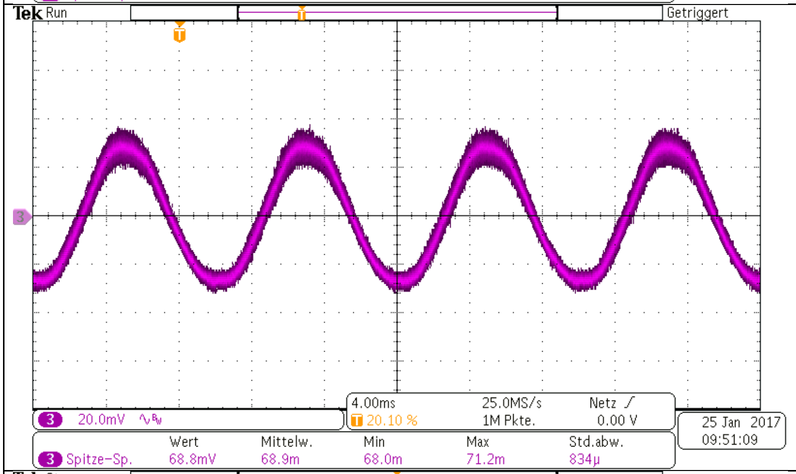
3.18 Output ripple and noise waveform



Picture 84. Output ripple & Noise waveform @ 230Vac, 24Vdc / 0% load

Channel 3: V_{out}
Channel 4: I_{out}

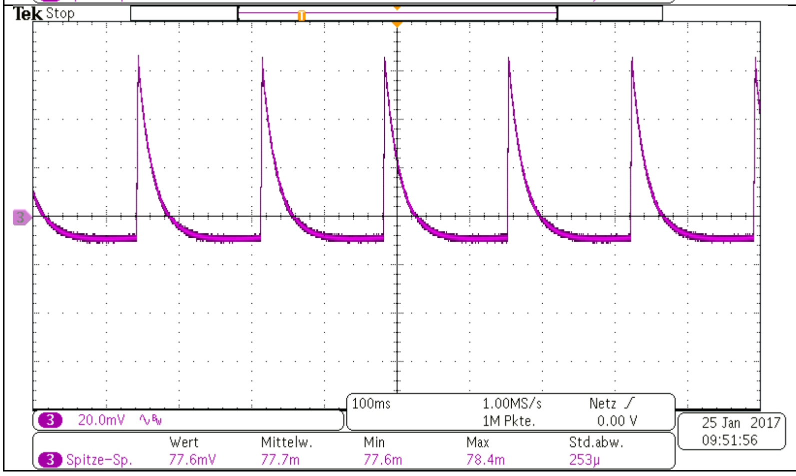
Result: pass



Picture 85. Output ripple & Noise waveform @ 230Vac, 24Vdc / 100% load

Channel 3: V_{out}
Channel 4: I_{out}

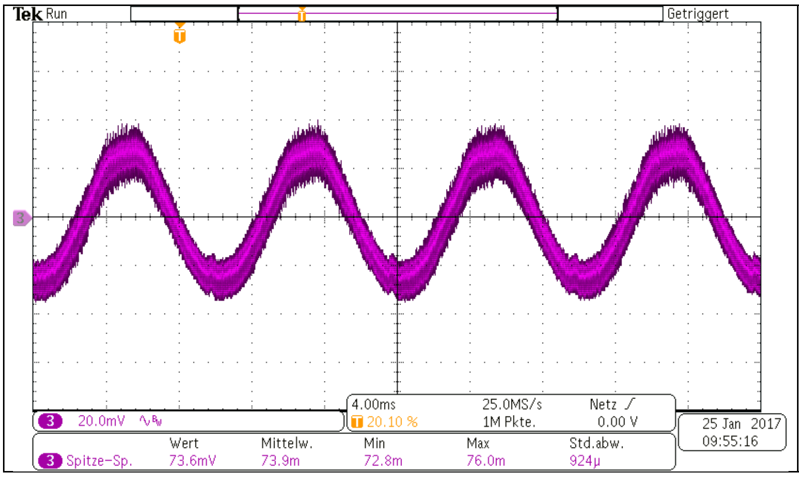
Result: pass



Picture 86. Output ripple & Noise waveform @ 230Vac, 28Vdc / 0% load

Channel 3: V_{out}
Channel 4: I_{out}

Result: pass



Picture 87. Output ripple & Noise waveform @ 230Vac, 28Vdc / 100% load

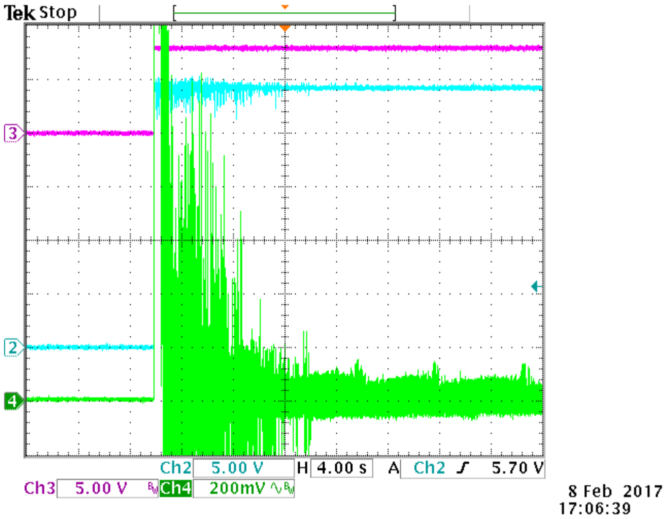
Channel 3: V_{out}
Channel 4: I_{out}

Result: pass

3.19 Cold Start at -40°C

This test is outside of the specified ambient temperature range. The test should show if the unit is able to start up at -40°C and to determine the time before the output is in specification.

Test condition: Cool down time at -40°C before start (during this time the power supply was powered off): 5h

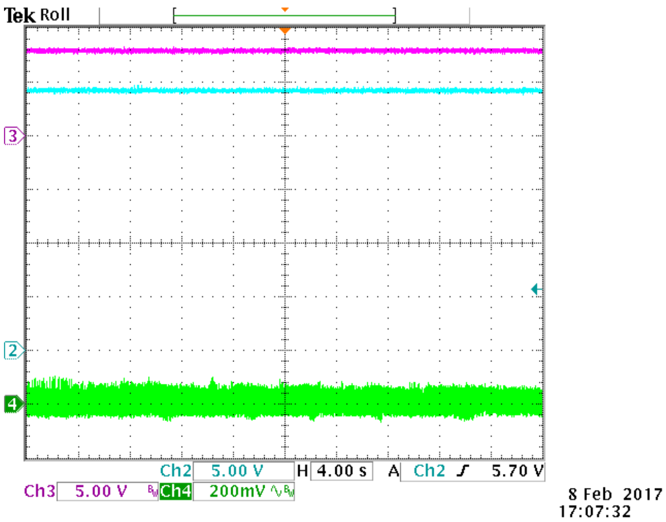


Picture 88. Output ripple & Noise at cold start

@ 180Vac, 24Vdc / 100% load

Time: Start

Channel 2: V_{out_dc}
Channel 3: DC_ok (ext. 8V)
Channel 4: V_{out_ac} (ripple&noise)

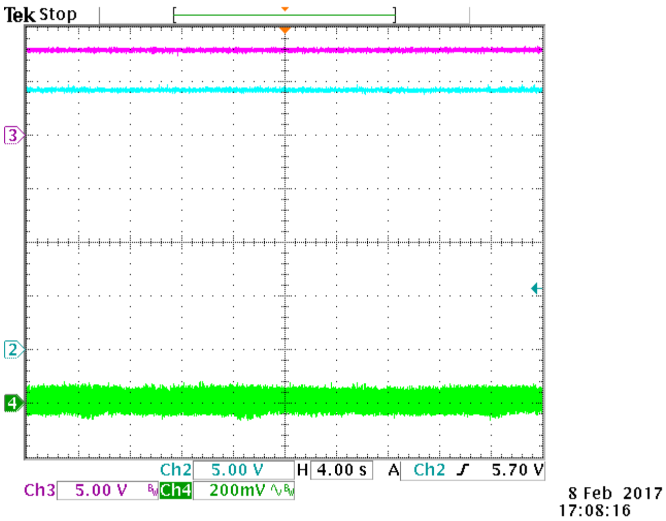


Picture 89. Output ripple & Noise at cold start

@ 180Vac, 24Vdc / 100% load

Time: after 1 minute

Channel 2: V_{out_dc}
Channel 3: DC_ok (ext. 8V)
Channel 4: V_{out_ac} (ripple&noise)

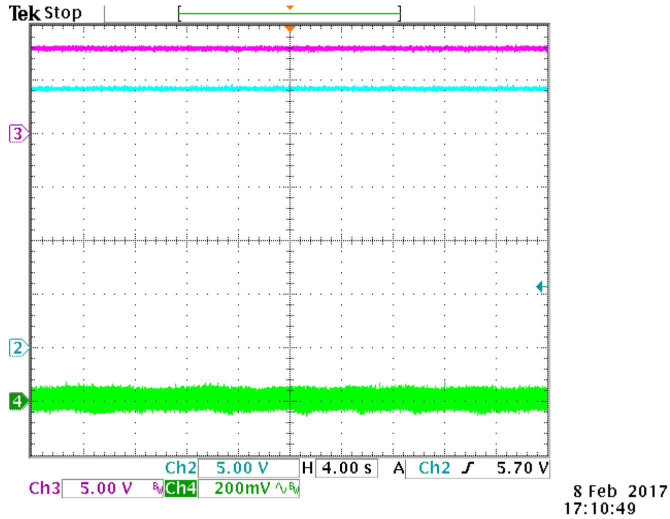


Picture 90. Output ripple & Noise at cold start

@ 180Vac, 24Vdc / 100% load

Time: after 2 minutes

Channel 2: V_{out_dc}
Channel 3: DC_ok (ext. 8V)
Channel 4: V_{out_ac} (ripple&noise)

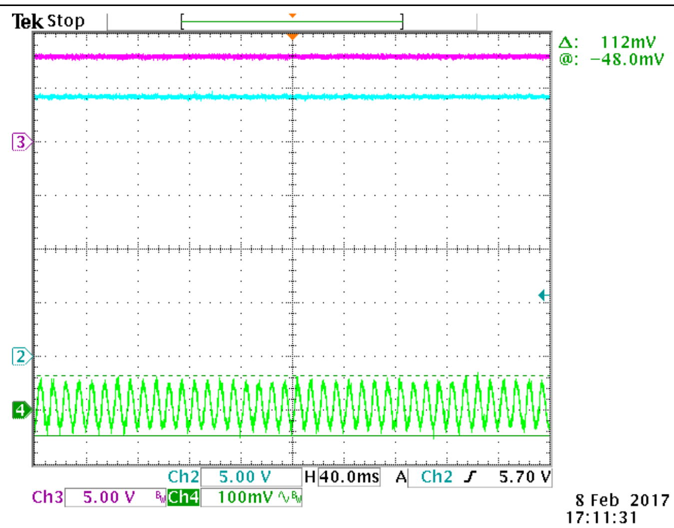


Picture 91. Output ripple & Noise at cold start

@ 180Vac, 24Vdc / 100% load

Time: after 4 minutes

Channel 2: V_{out_dc}
Channel 3: DC_ok (ext. 8V)
Channel 4: V_{out_ac} (ripple&noise)

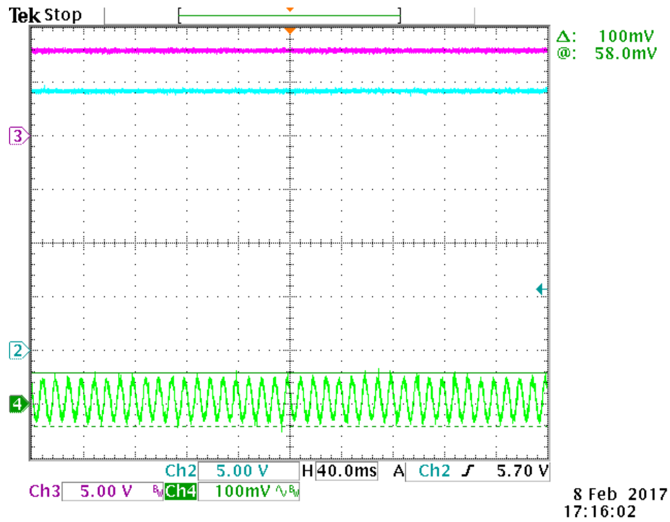


Picture 92. Output ripple & Noise at cold start

@ 180Vac, 24Vdc / 100% load

Time: after 5 minutes

Channel 2: V_{out_dc}
Channel 3: DC_ok (ext. 8V)
Channel 4: V_{out_ac} (ripple&noise)

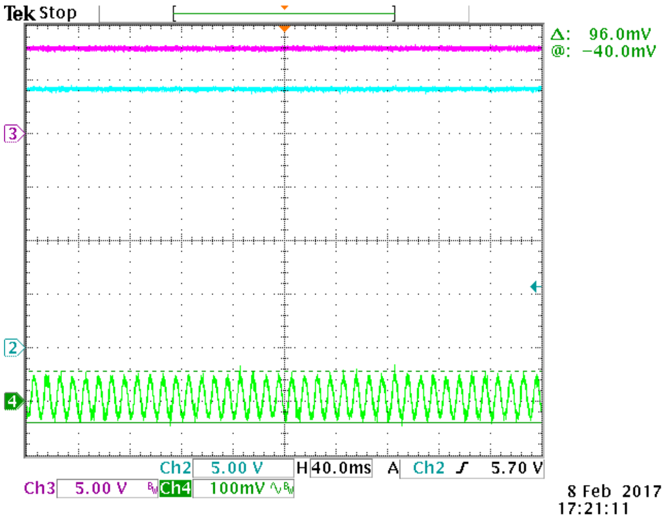


Picture 93. Output ripple & Noise at cold start

@ 180Vac, 24Vdc / 100% load

Time: after 10 minutes

Channel 2: V_{out_dc}
Channel 3: DC_ok (ext. 8V)
Channel 4: V_{out_ac} (ripple&noise)

	**Picture 94. Output ripple & Noise at cold start** **@ 180Vac, 24Vdc / 100% load** Time: after 15 minutes Channel 2: V_{out_dc} Channel 3: DC_ok (ext. 8V) Channel 4: V_{out_ac} (ripple&noise)

Result: The output voltage is after a time of approx. 5 minutes in specification.

3.20 Electro Magnetic Interference characteristics

For the complete EMI results see the separate test report from RS Schwarze:

Test Report No.: 2017012

This DVT shows only the conducted and radiated emissions.

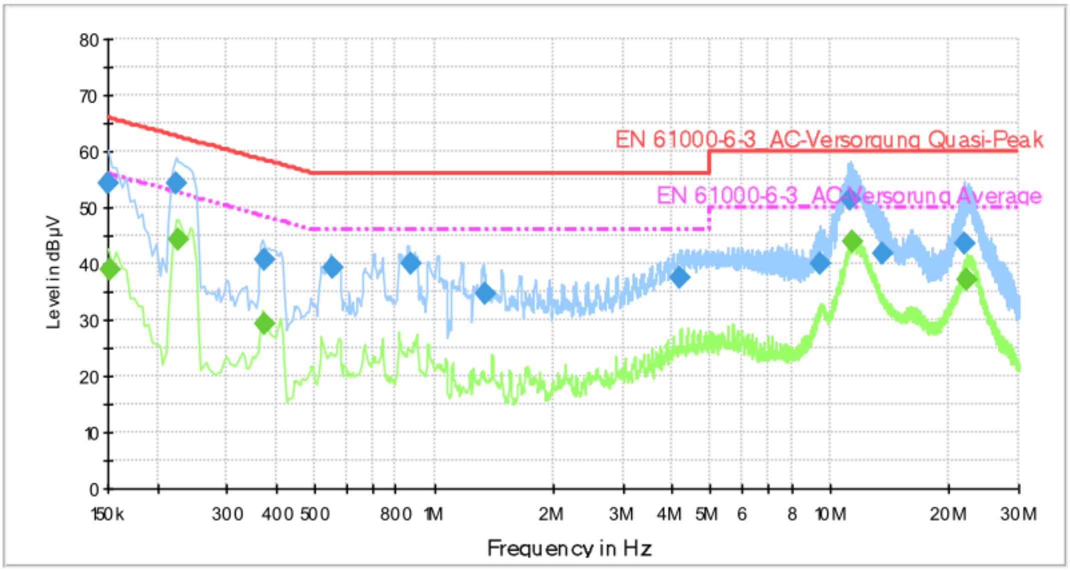
3.20.1 Conducted Emissions

Scan Setup: Voltage with 2-Line_NSLK_EN55016-2-1 pre [EMI conducted]

Hardware Setup:	Störspannung_NSLK_1-phasig
Receiver:	[ESU 8]
Level Unit:	dBµV

Subrange	Step Size	Detectors	IF BW	Meas. Time	Preamp
150 kHz - 30 MHz	4 kHz	PK+; AVG	9 kHz	0,01 s	0 dB

Voltage with 2-Line-LISN_NSLK_EN55016-2-1_AC_Wohn



EN 61000-6-3_AC-Versorgung Quasi-Peak.LimitLine
EN 61000-6-3_AC-Versorung Average.LimitLine
Preview Result 1-PK+
Preview Result 2-AVG
Final Result 1-QPK
Final Result 2-AVG

Final Result 1:

Frequency (MHz)	QuasiPeak (dBµV)	Meas. Time (s)	Bandwidth (kHz)	PE	Line	Corr. (dB)	Margin (dB)	Limit (dBµV)
0.150800	54.3	15.0	9.0	FLO	N	10.1	11.6	66.0
0.223600	54.3	15.0	9.0	FLO	N	10.1	8.4	62.7
0.373600	40.7	15.0	9.0	GN	N	10.1	17.7	58.4
0.555600	39.3	15.0	9.0	GN	L1	10.1	16.7	56.0
0.869600	40.0	15.0	9.0	GN	N	10.2	16.0	56.0
1.340800	34.8	15.0	9.0	GN	N	10.3	21.2	56.0
4.196800	37.6	15.0	9.0	GN	N	10.5	18.4	56.0
9.499600	40.1	15.0	9.0	FLO	N	11.0	19.9	60.0
11.242000	51.4	15.0	9.0	FLO	N	11.2	8.6	60.0
13.622400	41.6	15.0	9.0	FLO	L1	11.3	18.4	60.0
21.903200	43.7	15.0	9.0	FLO	N	12.1	16.3	60.0

Final Result 2:

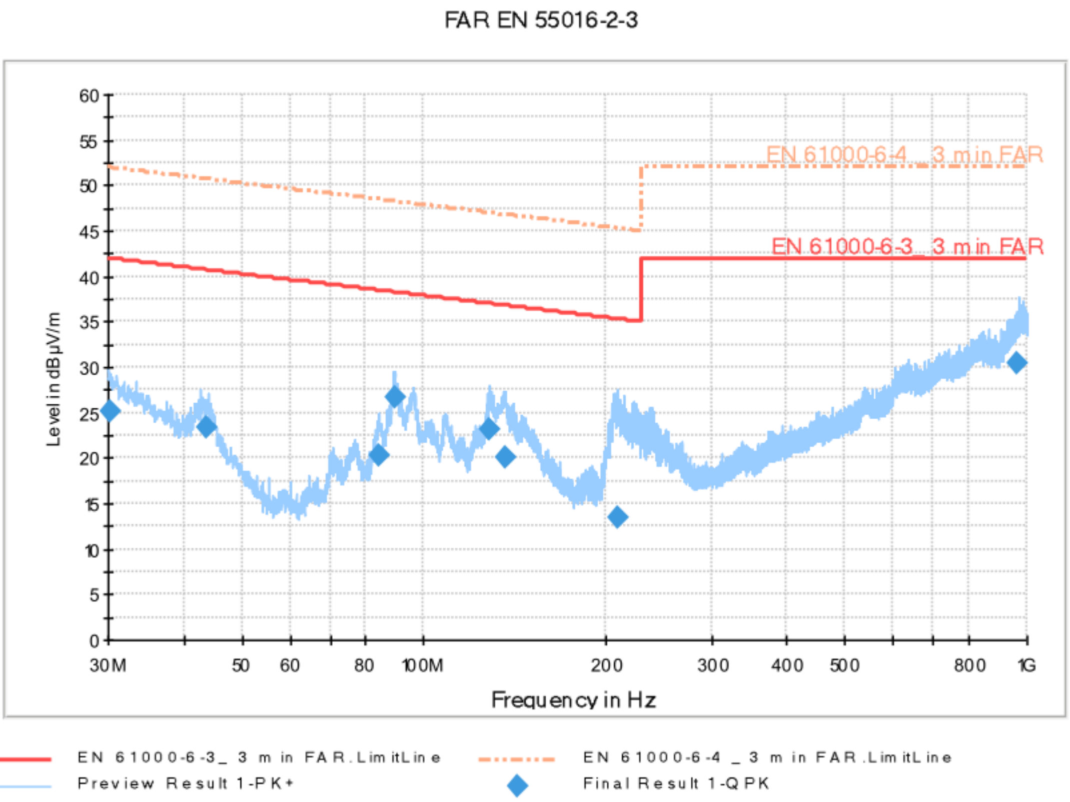
Frequency (MHz)	Average (dBµV)	Meas. Time (s)	Bandwidth (kHz)	PE	Line	Corr. (dB)	Margin (dB)	Limit (dBµV)
0.152400	38.9	15.0	9.0	GN	L1	10.0	16.9	55.9
0.224400	44.3	15.0	9.0	GN	N	10.1	8.4	52.7
0.374000	29.4	15.0	9.0	GN	N	10.1	19.0	48.4
11.332400	44.0	15.0	9.0	FLO	L1	11.1	6.0	50.0
22.079200	37.3	15.0	9.0	FLO	N	12.1	12.7	50.0

3.20.2 Radiated Emissions

Scan Setup: EN 55016-2-3 FAR max [EMI radiated]

Hardware Setup:	FAR_30MHz - 1 GHz
Receiver:	[ESU 8]
Level Unit:	dBµV/m

Subrange	Step Size	Detectors	IF BW	Meas. Time	Preamp
30 MHz - 1 GHz	50 kHz	PK+	120 kHz	0,02 s	20 dB



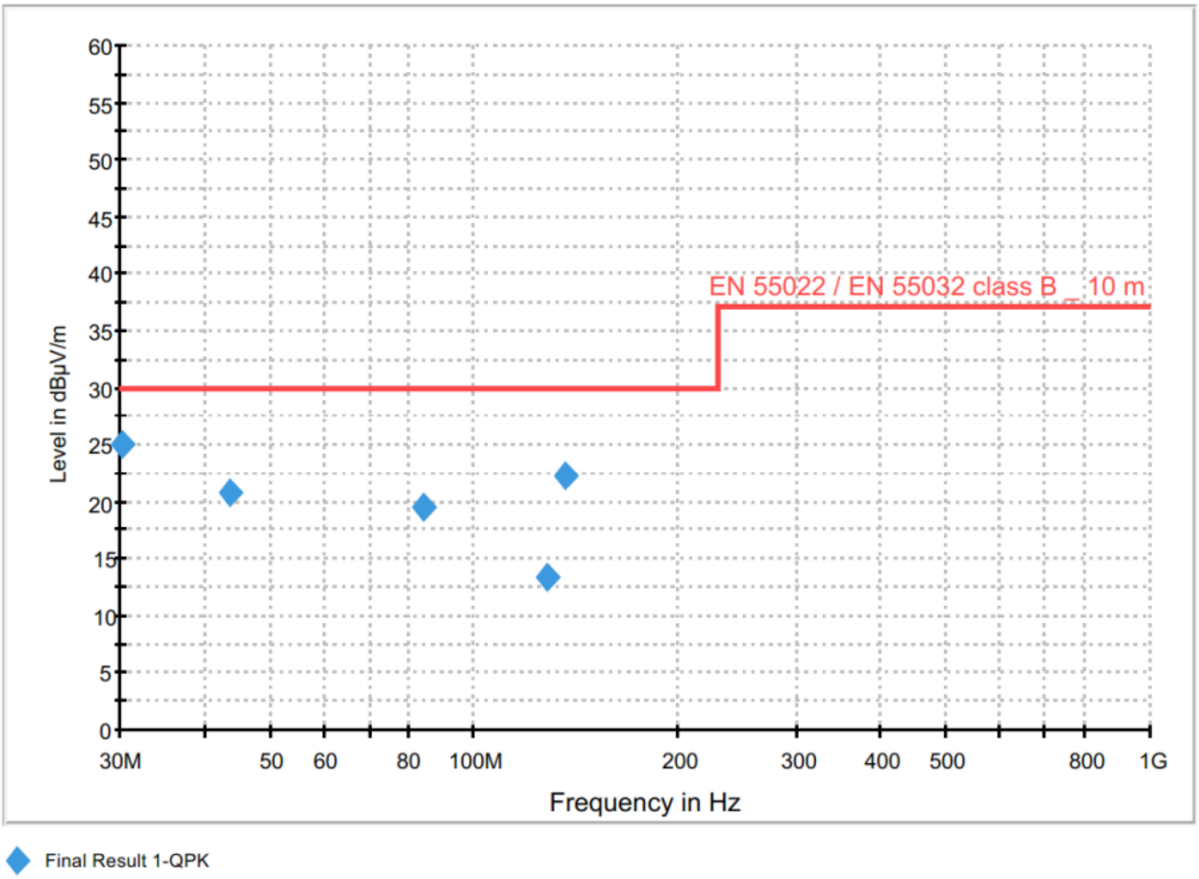
Final Result 1:

Frequency (MHz)	QuasiPeak (dBµV/m)	Meas. Time (s)	Bandwidth (kHz)	Height (cm)	Polarization	Azimuth (deg)	Corr. (dB)	Margin (dB)	Limit (dBµV/m)
30.150000	25.2	1.0	120.0	100.0	V	182.0	26.2	16.8	42.0
43.700000	23.4	1.0	120.0	100.0	V	248.0	19.3	17.3	40.7
84.450000	20.3	1.0	120.0	100.0	V	23.0	13.8	18.1	38.4
89.500000	26.7	1.0	120.0	100.0	V	8.0	14.3	11.6	38.2
128.850000	23.2	1.0	120.0	100.0	H	8.0	16.9	13.8	37.0
137.100000	20.0	1.0	120.0	100.0	V	120.0	16.3	16.8	36.8
209.100000	13.4	1.0	120.0	100.0	V	91.0	11.5	21.9	35.3
965.700000	30.4	1.0	120.0	100.0	V	105.0	30.6	11.6	42.0

Scan Setup: EN 55022 / EN 55032 OATS fin [EMI radiated]

Hardware Setup:	OATS_30 MHz - 1 GHz
Receiver:	[ESU 8]
Level Unit:	dBµV/m

Subrange	Step Size	Detectors	IF BW	Meas. Time	Preamp
30 MHz - 1 GHz	50 kHz	QPK	120 kHz	15 s	20 dB



Final Result 1:

Frequency (MHz)	QuasiPeak (dBµV/m)	Meas. Time (s)	Bandwidth (kHz)	Height (cm)	Polarization	Azimuth (deg)	Corr. (dB)	Margin (dB)	Limit (dBµV/m)
30.150000	25.0	15.0	120.0	369.0	V	15.0	19.2	5.0	30.0
43.700000	20.8	15.0	120.0	266.0	V	9.0	12.8	9.2	30.0
84.450000	19.4	15.0	120.0	123.0	V	9.0	8.8	10.6	30.0
128.850000	13.3	15.0	120.0	357.0	H	75.0	13.5	16.7	30.0
137.100000	22.2	15.0	120.0	283.0	V	15.0	13.2	7.8	30.0

3.21 Surge Immunity Test (IEC 61000-4-5)

Equipment used:

Surge Generator:	HAEFELY PSURGE 4.1		
Coupling Impedance:	Normal = 2Ω Common = 12Ω	Coupling Capacitance:	Normal = 18µF Common = 9µF

Test condition:

Input Voltage:	230Vac	Output Voltage:	Rated
Output Current:	80%	Number of Tests:	5 times
Polarity:	+, - alternate	Mode:	Common, Normal
Phase:	0, 90, 270 deg	Ambient Temperature:	25°C

Acceptable Conditions:

1. Output voltage regulation not to exceed ±5% of initial (before test) value during test.
2. Output voltage to be within regulation specification after the test.
3. Along with 1 and 2, no discharge of fire or smoke, as well as no output failure.

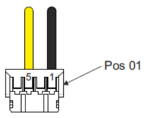
Test Result:

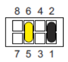
Test Voltage (kV) Common	DRF960-24-1	Test Voltage (kV) Normal	DRF960-24-1
0,5	Pass	0,5	Pass
1	Pass	1	Pass
2	Pass	2	Pass
4	Pass		

3.22 Parallel Operation

For the parallel operation of up to 5 units the following steps are needed.

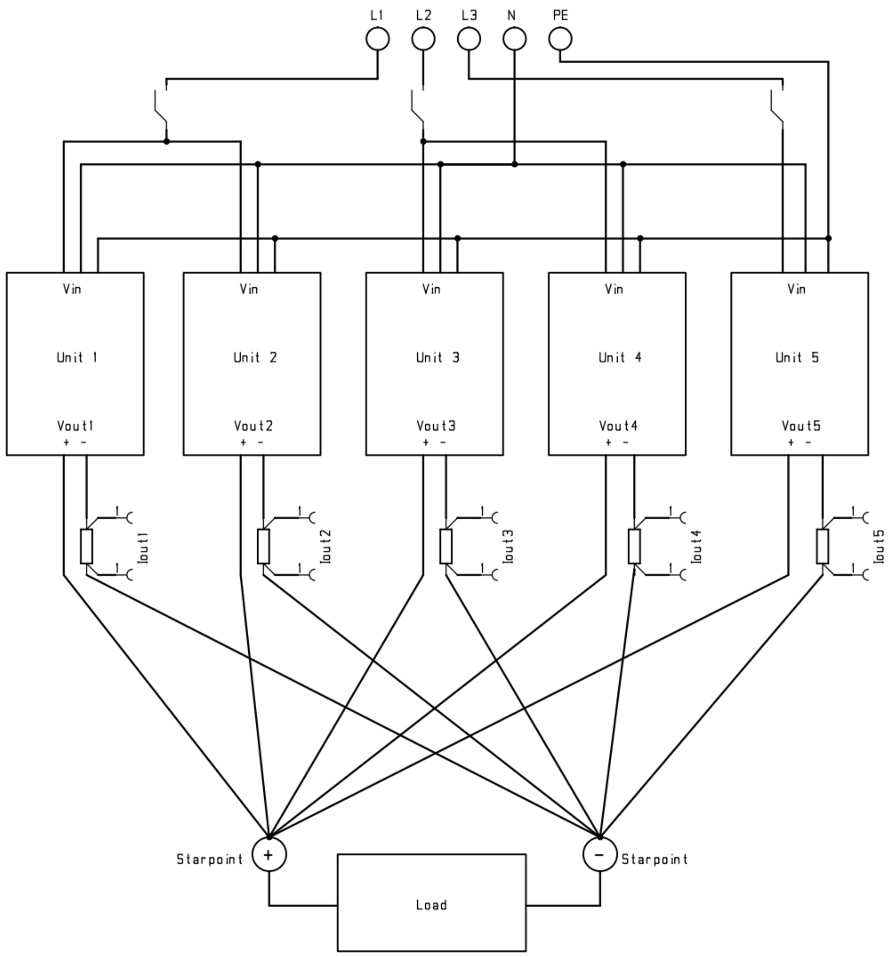
1. Activate the droop mode. Open the short circuit connection CB. (cut/remove the black wire at the signal connector)





2. Adjust the output voltage at all units to the same voltage level (±20mV).

3. Test Setup

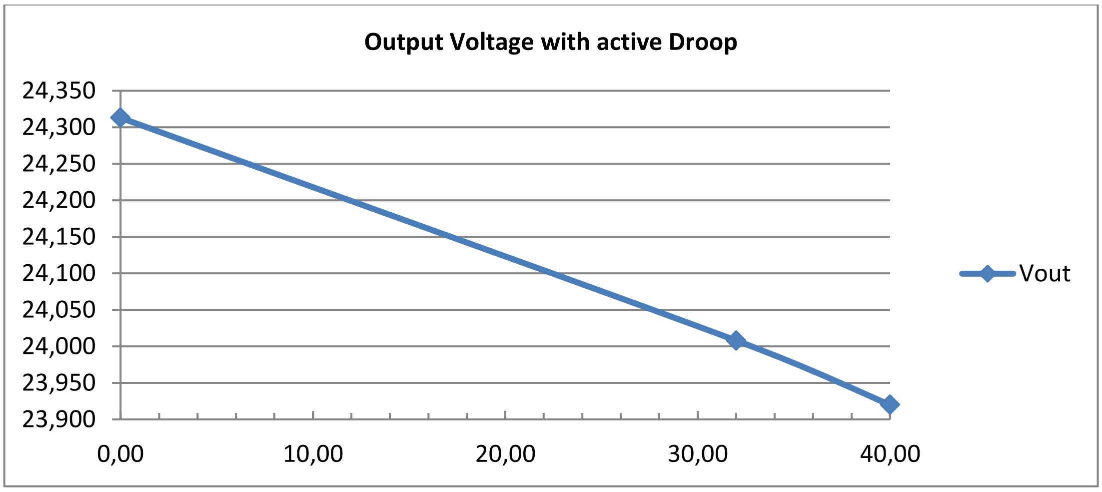


All connections from the units to the shunts and star points have the same length and wire size, to get approx. the same impedance between each unit and the star point.

3.22.1 Droop Voltage

With the active droop mode the output voltage will be reduced by approx. 300mV between 0%-80% load.

		Single Unit	
Iout		Vout	dVout
0%	0,00	24,313	
80%	32,00	24,008	0,305
100%	40,00	23,920	0,393



3.22.2 Current share behaviour (2 units)

Test of two units in parallel.

Test condition: Vin = 230Vac, Vout = 24V, Tamb. = 25°C, with actice droop system (CB contact is open)

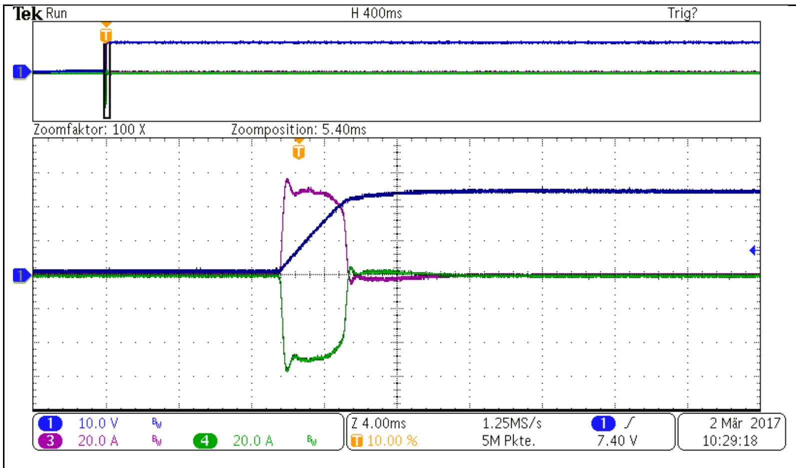
		Unit 1		Unit 2		Current Share	
Iout		Vout	Iout	Vout	Iout	Δ Iout	%
0%	0	24,31	0,00	24,32	0,00	0,00	0,00
5%	4	24,30	2,63	24,29	1,34	1,29	32,25
10%	8	24,30	4,72	24,29	3,23	1,48	18,51
20%	16	24,28	8,54	24,28	7,42	1,12	6,98
30%	24	24,24	12,43	24,24	11,53	0,89	3,71
40%	32	24,20	16,47	24,20	15,53	0,94	2,94
50%	40	24,15	20,48	24,15	19,50	0,98	2,44
60%	48	24,10	24,50	24,11	23,46	1,04	2,17
70%	56	24,05	28,54	24,06	27,41	1,13	2,02
80%	64	24,00	32,57	24,01	31,38	1,19	1,86

Condition: Vout =		Ta = 25°	Set Unit A + B to dVout<10mV @ 0A					
		Unit A		Unit B		Current Share	
	Set point	24,312		24,322		dVout_max	0,010
						Current Share	
Iout		Vout	Iout	Vout	Iout	Δ Iout	%
0%	0	24,321	0,010	24,320	0,092	0,08	0,00
5%	4	24,307	1,366	24,312	2,736	1,37	34,25
10%	8	24,301	3,402	24,306	4,698	1,30	16,21
20%	16	24,286	7,735	24,288	8,386	0,65	4,07
30%	24	24,251	11,806	24,252	12,313	0,51	2,11
40%	32	24,208	15,780	24,209	16,349	0,57	1,78
50%	40	24,164	19,753	24,165	20,369	0,62	1,54
60%	48	24,119	23,727	24,120	24,399	0,67	1,40
70%	56	24,073	27,729	24,074	28,405	0,68	1,21
80%	64	24,026	31,675	24,027	32,455	0,78	1,22
100%	80	23,932	39,627	23,933	40,499	0,87	1,09

Condition: Vout =		Ta = 25°	Set Unit A + B to dVout 20mV @ 0A				
		Unit A		Unit B		Current Share	
	Set point	24,312		24,332		dVout_max	0,020
						Current Share	
Iout		Vout	Iout	Vout	Iout	Δ Iout	%
0%	0	24,332	0,008	24,332	0,094	0,09	0,00
5%	4	24,313	0,926	24,321	3,187	2,26	56,52
10%	8	24,307	2,919	24,315	5,173	2,25	28,18
20%	16	24,292	7,302	24,298	8,790	1,49	9,30
30%	24	24,258	11,473	24,263	12,622	1,15	4,79
40%	32	24,216	15,461	24,220	16,626	1,16	3,64
50%	40	24,172	19,451	24,176	20,662	1,21	3,03
60%	48	24,126	23,443	24,131	24,677	1,23	2,57
70%	56	24,080	27,426	24,085	28,667	1,24	2,22
80%	64	24,033	31,403	24,038	32,690	1,29	2,01
100%	80	23,939	39,388	23,944	40,713	1,33	1,66

Condition: Vout =	Ta = 25°	Set Unit A + B to dVout >20mV @ 0A					
		Unit A		Unit B		Current Share	
	Set point	24,312		24,346		dVout_max	0,034
						Current Share	
Iout		Vout	Iout	Vout	Iout	Δ Iout	%
0%	0	24,349	0,017	24,350	0,103	0,09	0,00
5%	4	24,321	0,018	24,336	3,999	3,98	99,53
10%	8	24,310	1,632	24,328	6,450	4,82	60,23
20%	16	24,295	6,294	24,309	9,815	3,52	22,01
30%	24	24,264	10,758	24,274	13,347	2,59	10,79
40%	32	24,222	14,776	24,233	17,337	2,56	8,00
50%	40	24,179	18,740	24,189	21,365	2,63	6,56
60%	48	24,133	22,743	24,144	25,363	2,62	5,46
70%	56	24,088	26,714	24,099	29,385	2,67	4,77
80%	64	24,041	30,709	24,052	33,400	2,69	4,20
100%	80	23,947	38,679	23,959	41,414	2,73	3,42

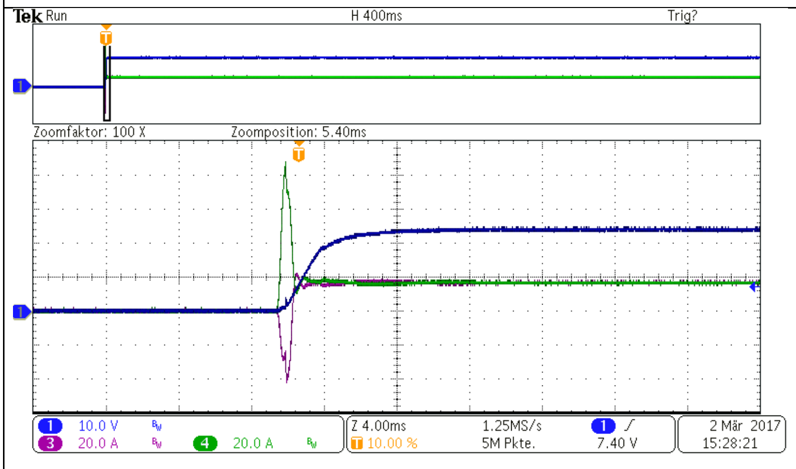
3.22.3 Output rise characteristics (2 units)



Picture 95. Output rise characteristics of two units in parallel
@ 230Vac, 24Vdc / 0A load

Channel 1: V_{out}
Channel 3: I_{out_unit1}
Channel 3: I_{out_unit2}

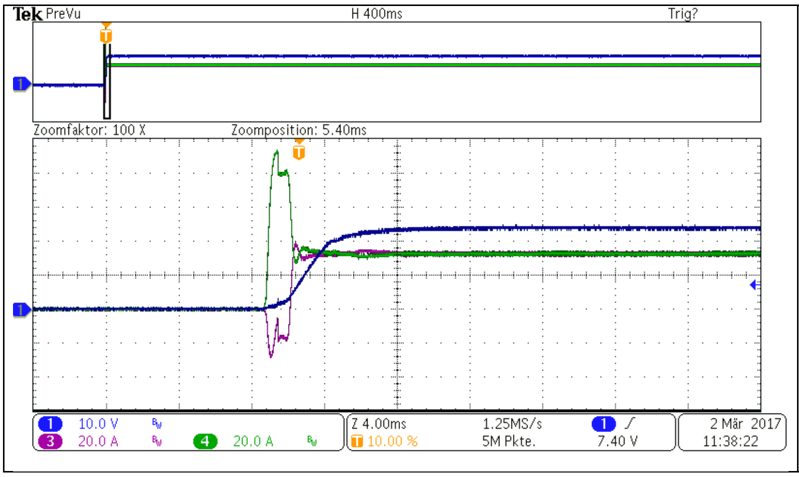
Result: pass



Picture 96. Output rise characteristics of two units in parallel
@ 230Vac, 24Vdc / 32A load

Channel 1: V_{out}
Channel 3: I_{out_unit1}
Channel 3: I_{out_unit2}

Result: pass



Picture 97. Output rise characteristics of two units in parallel
@ 230Vac, 24Vdc / 64A load

Channel 1: V_{out}
Channel 3: I_{out_unit1}
Channel 3: I_{out_unit2}

Result: pass

3.22.4 Current share behaviour (5 units)

Test of five units in parallel. Each unit needs a basic load of 680R to cover the zero load condition.

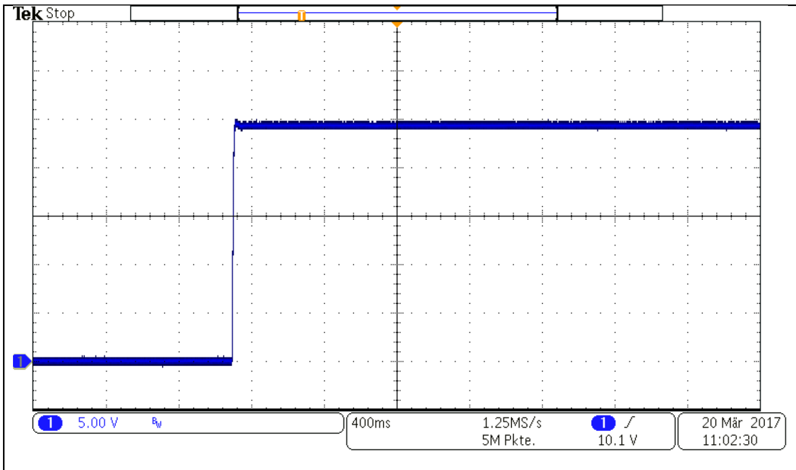
Test condition: Vin = 230Vac, Vout = 24V, Tamb. = 25°C, with actice droop system (CB contact is open).

Condition: Vout =		Ta = 25°C		Set Units to dVout<10mV @ 0A									
		Unit A		Unit B		Unit C		Unit D		Unit E		Current Share	
	Set point	24,339		24,342		24,344		24,347		24,348		dVout_max	0,009
												Current Share	
I_Load		Vout	Iout	Vout	Iout	Vout	Iout	Vout	Iout	Vout	Iout	Δ Iout_max	%
0%	0	24,353	0,015	24,353	0,020	24,352	0,024	24,353	0,025	24,353	0,020	0,01	0,00
5%	10	24,338	1,388	24,338	1,490	24,340	1,956	24,342	2,455	24,344	2,962	1,57	15,74
10%	20	24,331	3,370	24,331	3,513	24,334	4,025	24,335	4,411	24,337	4,931	1,56	7,81
20%	40	24,316	7,657	24,316	7,688	24,318	8,074	24,319	8,340	24,319	8,538	0,88	2,20
30%	60	24,282	11,727	24,282	11,762	24,284	12,033	24,284	12,365	24,283	12,347	0,64	1,06
40%	80	24,239	15,674	24,240	15,825	24,242	16,027	24,242	16,326	24,241	16,367	0,69	0,87
50%	100	24,195	19,611	24,195	19,854	24,197	20,051	24,198	20,407	24,196	20,351	0,80	0,80
60%	120	24,148	23,566	24,149	23,867	24,151	24,051	24,152	24,428	24,150	24,350	0,86	0,72
70%	140	24,101	27,548	24,102	27,858	24,105	28,039	24,105	28,441	24,103	28,371	0,89	0,64
80%	160	24,053	31,504	24,055	31,840	24,058	32,083	24,058	32,444	24,055	32,425	0,94	0,59
90%	180	24,005	35,461	24,007	35,855	24,010	36,118	24,010	36,461	24,007	36,452	1,00	0,56
100%	200	23,957	39,425	23,958	39,821	23,962	40,149	23,962	40,463	23,959	40,466	1,04	0,52

Condition: Vout =	Ta = 25°C		Set Units to dVout =20mV @ 0A									
		Unit A		Unit B		Unit C		Unit D		Unit E			
	Set point	24,312		24,319		24,332		24,319		24,321		dVout_max	0,020
												Current Share	
I_Load		Vout	Iout	Vout	Iout	Vout	Iout	Vout	Iout	Vout	Iout	Δ Iout_max	%
0%	0	24,334	0,015	24,334	0,018	24,335	0,197	24,335	0,016	24,334	0,035	0,18	0,00
5%	10	24,314	0,538	24,322	2,666	24,326	3,543	24,316	1,112	24,321	2,416	3,01	30,05
10%	20	24,307	2,504	24,316	4,683	24,319	5,567	24,310	3,104	24,314	4,395	3,06	15,32
20%	40	24,293	7,072	24,299	8,506	24,301	9,095	24,294	7,373	24,297	8,217	2,02	5,06
30%	60	24,260	11,287	24,264	12,324	24,267	12,849	24,262	11,700	24,262	12,087	1,56	2,60
40%	80	24,218	15,275	24,222	16,318	24,225	16,816	24,220	15,716	24,220	16,122	1,54	1,93
50%	100	24,174	19,224	24,178	20,318	24,181	20,781	24,177	19,784	24,176	20,106	1,56	1,56
60%	120	24,129	23,195	24,133	24,314	24,136	24,797	24,132	23,805	24,131	24,131	1,60	1,34
70%	140	24,083	27,177	24,087	28,304	24,091	28,763	24,087	27,838	24,085	28,130	1,59	1,13
80%	160	24,037	31,125	24,041	32,281	24,045	32,767	24,041	31,837	24,039	32,174	1,64	1,03
90%	180	23,990	35,104	23,994	36,269	23,999	36,798	23,994	35,847	23,992	36,184	1,69	0,94
100%	200	23,942	39,078	23,947	40,251	23,952	40,820	23,947	39,864	23,944	40,196	1,74	0,87

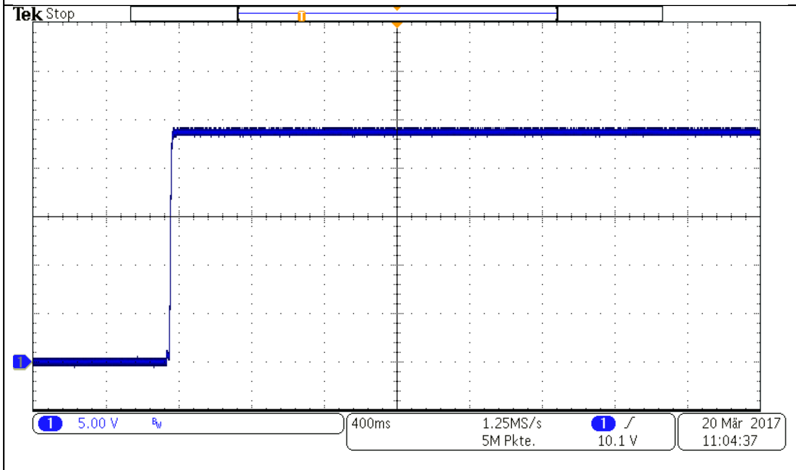
Condition: Vout =	Ta = 25°C		Set Units to dVout >20mV @ 0A										
		Unit A		Unit B		Unit C		Unit D		Unit E			
	Set point	24,312		24,319		24,344		24,347		24,322		dVout_max	0,035
												Current Share	
I_Load		Vout	Iout	Vout	Iout	Vout	Iout	Vout	Iout	Vout	Iout	Δ Iout_max	%
0%	0	24,349	0,011	24,349	0,019	24,349	0,023	24,350	0,182	24,349	0,017	0,17	0,00
5%	10	24,318	0,015	24,321	0,702	24,334	4,002	24,335	4,482	24,322	1,034	4,47	44,67
10%	20	24,312	2,080	24,314	2,749	24,327	6,000	24,328	6,360	24,315	3,005	4,28	21,40
20%	40	24,297	6,737	24,299	7,134	24,308	9,411	24,310	9,735	24,299	7,232	3,00	7,49
30%	60	24,265	11,069	24,266	11,346	24,273	13,038	24,275	13,361	24,266	11,400	2,29	3,82
40%	80	24,223	15,051	24,225	15,401	24,232	17,010	24,233	17,326	24,224	15,451	2,28	2,84
50%	100	24,179	19,027	24,181	19,434	24,188	20,990	24,188	21,314	24,180	19,454	2,29	2,29
60%	120	24,133	22,995	24,135	23,452	24,142	24,958	24,143	25,322	24,133	23,496	2,33	1,94
70%	140	24,087	26,979	24,089	27,454	24,096	28,946	24,097	29,344	24,087	27,499	2,36	1,69
80%	160	24,039	30,928	24,042	31,432	24,049	32,944	24,050	33,318	24,040	31,554	2,39	1,49
90%	180	23,992	34,885	23,994	35,440	24,003	36,973	24,003	37,309	23,993	35,581	2,42	1,35
100%	200	23,944	38,862	23,946	39,427	23,955	41,001	23,955	41,314	23,944	39,605	2,45	1,23

3.22.5 Output rise characteristics (5 units)



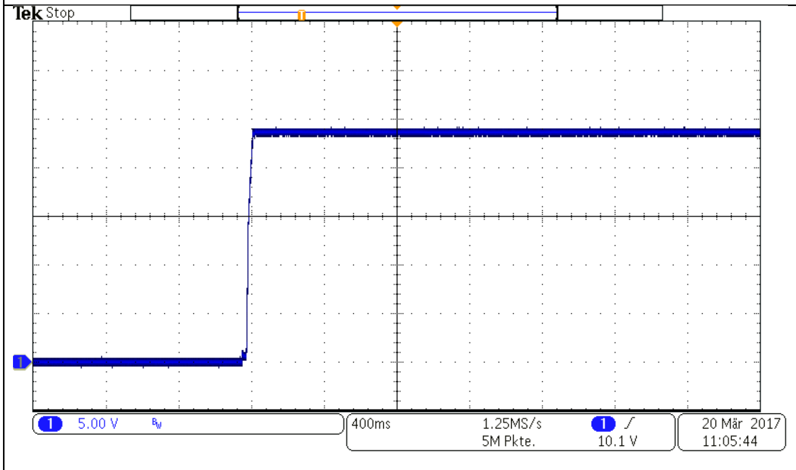
Picture 98. Output rise characteristics of five units in parallel
@ 230Vac, 24Vdc / 0A load

Channel 1: V_{out}



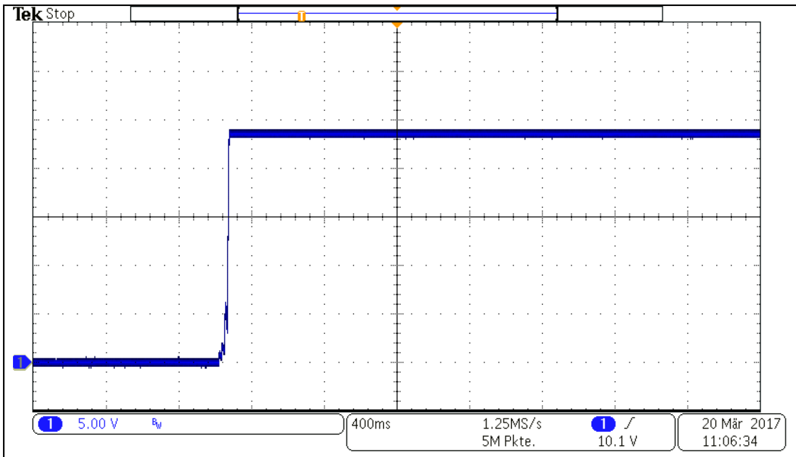
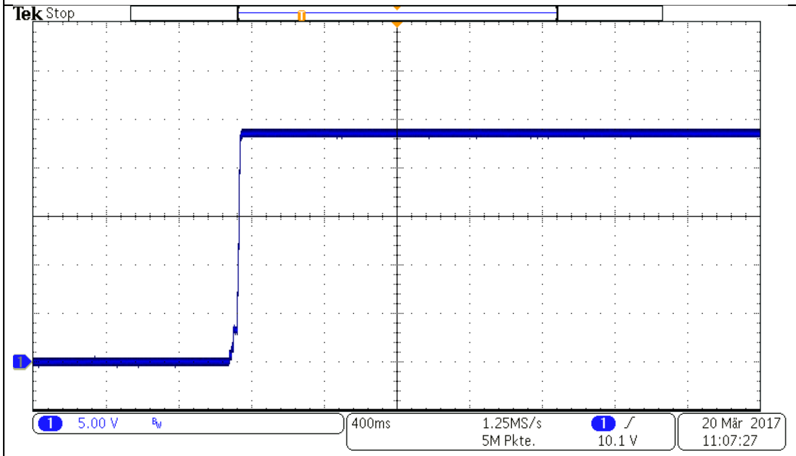
Picture 99. Output rise characteristics of five units in parallel
@ 230Vac, 24Vdc / 160A load

Channel 1: V_{out}



Picture 100. Output rise characteristics of five units in parallel
@ 230Vac, 24Vdc / 180A load

Channel 1: V_{out}

	**Picture 101. Output rise characteristics of five units in parallel** **@ 230Vac, 24Vdc / 200A load** Channel 1: V_{out}
	**Picture 102. Output rise characteristics of five units in parallel** **@ 230Vac, 24Vdc / 200A load + 69000µF** Channel 1: V_{out}

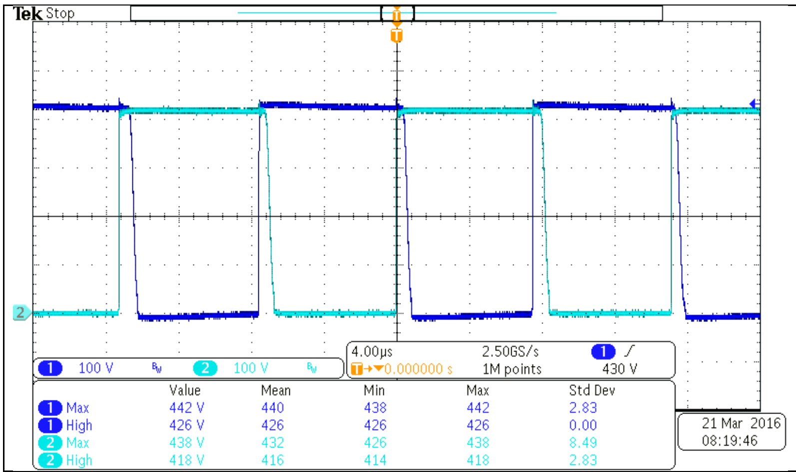
3.23 Programming Voltage

Adjust output between 24-28V by applying a voltage of 5-6V to the PV pin.

Programming Voltage [V]	Output Voltage [V]	Output Current [A]
5,000	23,97	40
5,011	24,00	40
5,500	26,45	36,3
5,846	28,01	34,3
6,000	28,78	34,3

4 Internal Voltages / Measurements

4.1 Switching waveforms

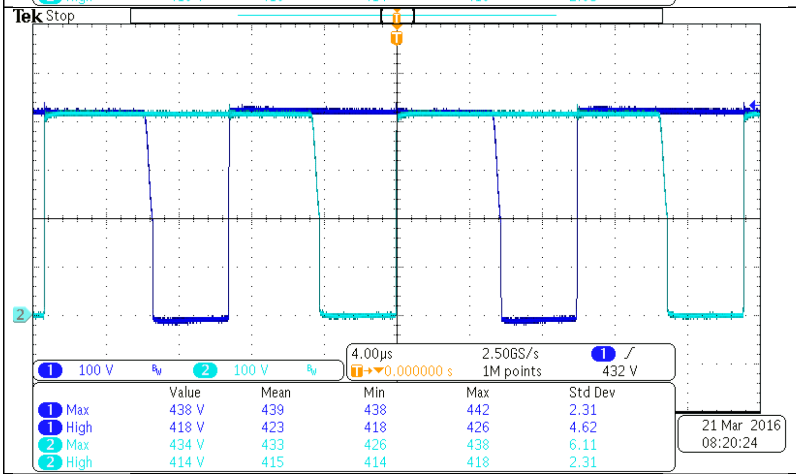


Picture 103. Working voltage PFC FET V5, V6 @ 180Vac and 100% load

$V_{D/S\ max}$ = 600V
$V_{D/S\ max\ measured}$ = 442V

Channel 1: V_{D/S_V5}
Channel 2: V_{D/S_V6}

Result: pass

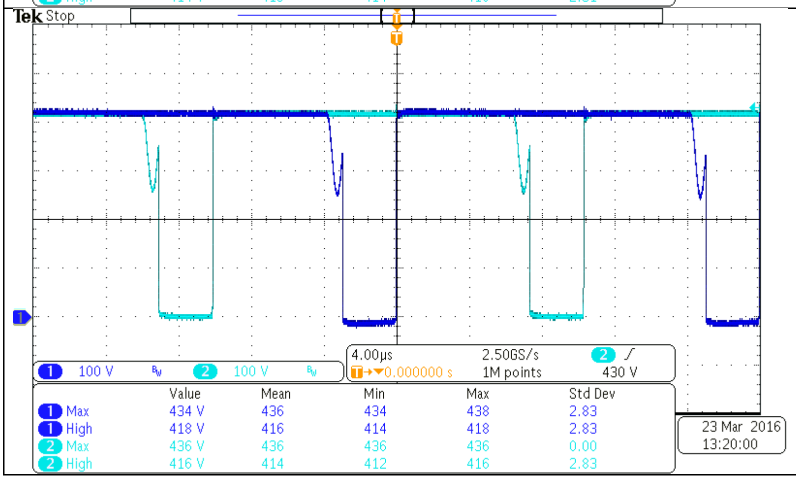


Picture 104. Working voltage PFC FET V5, V6 @ 230Vac and 100% load

$V_{D/S\ max}$ = 600V
$V_{D/S\ max\ measured}$ = 438V

Channel 1: V_{D/S_V5}
Channel 2: V_{D/S_V6}

Result: pass

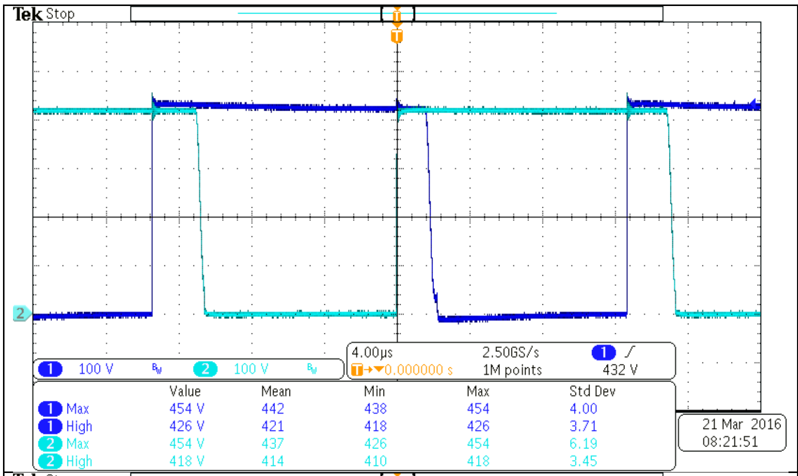


Picture 105. Working voltage PFC FET V5, V6 @ 277Vac and 100% load

$V_{D/S\ max}$ = 600V
$V_{D/S\ max\ measured}$ = V

Channel 1: V_{D/S_V5}
Channel 2: V_{D/S_V6}

Result: pass

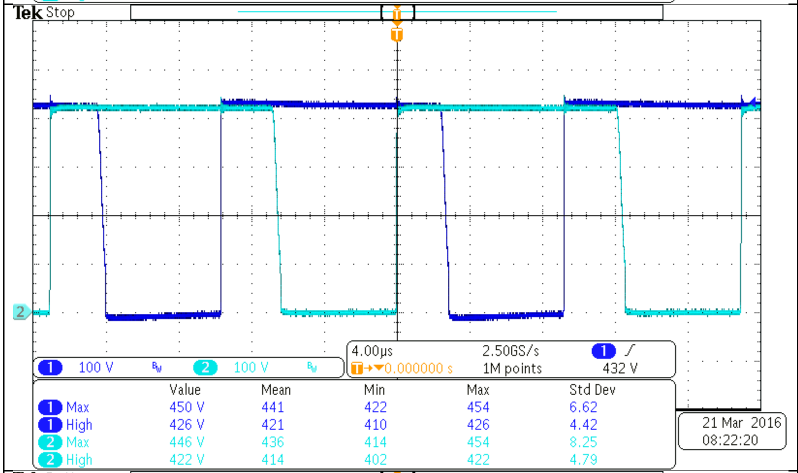


Picture 106. Working voltage PFC FET V5, V6 @ 180Vac and 150% load

$V_{D/S\ max}$ = 600V
$V_{D/S\ max\ measured}$ = 454V

Channel 1: V_{D/S_V5}
Channel 2: V_{D/S_V6}

Result: pass

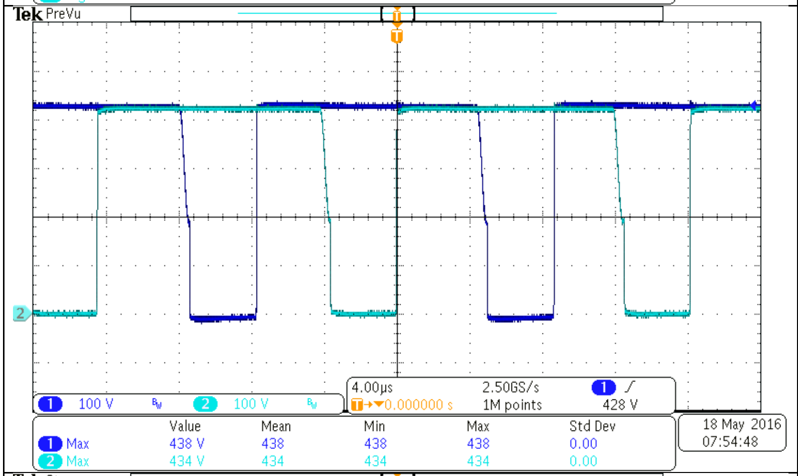


Picture 107. Working voltage PFC FET V5, V6 @ 230Vac and 150% load

$V_{D/S\ max}$ = 600V
$V_{D/S\ max\ measured}$ = 450V

Channel 1: V_{D/S_V5}
Channel 2: V_{D/S_V6}

Result: pass

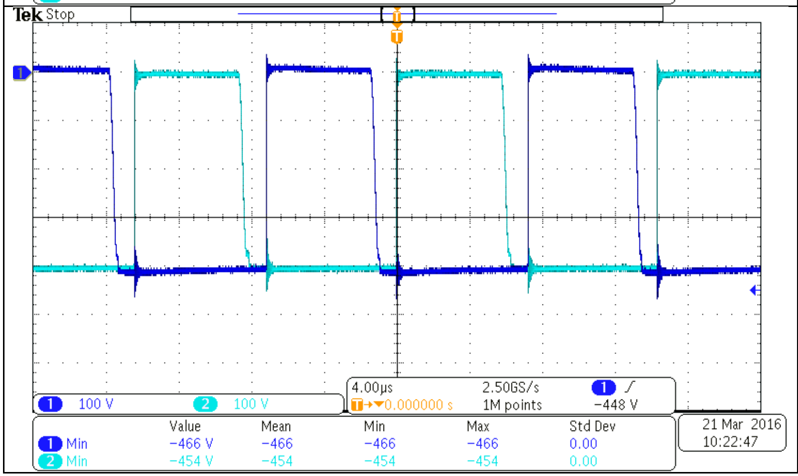


Picture 108. Working voltage PFC FET V5, V6 @ 277Vac and 150% load

$V_{D/S\ max}$ = 600V
$V_{D/S\ max\ measured}$ = 438V

Channel 1: V_{D/S_V5}
Channel 2: V_{D/S_V6}

Result: pass

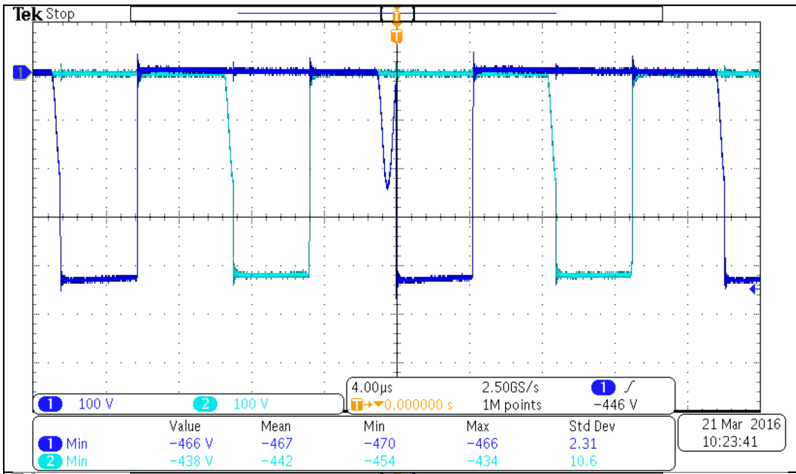


Picture 109. Working voltage PFC Diode D10, D14 @ 180Vac and 100% load

$V_{D/S\ max}$ = 600V
$V_{D/S\ max\ measured}$ = 466V

Channel 1: V_{D10}
Channel 2: V_{D14}

Result: pass

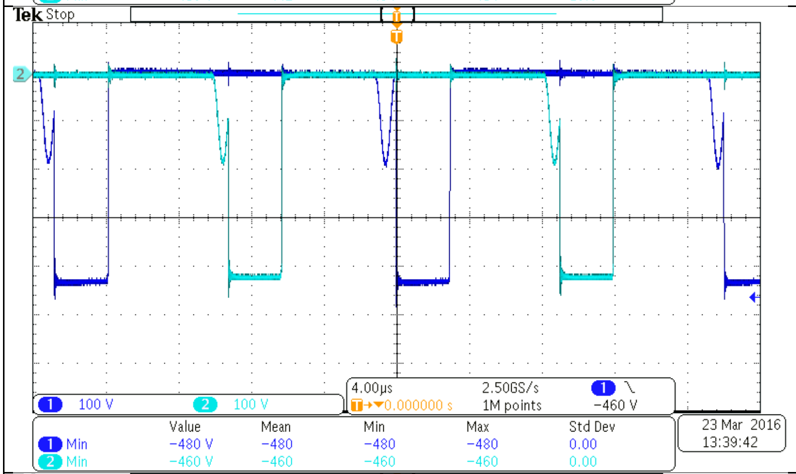


Picture 110. Working voltage PFC Diode D10, D14 @ 230Vac and 100% load

$V_{D/S\ max}$ = 600V
$V_{D/S\ max\ measured}$ = 470V

Channel 1: V_{D10}
Channel 2: V_{D14}

Result: pass

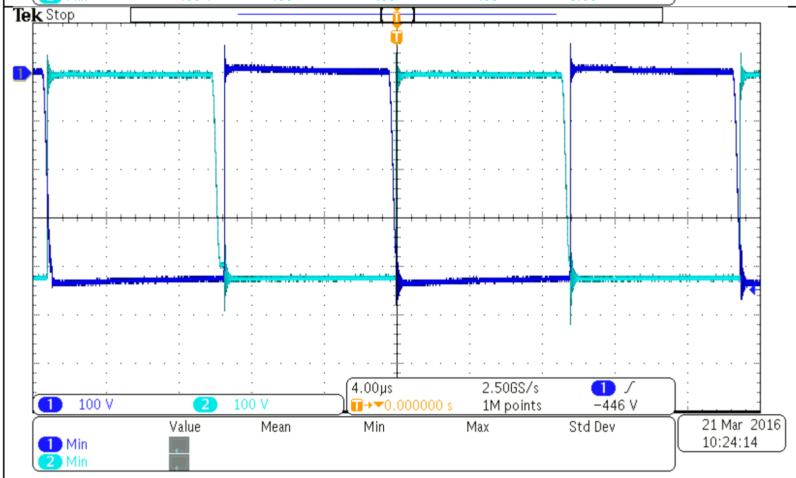


Picture 111. Working voltage PFC Diode D10, D14 @ 277Vac and 100% load

$V_{D/S\ max}$ = 600V
$V_{D/S\ max\ measured}$ = 480V

Channel 1: V_{D10}
Channel 2: V_{D14}

Result: pass

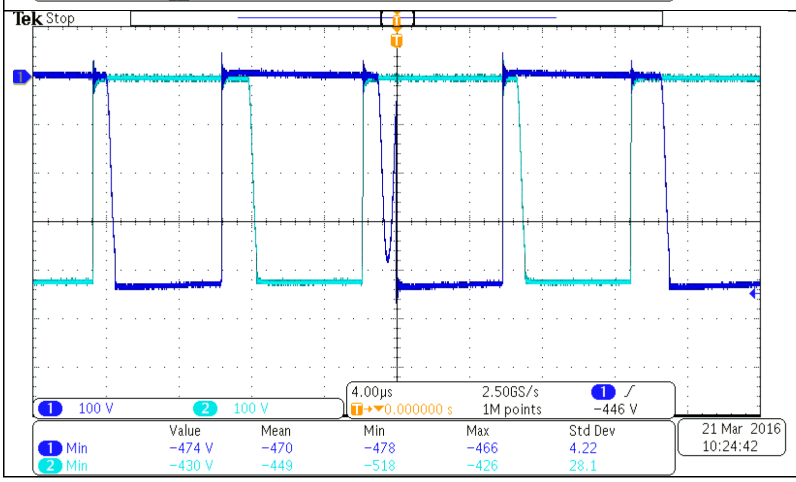


Picture 112. Working voltage PFC Diode D10, D14 @ 180Vac and 150% load

$V_{D/S\ max}$ = 600V
$V_{D/S\ max\ measured}$ = 520V

Channel 1: V_{D10}
Channel 2: V_{D14}

Result: pass

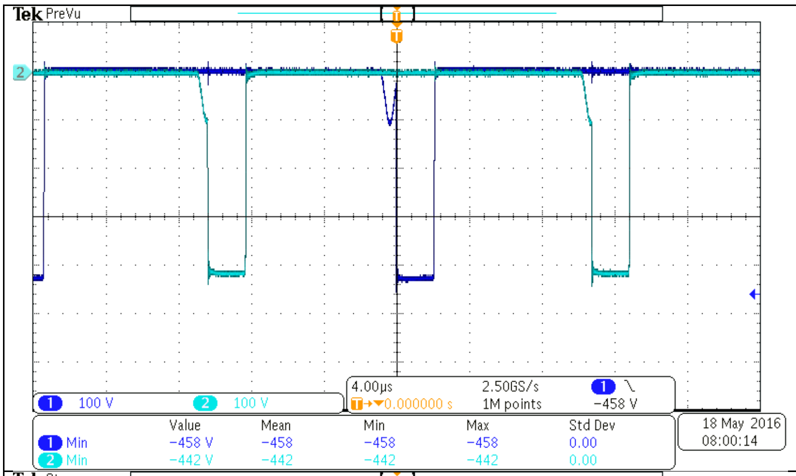


Picture 113. Working voltage PFC Diode D10, D14 @ 230Vac and 150% load

$V_{D/S\ max}$ = 600V
$V_{D/S\ max\ measured}$ = 478V

Channel 1: V_{D10}
Channel 2: V_{D14}

Result: pass

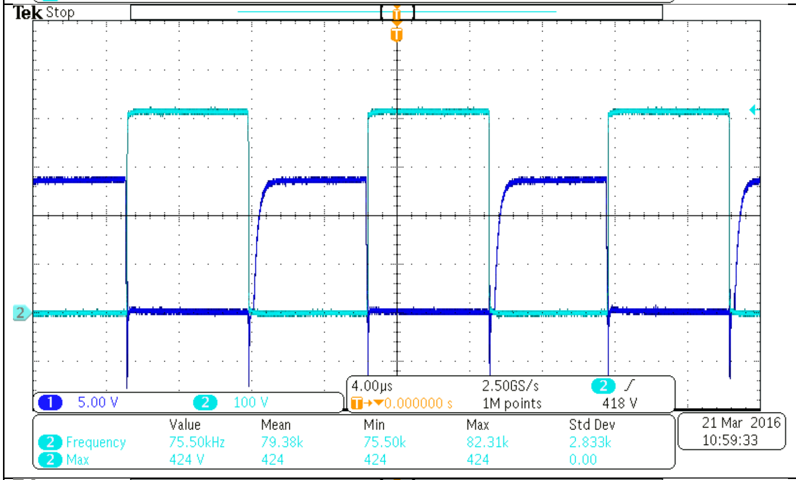


Picture 114. Working voltage PFC Diode D10, D14 @ 277Vac and 150% load

$V_{D/S\ max}$ = 600V
$V_{D/S\ max\ measured}$ = 458V

Channel 1: V_{D10}
Channel 2: V_{D14}

Result: pass

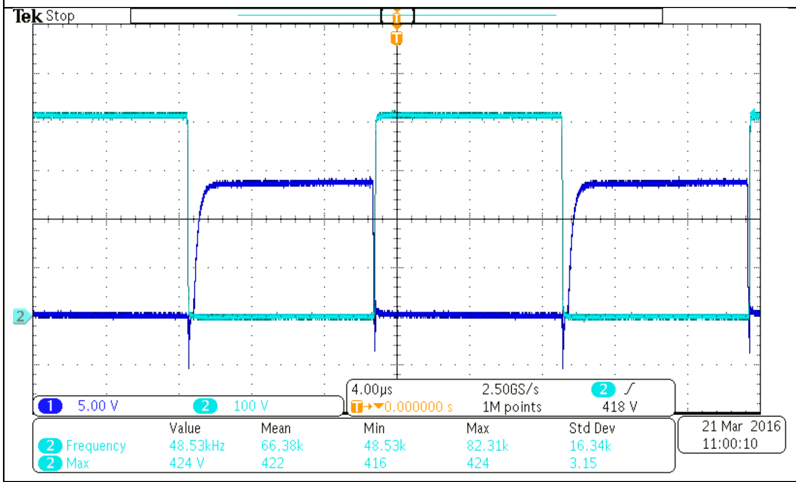


Picture 115. Working voltage LLC FET V9 @ Vbulk = 410 Vdc and 24V / 100% load

$V_{D/S\ max}$ = 650V
$V_{D/S\ max\ measured}$ = 424V

Channel 1: $V_{G/S}$
Channel 2: $V_{D/S}$

Result: pass

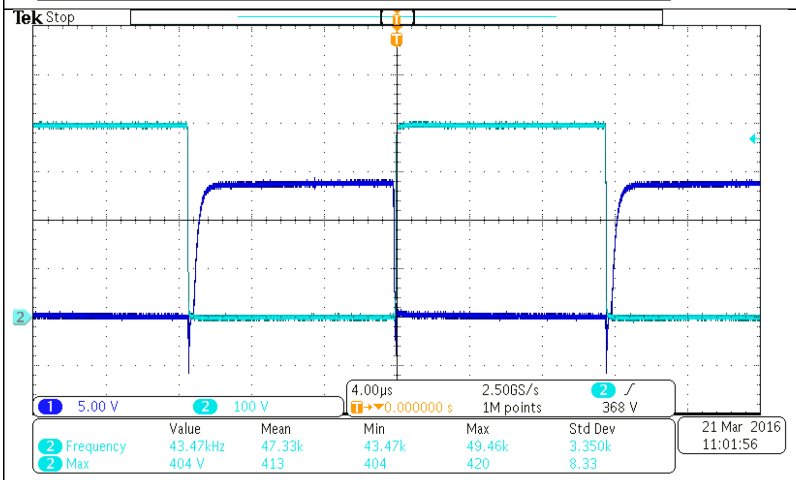


Picture 116. Working voltage LLC FET V9 @ Vbulk = 410 Vdc and 24V / 150% load

$V_{D/S\ max}$ = 650V
$V_{D/S\ max\ measured}$ = 424V

Channel 1: $V_{G/S}$
Channel 2: $V_{D/S}$

Result: pass

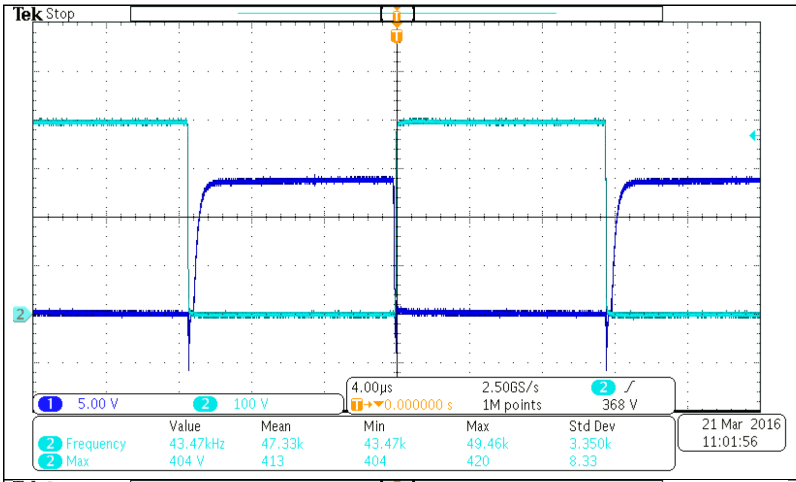


Picture 117. Working voltage LLC FET V9 @ Vbulk = 410 Vdc and 28V / 100% load

$V_{D/S\ max}$ = 650V
$V_{D/S\ max\ measured}$ = 420V

Channel 1: $V_{G/S}$
Channel 2: $V_{D/S}$

Result: pass



Picture 118. Working voltage LLC FET V9 @ Vbulk = 410 Vdc and 28V / 150% load

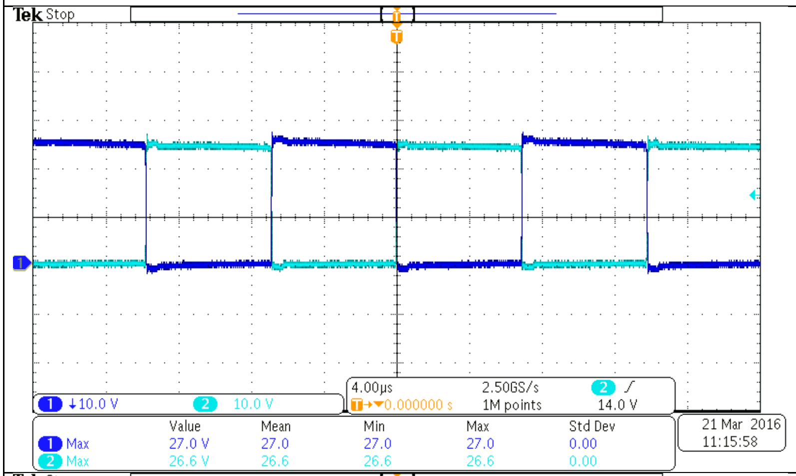
$V_{D/S\ max}$ = 650V

$V_{D/S\ max\ measured}$ = 424V

Channel 1: $V_{G/S}$

Channel 2: $V_{D/S}$

Result: pass



Picture 119. Working voltage LLC Rectifier FET V1, V3 @ 230Vac 24V / 100% load

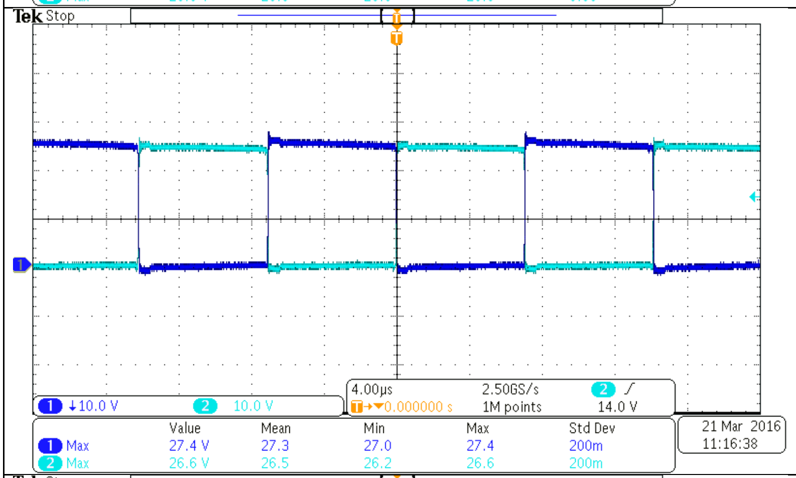
$V_{D/S\ max}$ = 40V

$V_{D/S\ max\ measured}$ = 27V

Channel 1: V_{D/S_V1}

Channel 2: V_{D/S_V3}

Result: pass



Picture 120. Working voltage LLC Rectifier FET V1, V3 @ 230Vac 24V / 150% load

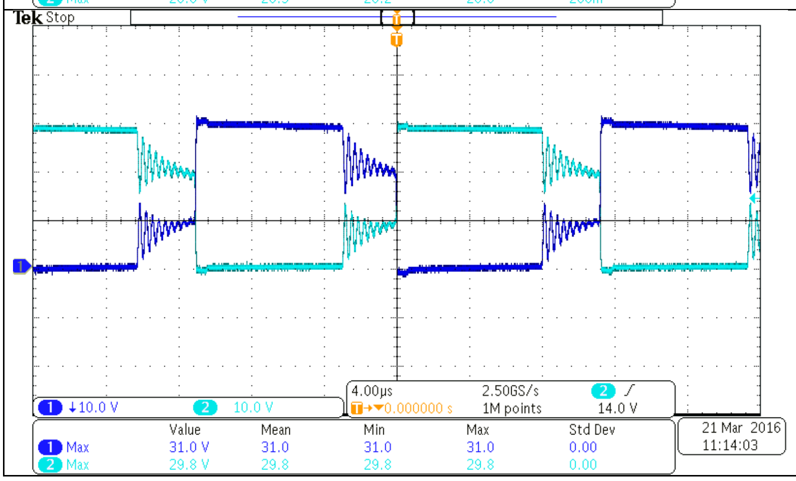
$V_{D/S\ max}$ = 40V

$V_{D/S\ max\ measured}$ = 27,4V

Channel 1: V_{D/S_V1}

Channel 2: V_{D/S_V3}

Result: pass



Picture 121. Working voltage LLC Rectifier FET V1, V3 @ 230Vac 28V / 100% load

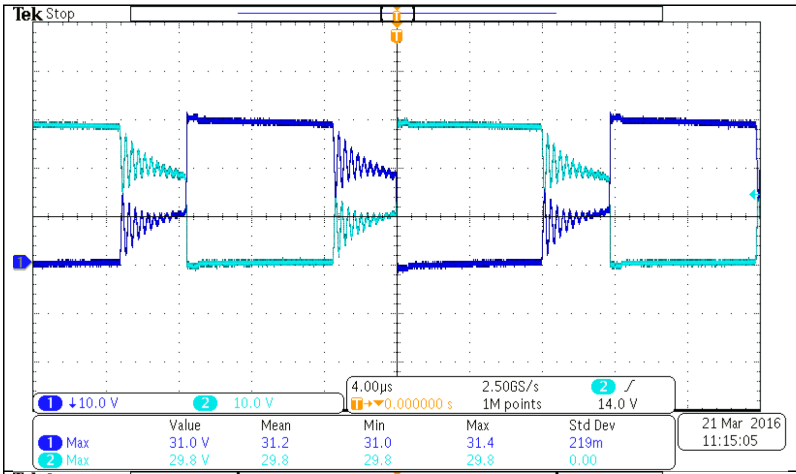
$V_{D/S\ max}$ = 40V

$V_{D/S\ max\ measured}$ = 31V

Channel 1: V_{D/S_V1}

Channel 2: V_{D/S_V3}

Result: pass

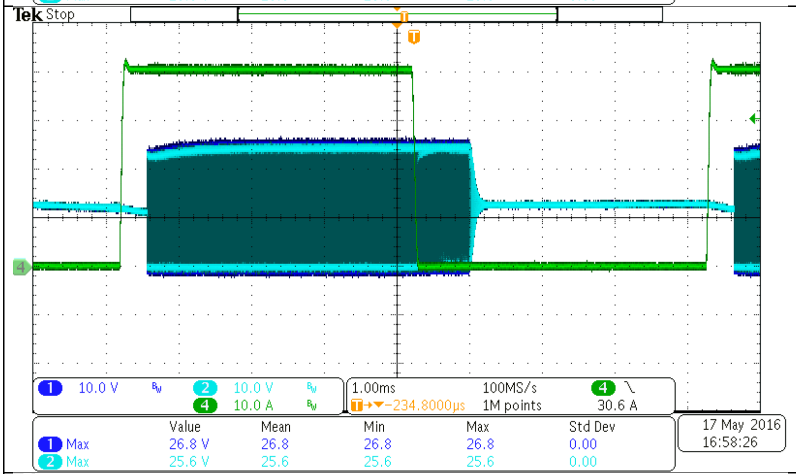


Picture 122. Working voltage LLC Rectifier FET V1, V3 @ 230Vac 28V / 150% load

$V_{D/S\ max}$ = 40V
$V_{D/S\ max\ measured}$ = 31,4V

Channel 1: V_{D/S_V1}
Channel 2: V_{D/S_V3}

Result: pass



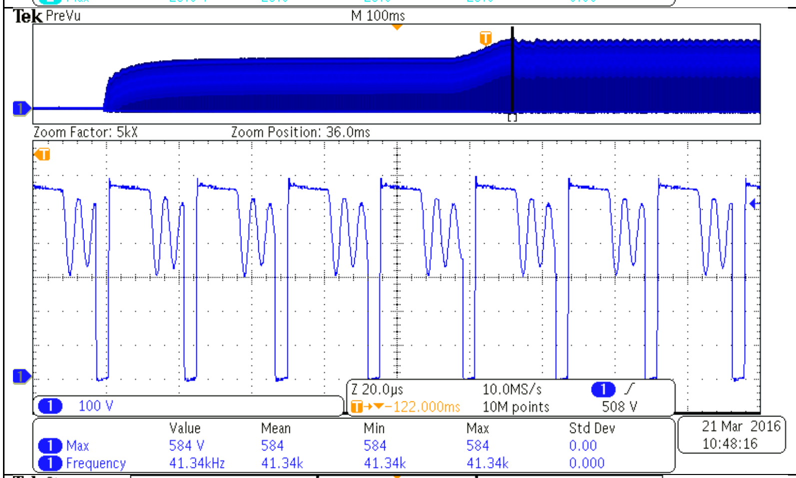
Picture 123. Working voltage LLC Rectifier FET V3 @ load steps 0A-40A

Worst case condition

$V_{D/S\ max}$ = 30V
$V_{D/S\ max\ measured}$ = 26,8V

Channel 3: $V_{D/S}$

Result: pass

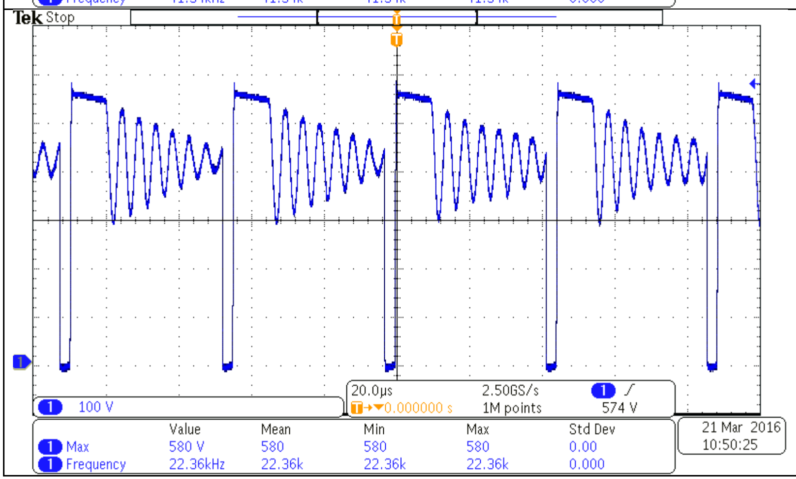


Picture 124. Working voltage Aux. Supply IC9 @ start up and 100% load

$V_{D/S\ max}$ (Pin8) = 700V
$V_{D/S\ max\ measured}$ = 584V

Channel 1: V_{D/S_Pin8}

Result: pass

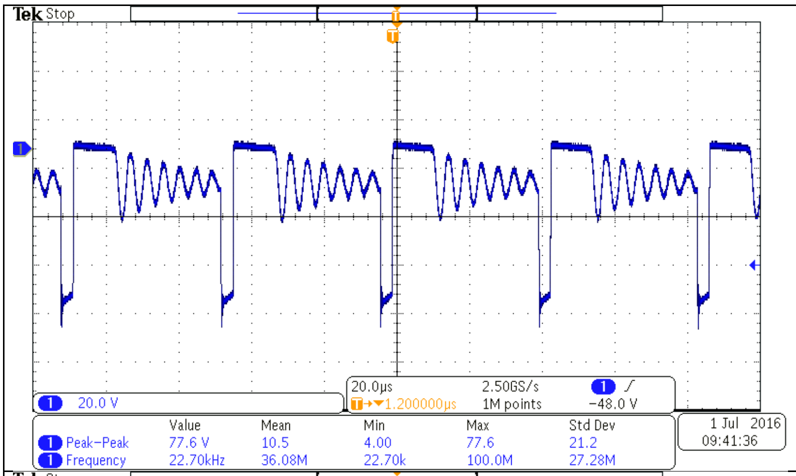


Picture 125. Working voltage Aux. Supply IC9 @ 410Vdc and 100% load

$V_{D/S\ max}$ (Pin8) = 700V
$V_{D/S\ max\ measured}$ = 580V

Channel 3: $V_{D/S}$

Result: pass

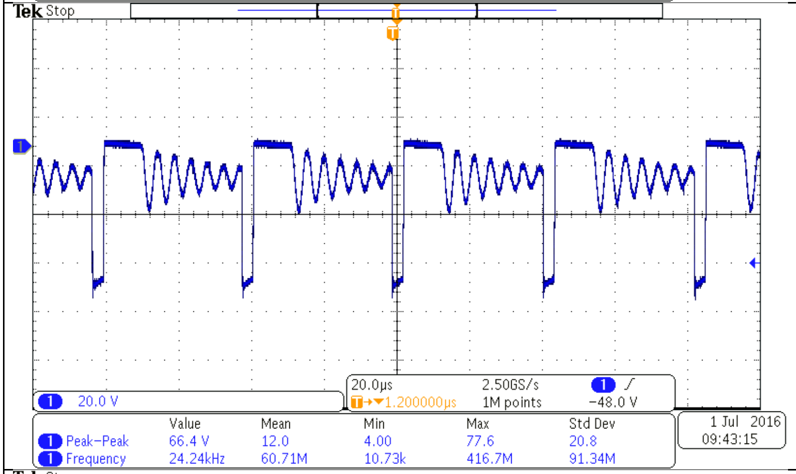


Picture 126. Working voltage Aux. Supply D39 @ 410Vdc and 100% load

$V_{D39\ max}$ = 100V
$V_{D39\ max\ measured}$ = 77,6V

Channel 1: V_{D39}

Result: pass

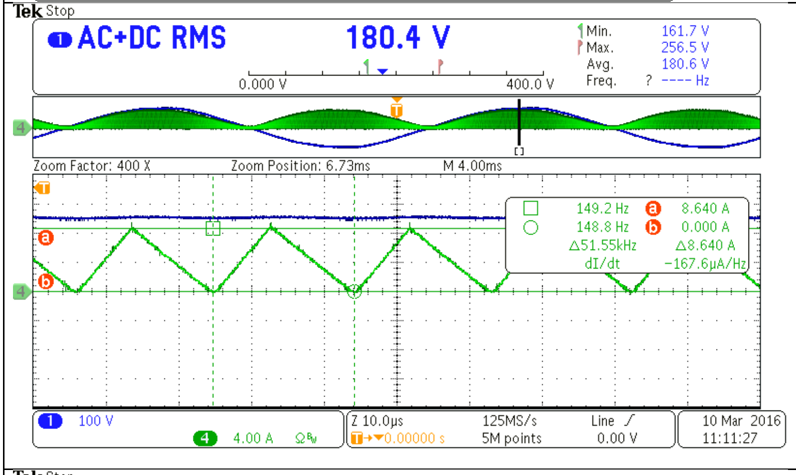


Picture 127. Working voltage Aux. Supply D40 @ 410Vdc and 100% load

$V_{D39\ max}$ = 100V
$V_{D39\ max\ measured}$ = 66,4V

Channel 1: V_{D39}

Result: pass

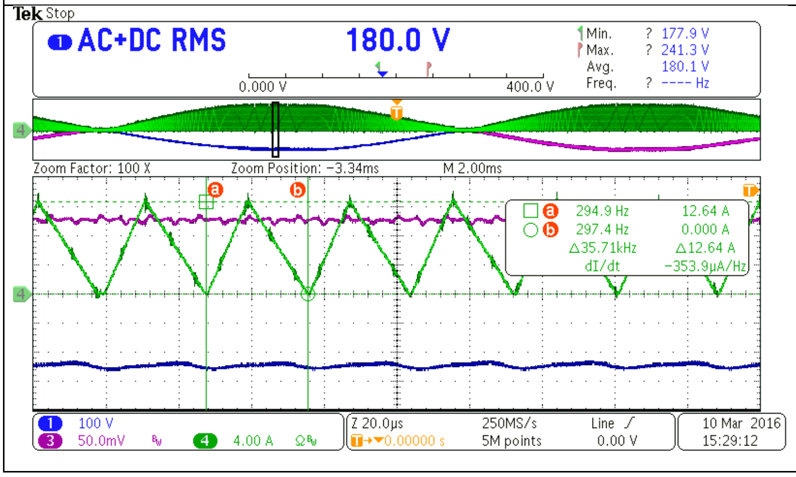


Picture 128. Current in PFC choke @ 180VAC 24VDC / 100% load

$I_{PFC\text{-}Choke,\ rated}$ = 14A
$I_{PFC\text{-}Choke\ measured}$ = 8,64A

Channel 1: Vin
Channel 4: $I_{PFC\text{-}Choke}$

Result: pass

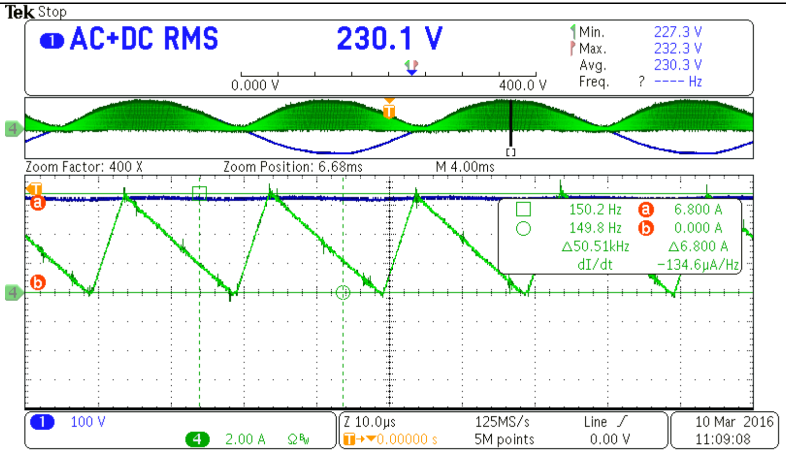


Picture 129. Current in PFC choke @ 180VAC 24VDC / 150% load

$I_{PFC\text{-}Choke,\ rated}$ = 14A
$I_{PFC\text{-}Choke\ measured}$ = 12,64A

Channel 1: Vin
Channel 4: $I_{PFC\text{-}Choke}$

Result: pass

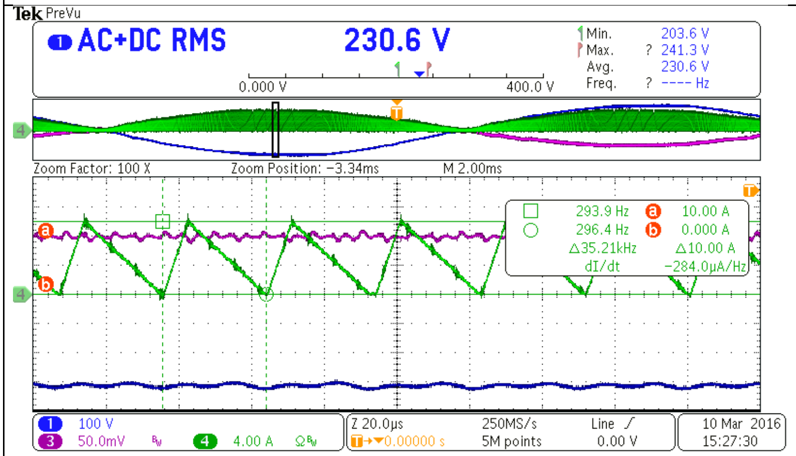


Picture 130. Current in PFC choke
@ 230VAC 24VDC / 100% load

$I_{PFC\text{-}Choke,\ rated}$ = 14A
$I_{PFC\text{-}Choke\ measured}$ = 6,80A

Channel 1: Vin
Channel 4: $I_{PFC\text{-}Choke}$

Result: pass

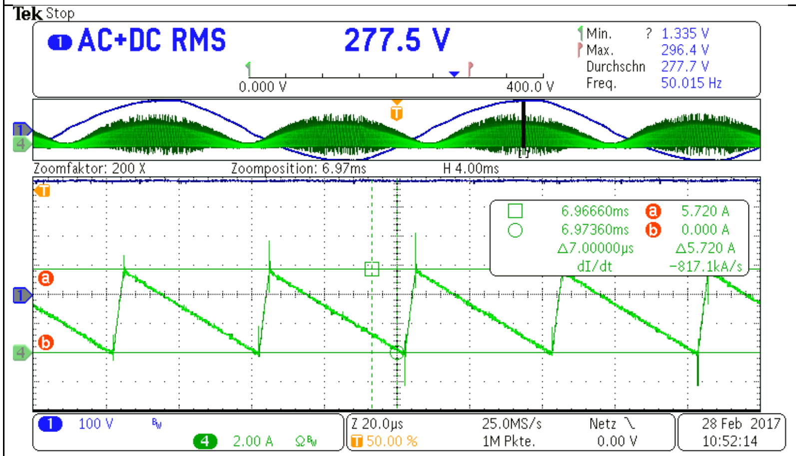


Picture 131. Current in PFC choke
@ 230VAC 24VDC / 150% load

$I_{PFC\text{-}Choke,\ rated}$ = 14A
$I_{PFC\text{-}Choke\ measured}$ = 10A

Channel 1: Vin
Channel 4: $I_{PFC\text{-}Choke}$

Result: pass

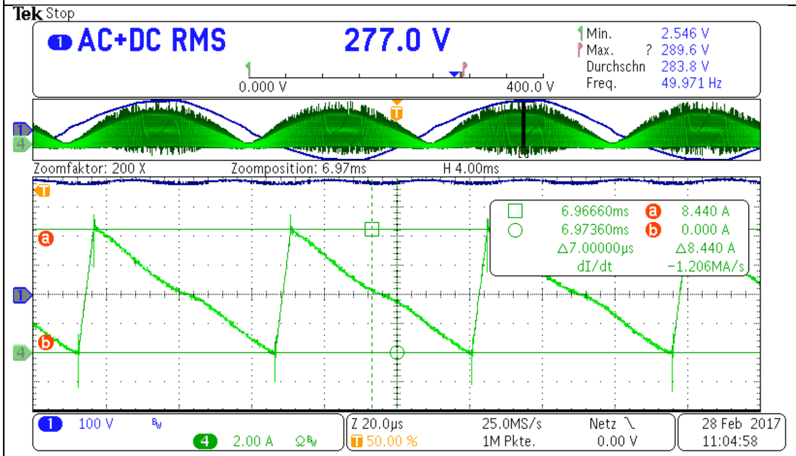


Picture 132. Current in PFC choke
@ 277VAC 24VDC / 100% load

$I_{PFC\text{-}Choke,\ rated}$ = 14A
$I_{PFC\text{-}Choke\ measured}$ = 5,72A

Channel 1: Vin
Channel 4: $I_{PFC\text{-}Choke}$

Result: pass

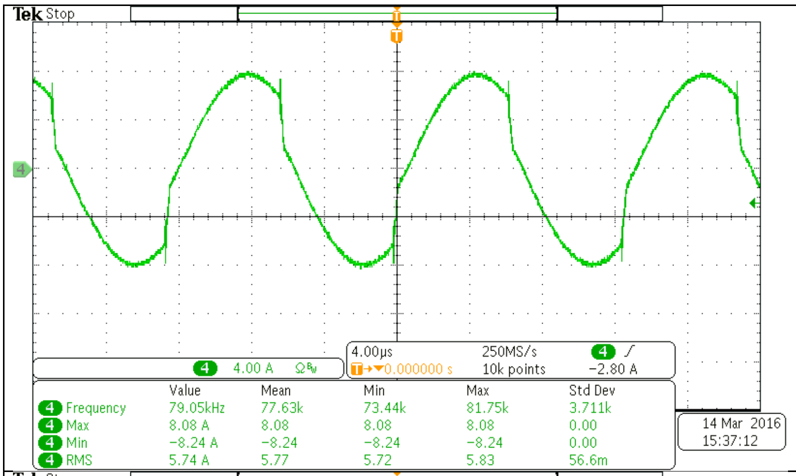


Picture 133. Current in PFC choke
@ 277VAC 24VDC / 150% load

$I_{PFC\text{-}Choke,\ rated}$ = 14A
$I_{PFC\text{-}Choke\ measured}$ = 8,44A

Channel 1: Vin
Channel 4: $I_{PFC\text{-}Choke}$

Result: pass

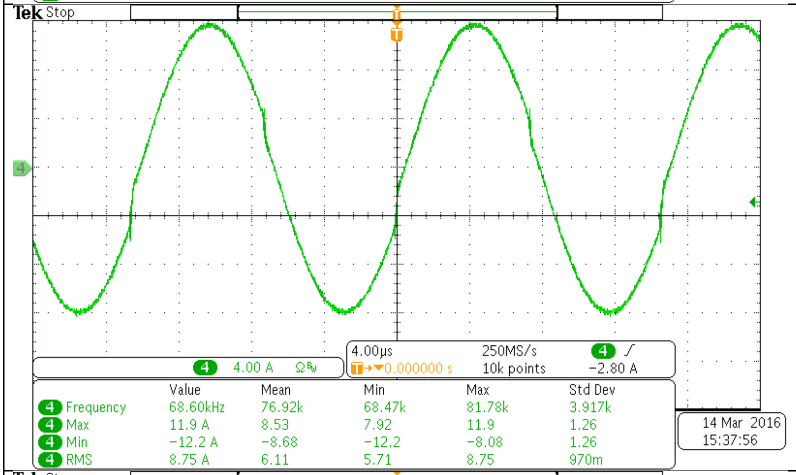


Picture 134. Current in LLC choke
@ 24VDC / 100% load

$I_{LLC\text{-}Choke,\ rated}$ = 23A
$I_{LLC\text{-}Choke\ measured}$ = 8,24A

Channel 4: $I_{LLC\text{-}Choke}$

Result: pass

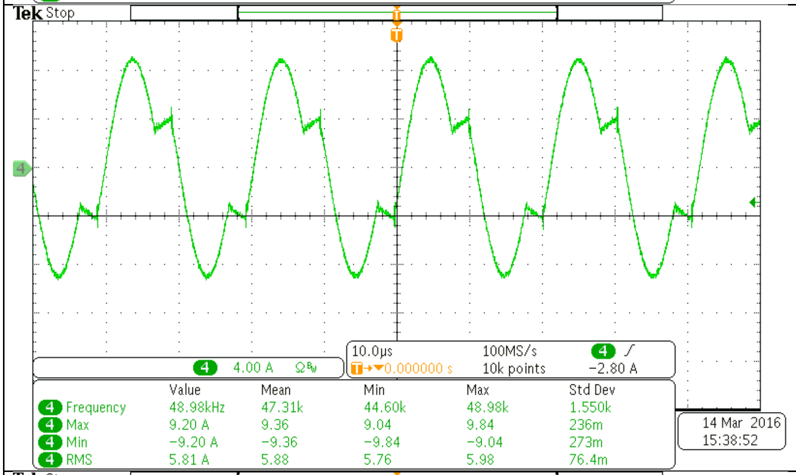


Picture 135. Current in LLC choke
@ 24VDC / 150% load

$I_{LLC\text{-}Choke,\ rated}$ = 23A
$I_{LLC\text{-}Choke\ measured}$ = 12,2A

Channel 4: $I_{LLC\text{-}Choke}$

Result: pass

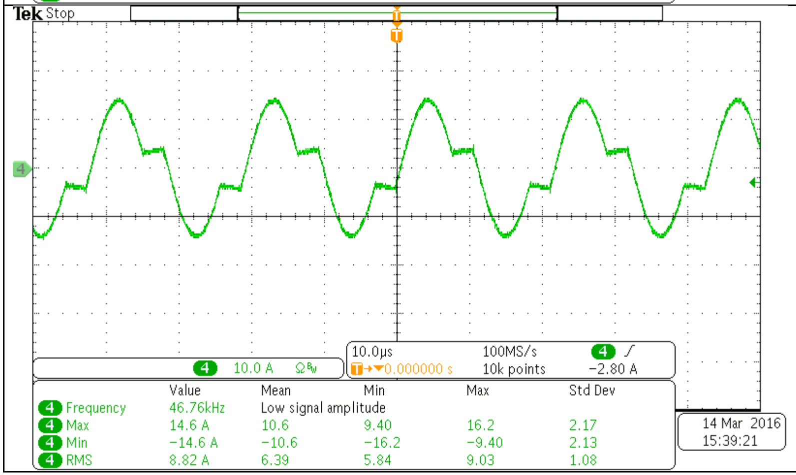


Picture 136. Current in LLC choke
@ 28VDC / 100% load

$I_{LLC\text{-}Choke,\ rated}$ = 23A
$I_{LLC\text{-}Choke\ measured}$ = 9,84A

Channel 4: $I_{LLC\text{-}Choke}$

Result: pass

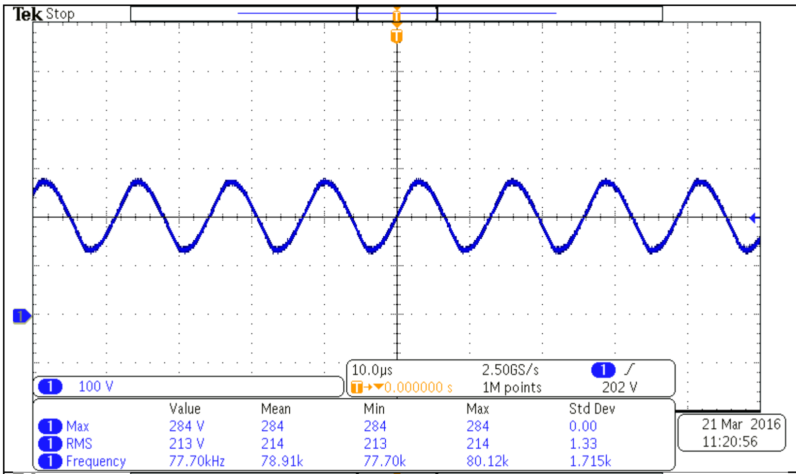


Picture 137. Current in LLC choke
@ 28VDC / 100% load

$I_{LLC\text{-}Choke,\ rated}$ = 23A
$I_{LLC\text{-}Choke\ measured}$ = 16,2A

Channel 4: $I_{LLC\text{-}Choke}$

Result: pass

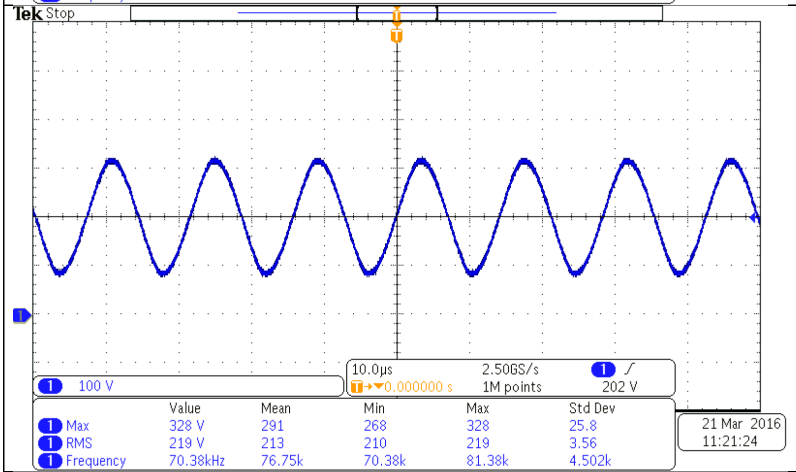


Picture 138. Working voltage at the Resonance caps C152-C163 @ Vbulk = 410V
24VDC / 100% load

V_{res_cap} = 630V
$V_{res\_cap\ measured}$ = 284V

Channel 1: V_{res_cap}

Result: pass

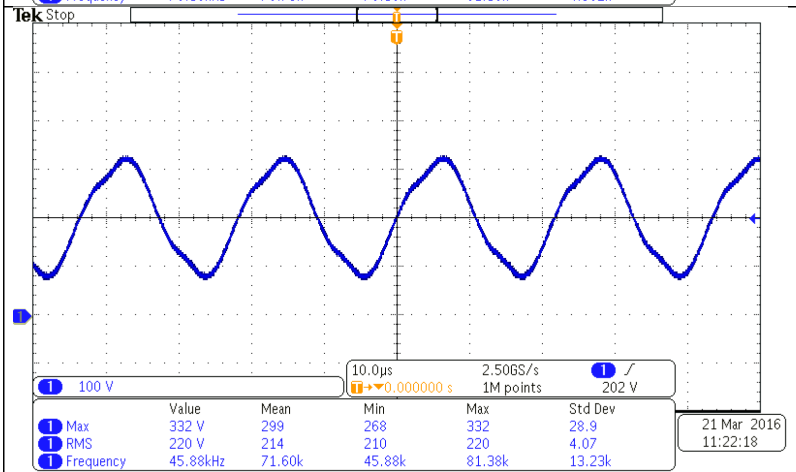


Picture 139. Working voltage at the Resonance caps C152-C163 @ Vbulk = 410V
24VDC / 150% load

V_{res_cap} = 630V
$V_{res\_cap\ measured}$ = 328V

Channel 1: V_{res_cap}

Result: pass

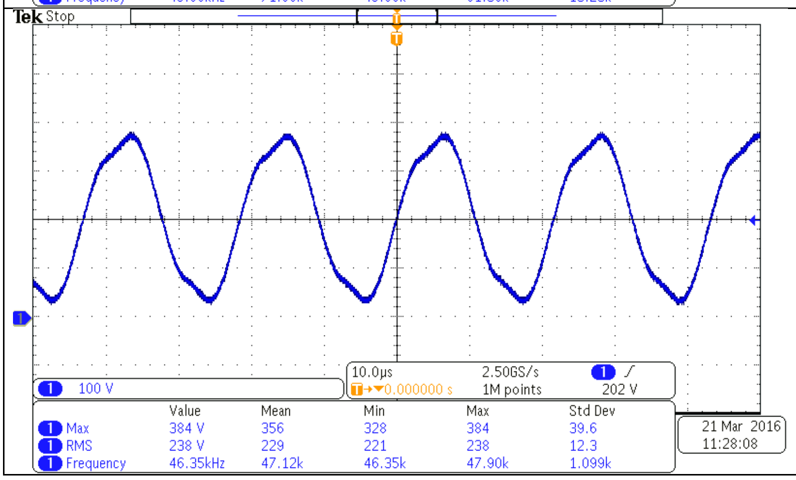


Picture 140. Working voltage at the Resonance caps C152-C163 @ Vbulk = 410V
28VDC / 100% load

V_{res_cap} = 630V
$V_{res\_cap\ measured}$ = 332V

Channel 1: V_{res_cap}

Result: pass



Picture 141. Working voltage at the Resonance caps C152-C163 @ Vbulk = 410V
28VDC / 150% load

V_{res_cap} = 630V
$V_{res\_cap\ measured}$ = 384V

Channel 1: V_{res_cap}

Result: pass

5 Reliability data

5.1 Calculated values of MTBF

The MTBF calculation was done with the Software EXAR 11 and the used standard is SN29500 (EN/IEC 61709).

The following results are valid under following conditions:

- SNA: Nonmobile operation ground benign
- ZF: Continuous operation 8760 h per year

Ambient Temperature [°C]	Separate Document	Failure Rate [fit]	MTBF [a]	MTFF [h]
25	MTBF-25deg-SN29500-DRF960-24-1.pdf	906	126	1103504
40	MTBF-40deg-SN29500-DRF960-24-1.pdf	1525	74,9	655893
50	MTBF-50deg-SN29500-DRF960-24-1.pdf	2225	51,3	449534

The complete calculations you can find in the separate documents.

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5.3 Component derating

5.3.1 Calculating method

5.3.1.1 Measuring Conditions

Input: 240VAC	Ambient temperature: 50°C
Output : 24V, 40A(100%)	Mounting method: Standard Mounting

5.3.1.2 Semiconductors

Compared with maximum junction temperature and actual one which is calculated based on case temperature, power dissipation and thermal impedance.

5.3.1.3 IC, Resistors, Capacitors, etc.

Ambient temperature, operating condition, power dissipation and so on are within derating criteria.

5.3.1.4 Calculating Method of Thermal Impedance

$$\Theta(j-c) = \frac{Tj(max) - Tc}{Pc(max)} \qquad \Theta(j-a) = \frac{Tj(max) - Ta}{Pc(max)} \qquad \Theta(j-l) = \frac{Tj(max) - Tl}{Pc(max)}$$

T_c:	Case temperature at start point of derating; 25°C in general
T_a:	Ambient temperature at start point of derating; 25°C in general
T_l:	Lead temperature at start point of derating; 25°C in general
$P_{c(max)}$:	Maximum collector dissipation
Θ(j-c):	Thermal impedance between junction and case
Θ(j-a):	Thermal impedance between junction and air
Θ(j-l):	Thermal impedance between junction and lead

5.3.2 Component derating list

Position	Vin = 240VAC	Load = 100%	Ta = 50°C
V5 TK31N60W Toshiba	Tjmax = 150 °C Pd = 2,6W Tj = Tc+(Θ(j-c) x Pd) =92,8°C D.F. = 61,87%	Θ(j-c) = 0,543 °C/W ΔTc = 41,4°C	 Tc = 91,40°C
V6 TK31N60W Toshiba	Tjmax = 150 °C Pd = 2,6W Tj = Tc+(Θ(j-c) x Pd) =92,8°C D.F. = 61,87%	Θ(j-c) = 0,543 °C/W ΔTc = 41,4°C	 Tc = 91,40°C
V7 IPP60R074C6 Infineon	Tjmax = 150 °C Pd = 3,2W Tj = Tc+(Θ(j-c) x Pd) =99,6°C D.F. = 66,41%	Θ(j-c) = 0,26 °C/W ΔTc = 48,79°C	 Tc = 98,79°C
V9 IPP60R074C6 Infineon	Tjmax = 150 °C Pd = 3,2W Tj = Tc+(Θ(j-c) x Pd) =99,6°C D.F. = 66,41%	Θ(j-c) = 0,26 °C/W ΔTc = 48,79°C	 Tc = 98,79°C
V1 IPB011N04NG Infineon	Tjmax = 175 °C Pd = 2,8W Tj = Tc+(Θ(j-c) x Pd) = 114,67°C D.F. = 65,52%	Θ(j-c) = 0,6 °C/W ΔTc = 62,99°C	 Tc = 112,99°C
V2 IPB011N04NG Infineon	Tjmax = 175 °C Pd = 2,8W Tj = Tc+(Θ(j-c) x Pd) = 113,34°C D.F. = 64,77%	Θ(j-c) = 0,6 °C/W ΔTc = 61,66°C	 Tc = 111,66°C
V3 IPB011N04NG Infineon	Tjmax = 175 °C Pd = 2,8W Tj = Tc+(Θ(j-c) x Pd) = 113,18°C D.F. = 64,67%	Θ(j-c) = 0,6 °C/W ΔTc = 61,5°C	 Tc = 111,5°C
V4 IPB011N04NG Infineon	Tjmax = 175 °C Pd = 2,8W Tj = Tc+(Θ(j-c) x Pd) = 112,35°C D.F. = 64,2%	Θ(j-c) = 0,6 °C/W ΔTc = 60,67°C	 Tc = 110,76°C
D21 GSIB2560E3 Vishay	Tjmax = 150 °C Pd = 8,8W Tj = Tc+(Θ(j-c) x Pd) = 104,46°C D.F. = 69,64%	Θ(j-c) = 1,0 °C/W ΔTc = 45,66°C	 Tc = 95,66°C
D10 STTH15L06D STMicro	Tjmax = 175 °C Pd = 2W Tj = Tc+(Θ(j-c) x Pd) = 104,83°C D.F. = 59,9%	Θ(j-c) = 1,7 °C/W ΔTc = 51,43°C	 Tc = 101,43°C
D14 STTH15L06D STMicro	Tjmax = 175 °C Pd = 2W Tj = Tc+(Θ(j-c) x Pd) = 104,83°C D.F. = 59,9%	Θ(j-c) = 1,7 °C/W ΔTc = 51,43°C	 Tc = 101,43°C
D39 STPS1H100A STMicro	Tjmax = 175 °C Pd = 0,047W Tj = Tc+(Θ(j-c) x Pd) = 79,78°C D.F. = 45,59%	Θ(j-l) = 30 °C/W ΔTc = 28,37°C	 Tc = 78,37°C
D40 STPS1H100A STMicro	Tjmax = 175 °C Pd = 0,047W Tj = Tc+(Θ(j-c) x Pd) = 93,43°C D.F. = 53,39%	Θ(j-l) = 30 °C/W ΔTc = 42,02°C	 Tc = 92,02°C
Position	Vin = 230VAC	Load = 100%	Ta = 50°C
IC15 FOD817B Fairchild	Tjmax = 125 °C Pd = 0W Tj = Tc+(Θ(j-c) x Pd) = 81,18°C D.F. = 64,94%	Θ(j-c) = 210 °C/W ΔTc = 31,18°C	 Tc = 81,18°C

IC16 FOD817B Fairchild	Tjmax = 125 °C Pd = 0W Tj = Tc+(Θ(j-c) x Pd) = 81,18°C D.F. = 64,94%	Θ(j-c) = 210 °C/W ΔTc = 31,18°C	 Tc = 81,18°C
IC18 FOD817B Fairchild	Tjmax = 125 °C Pd = 0W Tj = Tc+(Θ(j-c) x Pd) = 81,18°C D.F. = 64,94%	Θ(j-c) = 210 °C/W ΔTc = 31,18°C	 Tc = 81,18°C
IC20 FOD817B Fairchild	Tjmax = 125 °C Pd = 0W Tj = Tc+(Θ(j-c) x Pd) = 81,18°C D.F. = 64,94%	Θ(j-c) = 210 °C/W ΔTc = 31,18°C	 Tc = 81,18°C
IC9 TEA1721A NXP	Tjmax = 150 °C Pd = 0,19W Tj = Tc+(Θ(j-c) x Pd) = 109,65°C D.F. = 73,1%	Θ(j-c) = 136 °C/W ΔTc = 33,81°C	 Tc = 83,81°C
IC2 NCP1631 Onsemi	Tjmax = 150 °C Pd = 0,12W Tj = Tc+(Θ(j-c) x Pd) = 100,06°C D.F. = 66,7%	Θ(j-c) = 145 °C/W ΔTc = 32,66°C	 Tc = 82,66°C
IC1 L6699A STMicro	Tjmax = 150 °C Pd = 0,15W Tj = Tc+(Θ(j-c) x Pd) = 111°C D.F. = 74%	Θ(j-c) = 120 °C/W ΔTc = 43,0°C	 Tc = 93,00°C
IC5 ZXGD3101N8 Diodes Inc.	Tjmax = 150 °C Pd = 0,18W Tj = Tc+(Θ(j-c) x Pd) = 134,3°C D.F. = 89,53%	Θ(j-l) = 120 °C/W ΔTc = 62,66°C	 Tc = 112,66°C
IC6 ZXGD3101N8 Diodes Inc.	Tjmax = 150 °C Pd = 0,18W Tj = Tc+(Θ(j-c) x Pd) = 123,3°C D.F. = 82,22%	Θ(j-l) = 120 °C/W ΔTc = 51,73°C	 Tc = 101,73°C
IC7 ZXGD3101N8 Diodes Inc.	Tjmax = 150 °C Pd = 0,18W Tj = Tc+(Θ(j-c) x Pd) = 130,0°C D.F. = 86,69%	Θ(j-l) = 120 °C/W ΔTc = 58,44°C	 Tc = 108,44°C
IC8 ZXGD3101N8 Diodes Inc.	Tjmax = 150 °C Pd = 0,18W Tj = Tc+(Θ(j-c) x Pd) = 121,1°C D.F. = 80,75%	Θ(j-l) = 120 °C/W ΔTc = 49,52°C	 Tc = 99,52°C

5.4 Capacitor lifetime

	rated values					applied values			Calculated	
Pos.	**Capacity [µF]**	**Voltage [V]**	**Ripple Current [A]**	**Lifetime [h]**	**Temp [°C]**	**Voltage [V]**	**Ripple Current [A]**	**Temp [°C]**	**Lifetime [h]**	**Lifetime [yr]**
C1	150	450	0,97	5000	105	410	0,47	<65,34 Assumption: use Temp of C2	>101164	>11,54
C2	150	450	0,97	5000	105	410	0,47	65,34	101164	11,54
C3	150	450	0,97	5000	105	410	0,47	<57,22 Assumption: use Temp of C4	>177608	>20,26
C4	150	450	0,97	5000	105	410	0,47	57,22	177608	20,26
C89	1800	35	4,10	10000	105	24	1,45	71,80	134743	15,37
C90	1800	35	4,10	10000	105	24	1,45	<71,80 Assumption: use Temp of C89	>134743	>15,37
C91	1800	35	4,10	10000	105	24	1,45	<71,80 Assumption: use Temp of C89	>134743	>15,37
C92	1800	35	4,10	10000	105	24	1,45	<71,80 Assumption: use Temp of C89	>134743	>15,37
C8	220	35	4,00	3000	105	24	1,15	70,34	162226	18,5
C9	220	35	4,00	3000	105	24	1,15	<70,34 Assumption: use Temp of C8	>162226	>18,5
C10	220	35	4,00	3000	105	24	1,15	<70,34 Assumption: use Temp of C8	>162226	>18,5
C11	220	35	4,00	3000	105	24	1,15	<70,34 Assumption: use Temp of C8	>162226	>18,5
C114	220	35	4,00	3000	105	24	1,15	<70,34 Assumption: use Temp of C8	>162226	>18,5
C54	220	35	0,84	7000	105	13,5	0,26	59,57	222611	25,39
C55	220	35	0,84	7000	105	12,5	0,22	<59,57 Assumption: use Temp of C54	224900	25,65
Minimum lifetime of the capacitors at 230Vac / 24Vdc /30A / Tamb.=40°C									**101164**	**11,54**

6 List of equipment used

	Equipment Used	Manufacturer	Model No.
1	Mixed Domain Oscilloscop	Tektronix	MDO3024
2	Datalogger	Agilent	34970A
3	Datalogger	Keyside	34972A
4	Power Analyzer	Zimmer	LMG450
5	AC Source	Chroma	61703
6	Electronic Load	Promed	M9716
7	Electronic Load	Promed	M9716B
8	Electronic Load	Promed	M9717
9	Modular Impuls Generator	H+H	MIG0603IN2
10	Coupling Network	H+H	CDN2000-06-32
11	EMI Test Receiver	Rohde & Schwarz	ESBC 1082.8007
12	Artifical Mains	Schwarzbeck Mess Elektronik	NSLK8126
13	Climatic Chamber	Heraeus Vötsch	VMT04/240
14	Multimeter	Fluke	179
15	Current Probe	LEM	HTB-200
16	Current Probe	Chauvin Arnoux	E1N