

***TDK-Lambda***

**TPS4000-48**

**Evaluation Data**

September 8, 2020

## INDEX

Load/Line Regulation .....	4
Temperature Drift .....	4
Efficiency vs Output Current .....	5
Power Factor vs Output Current .....	6
Inrush Characteristics .....	7
Output Rise Characteristics .....	13
AC ON Control .....	13
Remote On/Off Control .....	15
Rise Time & Overshoot .....	17
Hold-Up Time Characteristics .....	19
Ripple Characteristics .....	20
OCP Characteristics .....	24
Local Mode .....	24
Remote Mode .....	25
Conducted Emissions .....	26
Radiated Emissions .....	29
Current Share .....	31

## TERMINOLOGY USED

- $V_{out}$  = Output Voltage
- $I_{out}$  = Output Current
- $V_{in}$  = Input Voltage
- $I_{in}$  = Input Current
- $I_{lim}$  = Current Limit
- $T_a$  = Ambient Temperature
- OVP = Over-voltage protection
- OCP – Over-current protection

## Load/Line Regulation

V<sub>out</sub> = 48Vdc, 100% load = 83.5A, T<sub>a</sub> = 25°C

V<sub>out</sub> adjusted with trim Pot (V<sub>out ADJ</sub>) and measured across output bus bars. Remote sense connected to bus bars.

I <sub>out</sub> /V <sub>in</sub>	350VAC	400VAC	480VAC	528VAC	Line Regulation	
0% Load	48.040	48.045	48.044	48.039	0.006	0.012%
12.5% Load	48.045	48.050	48.050	48.045	0.005	0.010%
25.0% Load	48.051	48.051	48.045	48.045	0.006	0.012%
37.5% Load	48.051	48.051	48.045	48.046	0.006	0.012%
50.0% Load	48.051	48.046	48.046	48.050	0.005	0.010%
62.5% Load	48.051	48.046	48.045	48.051	0.006	0.012%
75.0% Load	48.046	48.046	48.051	48.051	0.005	0.010%
87.5% Load	48.046	48.046	48.050	48.049	0.004	0.008%
100% Load	48.046	48.051	48.050	48.045	0.006	0.012%
Load Regulation	0.011	0.006	0.007	0.012		
	0.022%	0.012%	0.014%	0.025%		

**Note 1:** If V<sub>out</sub> programming with PMBus, settings are not stored after Input AC source power cycling.

## Temperature Drift

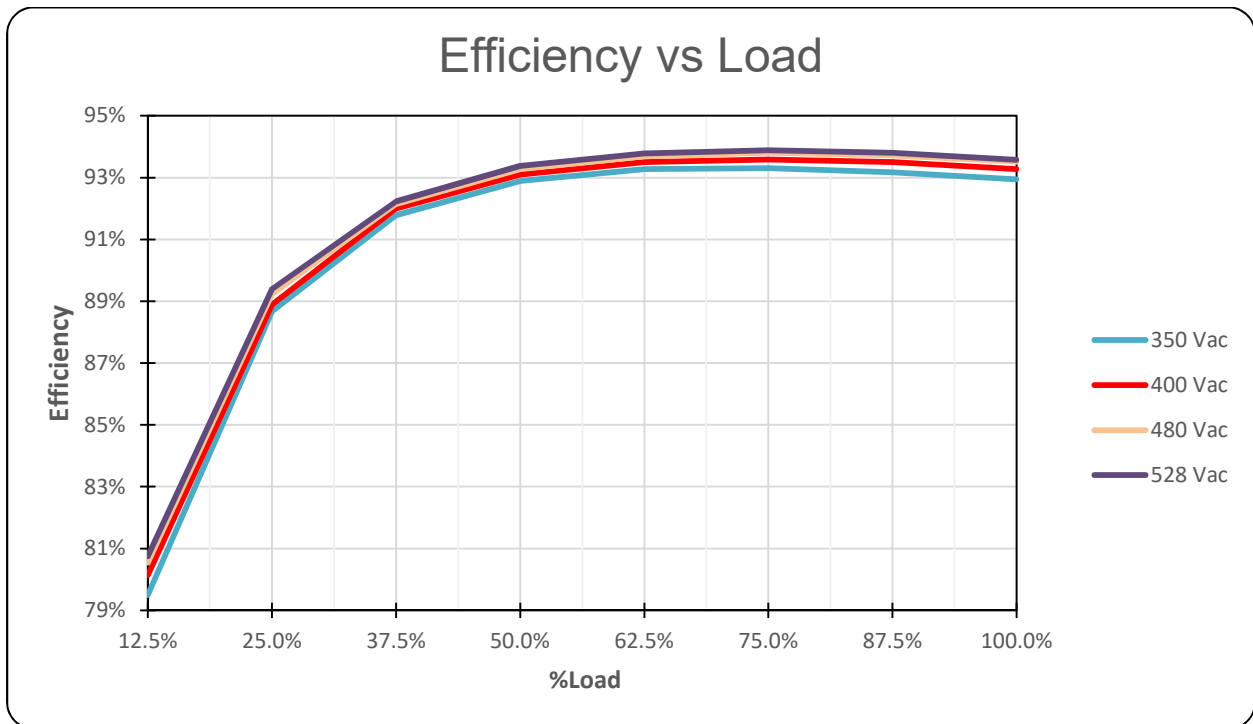
V<sub>out</sub> = 48Vdc, 100% load = 83.5A

V <sub>in</sub> (VAC)	I <sub>out</sub> (%)	V <sub>out</sub> @ -40°C	V <sub>out</sub> @ 25°C	V <sub>out</sub> @ 50°C	V <sub>out</sub> Delta	Overall Temperature Coefficient (ppm)
400	100%	48.109	48.058	48.022	0.036	29.96
480	100%	48.110	48.057	48.020	0.037	30.80
400	0%	48.105	48.047	48.021	0.026	21.65
480	0%	48.106	48.048	48.014	0.034	28.31

## Efficiency vs Output Current

Vout = 48Vdc, 100% Load = 83.5A, Ta = 25°C

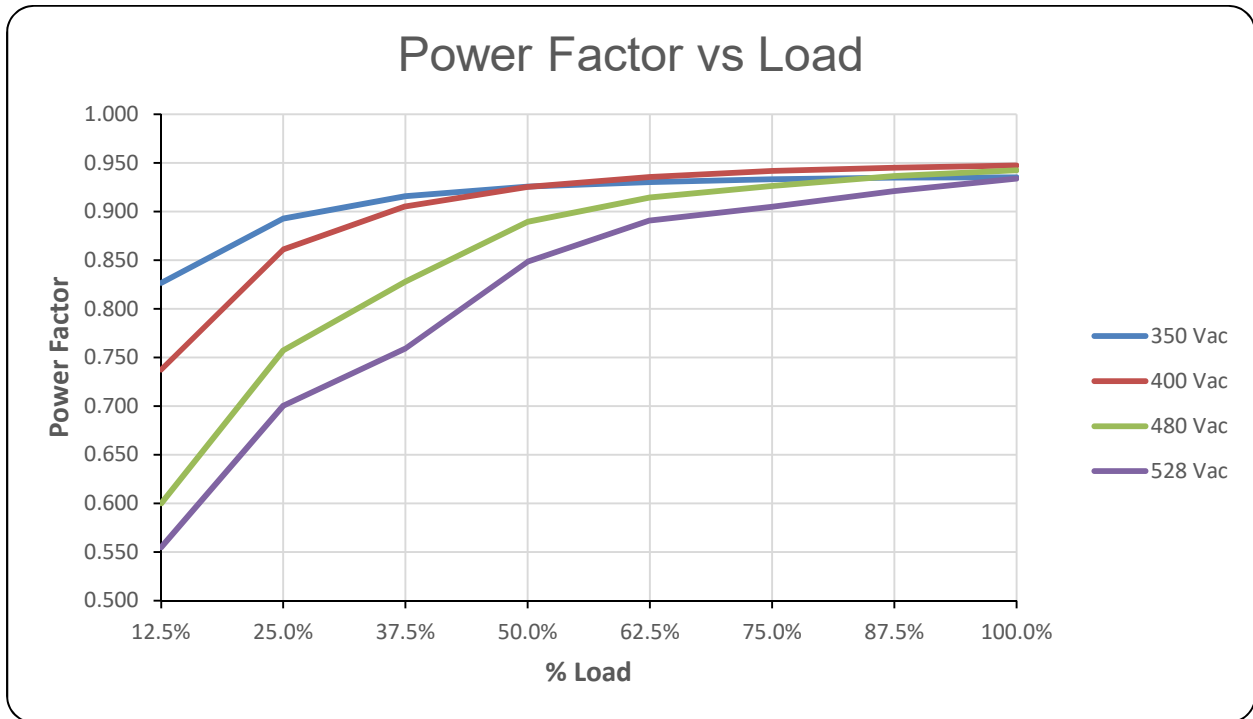
Iout(%) / Vin	350 VAC	400 VAC	480 VAC	528 VAC
12.5% Load	79.49%	80.14%	80.54%	80.75%
25.0% Load	88.67%	88.89%	89.23%	89.39%
37.5% Load	91.78%	92.00%	92.15%	92.23%
50.0% Load	92.89%	93.10%	93.27%	93.38%
62.5% Load	93.27%	93.50%	93.69%	93.78%
75.0% Load	93.31%	93.59%	93.80%	93.89%
87.5% Load	93.17%	93.50%	93.72%	93.80%
100.0% Load	92.94%	93.27%	93.51%	93.58%



## Power Factor vs Output Current

Vout = 48Vdc, 100% Load = 83.5A, Ta = 25°C

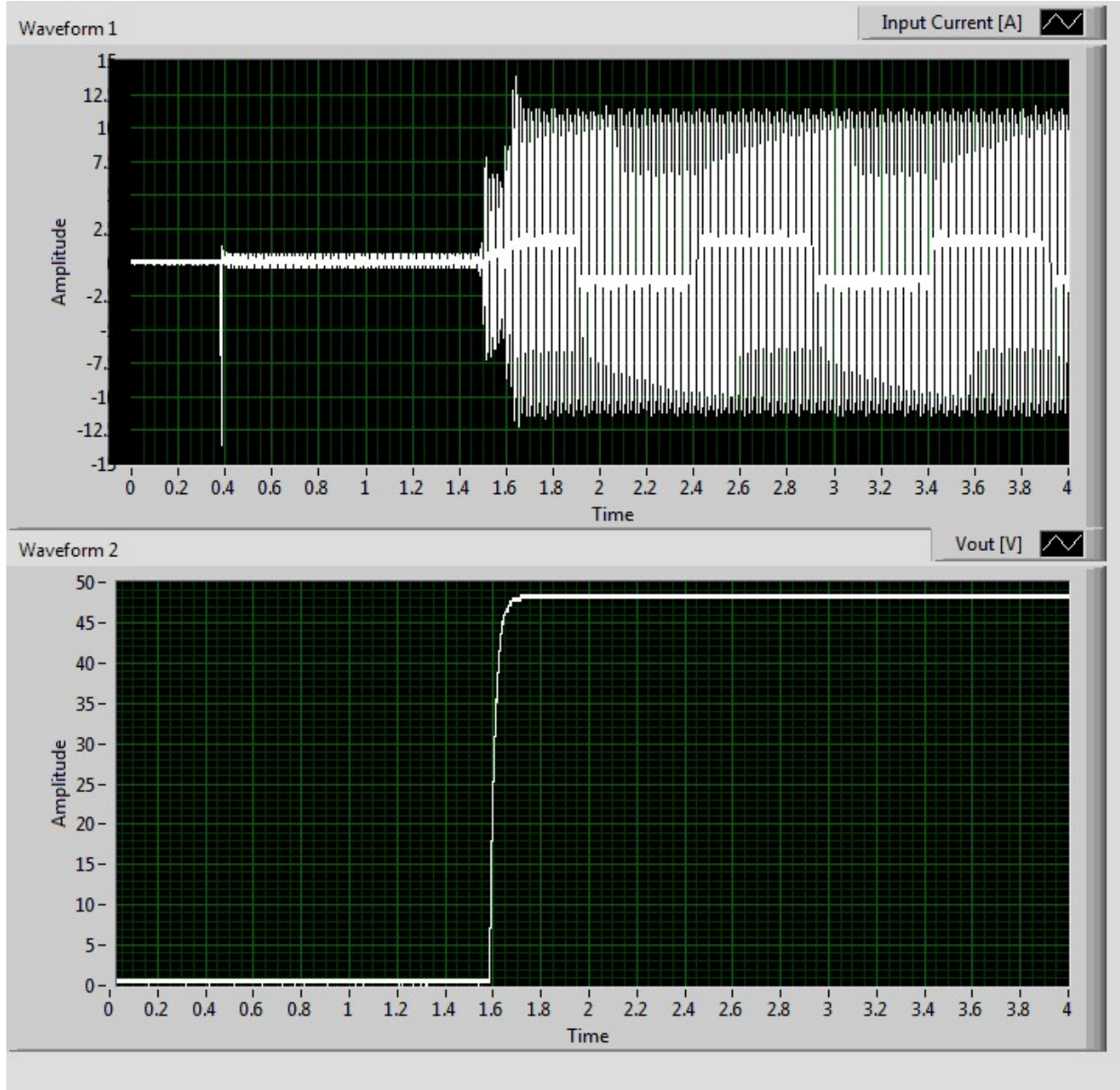
Iout(%) / Vin	350 VAC	400 VAC	480 VAC	528 VAC
12.5% Load	0.8268	0.7376	0.6001	0.5551
25.0% Load	0.8929	0.8609	0.7574	0.7002
37.5% Load	0.9157	0.9051	0.8278	0.7591
50.0% Load	0.9256	0.9254	0.8895	0.8485
62.5% Load	0.9304	0.9355	0.9144	0.8908
75.0% Load	0.9332	0.9416	0.9263	0.9048
87.5% Load	0.9348	0.9452	0.9366	0.9212
100.0% Load	0.9353	0.9475	0.9424	0.9340



## Inrush Characteristics

Inrush Current <25A peak per phase @ 400-480VAC input (excluding initial spike charging capacitors lasting < 2ms)

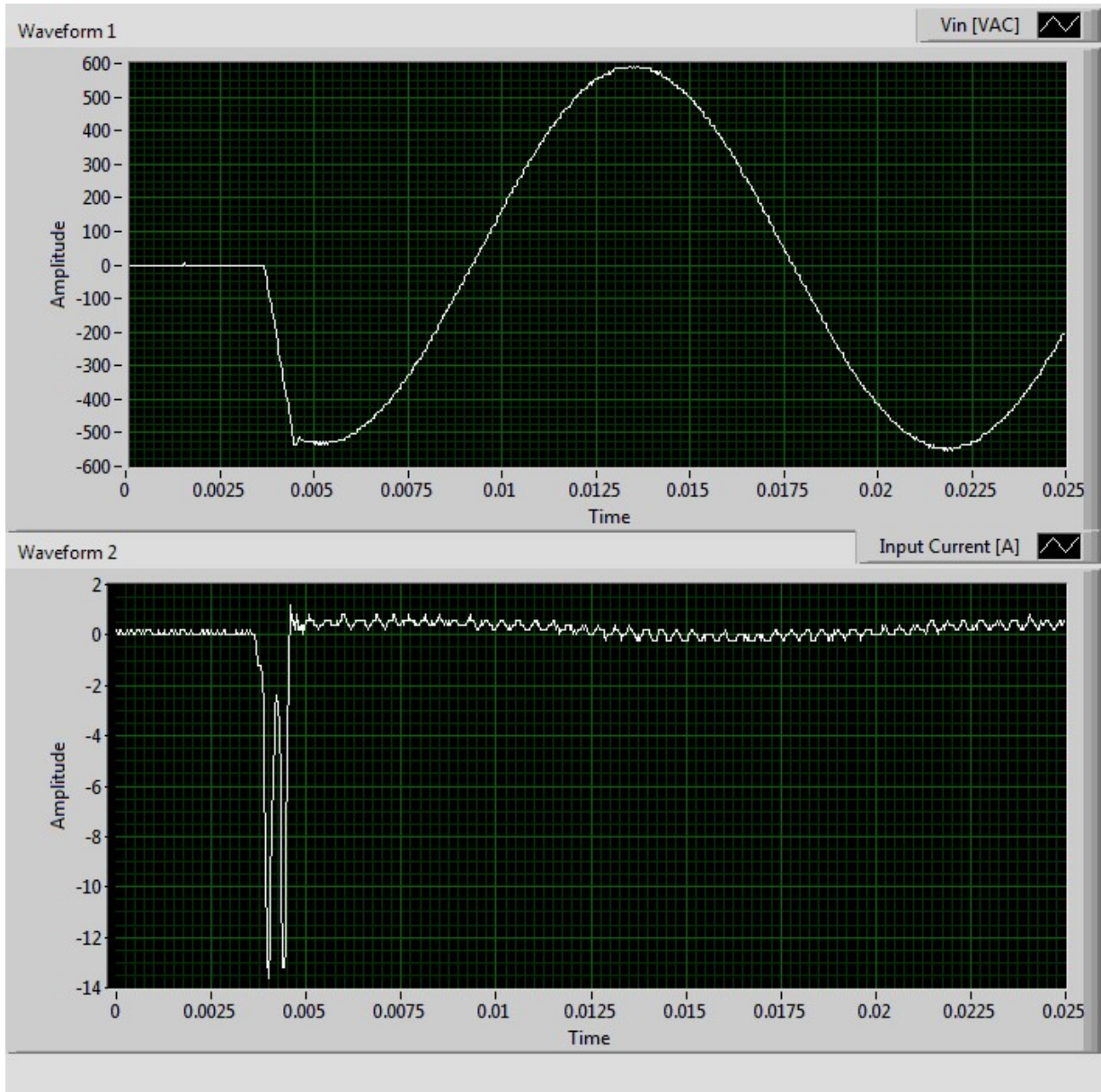
Vout =48Vdc, Ta=25°C, %100 Load = 83.5A



**Figure 1: Inrush @ 400VAC, 100% Load**

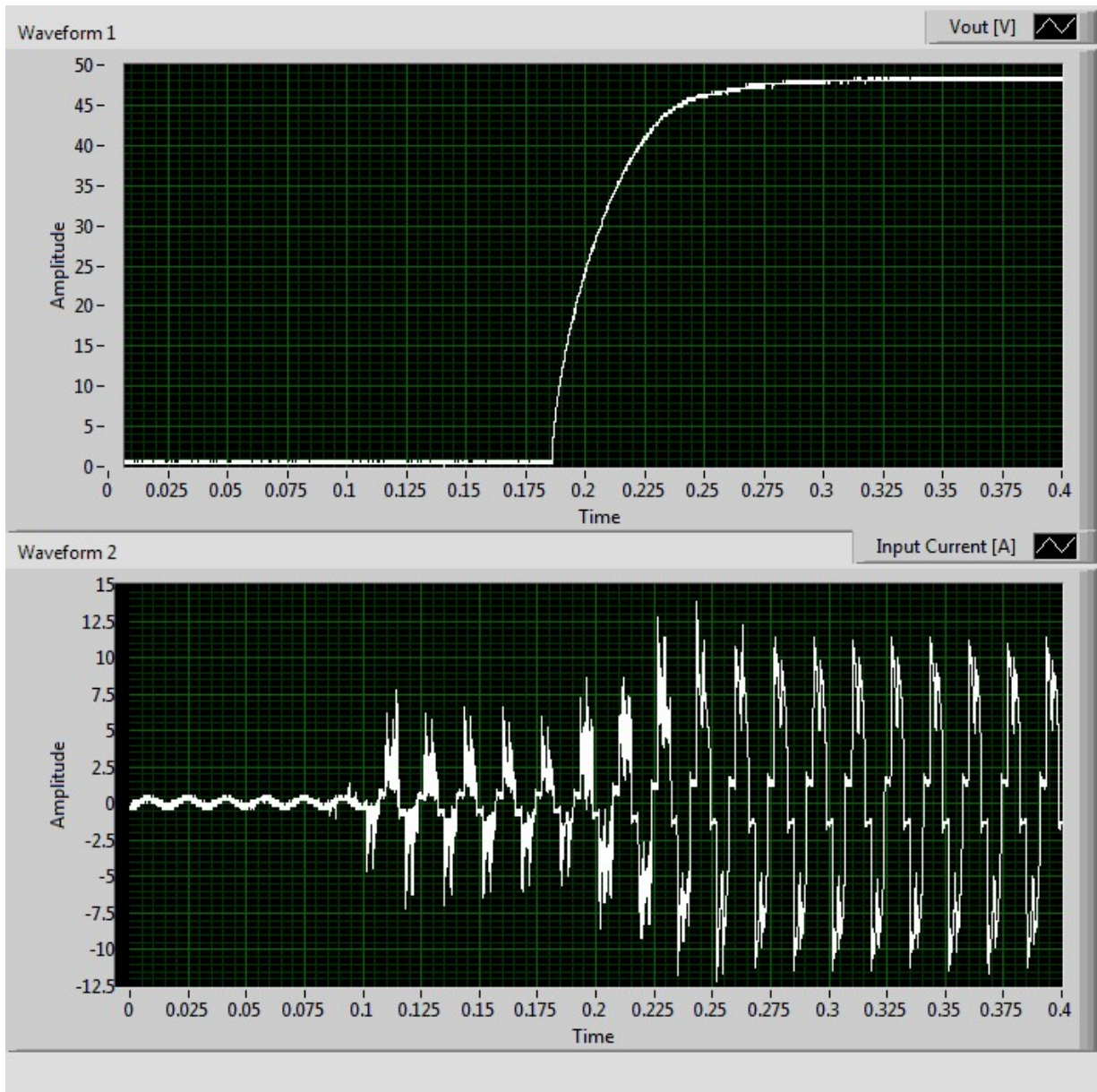
WAVEFORM 1 – Inrush Current, 2.5A/DIV

WAVEFORM 2 – Vout, 5V/DIV



**Figure 2:** Inrush @ 400VAC, 100% Load. Initial spike charging capacitors  
 WAVEFORM 1 – Vin, 100V/DIV                      WAVEFORM 2 – Inrush Current, 2A/DIV

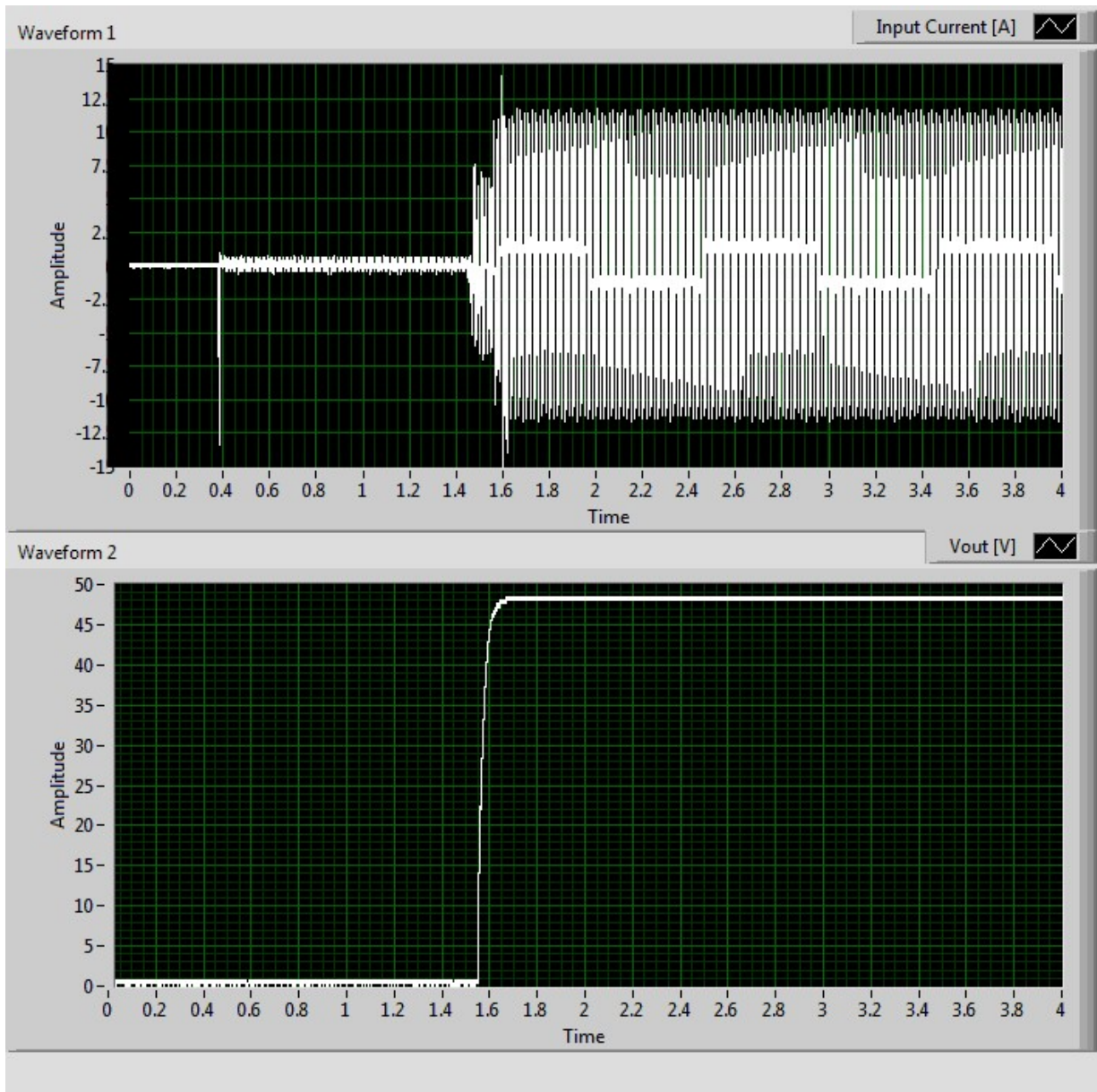




**Figure 3: Inrush @ 400VAC, 100% Load.**

WAVEFORM 1 – Vout, 5V/DIV

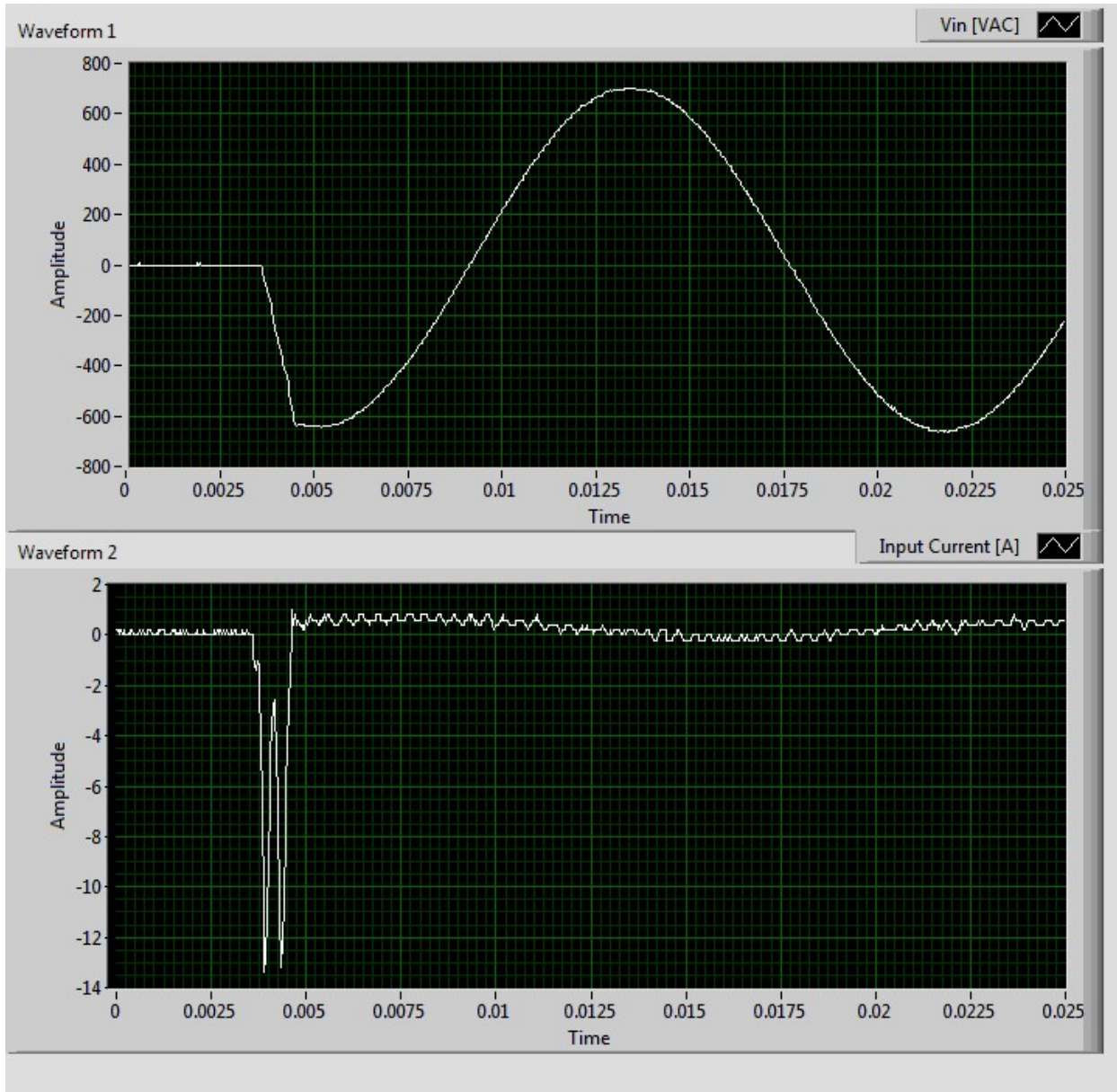
WAVEFORM 2 – Inrush Current, 2.5A/DIV



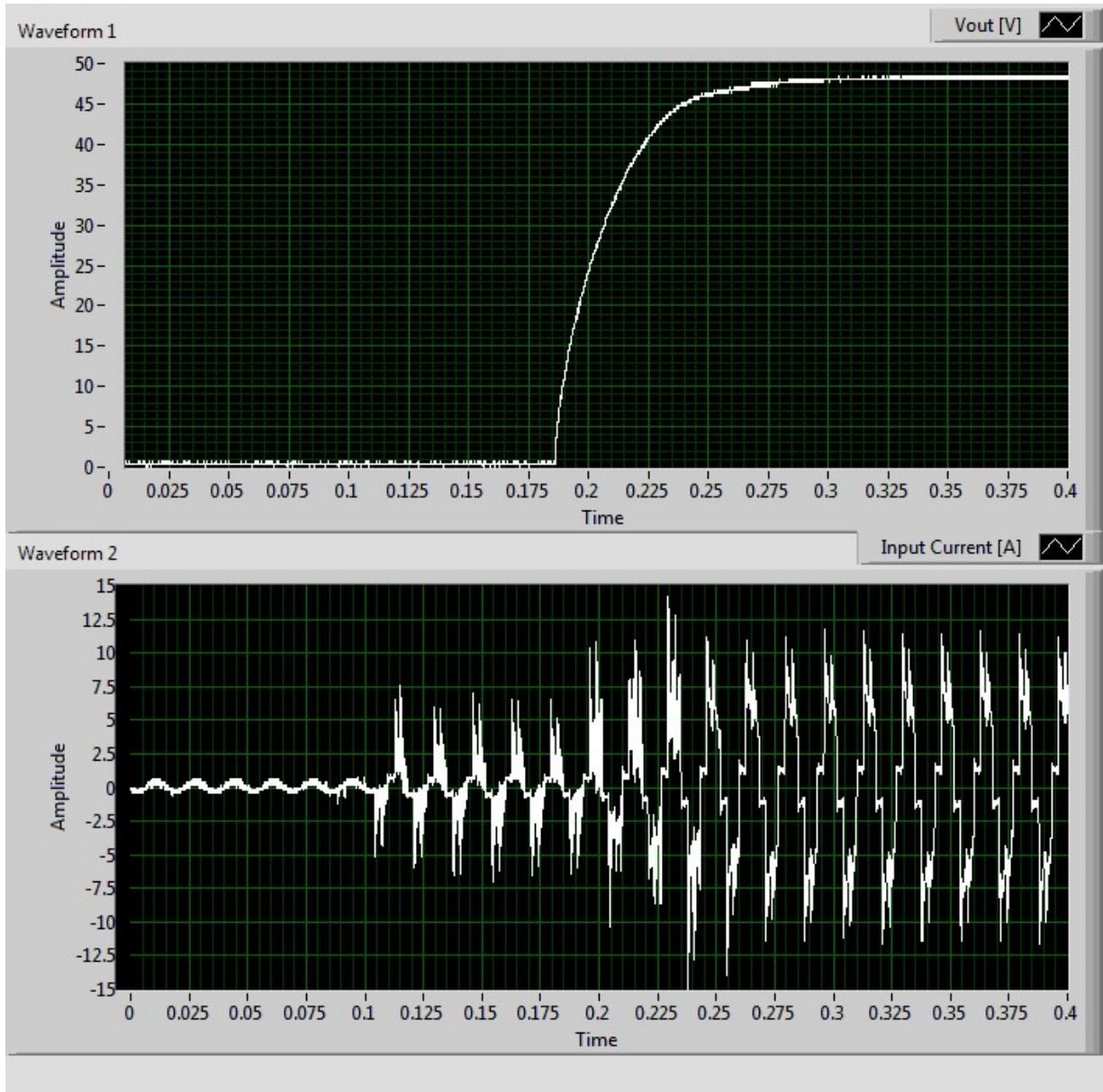
**Figure 4: Inrush @ 480VAC, 100% Load**

WAVEFORM 1 – Inrush Current, 2.5A/DIV

WAVEFORM 2 – Vout, 5V/DIV



**Figure 5: Inrush @ 480VAC, 100% Load. Initial spike charging capacitors**  
 WAVEFORM 1 – Vin, 200V/DIV                      WAVEFORM 2 – Inrush Current, 2A/DIV



**Figure 6: Inrush @ 480VAC, 100% Load.**

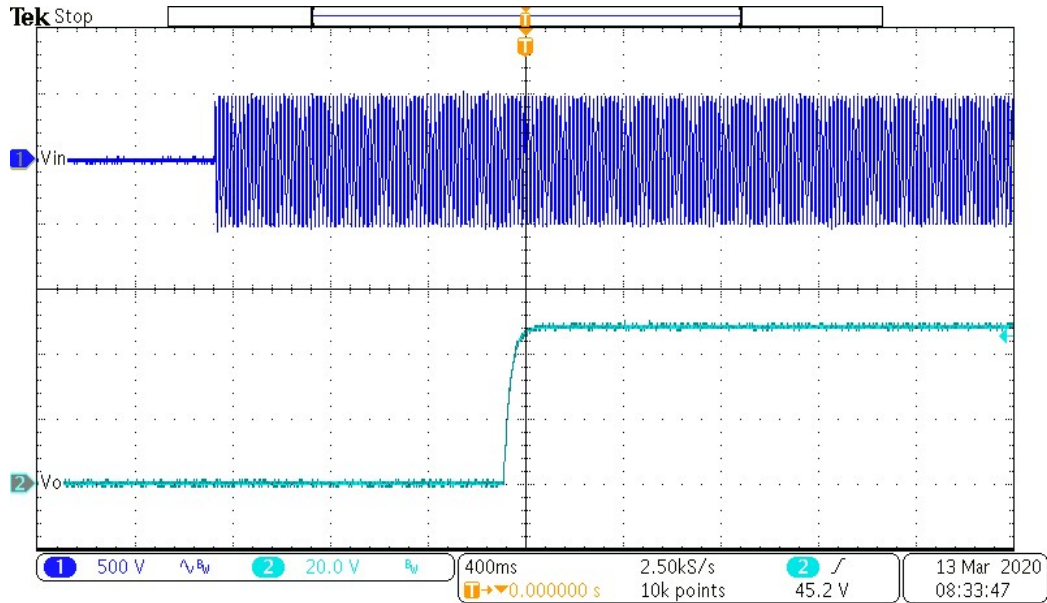
WAVEFORM 1 – Vout, 5V/DIV

WAVEFORM 2 – Inrush Current, 2.5A/DIV

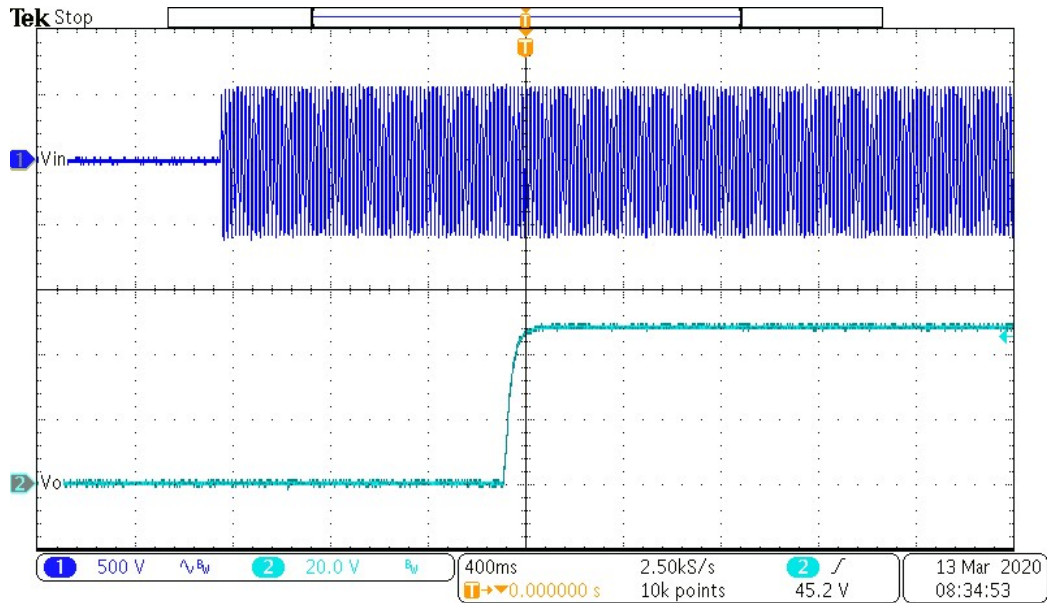
## Output Rise Characteristics

$V_{out} = 48V_{dc}$ ,  $T_a = 25^{\circ}C$ ,  $I_{out} = 83.5A$

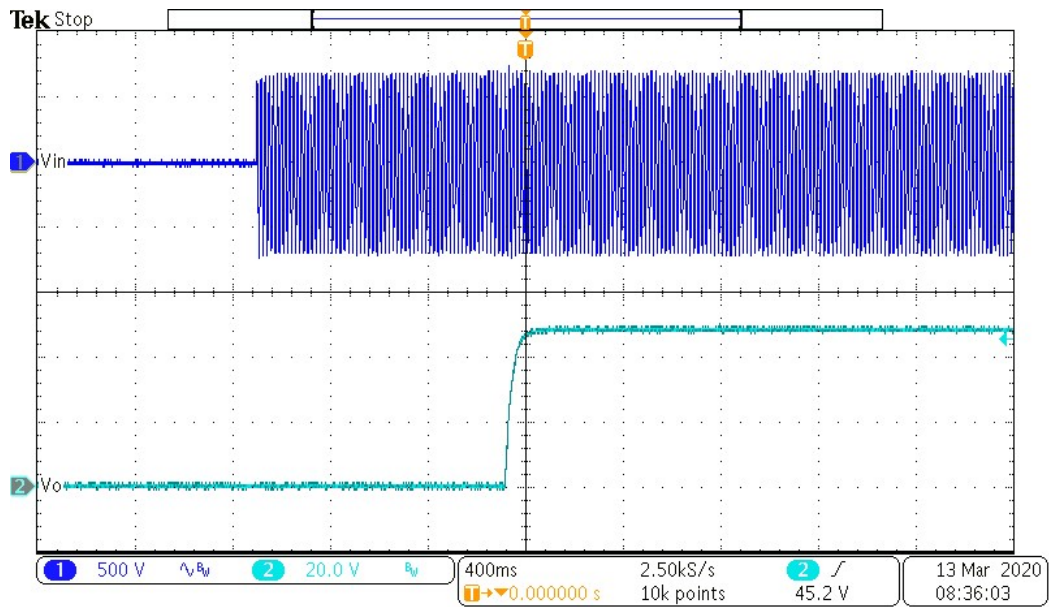
**AC ON Control** - Output Rise time from application of input voltage



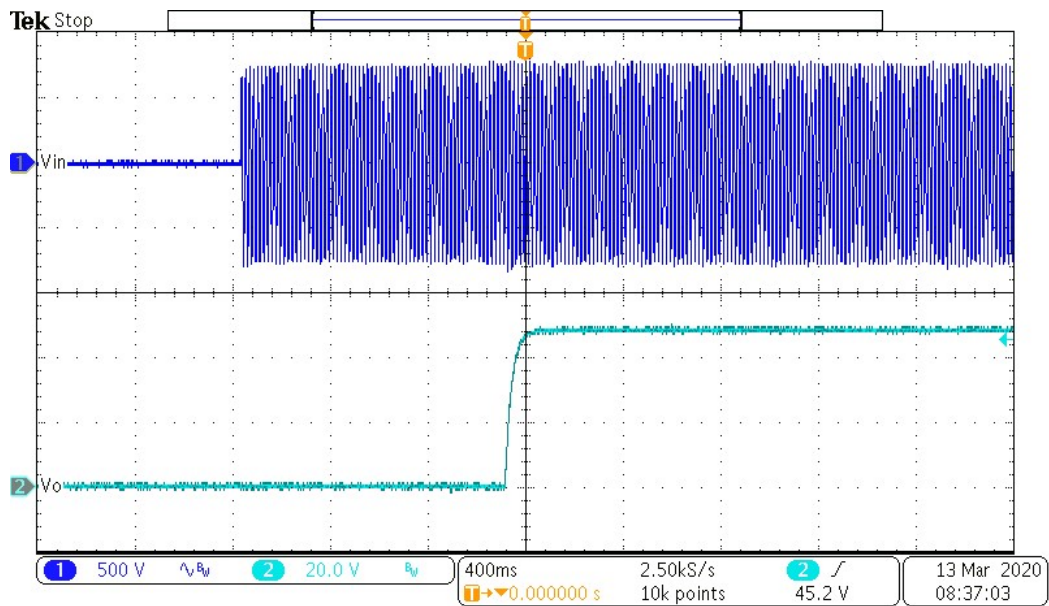
**Figure 7:** Turn ON Time from  $V_{in} = 350V_{AC}$ .  
(CH1:  $V_{in}$ , 500V/div; CH2:  $V_{out}$ , 20V/div)



**Figure 8:** Turn ON Time from  $V_{in} = 400V_{AC}$ .  
(CH1:  $V_{in}$ , 500V/div; CH2:  $V_{out}$ , 20V/div)

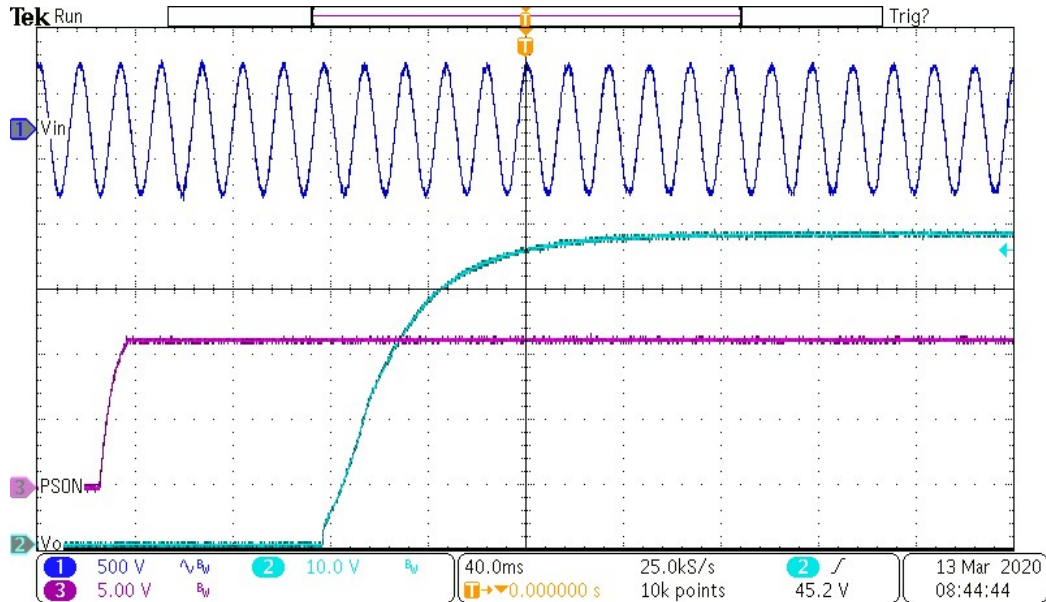


**Figure 9: Turn ON Time from  $V_{in} = 480\text{VAC}$ .**  
 (CH1:  $V_{in}$ , 500V/div; CH2:  $V_{out}$ , 20V/div)

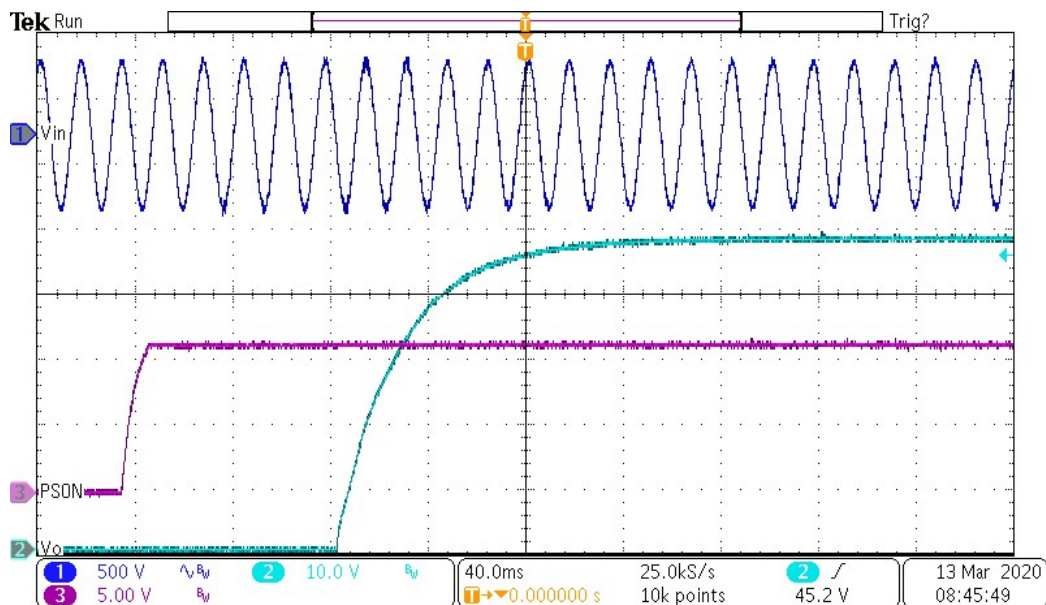


**Figure 10: Turn ON Time from  $V_{in} = 528\text{VAC}$ .**  
 (CH1:  $V_{in}$ , 500V/div; CH2:  $V_{out}$ , 20V/div)

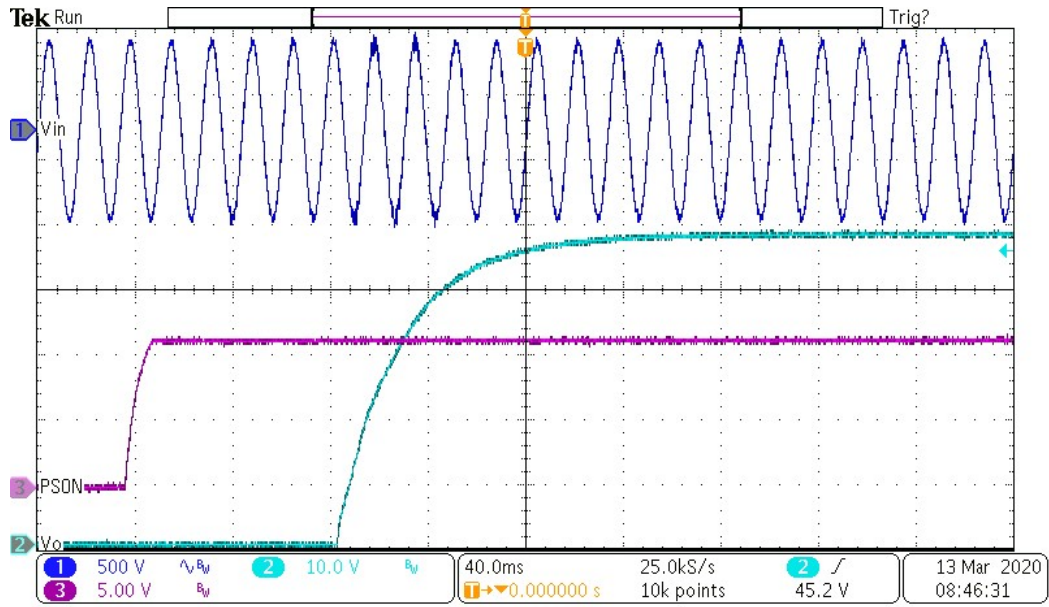
**Remote On/Off Control** – TTL voltage level compatible signal connected between pins 14(PSON) and 18(-SNS) of the Signal Connector. With the Output Enable switch in the ON position, a Logic High or Open will enable the output. A Logic Low or Short will disable the output.



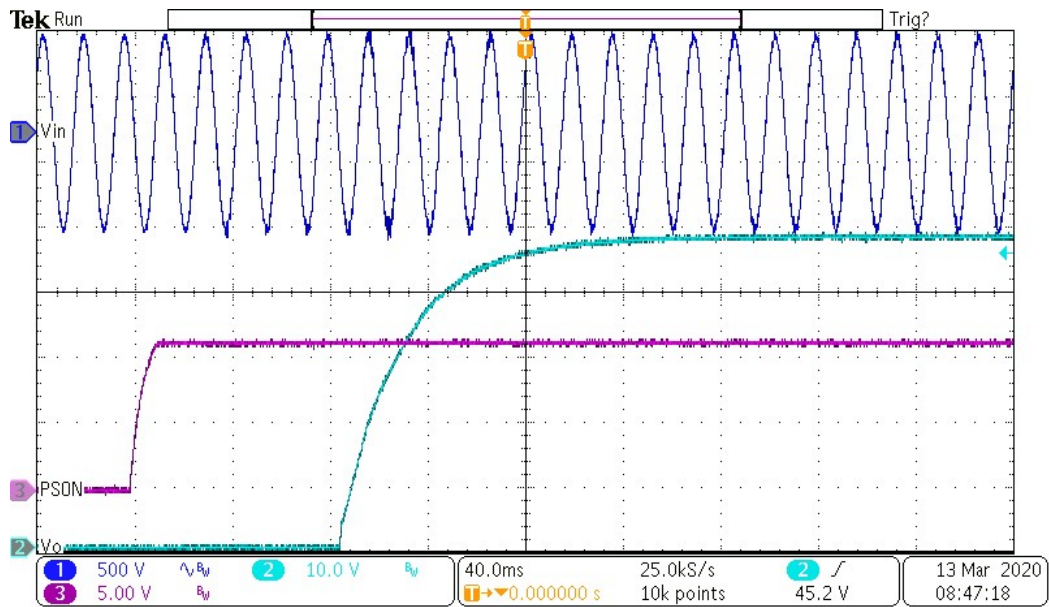
**Figure 11: Rise Time from Remote On-Off 350VAC 100% load.**  
(CH1:Vin,500V/div;CH2:Vout,10V/div; CH3:PSON,5V/div)



**Figure 12: Rise Time from Remote On-Off 400VAC 100% load.**  
(CH1:Vin,500V/div;CH2:Vout,10V/div;CH3:PSON,5V/div)



**Figure 13: Rise Time from Remote On-Off 480VAC 100% load.**  
 (CH1:Vin,500V/div;CH2:Vout,10V/div;CH3:PSON,5V/div)

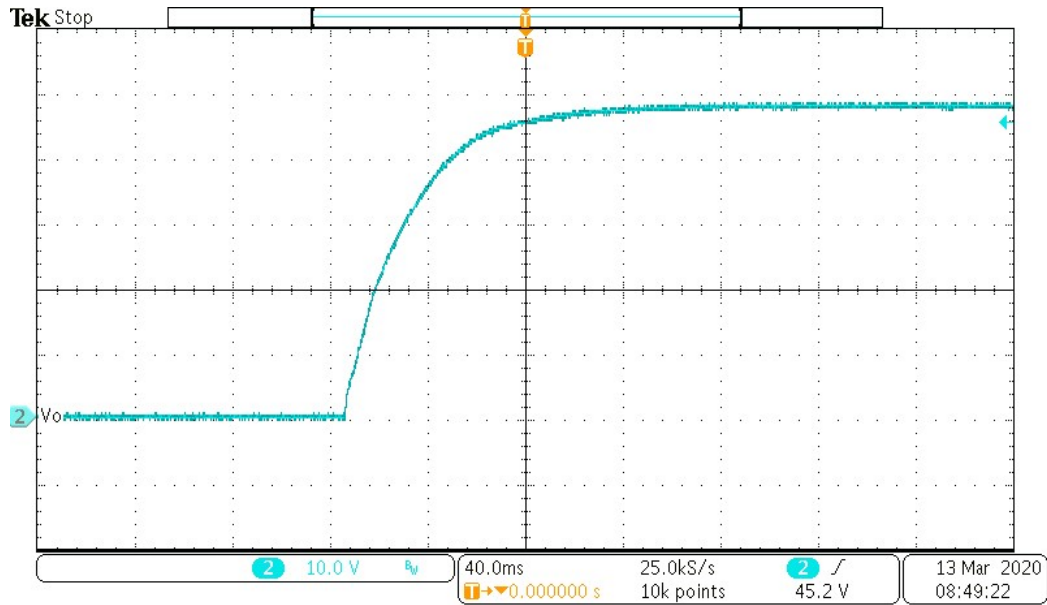


**Figure 14: Rise Time from Remote On-Off 528VAC 100% load.**  
 (CH1:Vin,500V/div;CH2:Vout,10V/div;CH3:PSON,5V/div)

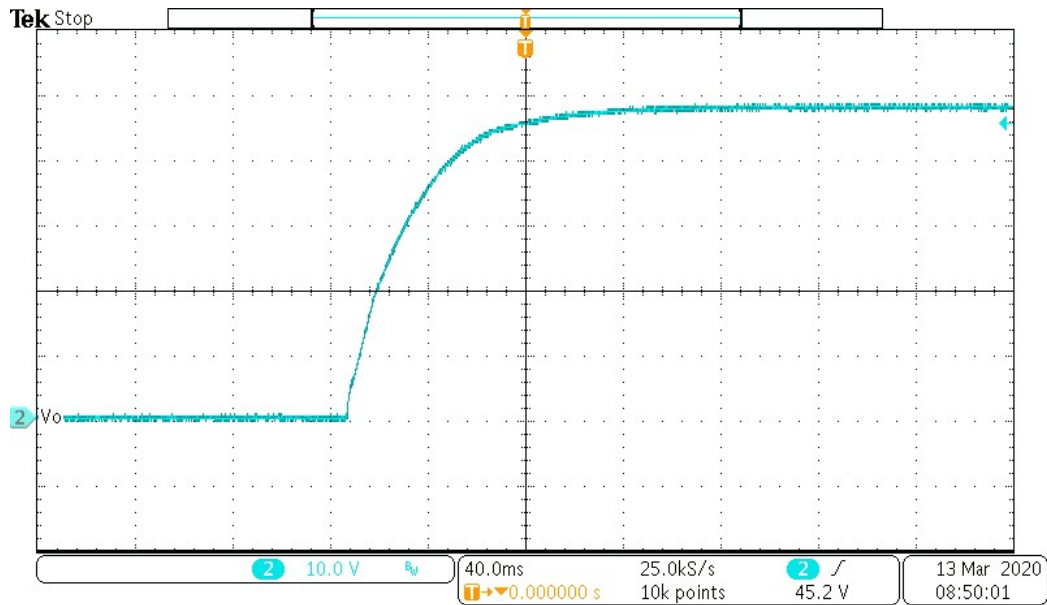


## Rise Time & Overshoot

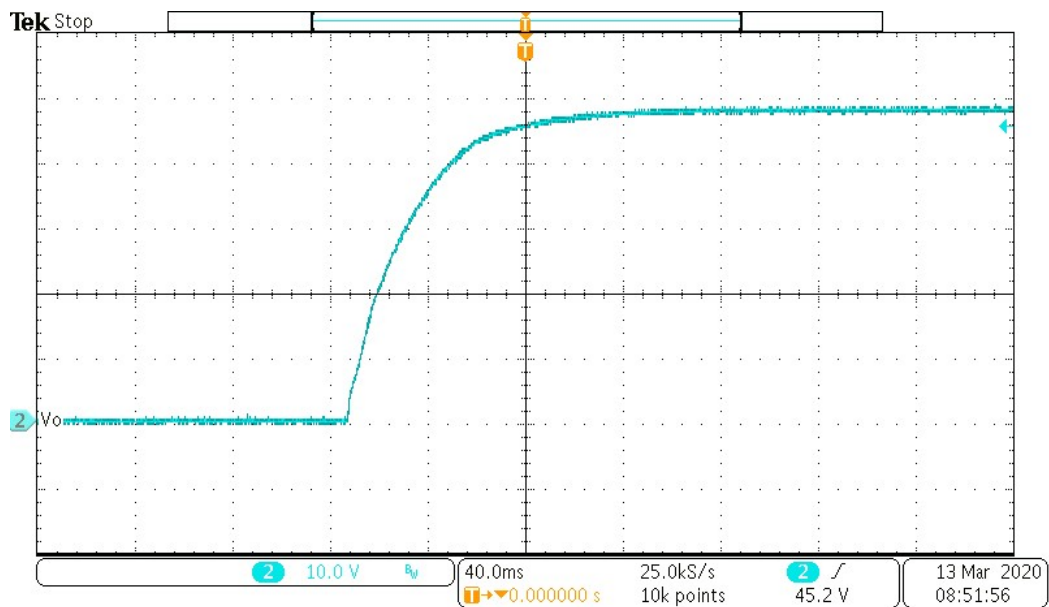
$V_{out} = 48V_{dc}$ , 100% Load = 83.5A,  $T_a = 25^{\circ}C$



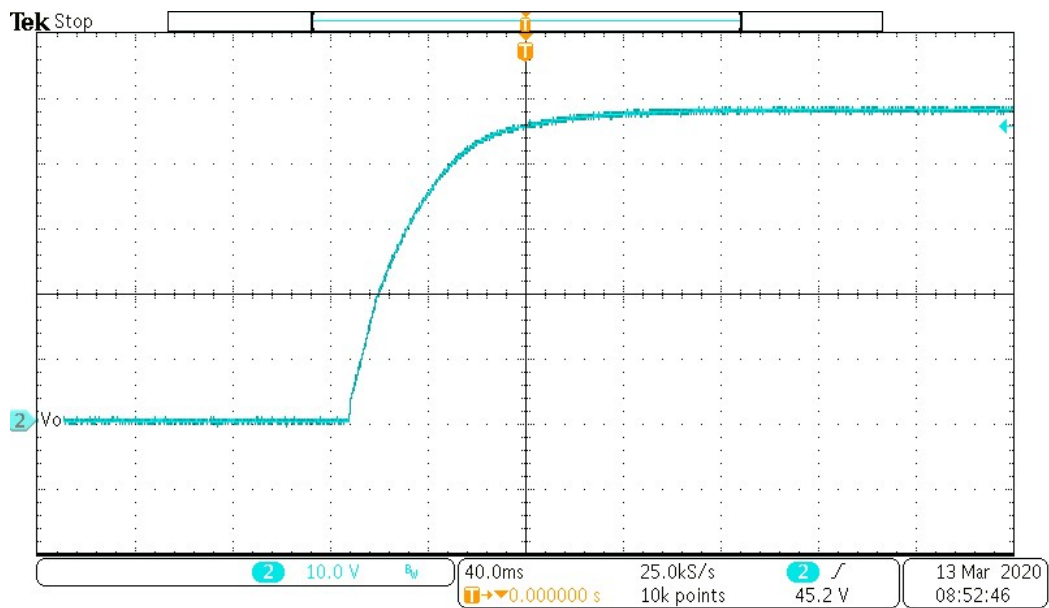
**Figure 15:** Rise Characteristics at Turn On 350VAC 0% load  
(CH2: Vout, 10V/div).



**Figure 16:** Rise Characteristics at Turn On 350VAC 100% load  
(CH2: Vout, 10V/div)



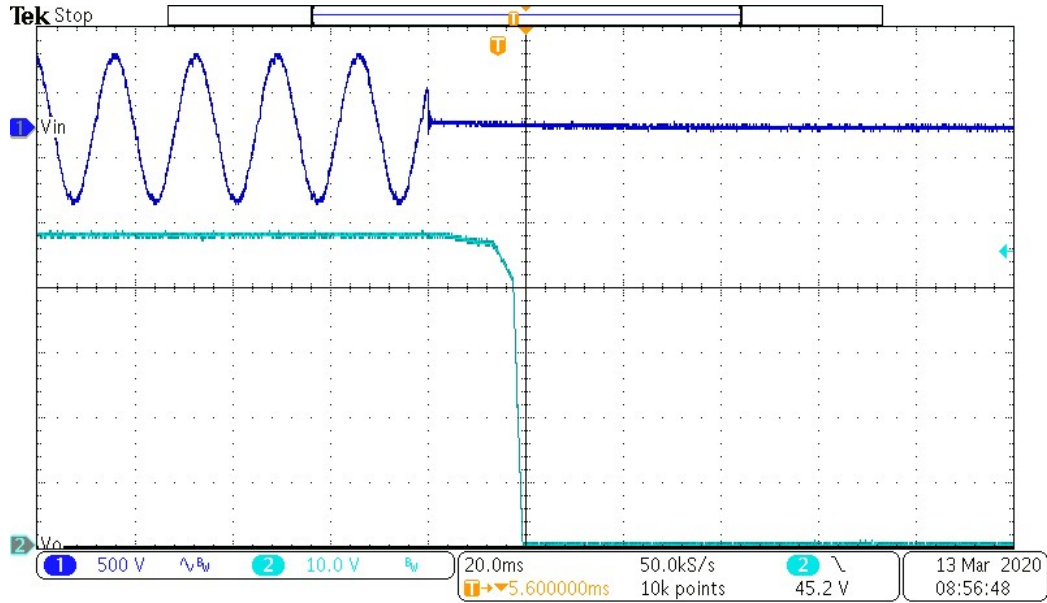
**Figure 17: Rise Characteristics at Turn On 400VAC 0% load**  
(CH2: Vout, 10V/div).



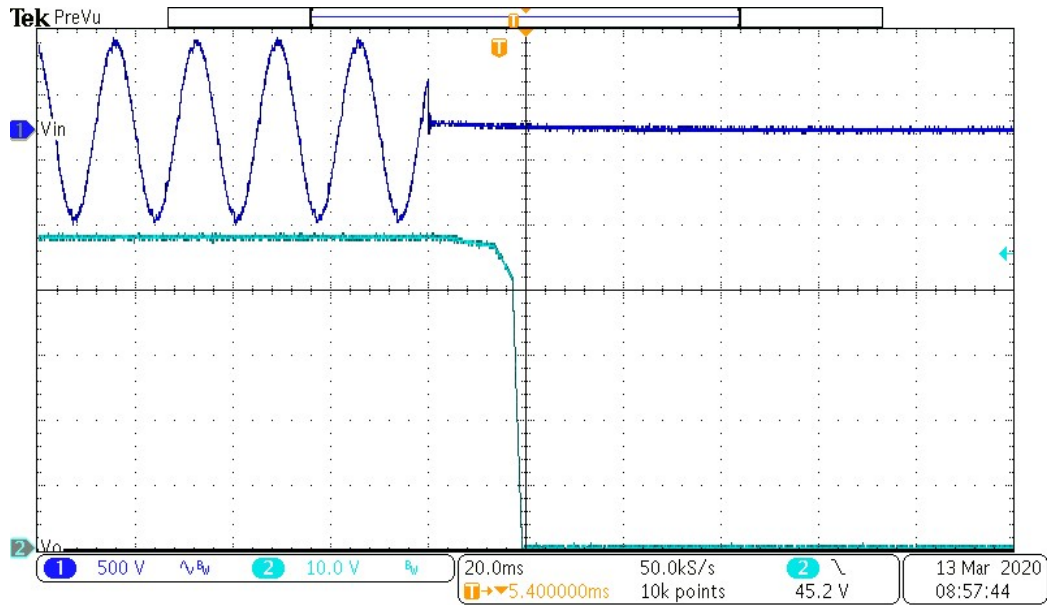
**Figure 18: Rise Characteristics at Turn On 400VAC 100% load**  
(CH2: Vout, 10V/div).

## Hold-Up Time Characteristics

$V_{out} = 48V_{dc}$ ,  $T_a = 25^{\circ}C$ , 100% Load = 83.5A



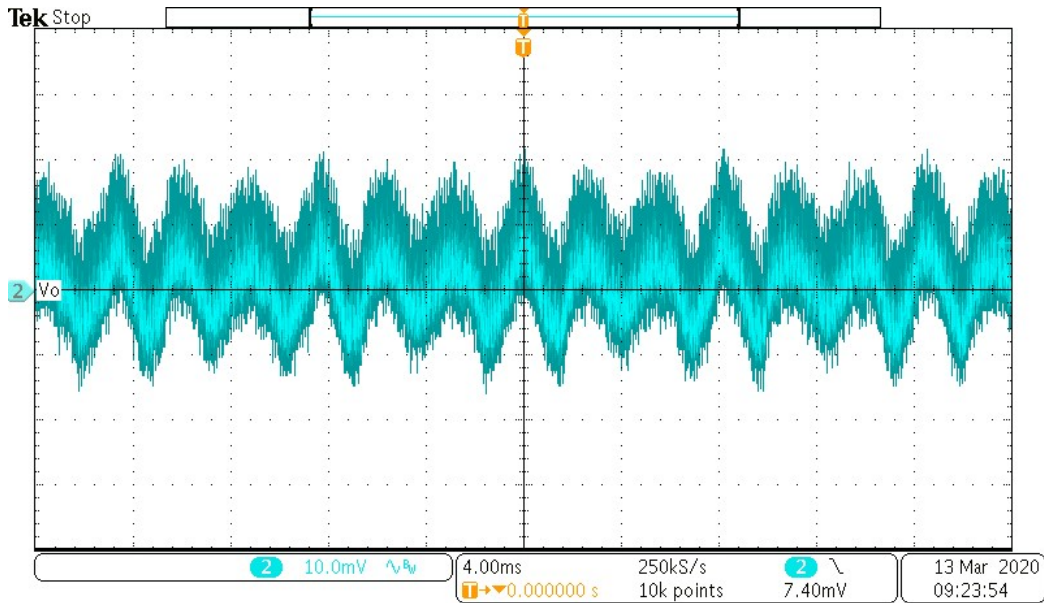
**Figure 19: HOLD-UP TIME 400VAC 100% Load**  
( CH1:  $V_{in}$ , 500V/div, CH2:  $V_{out}$ , 10V/div ) .



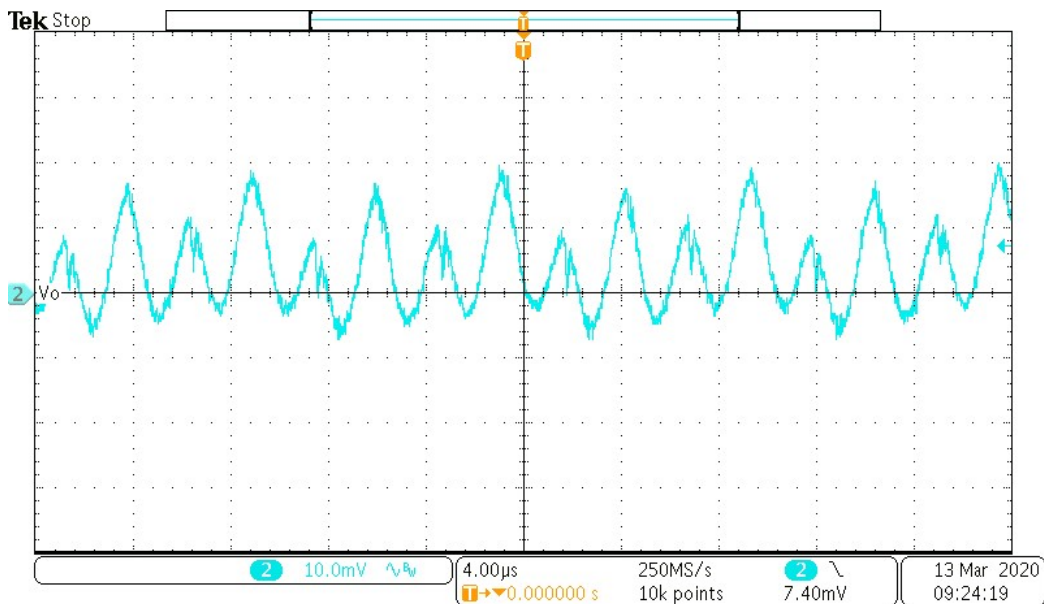
**Figure 20: HOLD-UP TIME 480VAC 100% Load**  
( CH1:  $V_{in}$ , 500V/div, CH2:  $V_{out}$ , 10V/div ) .

## Ripple Characteristics

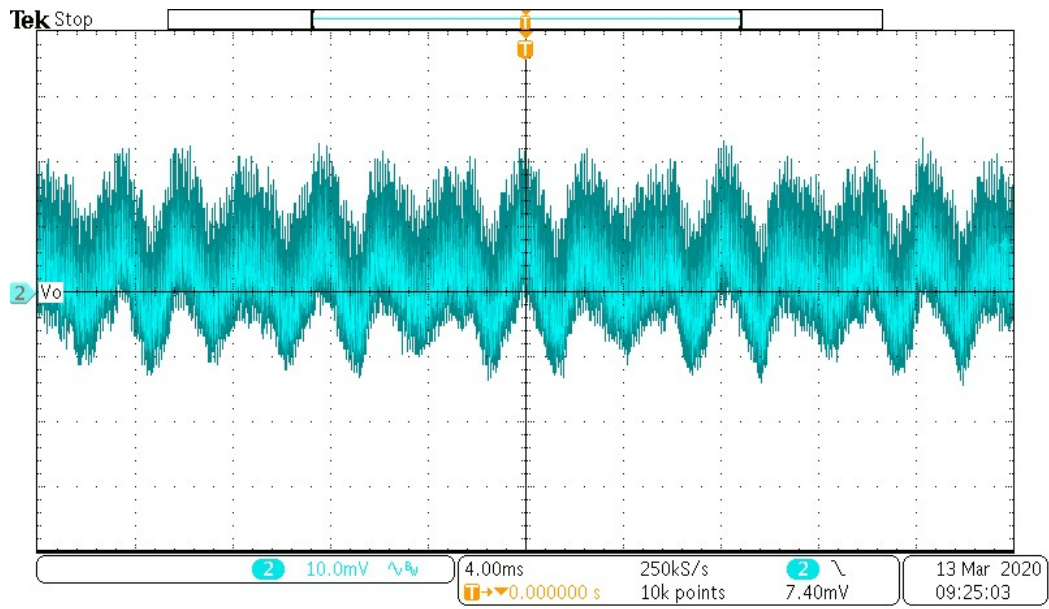
Ripple and Noise: 480mV pk-pk max, 20MHz bandwidth. Jeita RC-9131C Procedure.  
Vout = 48Vdc, Ta = 25°C, 100% Load = 83.5A



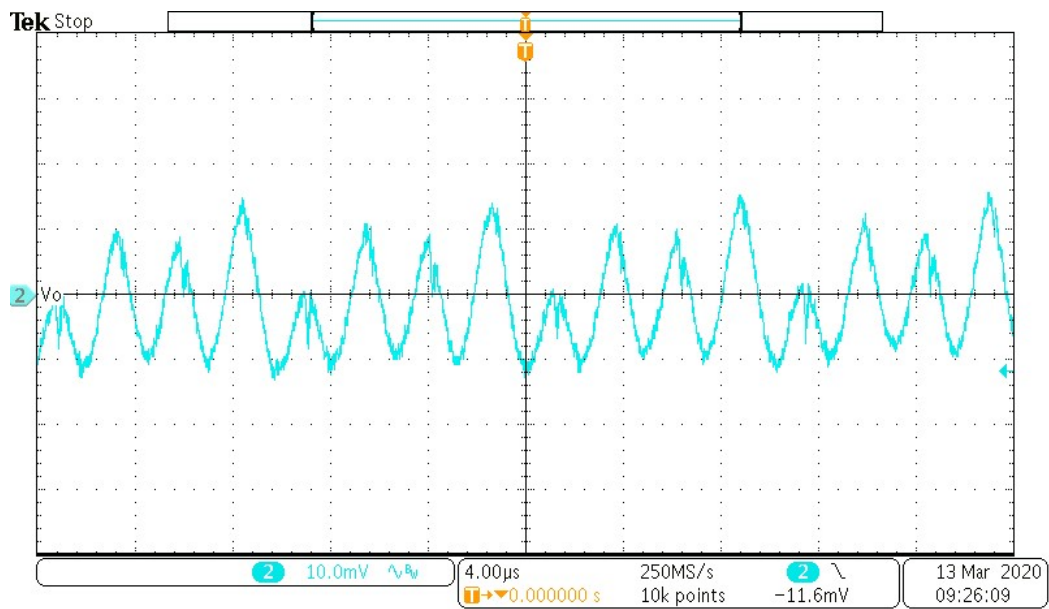
**Figure 21: Ripple at 100% Load @ 350VAC.**  
(CH1: Vout, 10mV/div, Timebase = 4ms/div)



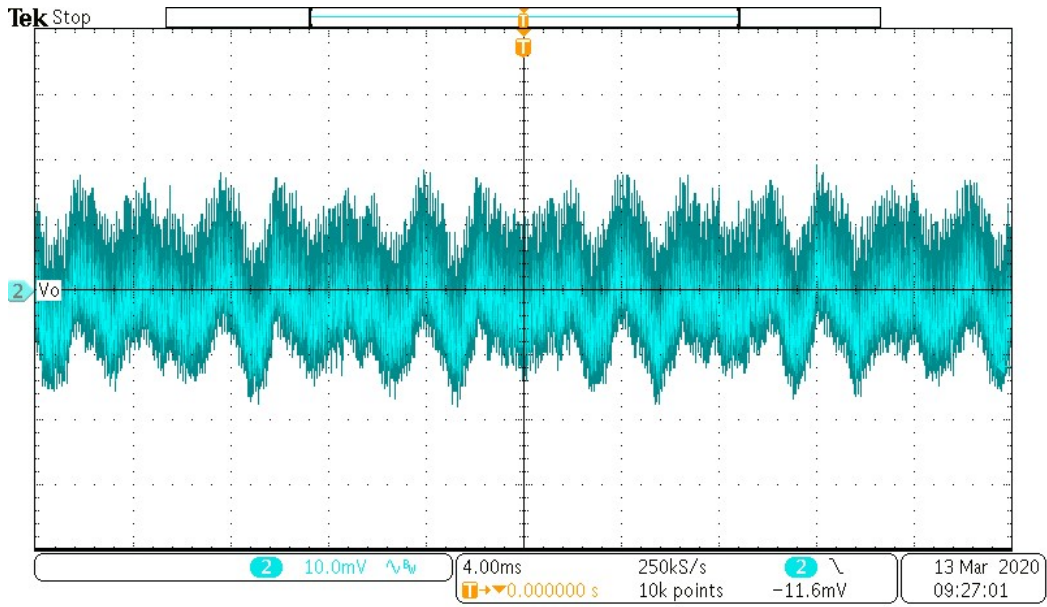
**Figure 22: Ripple at 100% Load @ 350VAC.**  
(CH1: Vout, 10mV/div, Timebase = 4µs/div).



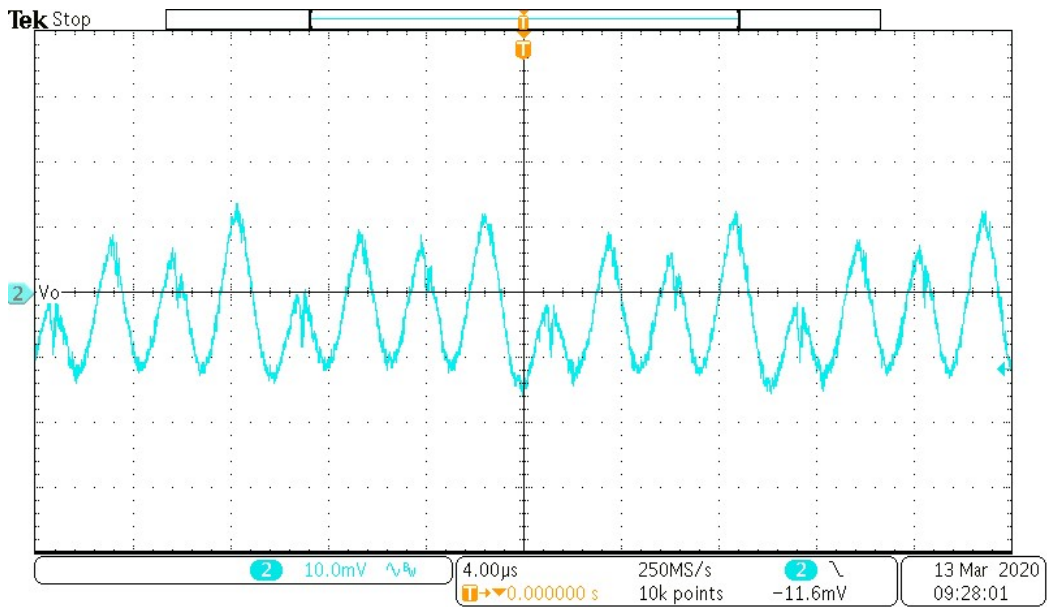
**Figure 23: Ripple at 100% Load @ 400VAC.**  
 (CH1: Vout, 10mV/div, Timebase = 4ms/div)



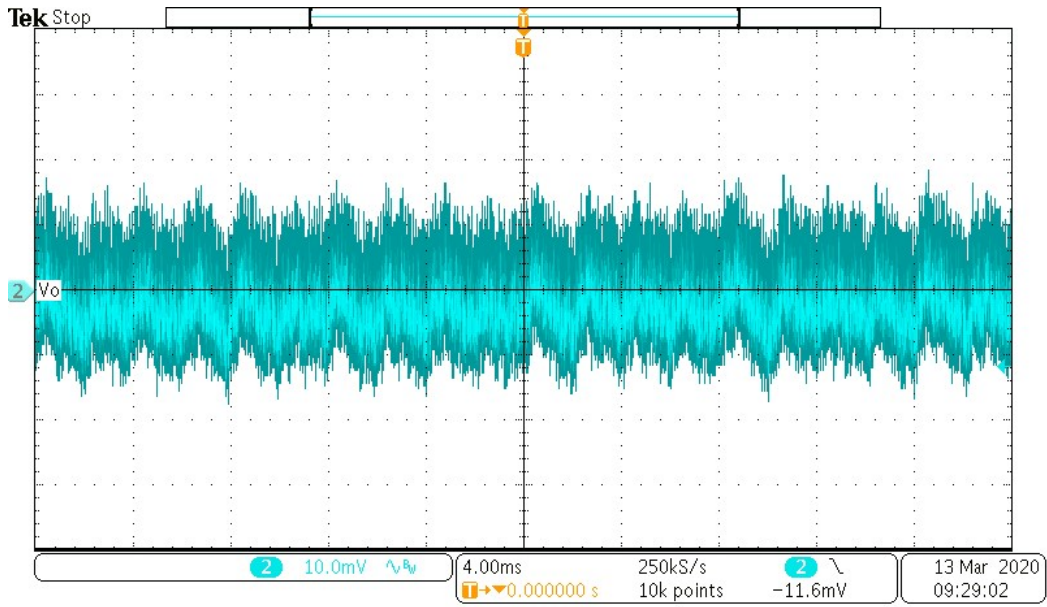
**Figure 24: Ripple at 100% Load @ 400VAC.**  
 (CH1: Vout, 10mV/div, Timebase = 4µs/div).



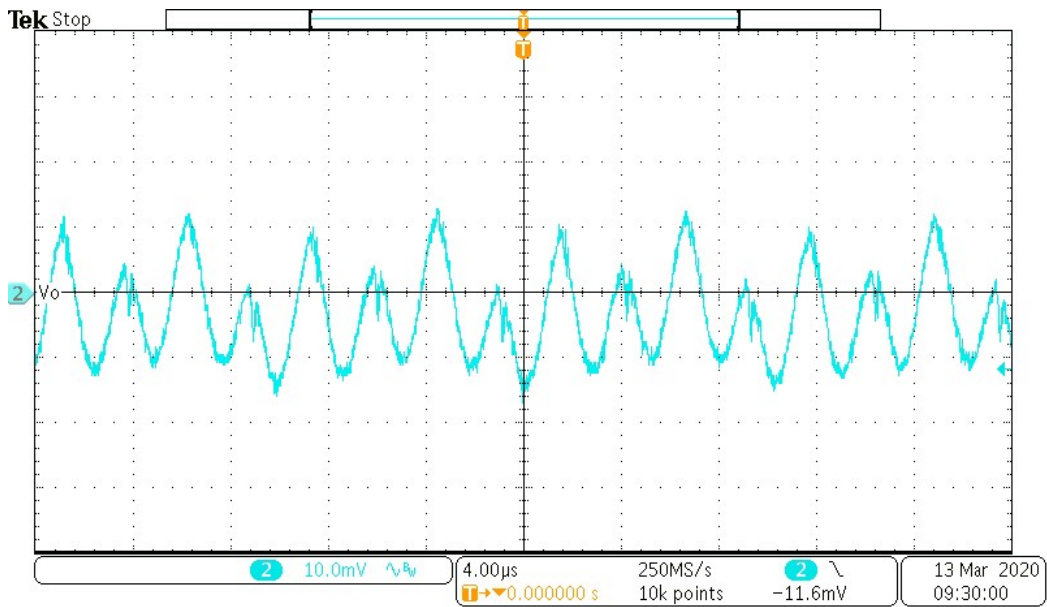
**Figure 25: Ripple at 100% Load @ 480VAC.**  
 (CH1: Vout, 10mV/div, Timebase = 4ms/div)



**Figure 26: Ripple at 100% Load @ 480VAC.**  
 (CH1: Vout, 10mV/div, Timebase = 4µs/div)



**Figure 27: Ripple at 100% Load @ 528VAC.**  
 (CH1: Vout, 10mV/div, Timebase = 4ms/div)



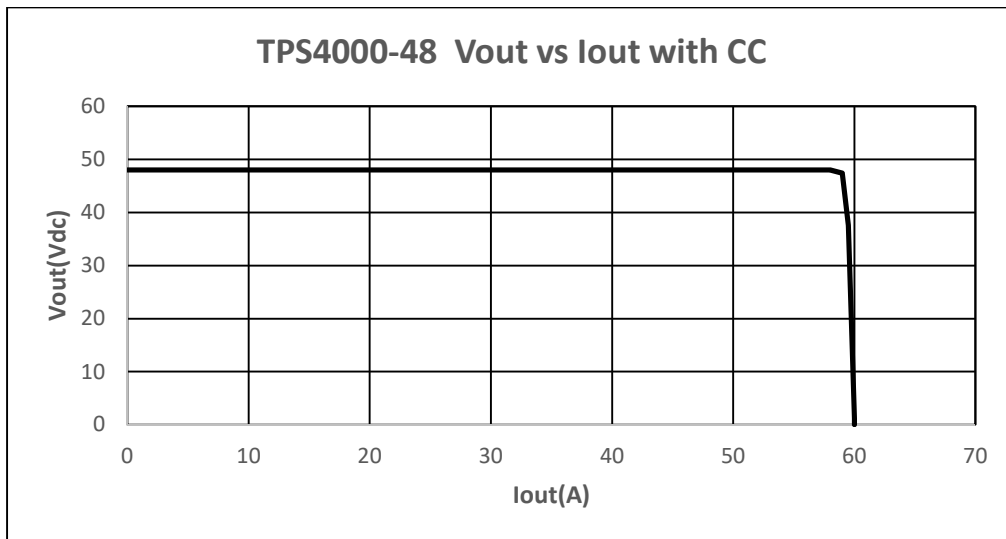
**Figure 28: Ripple at 100% Load @ 528VAC.**  
 (CH1: Vout, 10mV/div, Timebase = 4µs/div)

## OCP Characteristics

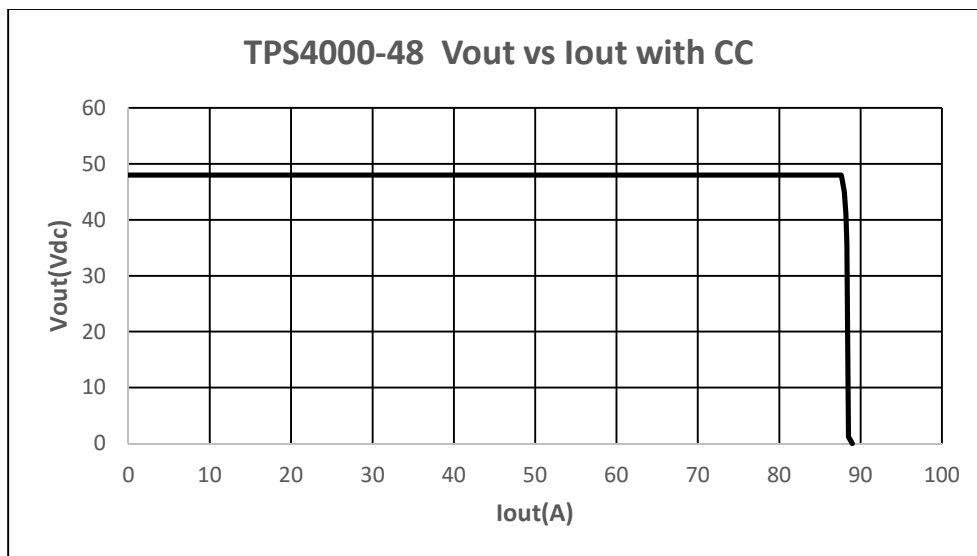
Vout =48Vdc, Ta=25°C

### Local Mode

In local mode, the current setpoint is adjustable via either the Ilimit Adjust trim pot(I<sub>LIMIT ADJ</sub>) or by applying a DC voltage to Signals Connector between pin #. 10(I<sub>ADJ</sub>) and pin # 18(-SNS or -Sense). See User manual for details.



**Figure 29:** OCP Dropout Curve. Ilimit setpoint= 58.45A. Local Mode



**Figure 30:** OCP Dropout Curve. Ilimit setpoint= 87.67A. Local Mode.

**Note 2:** Final OCP set point depends on the adjustment of trim Pot (I<sub>LIMIT ADJ</sub>) and the voltage level applied to terminal (I<sub>ADJ</sub>).

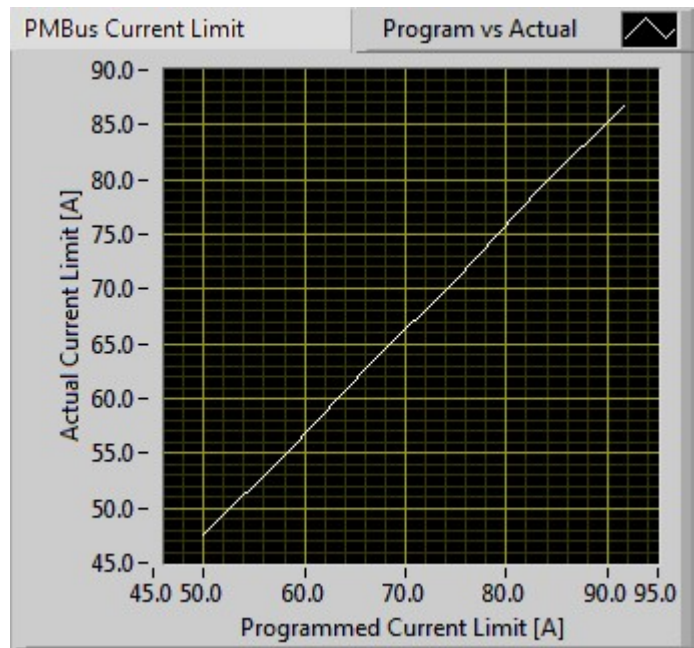


### Remote Mode

In remote mode, the current limit setpoint is programmable via the I2C Connector.

Programmed Current Limit at <u>Value</u> (Code) (Code)=(Nh,Nd):Nd(Dec)=(Value*24-304)*1 Nd(Dec)→Nh(Hex)	Actual Current Limit(A)
Current Limit when Ilim at 50.0A (0716h, 1814d)	47.481
Current Limit when Ilim at 58.3A (08A6h, 2214d)	54.978
Current Limit when Ilim at 66.6A (0A36h, 2614d)	63.308
Current Limit when Ilim at 75.0A (0BC6h, 3014d)	70.805
Current Limit when Ilim at 83.3A (0D55h, 3413d)	79.135
Current Limit when Ilim at 91.6A (0EE5h, 3813d)	86.632

**Note 3:** PMBus setting are not stored after Input AC source power cycling



## Conducted Emissions

EN 55032:2015 Class A/ FCC Part 15 Class A

(Note: Limits of EN 55032 and FCC Part 15 are identical)

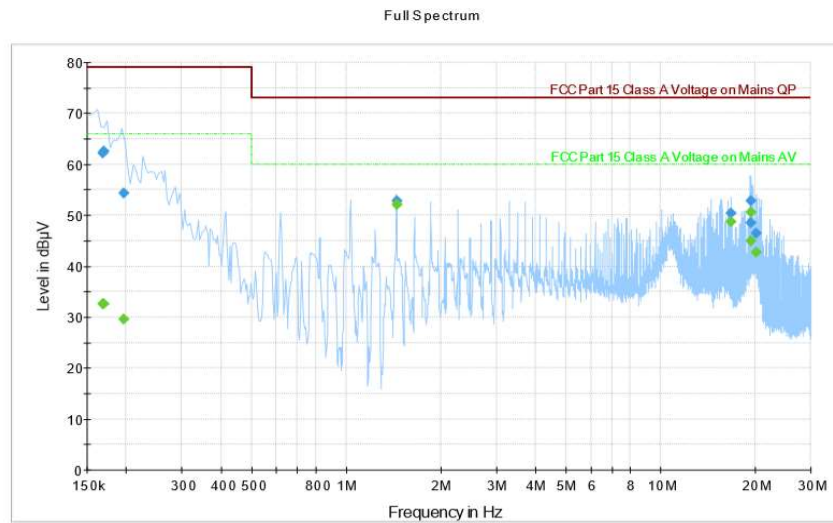
Vout =48Vdc, Ta=25°C, 100% Load = 83.5A

Section 8  
Test name  
Specification

Testing data  
Conducted disturbance at mains port  
Radio disturbance

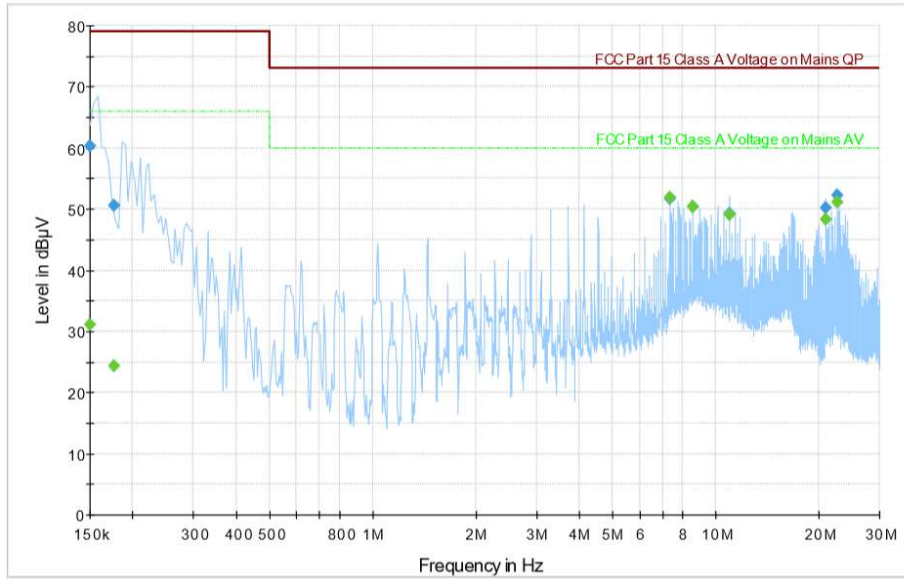


8.2.5 Test data, continued



**Figure 31:** Line 1 Conducted Emissions. Vin = 400VAC

Full Spectrum



L2

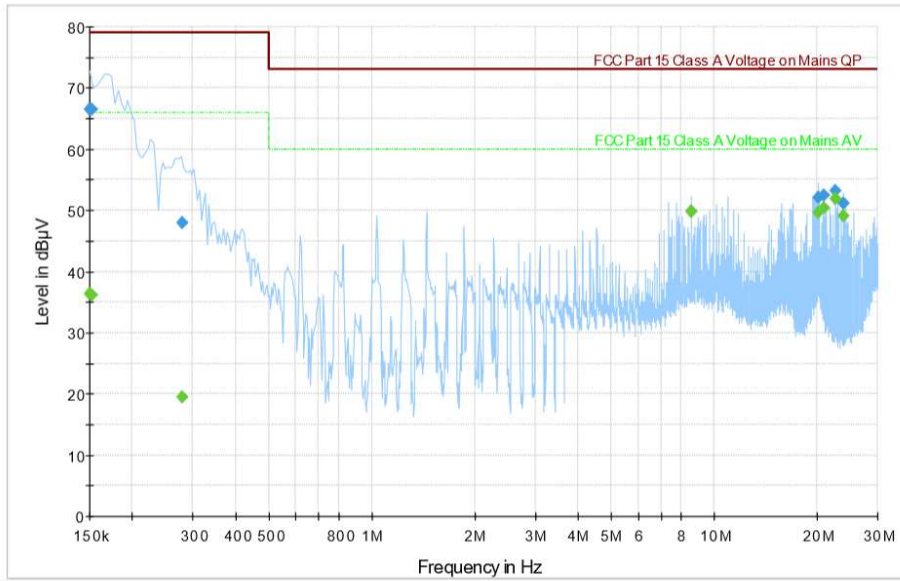
Figure 32: Line 2 Conducted Emissions.  $V_{in} = 400VAC$

Test name  
Specification

Conducted disturbance at mains port  
Radio disturbance



Full Spectrum



L3

**Figure 33:** Line 3 Conducted Emissions.  $V_{in} = 400VAC$

## Radiated Emissions

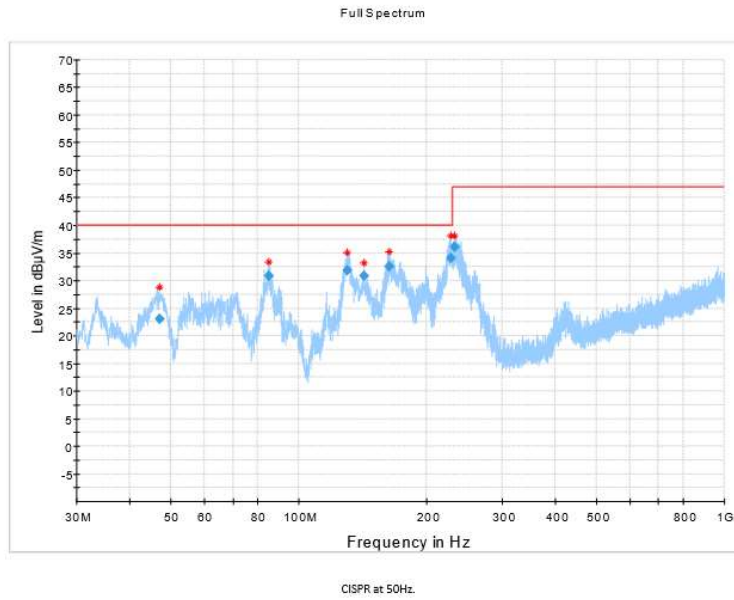
EN55032 Class A /FCC Part 15 Class A

Vout =48Vdc, Ta=25°C, %100 Load = 83.5A

Section 8      Testing data  
Test name      Radiated disturbance  
Specification      Radio disturbance

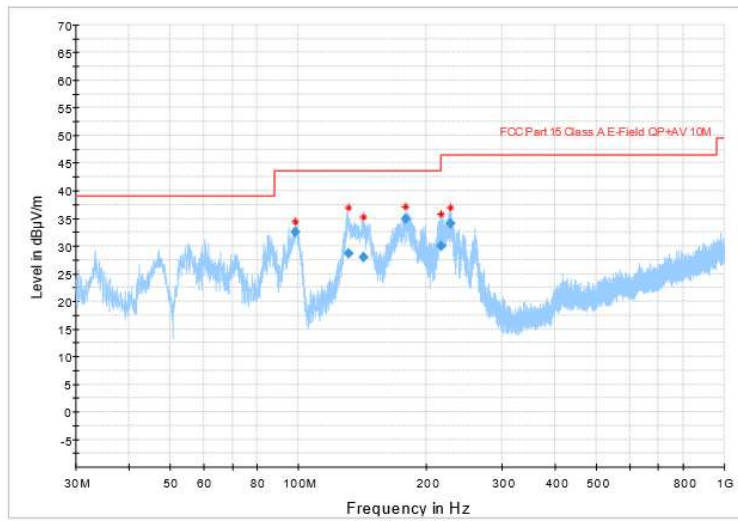


8.1.5 Test data



**Figure 34:** EN55032 Class A Radiated Emissions

Full Spectrum



FCC at 60Hz

The spectral plot is a summation of a vertical and horizontal scan. The spectral scan has been corrected with the associated transducer factors (i.e. antenna factors, cable loss, amplifier gains, and attenuators).

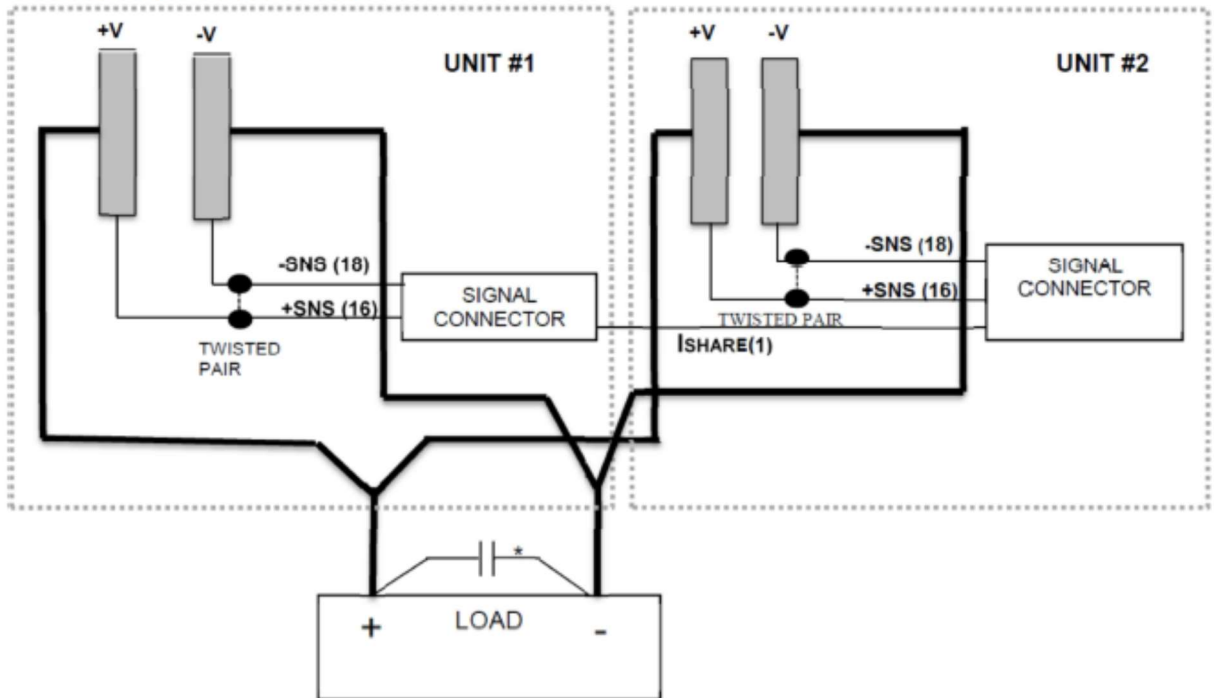
Figure 8.1-1: Radiated disturbance spectral plot (30 to 1000 MHz)

**Figure 35: FCC Part 15 Class A Radiated Emissions**

## Current Share

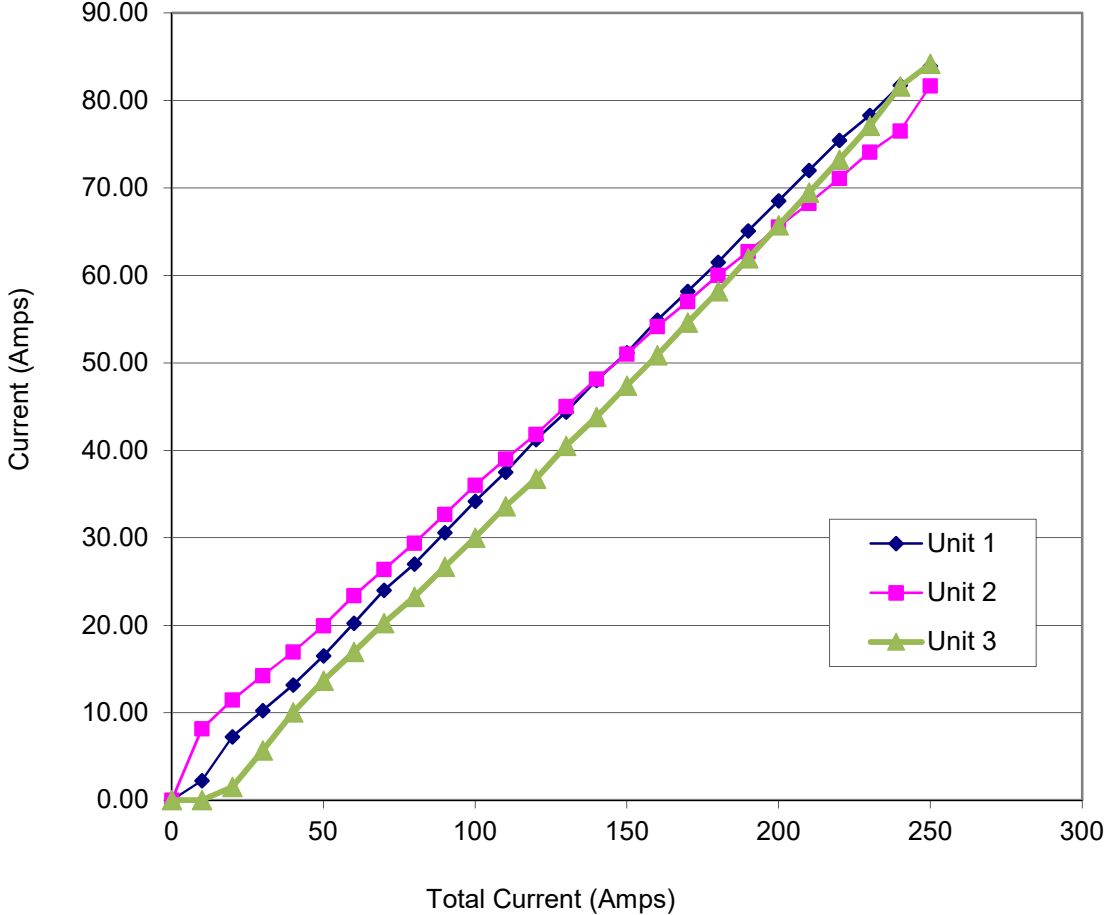
$V_{in} = 480VAC$ ,  $V_{out} = 48Vdc$ ,  $T_a = 25^{\circ}C$

### Parallel Operation Setup



**Figure 36:** Typical Local Sense Parallel Operation Setup

### Current Share - Local Sensing

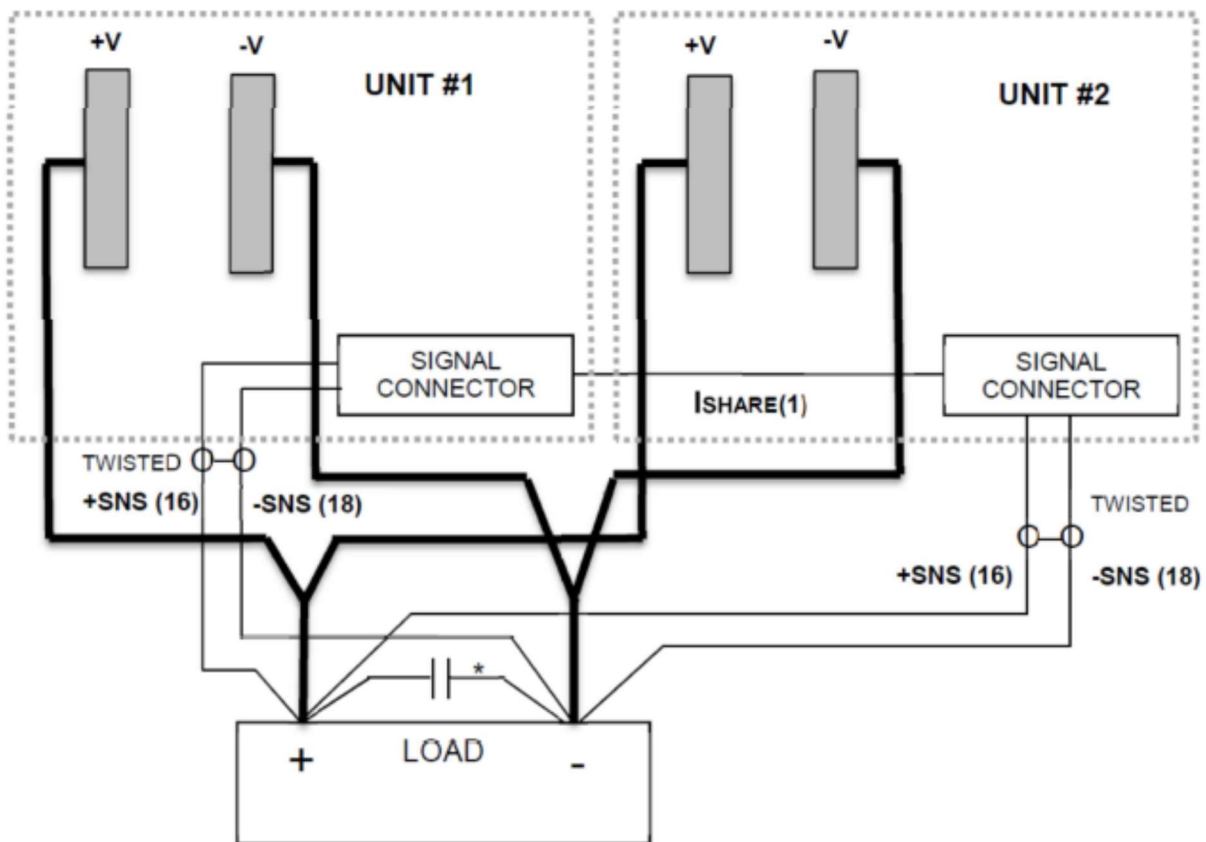




Vin=480Vac      Tamb=25°C

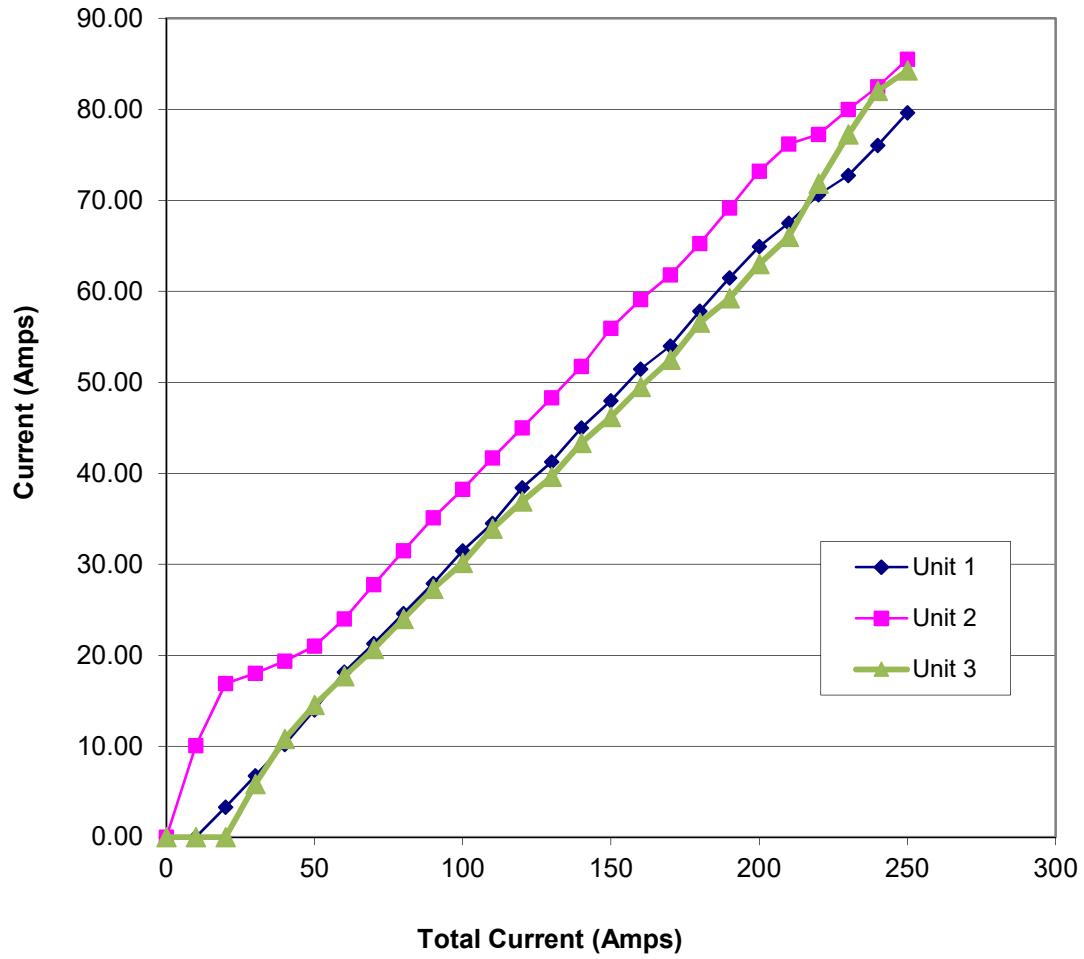
I <sub>total</sub>	I <sub>1</sub> (A)	I <sub>2</sub> (A)	I <sub>3</sub> (A)	Delta I [% of I total]
0	0.00	0.00	0.00	N/A
10	2.25	8.18	0.00	81.75%
20	7.27	11.46	1.50	49.80%
30	10.25	14.25	5.70	28.50%
40	13.20	16.95	10.05	17.25%
50	16.50	19.95	13.65	12.60%
60	20.25	23.40	16.95	10.75%
70	24.00	26.40	20.25	8.79%
80	27.00	29.40	23.25	7.69%
90	30.60	32.70	26.70	6.67%
100	34.20	36.00	30.00	6.00%
110	37.50	39.00	33.60	4.91%
120	41.25	41.82	36.75	4.23%
130	44.40	45.00	40.50	3.46%
140	48.00	48.15	43.80	3.11%
150	51.15	51.00	47.40	2.50%
160	54.90	54.15	50.85	2.53%
170	58.20	57.00	54.60	2.12%
180	61.50	60.00	58.20	1.83%
190	65.10	62.70	61.95	1.66%
200	68.55	65.55	65.70	1.50%
210	72.00	68.25	69.45	1.79%
220	75.45	71.10	73.23	1.98%
230	78.30	74.10	77.10	1.83%
240	81.75	76.50	81.60	2.19%
250	83.93	81.66	84.18	1.01%

**Table 1:** Current Share - Local Sense (Sense signals connected to bus bars)



**Figure 37:** Typical Remote Sense Parallel Operation Setup

### Current Share - Remote Sensing



Vin=480Vac Tamb=25°C

Itotal	I1(A)	I2(A)	I3(A)	Delta I [% of I total]
0	0.00	0.00	0.00	N/A
10	0.00	10.05	0.00	100.50%
20	3.30	16.88	0.00	84.38%
30	6.75	18.00	5.85	40.50%
40	10.20	19.35	10.80	22.88%
50	14.00	21.00	14.55	14.00%
60	18.15	24.00	17.70	10.50%
70	21.30	27.75	20.70	10.07%
80	24.60	31.50	24.00	9.38%
90	27.90	35.10	27.30	8.67%
100	31.50	38.25	30.15	8.10%
110	34.50	41.70	33.90	7.09%
120	38.40	45.00	36.90	6.75%
130	41.25	48.30	39.60	6.69%
140	45.00	51.75	43.35	6.00%
150	48.00	55.95	46.20	6.50%
160	51.45	59.10	49.50	6.00%
170	54.00	61.80	52.50	5.47%
180	57.83	65.25	56.55	4.83%
190	61.50	69.15	59.25	5.21%
200	64.95	73.20	63.00	5.10%
210	67.50	76.20	66.00	4.86%
220	70.65	77.25	71.85	3.00%
230	72.75	80.01	77.25	3.16%
240	76.05	82.50	82.05	2.69%
250	79.65	85.50	84.30	2.34%

**Table 2:** Current Share- Remote Sense (Sense signals connected at load)