TPS4000-24

Evaluation Data

3-25-2020

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TERMINOLOGY USED

- Vout = Output Voltage
- Iout = Output Current
- Vin = Input Voltage
- Iin = Input Current
- Ilim = Current Limit
- Ta = Ambient Temperature
- OVP = Over-voltage protection
- OCP – Over-current protection

Load/Line Regulation

Vout = 24Vdc, 100% load = 167A, Ta = 25°C
Vout adjusted with trim Pot ($V_{out\ ADJ}$) and measured across output bus bars. Remote sense connected to bus bars.

Iout\Vin	350VAC	400VAC	480VAC	528VAC	Line Regulation	
0% Load	24.102	24.101	24.102	24.101	0.001	0.004%
12.5% Load	24.103	24.105	24.109	24.108	0.005	0.021%
25.0% Load	24.106	24.107	24.109	24.105	0.004	0.016%
37.5% Load	24.106	24.104	24.104	24.108	0.004	0.016%
50.0% Load	24.102	24.106	24.107	24.105	0.005	0.021%
62.5% Load	24.105	24.106	24.102	24.102	0.004	0.016%
75.0% Load	24.100	24.101	24.101	24.104	0.004	0.016%
87.5% Load	24.098	24.102	24.102	24.099	0.004	0.016%
100% Load	24.100	24.097	24.097	24.096	0.004	0.016%
Load Regulation	0.008	0.010	0.012	0.012		
	0.033%	0.041%	0.049%	0.049%		

Note 1: If Vout programming with PMBus, setting are not stored after Input AC source power cycling.

Temperature Drift

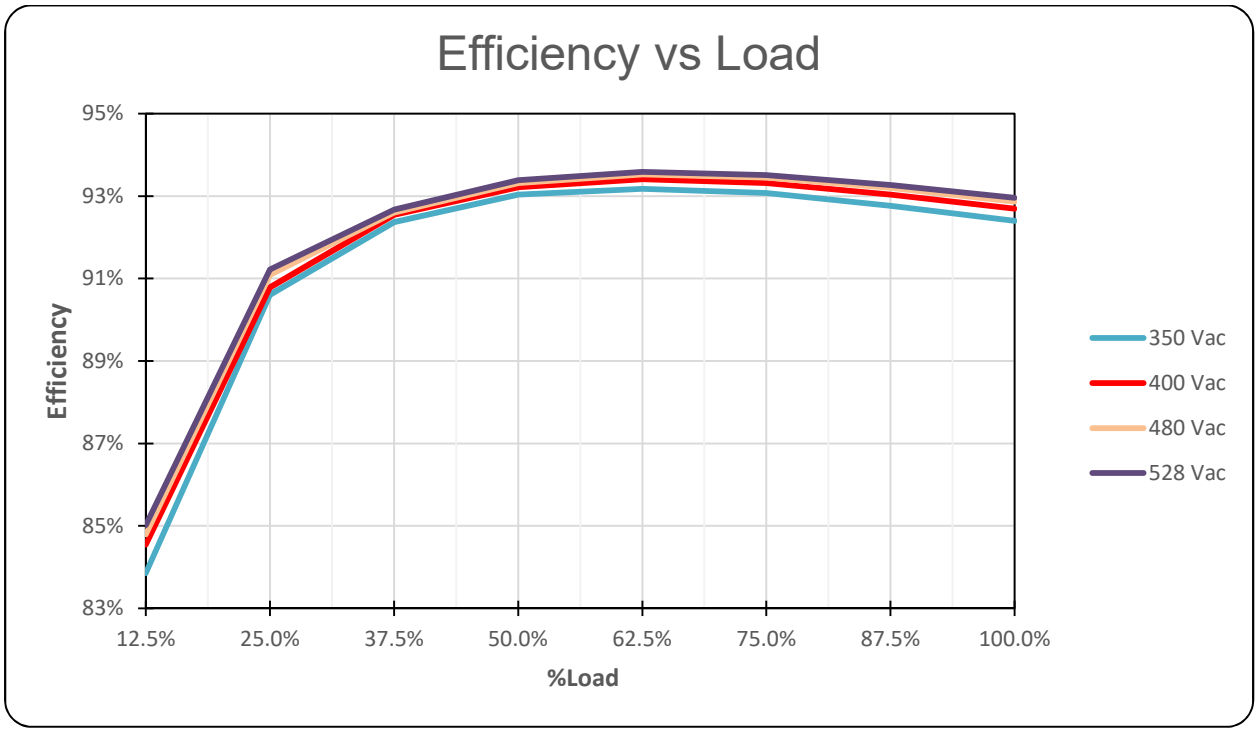
Vout =24Vdc, 100% load = 167A

Vin (VAC)	Iout (%)	Vout @ -40°C	Vout @ 25°C	Vout @ 50°C	Vout Delta	Overall Temperature Coefficient (ppm)
400	100%	24.087	24.097	24.014	0.083	137.78
480	100%	24.090	24.097	24.014	0.083	137.78
400	0%	24.081	24.101	24.011	0.090	149.37
480	0%	24.087	24.102	24.011	0.091	151.02

Efficiency vs Output Current

Vout = 24Vdc, 100% Load = 167A, Ta = 25°C

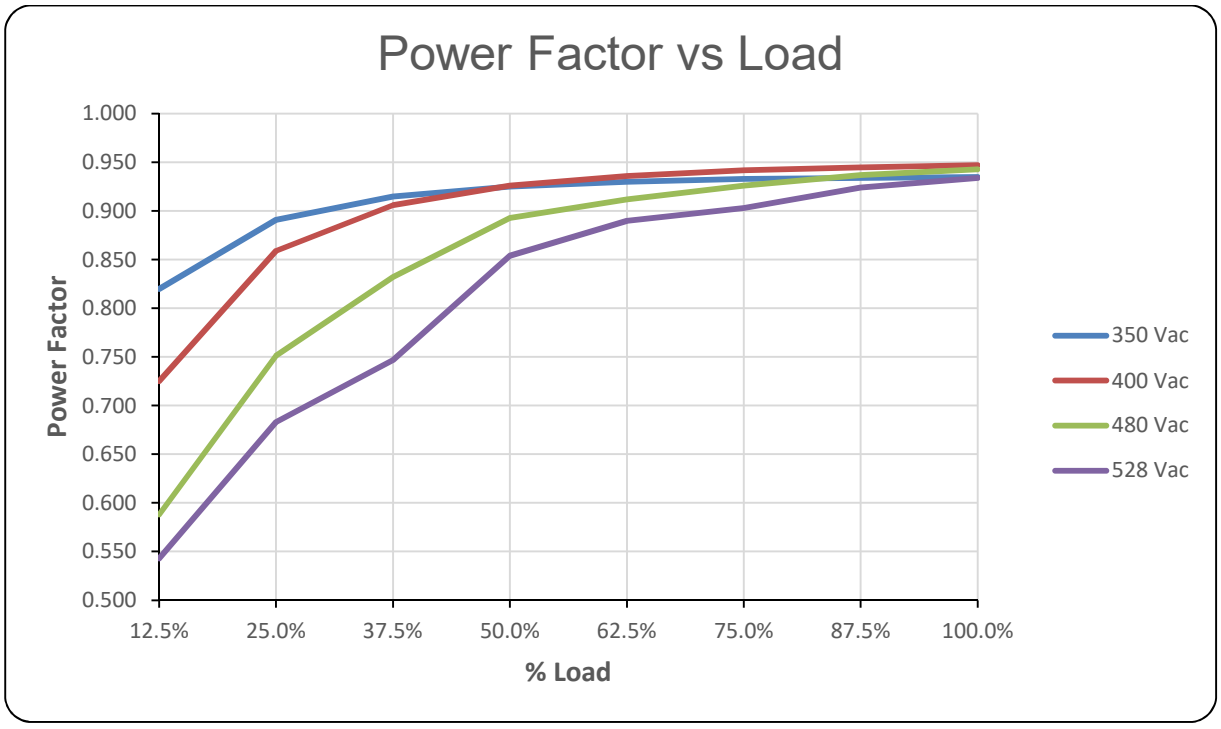
Iout(%) / Vin	350 VAC	400 VAC	480 VAC	528 VAC
12.5% Load	83.85%	84.54%	84.79%	85.02%
25.0% Load	90.61%	90.79%	91.09%	91.22%
37.5% Load	92.37%	92.55%	92.60%	92.67%
50.0% Load	93.04%	93.22%	93.32%	93.39%
62.5% Load	93.18%	93.41%	93.53%	93.59%
75.0% Load	93.08%	93.32%	93.45%	93.51%
87.5% Load	92.77%	93.04%	93.20%	93.27%
100.0% Load	92.40%	92.70%	92.87%	92.96%



Power Factor vs Output Current

Vout = 24Vdc, 100% Load = 167A, Ta = 25°C

Iout(%) / Vin	350 VAC	400 VAC	480 VAC	528 VAC
12.5% Load	0.820	0.725	0.588	0.543
25.0% Load	0.891	0.859	0.751	0.683
37.5% Load	0.915	0.906	0.832	0.747
50.0% Load	0.925	0.926	0.893	0.854
62.5% Load	0.930	0.936	0.912	0.890
75.0% Load	0.933	0.942	0.926	0.903
87.5% Load	0.934	0.945	0.937	0.924
100.0% Load	0.935	0.947	0.943	0.934



Inrush Characteristics

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

Vout =24Vdc, Ta=25°C, %100 Load = 167A

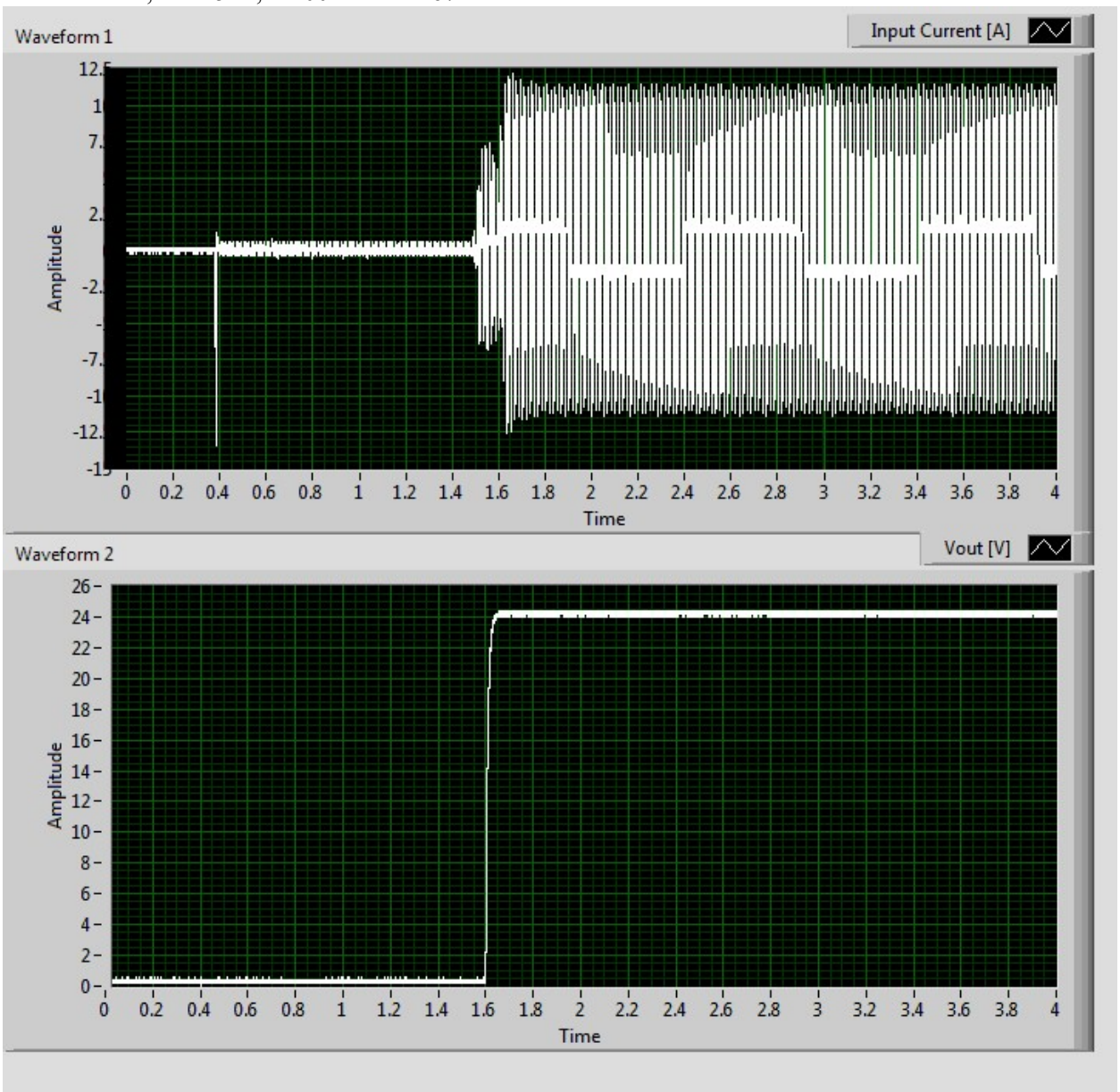


Figure 1: Inrush @ 400VAC, 100% Load

WAVEFORM 1 – Inrush Current, 2A/DIV

WAVEFORM 2 – Vout, 2V/DIV

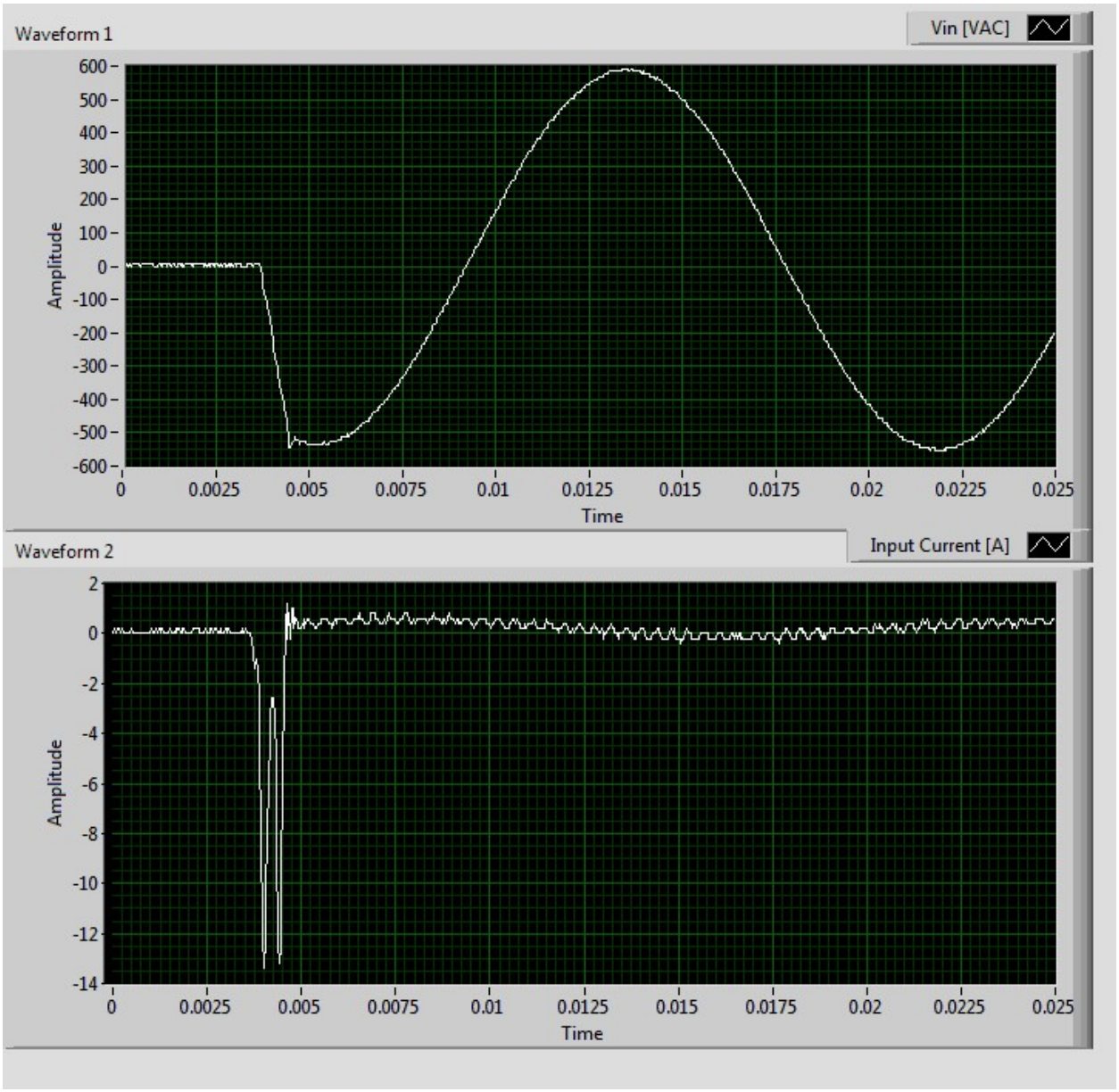


Figure 2: Inrush @ 400VAC, 100% Load. Initial spike charging capacitors

WAVEFORM 1 – Vin, 100V/DIV WAVEFORM 2 – Inrush Current, 2A/DIV

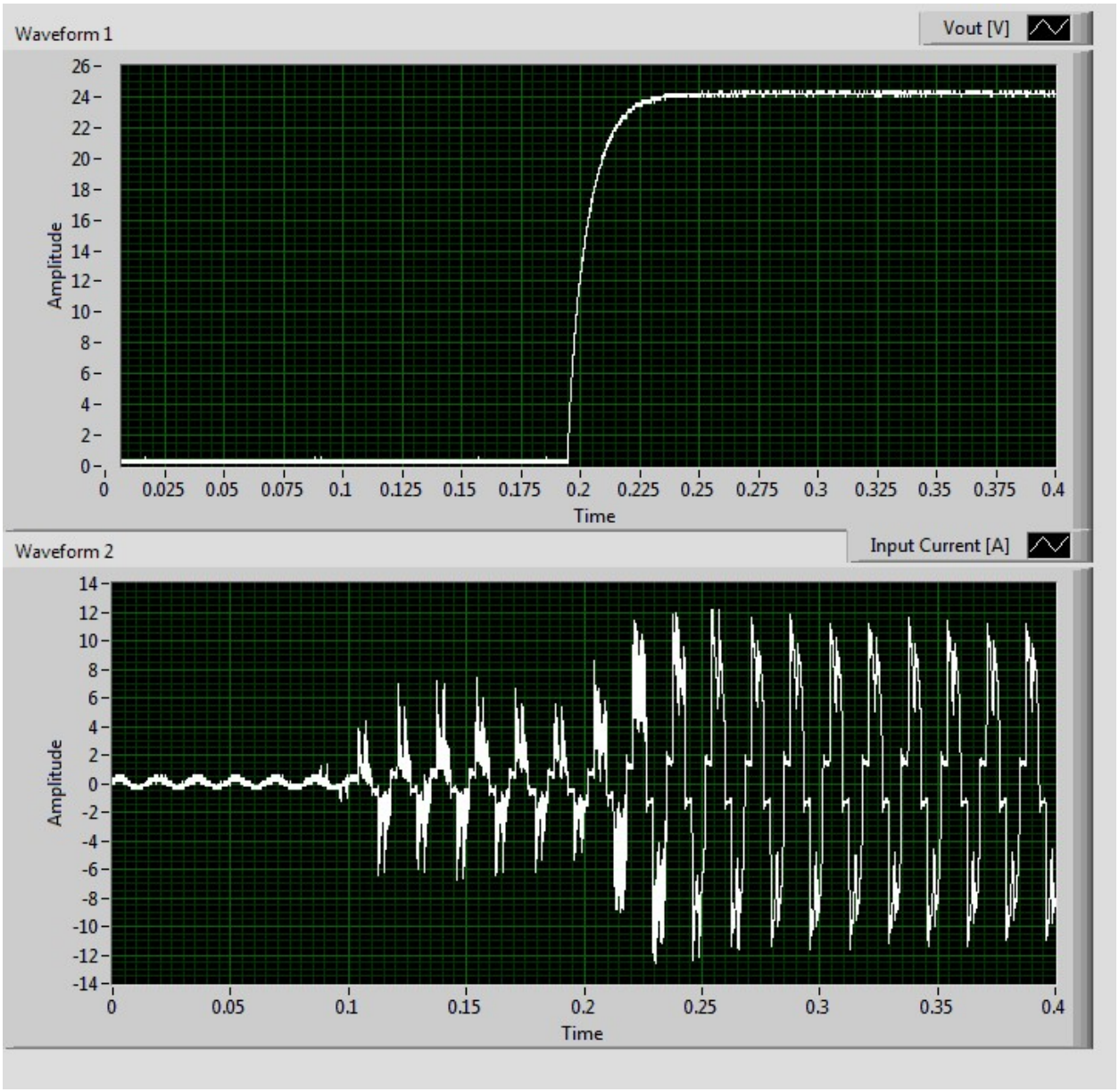


Figure 3: Inrush @ 400VAC, 100% Load.

WAVEFORM 1 – Vout, 2V/DIV

WAVEFORM 2 – Inrush Current, 2A/DIV

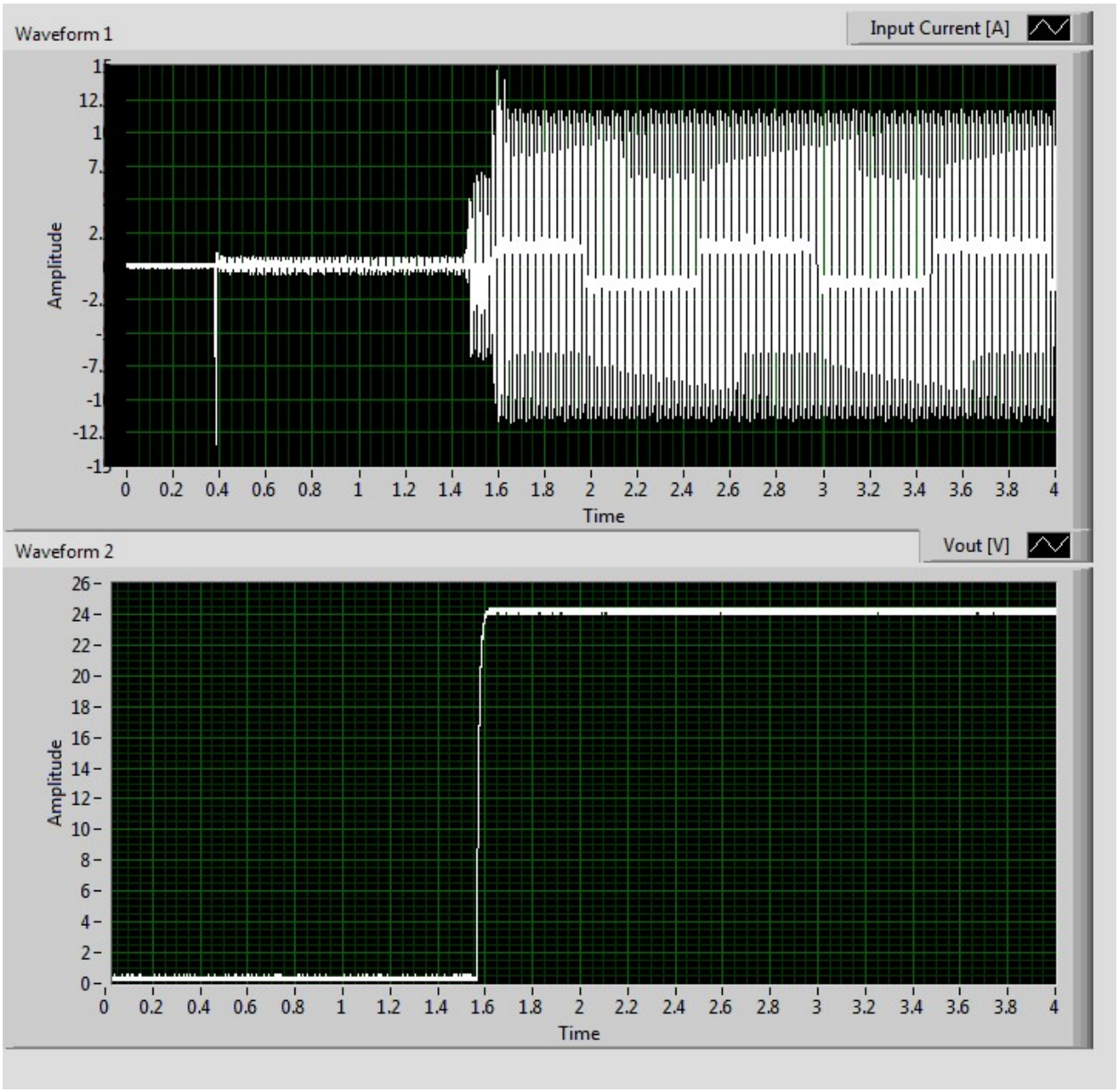


Figure 4: Inrush @ 480VAC, 100% Load

WAVEFORM 1 – Inrush Current, 2.5A/DIV

WAVEFORM 2 – Vout, 2V/DIV

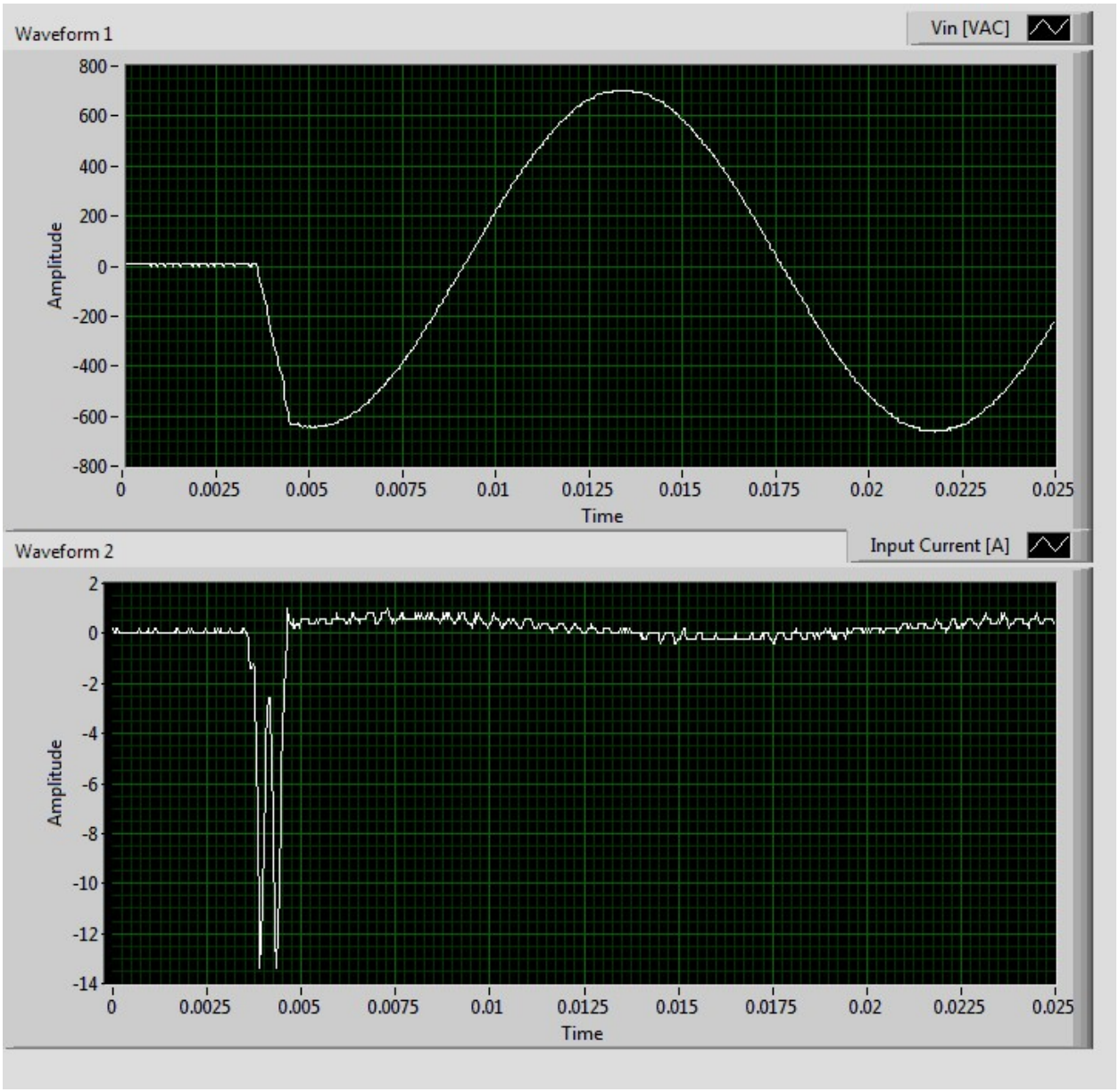


Figure 5: Inrush @ 480VAC, 100% Load. Initial spike charging capacitors

WAVEFORM 1 – Vin, 200V/DIV WAVEFORM 2 – Inrush Current, 2A/DIV

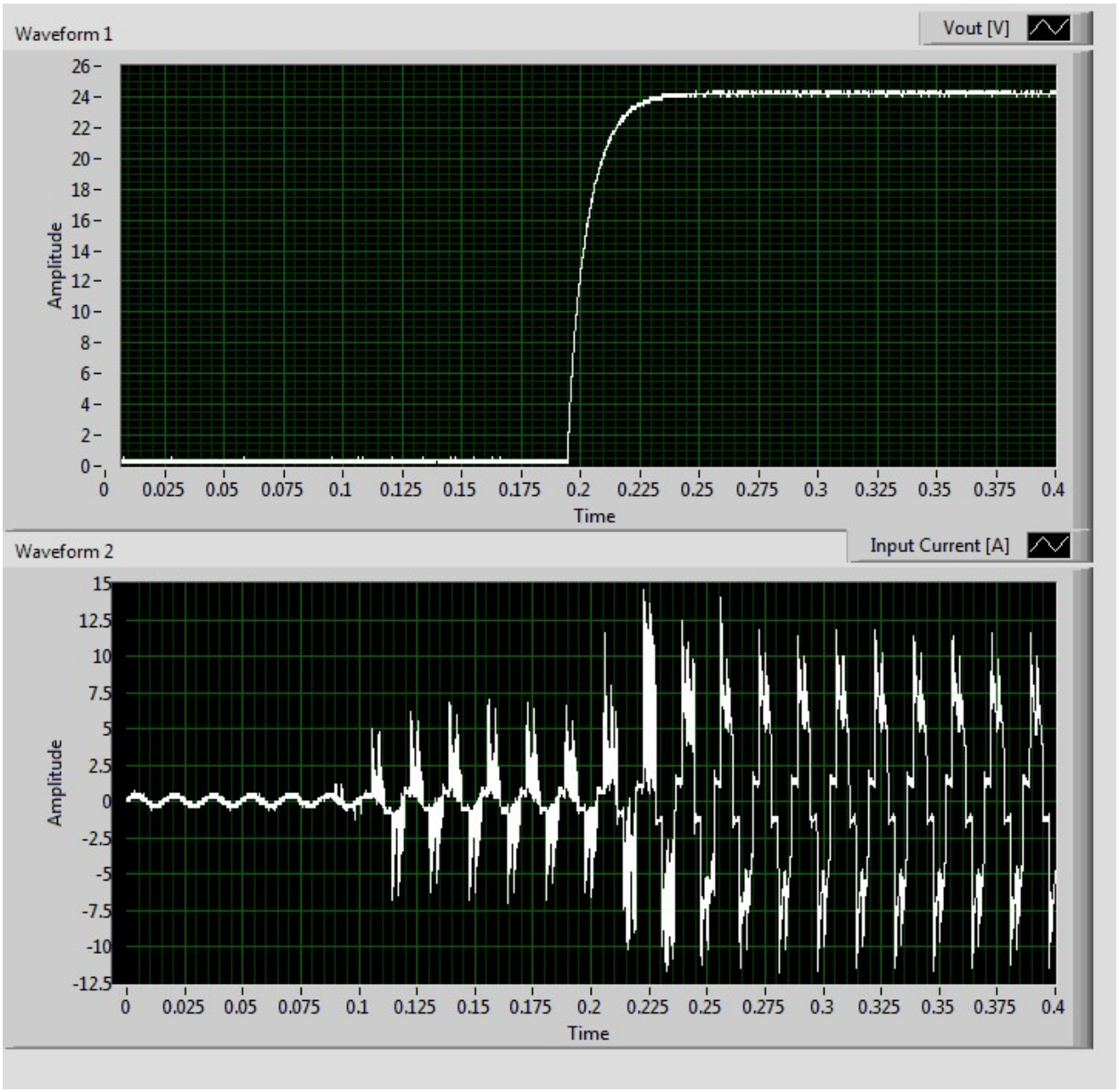


Figure 6: Inrush @ 480VAC, 100% Load.

WAVEFORM 1 – Vout, 2V/DIV WAVEFORM 2 – Inrush Current, 2.5A/DIV

Output Rise Characteristics

Vout = 24Vdc, Ta = 25°C, Iout = 167A

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

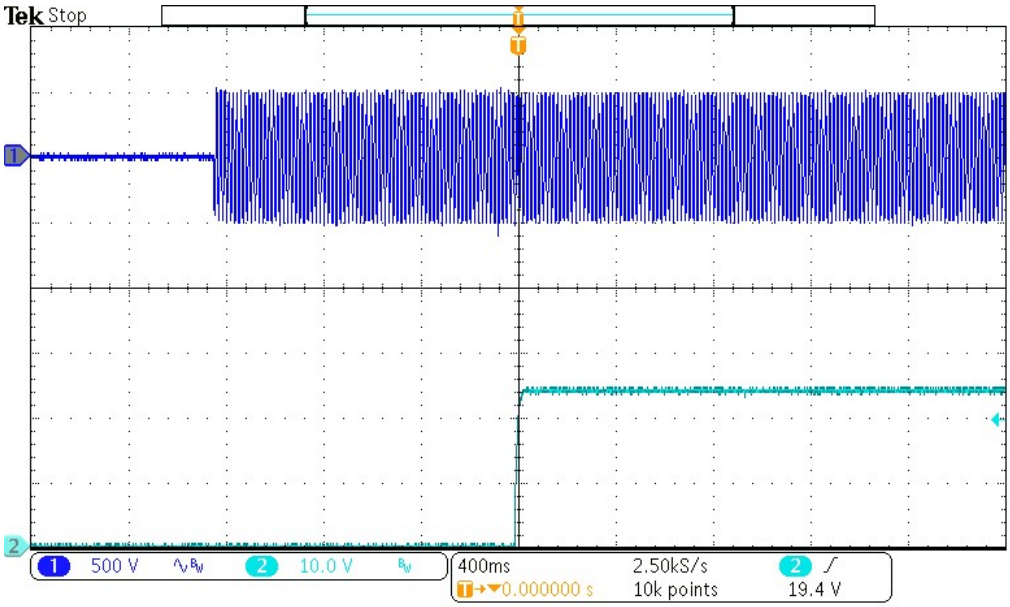


Figure 7: Turn ON Time from Vin = 350VAC.
(CH1: Vin, 500V/div; CH2: Vout, 10V/div)

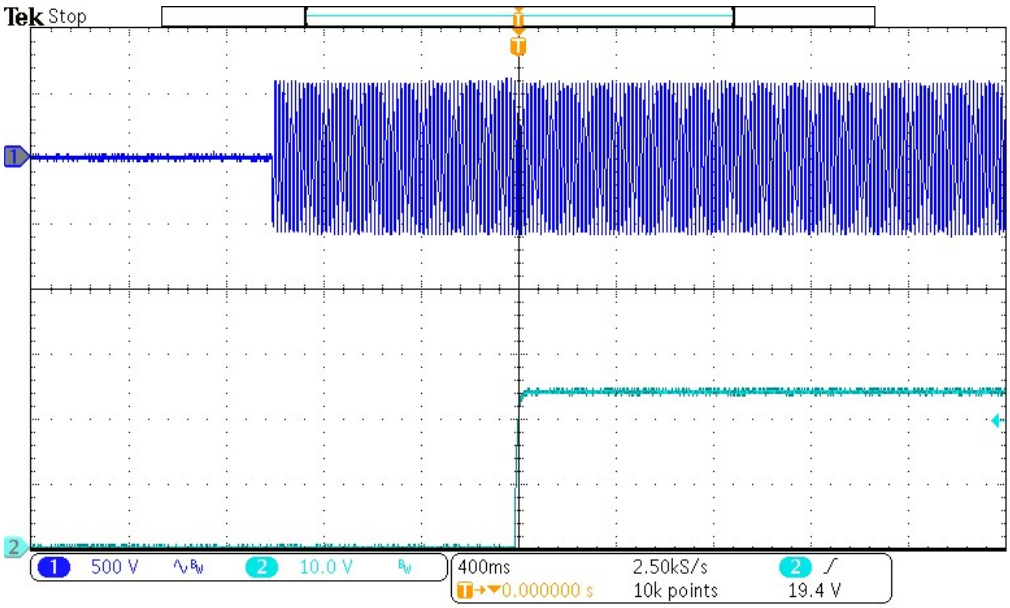


Figure 8: Turn ON Time from Vin = 400VAC.
(CH1: Vin, 500V/div; CH2: Vout, 10V/div)

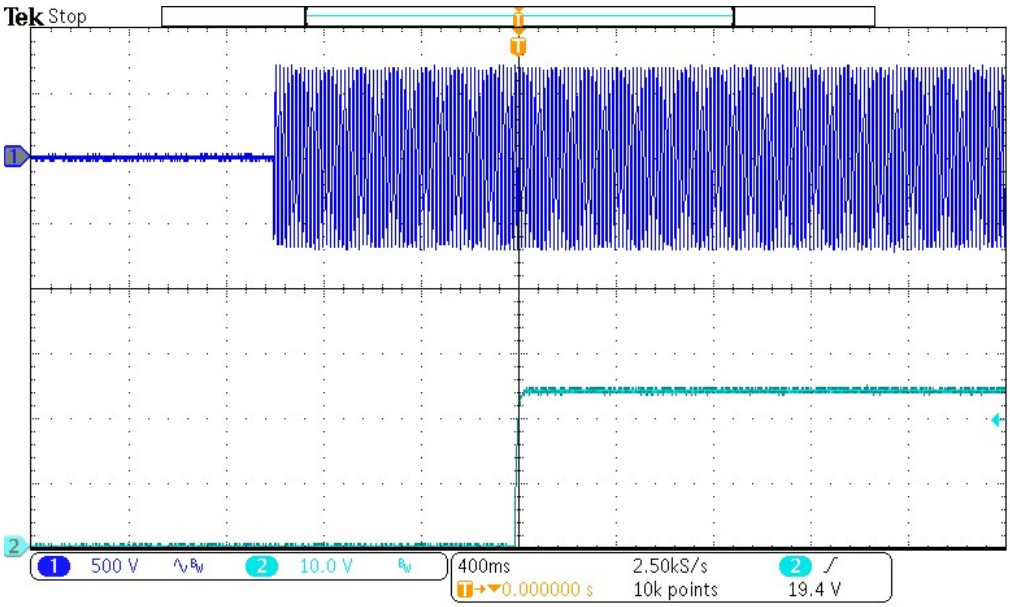


Figure 9: Turn ON Time from Vin = 480VAC.
(CH1: Vin, 500V/div; CH2: Vout, 10V/div)

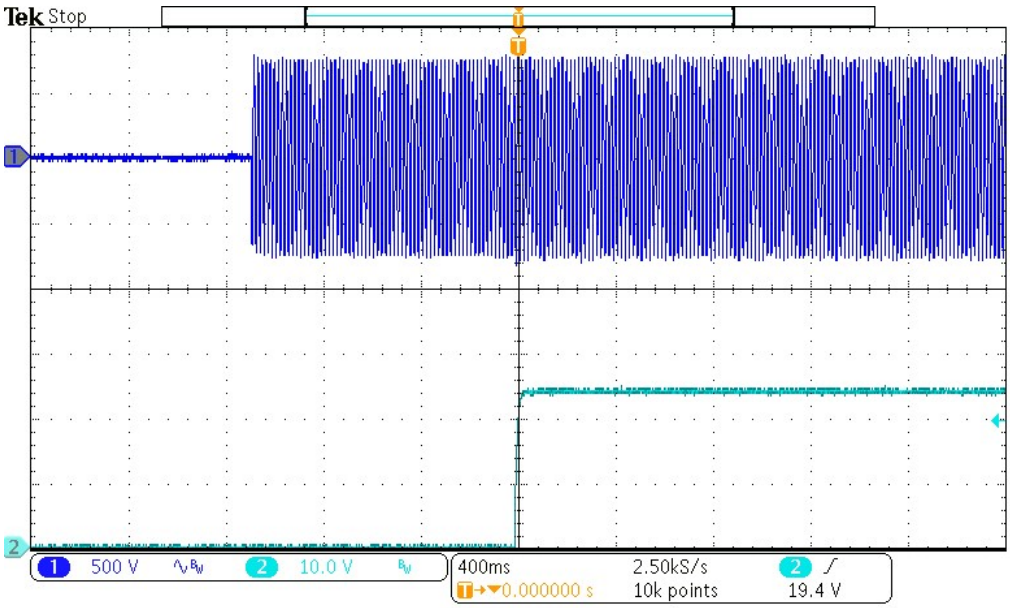


Figure 10: Turn ON Time from Vin = 528VAC.
(CH1: Vin, 500V/div; CH2: Vout, 10V/div)

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.

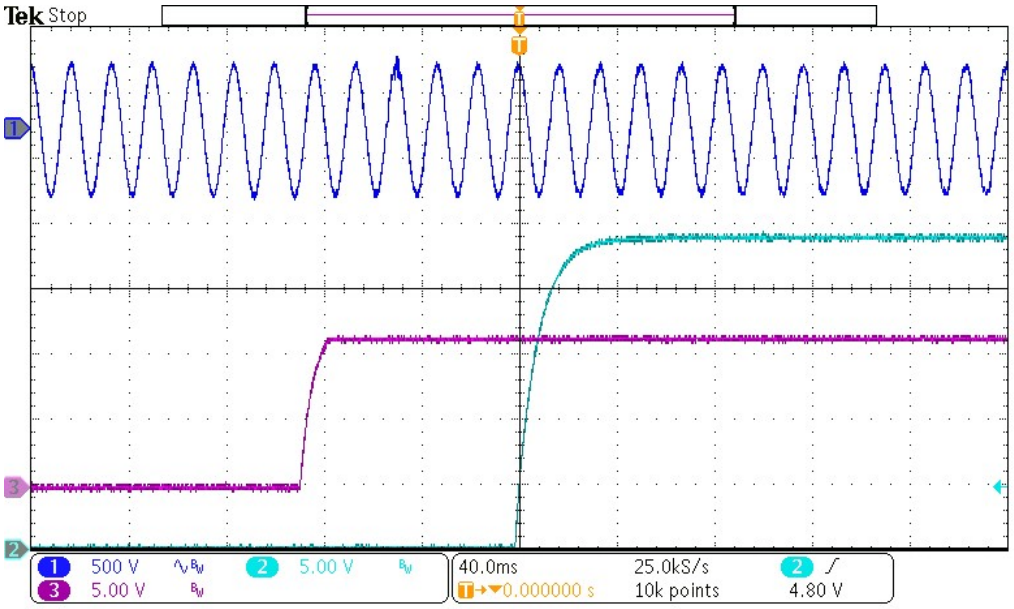


Figure 11: Rise Time from Remote On-Off 350VAC 100% load.
(CH1:Vin,500V/div;CH2:Vout,5V/div;CH3:PSON,5V/div)

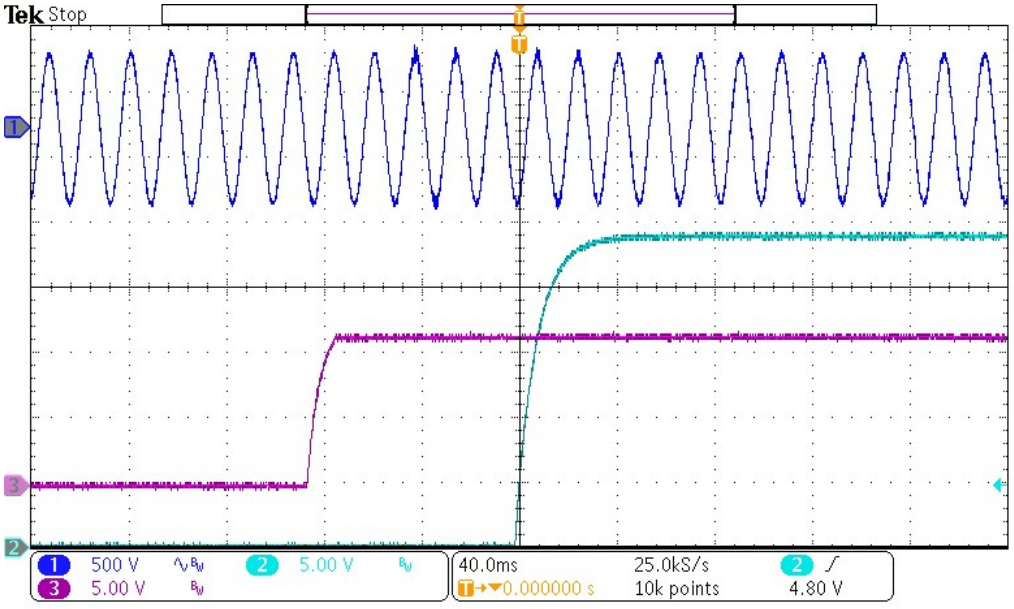


Figure 12: Rise Time from Remote On-Off 400VAC 100% load.
(CH1:Vin,500V/div;CH2:Vout,5V/div;CH3:PSON,5V/div)

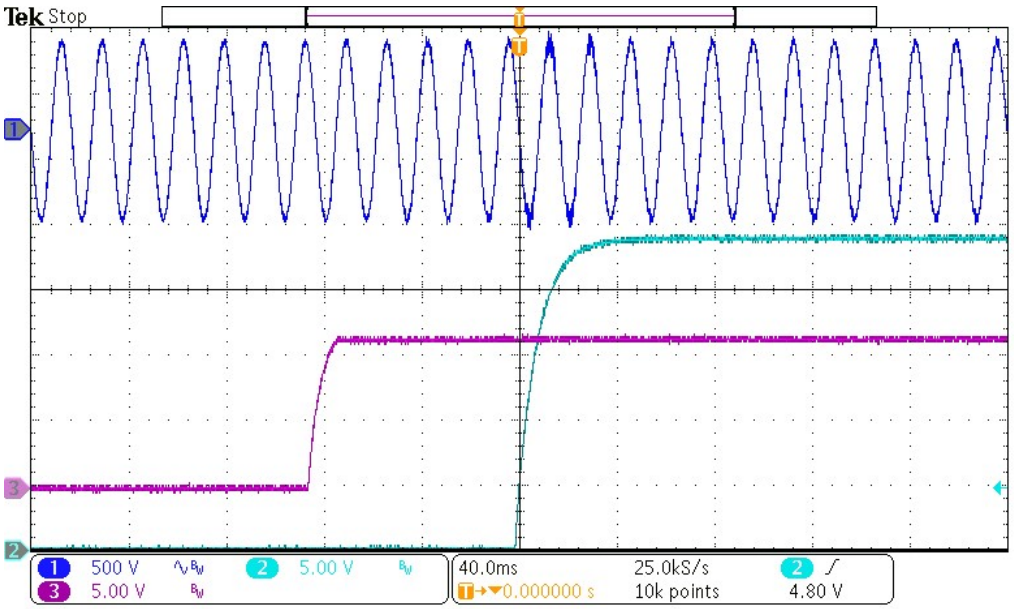


Figure 13: Rise Time from Remote On-Off 480VAC 100% load.
(CH1:Vin,500V/div;CH2:Vout,5V/div;CH3:PSON,5V/div)

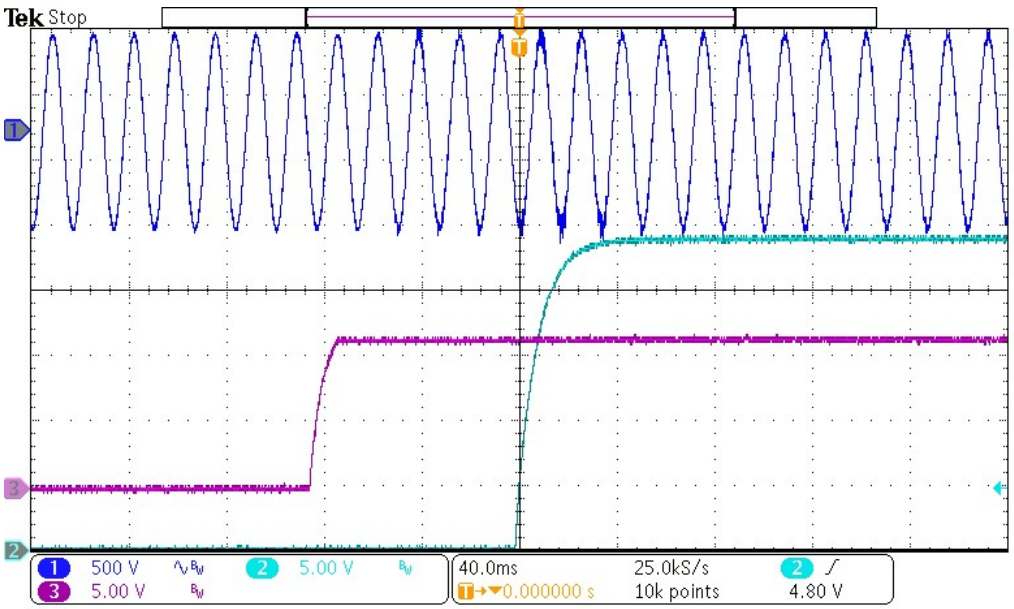


Figure 14: Rise Time from Remote On-Off 528VAC 100% load.
(CH1:Vin,500V/div;CH2:Vout,5V/div;CH3:PSON,5V/div)

Rise Time & Overshoot

Vout = 24Vdc, 100% Load = 167A, Ta = 25°C

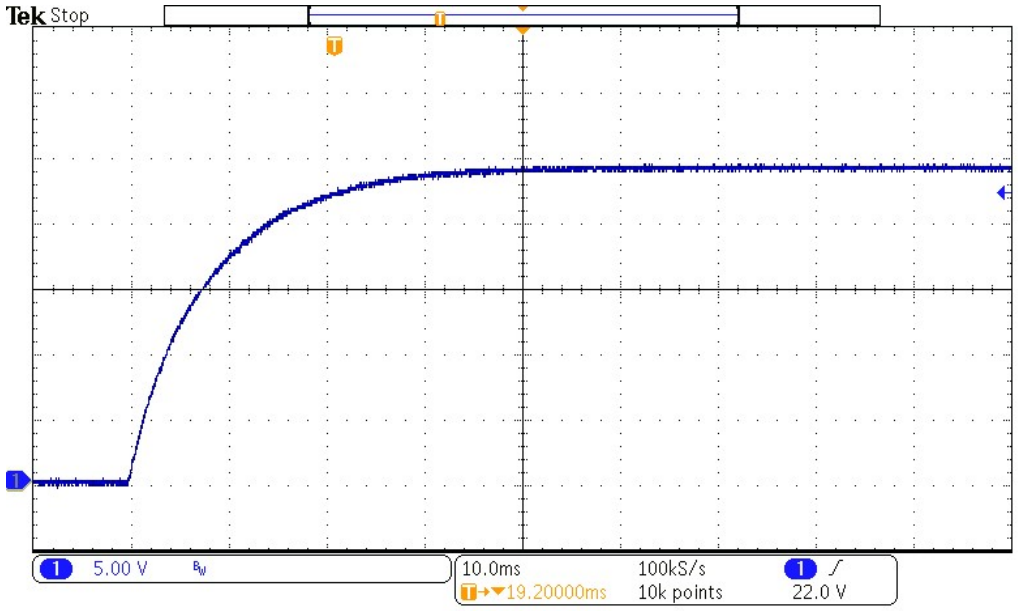


Figure 15: Rise Characteristics at Turn On 350VAC 0% load (CH1: Vout, 5V/div).

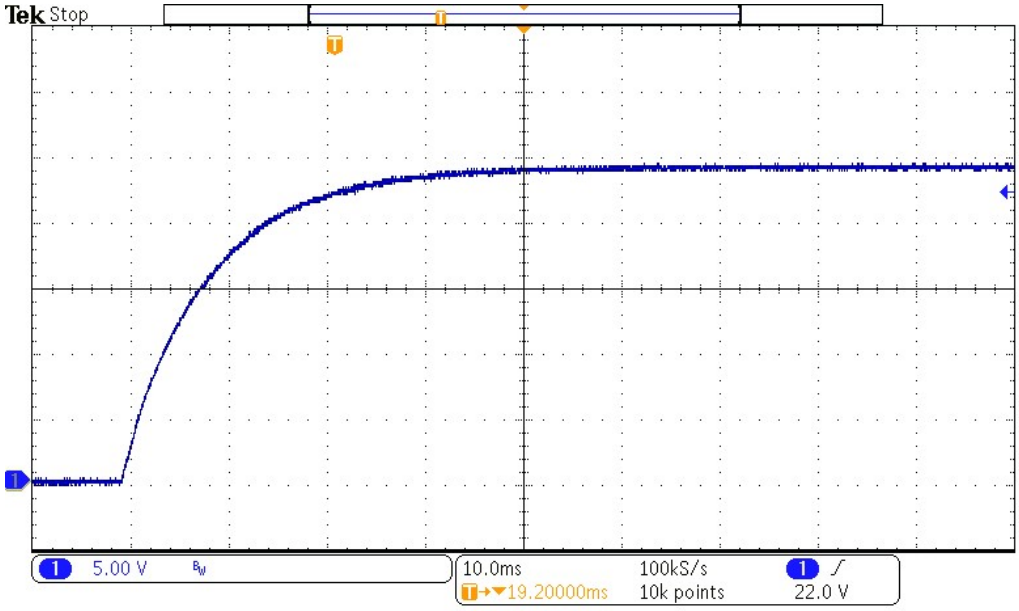


Figure 16: Rise Characteristics at Turn On 350VAC 100% load (CH1: Vout, 5v/div)

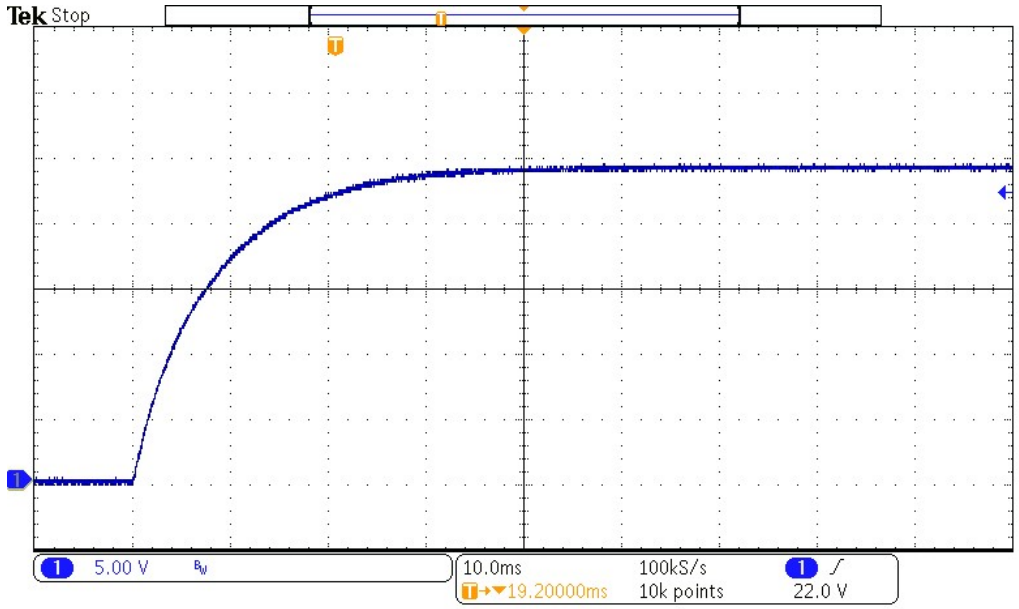


Figure 17: Rise Characteristics at Turn On 400VAC 0% load (CH1: Vout, 5v/div).

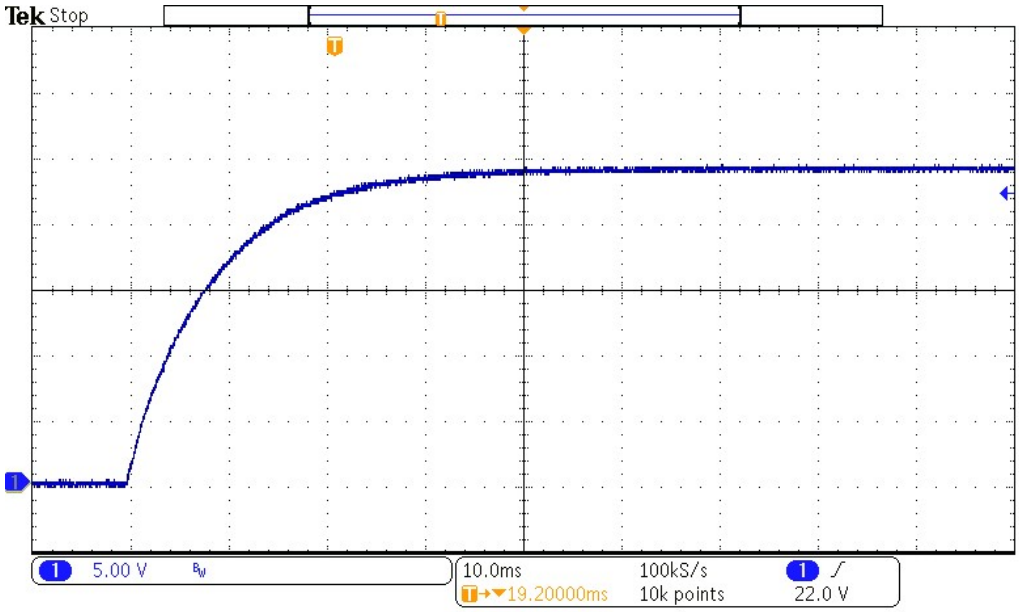


Figure 18: Rise Characteristics at Turn On 400VAC 100% load (CH1: Vout, 5v/div).

Hold-Up Time Characteristics

Vout =24Vdc, Ta=25°C, 100% Load = 167A

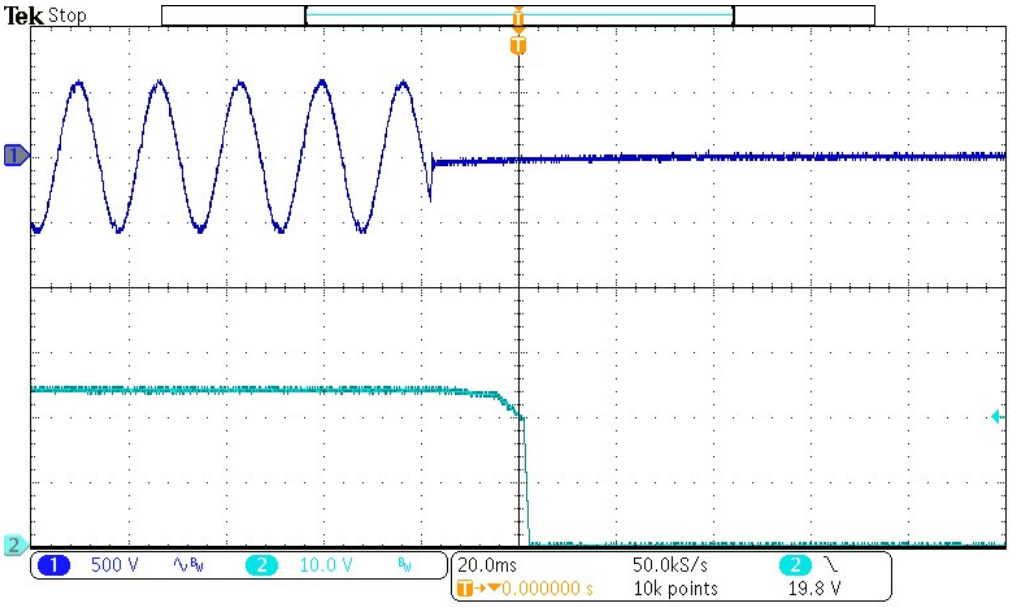


Figure 19: HOLD-UP TIME 400VAC 100% Load
(CH1: Vin, 500V/div, CH2:Vout, 10V/div) .

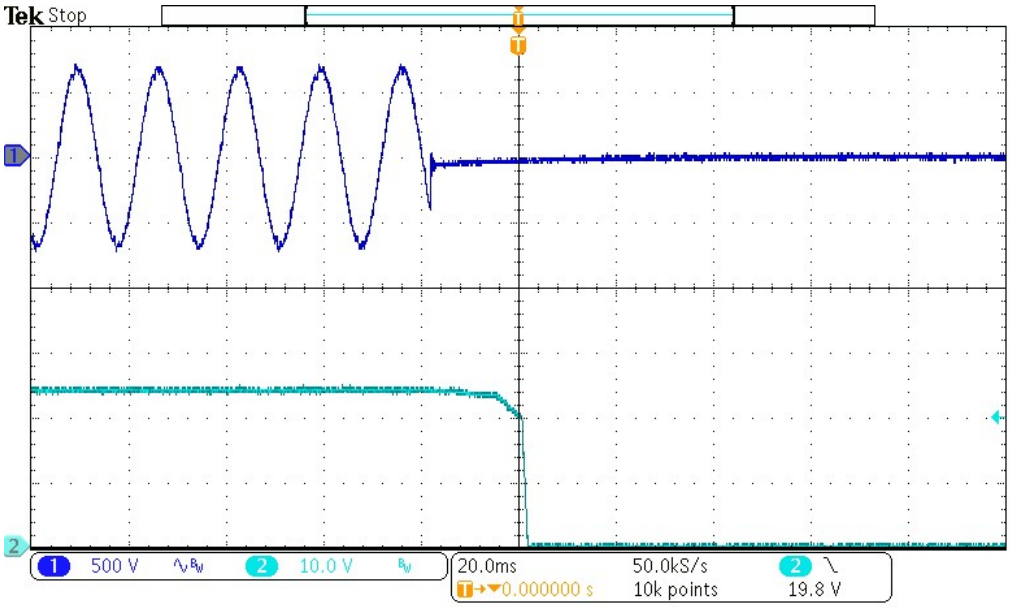


Figure 20: HOLD-UP TIME 480VAC 100% Load
(CH1: Vin, 500V/div, CH2: Vout, 10V/div).

Ripple Characteristics

Ripple and Noise: 240mV pk-pk max, 20MHz bandwidth. Jeita RC-9131C Procedure.
Vout =24Vdc, Ta=25°C, 100% Load = 167A

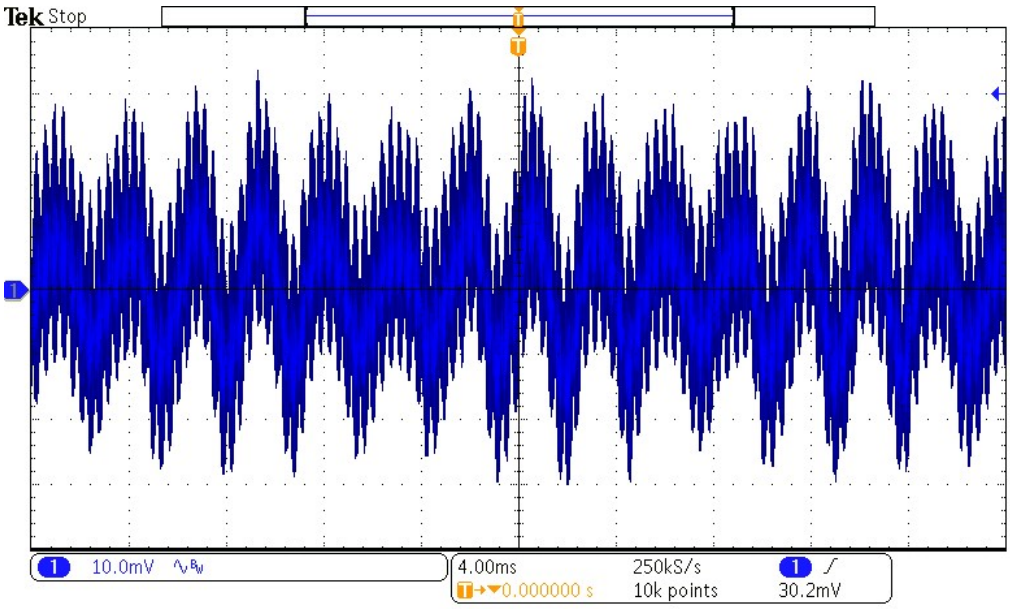


Figure 21: Ripple at 100% Load @ 350VAC.
(CH1: Vout, 10mV/div, Timebase = 4ms/div)

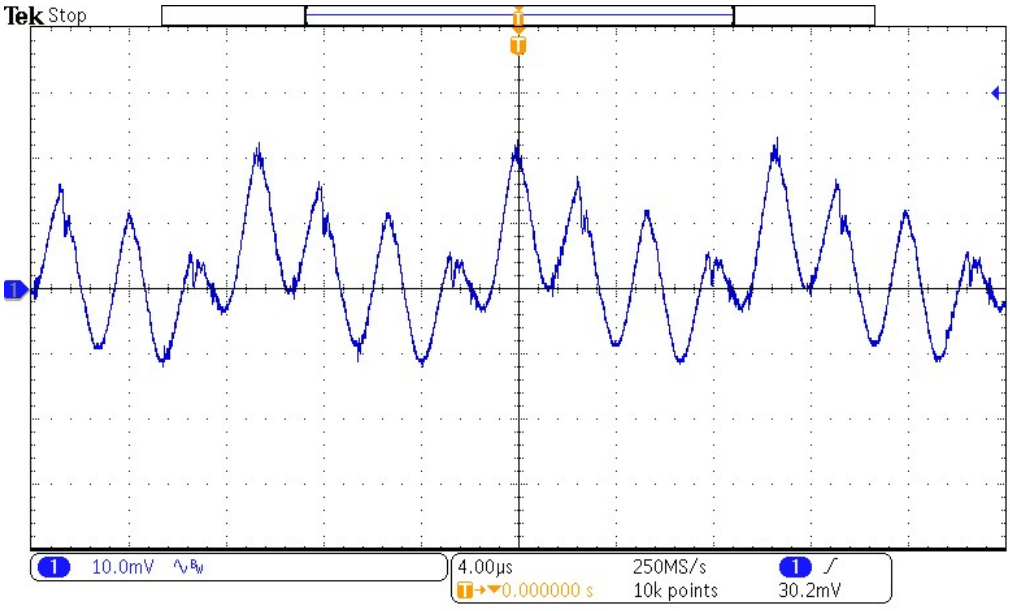


Figure 22: Ripple at 100% Load @ 350VAC.
(CH1: Vout, 10mV/div, Timebase = 4µs/div).

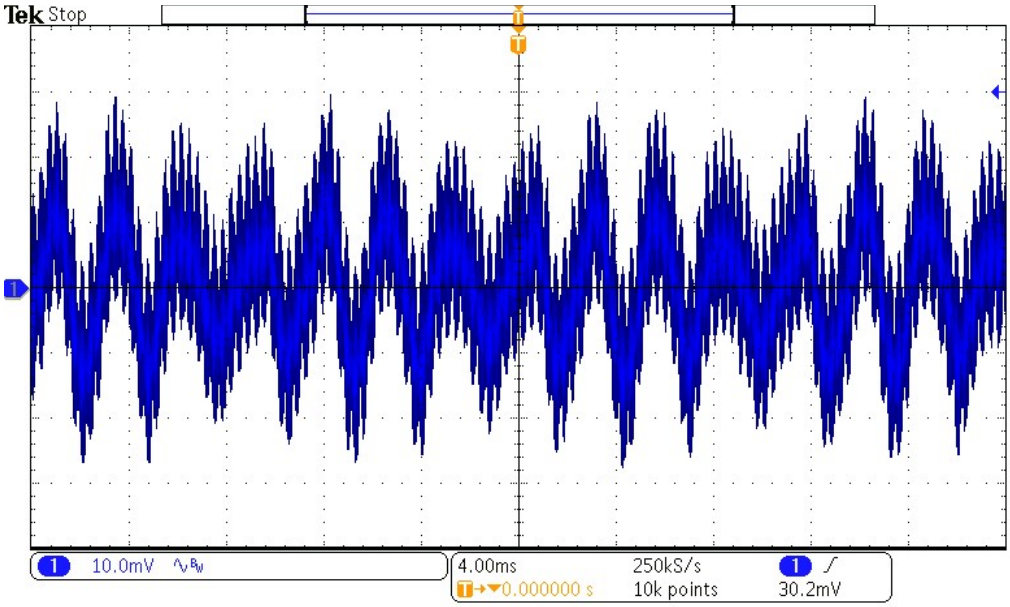


Figure 23: Ripple at 100% Load @ 400VAC.
(CH1: Vout, 10mV/div, Timebase = 4ms/div)

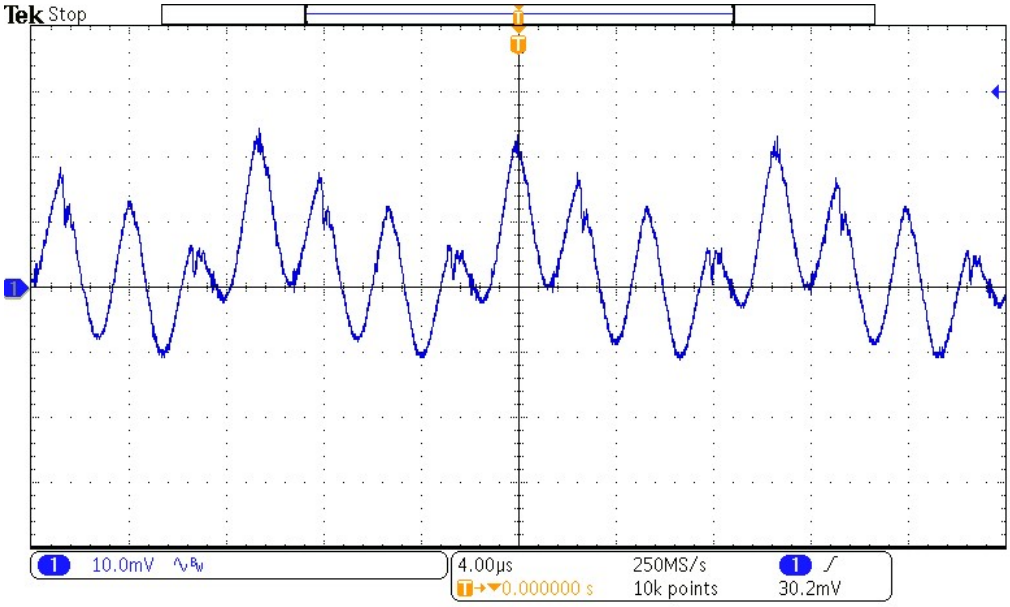


Figure 24: Ripple at 100% Load @ 400VAC.
(CH1: Vout, 10mV/div, Timebase = 4µs/div).

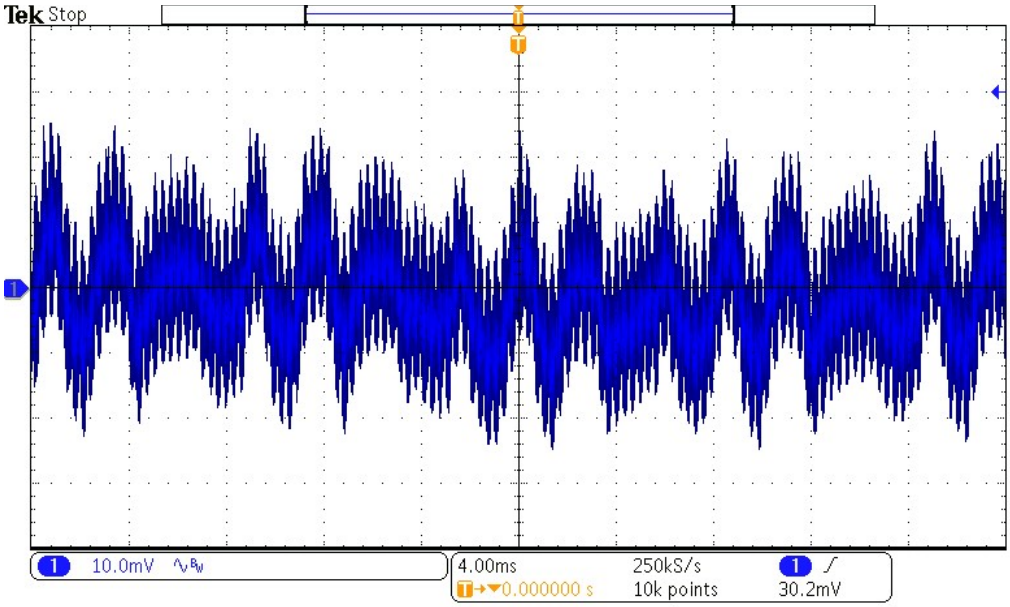


Figure 25: Ripple at 100% Load @ 480VAC.
(CH1: Vout, 10mV/div, Timebase = 4ms/div)

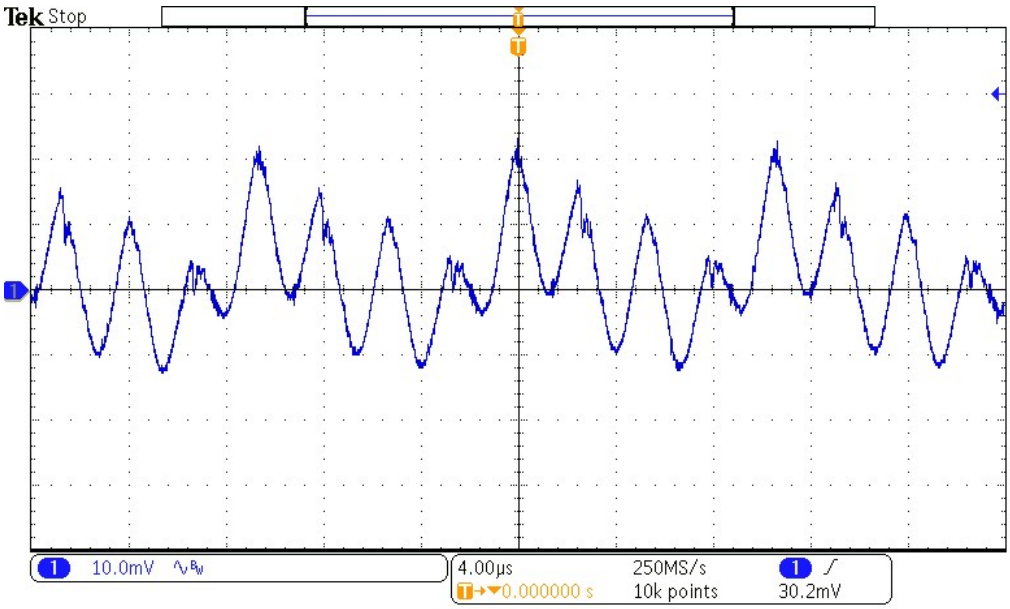


Figure 26: Ripple at 100% Load @ 480VAC.
(CH1: Vout, 10mV/div, Timebase = 4µs/div)

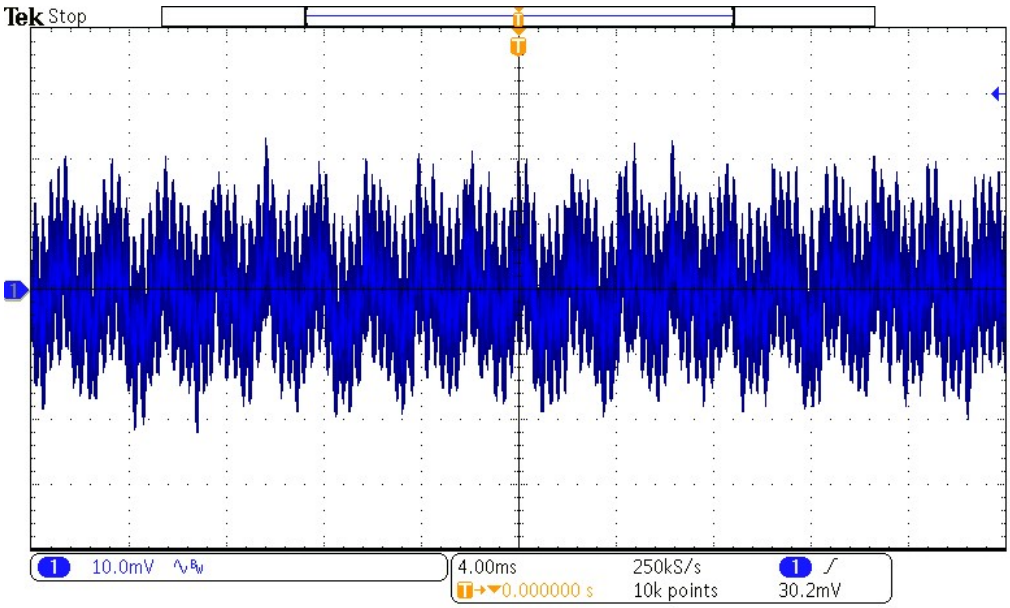


Figure 27: Ripple at 100% Load @ 528VAC.
(CH1: Vout, 10mV/div, Timebase = 4ms/div)

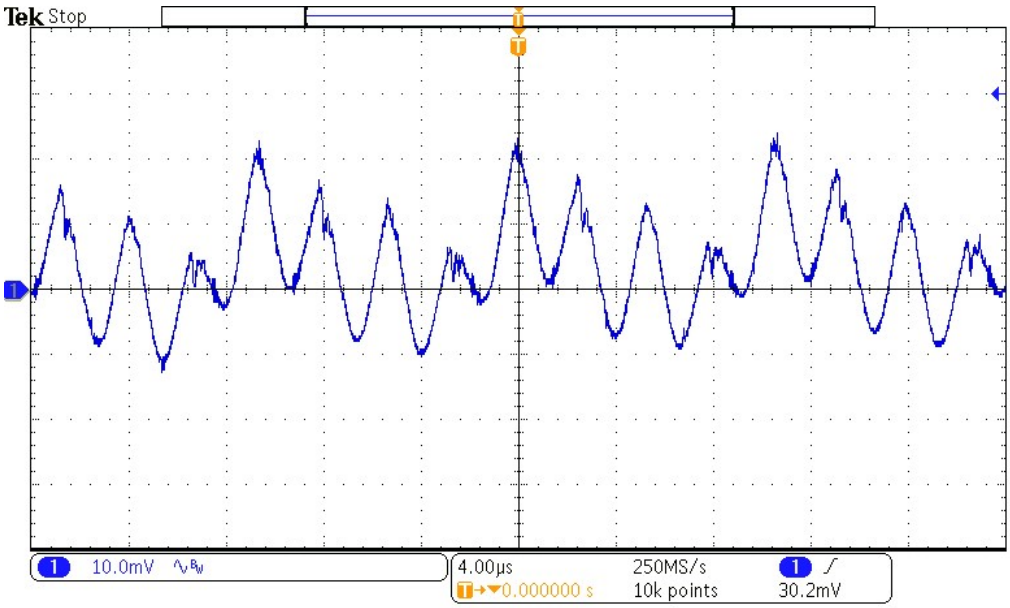


Figure 28: Ripple at 100% Load @ 528VAC.
(CH1: Vout, 10mV/div, Timebase = 4µs/div)

OCP Characteristics

Vout =24Vdc, Ta=25°C

Local Mode

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

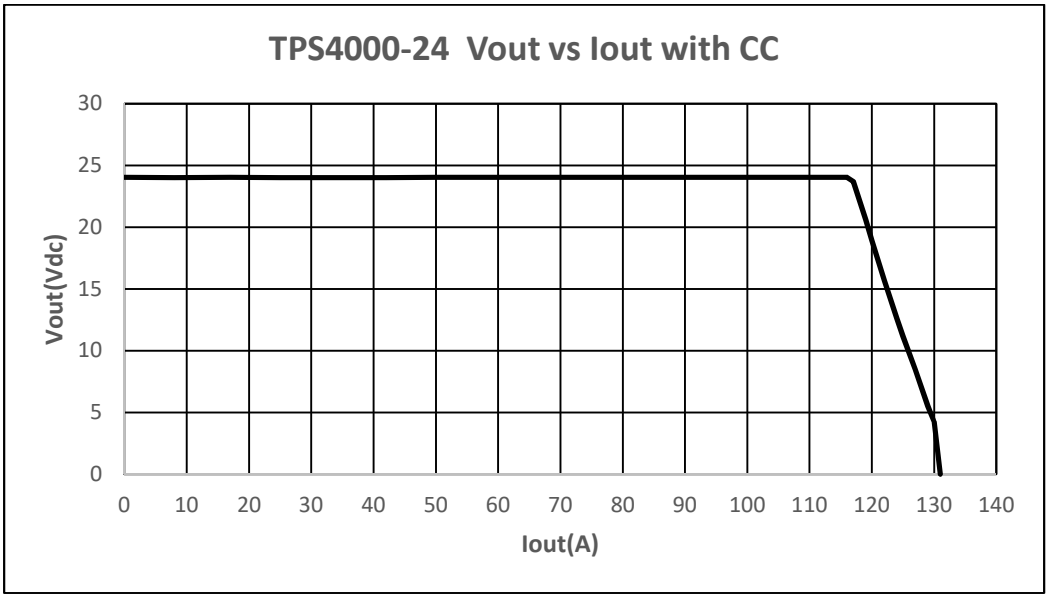


Figure 29: OCP Dropout Curve. Ilimit setpoint= 117A. Local Mode

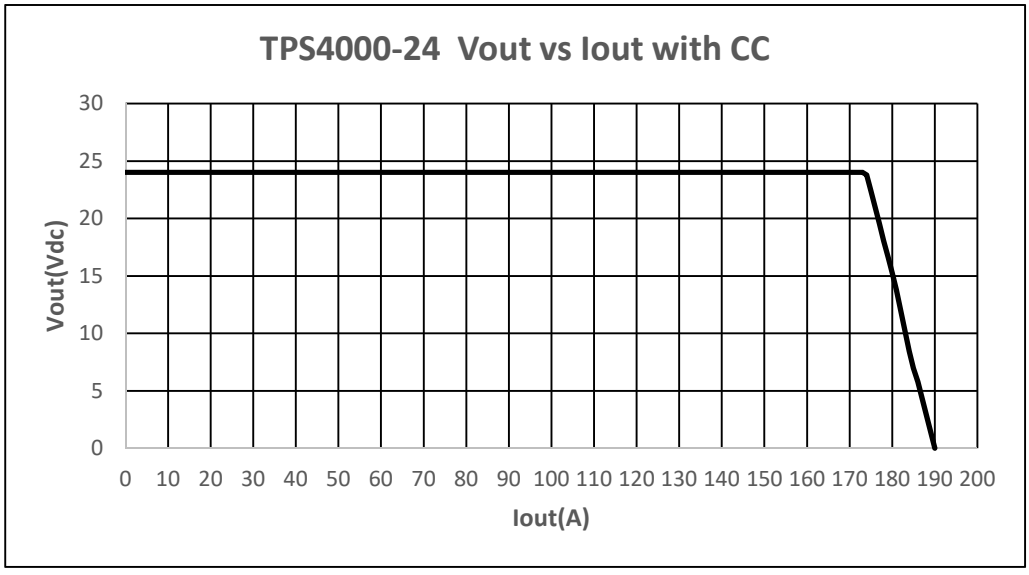


Figure 30: OCP Dropout Curve. Ilimit setpoint= 174A. Local Mode

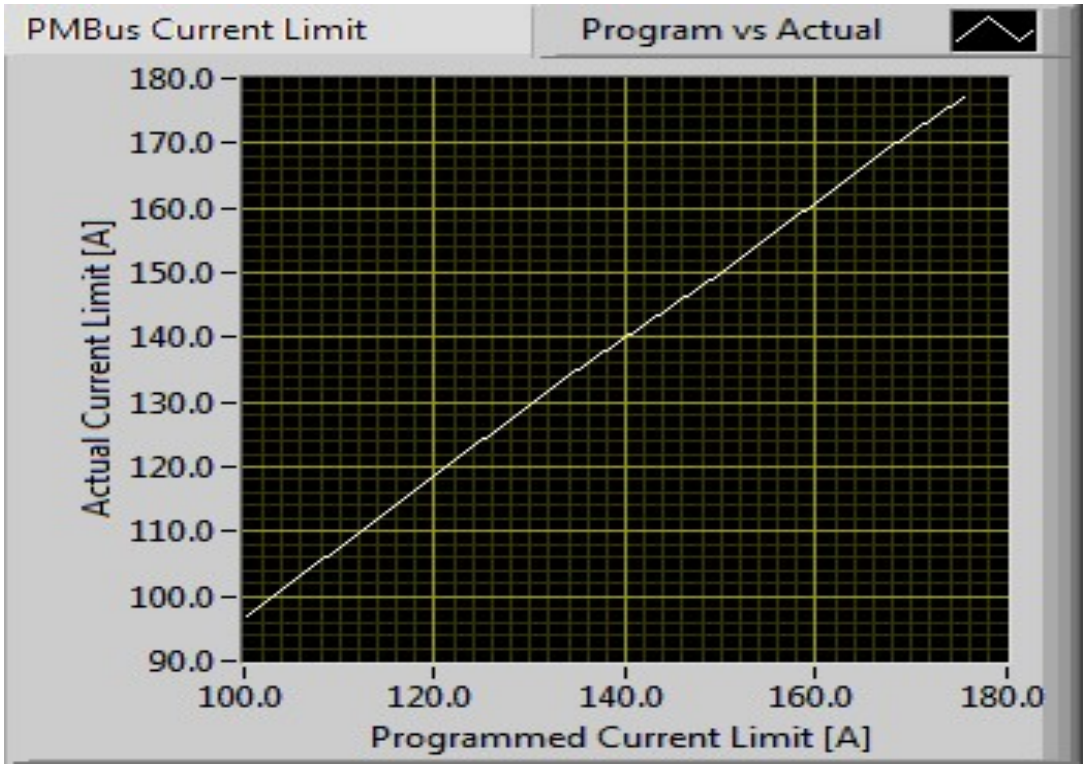
Note 2: Final OCP set point depends on the adjustment of trim Pot ($I_{LIMIT\ ADJ}$) and the voltage level applied to terminal (I_{ADJ}).

Remote Mode

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

Programmed Current Limit at Value (Code) (Code)=(Nh,Nd):Nd(Dec)=(Value*24-304)*1 Nd(Dec)→Nh(Hex)	Actual Current Limit(A)
Current Limit when Ilim at 100.2A (0835h, 2101d)	96.86
Current Limit when Ilim at 116.9A (09C6h, 2502d)	115.23
Current Limit when Ilim at 133.6A (0B56h, 2902d)	133.6
Current Limit when Ilim at 150.3A (0CE7h, 3303d)	150.3
Current Limit when Ilim at 167.0A (0E78h, 3704d)	168.67
Current Limit when Ilim at 175.3A (0F3Fh, 3903d)	177.02

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



Conducted Emissions

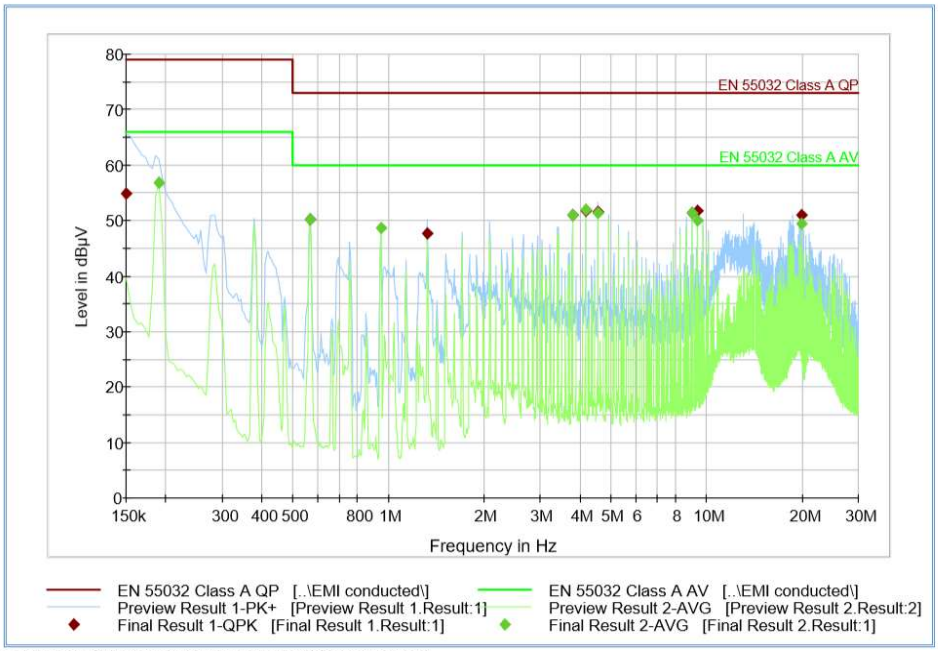
EN 55032:2015 Class A

Vout =24Vdc, Ta=25°C, %100 Load = 167A

Report No. SD72130536-0817

America

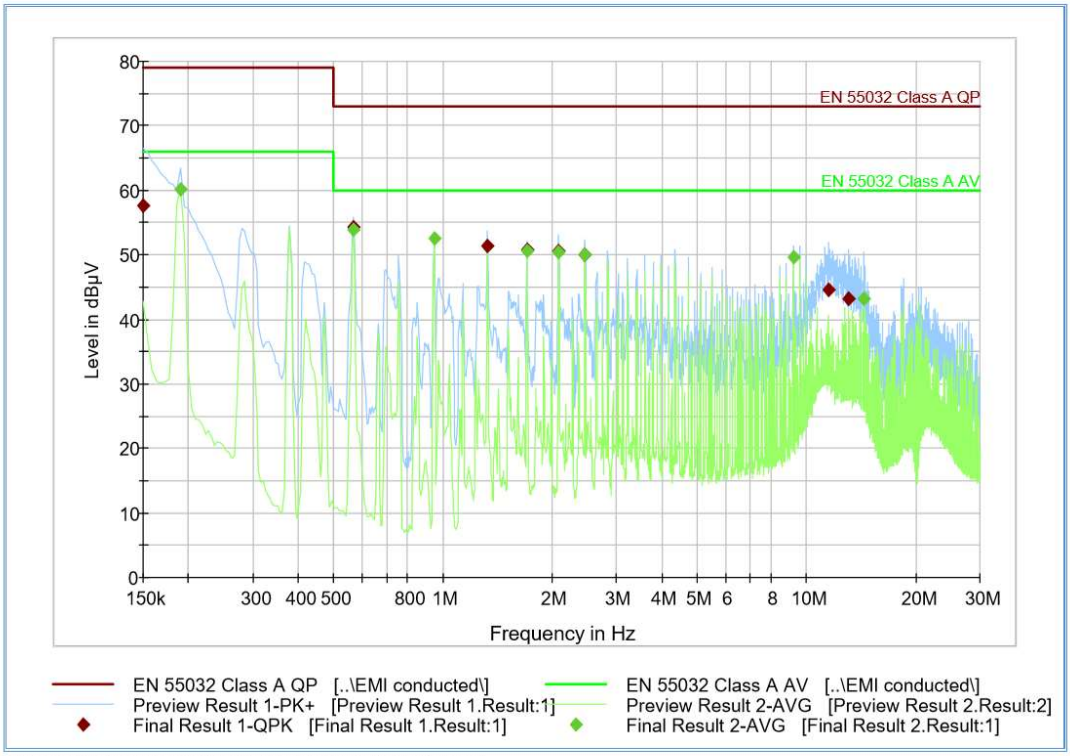
2.1.11 FCC Part 15 Subpart B / EN 55032 Line 1 (400VAC/60Hz)



Note: Limits of FCC Part 15 Subpart B and EN 55032 are identical

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

2.1.12 FCC Part 15 Subpart B / EN 55032 Line 2 (400VAC/60Hz)

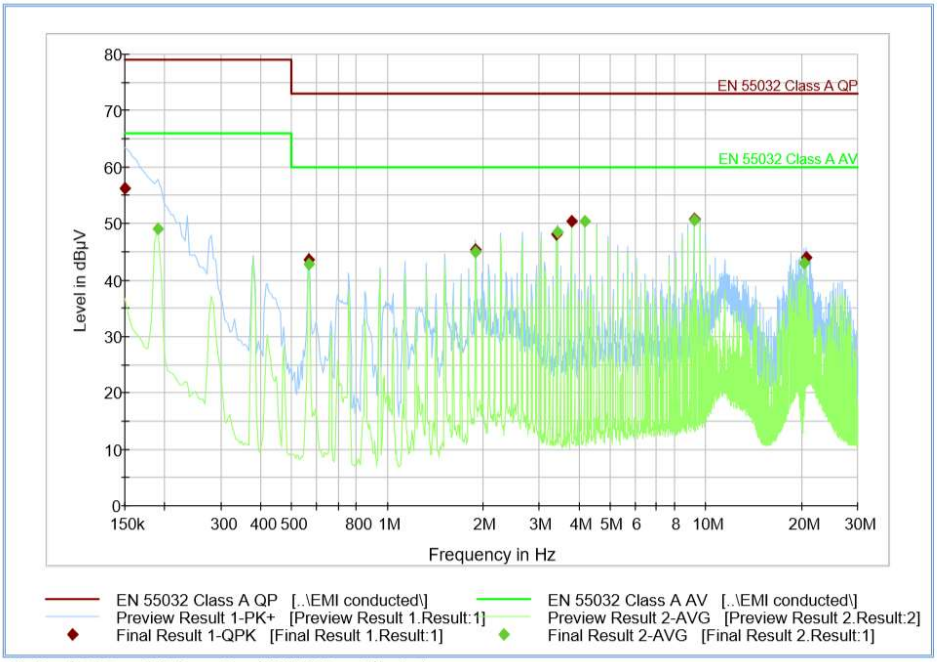


Note: Limits of FCC Part 15 Subpart B and EN 55032 are identical

Figure 32: Line 2 Conducted Emissions. Vin = 400VAC

America

2.1.13 FCC Part 15 Subpart B / EN 55032 Line 3 (400VAC/60Hz)



Note: Limits of FCC Part 15 Subpart B and EN 55032 are identical

Figure 33: Line 3 Conducted Emissions. Vin = 400VAC

Radiated Emissions

EN55032 Class A /FCC Part 15 Class A

Vout =24Vdc, Ta=25°C, %100 Load = 167A

Report No. SD72130536-0817

America

2.2.11 Below 1GHz Radiated Emission Test (EN 55032)

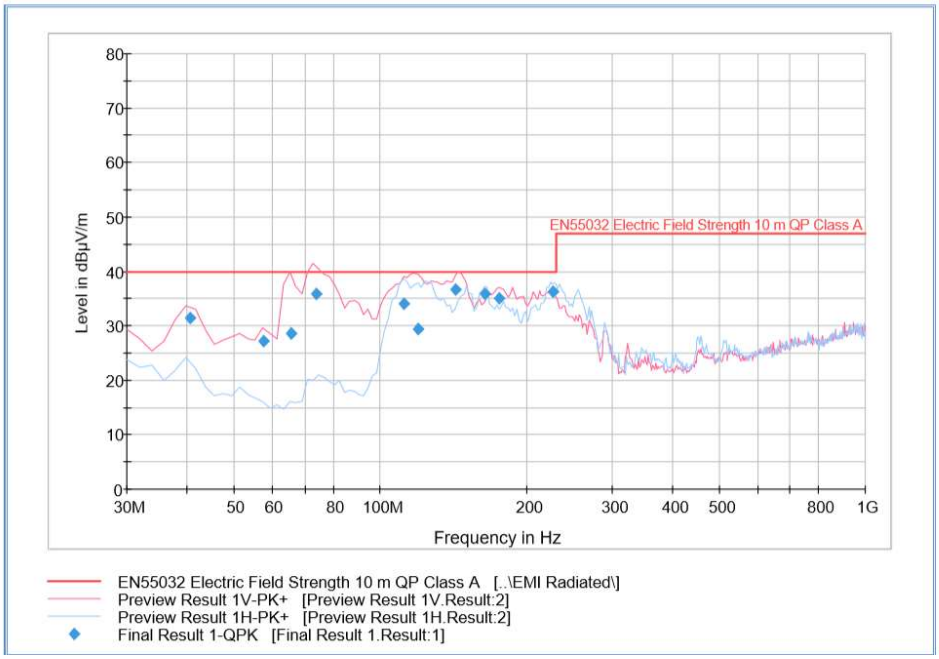


Figure 34: EN55032 Class A Radiated Emissions

America

2.2.12 Below 1GHz Radiated Emission Test (FCC Part 15 Subpart B)

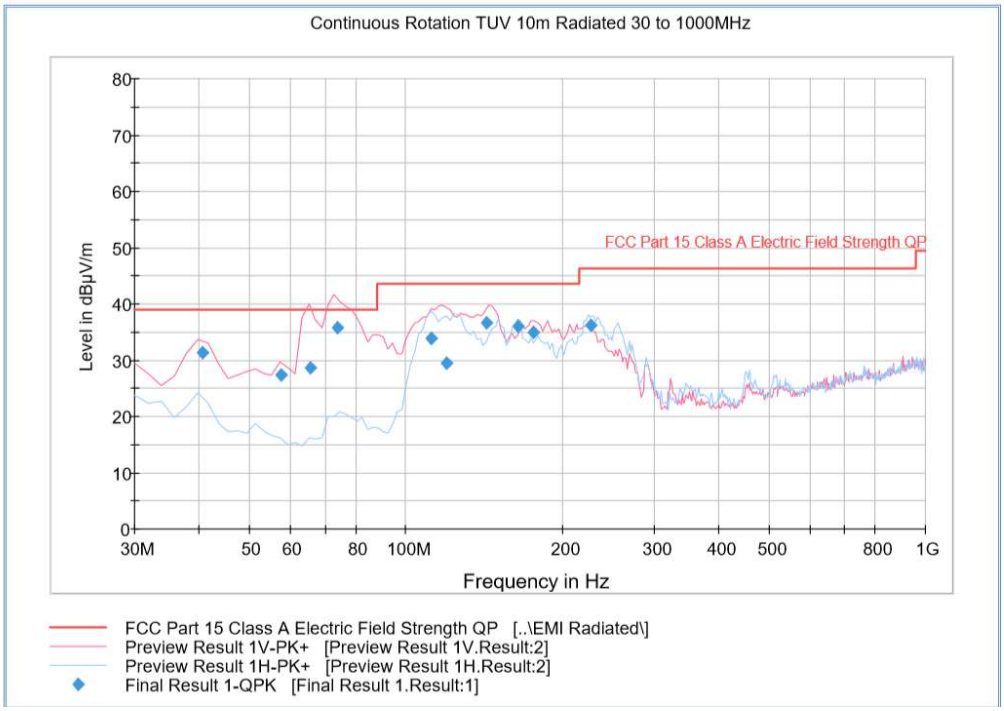


Figure 35: FCC Part 15 Class A Radiated Emissions

Current Share

Vin = 480VAC, Vout = 24Vdc, Ta = 25°C

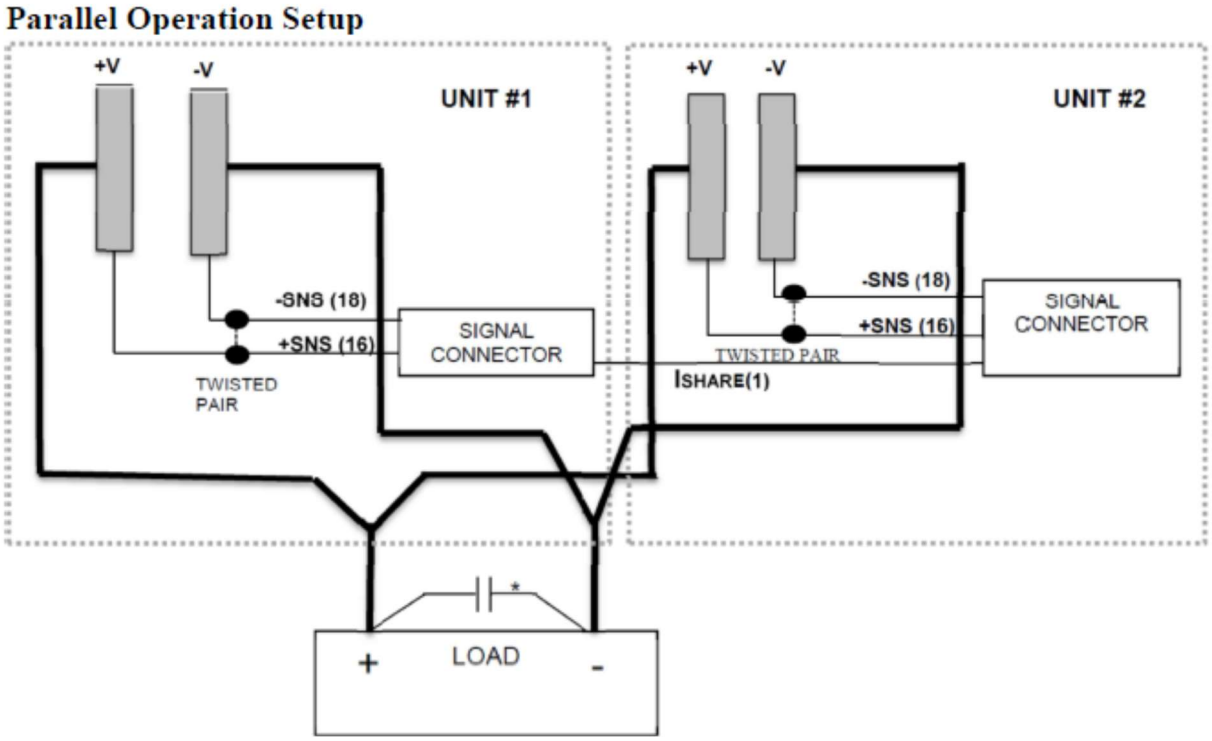
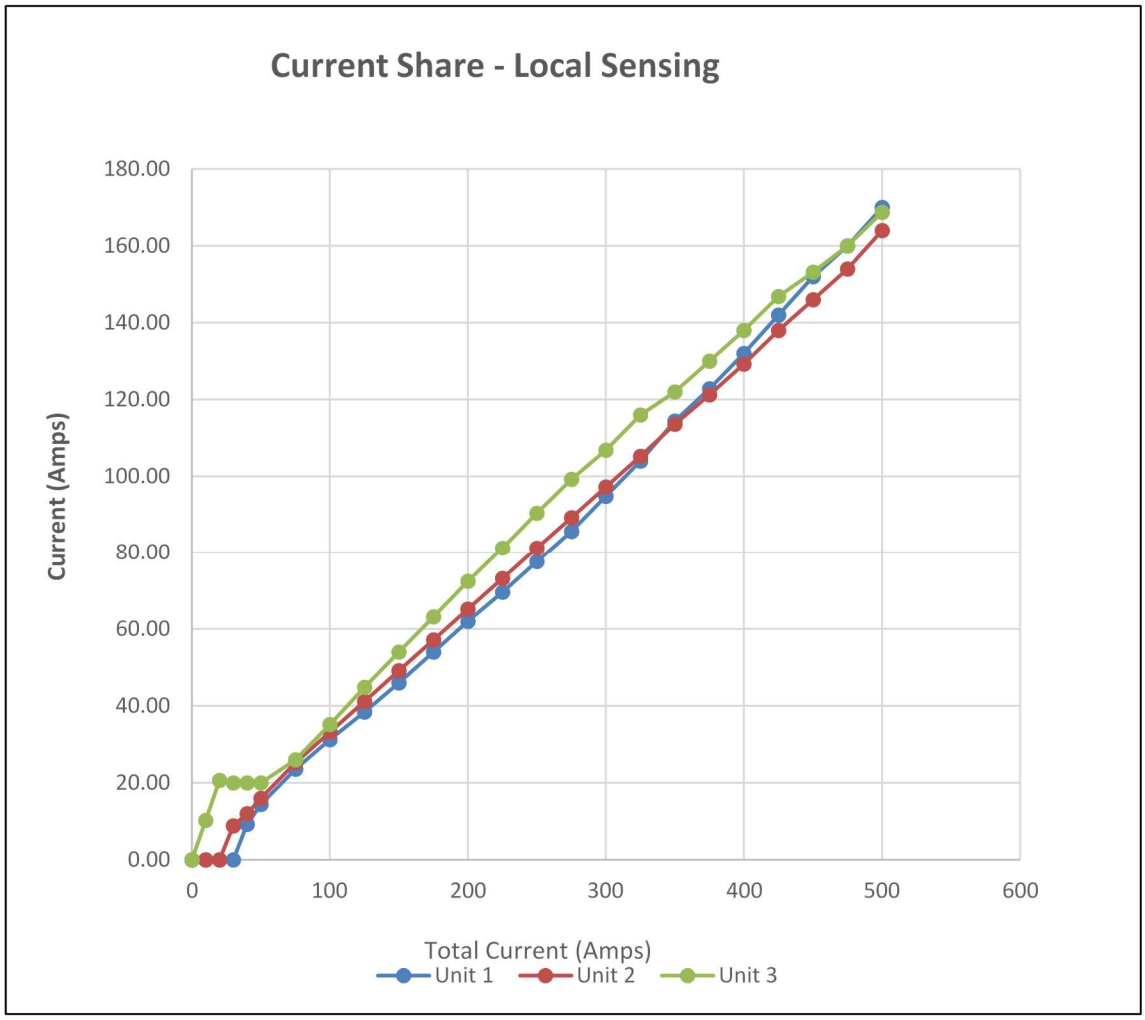


Figure 36: Typical Local Sense Parallel Operation Setup


Current Share - Local Sensing
180.00
160.00
140.00
120.00
100.00
80.00
60.00
40.00
20.00
0.00
Current (Amps)
0
100
200
300
400
500
600
Total Current (Amps)
Unit 1
Unit 2
Unit 3

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	0.00	10.20	102.00%
20	0.00	0.00	20.68	103.40%
30	0.00	8.80	20.00	66.67%
40	9.20	12.00	20.00	27.00%
50	14.40	16.00	20.00	11.20%
75	23.60	25.20	26.00	3.20%
100	31.20	33.20	35.20	4.00%
125	38.40	41.20	44.80	5.12%
150	46.00	49.20	54.00	5.33%
175	54.00	57.20	63.20	5.26%
200	62.00	65.20	72.40	5.20%
225	69.60	73.20	81.20	5.16%
250	77.60	81.20	90.40	5.12%
275	85.60	89.20	99.20	4.95%
300	94.80	97.20	106.80	4.00%
325	104.00	105.20	116.00	3.69%
350	114.40	113.60	122.00	2.40%
375	122.80	121.20	130.00	2.35%
400	132.00	129.20	138.00	2.20%
425	142.00	138.00	146.80	2.07%
450	152.00	146.00	153.20	1.60%
475	160.00	154.00	160.00	1.26%
500	170.00	164.00	168.80	1.20%

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

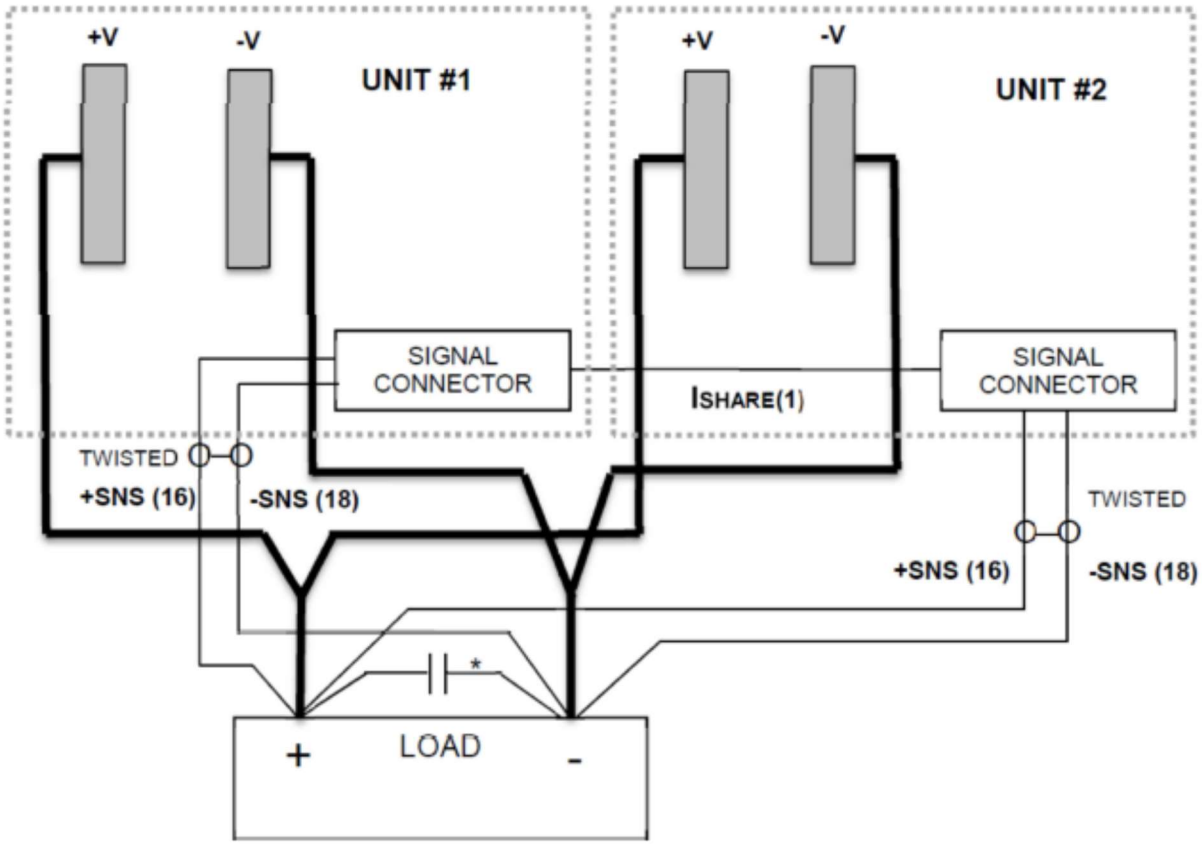
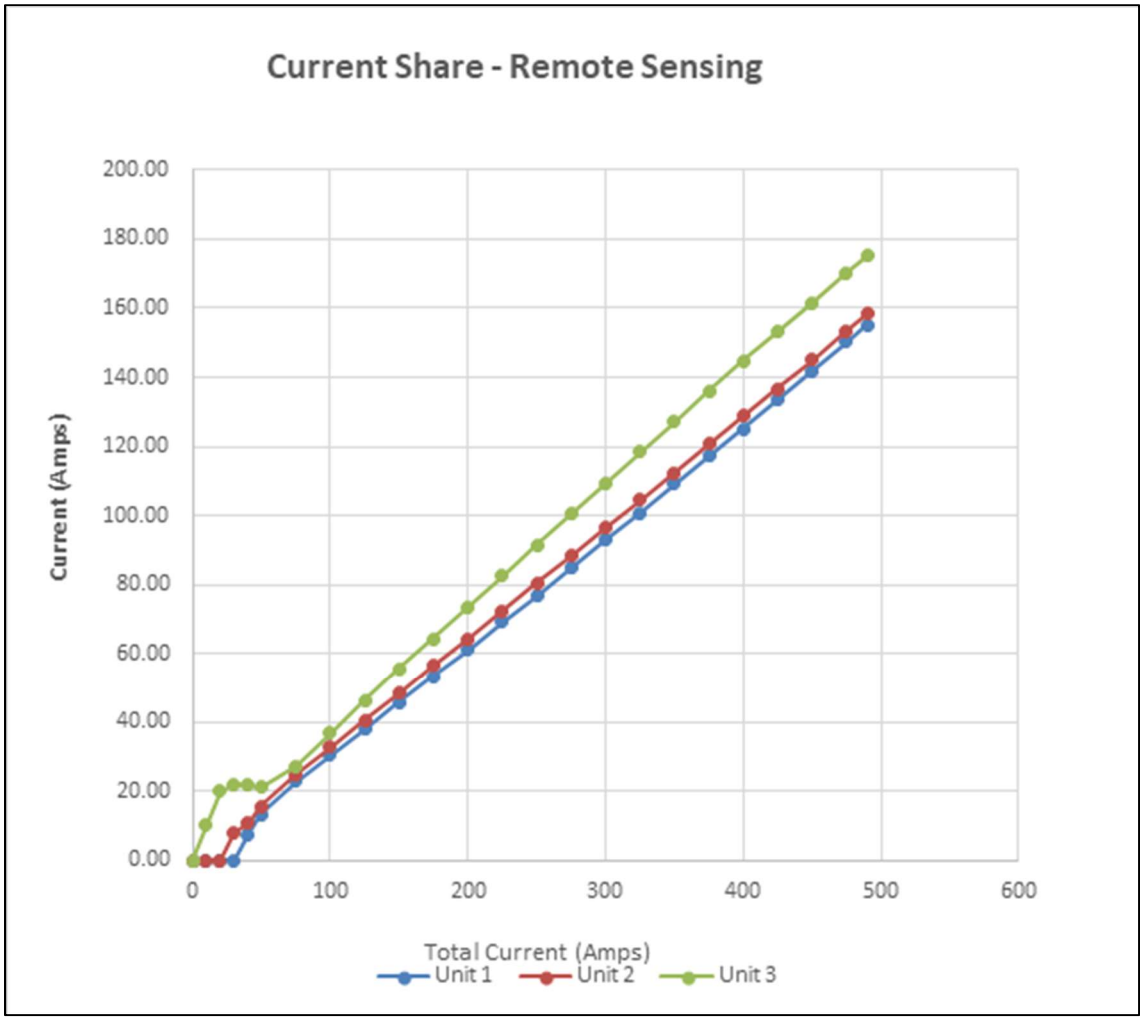


Figure 37: Typical Remote Sense Parallel Operation Setup


Current Share - Remote Sensing
Current (Amps)
200.00
180.00
160.00
140.00
120.00
100.00
80.00
60.00
40.00
20.00
0.00
0
100
200
300
400
500
600
Total Current (Amps)
Unit 1
Unit 2
Unit 3

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	0.00	10.00	100.00%
20	0.00	0.00	20.00	100.00%
30	0.00	8.00	22.00	73.33%
40	7.60	10.80	21.60	35.00%
50	13.20	15.60	21.20	16.00%
75	22.80	24.80	27.20	5.87%
100	30.40	32.80	36.80	6.40%
125	38.00	40.40	46.40	6.72%
150	45.60	48.40	55.60	6.67%
175	53.20	56.40	64.40	6.40%
200	61.20	64.40	73.60	6.20%
225	69.20	72.40	82.40	5.87%
250	76.80	80.40	91.60	5.92%
275	84.80	88.40	100.40	5.67%
300	92.80	96.40	109.20	5.47%
325	100.80	104.40	118.40	5.42%
350	109.20	112.40	127.20	5.14%
375	117.20	120.80	136.00	5.01%
400	125.20	128.80	144.80	4.90%
425	133.60	136.80	153.20	4.61%
450	142.00	145.20	161.60	4.36%
475	150.40	153.60	170.40	4.21%
490	155.20	158.40	175.20	4.08%

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