ON Semiconductor®

# NCP13992+NCL2801
# 150W lighting Solution

# 150W lighting Solution

## Value Proposition

This design used Onsemi's NCL2801 PFC controller, NCP13992 half bridge resonant converter controller,have a high PF value, low THD performance, suitable for lighting solution.

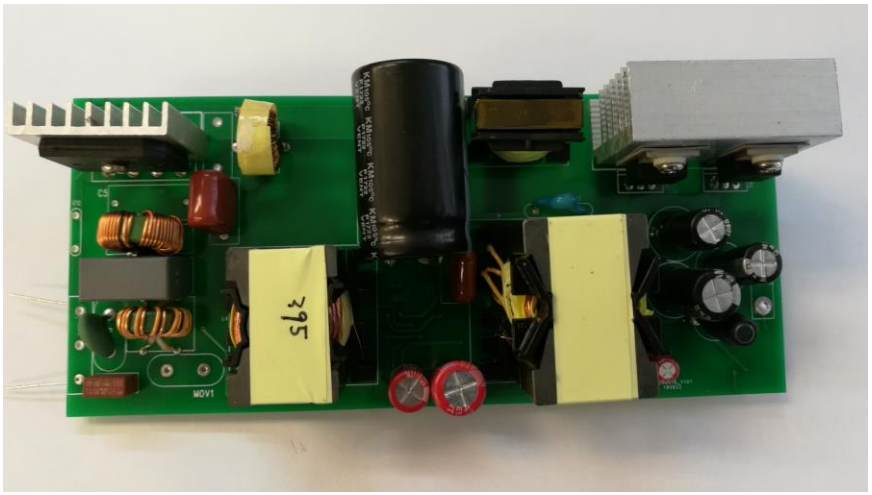
## Specifications and Features

- Half bridge Resonant current mode control
- Automatic Dead-time with Maximum Dead-time Clamp
- Rated Output power: 150W
- Excellent PF value performance
- Excellent THD value performance
- Standby power: <0.3W in Universal AC input voltage(No cable plug in)
- Full load Efficiency: >93%@ at board end, 230Vac
- CC/CV mode
- Output OCP
- Brown-out protection
- Open loop protection
- Switching frequency: ~100KHz @230Vac and full load

## Market & Applications

- Lighting

## Demoboard Photo



# Solution Block Diagram

ONSEMI's Key Parts:

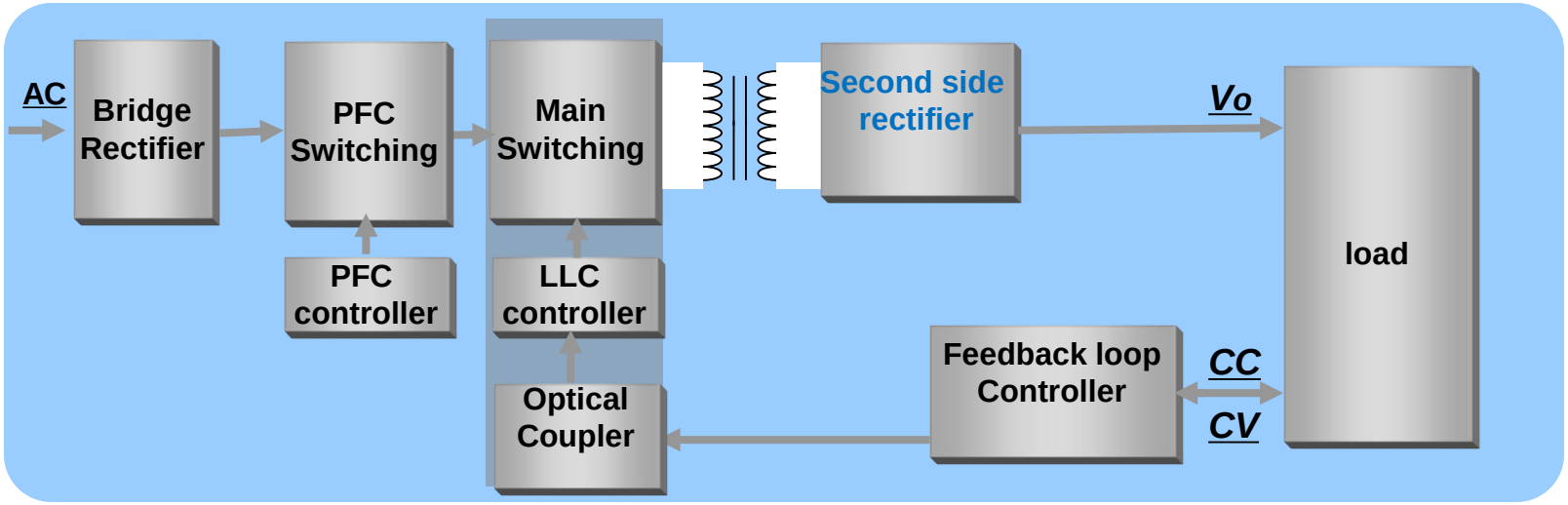
PFC Controller—NCL2801CDB

Primary half bridge resonant Controller---NCP13992AC

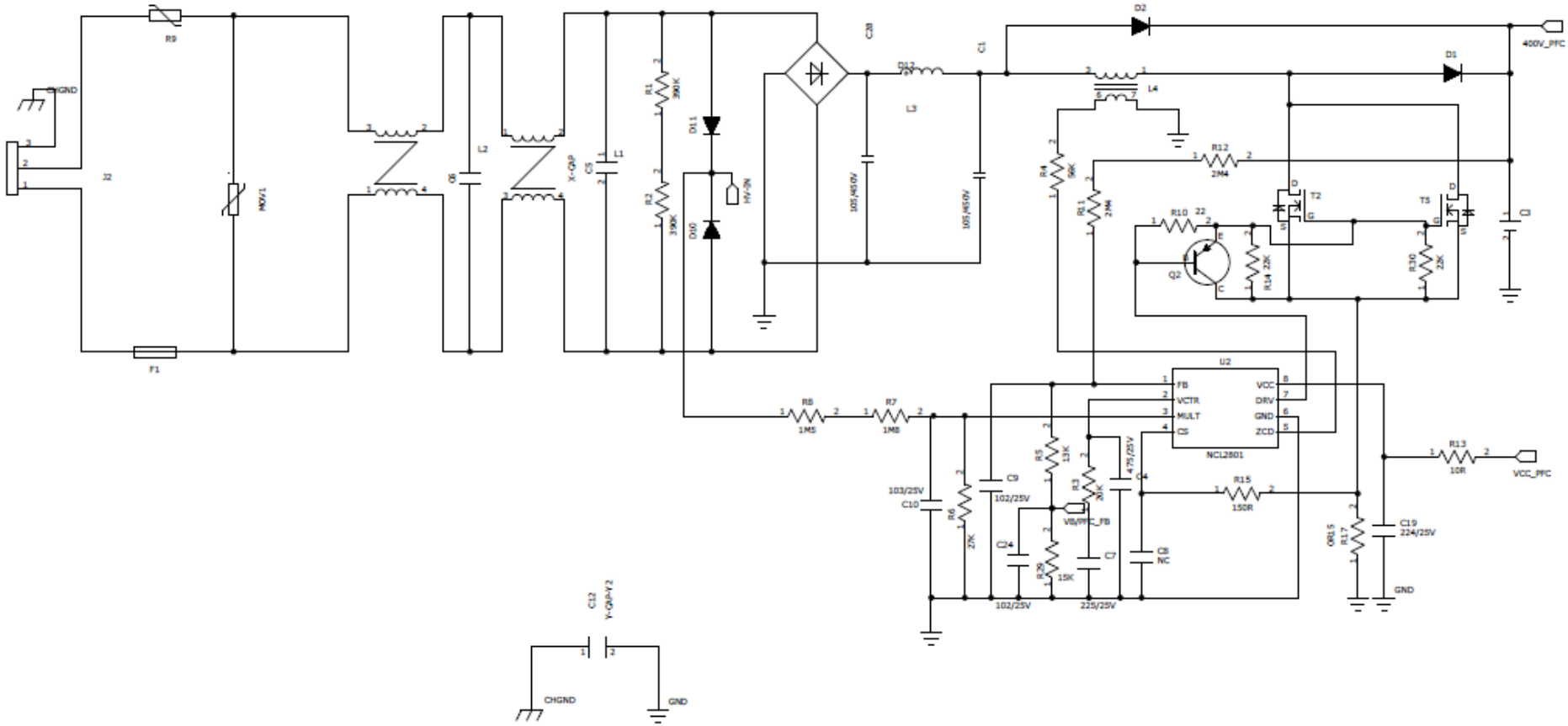
Second side rectifier Diode---MBR30L60

Switch FET---FCD260N65/FCD600N65

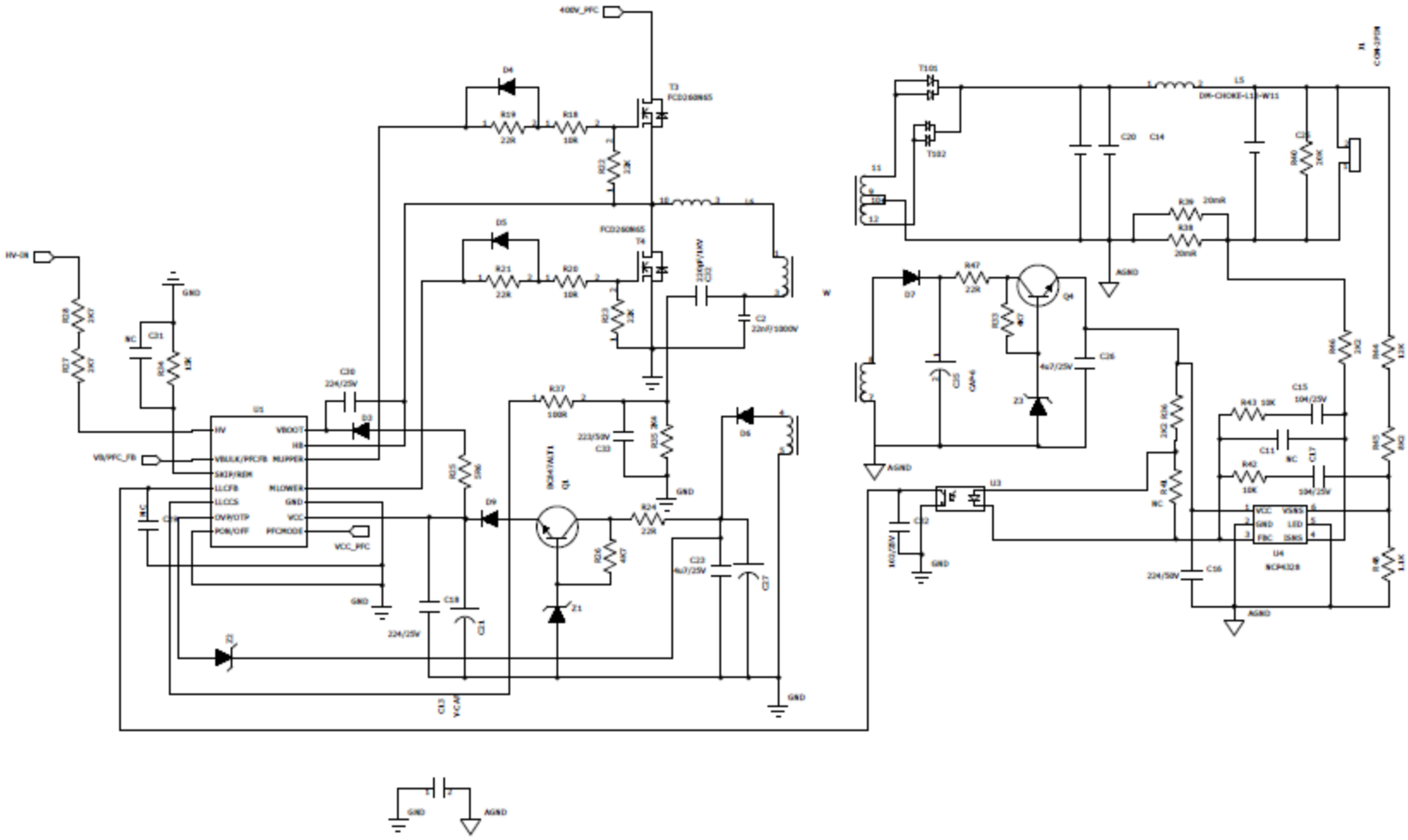
Second side CC/CV controller IC-NCP4328



# Schematic(PFC part)



# Schematic(LLC part)



# Key Design Specifications

| No. | Description | Symbol | Min | Type | Max | Unit | Test condition |
|---|---|---|---|---|---|---|---|
| 1 | Input Voltage Range | Vin(min/max) | 90 | 115/230 | 270 | Vac | |
| 2 | Input Current | Irms | | | 2 | A | 90Vac and full load |
| 3 | Rated Input Frequency | fin | 50 | | 60 | Hz | |
| 4 | Input Frequency Range | Fin(min/max) | 47 | | 63 | Hz | |
| 5 | Rated Output Power | Pout | | 150 | | W | |
| 6 | Efficiency At Full Load | η | 93 | | | % | Tested at board end, 230Vac |
| 7 | Output Voltage and Current.(CC mode) | Vout/Iout | | 24V/0-6A | | V/A | 90Vac-270Vac |
| 8 | Output Voltage and Current.(CV mode) | Vout/Iout | | 11-24V/6A | | V/A | 90Vac-270Vac |
| 9 | No load power | Pstandby | | | <0.3 | W | 115&230Vac input |
| | | | | | | | |
| | | | | | | | |

# Test data

| Sample | 90Vin, 60Hz | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| No. | Full Load | Full Load | Full Load | Full Load | Full Load | Half Load | No Load | | Output | Efficiency |
| | | | Input Power | PF | THD | THD | Input Power | Ripple/noise | Power | |
| Spec. | 22.8~25.2V | 5.7-6.3A | | >0.9 | <10% | <10% | W | mVp-p | | |
| 6A load | 23.84 | 6.00 | 158.7 | | | | | 116.00 | 143.06 | 90.1% |
| 4.5A load | 23.86 | 4.50 | 118.45 | | | | | | 107.37 | 90.6% |
| 3A load | 23.879 | 3.00 | 79.10 | | | | | | 71.64 | 90.6% |
| 1.5A load | 23.90 | 1.50 | 40.58 | | | | | | 35.85 | 88.3% |
| 0A load | | | | | | | | | | |

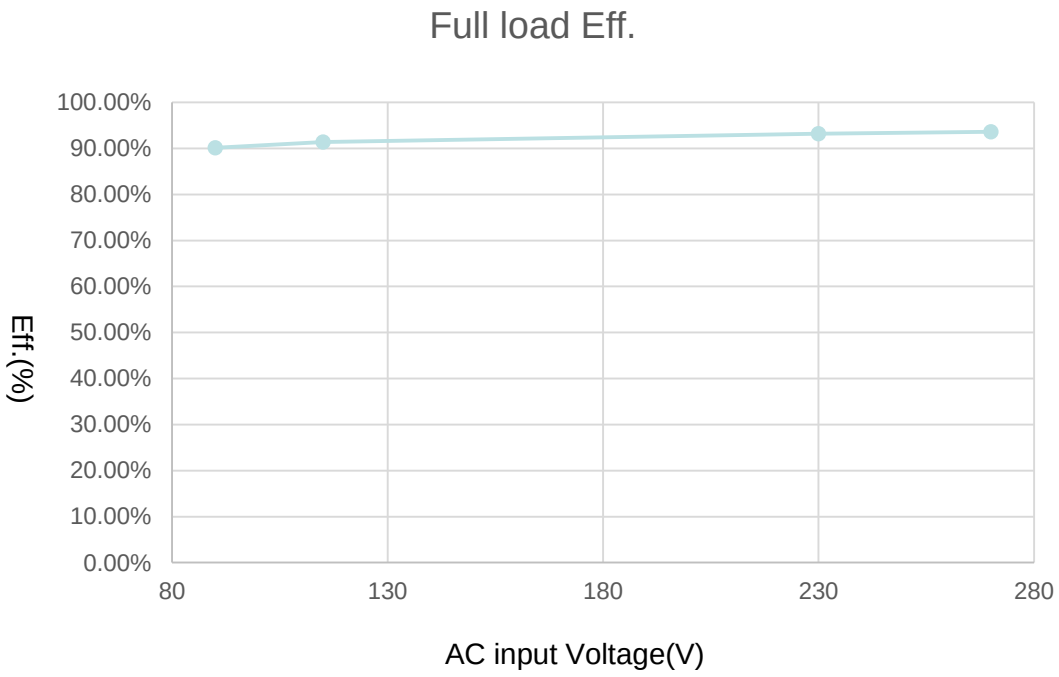
| | 115Vin, 60Hz | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Full Load | Full Load | Full Load | Full Load | Full Load | Half Load | No Load | | Output | Efficiency |
| | | | Input Power | PF | THD | THD | Input Power | Ripple/noise | Power | |
| Spec. | 22.8~25.2V | 5.7-6.3A | | >0.9 | <10% | <10% | W | mVp-p | | |
| 6A load | 23.85 | 6.00 | 156.59 | | | | | 88.00 | 143.07 | 91.4% |
| 4.5A load | 23.86 | 4.50 | 117.09 | | | | | | 107.37 | 91.7% |
| 3A load | 23.88 | 3.00 | 78.39 | | | | | | 71.64 | 91.4% |
| 1.5A load | 23.90 | 1.50 | 40.21 | | | | | | 35.84 | 89.1% |
| 0A load | | 0.00 | | | | | 0.25 | | | |

# Test data

| | 230Vin, 50Hz | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Full Load | Full Load | Full Load | Full Load | Full Load | Half Load | No Load | | Output | Efficiency |
| | | | Input Power | PF | THD | THD | Input Power | Ripple/noise | Power | |
| Spec. | 22.8~25.2V | 5.7-6.3A | | >0.9 | <10% | <10% | W | mVp-p | | >90% |
| 6A load | 23.85 | 6.00 | 153.57 | | | | | 84.00 | 143.07 | 93.2% |
| 4.5A load | 23.86 | 4.50 | 115.17 | | | | | | 107.38 | 93.2% |
| 3A load | 23.88 | 3.00 | 77.20 | | | | | | 71.64 | 92.8% |
| 1.5A load | 23.90 | 1.50 | 39.64 | | | | | | 35.85 | 90.4% |
| 0A load | | 0.00 | | | | | 0.25 | | | |

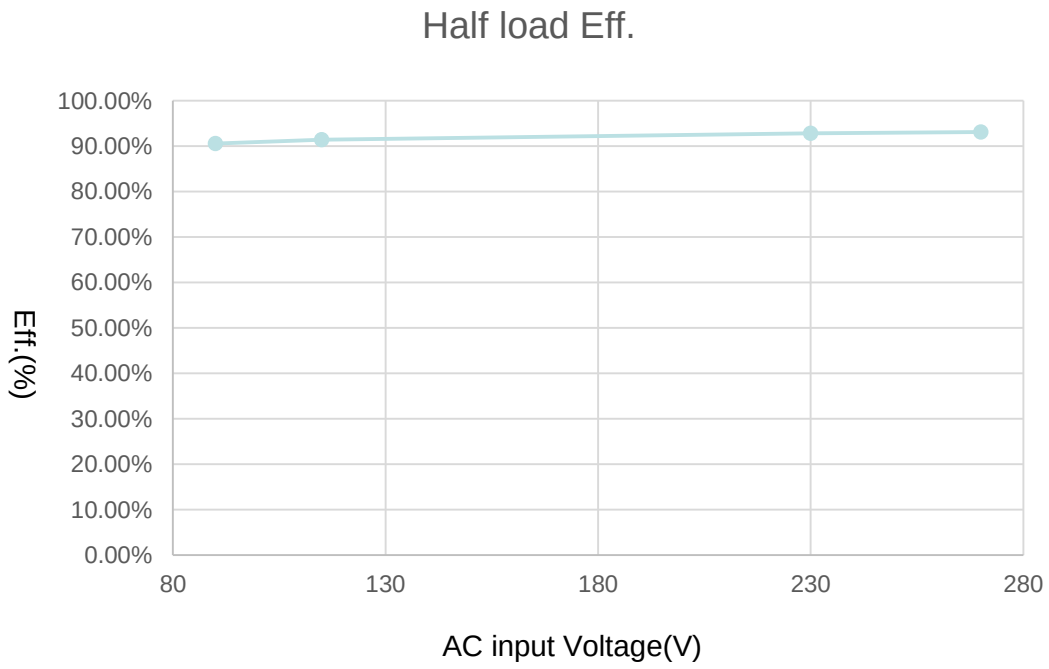
| Sample | 270Vin, 50Hz | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| No. | Full Load | Full Load | Full Load | Full Load | Full Load | Half Load | No Load | | Output | Efficiency |
| | | | Input Power | PF | THD | THD | Input Power | Ripple/noise | Power | |
| Spec. | 22.8~25.2V | 5.7-6.3A | | >0.9 | <10% | <10% | W | mVp-p | | >90% |
| 6A load | 23.85 | 6.00 | 152.89 | | | | | 82.00 | 143.07 | 93.6% |
| 4.5A load | 23.86 | 4.50 | 114.68 | | | | | | 107.37 | 93.6% |
| 3A load | 23.88 | 3.00 | 76.91 | | | | | | 71.64 | 93.1% |
| 1.5A load | 23.90 | 1.50 | 39.38 | | | | | | 35.84 | 91.0% |
| 0A load | | 0.00 | 0.00 | | | | | | | |

# Full load Efficiency



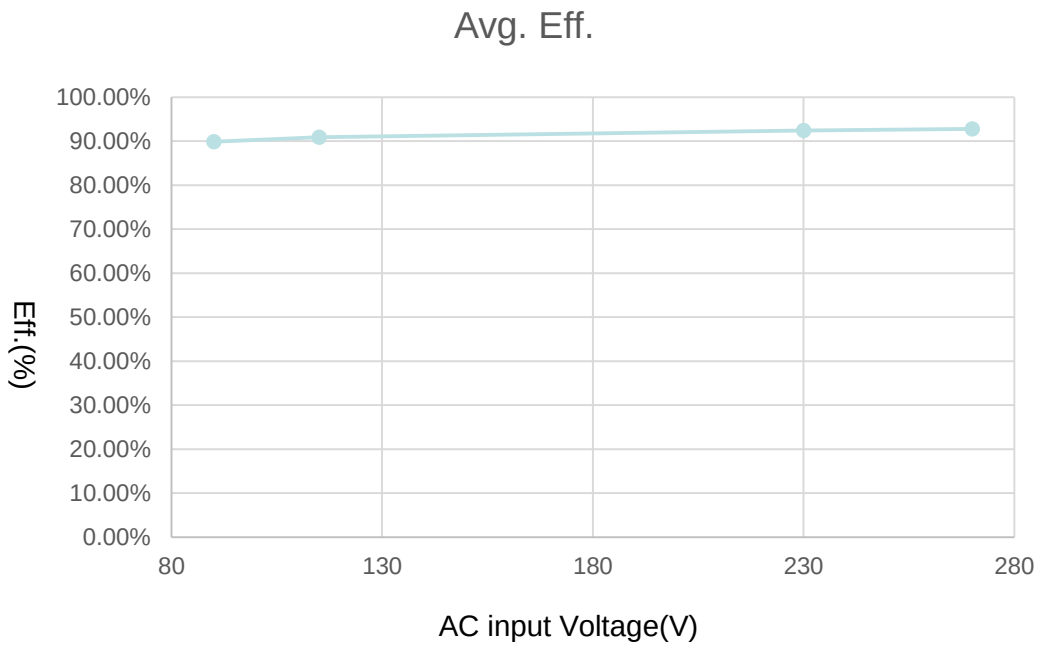

Test condition: all efficiency are tested at board end

# Half load Efficiency



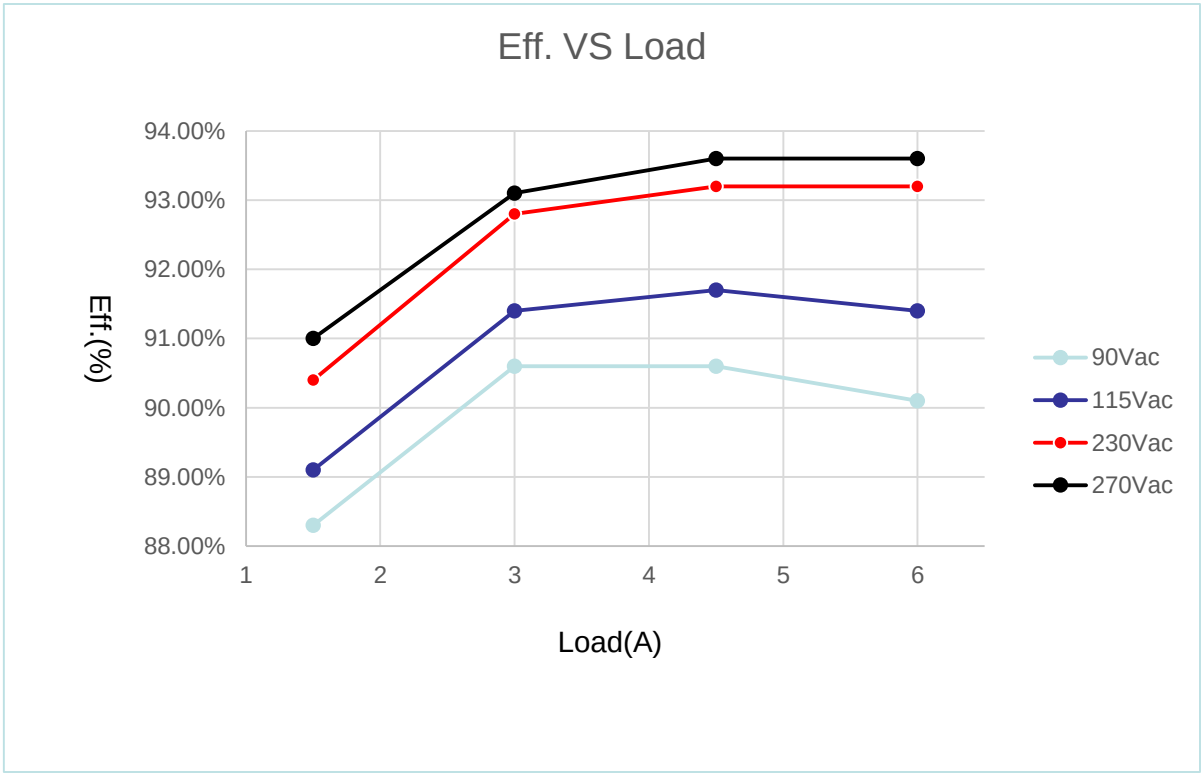

Test condition: all efficiency are tested at board end

# Avg. Efficiency



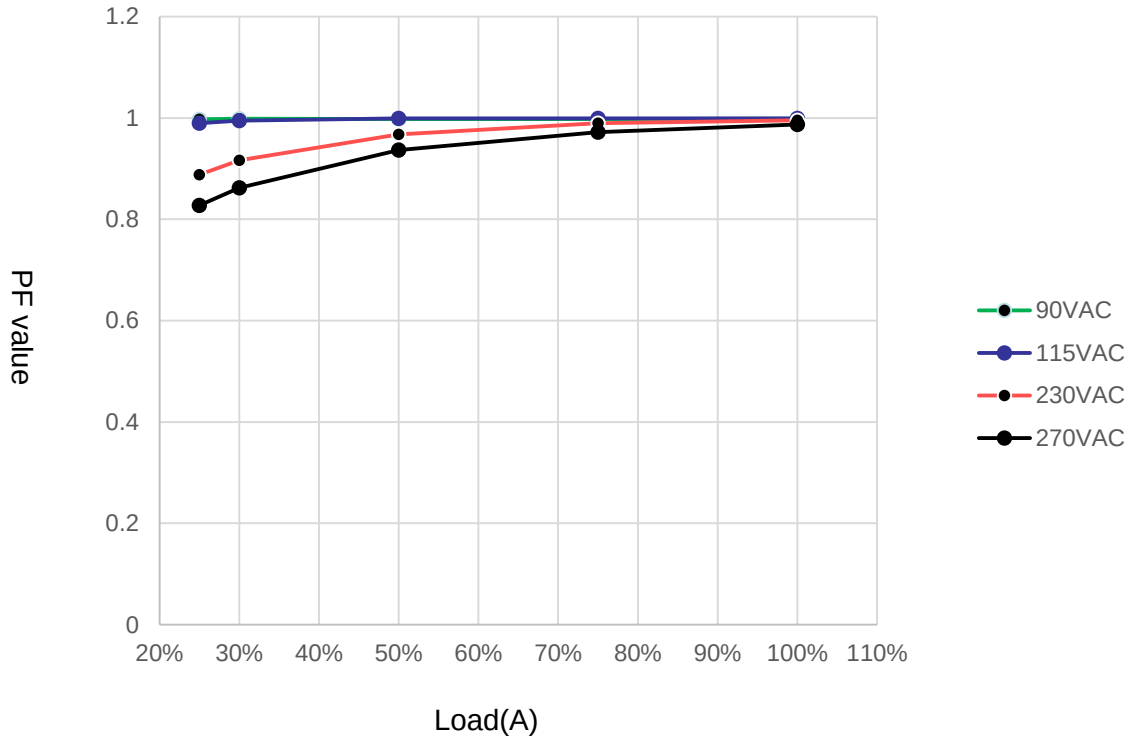

Test condition: all efficiency are tested at board end

# Eff. VS Load

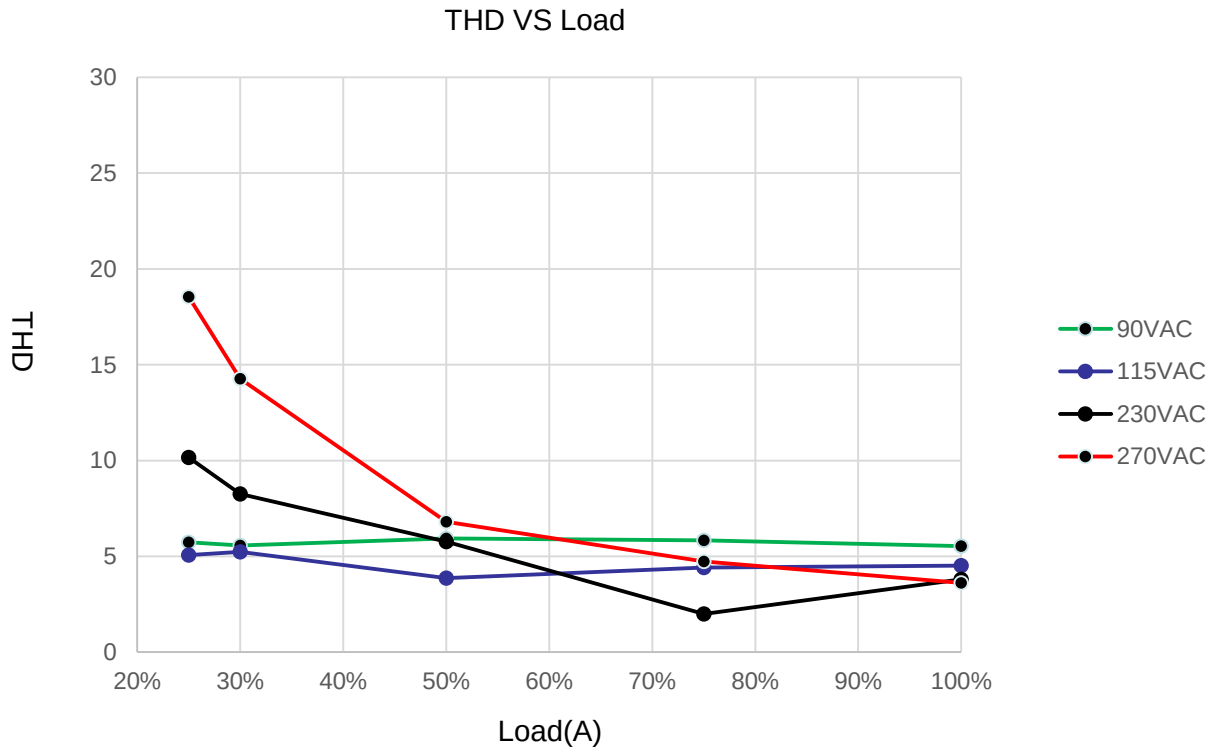



Test condition: all efficiency are tested at board end

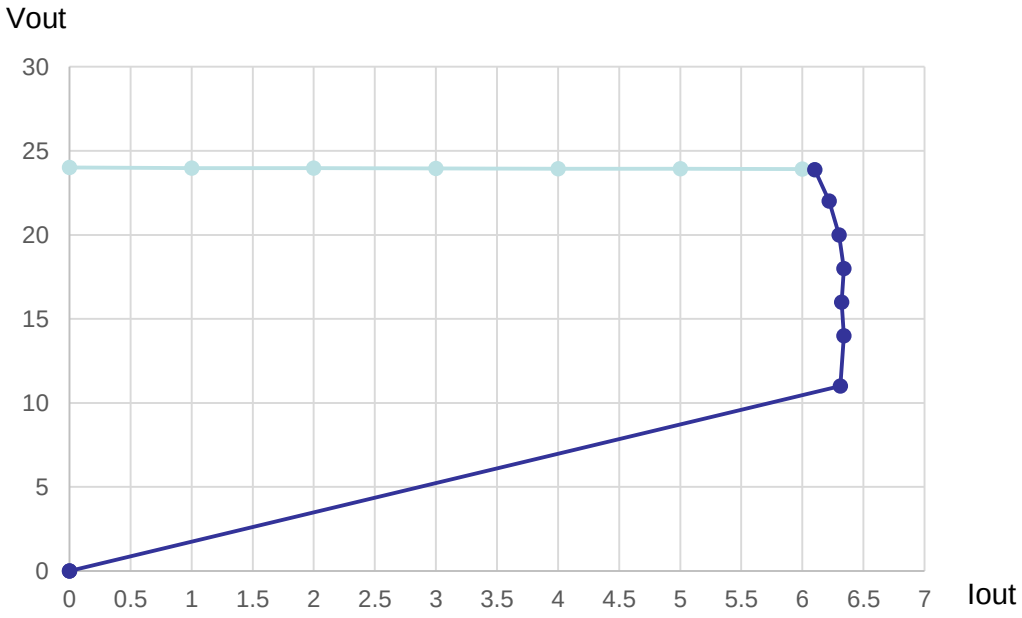
# PF value



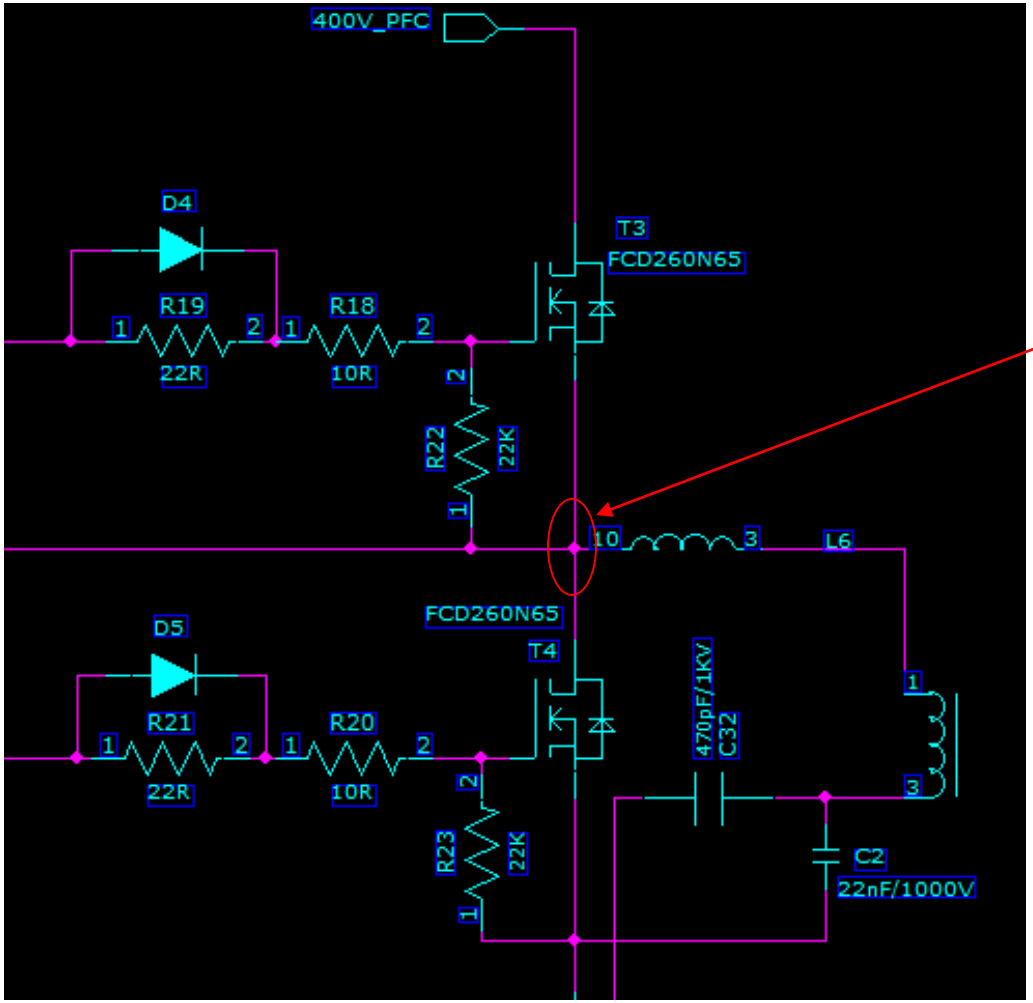
# THD value



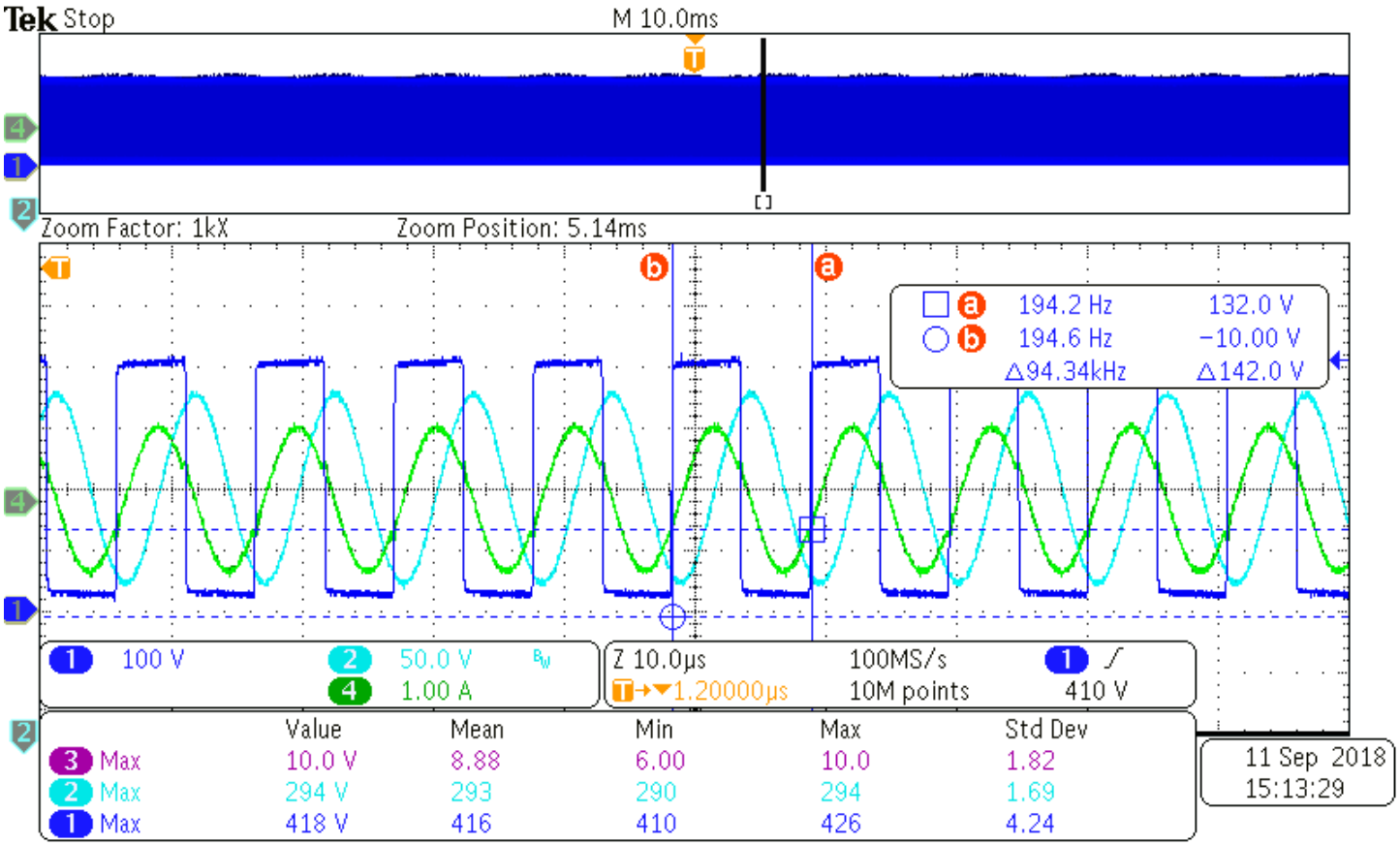
# CV Curve at 230Vac input



# LLC part circuit

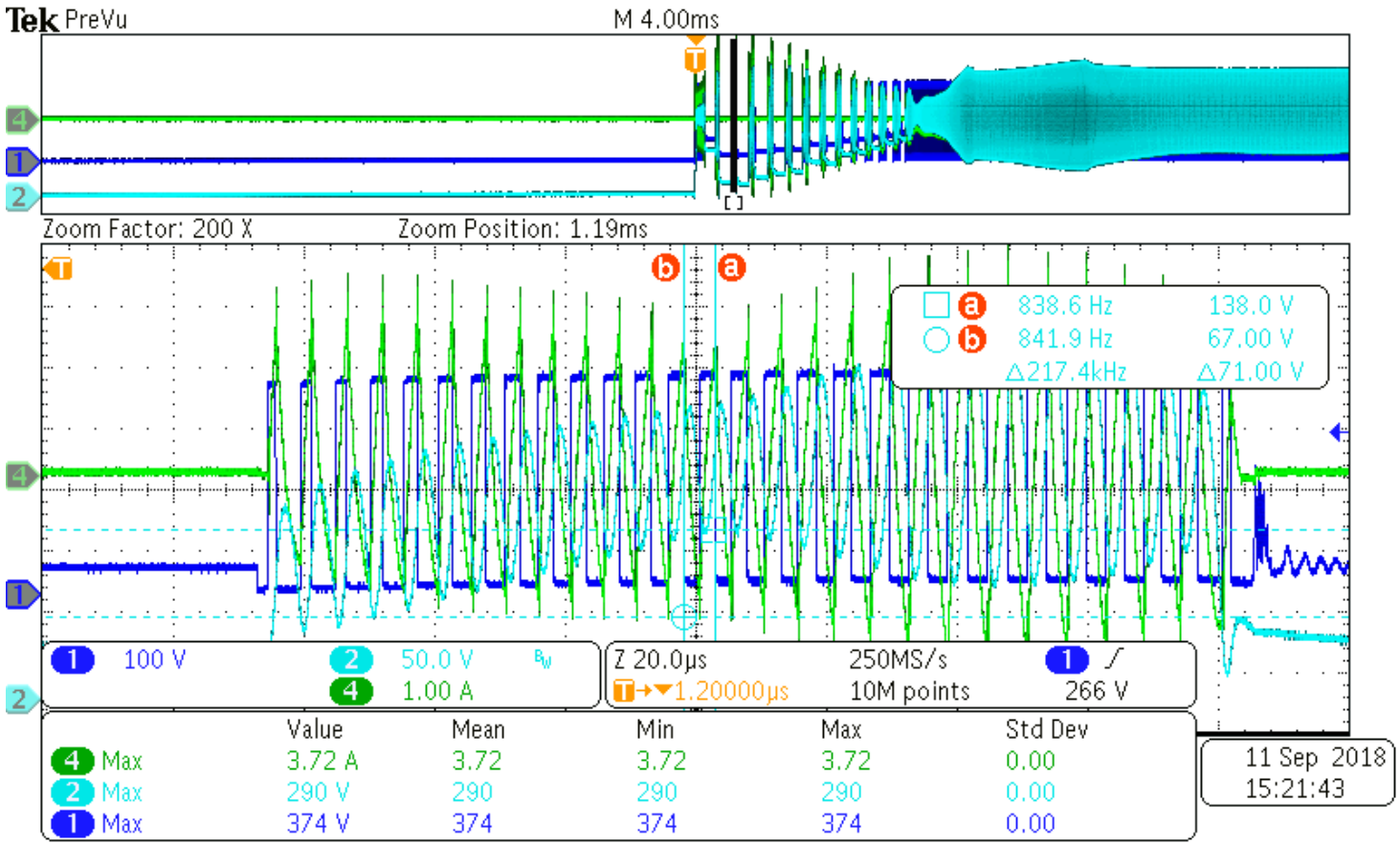


# LLC part wave form(normal condition)



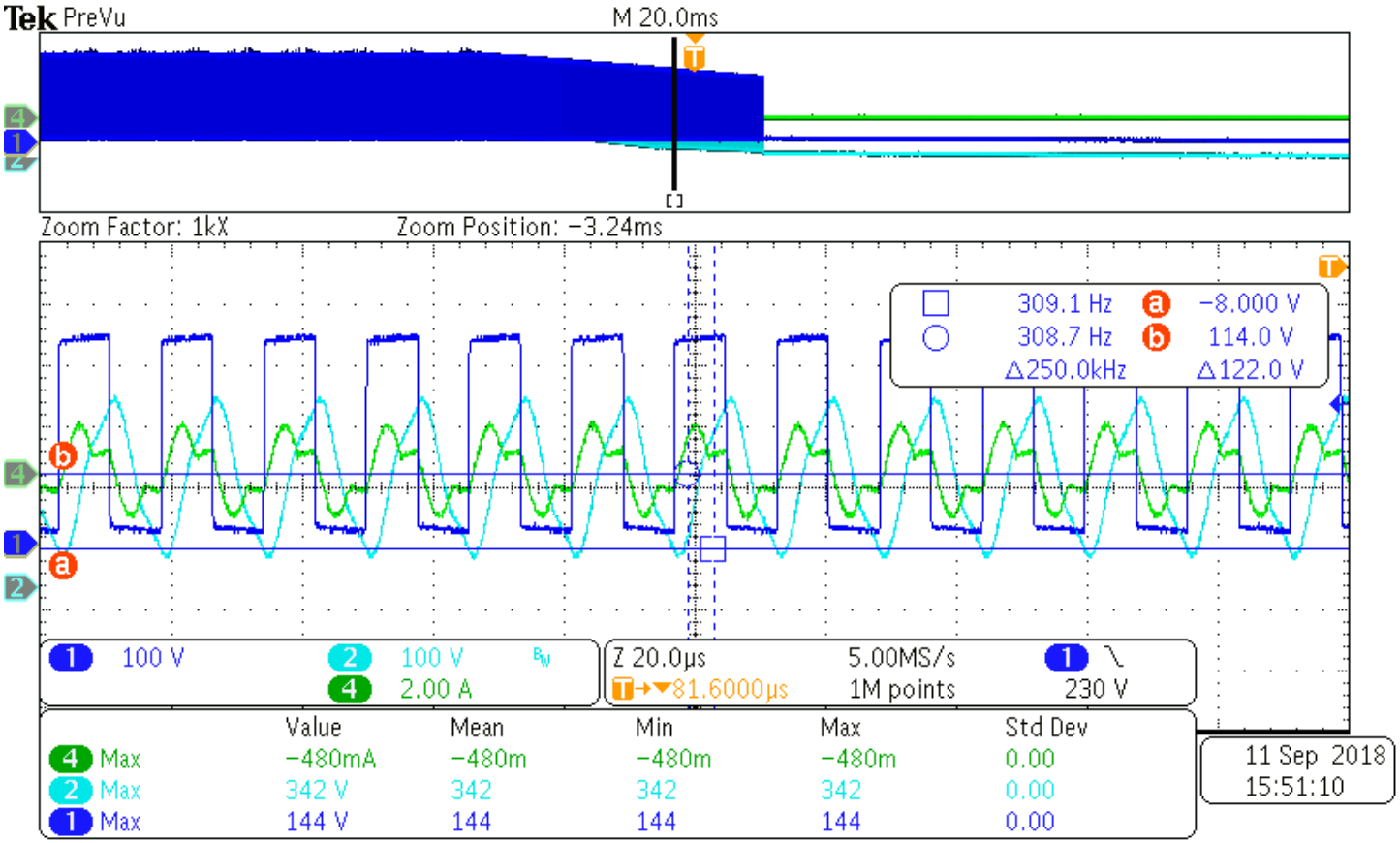

CH1-VHB CH2- resonant cap C2 voltage
CH4- resonant current

# LLC part wave form(start up)



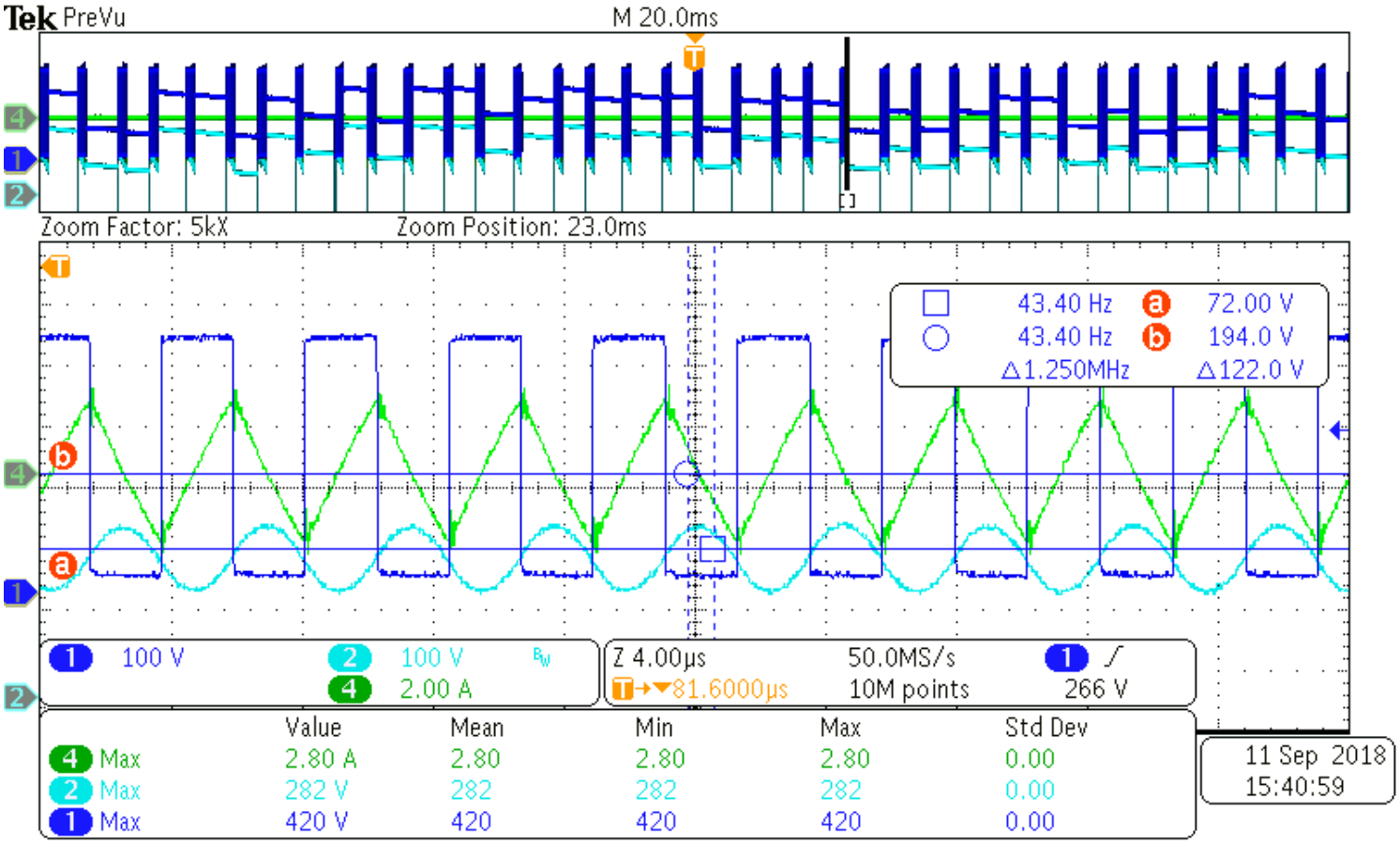

CH1-VHB CH2- resonant cap C2 voltage
CH4- resonant current

# LLC part wave form(shut down)



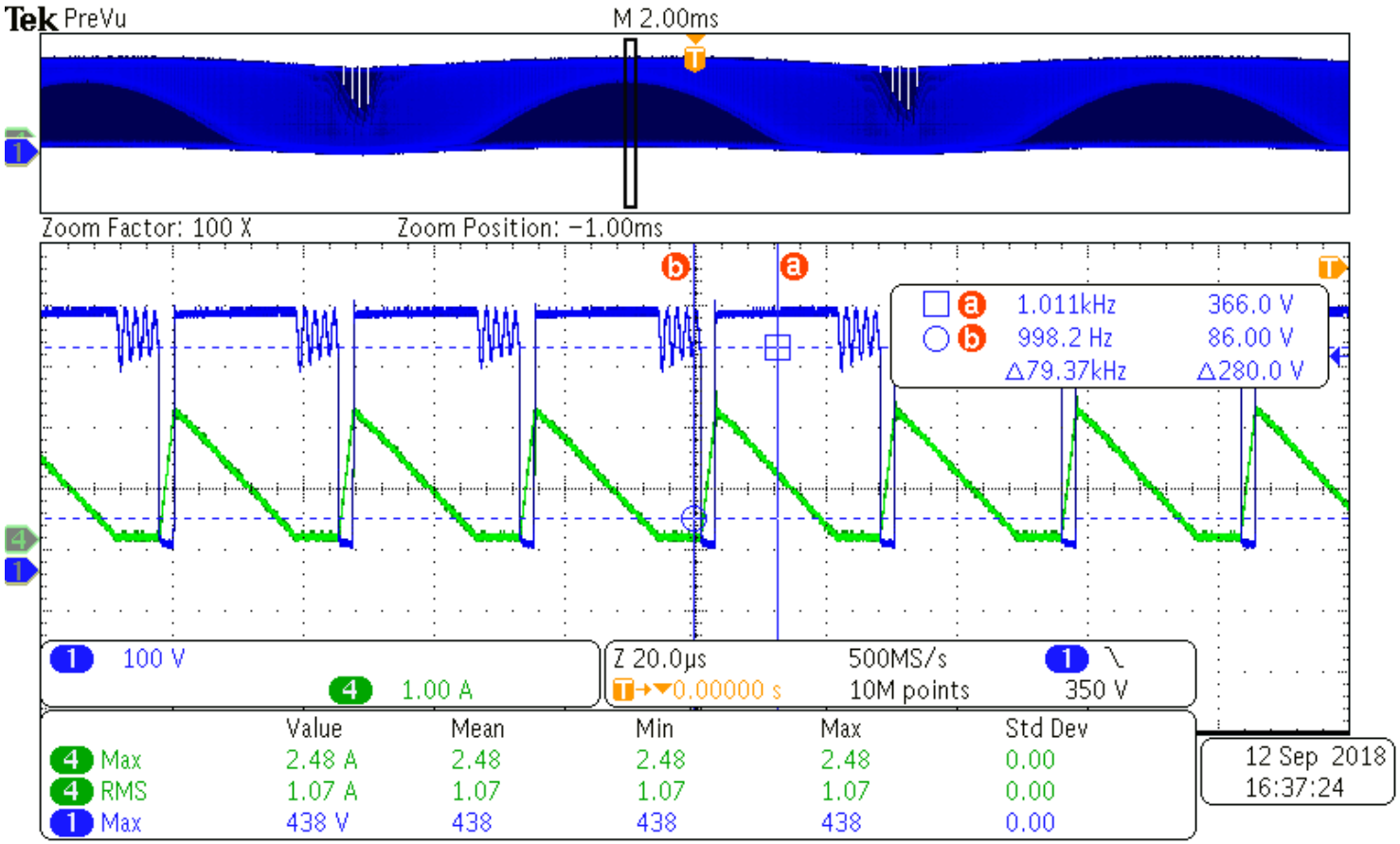

CH1-VHB CH2- resonant cap C2 voltage
CH4- resonant current

# LLC part wave form(output short circuit)




CH1-VHB CH2- resonant cap C2 voltage
CH4- resonant current

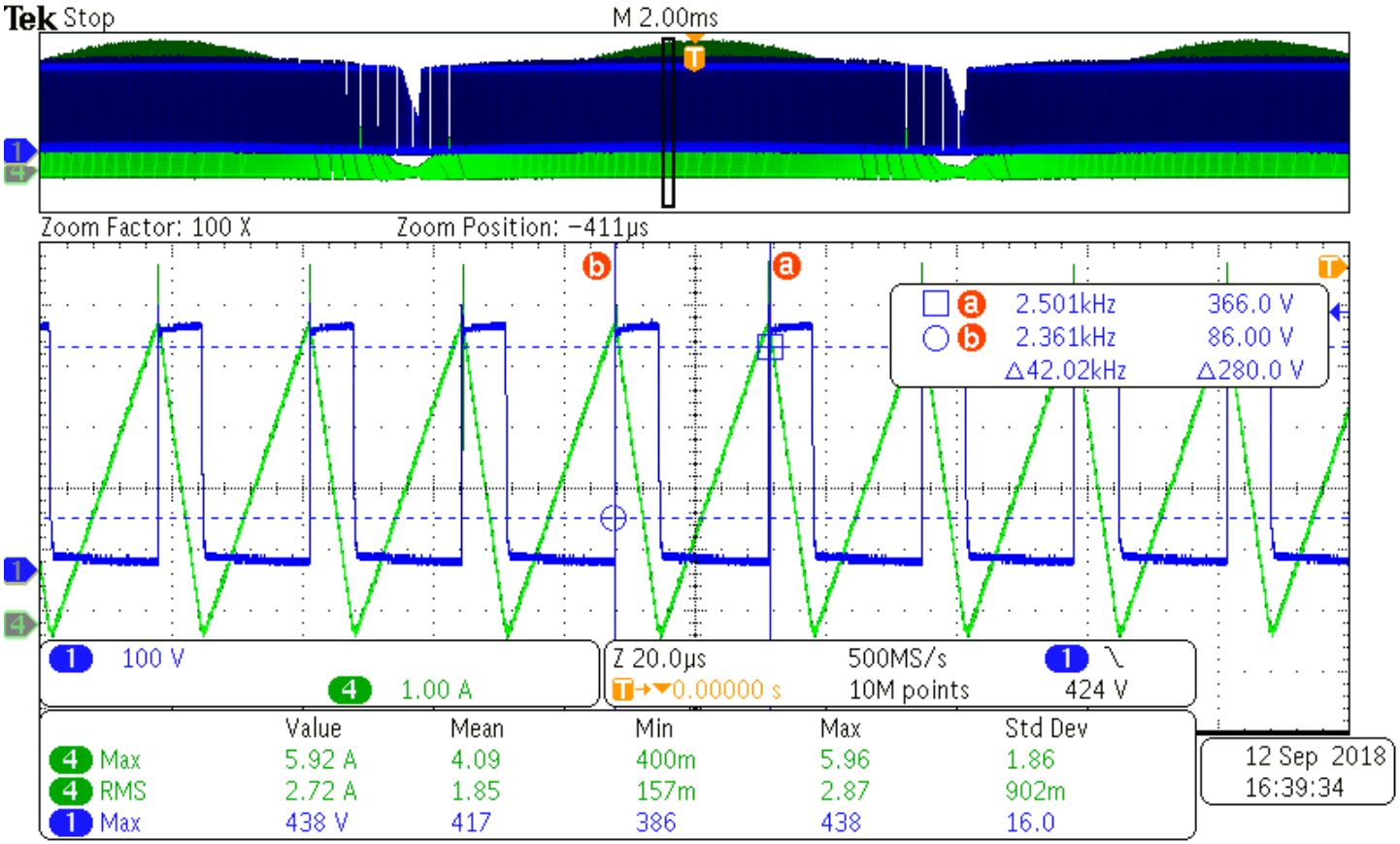
# PFC part MOSFET wave form(270VAC)




CH1-Vdrain

CH4- PFC MOSFET current

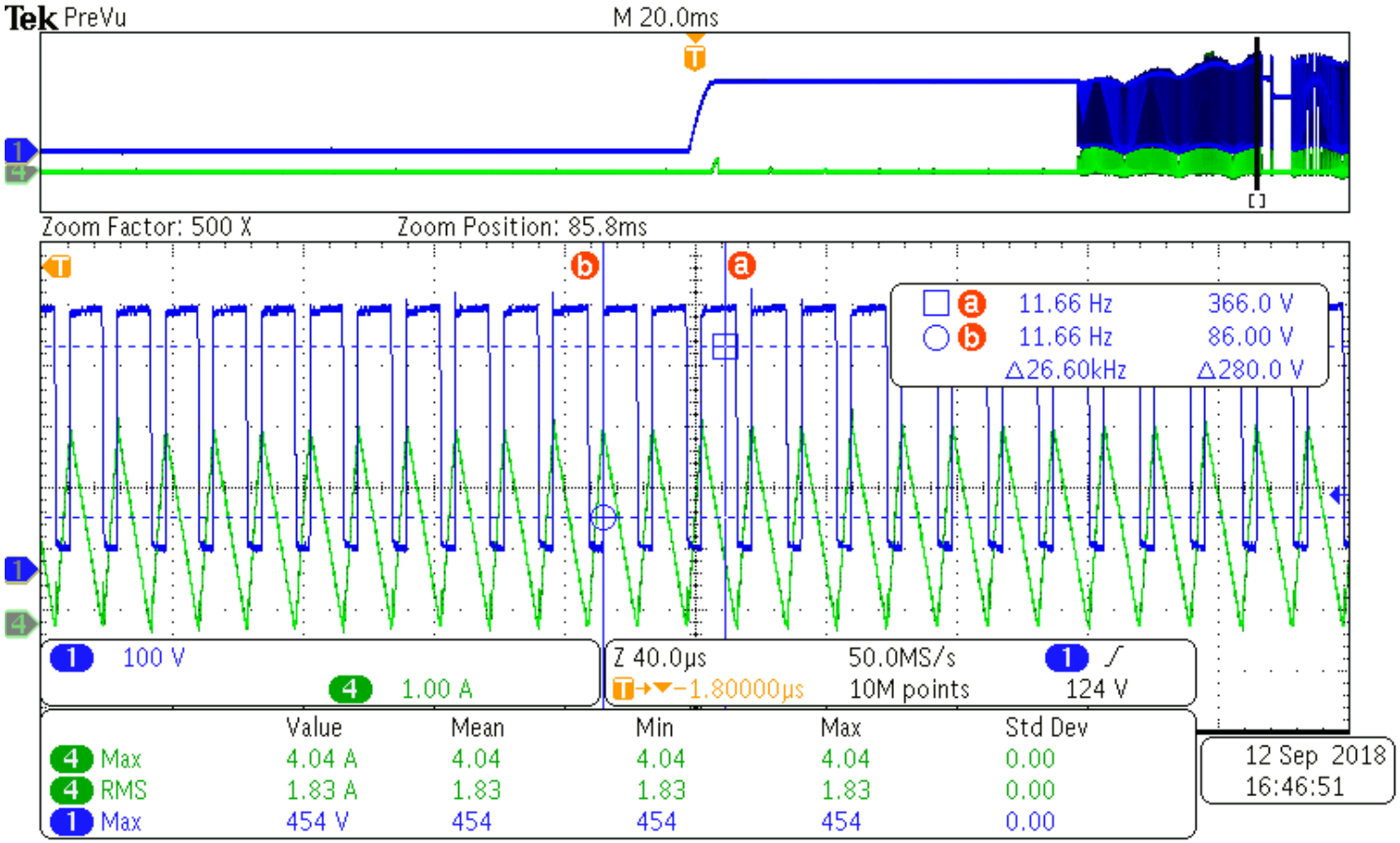
# PFC part MOSFET wave form(90VAC)




CH1-Vdrain

CH4- PFC MOSFET current

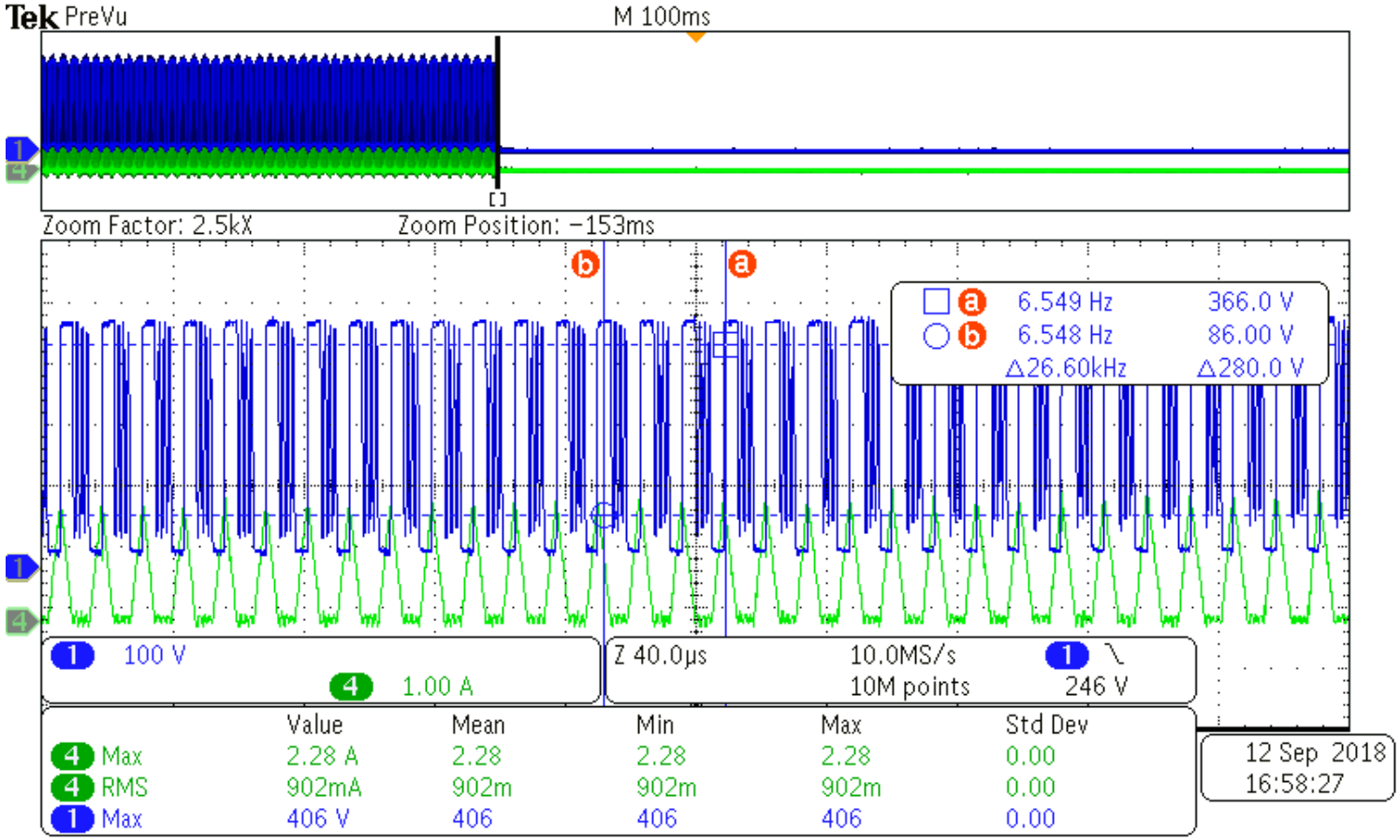
# PFC part MOSFET wave form(90VAC start up)




CH1-Vdrain

CH4- PFC MOSFET current

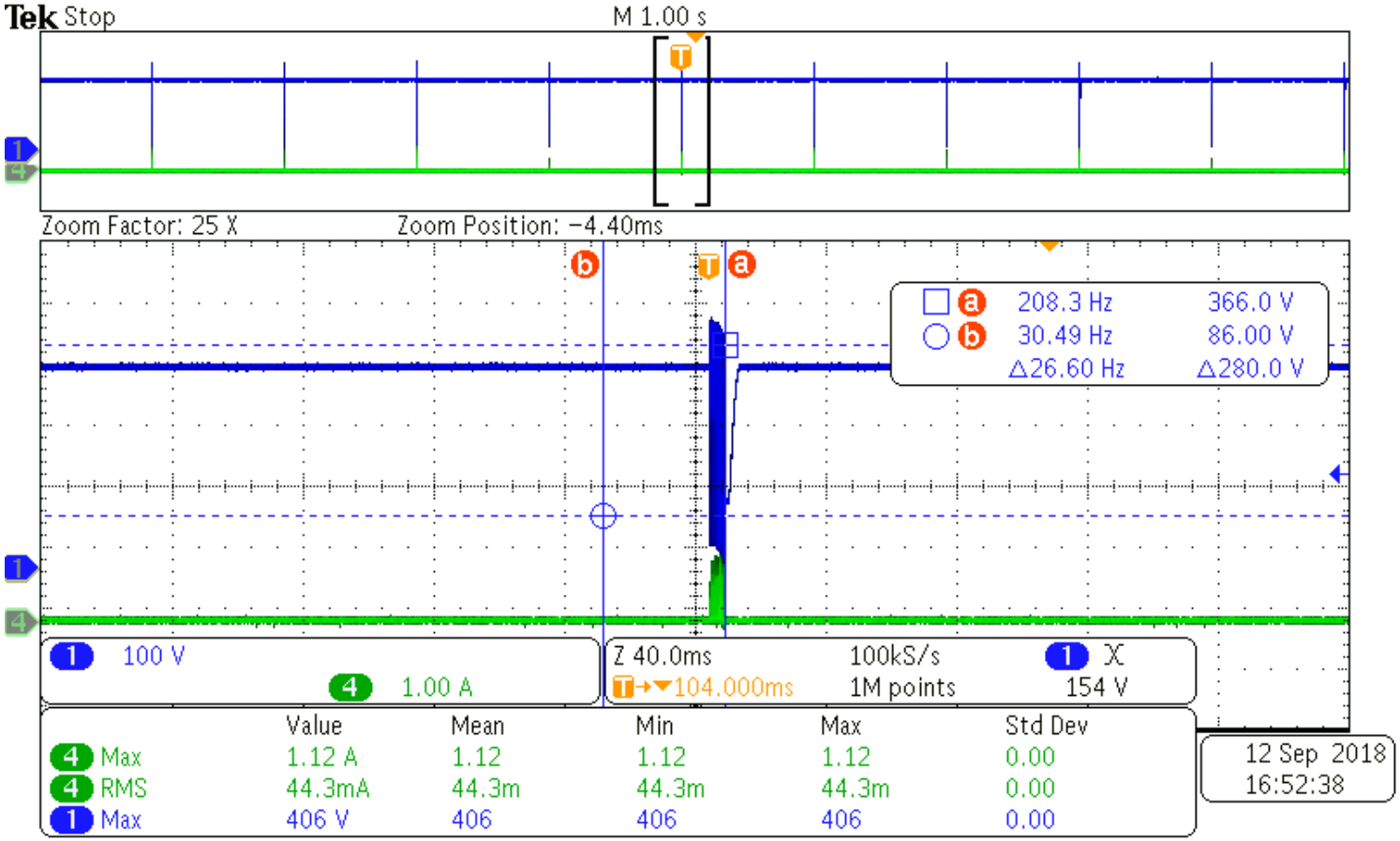
# PFC part MOSFET wave form(shut down)




CH1-Vdrain

CH4- PFC MOSFET current

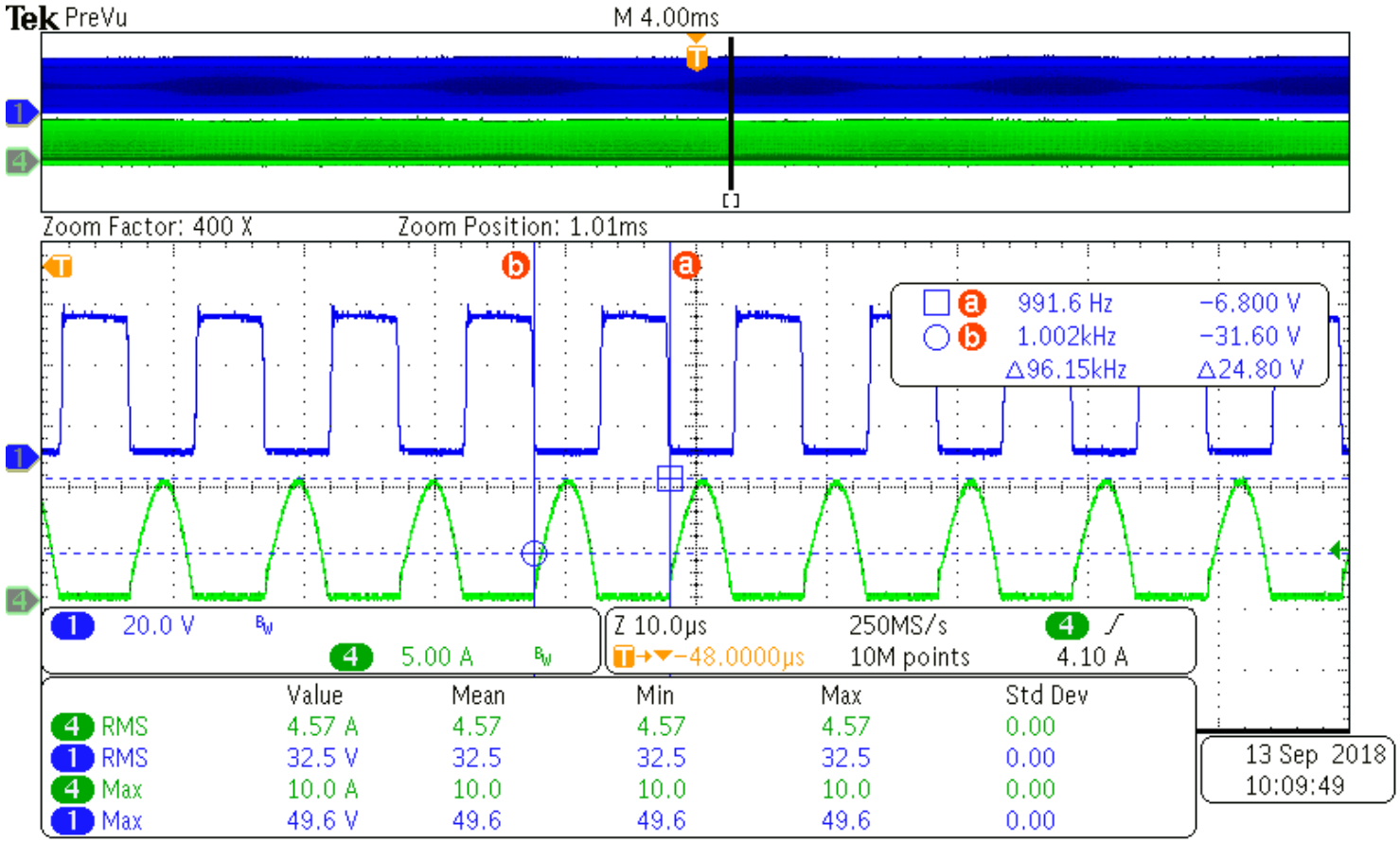
# PFC part MOSFET wave form(short circuit)




CH1-Vdrain

CH4- PFC MOSFET current

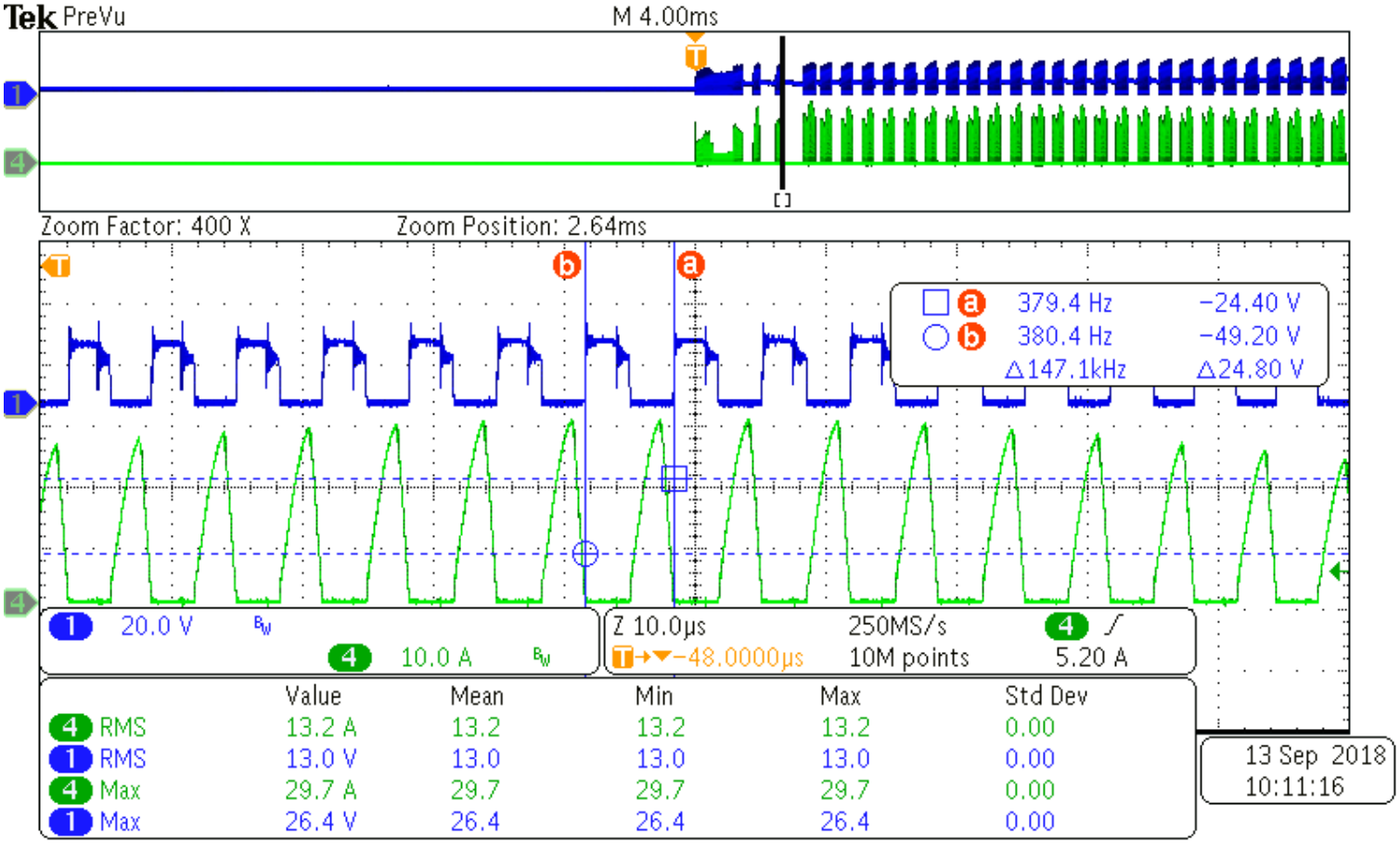
# Second side rectifier wave form(normal)




CH1- Second side rectifier diode voltage

CH4- Second side rectifier diode current

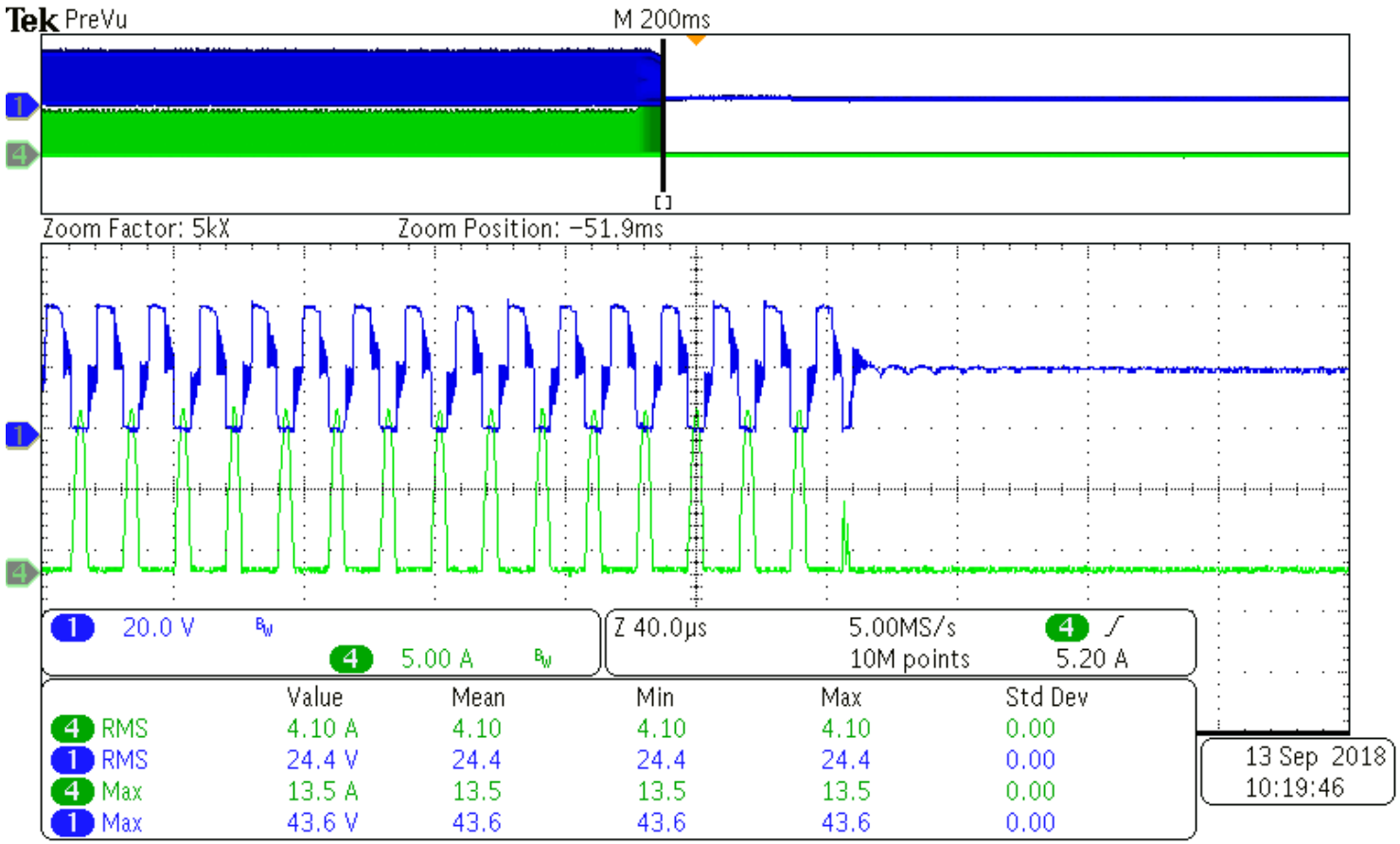
# Second side rectifier wave form(start up)




CH1- Second side rectifier diode voltage

CH4- Second side rectifier diode current

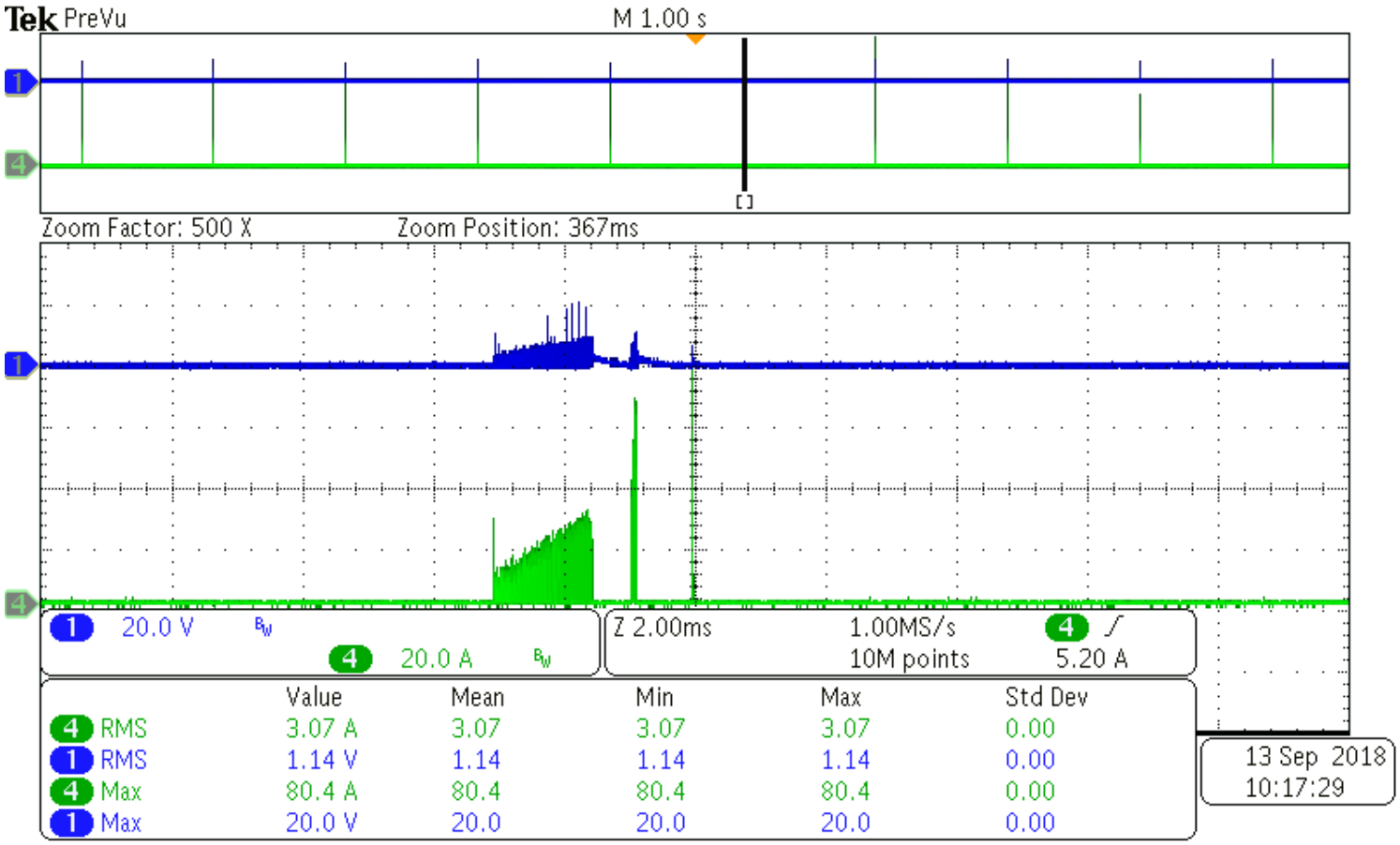
# Second side rectifier wave form(shut down)




CH1- Second side rectifier diode voltage

CH4- Second side rectifier diode current

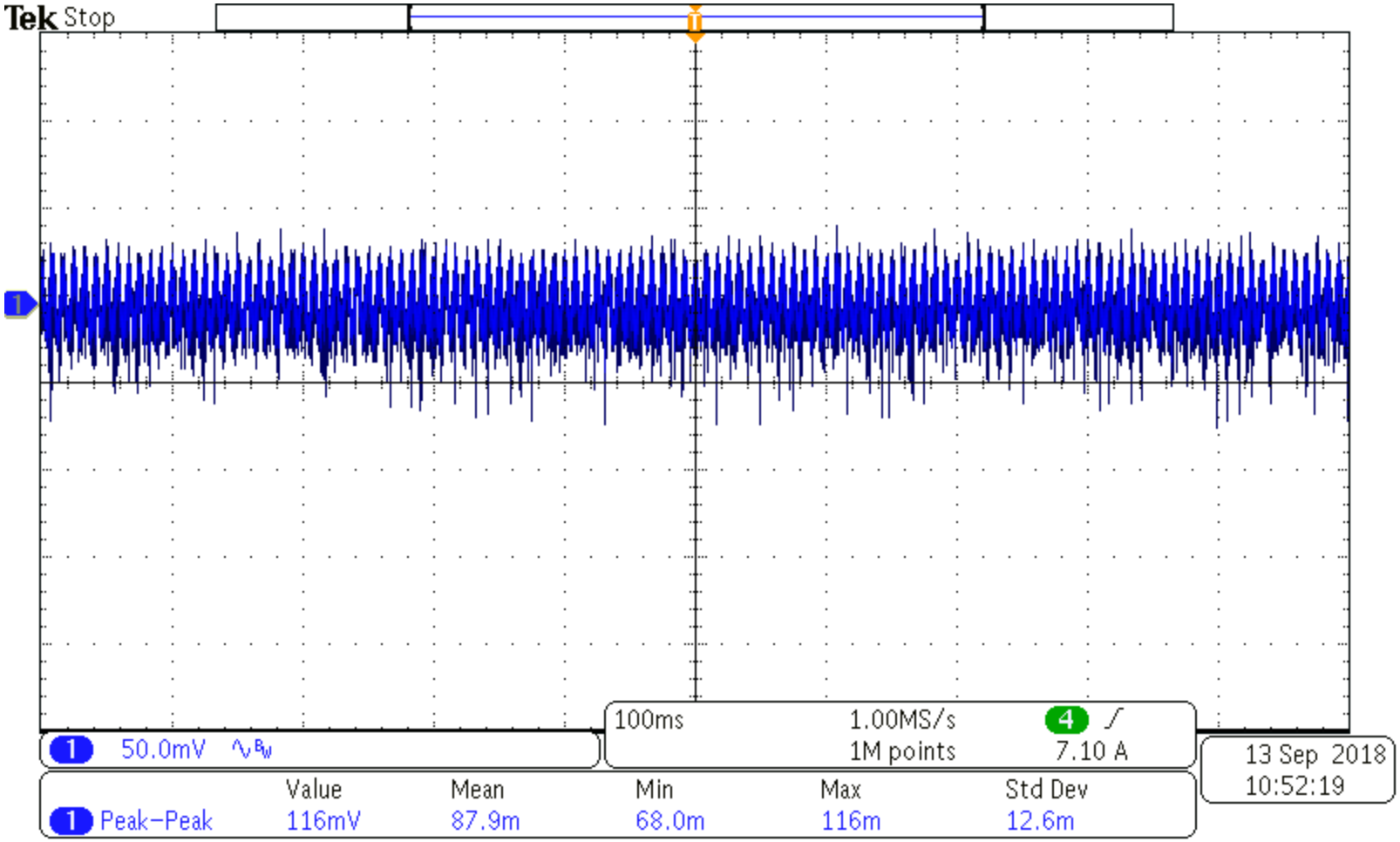
# Second side rectifier wave form(short circuit)



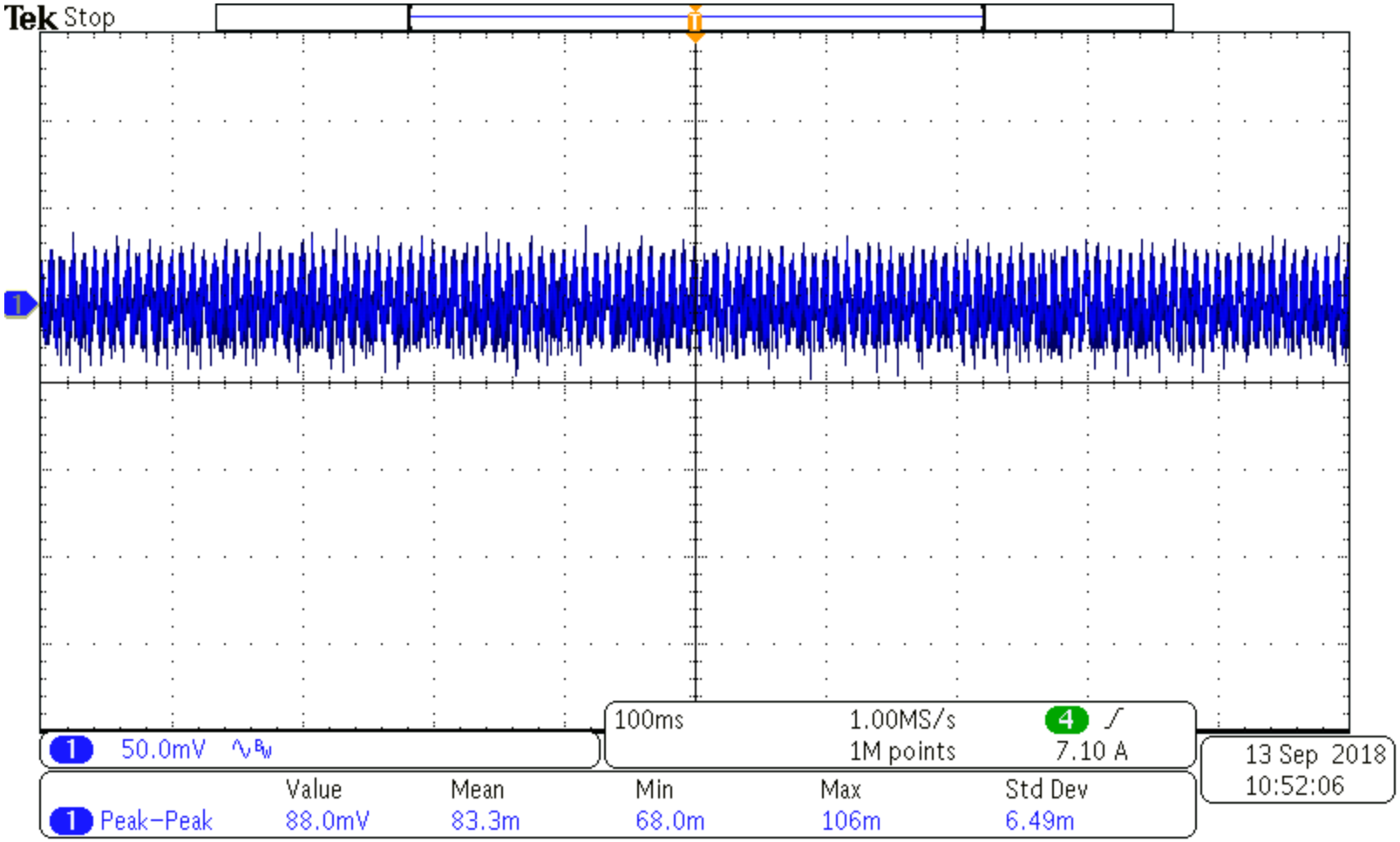

CH1- Second side rectifier diode voltage

CH4- Second side rectifier diode current

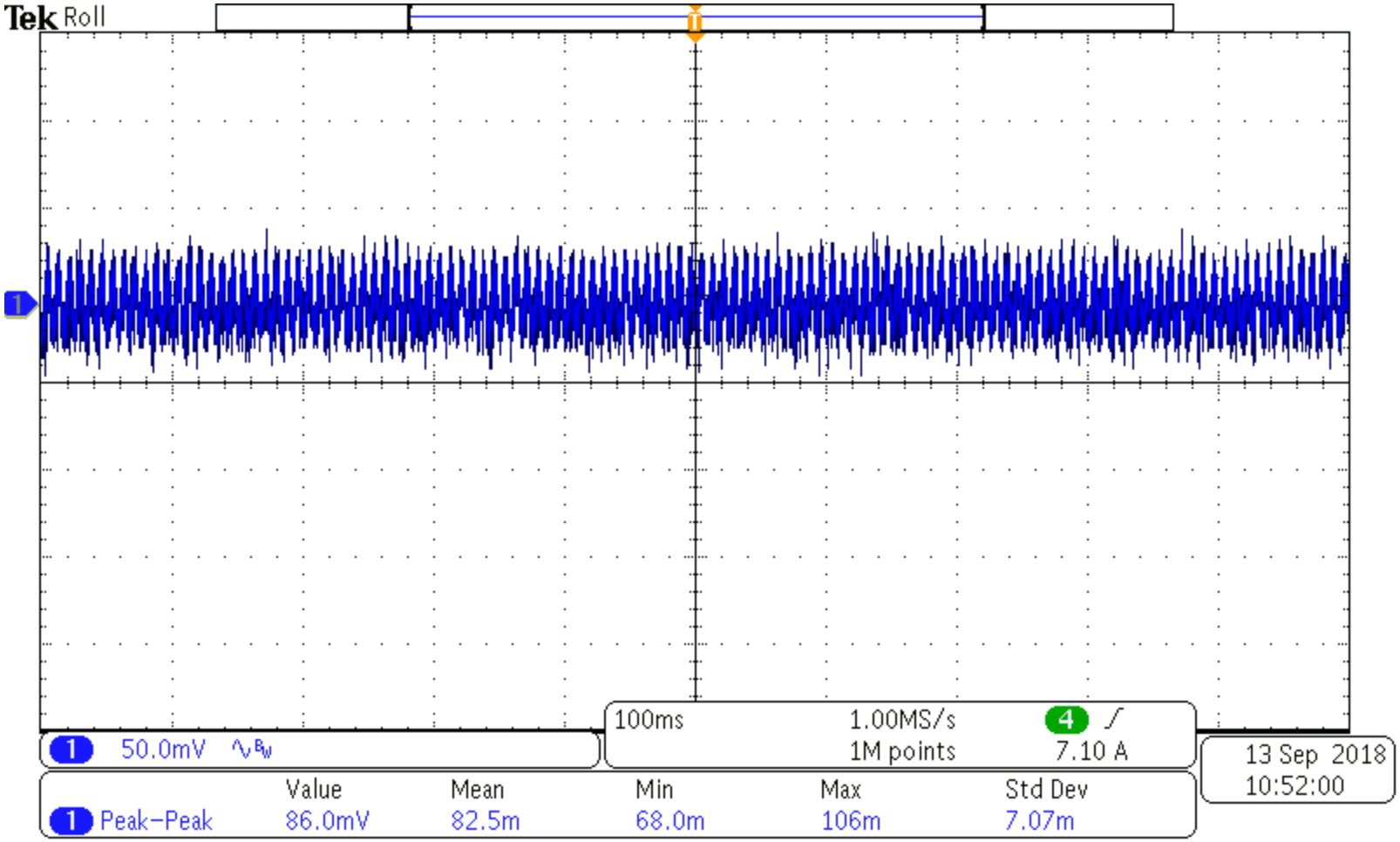
# Output voltage ripple(90Vac)



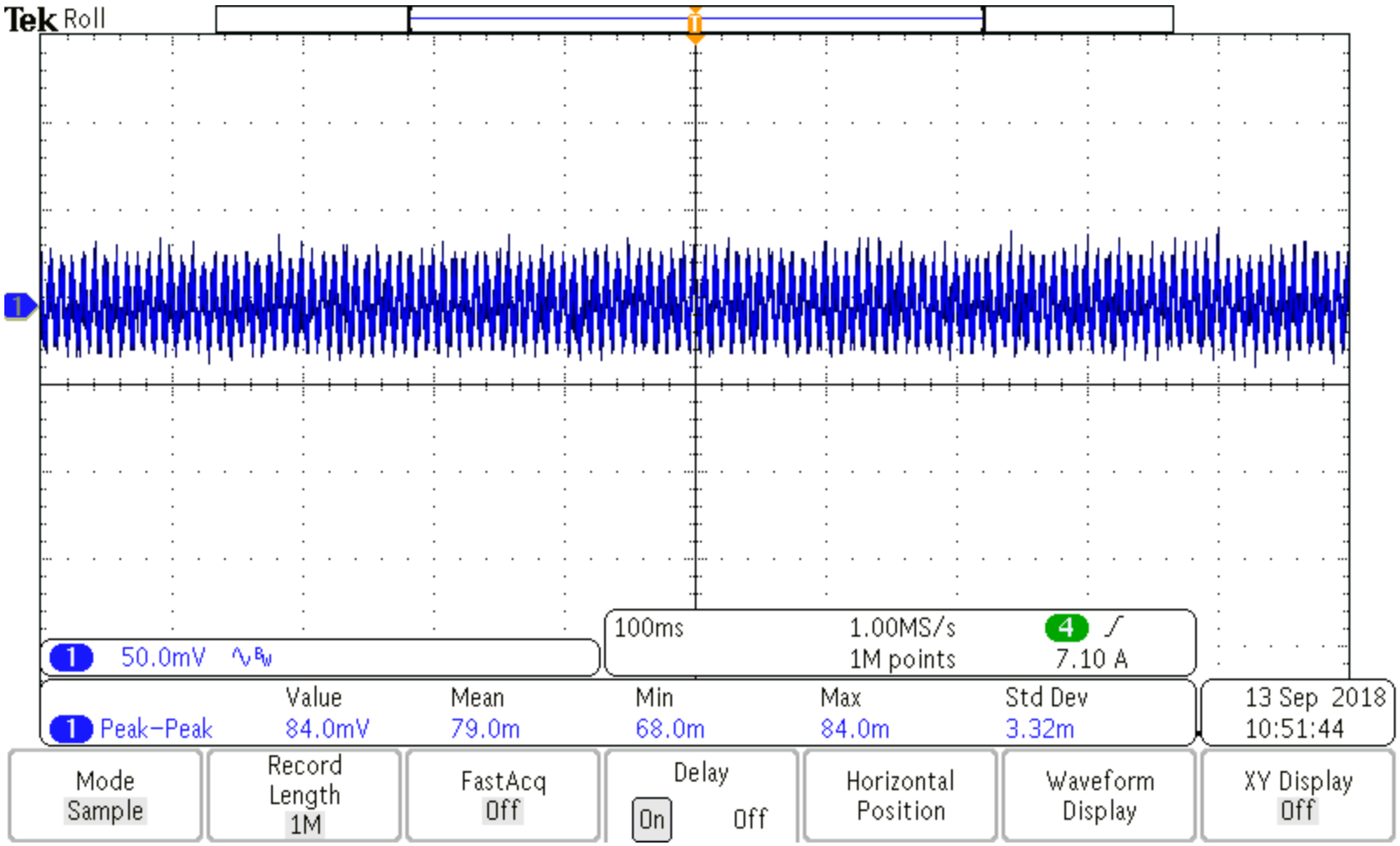
# Output voltage ripple(115Vac)



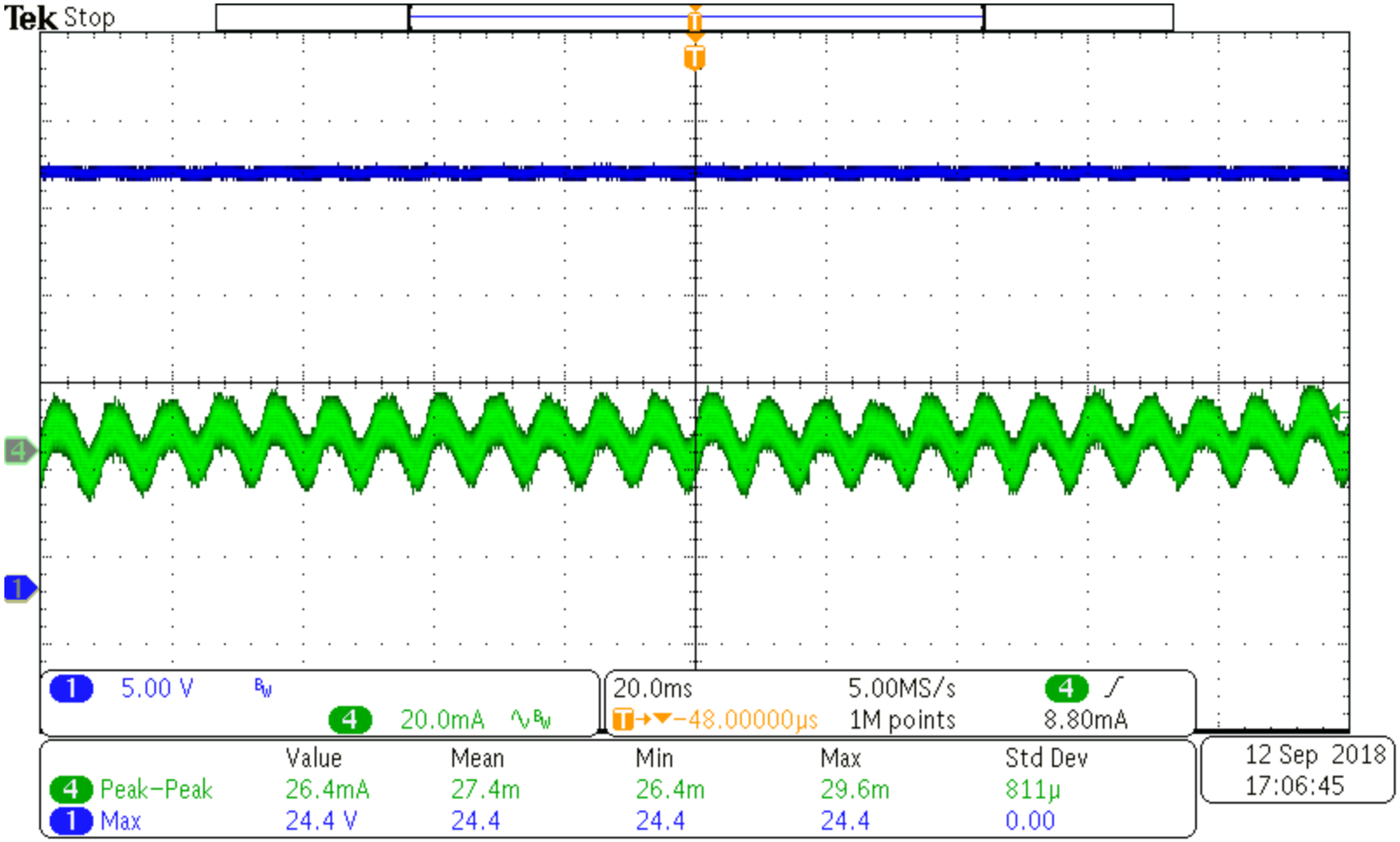
# Output voltage ripple(230Vac)



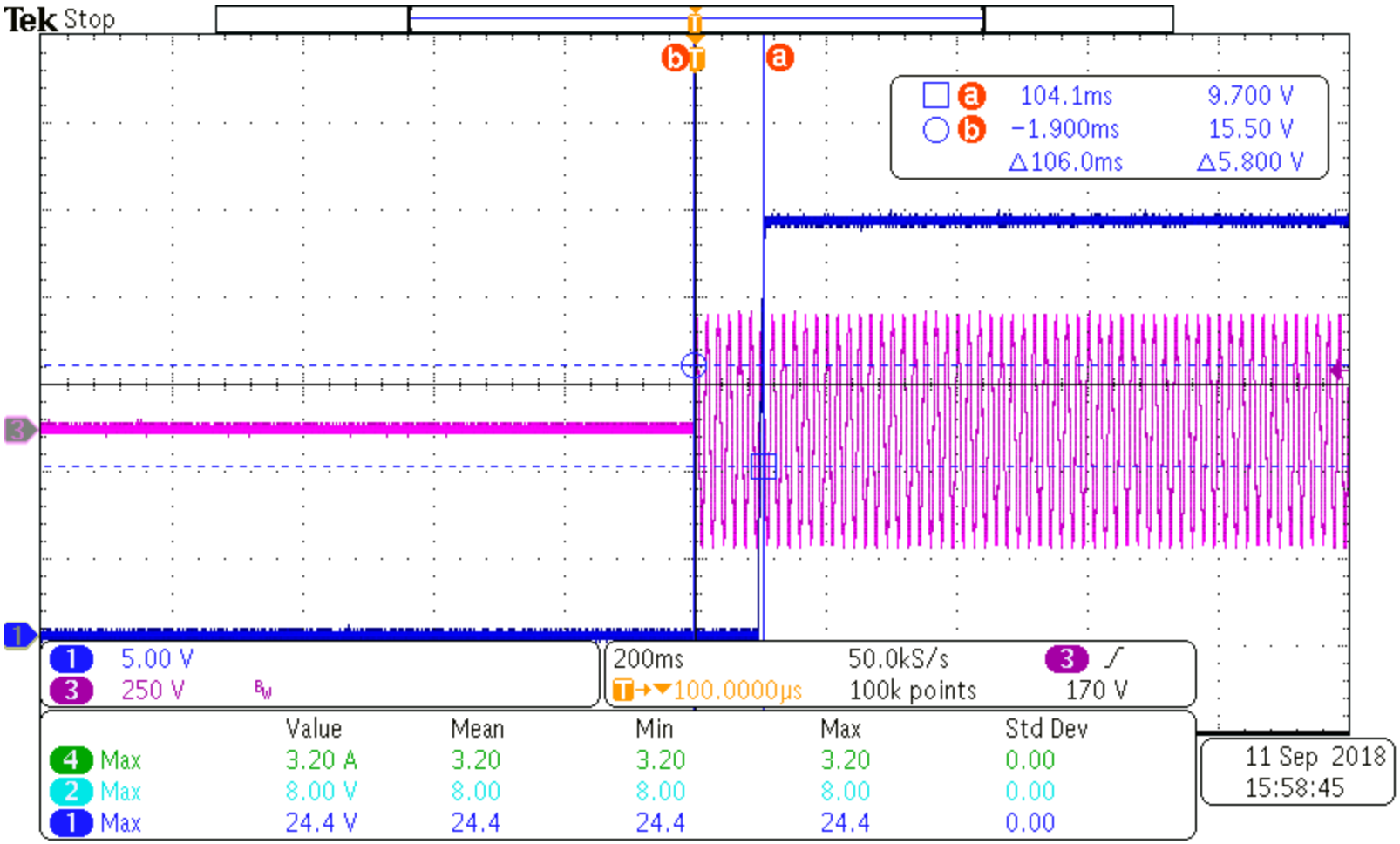
# Output voltage ripple(270Vac)



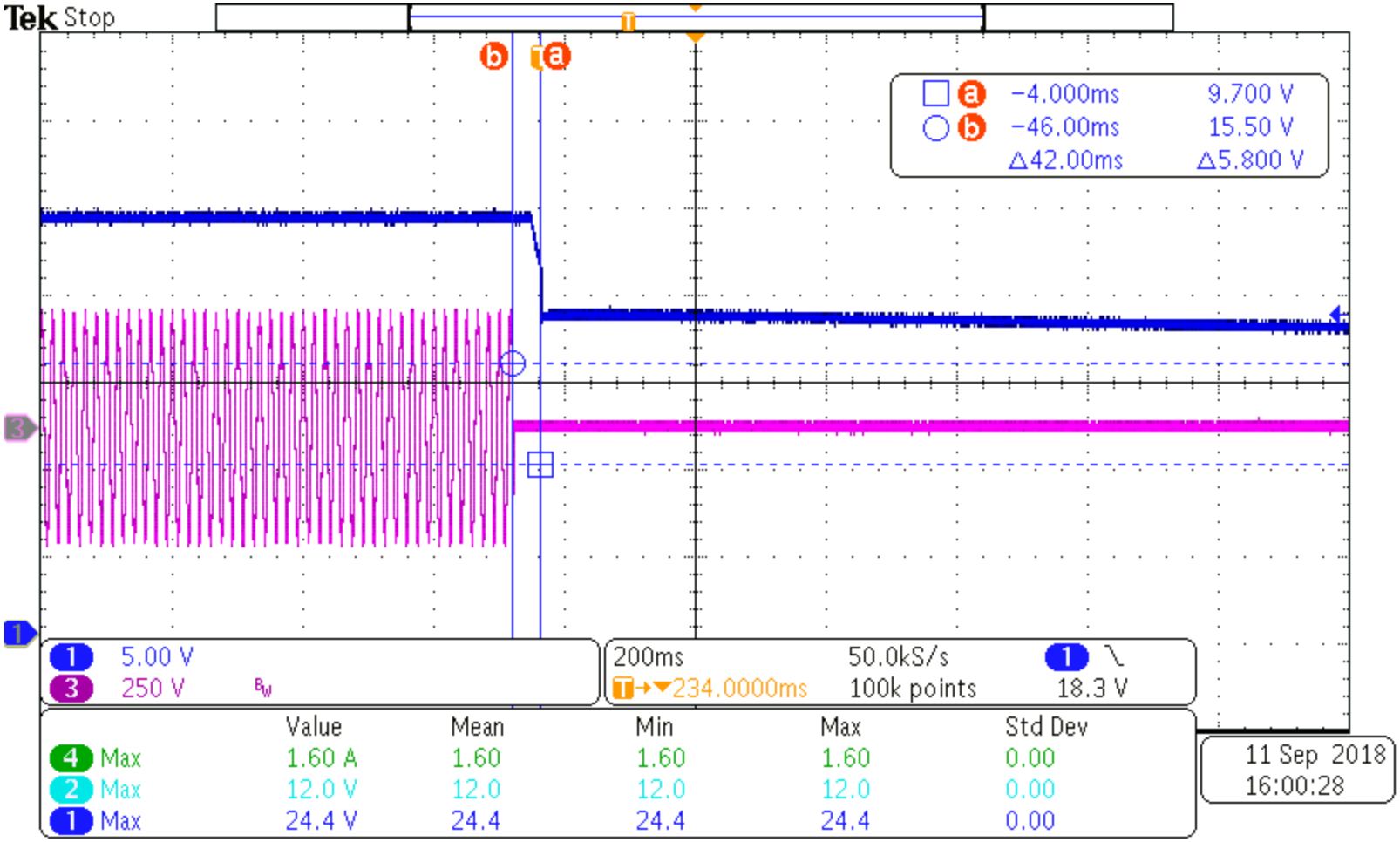
# Output current ripple



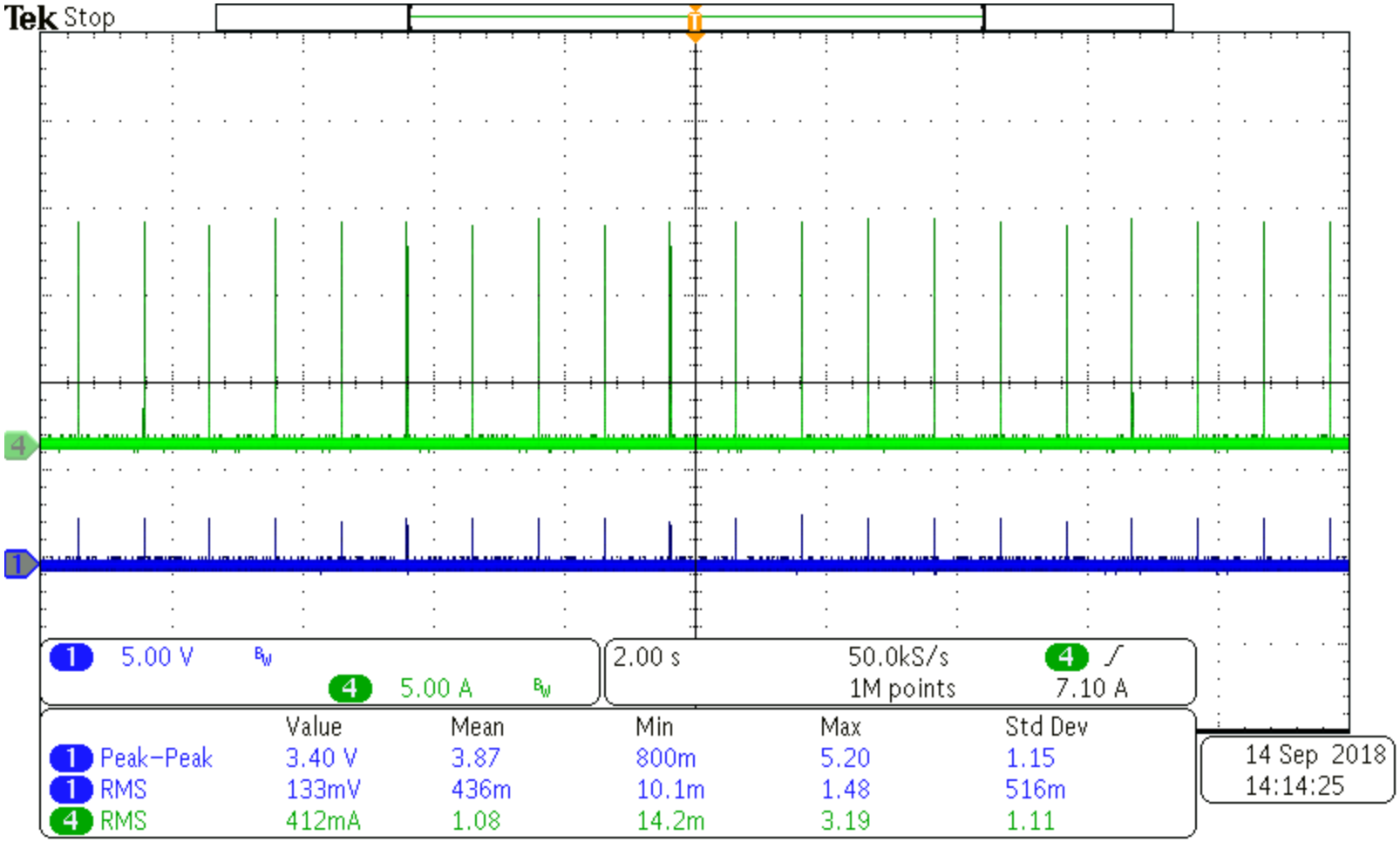
# Start up delay time



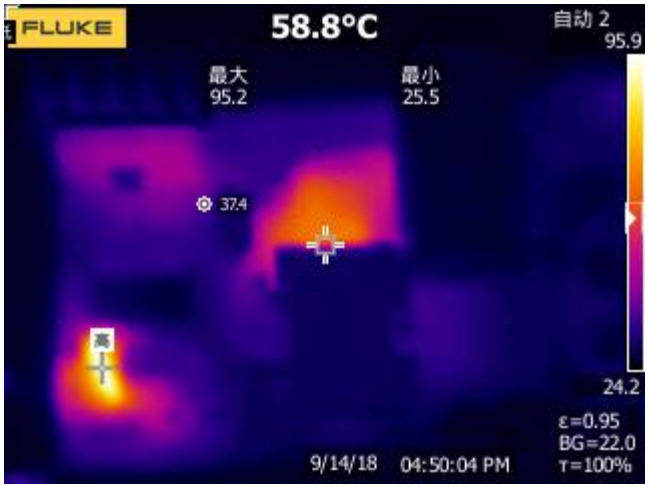
# Hold-up time



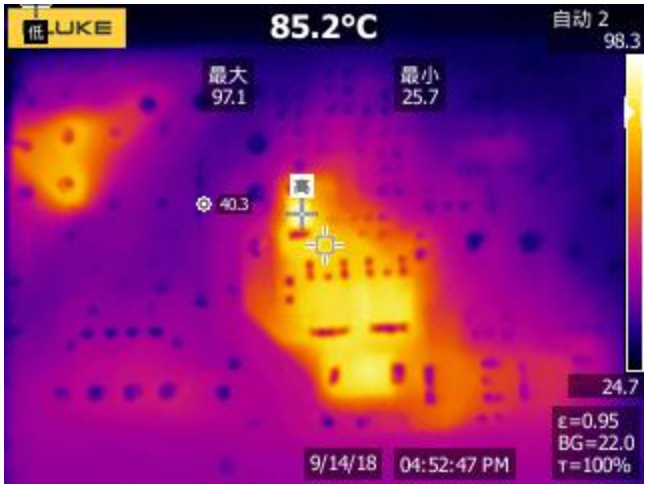
# Output voltage VS current(short circuit)



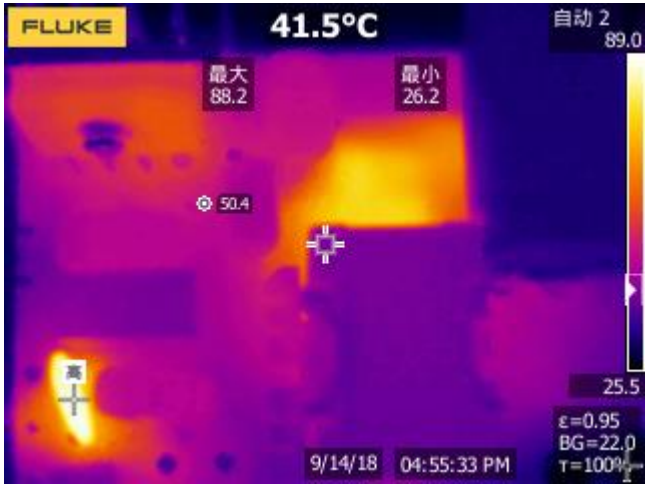
# Thermal Image At 24V6A



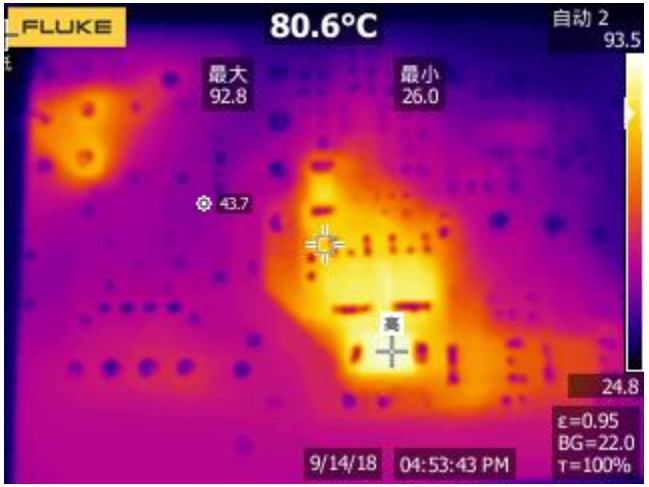

90Vac, component side




90Vac, back side

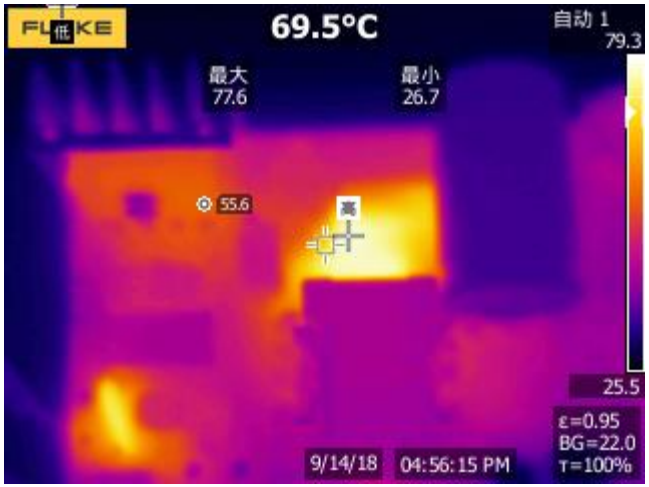



115Vac, component side

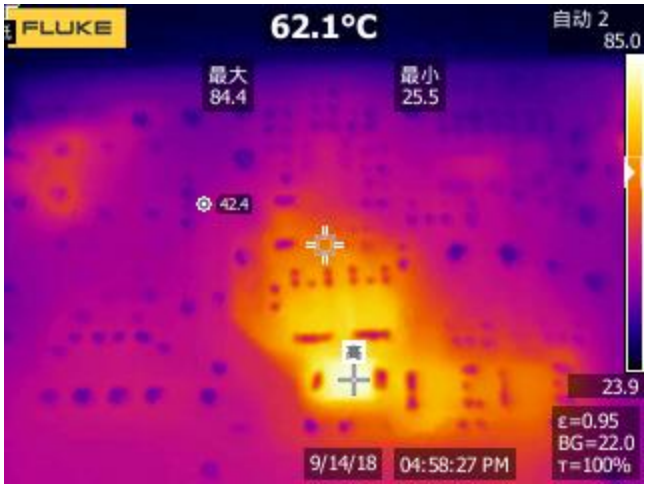



115Vac, back side

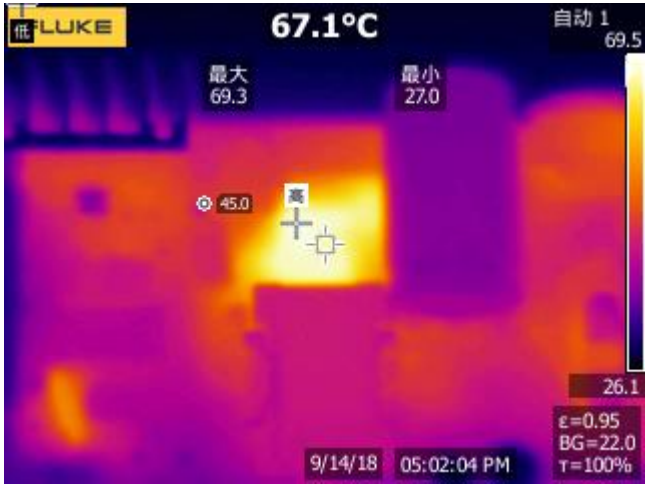
# Thermal Image At 24V6A



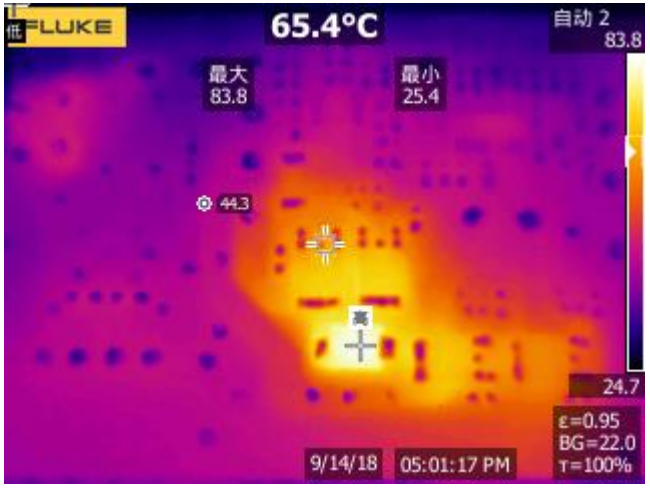

230Vac, component side




230Vac, back side




264Vac, component side




264Vac, back side

# BOM

| Item | Qty | Reference | Type | Part Name | MFR | Value | Package | Description |
|---|---|---|---|---|---|---|---|---|
| 1 | 1 | R9 | NTC | SPNL09D1R5MBI | SUNLORD | 1.5ohm | | |
| 2 | 1 | F1 | FUSE | 3.15A/250VAC | HOLLFUSE | 3.15A/250VAC | | |
| 3 | 1 | MOV1 | VARISTOR | 14D471 | WE | 14D471 | | |
| 4 | 1 | L1 | Common filter | | WE | 100uH | | |
| 5 | 1 | L2 | Common filter | | WE | 10mH | | |
| 6 | 1 | L3 | Dis-common filter | | WE | 100uH | | |
| 7 | 1 | L4 | PFC choke | | WE | 400uH | PQ2625 | |
| 8 | 1 | L5 | Output dis-com filter | | WE | 5uH | | |
| 9 | 1 | L6 | LLC resonant choke | | WE | 100uH | EE19 | |
| 10 | 1 | W | LLC transformer | | WE | 850uH | PQ3230 | |
| 11 | 2 | R1,R2 | Resistor | Std | Std | 470K/0805 | 0805 | |
| 12 | 1 | R7 | Resistor | Std | Std | 1M8/0805 | 0805 | |
| 13 | 1 | R8 | Resistor | Std | Std | 1M5/0805 | 0805 | |
| 14 | 4 | R14,R30,R22,R23 | Resistor | Std | Std | 22K/0805 | 0805 | |
| 15 | 1 | R6 | Resistor | Std | Std | 27K/0805 | 0805 | |
| 16 | 1 | R5 | Resistor | Std | Std | 13K/0805 | 0805 | |
| 17 | 2 | R29, R34 | Resistor | Std | Std | 15K/0805 | 0805 | |
| 18 | 1 | R3 | Resistor | Std | Std | 20K/0805 | 0805 | |
| 19 | 1 | R15 | Resistor | Std | Std | 150R/0805 | 0805 | |
| 20 | 1 | R17 | Resistor | Std | panasonic | 0R15/2510 | 2512 | |
| 21 | 3 | R13,R18,R20 | Resistor | Std | Std | 10R/0805 | 0805 | |
| 22 | 5 | R10,R19,R21,R24,R47 | Resistor | Std | Std | 22R/0805 | 0805 | |
| 23 | 2 | R12,R11 | Resistor | Std | Std | 2M4/0805 | 0805 | |
| 24 | 1 | R4 | Resistor | Std | Std | 56K/0805 | 0805 | |
| 25 | 2 | R27,R28 | Resistor | Std | Std | 2K7/0805 | 0805 | |
| 26 | 1 | R25 | Resistor | Std | Std | 5R6/0805 | 0805 | |
| 27 | 1 | R37 | Resistor | Std | Std | 100R/0805 | 0805 | |
| 28 | 3 | R35,R36,R46 | Resistor | Std | Std | 2K2/0805 | 0805 | |
| 29 | 2 | R26,R33 | Resistor | Std | Std | 4K7/0805 | 0805 | |
| 30 | 1 | R32 | Resistor | Std | Std | NC | 0805 | |
| 31 | 2 | R38,R39 | Resistor | Std | panasonic | 0R02 | 2512 | |
| 32 | 1 | R43 | Resistor | Std | Std | 1K/0805 | 0805 | |
| 33 | 1 | R42 | Resistor | Std | Std | 10K/0805 | 0805 | |
| 34 | 1 | R44 | Resistor | Std | Std | 8.2K | 0805 | |

# BOM(Continued)

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 35 | 1 | R45 | Resistor | Std | Std | 12K | 0805 | |
| 36 | 1 | R48 | Resistor | Std | Std | 1K1/0805 | 0805 | |
| 37 | 2 | C5,C6 | X-cap | | WE | 275VAC/474 | | |
| 38 | 1 | C3 | E-cap | | WE | 150uF/450V | | |
| 39 | 3 | C14,C25,C20 | E-cap | | WE | 35V/560uF | | |
| 40 | 1 | C1 | Film capacitor | | panasonic | 450V/1uF | | |
| 41 | 1 | C2 | Film capacitor | | panasonic | 22nF/1600V | | |
| 42 | 5 | C9,C24,C22 | Ceramic cap | | WE | 102/25V | 0805 | |
| 43 | 2 | C7,C19 | Ceramic cap | | WE | 225/25V | 0805 | |
| 44 | 1 | C8 | Ceramic cap | | WE | NC | 0805 | |
| 45 | 3 | C18,C30,C16 | Ceramic cap | | WE | 224/25V | 0805 | |
| 46 | 1 | C4 | Ceramic cap | | WE | 475/25V | 0805 | |
| 47 | 2 | C10,C31 | Ceramic cap | | WE | 103/25V | 805 | |
| 48 | 2 | C21,C35 | Ceramic cap | | WE | 47uF/35V | 0805 | |
| 49 | 2 | C33,C15 | Ceramic cap | | WE | 223/25V | 0805 | |
| 50 | 1 | C17 | Ceramic cap | | WE | 104/25V | 0805 | |
| 51 | 2 | C23,C26 | Ceramic cap | | WE | 4u7/25V | 0805 | |
| 52 | 1 | C32 | Ceramic cap | | WE | 220pf/1KV | 1206 | |
| 53 | 1 | Q2 | BJT | BC807 | ON | | SO23 | |
| 54 | 2 | Q1,Q4 | BJT | BC817 | ON | | SO23 | |
| 55 | 2 | T2,T5 | MOSFET | FCD260N65 | ON | | D-PARK/TO252 | |
| 56 | 2 | T3,T4 | MOSFET | FCD600N65 | ON | | D-PARK/TO252 | |
| 57 | 2 | T101,T102 | DIODE | MBR20L60 | ON | | TO-220 | |
| 58 | 1 | D1 | Diode | MUR460 | ON | | SMC | |
| 59 | 2 | D4,D5 | DIODE | 1N4148 | ON | | SOD323 | |
| 60 | 4 | D2,D3,D10,D11 | Diode | ES1J | ON | | SMA | |
| 61 | 1 | D12 | Diode bridge | GBU806 | ON | | Micro-DIP | |
| 62 | 3 | D6,D9,D7 | DIODE | RS1D | ON | | SMA | |
| 63 | 1 | U1 | LLC controller | NCP13992AC | ON | | | |
| 64 | 1 | U2 | PFC controller | NCL2801CDB | ON | | | |
| 65 | 1 | U3 | Optical coupler | FODM1007 | ON | | LSOP4 | |
| 66 | 1 | U4 | Second side CC/CV controller | NCP4328BSNT1G | ON | | | |
| 67 | 2 | Z2,Z3 | Zener | MMSZ15 | ON | 15V | SOD323 | |
| 68 | 1 | Heat-sink for bridge diode | | | | | | |
| 69 | 1 | Heat-sink for second side rectifier | | | | | | |

# Conclusion

- Suitable for lighting requirement
- High PF value
- Low THD value
- Full load efficiency >93% at 24V output, 230Vac
- <0.3W standby power
- <200mV ripple and noise
- OCP protection
- CC and CV mode
- Not Test EMI yet