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ON Semiconductor

Design Note – DN05119/D

NCP1568 Ultra-High Density USBPD Laptop Adapter

Device	Application	Input Voltage	Output Power	Topology	I/O Isolation
NCP1568 NCP51530 NCP4306 FDMS86202	Ultra-High Density USBPD Laptop Adapter	90 Vac – 265 Vac	60 Watt	Active-Clamp Flyback	Isolated (3kV)

SPECIFICATIONS

Output Voltage	5, 9, 15, 20 V
Ripple	1 V
Nominal Current	3 A
Max Current	3 A
Min Current	Zero

Circuit Description

This design note describes a 60 W universal input 5 V, 9 V, 15 V and 20 V output ultra-high density power supply for laptop adapters. This featured power supply is an active-clamp flyback topology utilizing ON Semiconductor's NCP1568 PWM controller, NCP51530 HB Driver, NCP4306 SR Controller and FDMS86202 SR FET. This design note provides complete circuit schematic, PCB, BOM and transformer information of the evaluation board. It also provide efficiency, transient response, output ripple and thermal data of the evaluation board.

This design utilized NCP1568 and NCP51530 for the active-clamp flyback topology. Active-clamp flyback topology effectively recycles the leakage energy. Another feature of this topology is the ZVS operation of the power MOSFETS. Because of no leakage losses and ZVS operation, this topology is suited for high frequency operation which results in size reduction of the transformer. Hence active-clamp flyback topology is well suited for high power density sub 100 W power supplies. A ZVS fixed switching frequency power converter also simplifies EMI design and can be easily designed to avoid interference with other sensitive circuits in the system.

NCP1568 is a highly integrated AC-DC PWM controller designed to implement an active-clamp flyback topology. It features adaptive frequency scheme which optimizes frequency of operation and hence the efficiency over all load and input voltages. The NCP1568 features a HV startup circuit along. It also has integrated X2 discharge circuit.

NCP51530 is a 700 V high side and low side driver with 2 A current drive capability for AC-DC power supplies and inverters. NCP51530 offers best in class propagation delay, low quiescent current and low switching current at high frequencies of operation. This device is tailored for highly efficient power supplies operating at high frequencies.

NCP4306 is high performance driver tailored to control a synchronous rectification MOSFET in switch mode power supplies.

Key Features

- Universal AC input operation (90 - 265 Vac)
- High full load and average efficiency
- Low standby power
- Very low ripple and noise
- High frequency operation up to 450 kHz
- Inherent SCP and OCP protection
- Thermal and OVP protection
- Adaptive frequency operation based on AC input and output load conditions
- Adaptive ZVS operation
- Smaller EMI components
- Smooth startup operation

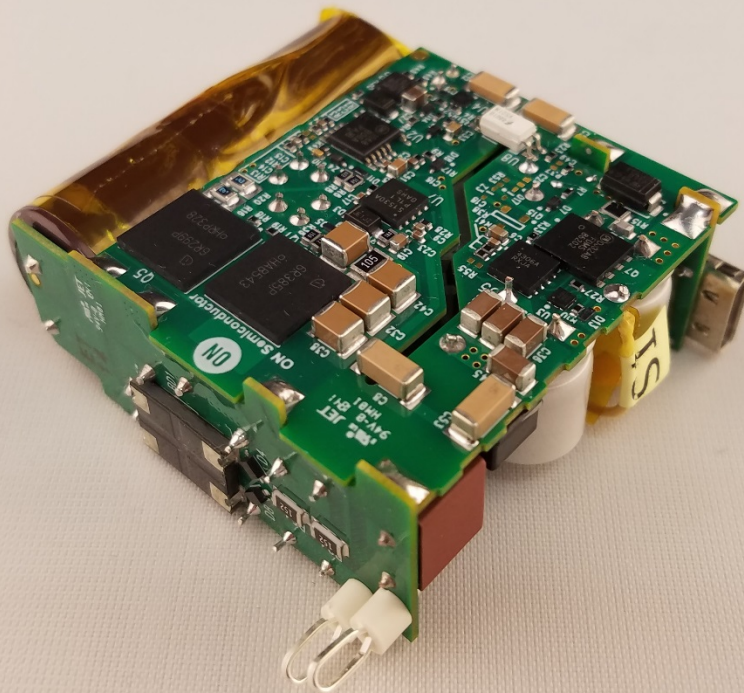


Figure 1 Full Top View of UHD Board

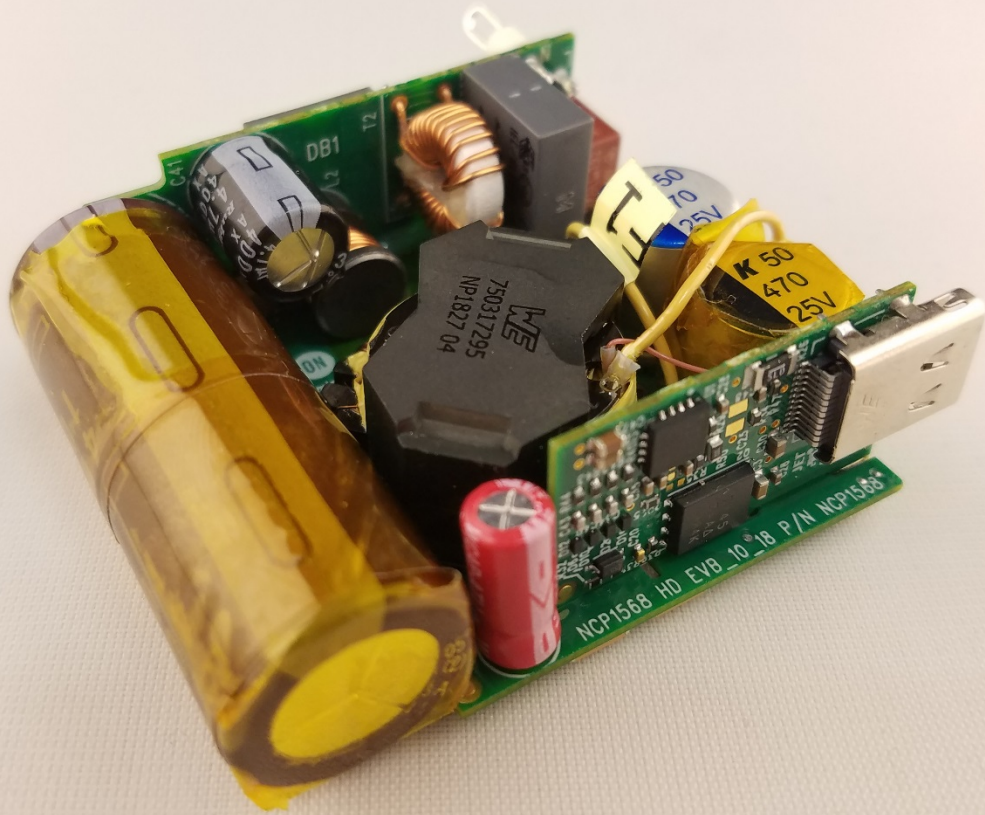


Figure 2 Full Bottom View of UHD Board

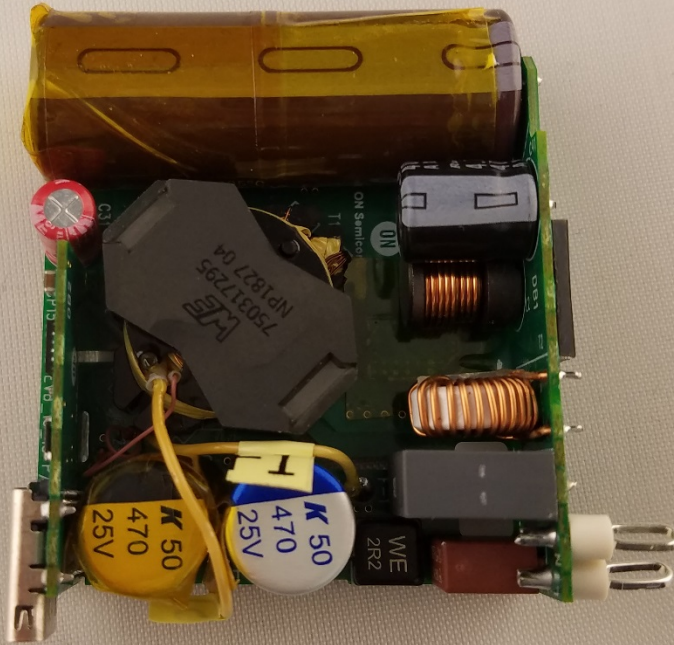


Figure 4 Bottom View of the Demo Board

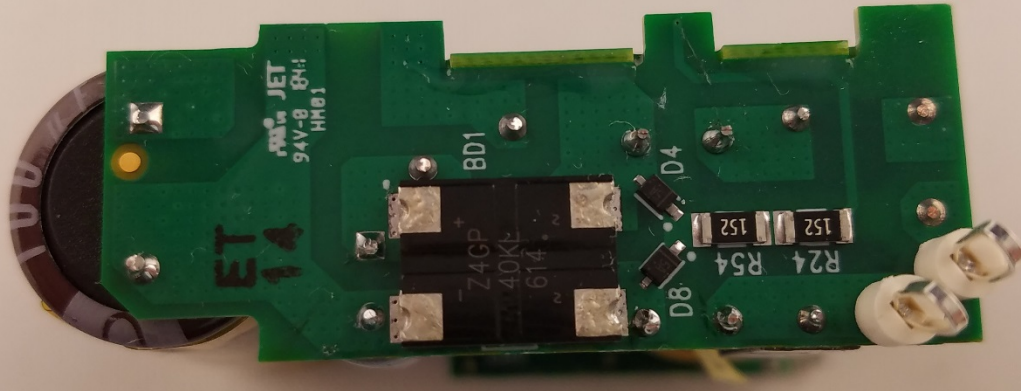


Figure 5 Bottom View of Daughter Card

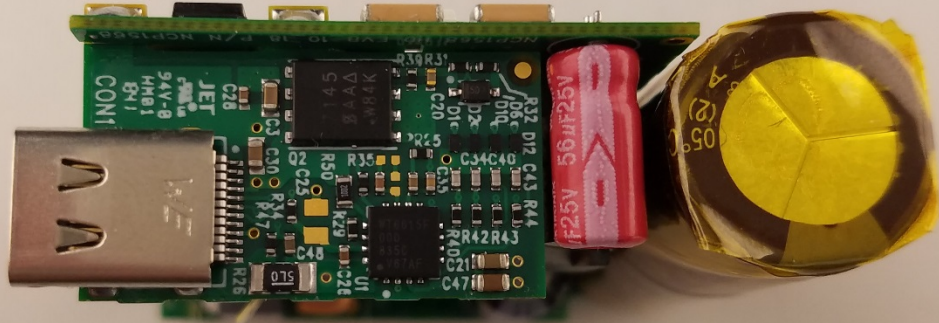
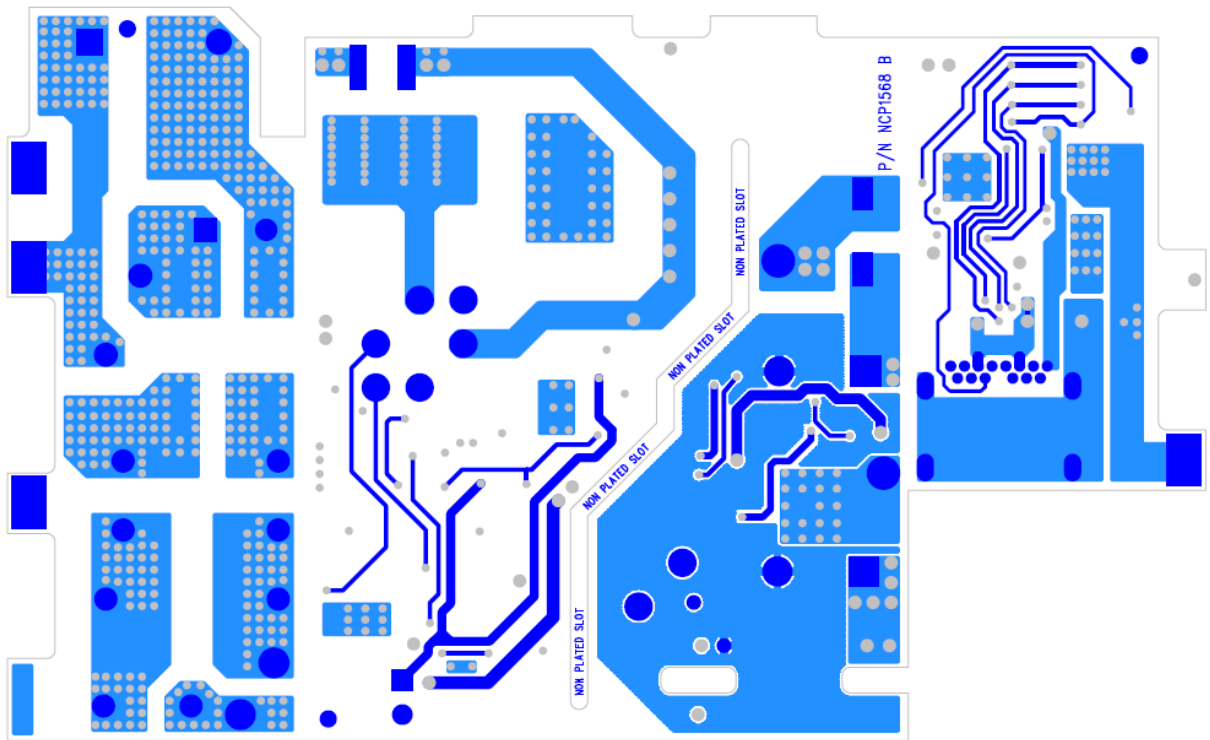


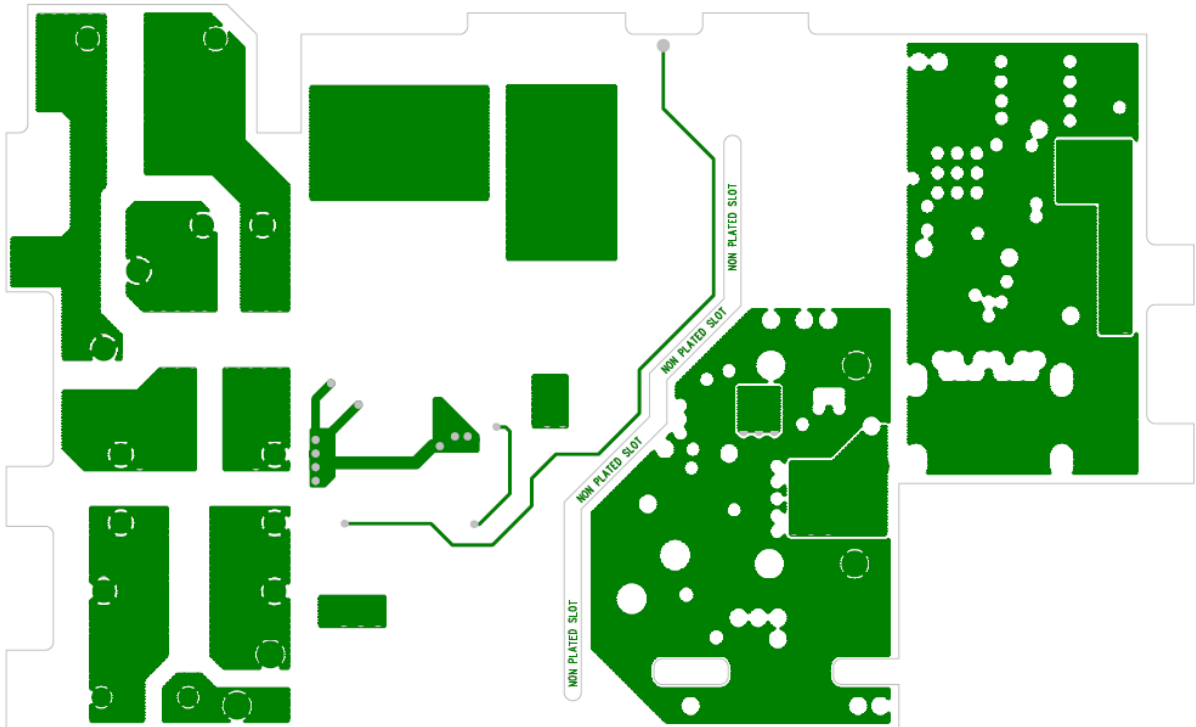
Figure 6 Top View of Daughter Card

Main Board Layout

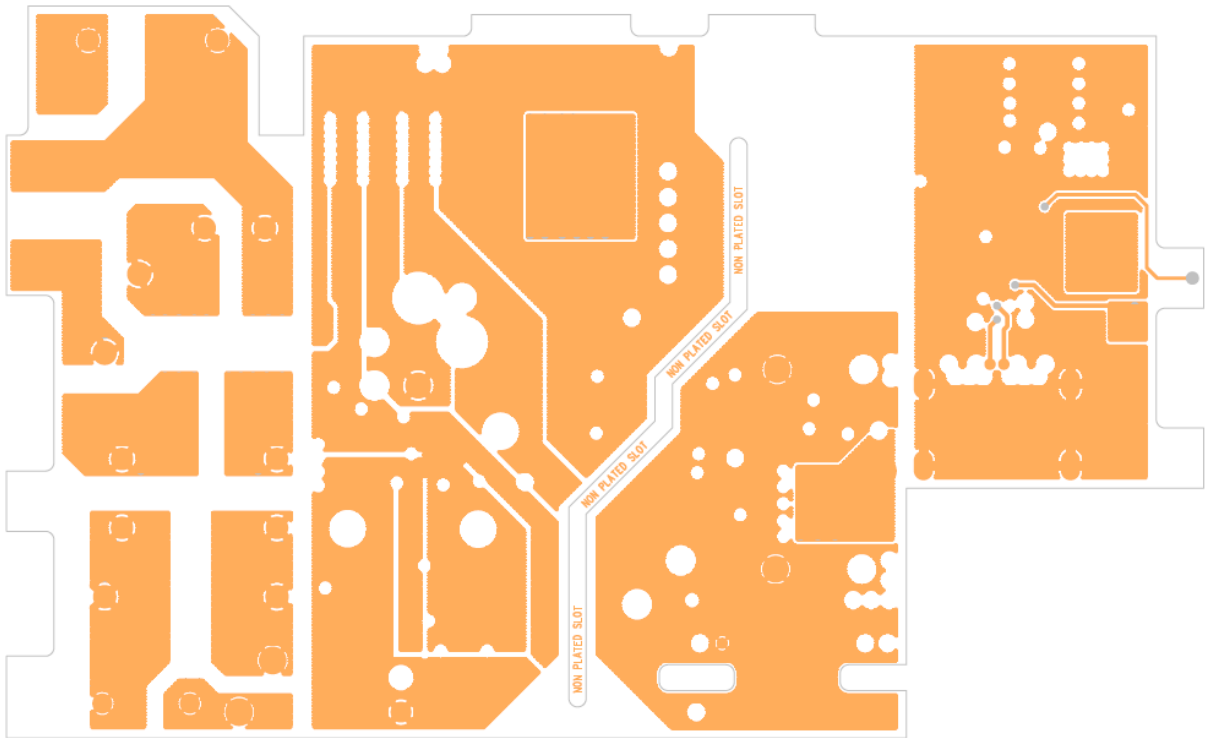
Top (Layer 1)



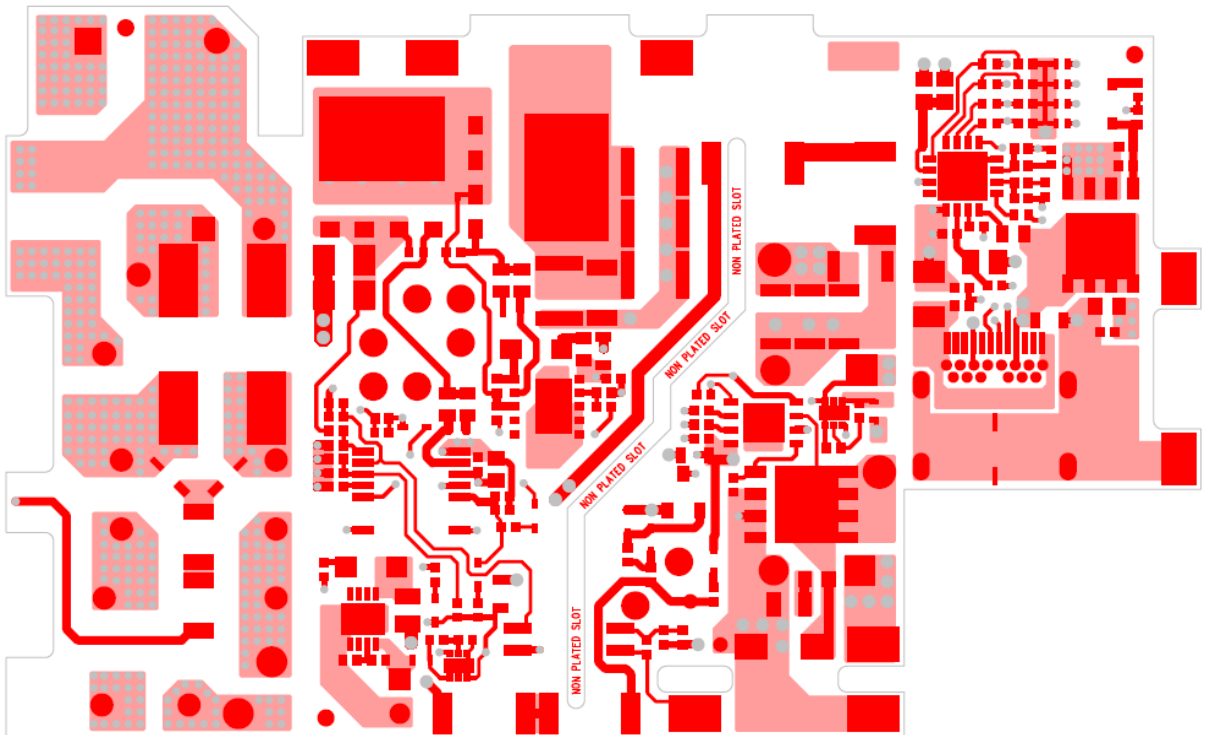
Inner Signal (Layer 2)



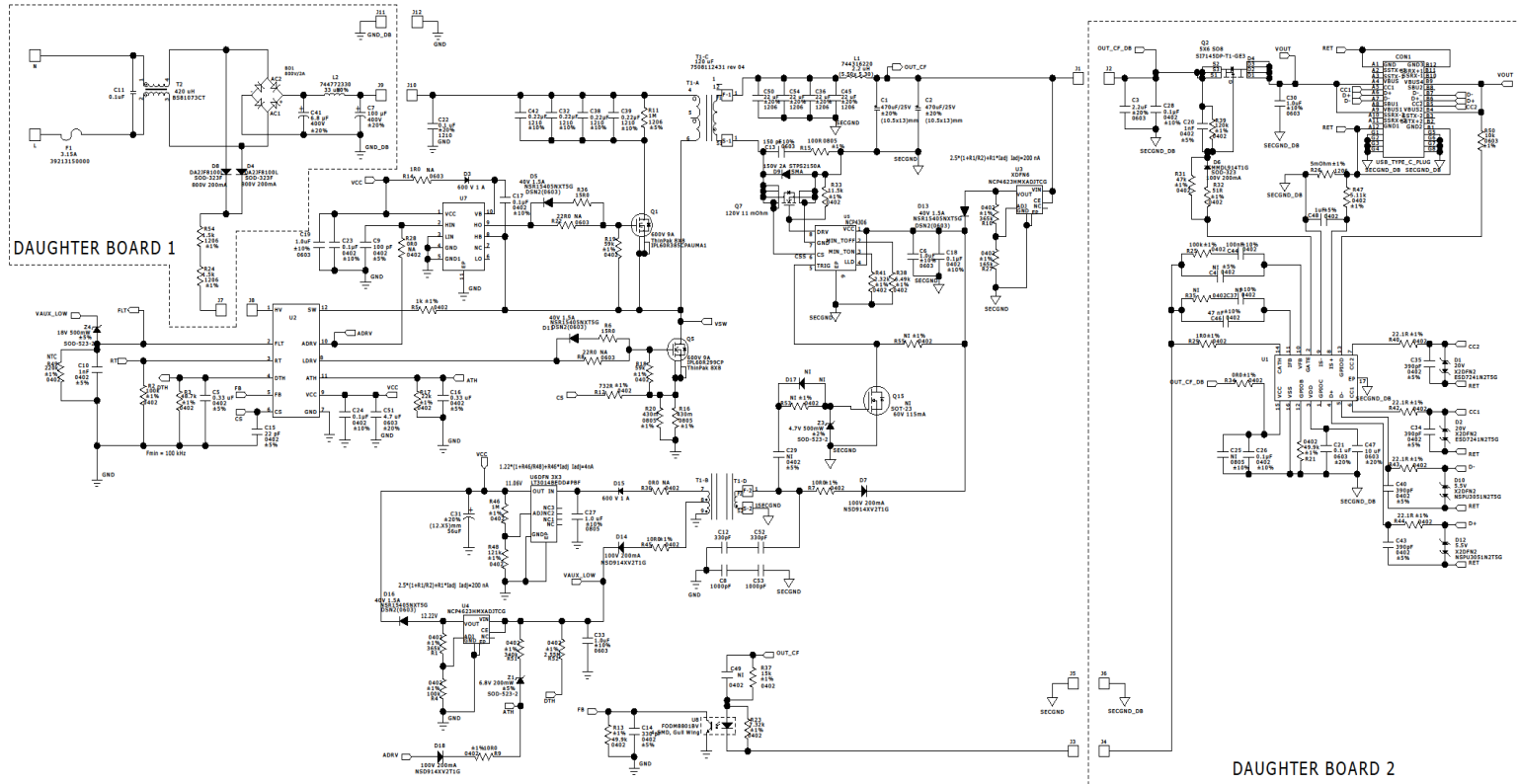
Inner Signal (Layer 3)



Bottom (Layer 4)



DN05119/D



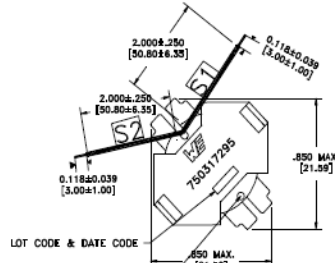
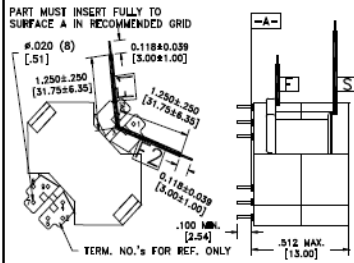
Board Schematic

NOTE: For detailed version, see separate [Schematic PDF](#)

Magnetic Design

CUSTOMER TERMINAL	RoHS	LEAD(Pb)--FREE
Sn 96%, Ag 4%	Yes	Yes

more than you expect



key locates terminal 4-9 side

ELECTRICAL SPECIFICATIONS @ 25° C unless otherwise noted:

PARAMETER	TEST CONDITIONS	VALUE
D.C. RESISTANCE	4-6 @20°C	0.152 ohms ±10%
D.C. RESISTANCE	7-8 @20°C	0.335 ohms ±10%
D.C. RESISTANCE	8-9 @20°C	0.068 ohms ±20%
D.C. RESISTANCE	S1-F1 @20°C	0.016 ohms ±20%
D.C. RESISTANCE	S2-F2 @20°C	0.312 ohms ±10%
INDUCTANCE	4-6 10kHz, 100mV, Ls	120µH ±10%
SATURATION CURRENT	4-6 20% rolloff from initial	4.5A
LEAKAGE INDUCTANCE	4-6 tie(8-9, S1+S2+F1+F2), 100kHz, 100mV, Ls	4.0µH typ., 7.0µH max.
INTERWINDING CAPACITANCE	6-F2 tie(4-5+6+8+9, S1+S2+F1+F2), 100kHz, 10mVAC, Cs	25.0pF typ.
DIELECTRIC	6-F2 tie(4+9, S1+S2), 3750VAC, 1 second	3000VAC, 1 minute
TURNS RATIO	(4-6):(8-7)	3:1, ±1%
TURNS RATIO	(4-6):(9-8)	8:1, ±1%
TURNS RATIO	(4-6):(S1-F1)	6:1, ±1%
TURNS RATIO	(4-6):(S2-F2)	8:1, ±1%

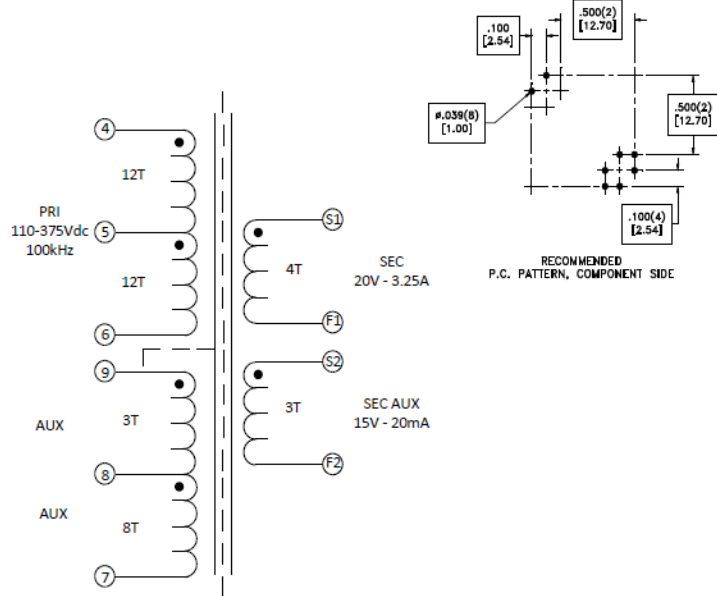
GENERAL SPECIFICATIONS:

OPERATING TEMPERATURE RANGE: -40°C to +125°C including temp rise.

Designed to comply with the following requirements as defined by IEC60950-1,

EN60950-1, UL60950-1/CSA60950-1 and AS/NZS60950.1:

- Reinforced insulation for a primary circuit at a working voltage of 265Vrms, 400Vpeak, Overvoltage Category II.



RECOMMENDED P.C. PATTERN, COMPONENT SIDE

Wire insulation & RoHS status not affected by wire color. Wire insulation color may vary depending on availability.

DFM	Packaging Specifications	 CONVENTION PLACEMENT	Tolerances unless otherwise specified: Angles: ±1° Decimals: ±.005 [.13] Fractions: ±1/64 Footprint: ±.001 [.03]	DRAWING TITLE	PART NO.
DATE	Method: Tray		This drawing is dual dimensioned. Dimensions in brackets are in millimeters.	TRANSFORMER	750317295
ENG	PKG-0002				
REV.	04				
DATE		www.wa-online.com/midcom			SPECIFICATION SHEET 1 OF 1

High Density Board Efficiency Data

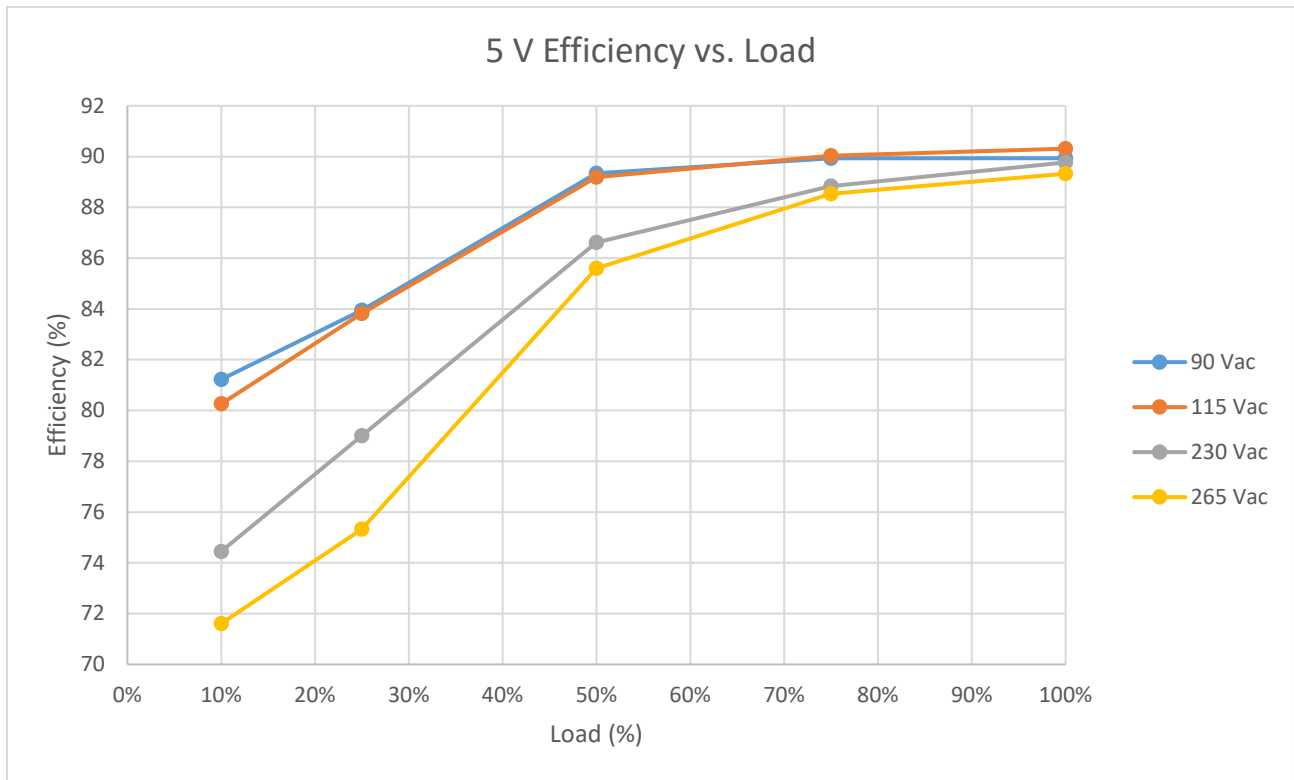


Figure 7 5V Efficiency Plot

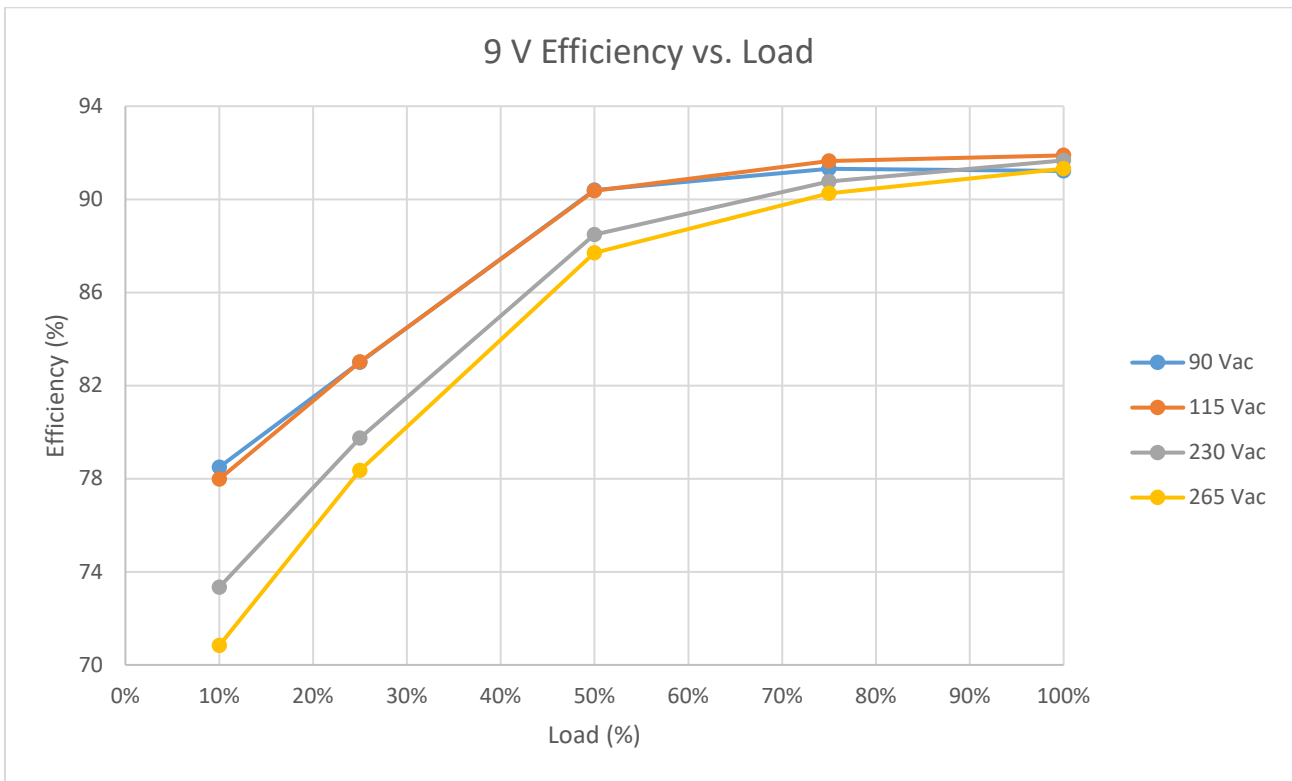


Figure 8 9V Efficiency Plot

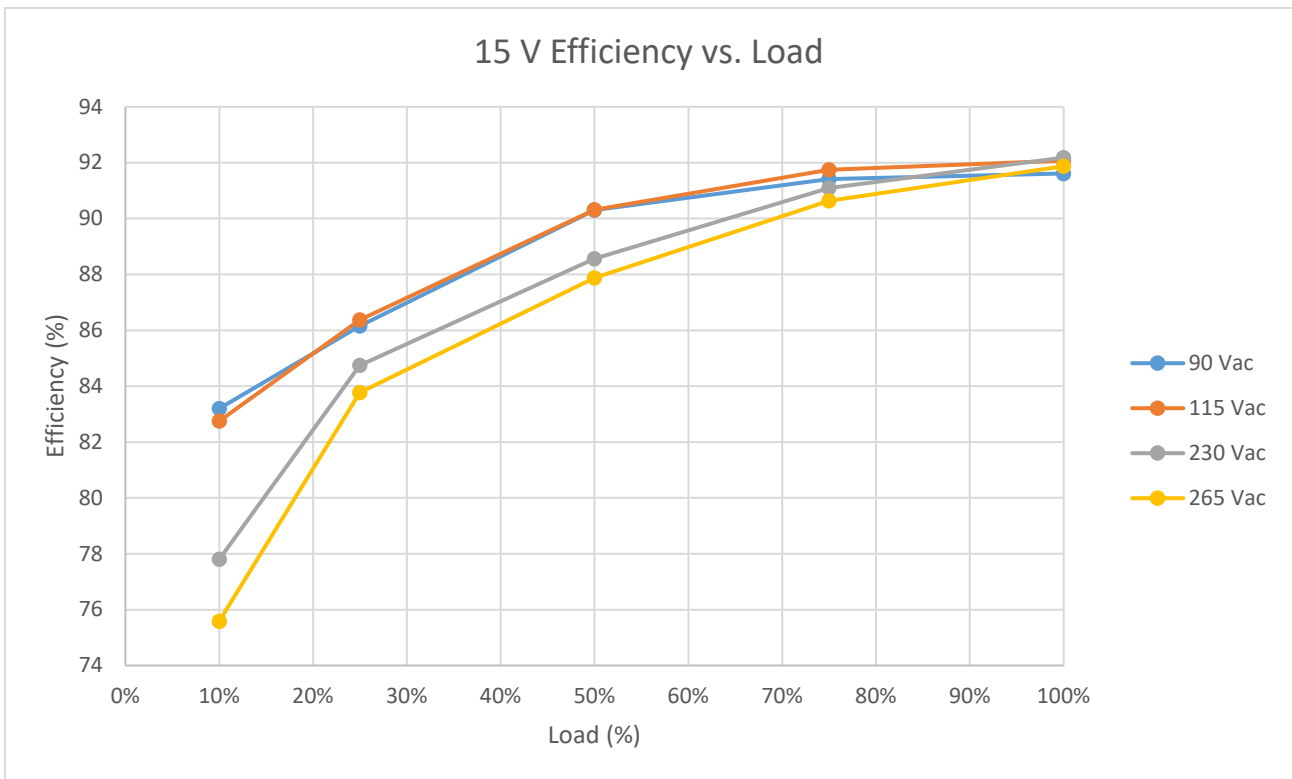


Figure 9 15V Efficiency Plot

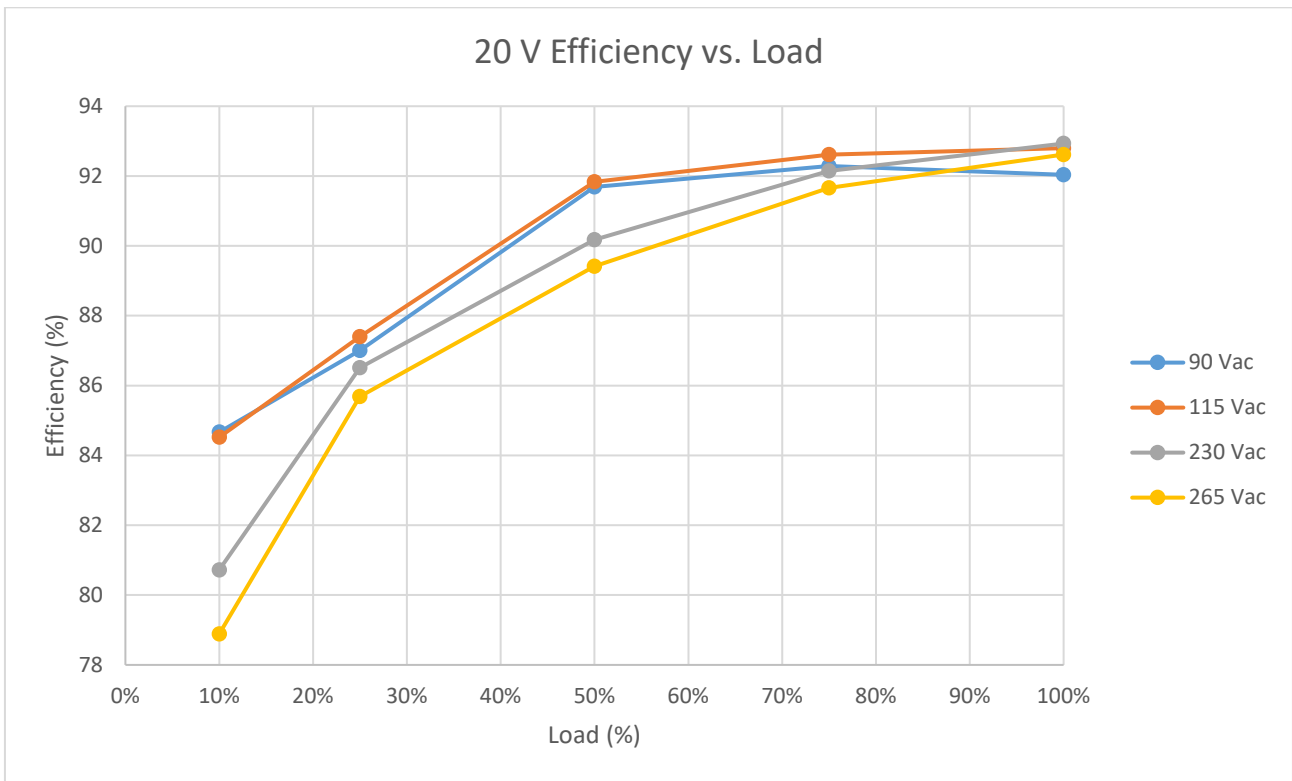


Figure 10 20V Efficiency Plot

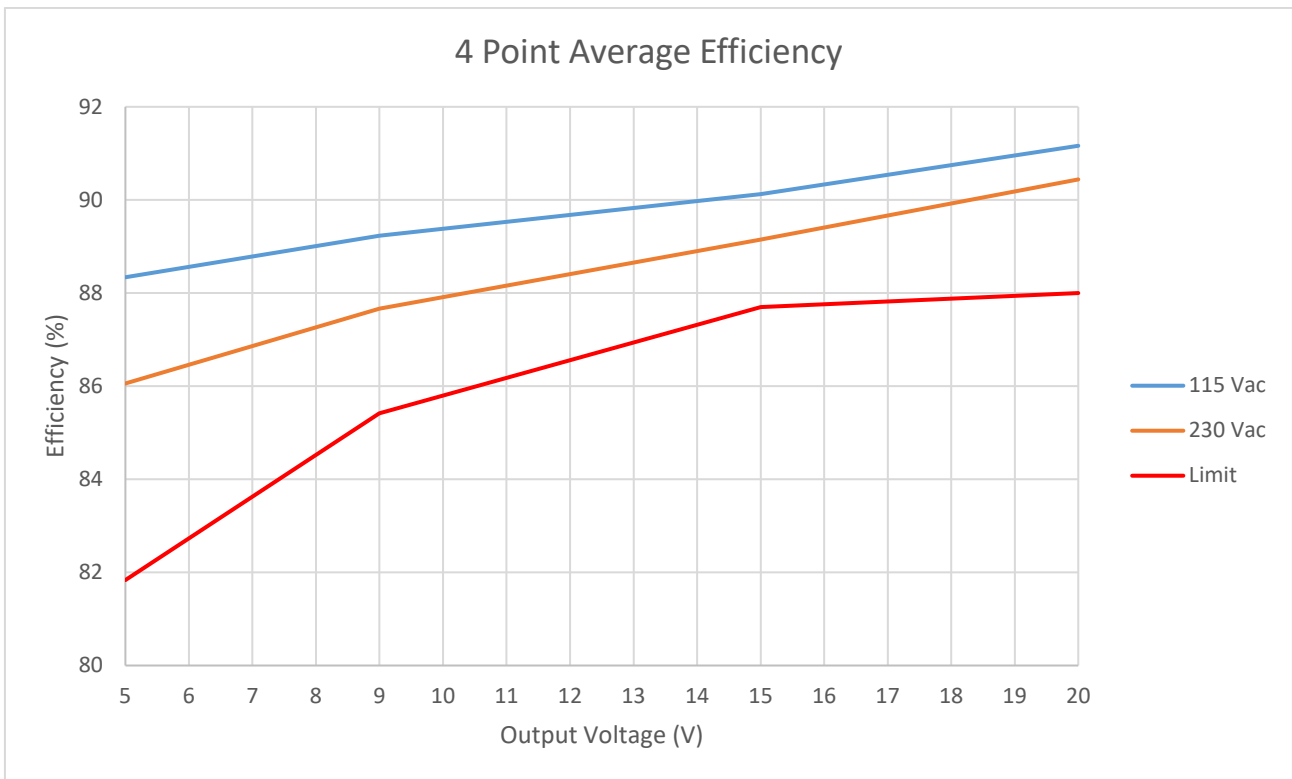


Figure 11 4-Point Average Efficiency Plot

Waveforms

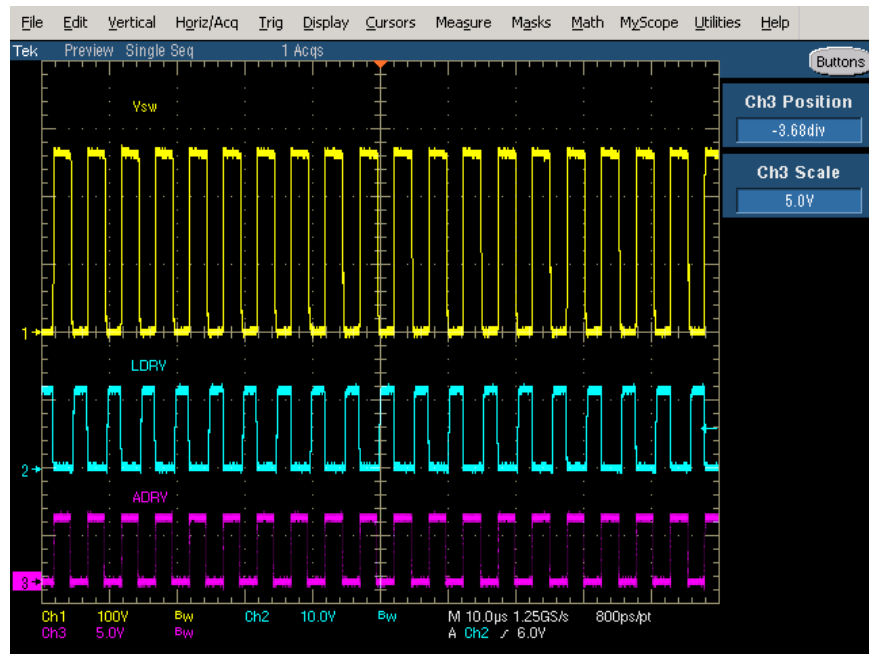


Figure 12 Steady State ACF Operation

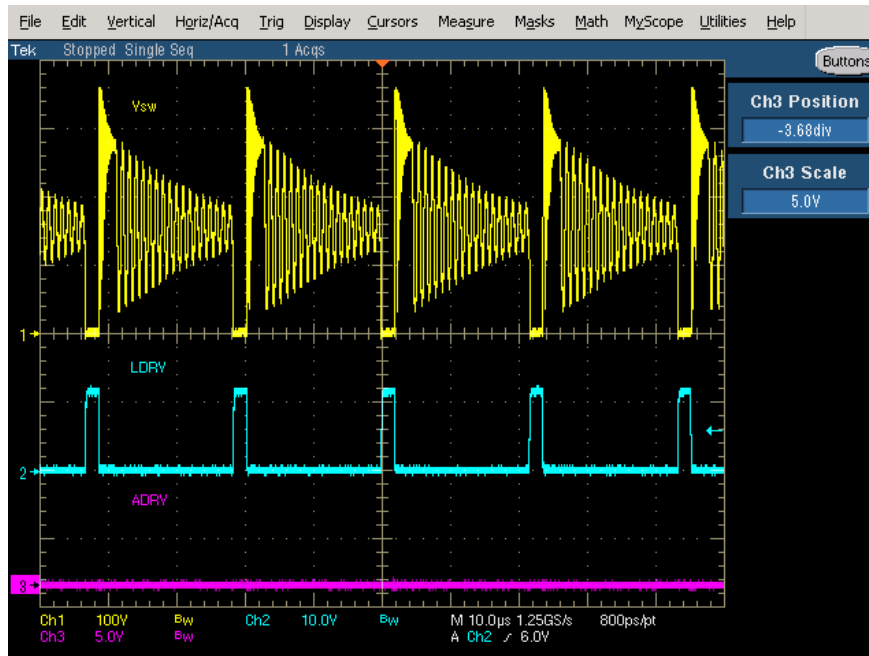


Figure 13 Steady State DCM Operation

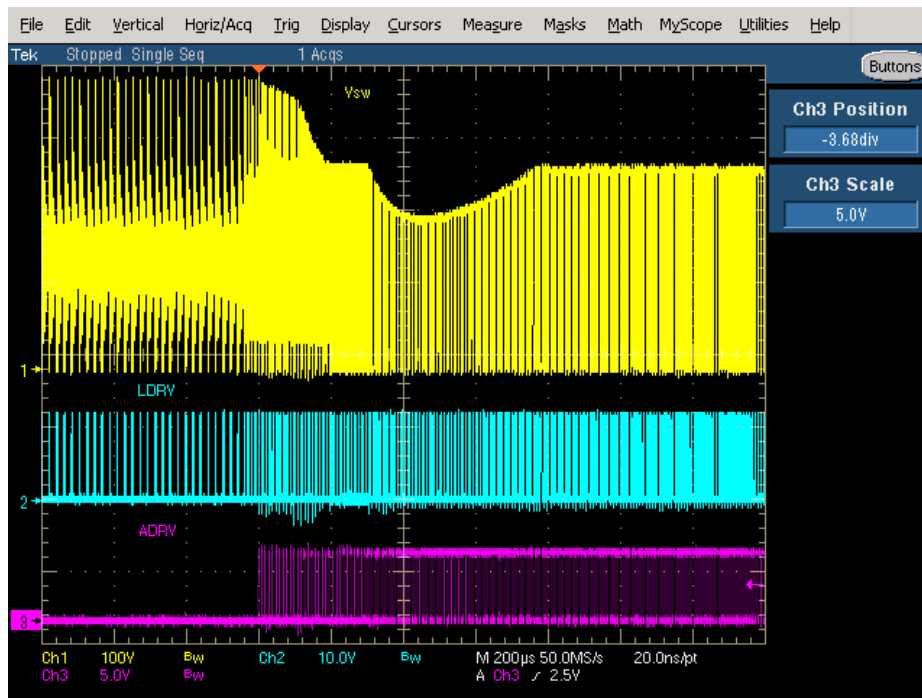


Figure 14 DCM to ACF Transition

Time from Applying Vac to First Switch

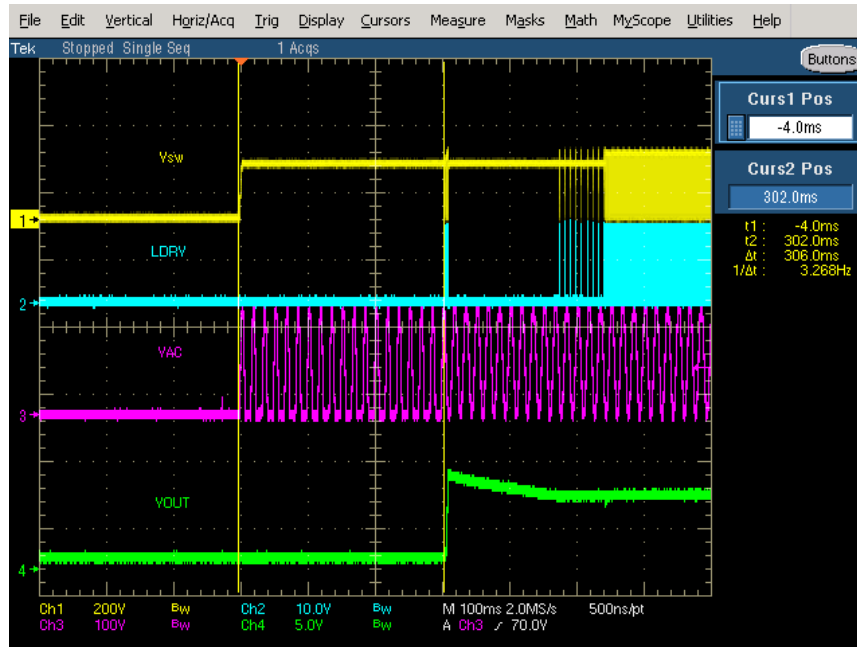


Figure 15 115 Vac Input, Time from Vac to First Switch

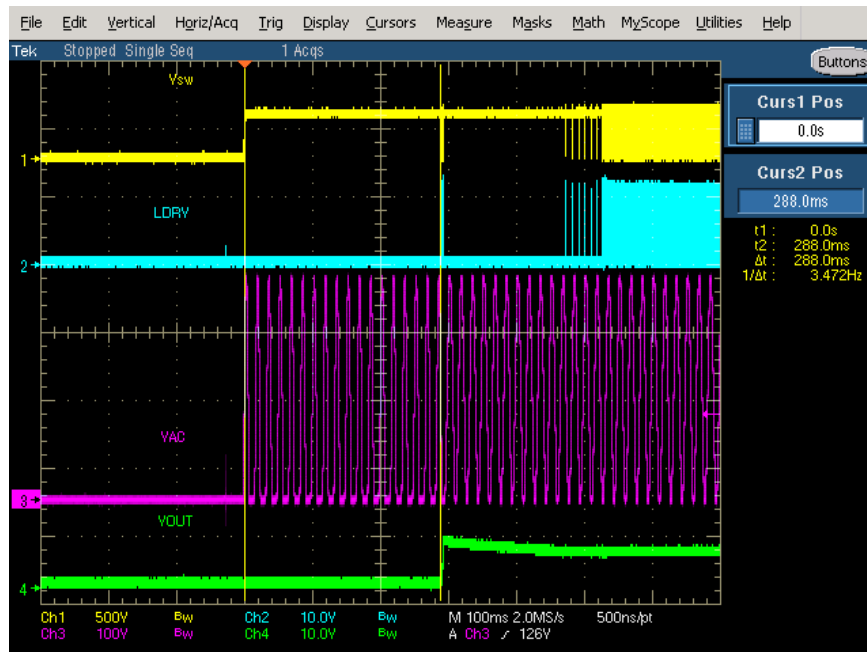


Figure 16 230 Vac Input, Time from Vac to First Switch

Time from Switch to 5 Vout

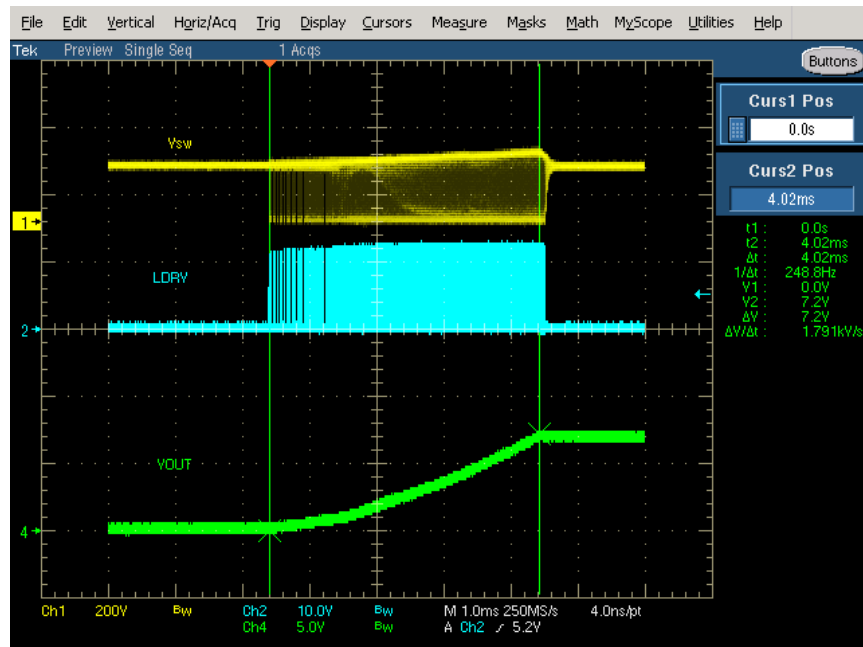


Figure 17 115 Vac Input, Time from First Switch to 5 Vout

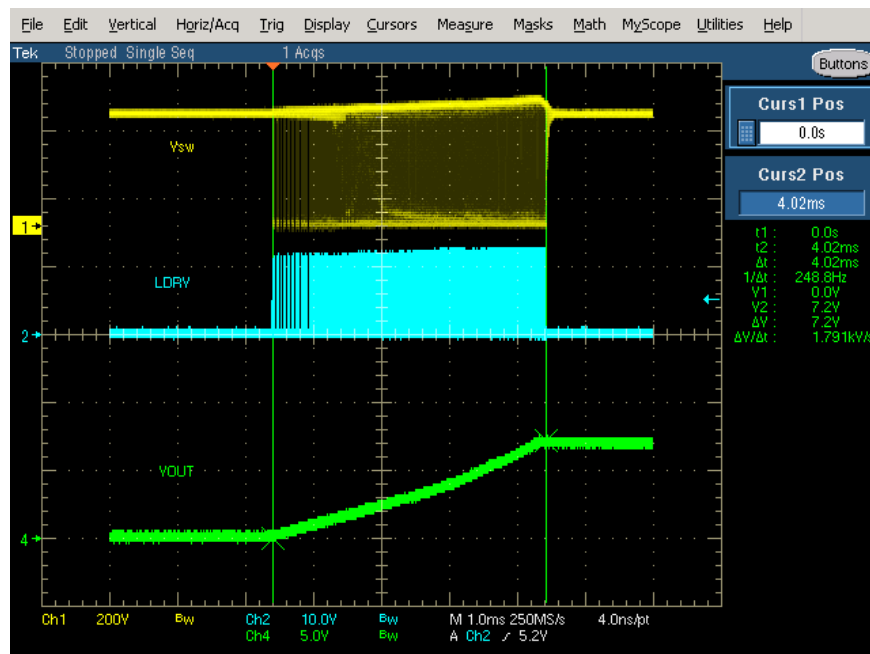


Figure 18 230 Vac Input, Time from First Switch to 5 Vout

Output Ripple

(Taken at output for 3A Load)

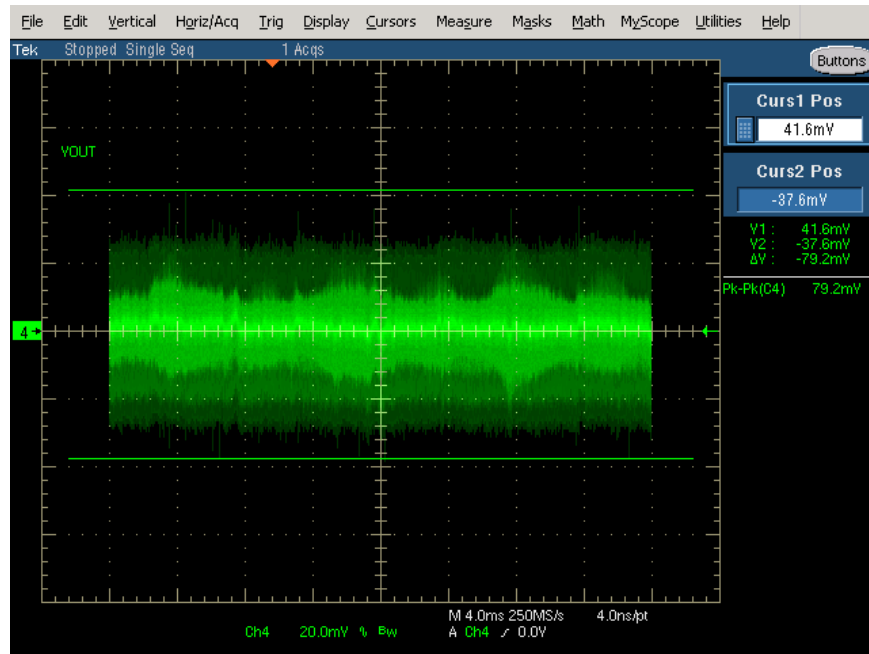


Figure 19 115 Vac 5 Vout Ripple

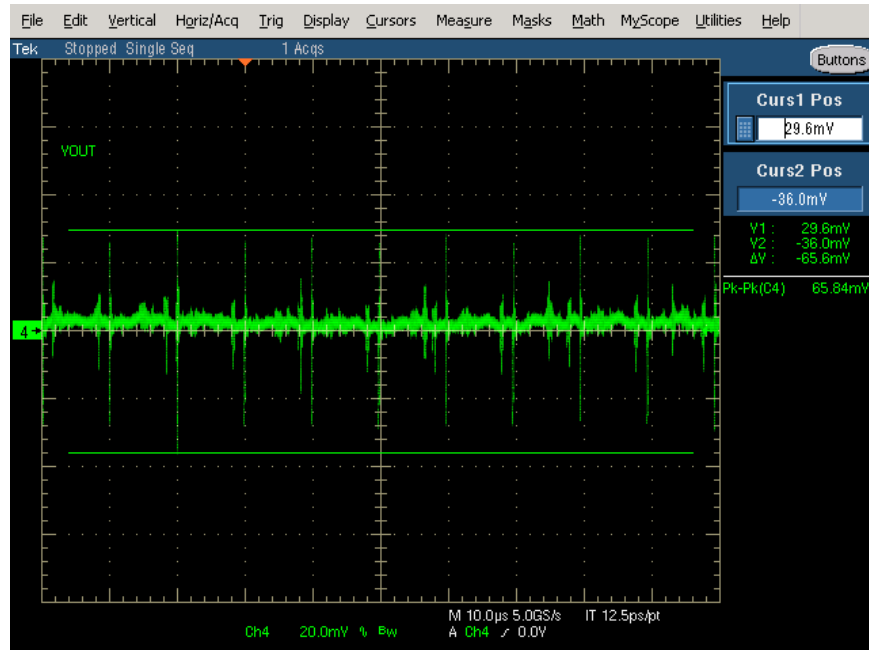


Figure 20 115 Vac 5 Vout Ripple Zoom

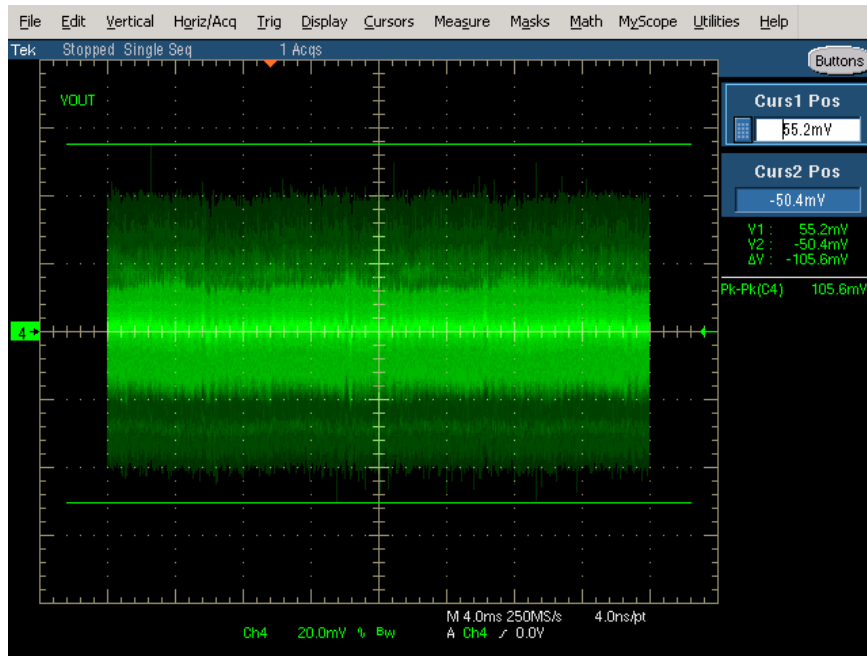


Figure 21 230 Vac 5 Vout Ripple

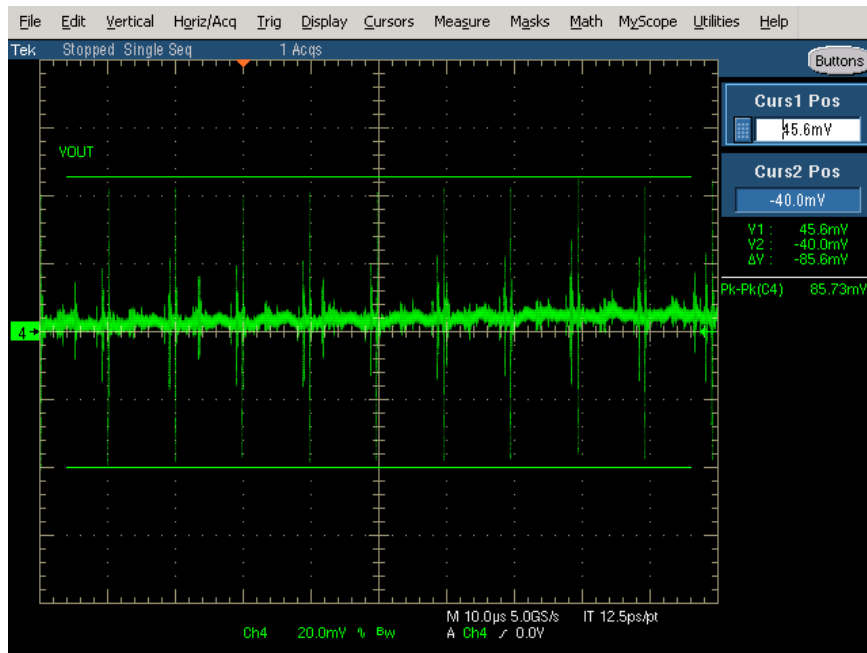


Figure 22 230 Vac 5 Vout Ripple Zoom

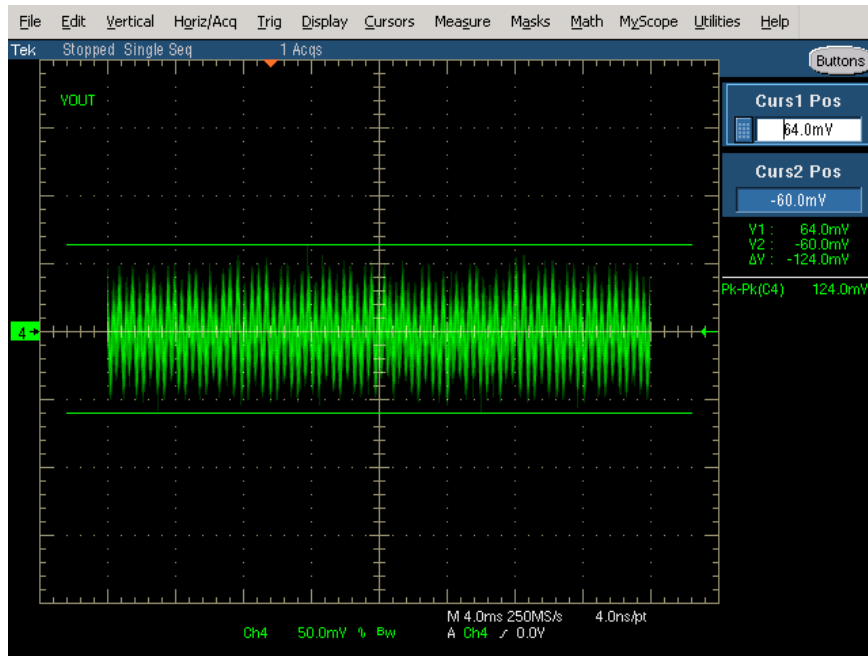


Figure 23 115 Vac 9 Vout Ripple

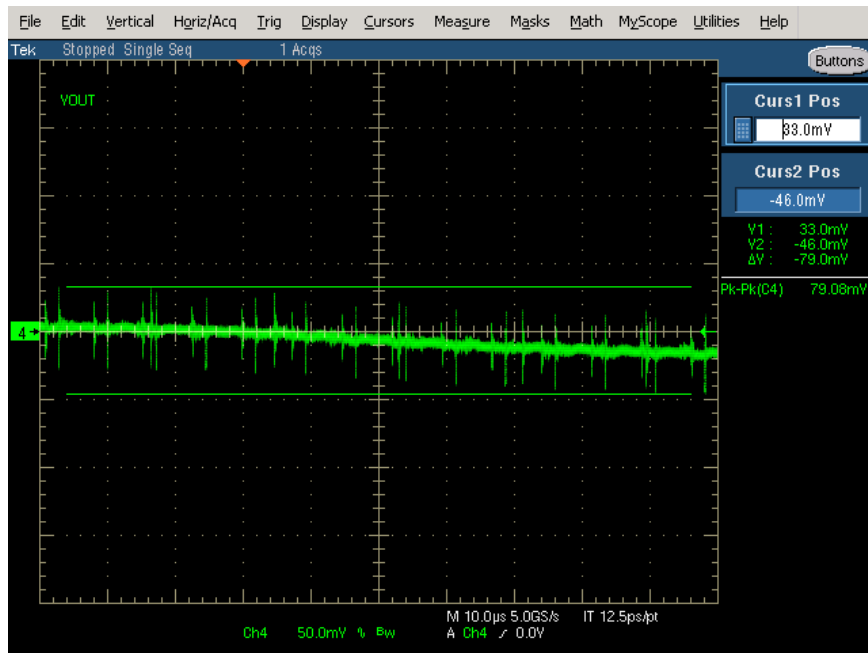


Figure 24 115 Vac 9 Vout Ripple Zoom

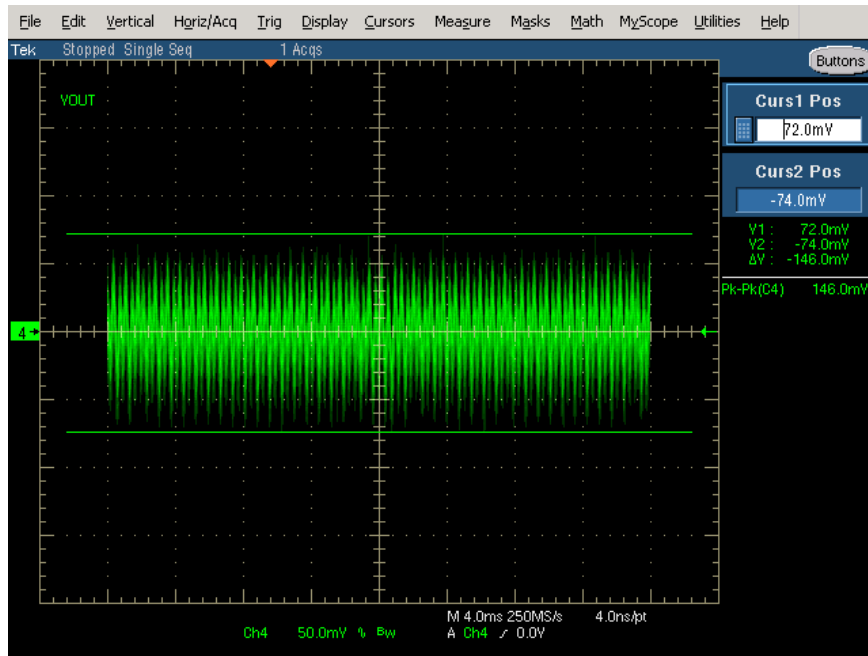


Figure 25 230 Vac 9 Vout Ripple

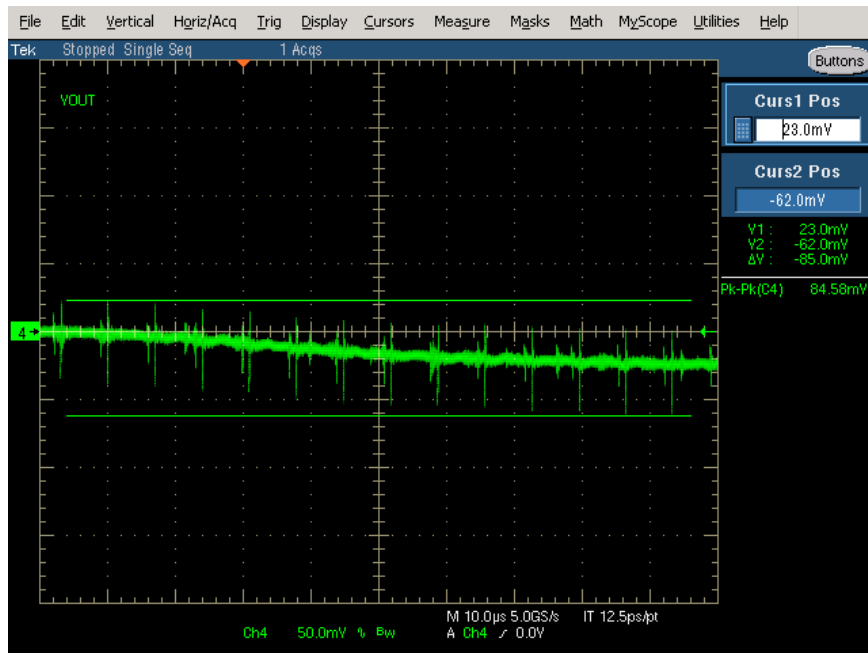


Figure 26 230 Vac 9 Vout Ripple Zoom

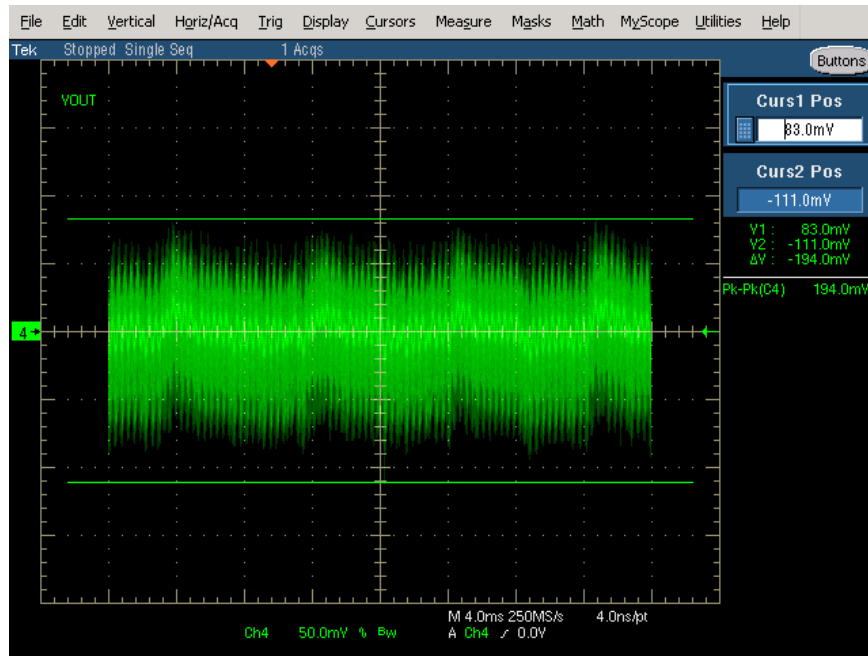


Figure 27 115 Vac 15 Vout Ripple

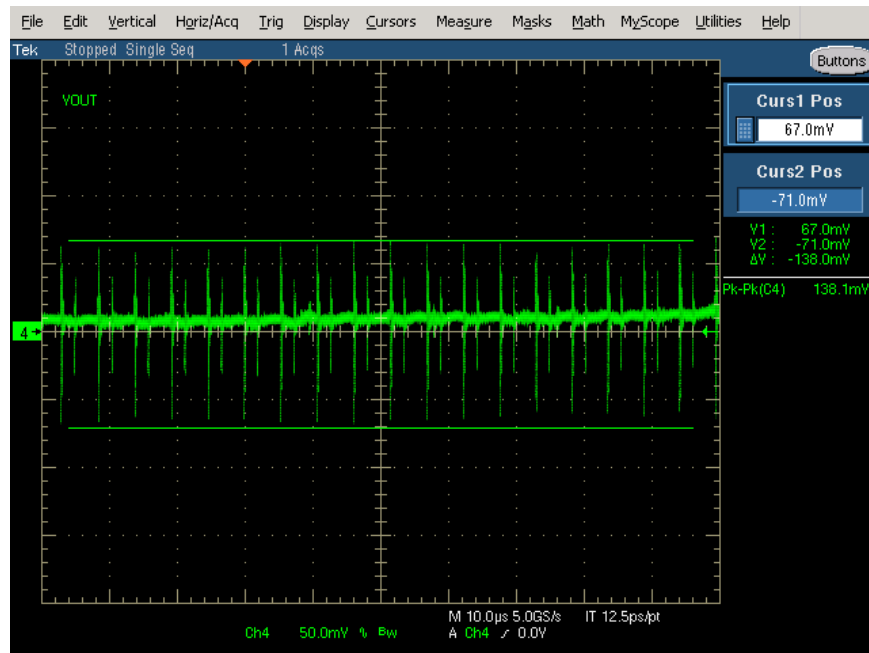


Figure 28 115 Vac 15 Vout Ripple Zoom

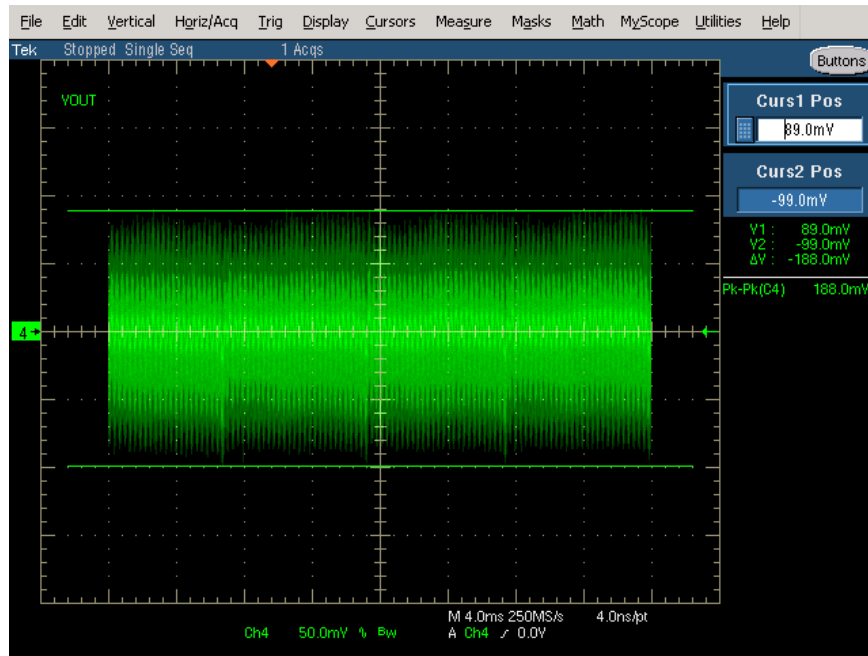


Figure 29 230 Vac 15 Vout Ripple

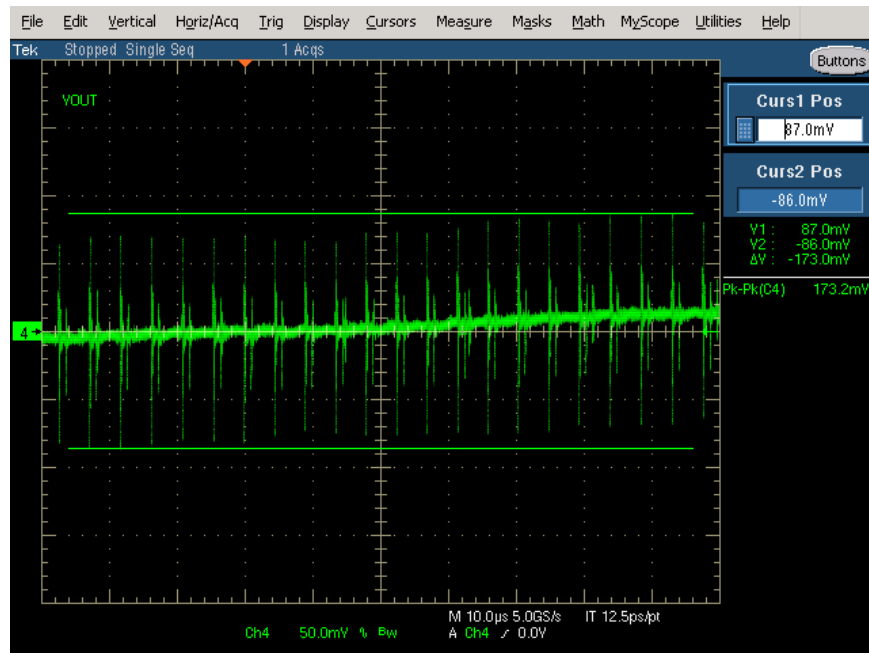


Figure 30 230 Vac 15 Vout Ripple Zoom

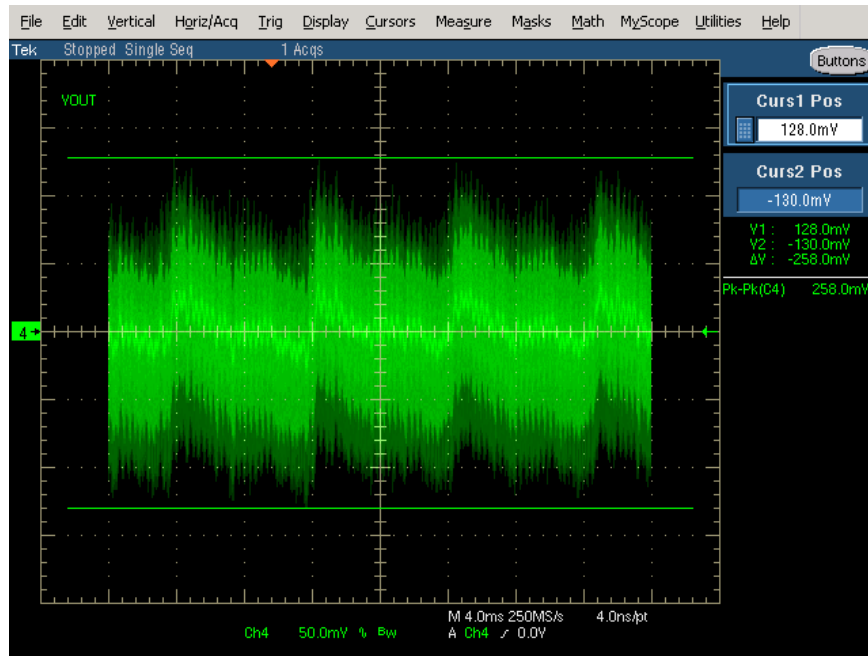


Figure 31 115 Vac 20 Vout Ripple

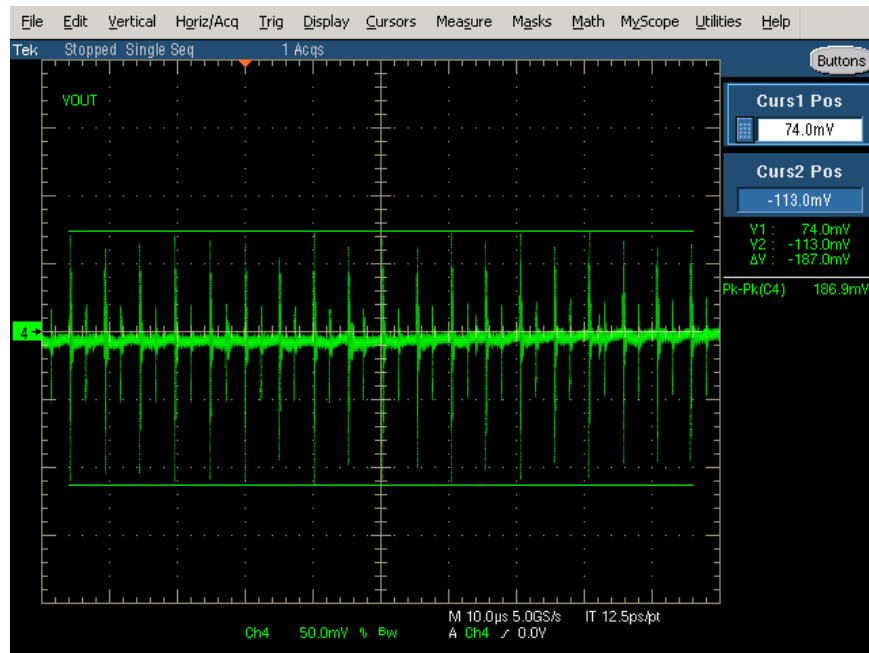


Figure 32 115 Vac 20 Vout Ripple Zoom

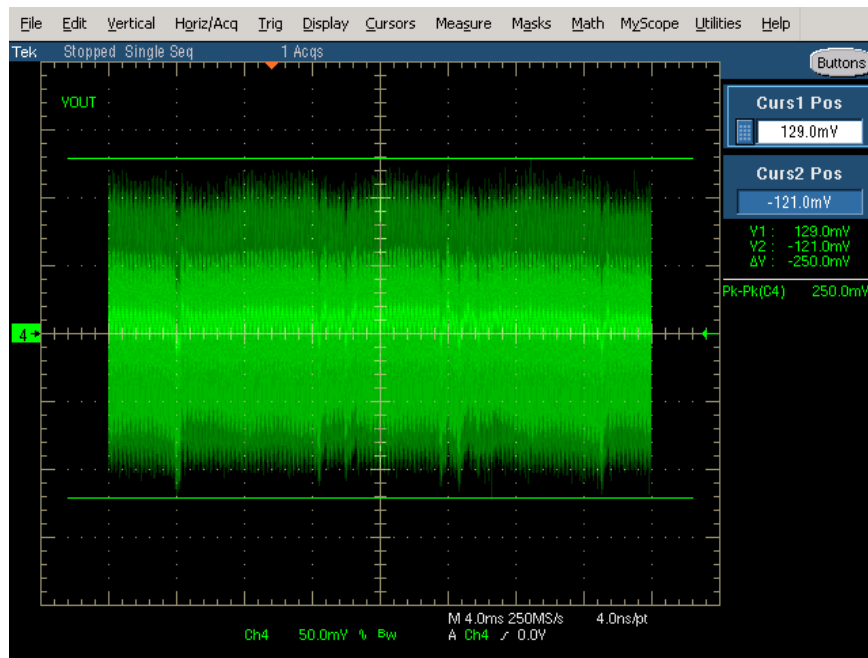


Figure 33 230 Vac 20 Vout Ripple

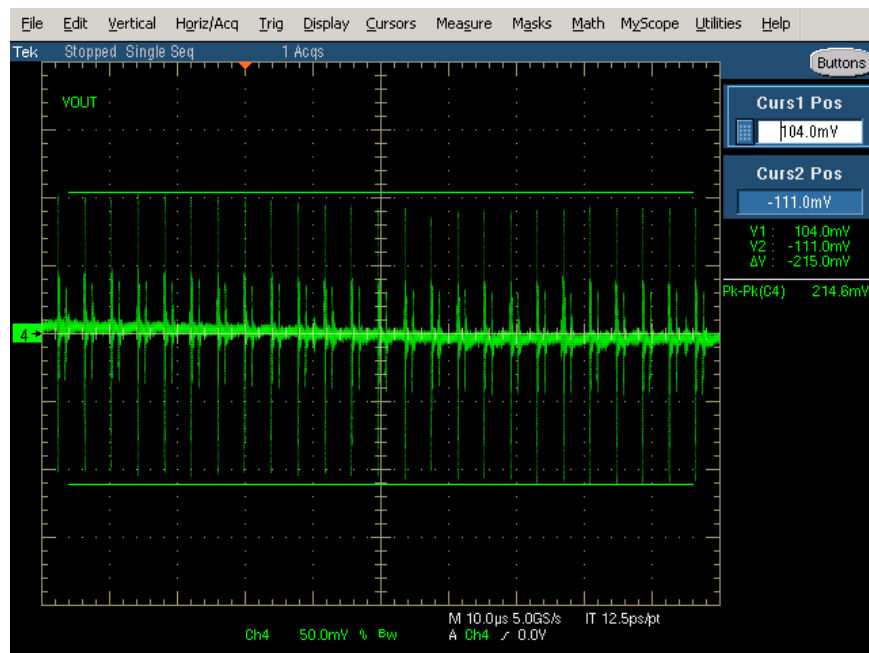


Figure 34 230 Vac 20 Vout Ripple Zoom

Transient Response

(0.1A – 3A, 150 mA/us, 20 ms)

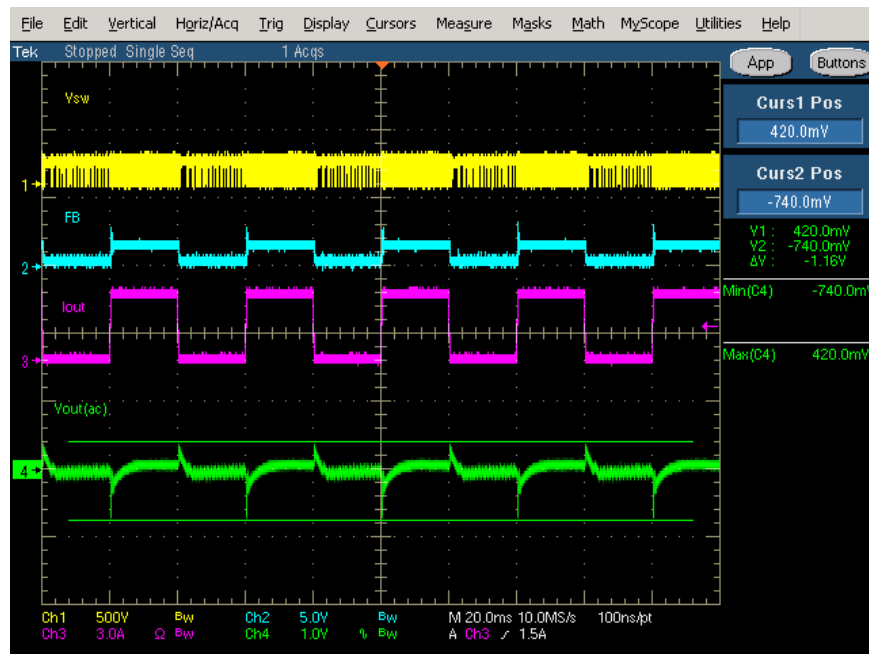


Figure 35 115 Vac 5 Vout Transient

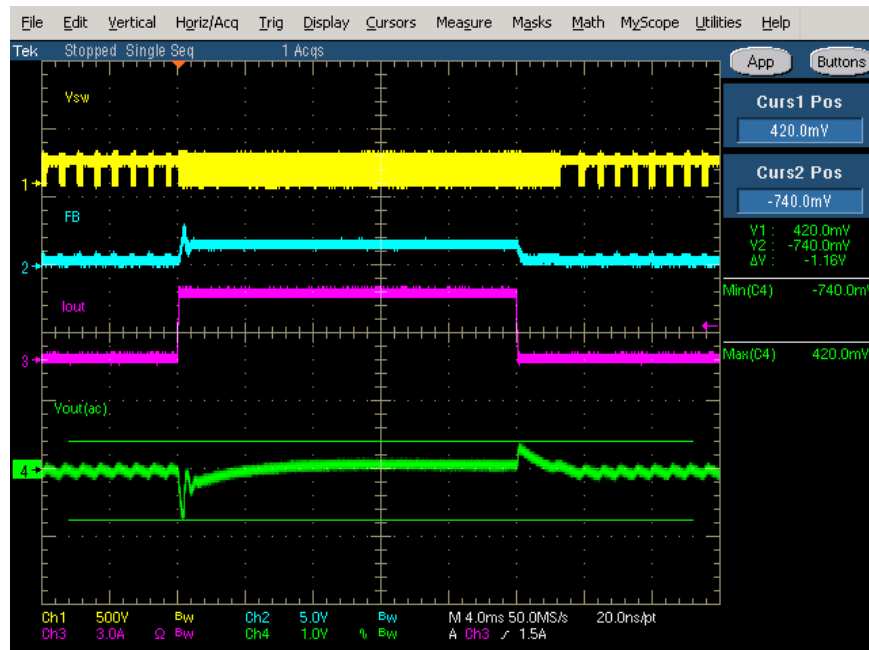


Figure 36 115 Vac 5 Vout Transient Zoom

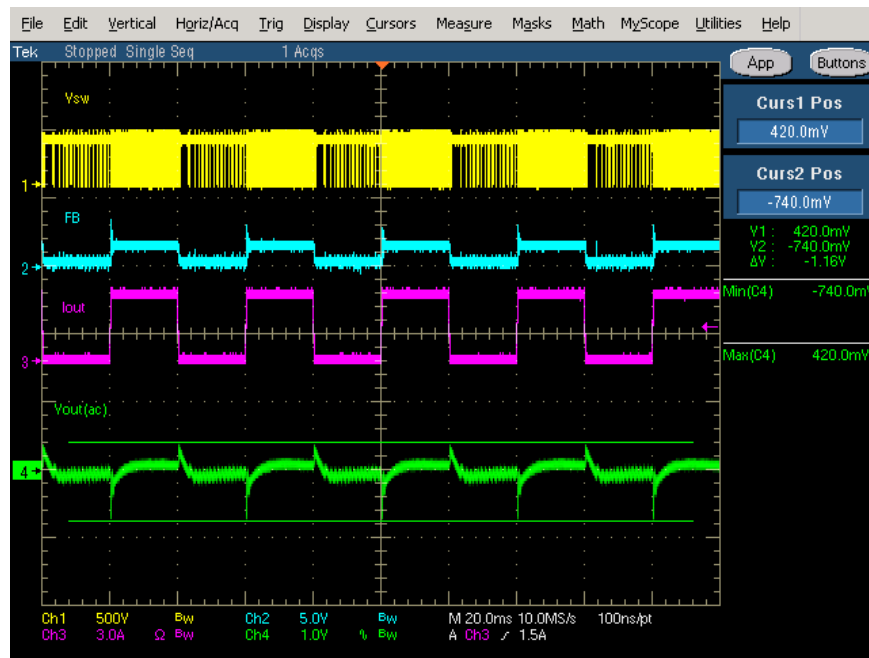


Figure 37 230 Vac 5 Vout Transient

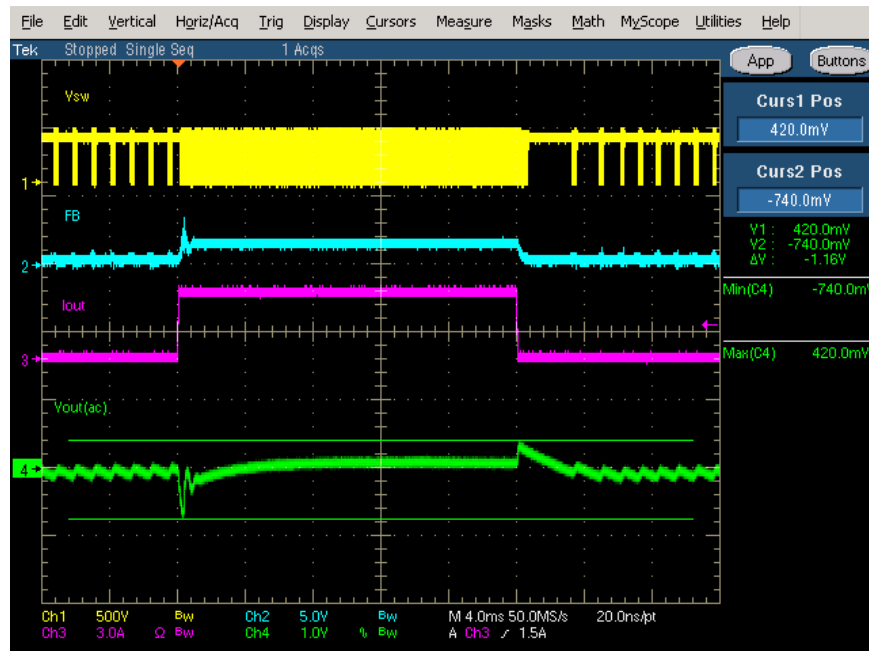


Figure 38 230 Vac 5 Vout Transient Zoom

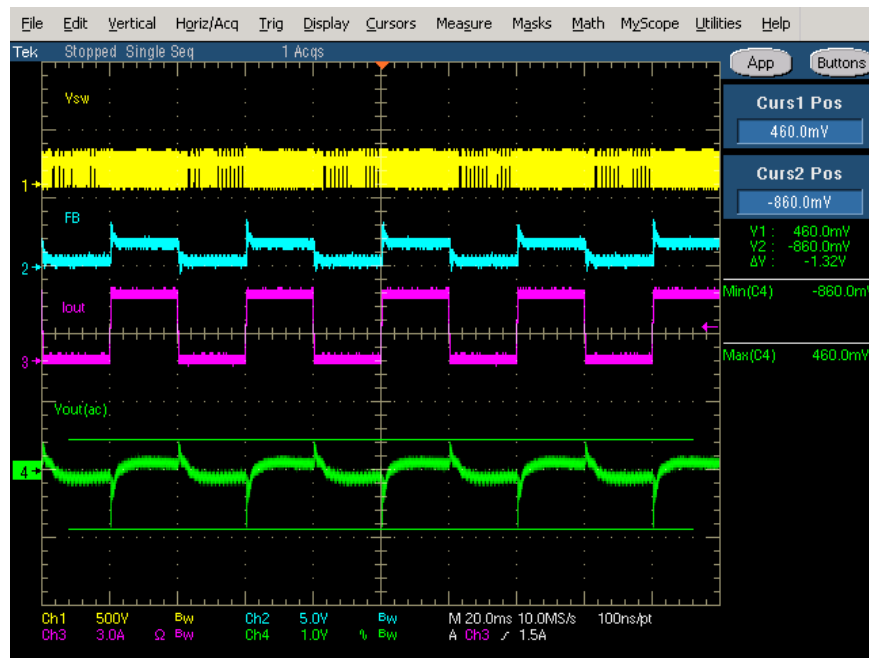


Figure 39 115 Vac 9 Vout Transient

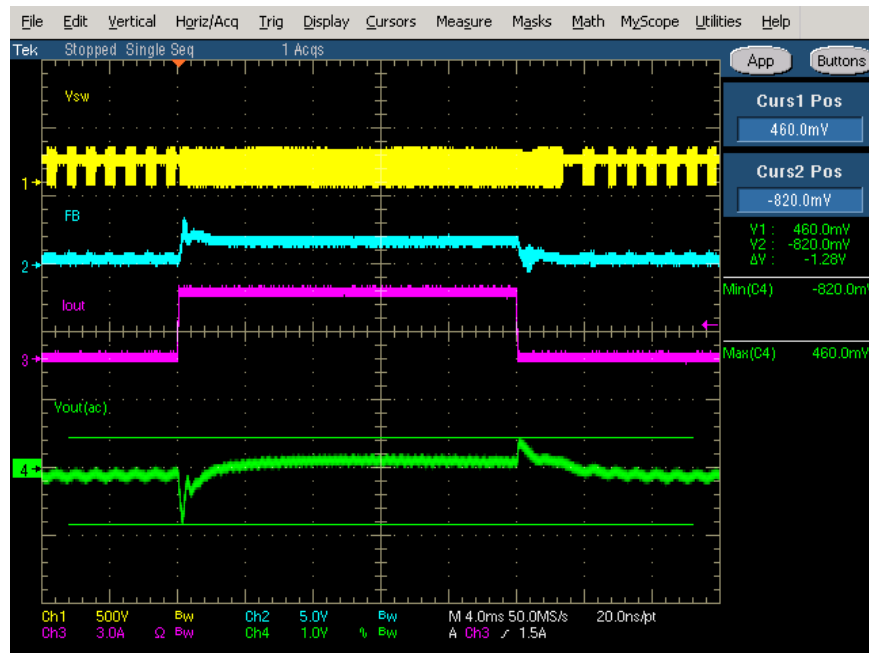


Figure 40 115 Vac 9 Vout Transient Zoom

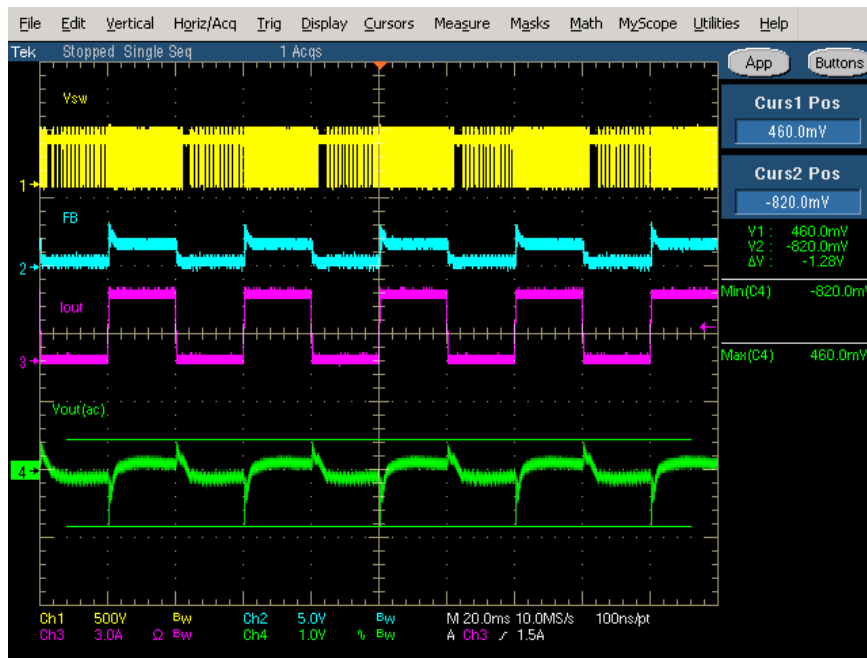


Figure 41 230 Vac 9 Vout Transient

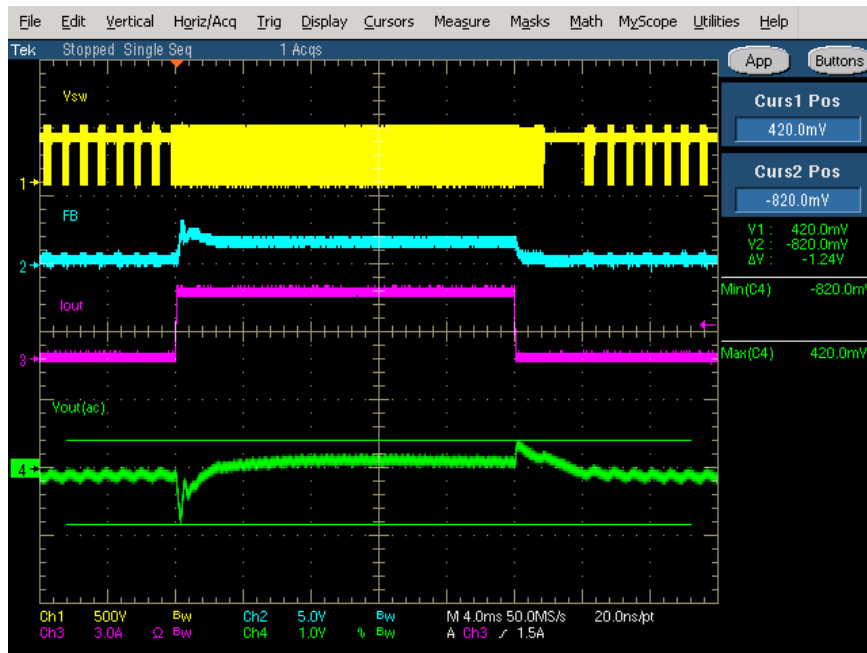


Figure 42 230 Vac 9 Vout Transient Zoom

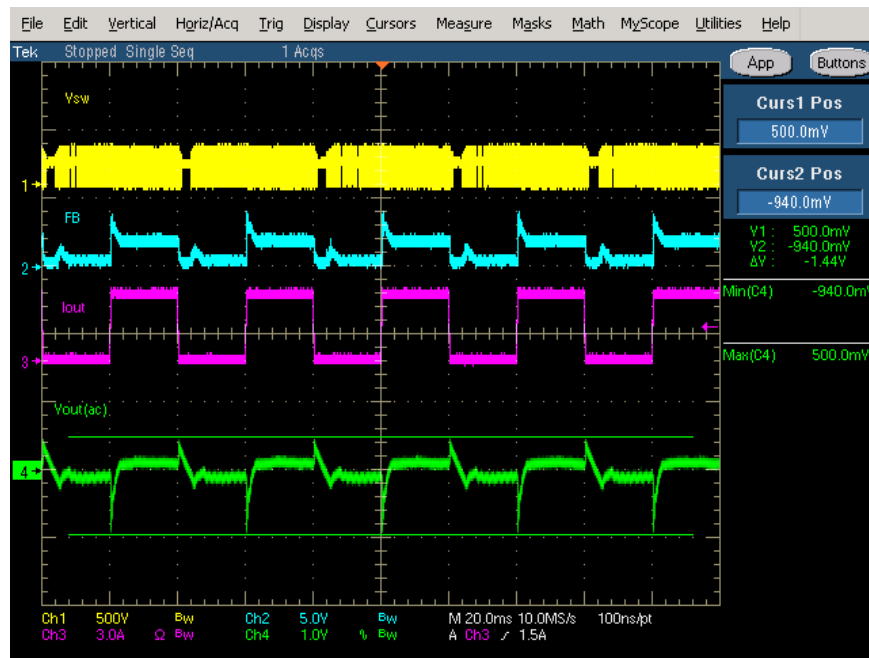


Figure 43 115 Vac 15 Vout Transient

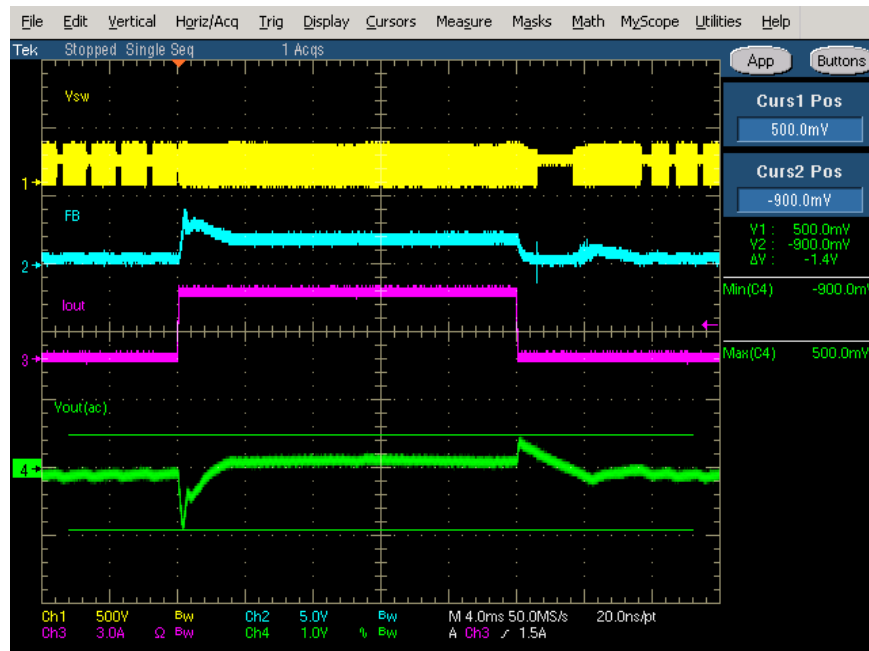


Figure 44 115 Vac 15 Vout Transient Zoom

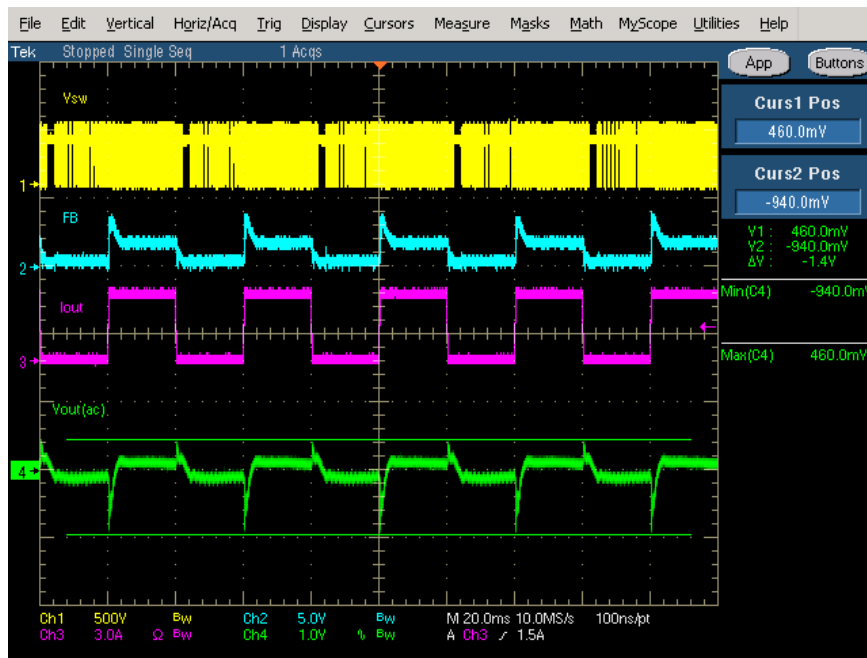


Figure 45 230 Vac 15 Vout Transient

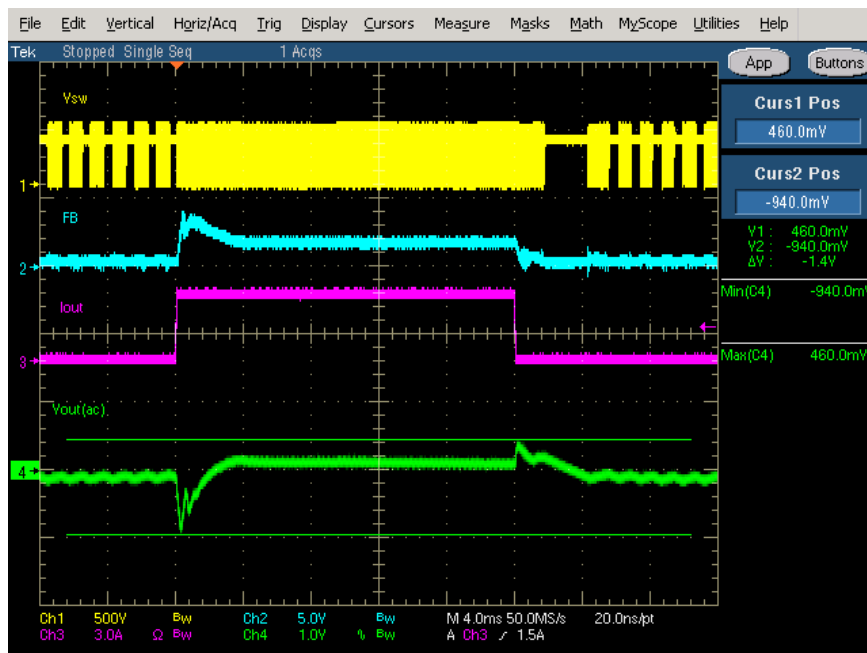


Figure 46 230 Vac 15 Vout Transient Zoom

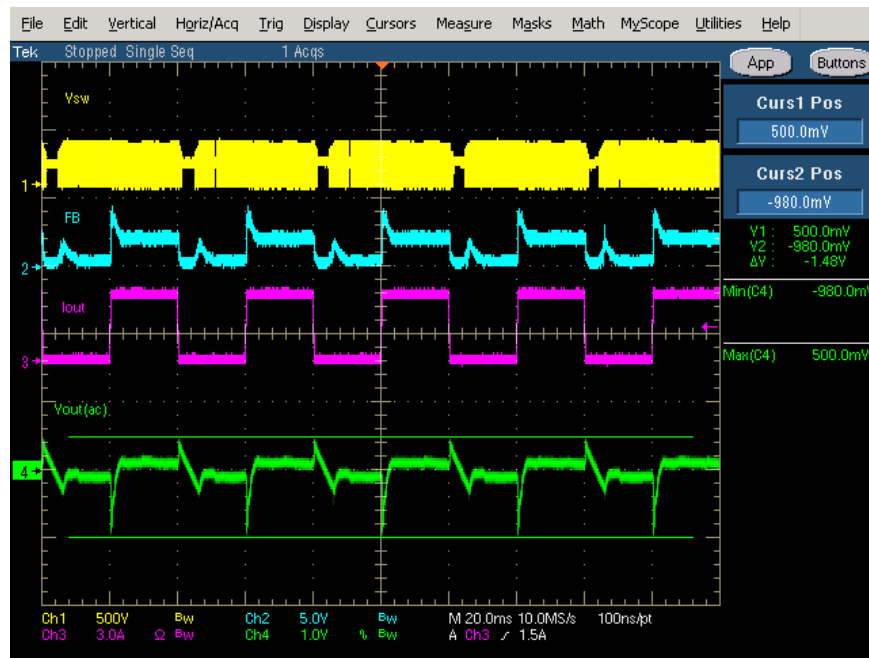


Figure 47 115 Vac 20 Vout Transient

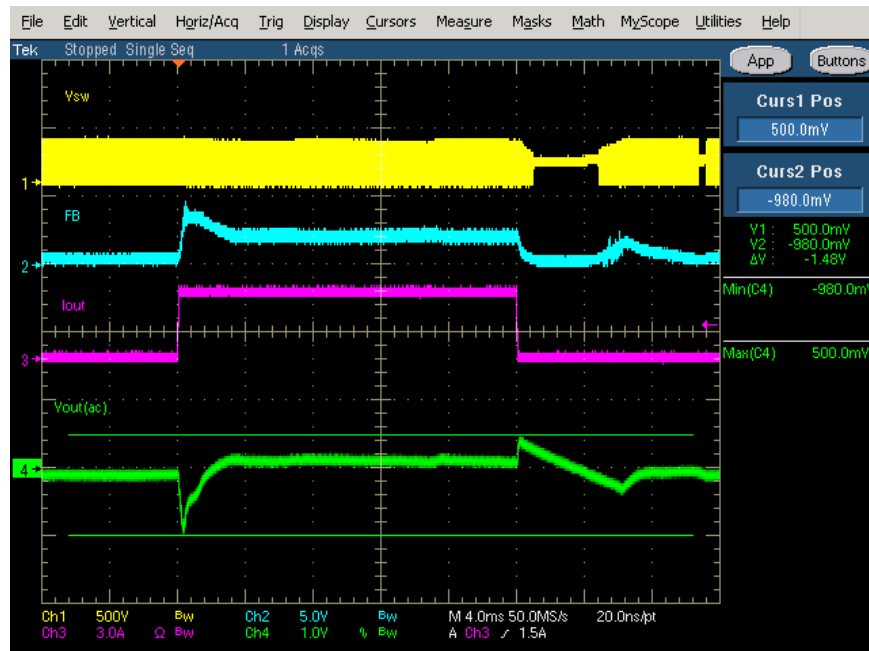


Figure 48 115 Vac 20 Vout Transient Zoom

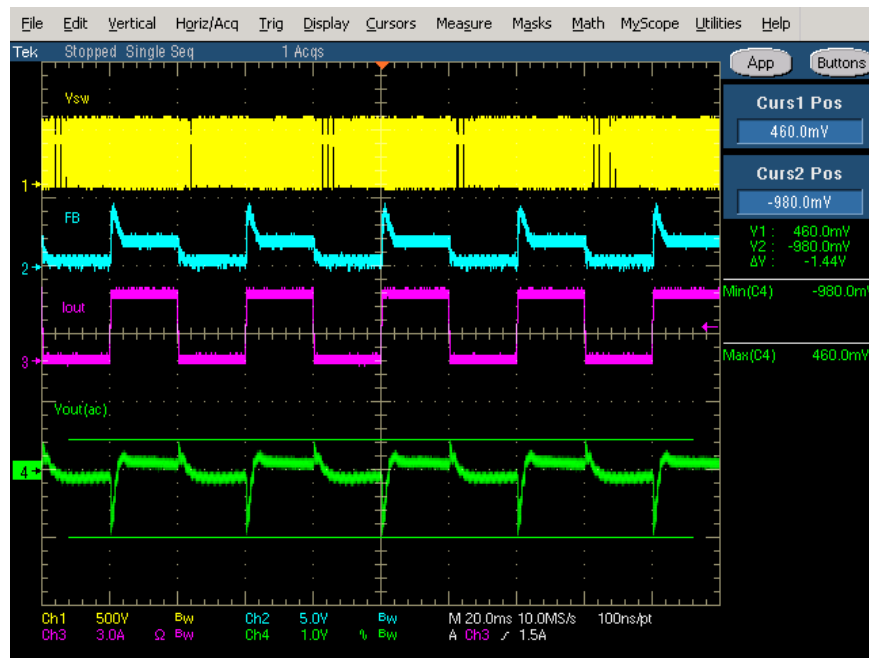


Figure 49 230 Vac 20 Vout Transient

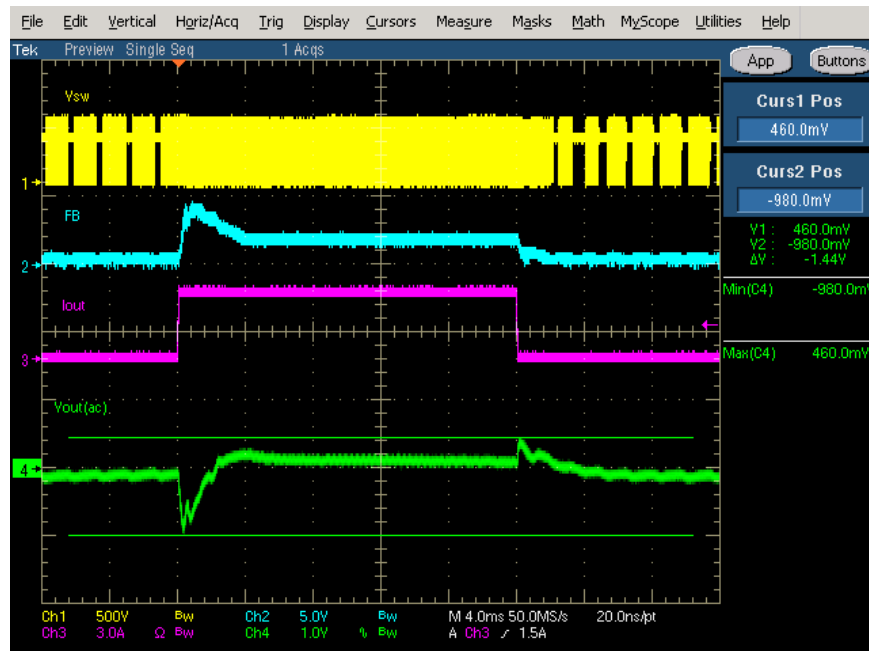
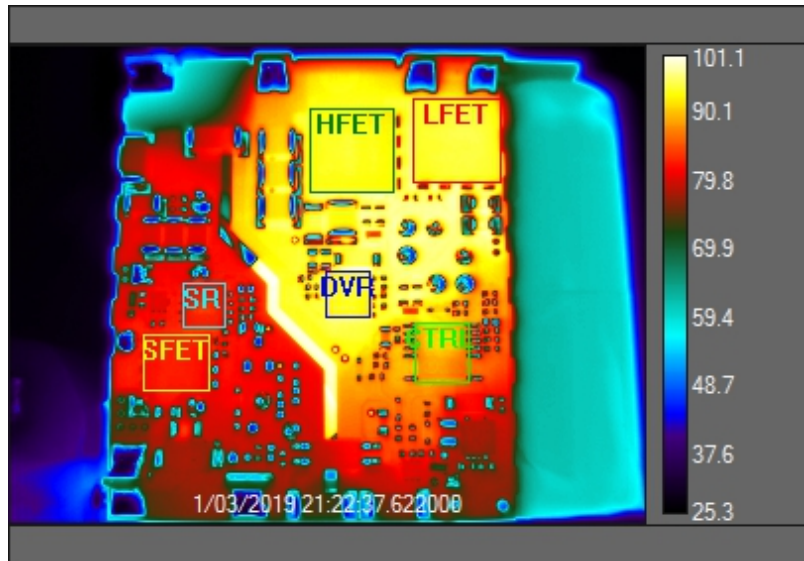


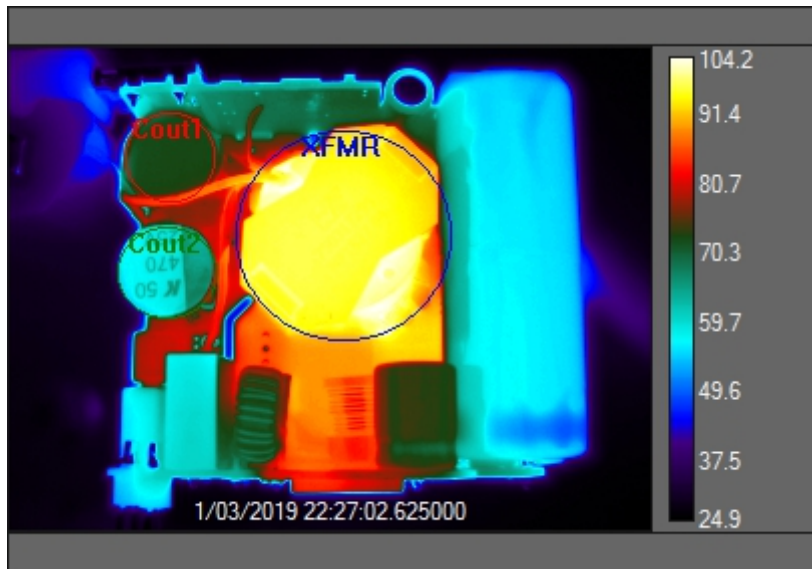
Figure 50 230 Vac 20 Vout Transient Zoom

Thermal Data

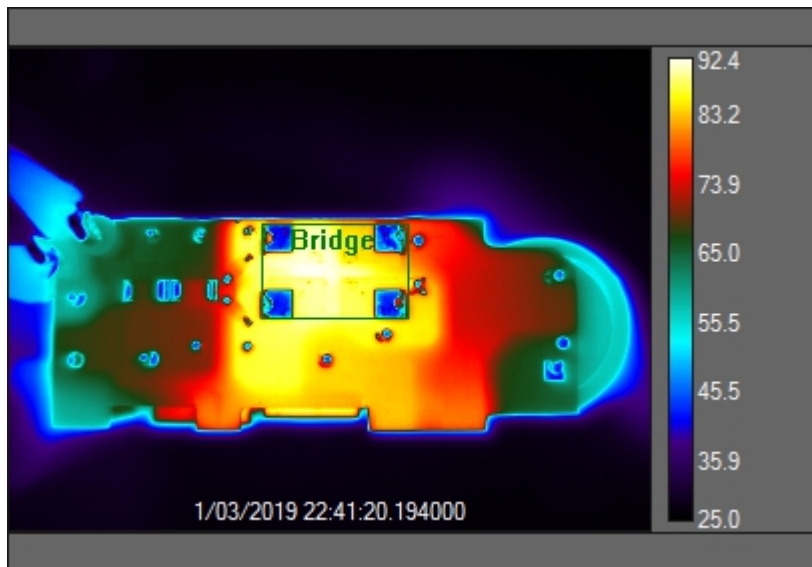
115 Vac Full Load



Statistic [units]	LFET	HFET	DVR	CTRL	SFET	SR
Mean [°C]	92.9	91.9	91.9	87.7	80.3	80.4
Std. Dev. [°C]	0.7	0.5	0.5	2.4	0.4	0.6
Center [°C]	(225.0, 47.0) 93.4	(172.0, 52.0) 92.7	(170.0, 124.5) 92.5	(217.5, 154.0) 89.2	(83.5, 159.0) 80.8	(97.5, 130.0) 81.4
Maximum [°C]	(230, 43) 93.8	(157, 72) 93.4	(169, 127) 93.1	(216, 145) 90.6	(82, 159) 81.0	(96, 133) 82.2
Minimum [°C]	(246, 27) 87.3	(192, 35) 90.5	(160, 114) 90.3	(230, 140) 62.8	(99, 171) 78.1	(88, 120) 79.1

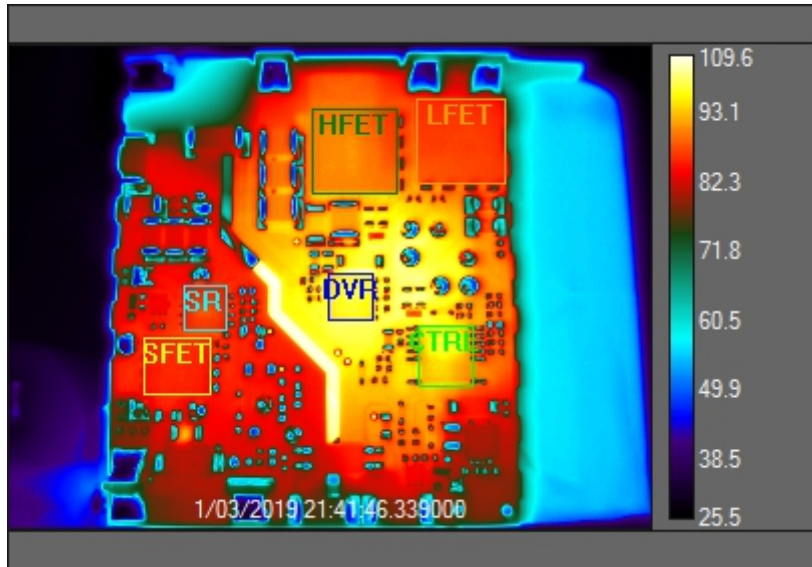


Statistic [units]	Cout1	Cout2	XFMR
Mean [°C]	71.2	58.8	93.1
Std. Dev. [°C]	2.7	4.6	5.3
Center [°C]	(80.0, 54.0) 70.7	(78.5, 111.5) 55.8	(166.5, 93.0) 94.7
Maximum [°C]	(92, 72) 86.9	(102, 114) 80.5	(142, 69) 104.2
Minimum [°C]	(59, 59) 67.6	(55, 116) 51.6	(151, 44) 43.7

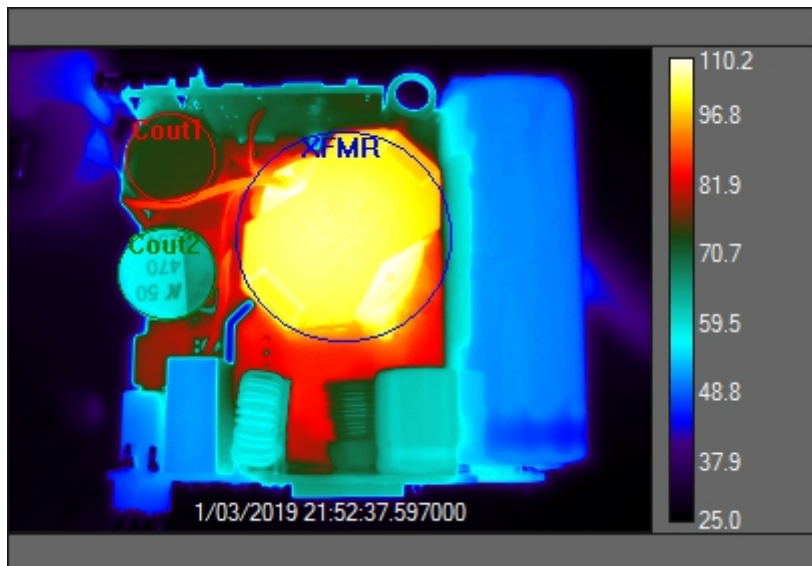


Statistic [units]	Bridge
Mean [°C]	77.0
Std. Dev. [°C]	17.5
Center [°C]	(162.5, 110.5) 89.9
Maximum [°C]	(151, 111) 92.6
Minimum [°C]	(138, 90) 34.1

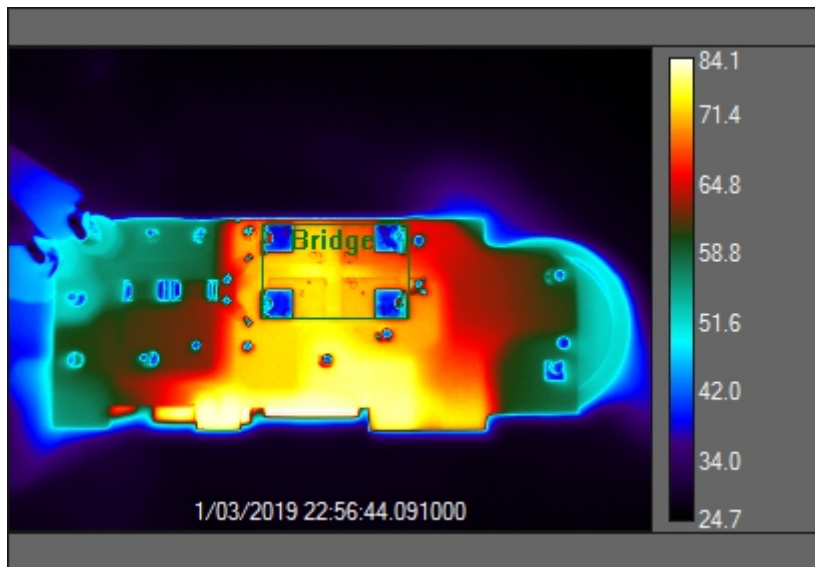
230 Vac Full Load



Statistic [units]	LFET	HFET	DVR	CTRL	SFET	SR
Mean [°C]	85.7	88.7	95.4	93.1	84.5	85.3
Std. Dev. [°C]	0.8	1.1	0.6	2.9	0.5	0.7
Center [°C]	(225.0, 47.0) 85.9	(172.0, 52.0) 89.8	(170.0, 124.5) 96.3	(217.5, 154.0) 95.0	(83.5, 159.0) 84.9	(97.5, 130.0) 86.6
Maximum [°C]	(204, 67) 87.8	(157, 72) 90.9	(169, 127) 97.0	(215, 149) 96.5	(90, 147) 85.2	(96, 133) 87.4
Minimum [°C]	(246, 27) 79.2	(192, 36) 85.1	(160, 114) 93.0	(230, 140) 65.4	(99, 172) 82.0	(88, 120) 83.9



Statistic [units]	Cout1	Cout2	XFMR
Mean [°C]	72.3	58.4	98.6
Std. Dev. [°C]	1.9	4.0	7.0
Center [°C]	(80.0, 54.0) 72.1	(78.5, 111.5) 57.3	(166.5, 93.0) 102.3
Maximum [°C]	(90, 73) 87.2	(102, 116) 79.2	(143, 70) 110.1
Minimum [°C]	(62, 42) 66.0	(55, 116) 49.6	(152, 45) 44.3



Statistic [units]	Bridge
Mean [°C]	63.1
Std. Dev. [°C]	12.6
Center [°C]	(162.5, 110.5) 71.8
Maximum [°C]	(151, 111) 73.8
Minimum [°C]	(138, 90) 31.2

BOM MAIN BOARD

Reference	Qty	Value	Tolerance	Footprint	Manufacturer	Manufacturer Part Number
BD1	1	800V/2A		4-SMD	Comp Chip	Z4DGP408L-HF
C10 C20	2	1nF	±5%	402	Murata	GMD155R71H102KA01D
C11	1	0.1uF	±20%	(13X5x11)mm	Kemet	R46KF310000P1M
C1-2	2	470uF/25V	±20%	(10.5x13)mm	Kemet	A750MS477M1EAAE015
C12 C52	2	330pF	±10%	1808 (4520 Metric)	Knowles Syfer	1808YA250331KXTSY2
C13	1	150 pF	±10%	603	TDK	C1608CH2E151K080AA
C14	1	330 pF	±5%	402	Kemet	C0402C331J3GAC7867
C15 C29	2	NI		402		
C17-18 C23-24 C26 C28	6	0.1µF	±10%	402	TDK	CGA2B3X5R1V104K050BB
C21	1	0.1 uF	±20%	603	Murata	GCM188R71E104KA57D
C22	1	0.1 uF	±20%	1210	KEMET	C1210C104KBRAC7800
C25	1	NI	±10%	805		
C27	1	1.0 uF	±10%	805	Taiyo Yuden	HMK212BBJ105KG-TE
C3	1	2.2uF	±20%	603	Kemet	GRM188R6YA225MA12D
C31	1	56uF	±20%	(12.X5)mm	Wurth Electronics Inc.	860080472003
C32 C38-39 C42	4	0.22µF	±10%	1210	TDK Corporation	C3225X7T2W224K200AA
C33	1	2.2uF	±20%	603	Kemet	GRM188R6YA225MA12D
C34-35 C40 C43	4	390pF	±5%	402	Murata	GRM1555C1H391JA01J
C36 C45 C50 C54	4	22 uF	±20%	1206	TDK	C3216X5R1V226M160AC
C37 C49	2	NI		402		
C4	1	8.2n	±5%	402	Kemet	C0402C822J5RAC786
C41	1	6.8 µF	±20%	(8X14)mm	Wurth	860021374009
C44	1	10nF	±10%	402	Murata	GCM155R71H103KA55D
C46	1	47 nF	±10%	402	TDK	C1005X6S1H473M050BB
C47	1	10 uF	±20%	603	Murata	GRT188R61C106ME13D
C48	1	1uF	±5%	402	TDK	C1005x5R1E105k050BC
C5 C16	2	0.33 uF	±5%	402	TDK	CGA2B3X7S1A334M050BB
C51	1	4.7 uF	±20%	603	Murata	GRT188R6YA475ME13D
C6 C19 C30	3	1.0uF	±10%	603	Samsung	CL10A105KL8NUNC
C7	1	100 µF	±20%	(14.5X42)mm	United Chemi-Con	EKXJ401ELL101MU40S
C8 C53	2	1000pF	±10%	1808 (4520 Metric)	Johanson Dielectrics Inc.	502R29W102KV3E-****-SC
C9	1	100 pF	±5%	402	Kemet	C0402C101J1HACTU
CON1	1	NA	NA	THT/SM	Wurth	632723300011
D10 D12	2	5.5V	NA	X2DFN2	ON Semiconductor	NSPU3051N2T5G
D1-2	2	20V	NA	X2DFN2	ON Semiconductor	ESD7241N2T5G
D17	1	NI		SOD-523		
D3 D15	2	600 V 1 A	NA	SOD-123T	ON Semiconductor	ES1JFL
D4 D8	2	800V 200mA	NA	SOD-323F	Panasonic	DA2JF8100L
D5 D11 D13 D16	4	40V 1.5A	NA	DSN2(0603)	ON Semiconductor	NSR15405NXT5G
D6	1	100V 200mA	NA	SOD-323	ON Semiconductor	MMDL914T1G

Reference	Qty	Value	Tolerance	Footprint	Manufacturer	Manufacturer Part Number
D7 D14 D18	3	100V 200mA	NA	SOD-523	ON Semiconductor	NSD914XV2T1G
D9	1	150V 2A	NA	SMA	STMicroelectronics	STPS2150A
F1	1	3.15A	250V	(8.5x4x8) mm	Littelfuse Inc.	39213150000
J1-12	12	NA	NA	2X3mm	NA	NA
L N	2					
L1	1	2.2 uH	20%	(5.50x 5.30)	Würth	744316220
L2	1	33 uH	10%	D = 7.8mm	Würth	744772330
Q1	1	600V 9A	NA	ThinPak 8X8	Infineon Technologies	IPL60R385CPAUMA1
Q15	1	NI		SOT-23		
Q2	1	2.6 mOhm		5X6 SO8	Vishay	SI7145DP-T1-GE3
Q5	1	600V 9A	NA	ThinPak 8X8	Infineon Technologies	IPL60R299CP
Q7	1	120V 11 mOhm	NA	SOIC8_FL	ON Semiconductor/Fairchild	FDMS86202
R1 R10	2	365k	±1%	402	Yageo	RC0402FR-07365KL
R11	1	1M	±5%	1206	Vishay	CRCW12061M00JNEAHP
R12	1	732R	±1%	402	Yageo	RC0402FR-07732RL
R13 R21	2	49.9k	±1%	402	Yageo	RC0402FR-0749K9L
R14	1	1R0	NA	603	Vishay	CRCW06031R00JNEA
R15	1	100R	±1%	805	Vishay	RCS0805100RJNEA
R16 R20	2	430m	±1%	805	Vishay	RCWE0805R430FKEA
R17	1	23.2k	±1%	402	Vishay	CRCW040223K2FKEDC
R18-19	2	59k	±1%	402	stackpole	RMCF0402FT59K0
R2 R4	2	100k	±1%	402	stackpole	RMCF0402FT100K
R23	1	7.32k	±1%	402	Yageo	RC0402FR-077K32L
R24 R54	2	1.5k	±1%	1206	Vishay	CRCW12061K50JNEA
R25	1	49.9k	±1%	402	Yageo	C0402FR-0749K9L
R26	1	5mOhm	±1%	1206	Visahy	WSLP12065L000FEA
R27	1	165k	±1%	402	Yageo	RC0402FR-07165KL
R28	1	0R0	NA	402	Panasonic Electronic Components	ERJ-2GE0R00X
R29	1	1R0	±1%	402	Vishay	CRCW04021R00JNEDIF
R3	1	46.4k	±1%	402	Yageo	RC0402FR-0746K4L
R30 R34	2	0R0	NA	402	Panasonic Electronic Components	ERJ-2GE0R00X
R31	1	47k	±1%	402	Vishay	CRCW040247K0FKEDC
R32	1	51R	±1%	402	Vishay	CRCW040251R0JNED
R33	1	11.5k	±1%	402	Vishay	CRCW040211K5FKED
R35	1	NI		402		
R37	1	15k	±1%	402	Vishay	CRCW040215K0JNED
R38	1	22.1k	±1%	402	Yageo	RC0402FR-0722K1L
R39	1	120k	±1%	402	Vishay	CRCW0402120KFKEDC
R40 R42-44	4	22.1R	±1%	402	Vishay	CRCW040222R1FKED
R41	1	2.32k	±1%	402	Yageo	RC0402FR-072K32L
R45	1	10R0	±1%	402	Vishay	CRCW040210R0FKED
R46	1	1M	±1%	402	Vishay	CRCW04021M00FKEDC

Reference	Qty	Value	Tolerance	Footprint	Manufacturer	Manufacturer Part Number
R47	1	5.11k	±1%	402	Vishay	CRCW04025K11FKTD
R48	1	121k	±1%	402	Vishay	RC0402FR-07121KL
R49	1	220k	±1%	402	Murata	NCP15WM224J03RC
R5	1	1k	±1%	402	Vishay	CRCW04021K00FKTD
R50	1	10k	±1%	603	Vishay	CRCW060310K0FKEB
R51	1	365k	±1%	402	Vishay	RC0402FR-07365KL
R52	1	2.55M	±1%	402	Vishay	CRCW04022M55FKED
R53 R55	2	NI		402		
R6 R36	2	15R0	NA	603	Vishay	CRCW060315R0JNEA
R7	1	10R0	±1%	402	Vishay	CRCW040210R0FKED
R8 R22	2	22R0	NA	603	Vishay	CRCW060322R0JNEA
R9	1	4.02k	±1%	402	Vishay	CRCW04024K02FKEDHP
T1	1	120 uF / Material: ML29D	10%	RM8LP	Würth w/ Hitachi Metals	750317295r04
T2	1	330 uH	10%		Bourns Electronics	TX9/5/3C-3E10 12Turns
U1	1	65W	na	QFN16	Weltrend	WT6615F
U2	1	30V 1000 MHz		Tssop 16	ON Semiconductor	NCP1568S02DBR2G
U3-4	2	ADJ	1%	XDFN6	ON Semiconductor	NCP4623HMXADJTCG
U5	1	20V	NA	DFN8	ON Semiconductor	NCP4306AADZZAMNTWG
U6	1	1.22	2%	DFN 3X3	TI	LT3014BEDD#PBF
U7	1		NA	DFN 10 4X4mm	ON Semiconductor	NCP51530AMNTWG
U8	1	1.17V 50mA	NA	4-SMD, Gull Wing	CEL	FODM8801BV
Z1	1	6.8V 200mW	±5%	SOD-523-2	ON Semiconductor	MM5Z6V8T1G
Z3	1	NI		SOD-523-2		
Z4	1	22V 500mW	±5%	SOD-523-2	ON Semiconductor	MM5Z22VT1G

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