



纳微 Navitas

*Let's go **GaNFast**™*

Magnetics Study Enables New Class of High Density AC/DC Converters

Tom Ribarich, Sr. Director Engineering Systems

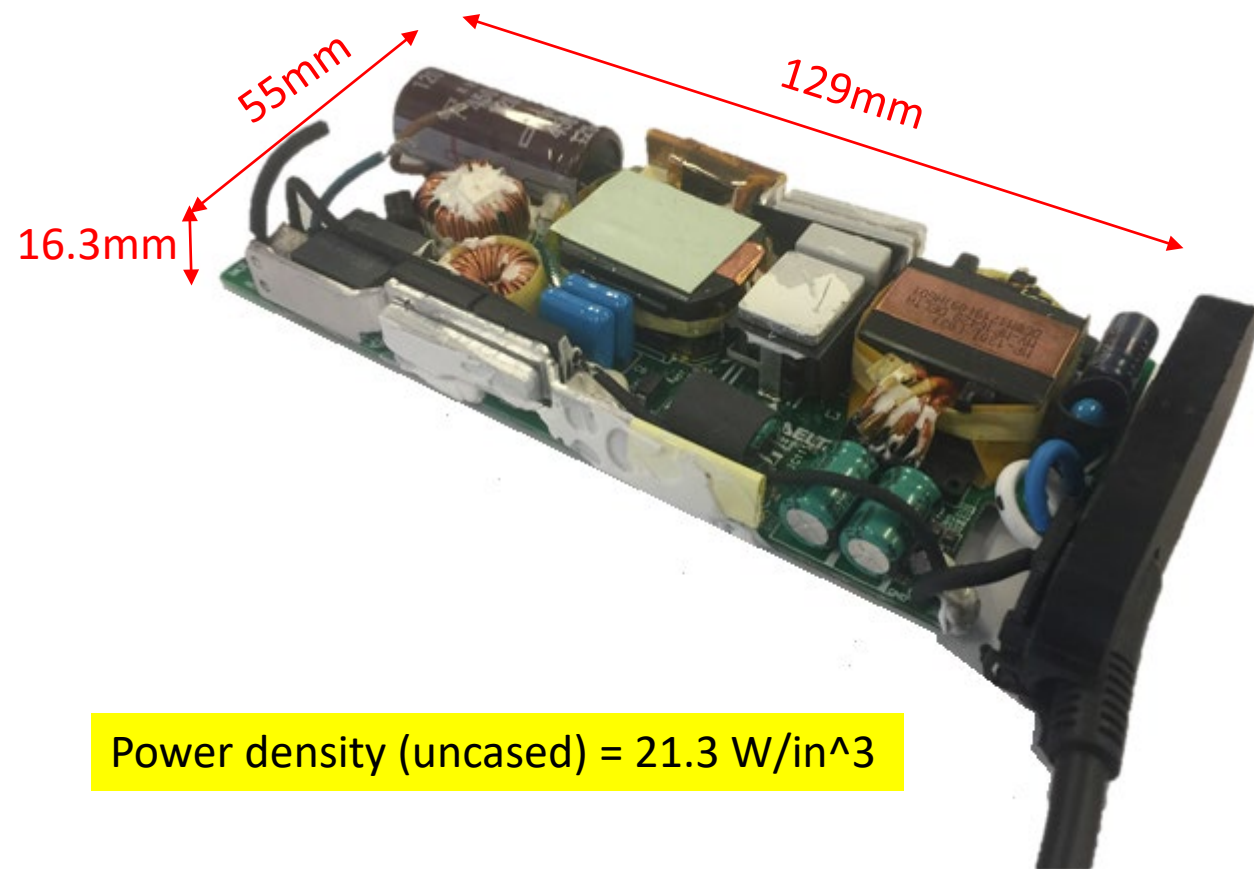
tom.ribarich@navitassemi.com



- Existing AC/DC converter teardowns
- AC/DC converter circuit architecture
- Magnetic Study DC-DC testing of PFC and LLC stages
- New 150W AC/DC converter specifications
- Build and test new high density AC/DC converter prototype



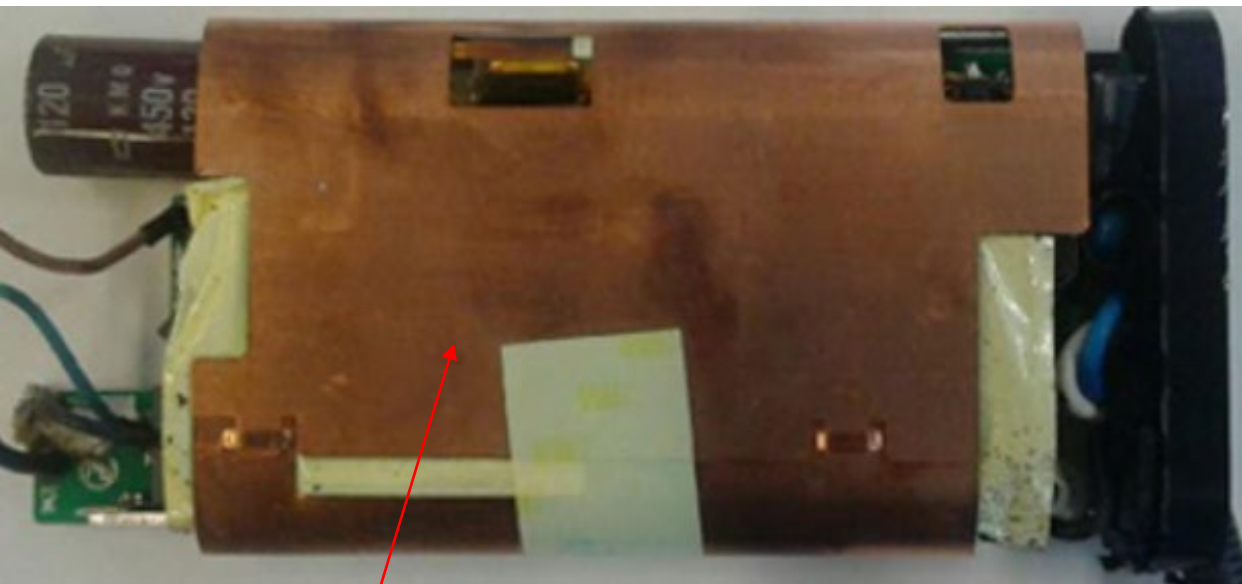
HP 150W Adapter (Delta)



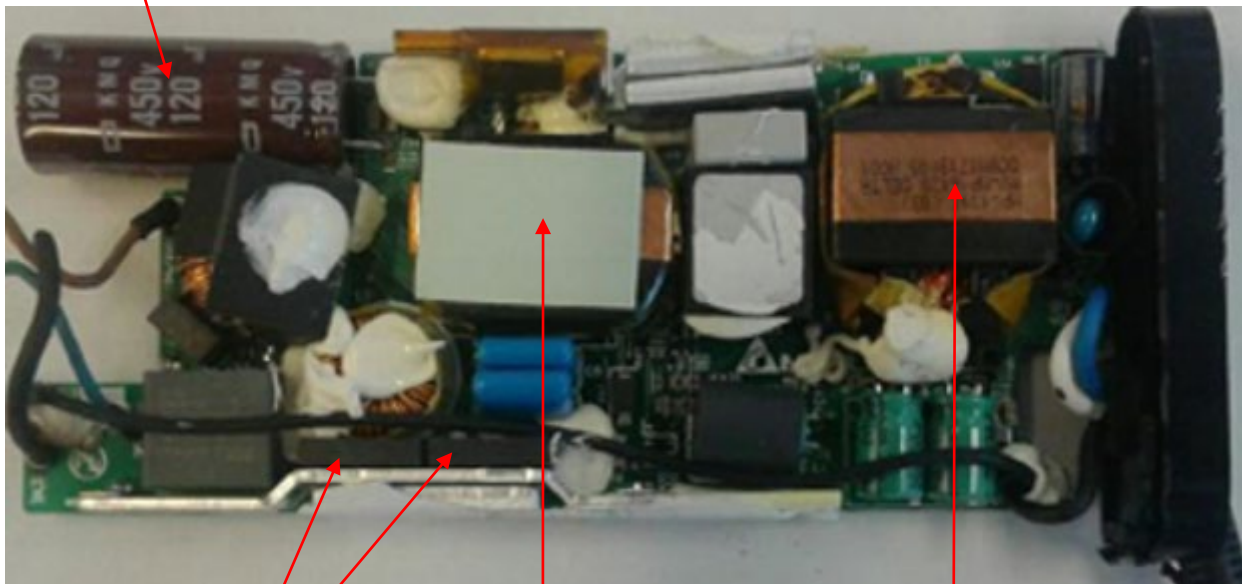
EFF = 92.6% @ 90VAC/100%



HP 150W Adapter (Delta)



Copper Wrapper



DC Bus Capacitor

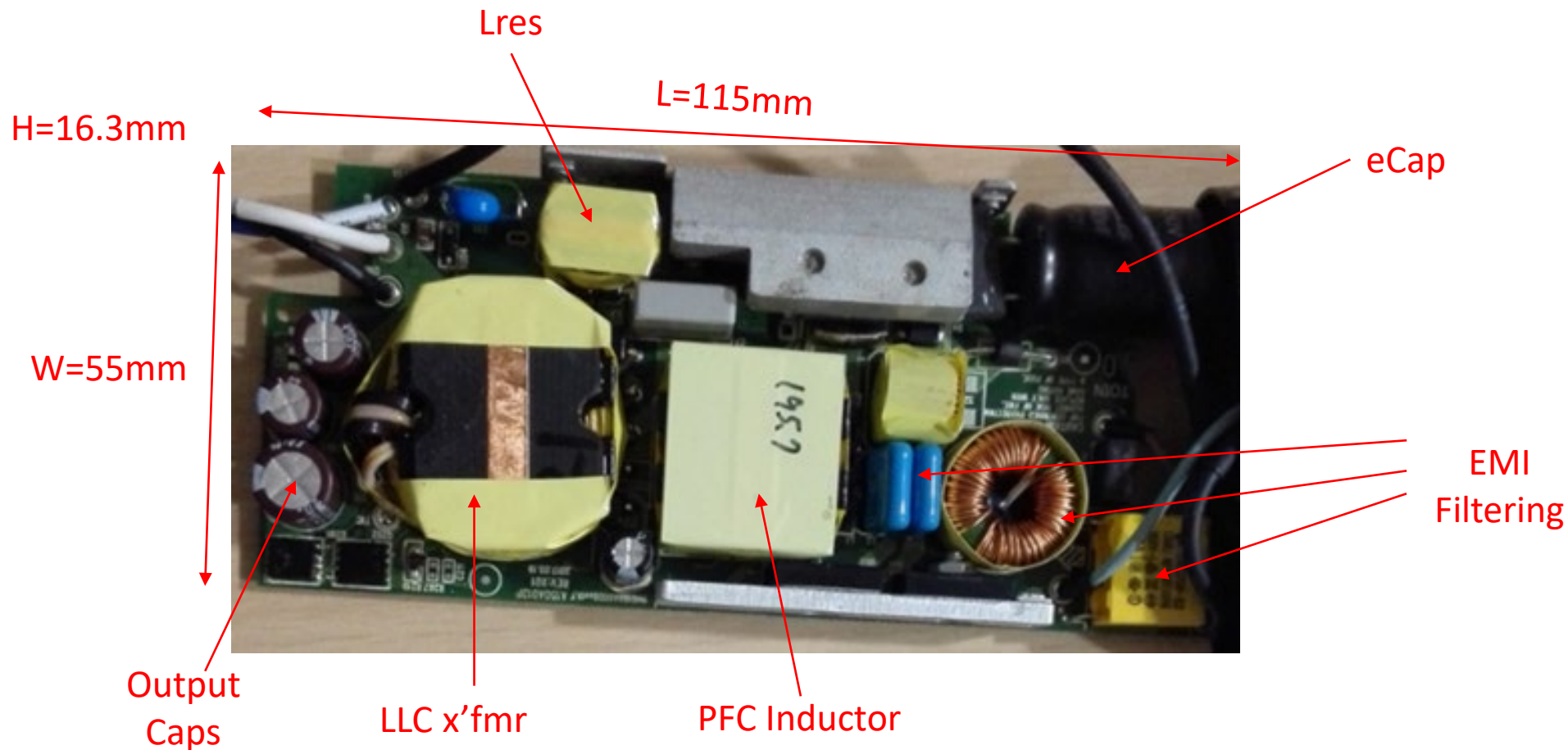
2x Input Bridge
w/heatsinking

PFC Inductor

LLC Transformer



HP 150W Adapter (Chicony/LiteON)

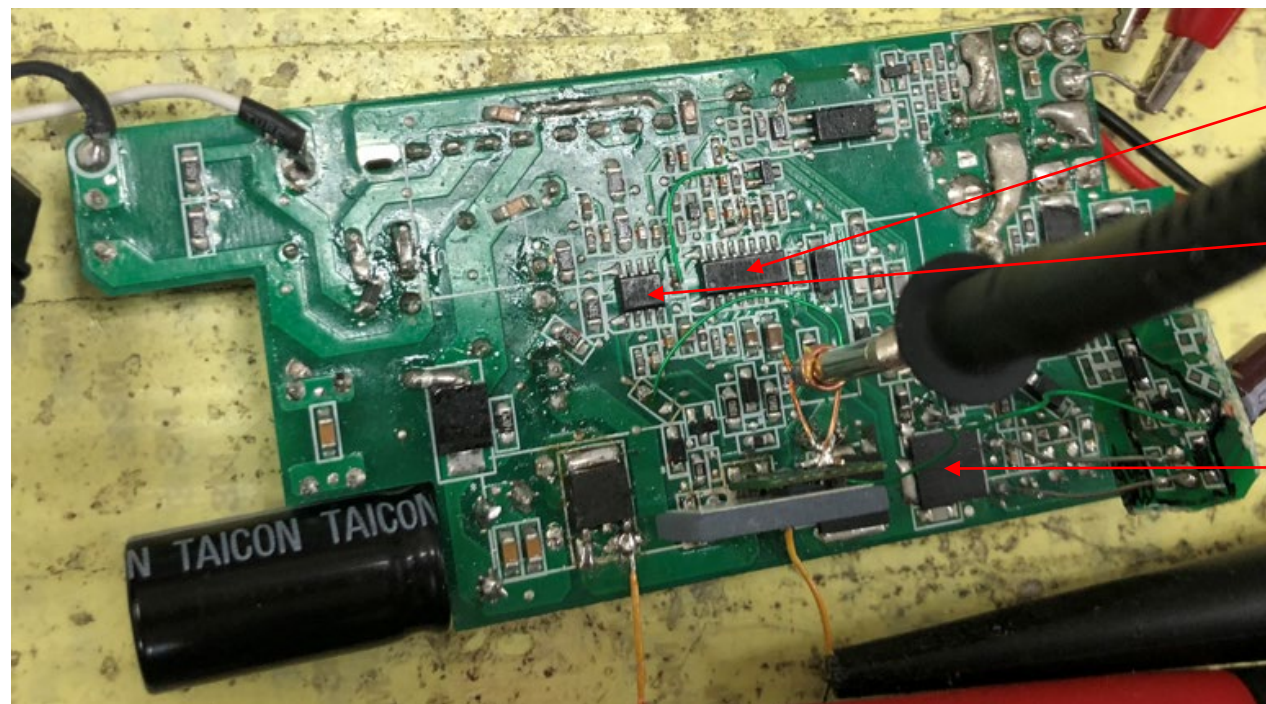


EFF = 92.7% @ 90VAC/100%

Power density (uncased) = 23.8 W/in³



HP 150W Adapter (Chicony/LiteON)



TEA19161 LLC

TEA19162 PFC

IFX 99 mOhm

EFF = 92.7% @ 90VAC/100%

Power density (uncased) = $16.3 \times 55 \times 115 = 23.8 \text{ W/in}^3$



$W=60$

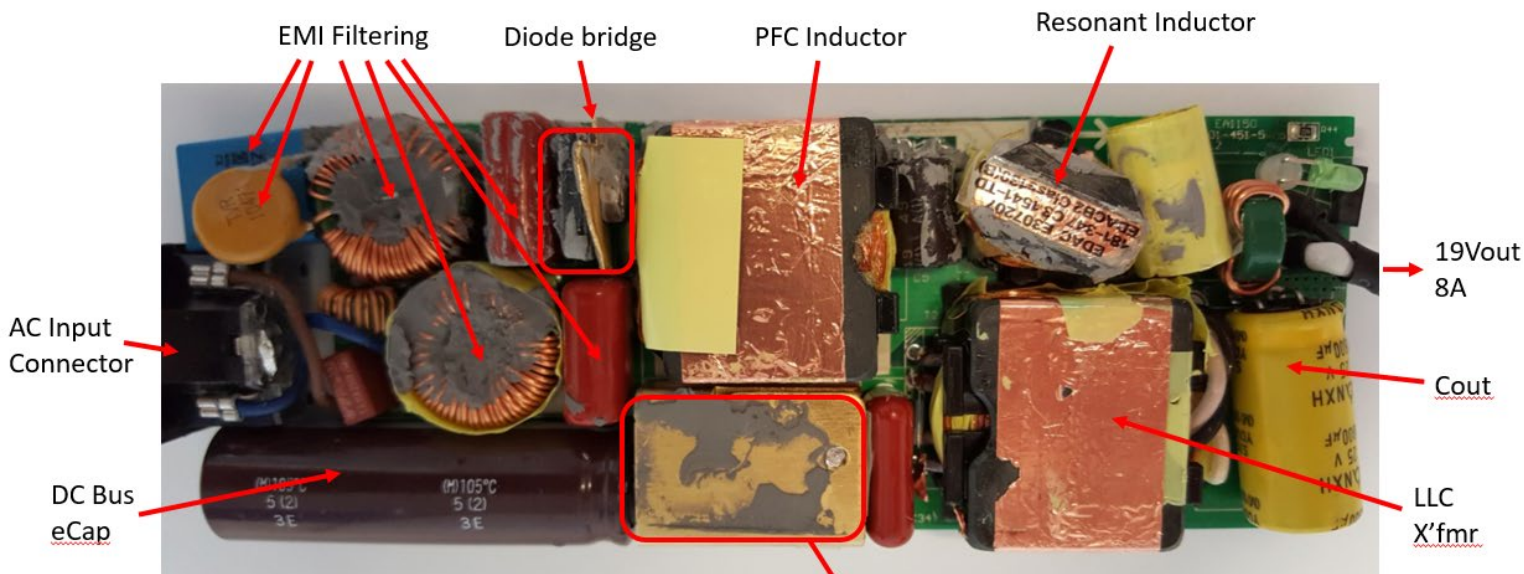


EFF = 91.5% @ 100VAC/100%

Power density (cased) = 12 W/in³



150W Adapter (Razor BLADE)



Power density (uncased) = 20.2 W/in³

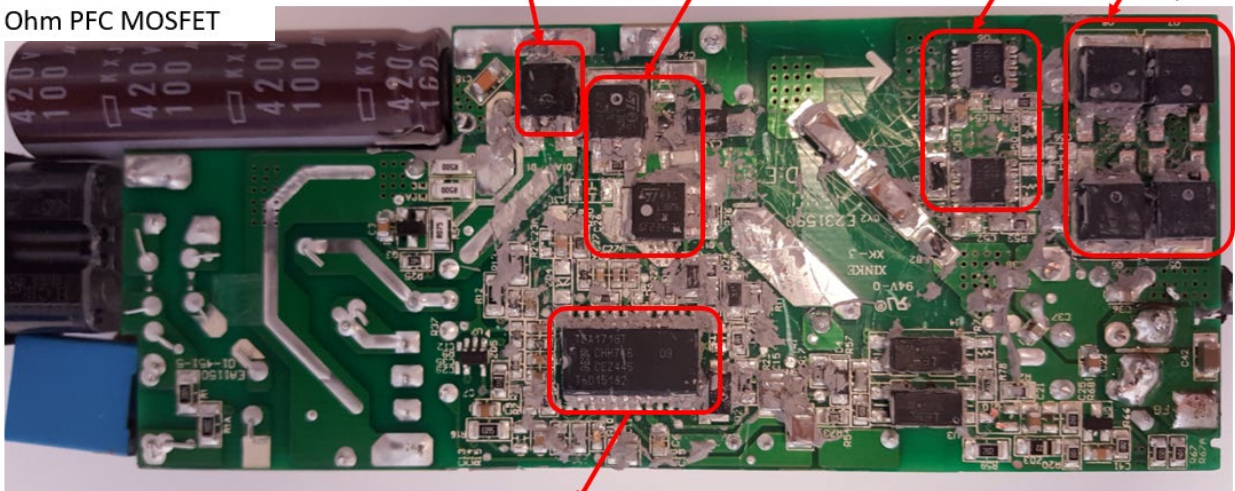
Underneath the heatsink:
Vishay SiHP30N60E 650V, 0.125 Ohm PFC MOSFET

PFC DIODE
NXP BYV25D-600: 600V/5A
rectifier diode, ultrafast

ST STD13NM60N:
650V, 0.36Ohm
HB MOSFETs

NXP TEA1791A:
SR controller

SR FETs
IPD088N06N3:
60V/8.8mOhm





150W Comparison

Company	L x W x H (mm) (uncased)	Size (cc) (uncased)	Power Density (W/in3) (uncased)	L x W x H (mm) (cased)	Size (cc) (cased)	Power Density (W/in3) (cased)
Delta HP	129 x 55 x 16.3	115.65	21.3	138 x 66.3 x 22.5	205.9	11.9
Razor BLADE	141.6 x 50.2 x 17.1	121.8	20.2	149.2 x 60.1 x 22.9	205.3	12.0
Chicony/ LiteON HP	115 x 55 x 16.2	103.1	23.8	138 x 66.3 x 22.5	205.9	11.9



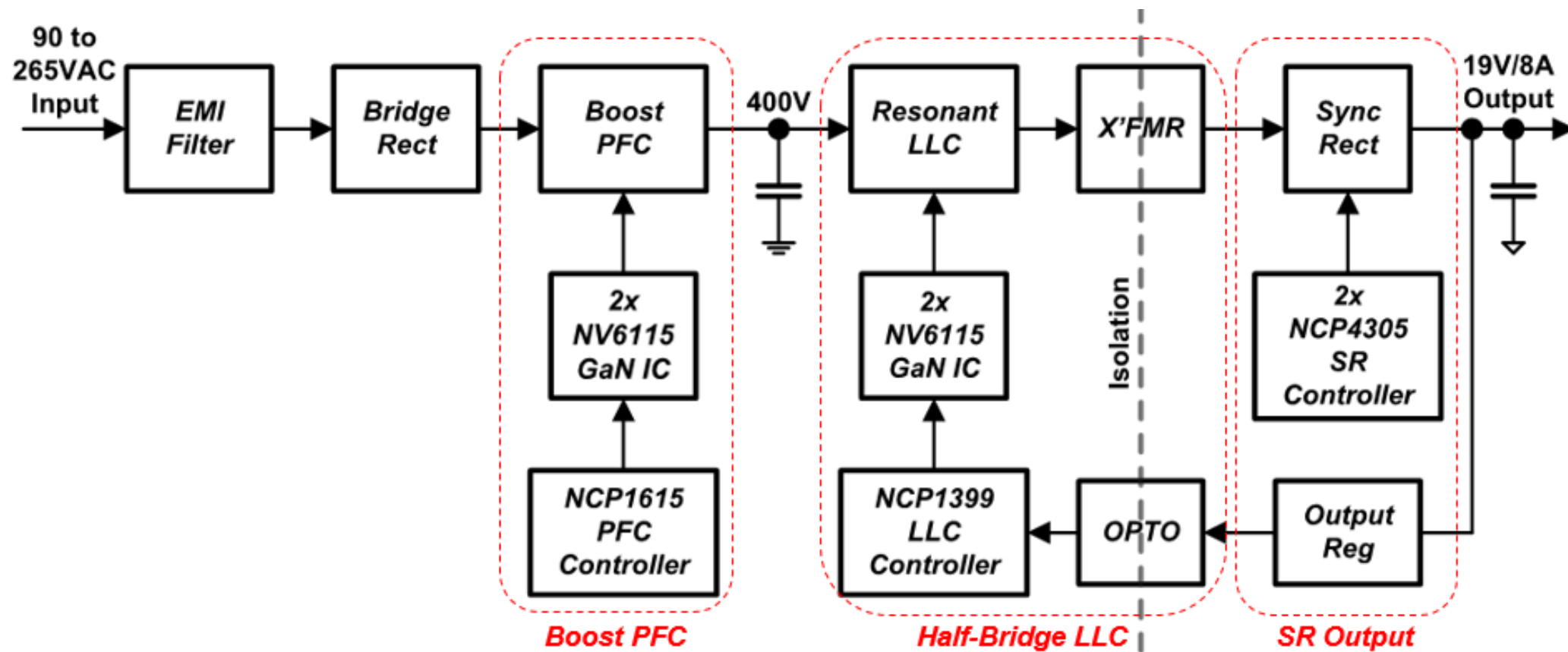
The Need for Speed

- Existing converters limited to 100kHz range
- Limitation due to switch capacitance
- GaN technology offers 20x reduction in switch capacitance
- GaN Power ICs can operate comfortably at 2MHz

- To shrink components we need to increase frequency!

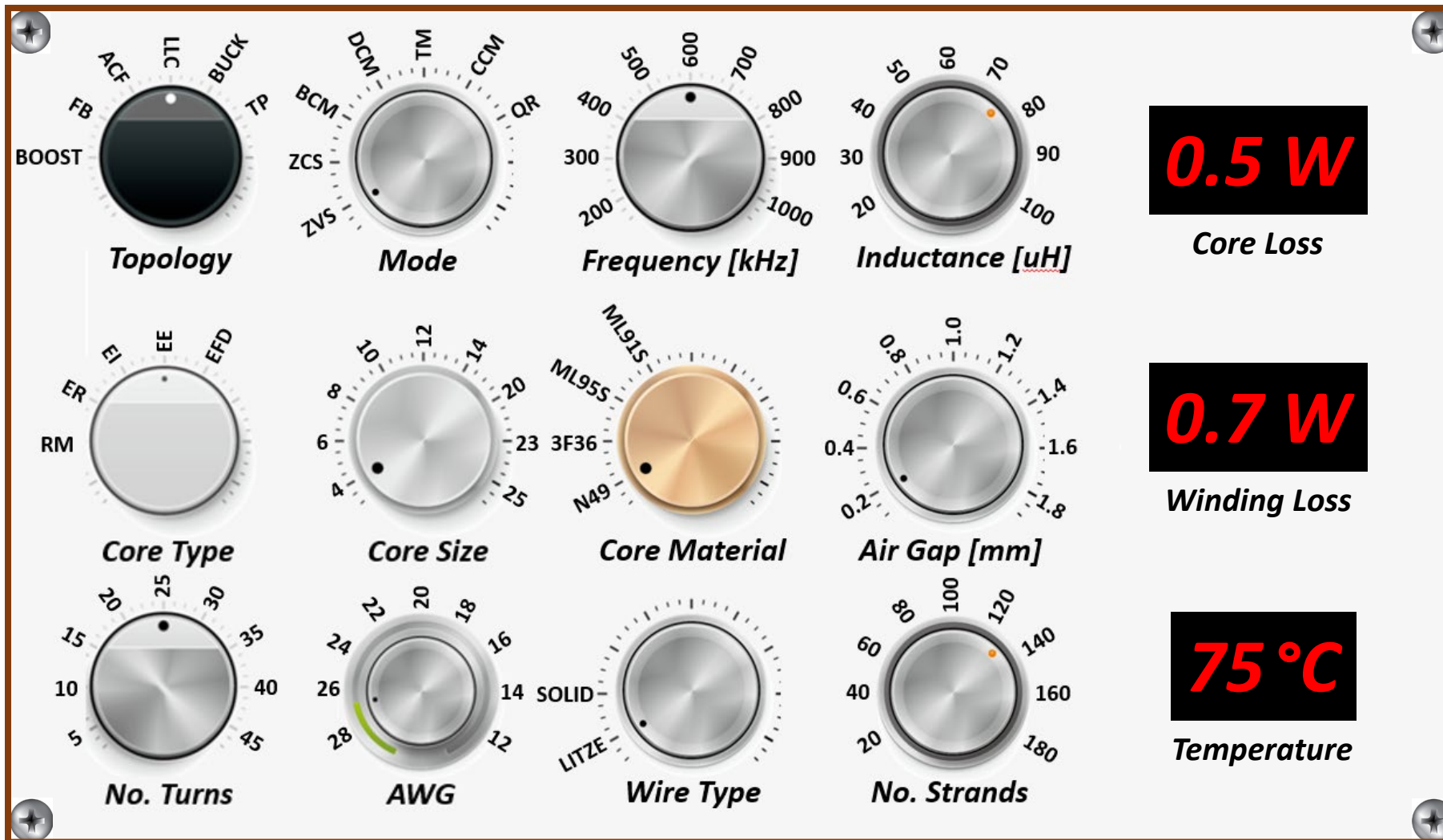


AC/DC Converter Architecture



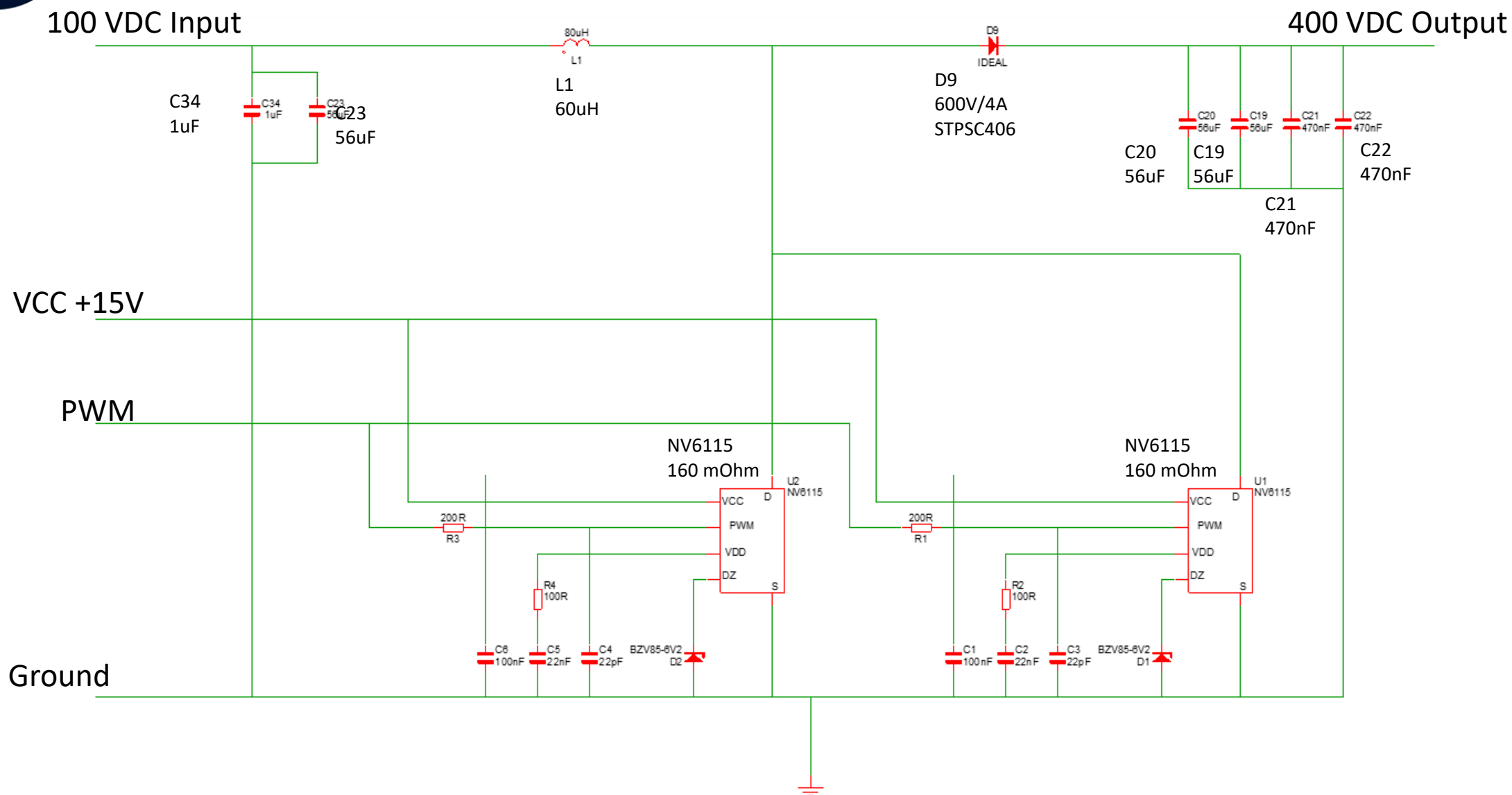


Magnetics Study → Many Knobs to Turn



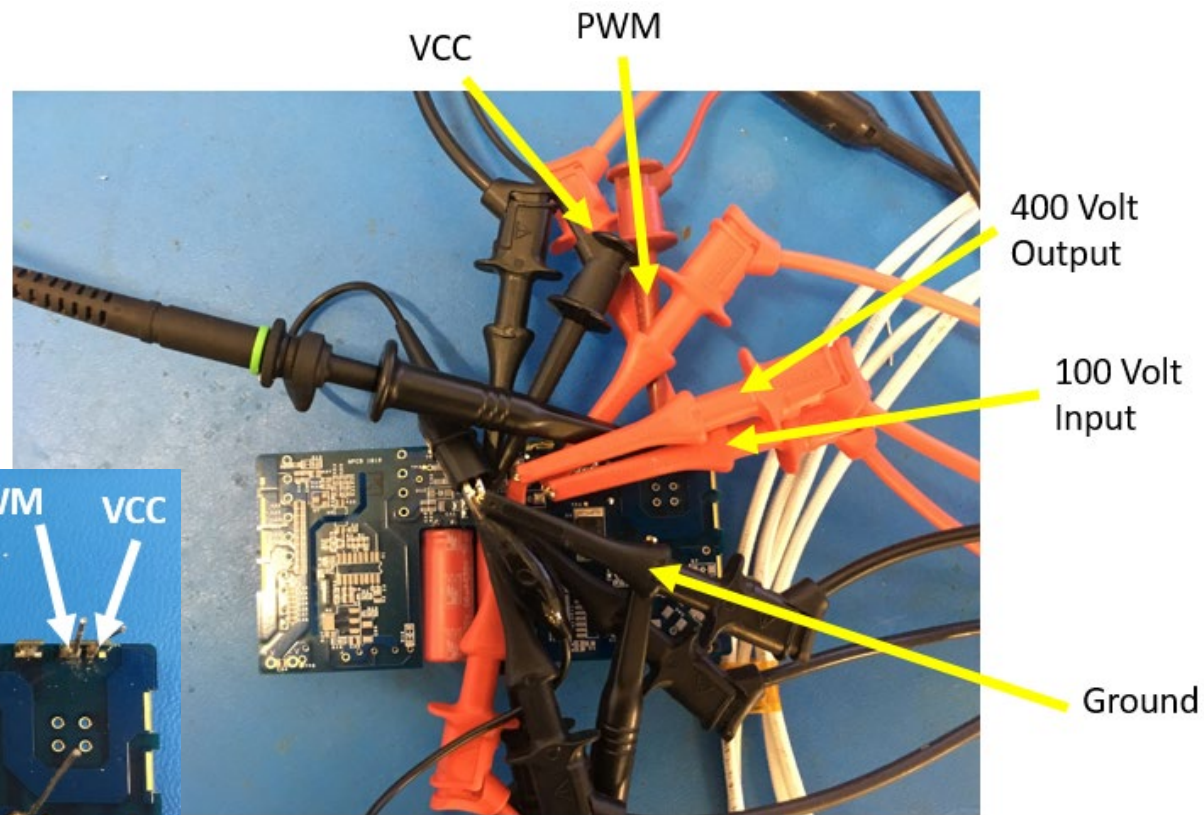
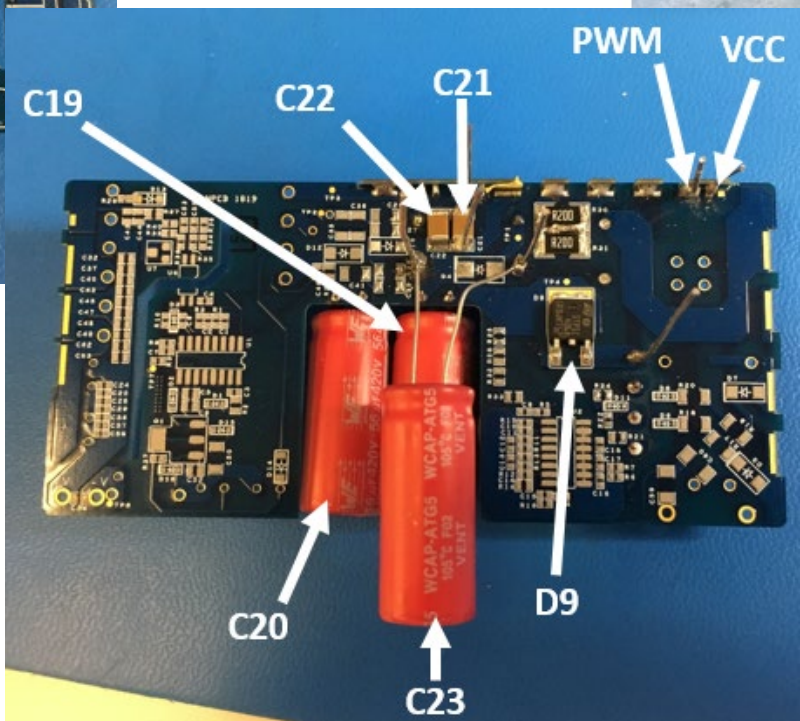
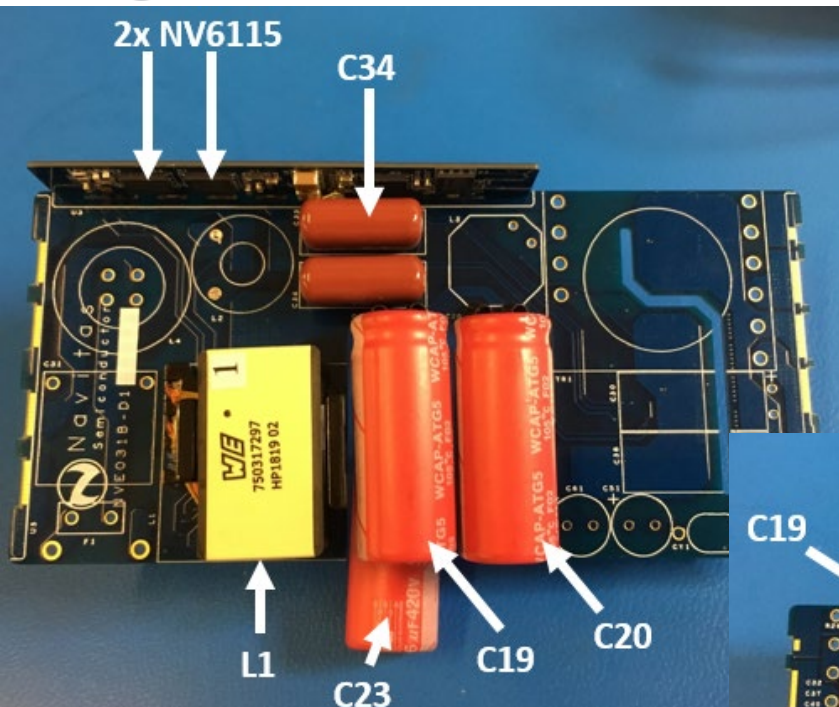


PFC Test Circuit (150W)





PFC Test Setup



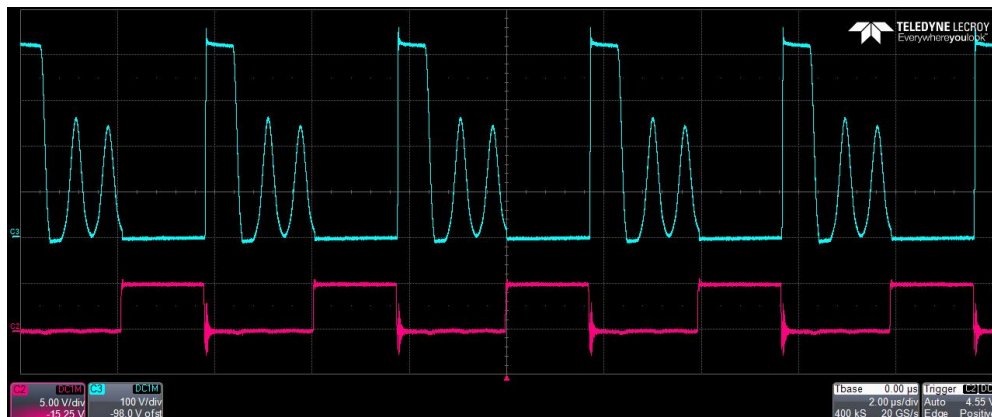


PFC Waveforms and Thermals (300kHz@100% load)

50%

DRAIN

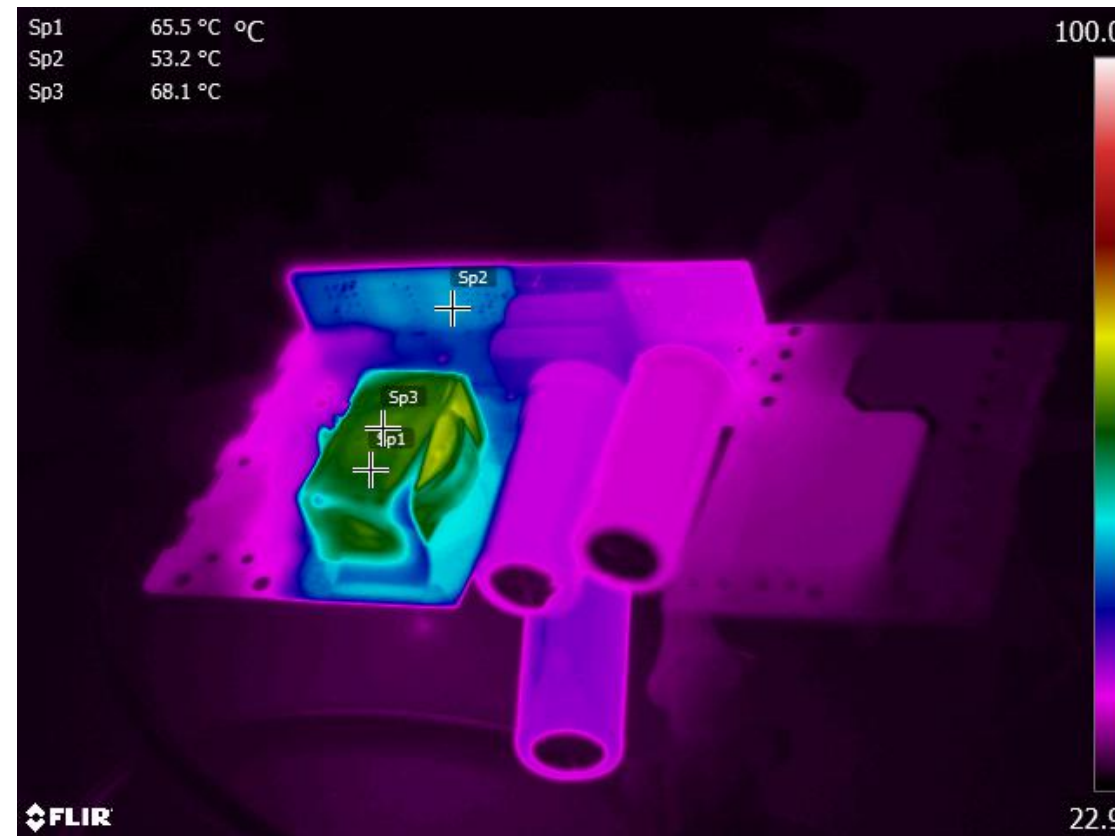
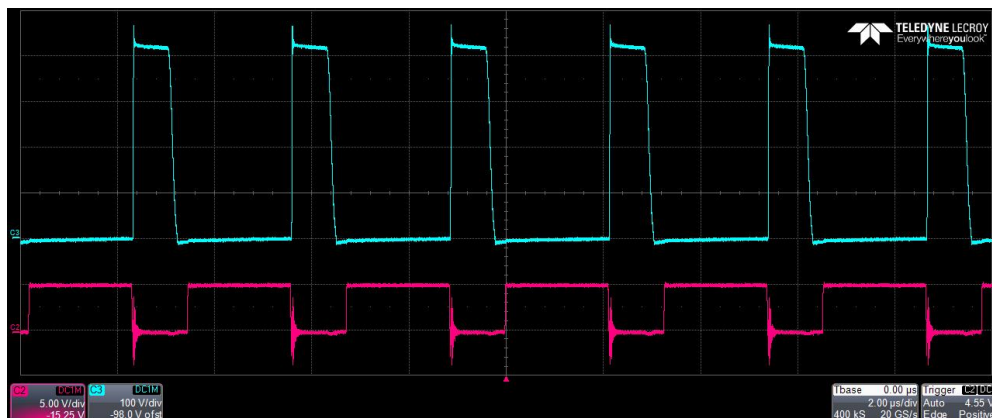
PWM



100%

DRAIN

PWM



ER23 Core Type

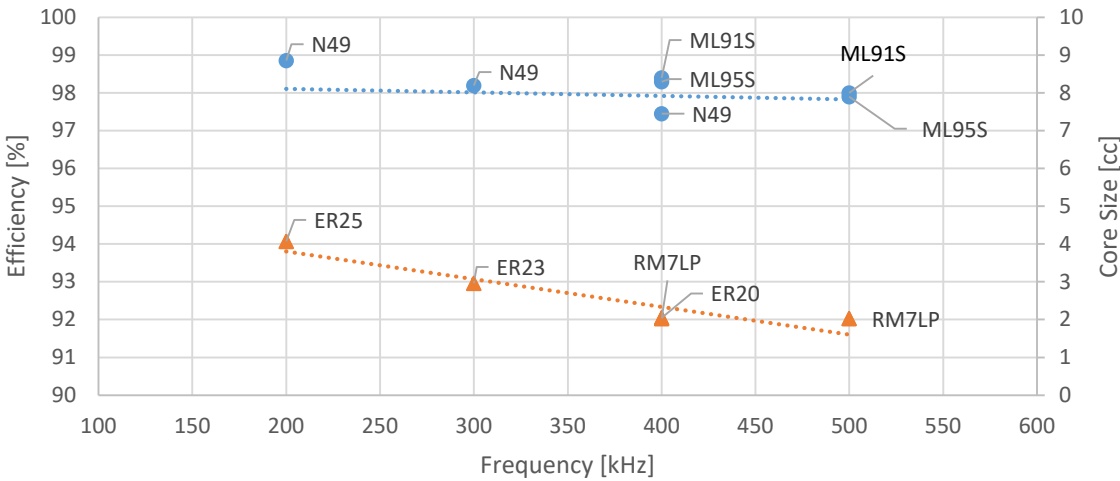


PFC Measurements



Version	V0	VK	V3	V4	V5	V6	V8	V9	V10	V11
Core Type	ER 25	ER 25	ER 23	ER 23	ER 20	ER 20	RM 7 LP	RM 7 LP	RM 7 LP	RM 7 LP
Core Material	N49	N49	N49	N49	N49	N49	ML91S	ML95S	ML91S	ML95S
Freq [kHz]	200	200	300	300	400	400	400	400	500	500
EFF [%]	97.74	98.86	97.33	98.2	97.45	97.42	98.4	98.3	97.9	98
L [uH]	80	80	60	63	45	44	44	44	35	35
Core Size [cc]	4.07	4.07	2.96	2.96	2.05	2.05	2.03	2.03	2.03	2.03
Temperature [degC]	82.8	58.3	107.2	68.1	122.1	95.9	94.8	102.2	58.7	63.3
No. of turns	25	30	18	24	18	18	25	25	20	24
Wire AWG	21.5	21.5	21.5	21.5	21.5	21.5	26	26	23.5	23.5
Strands #/AWG	177/44	177/44	177/44	177/44	177/44	177/44	100/46	100/46	175/46	175/46
Ae [mm2]	70.8	70.8	50	50	28.66	28.66	45.3	45.3	45.3	45.3

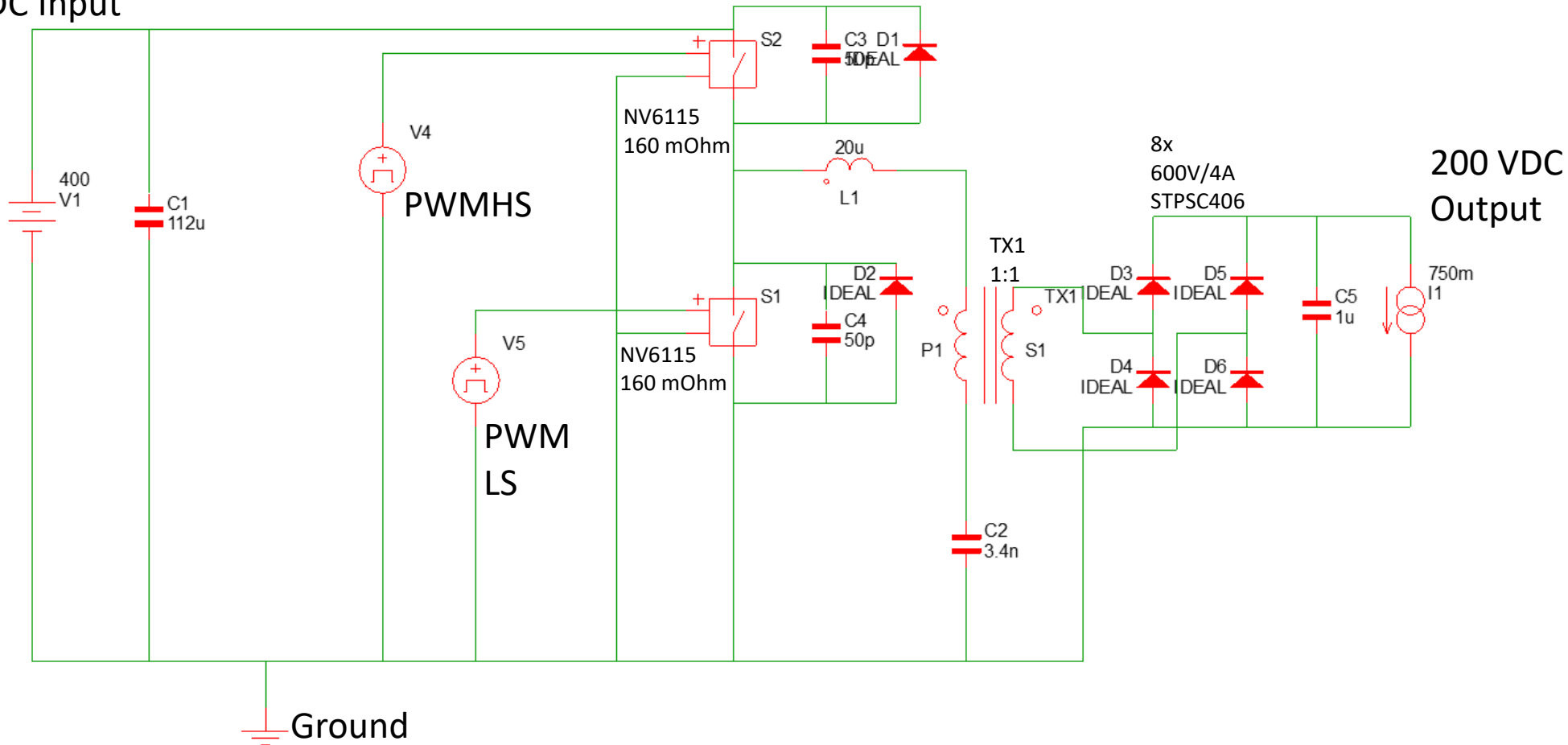
PFC Efficiency and Core Size vs. Frequency
(DC-DC Testing, Vin=100V, Vout=400V, 150W, CrCM)





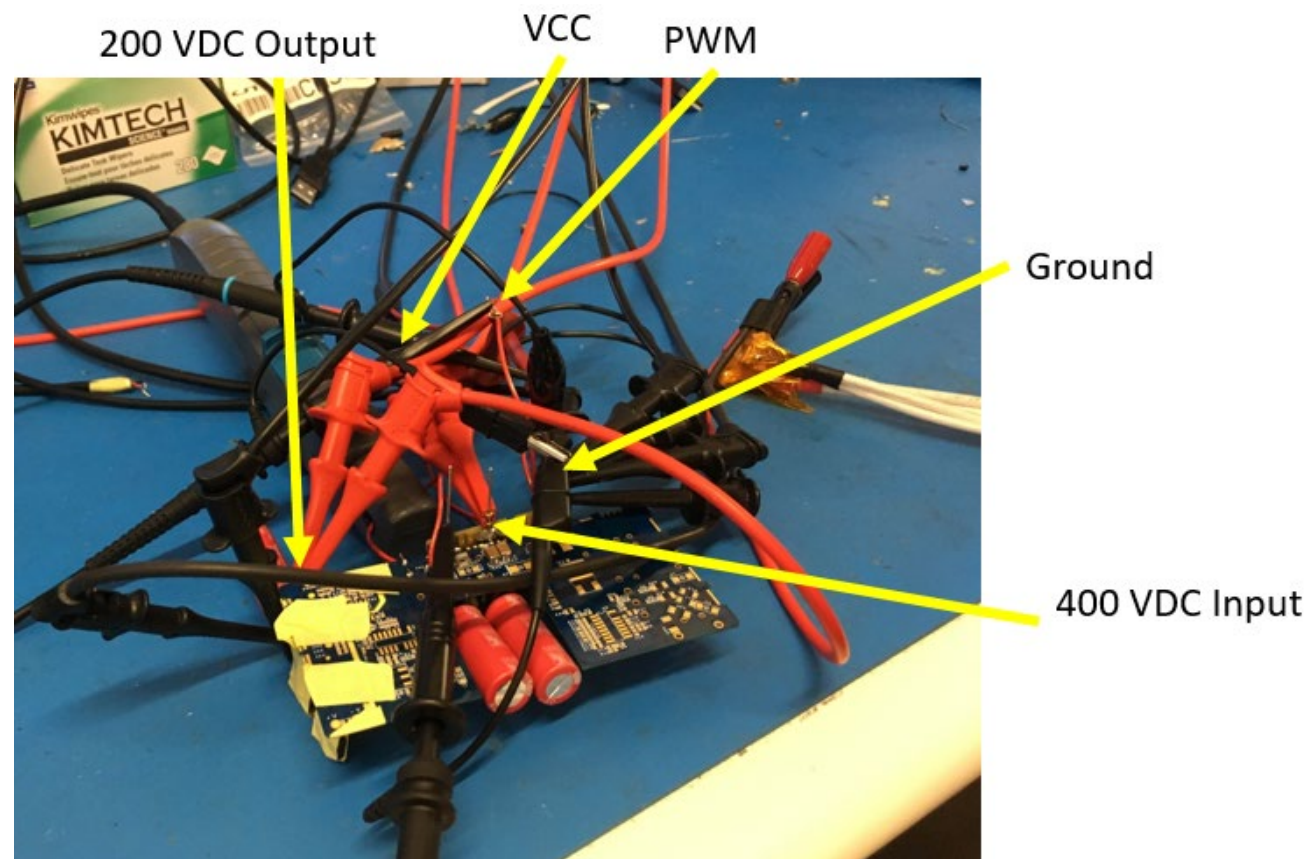
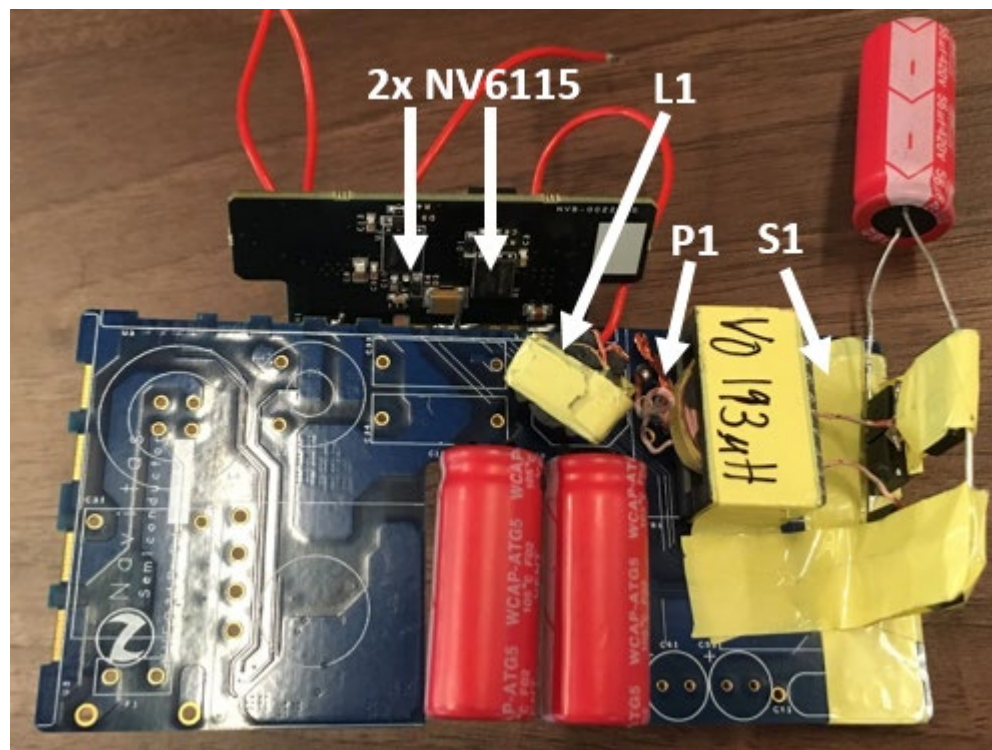
LLC Test Circuit

400 VDC Input





LLC Test Setup





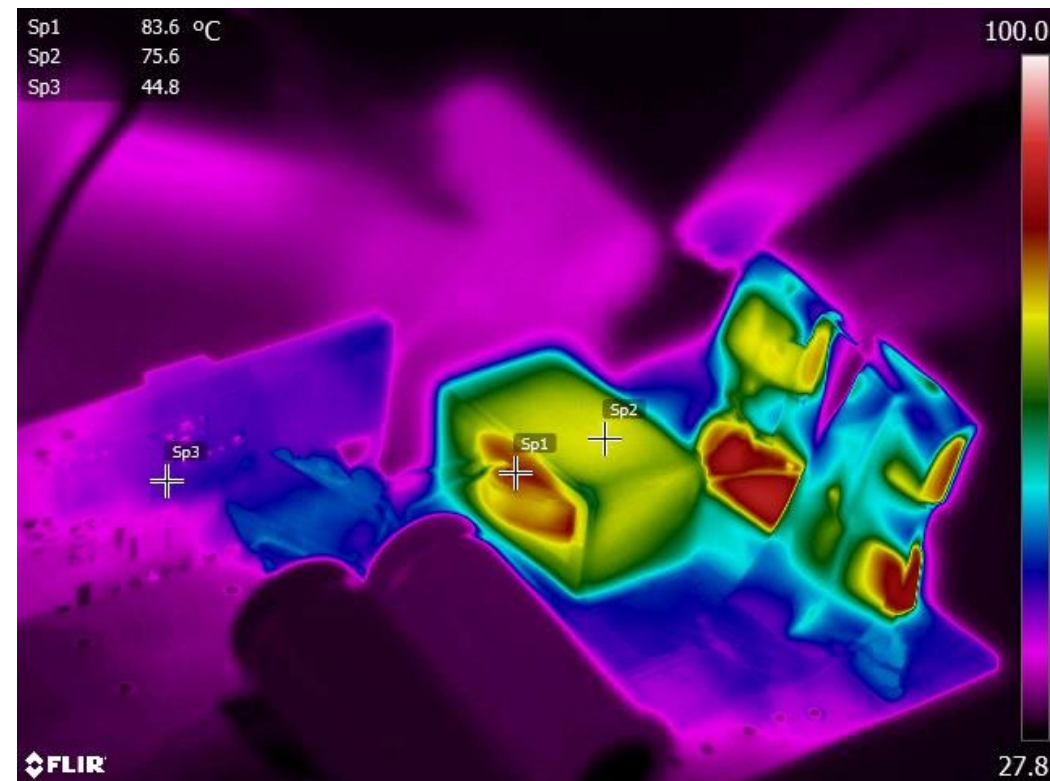
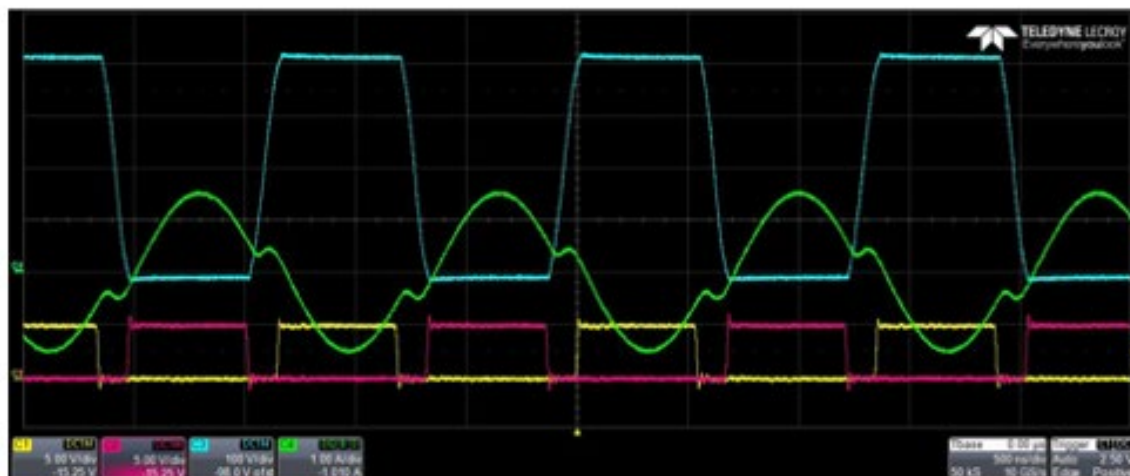
LLC Waveforms and Thermals (740kHz)

100%

DRAIN

CURRENT

PWM



ER23 Core Type

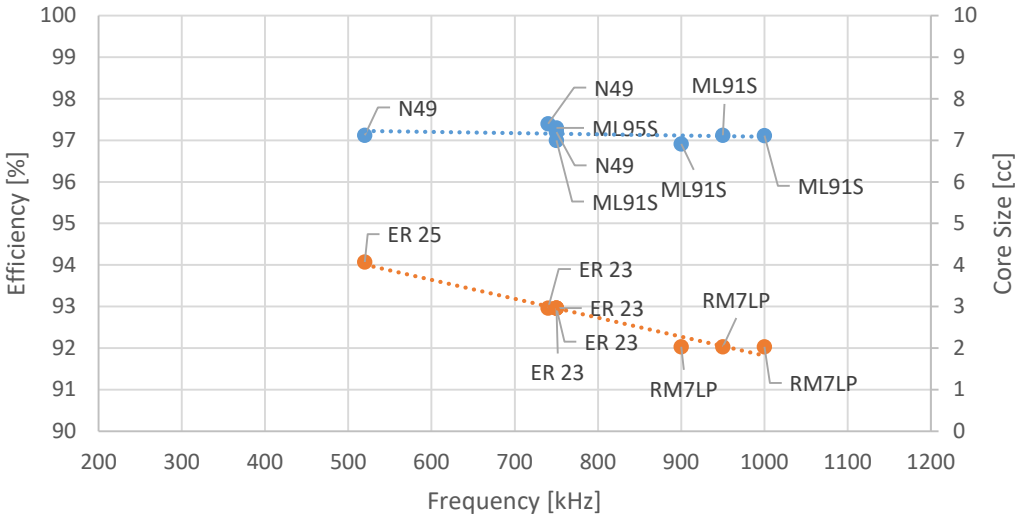


LLC Measurements



Version	V0	VK1	VK2	VK3	V8	LLC9	LLC10	LLC11
Core Type	ER 25	ER 23	ER 23	ER 23	ER 23	RM7LP	RM7LP	RM7LP
Core Material	N49	N49	ML91S	ML95S	N49	ML91S	ML91S	ML91S
Freq [kHz]	520	750	750	750	740	950	900	1000
EFF [%]	97.1	97.2	97.0	97.3	97.4	97.1	96.9	97.1
Lm [uH]	193	122	118	119	122	50	50	50
Core Size [cc]	4.07	2.96	2.96	2.96	2.96	2.03	2.03	2.03
Temperature [degC]	74.6	72.0	72.3	71.6	83.6	102.3	106.7	106.7
No. of turns	20	27	27	27	27	20	20	20
Strands #/AWG	60/44	40/44	40/44	40/44	177/48	40/44	40/44	40/44
Ae [mm2]	70.8	50	50	50	50	45.3	45.3	45.3

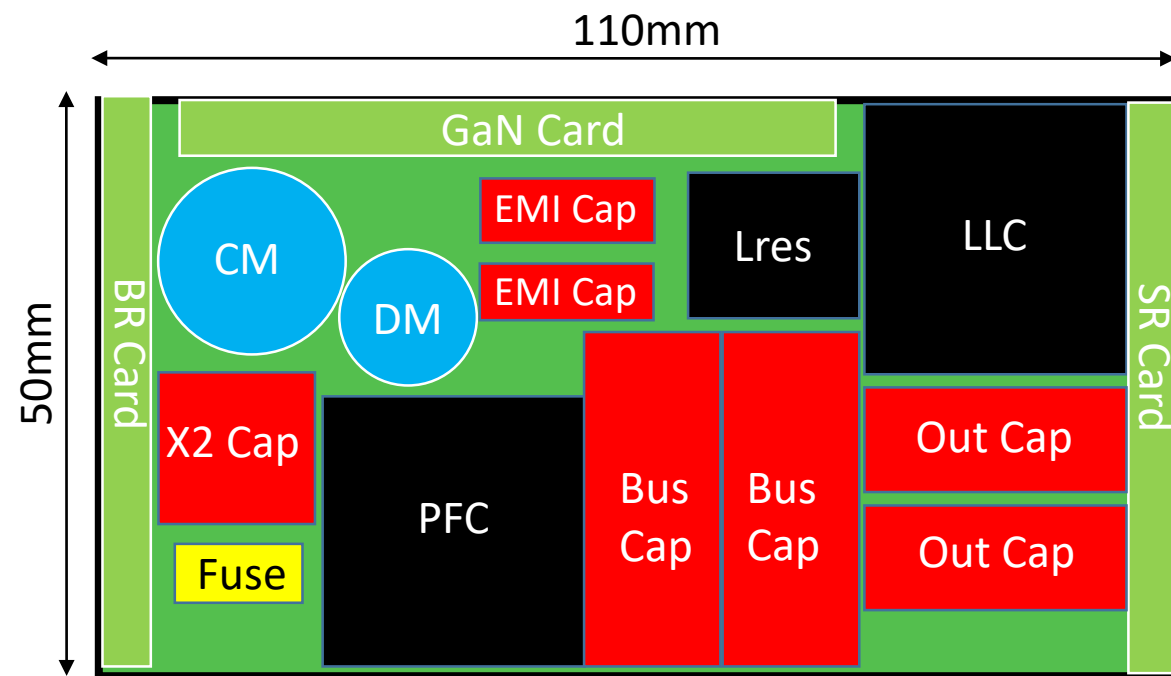
LLC Efficiency and Size vs Frequency
(Vin=400V, Vout=200V, Np:Ns=1:1, 50% duty cycle, Pout=150W)





150W Demoboard Specifications

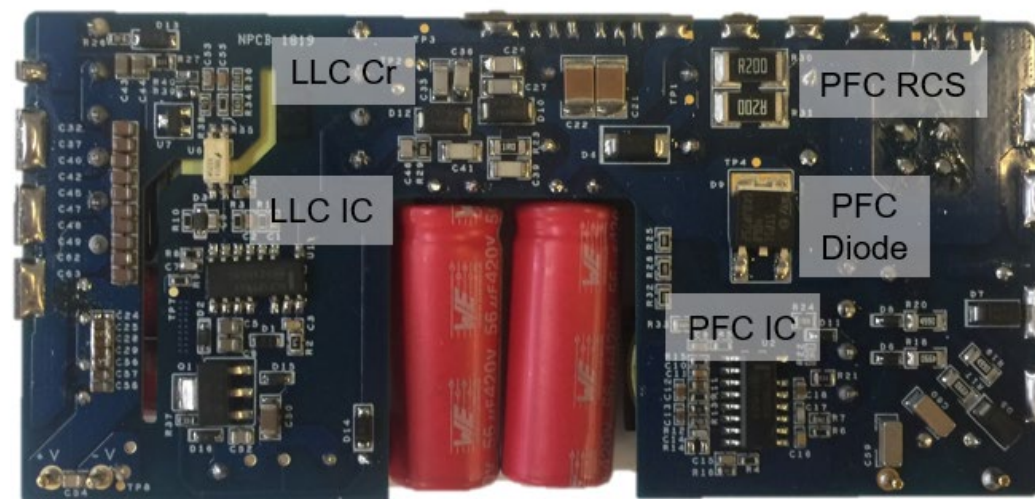
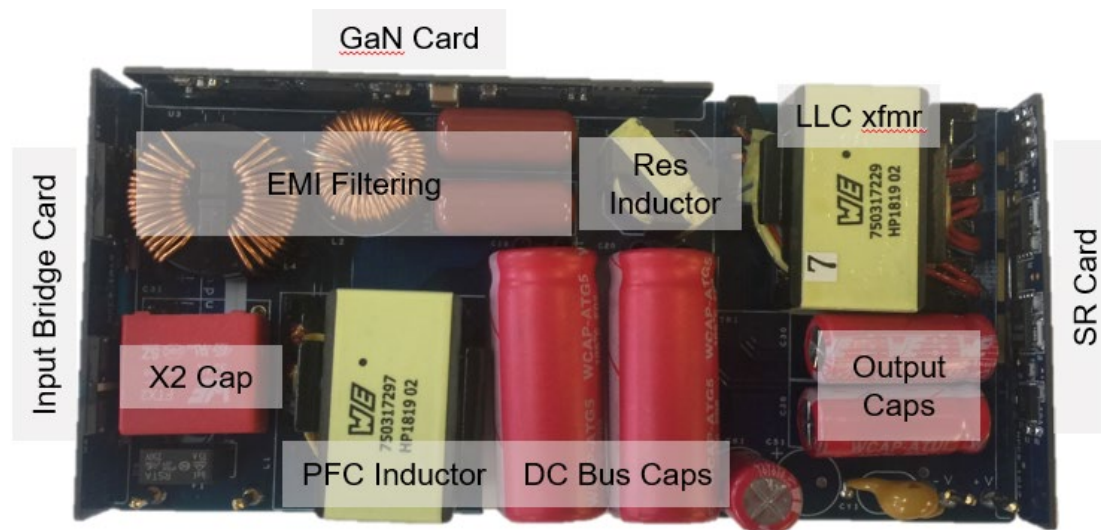
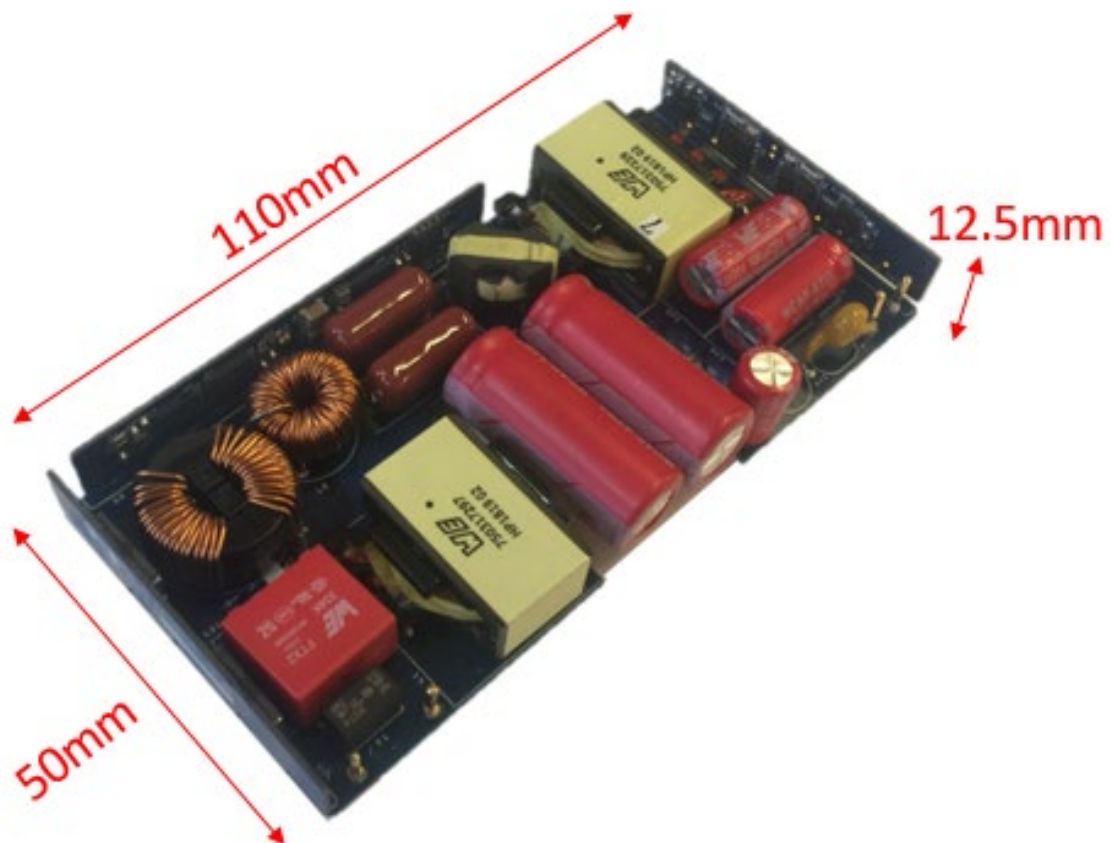
Ref.	Parameter		Value	Units
V_{IN}	Input Voltage		90-265	V_{AC}
			47-63	Hz
V_{OUT}	Output Voltage		19	V
I_{OUT}	Output Current (100% load)		8	A
I_{OUT_LIM}	Output Current Limitation (short-circuit or over-load)		9.5	A
P_{OUT}	Output Power (max)		150	W
F_{SW}	Switching Frequency	PFC (120V, 100% load)	200	kHz
		PFC (220V, 100% load)	100	kHz
		LLC	500	kHz
η	Efficiency	230 V_{AC} , 150 W	94.5	%
		115 V_{AC} , 150 W	93.2	%
P_{STBY}	Standby Power	115 V_{AC}	< 210	mW
		230 V_{AC}	< 210	mW
PF	Power Factor		0.95	
	Board Dimensions		110 x 50 x 12.5	mm
	Board Volume (uncased)		68.75	cc
	Power Density (uncased)		35.75	W/in ³
			2.18	W/cc



Proposed Floorplan



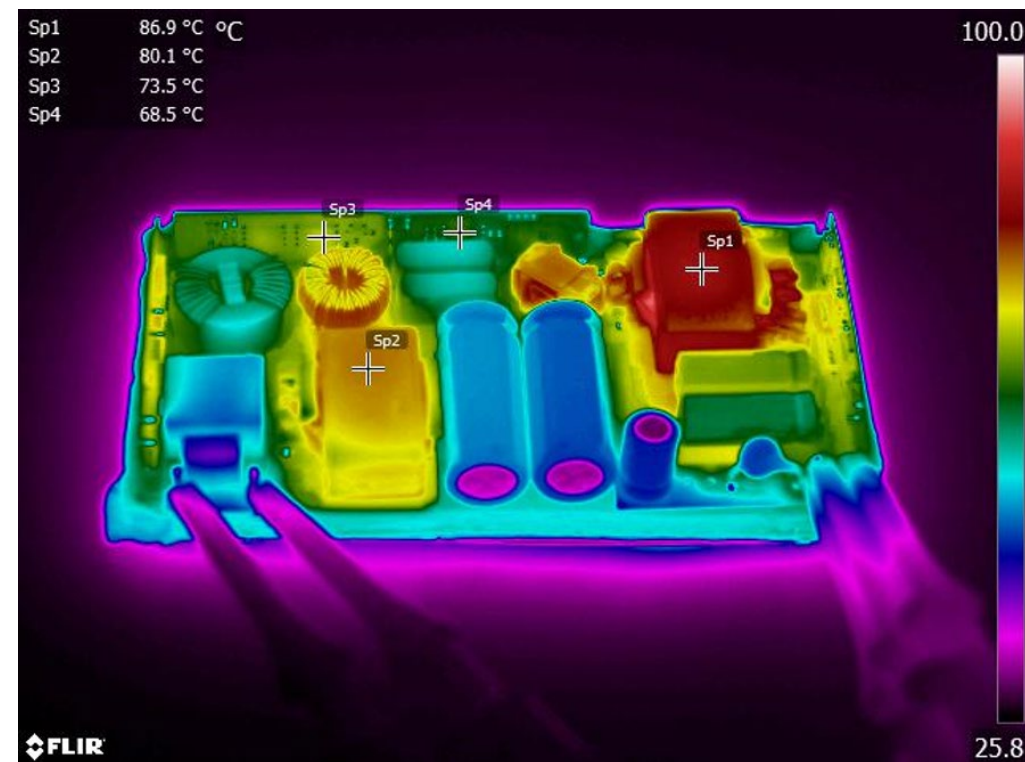
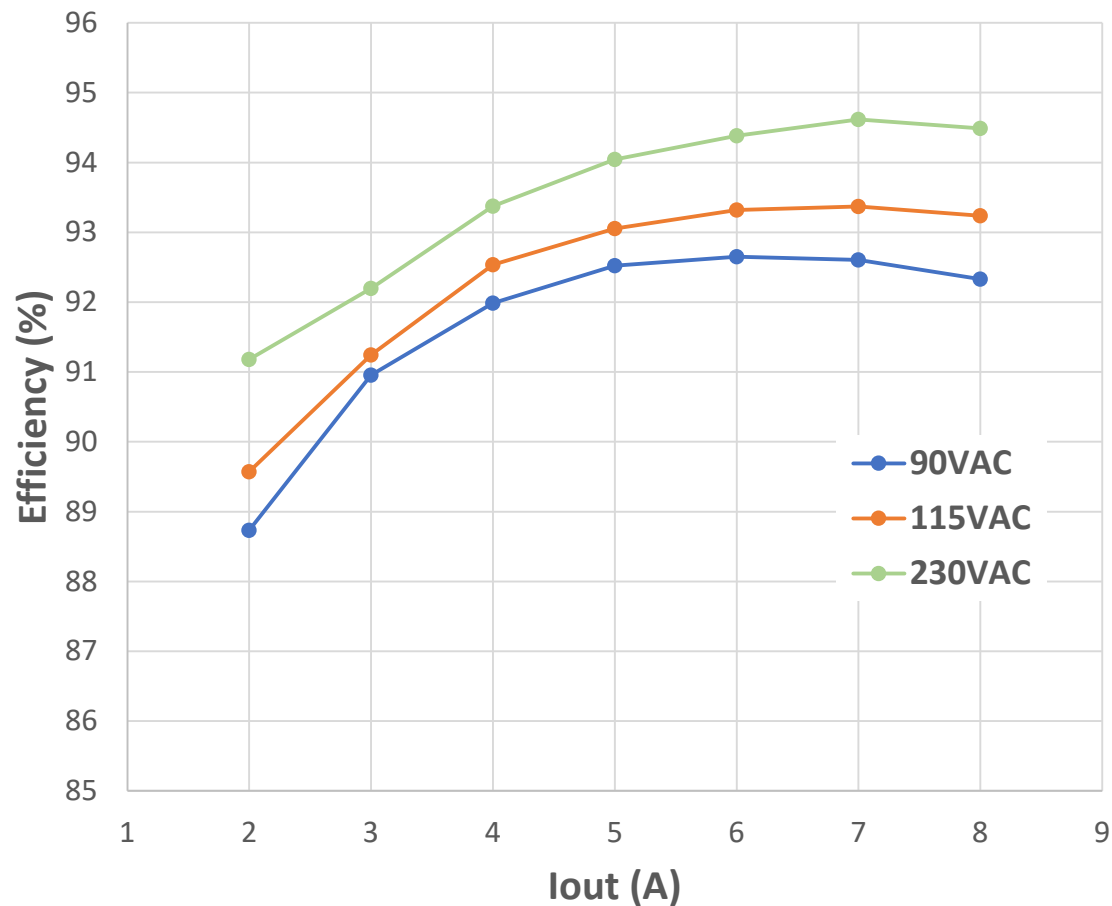
150W Demoboard





150W Demoboard Efficiency and Thermals

Efficiency vs IOUT



Vin=90VAC, 100% load, with copper wrapper



150W Comparison

Company	L x W x H (mm) (uncased)	Size (cc) (uncased)	Power Density (W/in3) (uncased)	L x W x H (mm) (cased)	Size (cc) (cased)	Power Density (W/in3) (cased)	Efficiency (%) @90VAC/100%
Navitas 150W	110 x 50 x 12.5	68.8	35.7	121 x 61 x 18.5	136.5	18.1	92.3
Delta HP	129 x 55 x 16.3	115.65 (+40.6%)	21.3 (-40.3%)	138 x 66.3 x 22.5	205.9 (+50.8%)	11.9 (-34.3%)	92.6
Razor BLADE	141.6 x 50.2 x 17.1	121.8 (+43.6%)	20.2 (-43.4%)	149.2 x 60.1 x 22.9	205.3 (+50.4%)	12.0 (-33.7%)	92.7
Chicony/ LiteON HP	115 x 55 x 16.2	103.1 (+33.3%)	23.8 (-33.3%)	138 x 66.3 x 22.5	205.9 (+50.8%)	11.9 (-34.3%)	91.5 (@100VAC)



Acknowledgements & Questions



Special Thanks To:

- *Isaac Cohen (Texas Instruments)*
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- *Jack Ribarich (Navitas Semiconductor)*
- *Wurth Electronics*



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