Design PMP20490 Test Results

PMP20490 2xTPS546C23 1200mV 60A Test Report:
425kHz per phase.
Board have two types of dynamic loads:

a) Self contained timer U501, driver U502 and switch Q500 with 11 parallel load resistors, R528 & R529 to control turn and turn off speeds. (See pages 8 & 9 below.)
b) Signal generator driven Q540 with 10 mOhm R542 to ground to allow scope to show both Vout and Iout at same time (See page 10 below.)

TPS546C23 is very similar to TPS546C20A except for pins 2 & 3 which are address pins in TPS546C23 and Voltage Select (VSEL) and Soft Start (SS) pins respectively on the TPS546C20A.
Also on PMP20490 models t2 & t3 I used Wurth S16100010 raised inductor 330 nH / 0.37 mOhms / 46A saturation (delta L -20%) as a second source for TDK VLB10090HT-R33K-B2 also 330 nH but 0.33mOhms and 45A (delta L -30%) saturation.

Most of the testing done in the PMP20292 Test Report is applicable here. I have focused upon thermal testing with the Wurth inductors, GUI selectable soft start and inductor saturation in overload (Wurth vs. TDK).
PMP20292 was done only with the TDK inductors.
The GUI did recognize correctly my programmed addresses of the master – 38d or 46oct; and on the slave 39d or 47oct on all 3 models t1 & t2 & t3.

All testing at 12Vin unless otherwise mentioned

Controlled turn on & turn off with default settings	page 2	model t2
Start up with Enable with 1msec setting without & with pre-bias	page 3	model t2
Output ripple at no load & full load Wurth inductors	page 4	model t2
Output ripple in overload to 80A with Wurth inductors	pages 5-6	model t2
Output ripple at no load & full load TDK inductors	page 7	model t1
Output ripple in overload to 75A with TDK inductors	page 8	model t1

Based upon saturation seen with TDK inductors above 70A for 2 phases, two phase applications above 50A should use the Wurth parts.

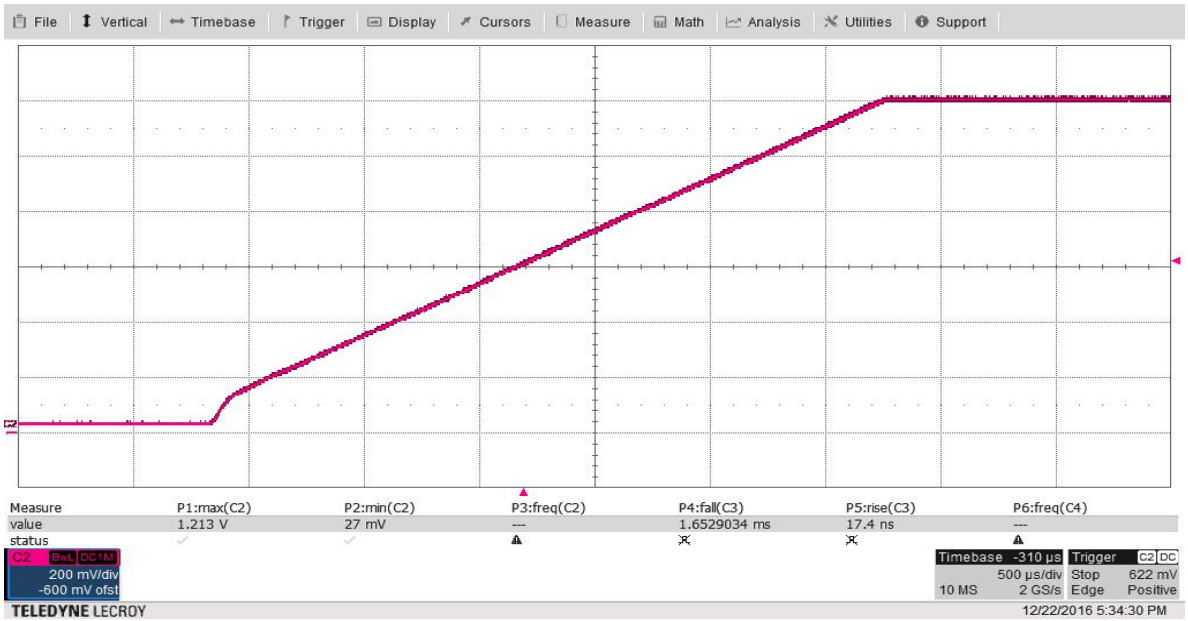
Step load response with on board Dynamic Load 12Vin 0A static	page 9	model t2
Load dump response with same dynamic load of 37A	page 10	model t2
Thermal images with Wurth inductors	pages 11-13	model t3
Efficiency data & graph (5Vin, 8Vin & 12Vin)	pages 14-17	model t2
Efficiency graphs for Wurth (model t2) vs. TDK (model t1)	page 18	

Results very similar

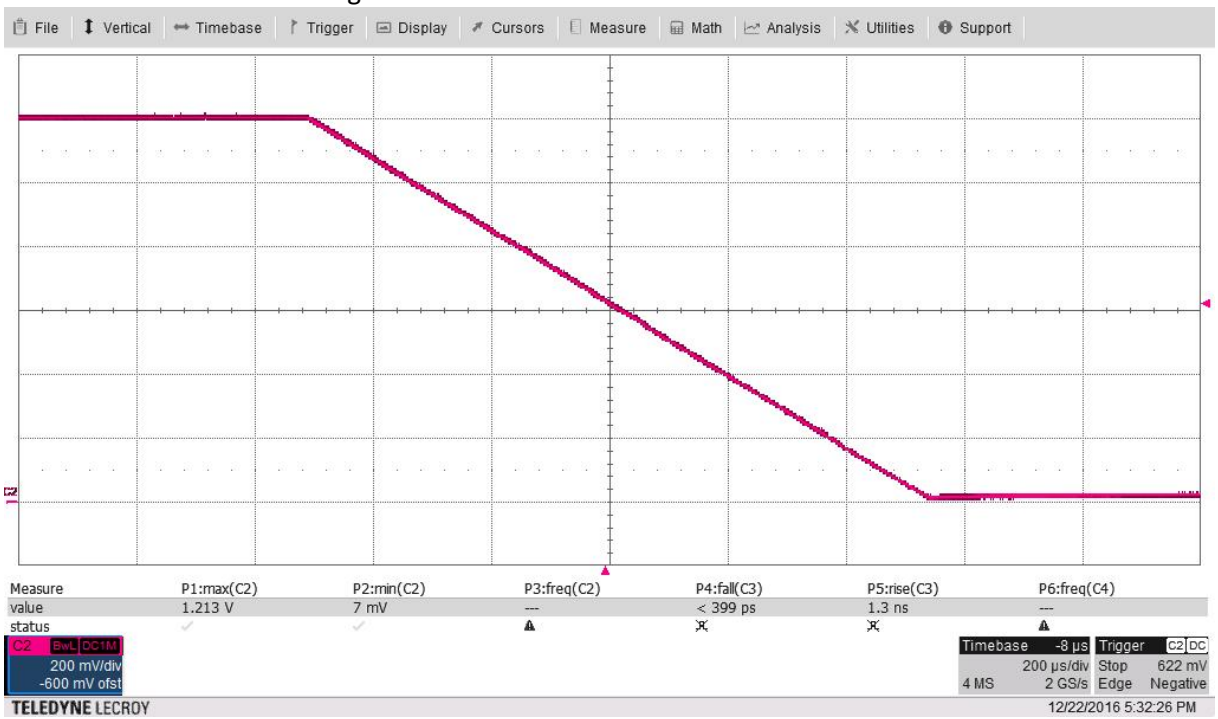
Board images: Top & Bottom & Edge to show U1 under L1	pages 19-20	models t1 & t2

Start up and soft off Model t2:

target rise & fall times 3 msec with default settings in TPS546C23
Model t2 1.202V when on and 110mA off 12.01Vin Input current 19mA when off
soft start no load



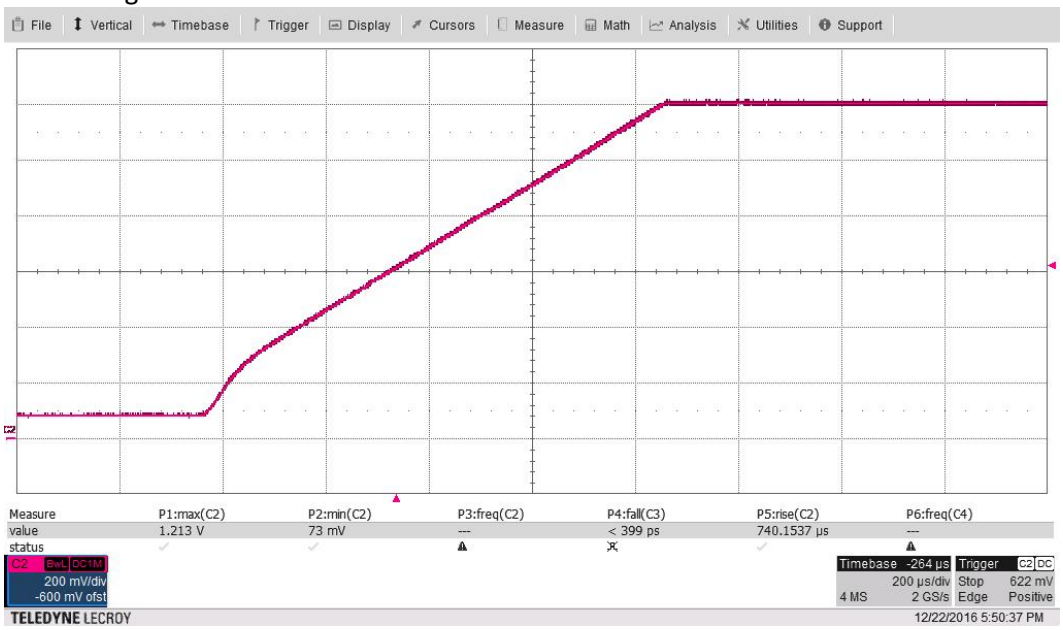
Monotonic with no overshoot and 2.9msec total rise time
Soft off no load default settings



While default soft start is 3msec, default soft-stop is ~1.05msec

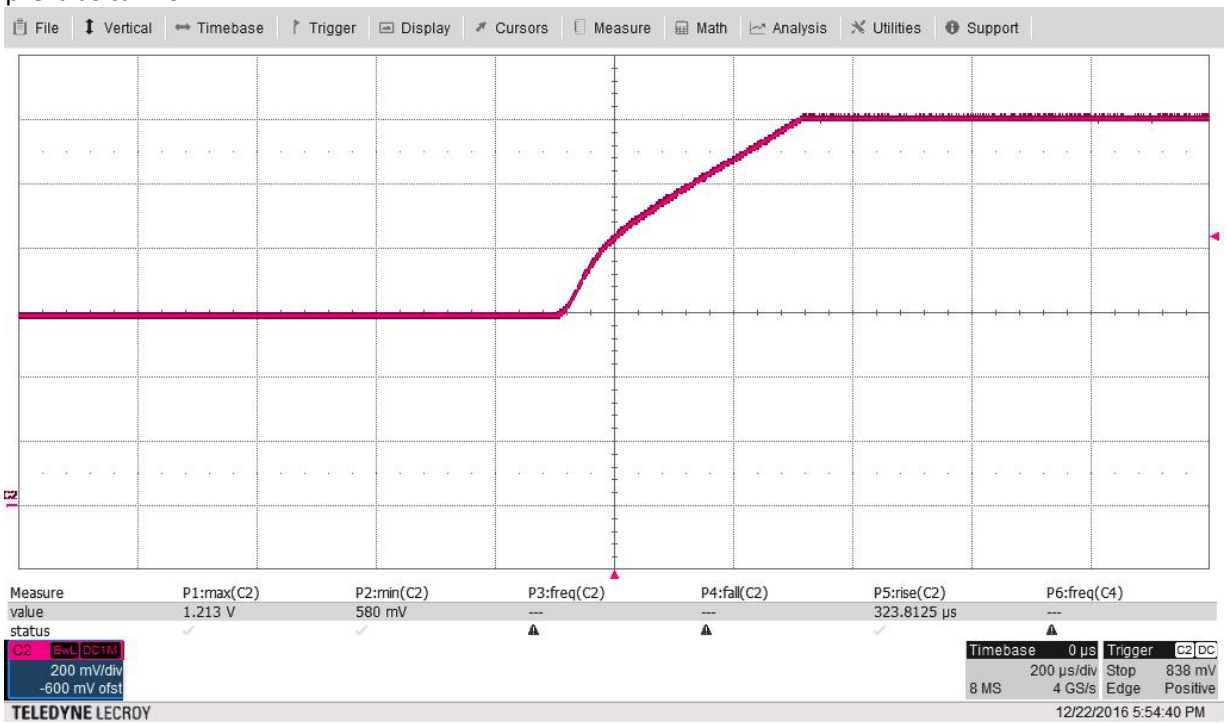
Start up Model t2: continued

Now change to 1 msec rise:



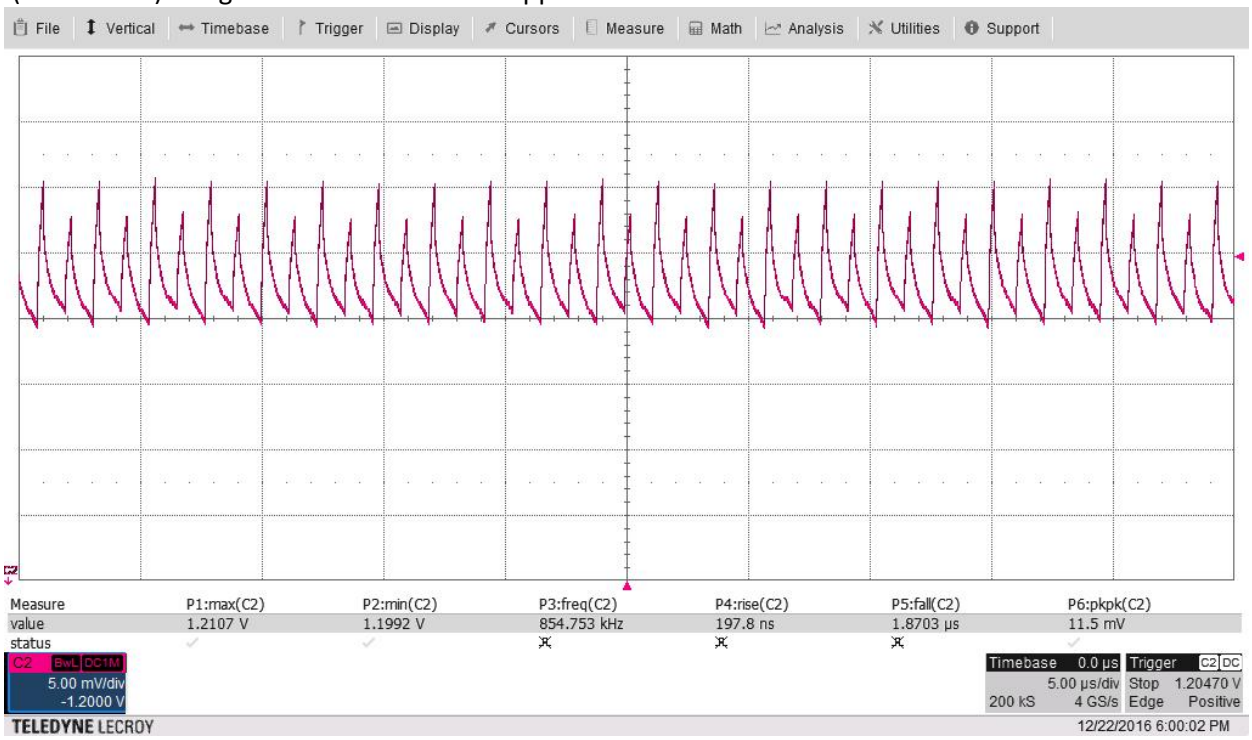
Monotonic with no overshoot and about 900usec rise

pre-bias turn on



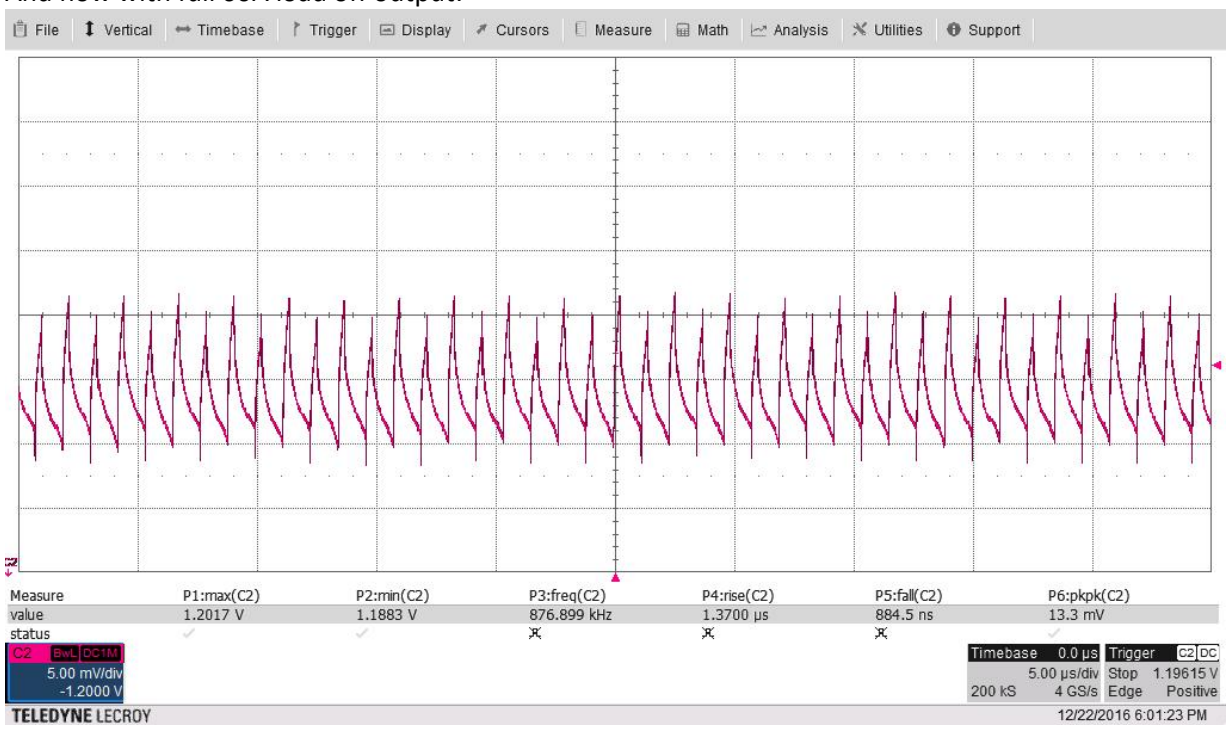
No dip and about 400usec for rise from 600mV to 1.2V without overshoot

Output Ripple at no & full load: December 22, 2106: 12.0 Vin: 1.2 Vout with no load model t2: Model t2 with Wurth inductors: Output ripple at different loads to see if inductor saturates: (20MHz BW) using J502 to measure Vout ripple



11.5 mV p-p Based upon 43 peaks in 50usec: 860kHz

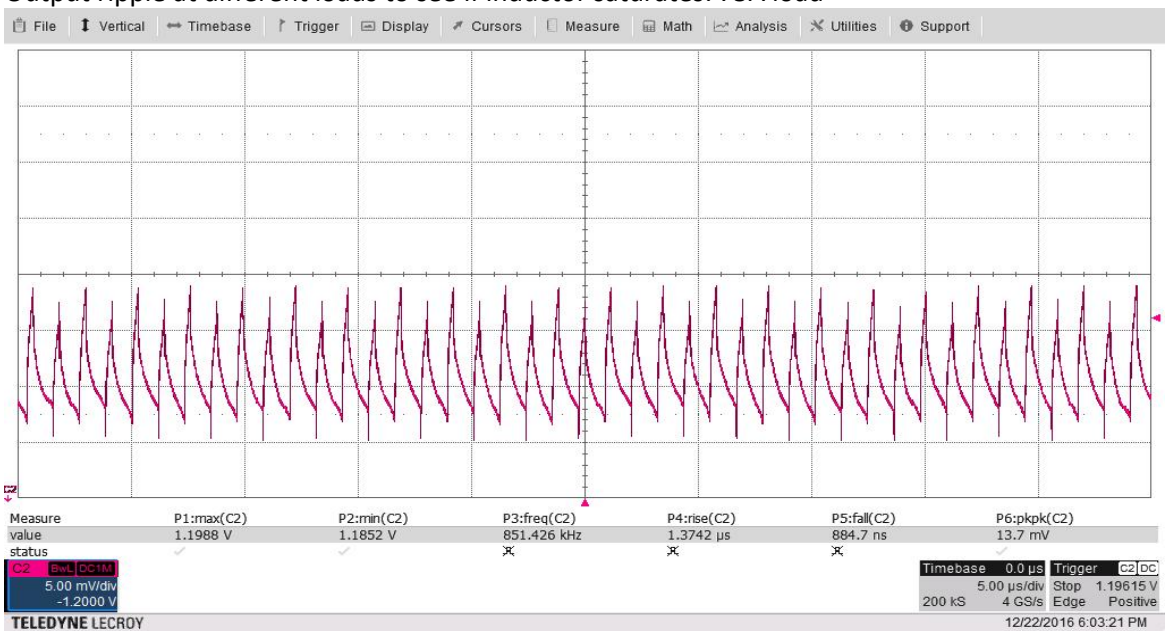
And now with full 60A load off output:



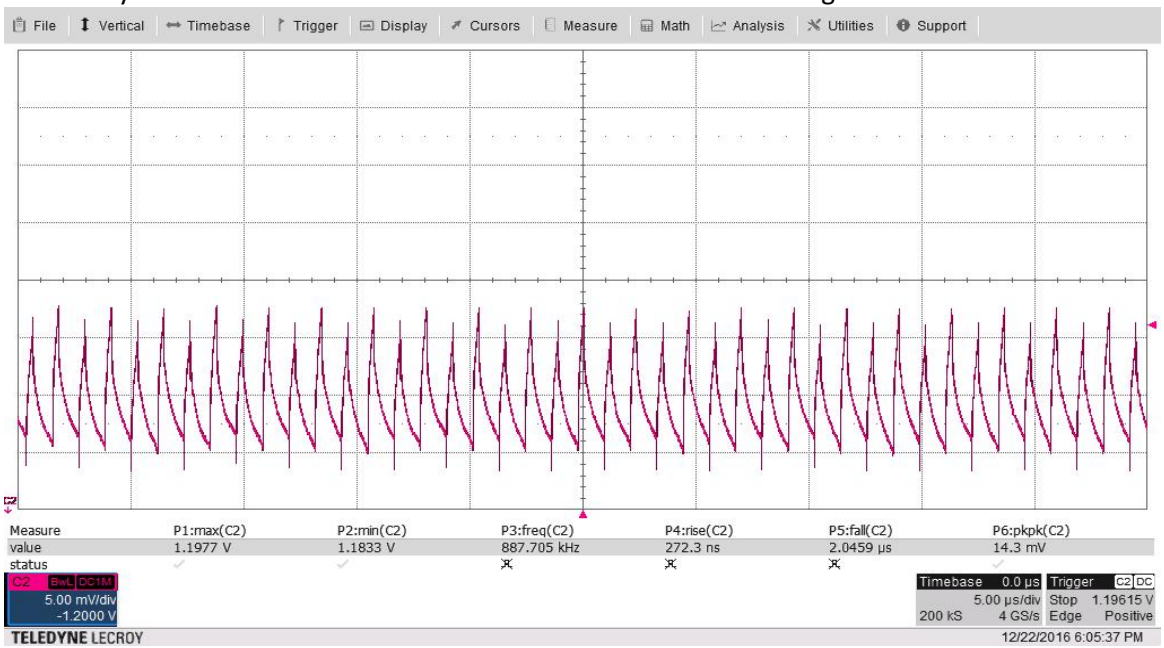
13.3mV p-p Based upon 43 peaks in 50usec: 860kHz

Output Ripple continued and now at overload:

December 22, 2106: 12.0 Vin: 1.2 Vout
model t2 with Wurth inductors:: (20MHz BW) using J502 to measure Vout ripple)
Output ripple at different loads to see if inductor saturates: 75A load



Now up to 13.7mV p-p
And finally at 80A run at ~3 minutes and TPS546C23's at over 100 degrees Celsius

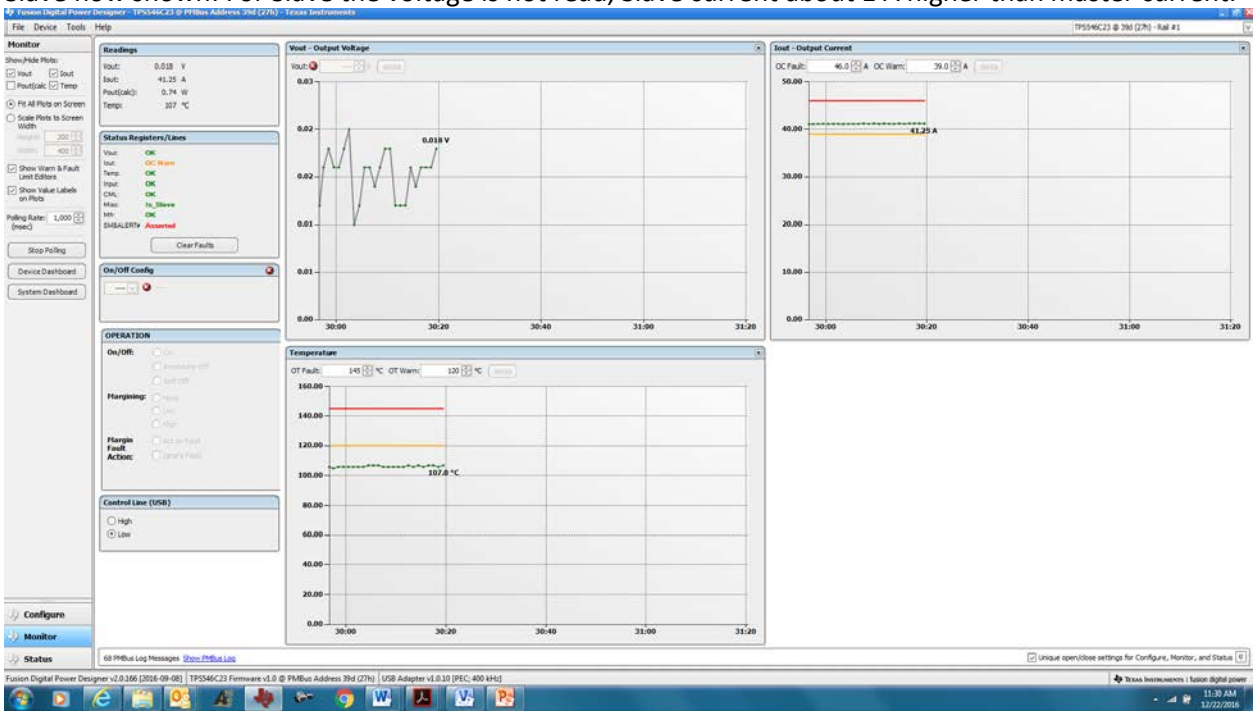


Now up to 14.3mV p-p No evidence of hard saturation of inductors:
This 80A run supports an application full load of 60A with the Wurth inductors.
Gradual reduction in inductance seen with increasing loading, but no hard saturation….
While scope frequency calculations jump around, I see 43 pulses consistently in 50usec for 860kHz

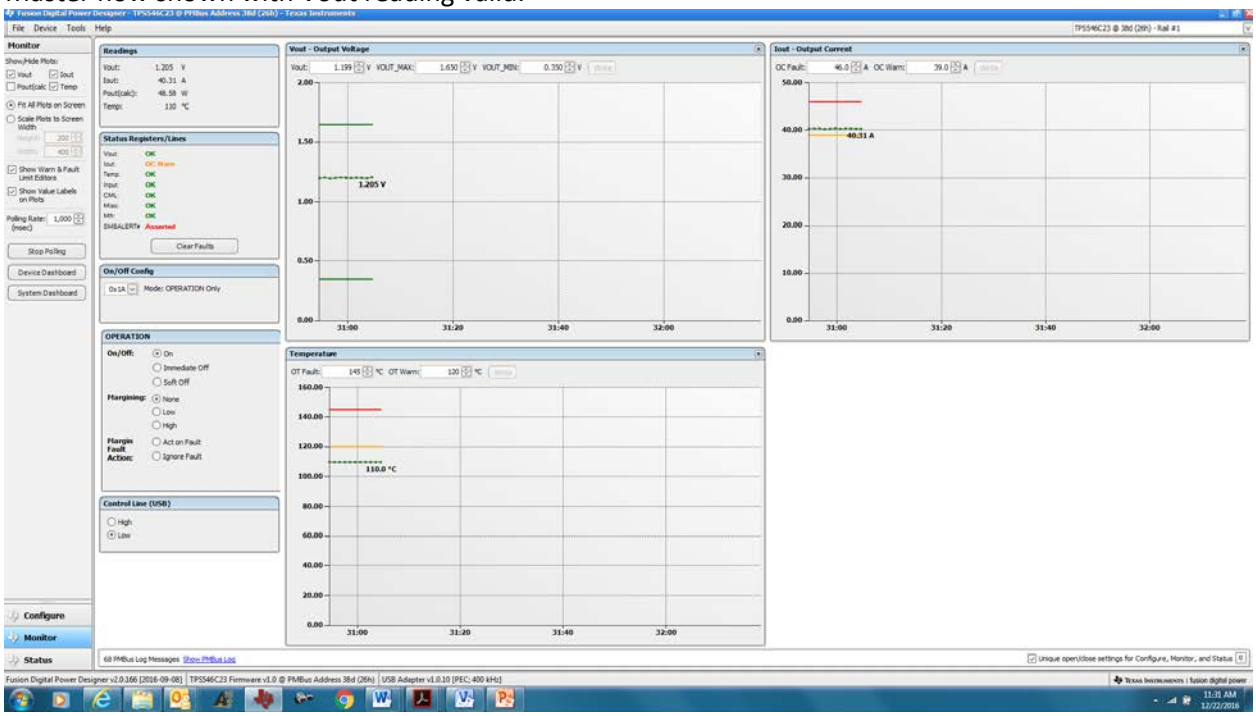
Output Ripple continued and now at overload showing GUI during the 80A test:

Model t2 with Wurth inductors December 22, 2016: GUI during 80A load test: Slave GUI captured before Master GUI before ripple scope picture at bottom of last page

Slave now shown: For Slave the voltage is not read, Slave current about 1 A higher than master current.

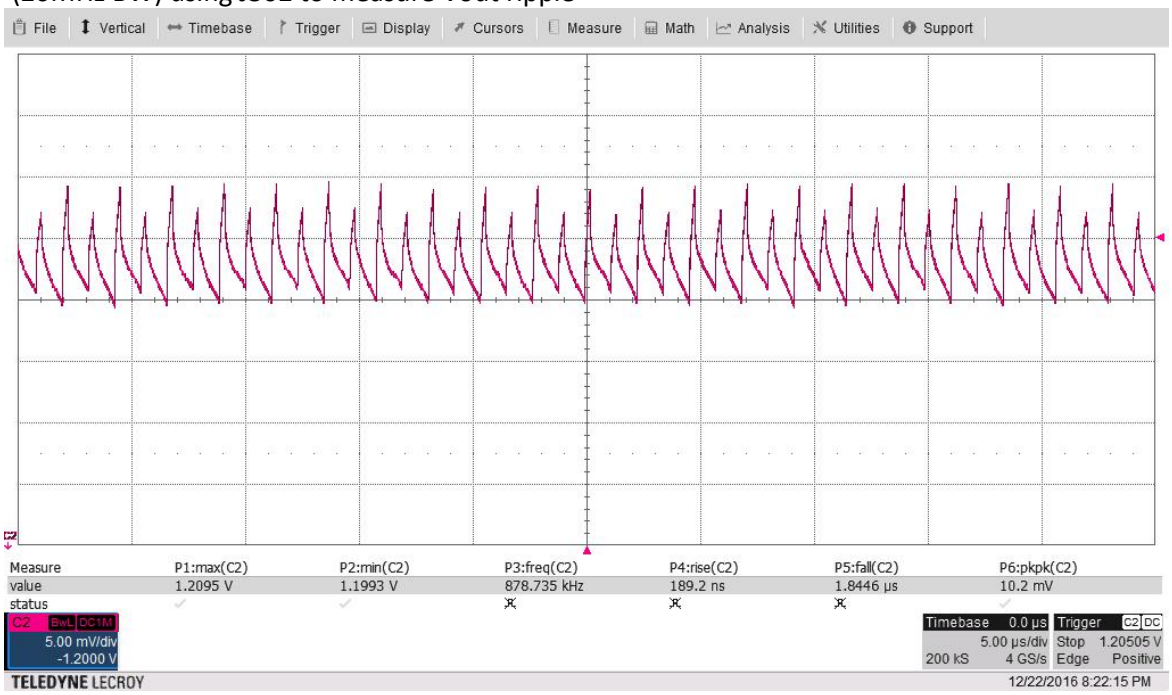


Master now shown with Vout reading valid:

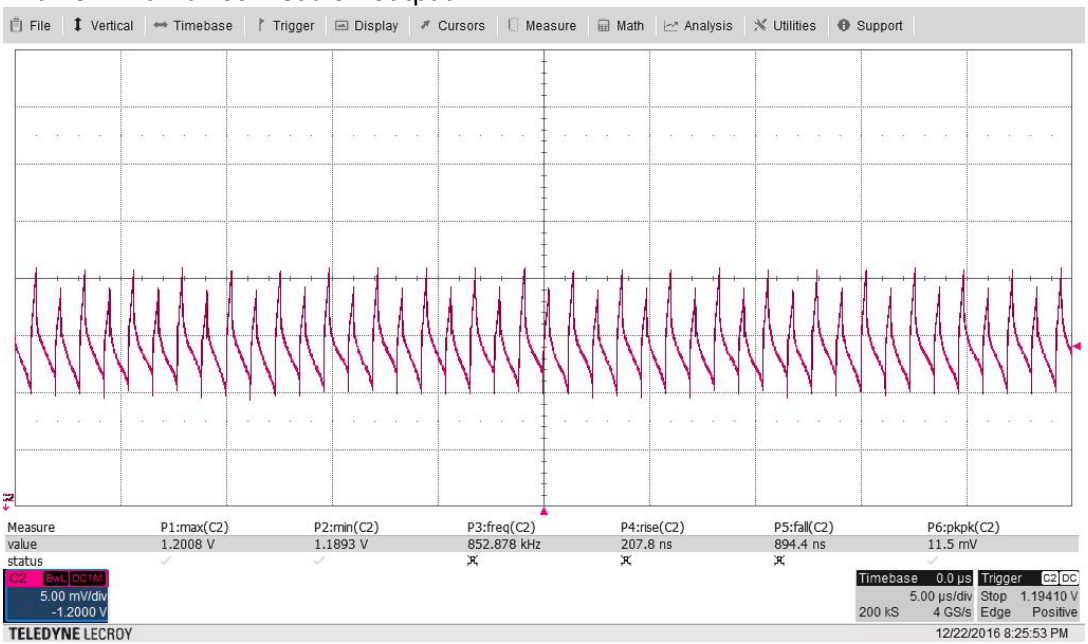


After this run: Back to 60A GUI 30.0A / 75 deg. C reading on master 30.9A / 75 deg. C reading on slave

Output Ripple at no & full load: December 22, 2106: 12.0 Vin: 1.2 Vout with no load model t1:
Model t1 1.202V when on and 112.5mA off 12.00Vin Input current 19mA when off
Model t1 with TDK inductors: Output ripple at different loads to see if inductor saturates:
(20MHz BW) using J502 to measure Vout ripple



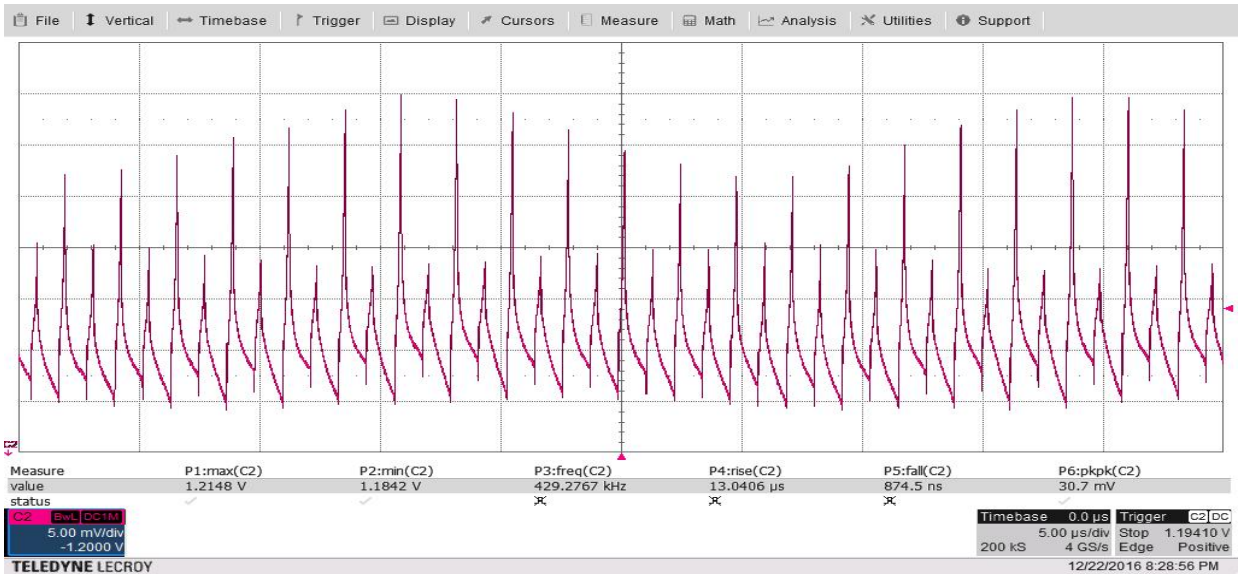
10.2 mV p-p Based upon 43 peaks in 50usec: 860kHz
And now with full 60A load off output:



11.5mV p-p Based upon 43 peaks in 50usec: 860kHz

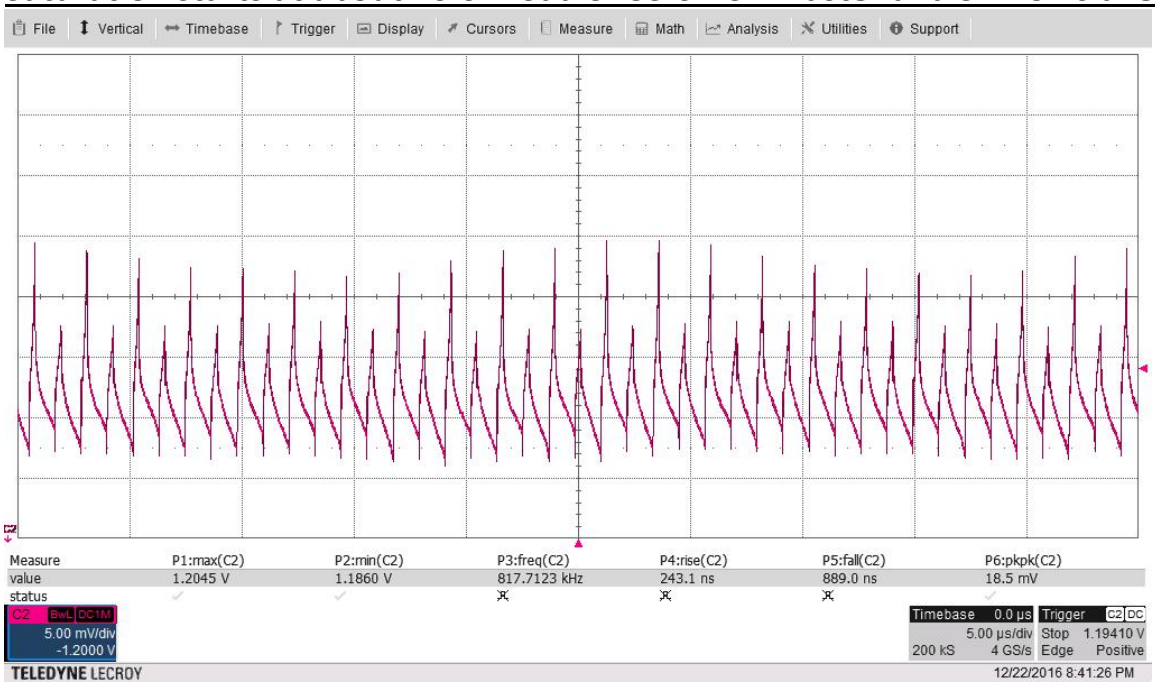
Output Ripple continued and now at overload:

December 22, 2106: 12.0 Vin: 1.2 Vout
model t1 with TDK inductors:: (20MHz BW) using J502 to measure Vout ripple)
Output ripple at different loads to see if inductor saturates:
75A load



Shutdown shortly afterwards

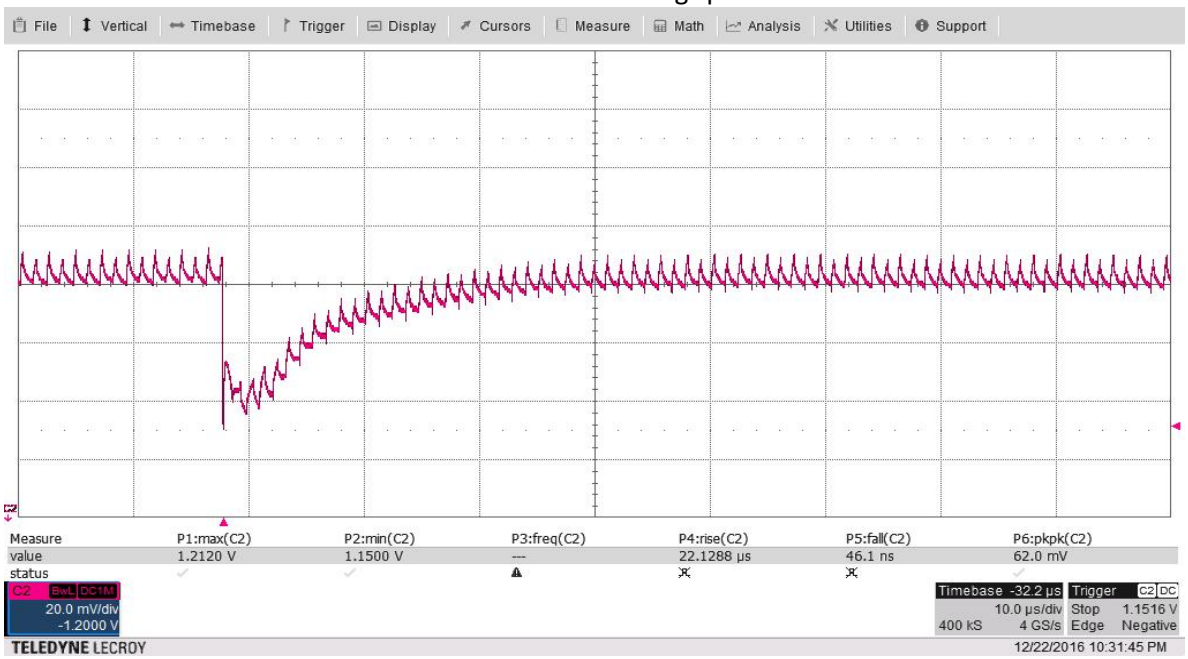
Saturation starts at about 70.6A load or 33.6A on master and 37A on slave



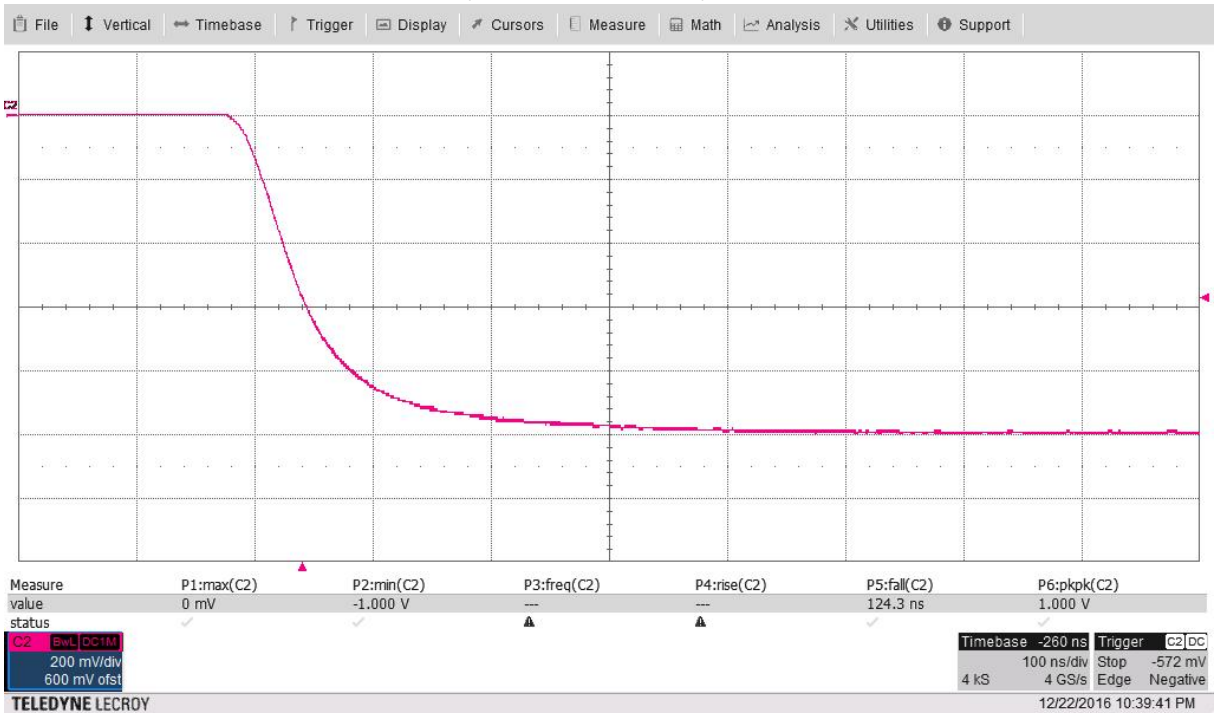
18.5mV p-p: **Based upon this ~70A saturation threshold, max recommended steady state load with TDK inductors is 50A.**

After this run: Back to 60A GUI 28.4A / 71.5 deg. C reading on master 31.6A / 73 deg. C reading on slave when fan is close, and about 5 degrees hotter when fan is far.

Step load response: using U501 / U502 / Q500 on board dynamic load (model t2)
12V 1.2Vout and 0A static load 37A additional load applied with 124 nsec rise time (10%-90%) Vout measured at J502 20 MHz BW Min Vout 1.150 including spike or 4.2% below 1.2V Dec 22

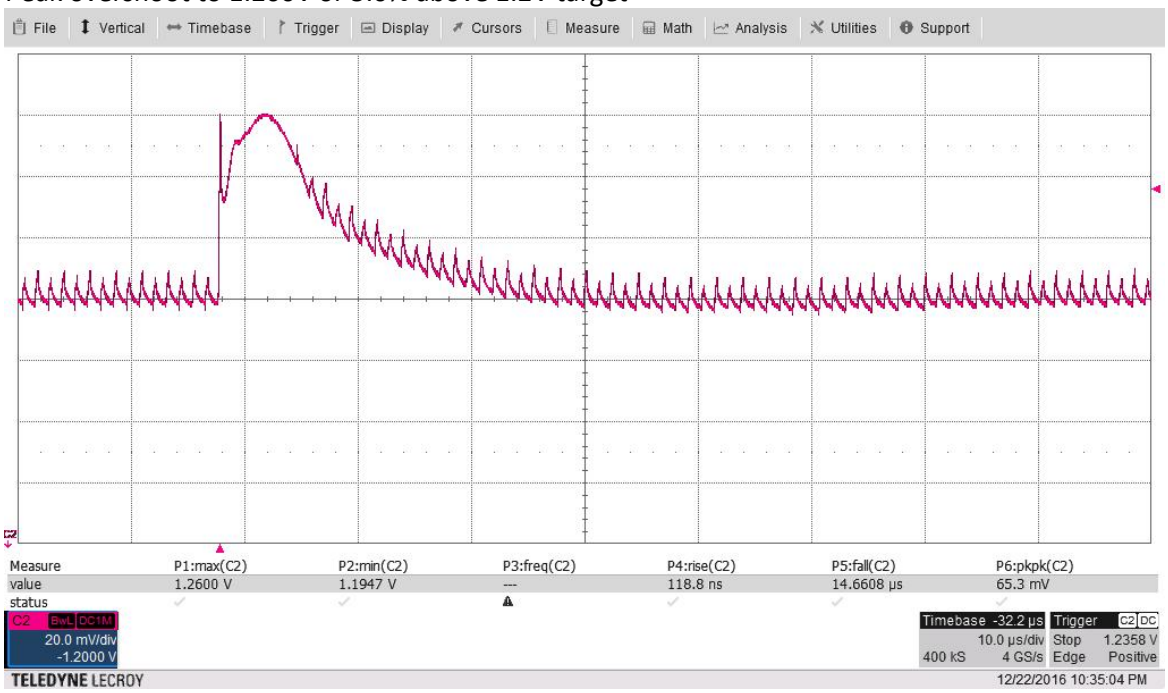


Q
Waveform across 300 mOhm dynamic load tied to Vout: 1.00V applied with 124 nsec 10% to 90% rise time: Close in tip & barrel on R505 (furthest of 11 parallel load resistors to drain of Q500)
200 MHz BW measurement: 1.00V/0.3 ohm = 3.33A times 11 resistors = 36.7A step
10% to 90% rise time 124nsec or 29.3A/124.3nsec or 236A/usec rate



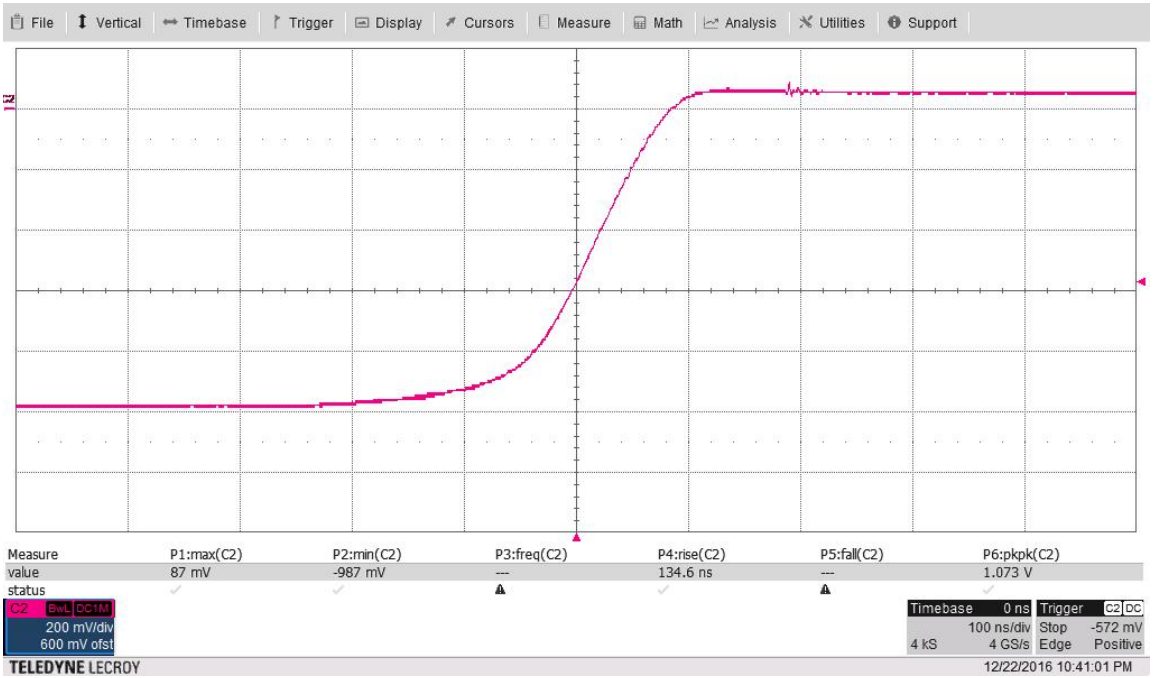
R528 now at 75 ohms sets speed of turn on and can be changed to get faster or slower turn on.

Load dump response: using U501 / U502 / Q500 on board dynamic load (model t2) Dec 22
12Vin 1.2V from 37A to 0A in with 134 nsec 90% to 10% fall time. Vout measured at J502 20 MHz BW
Peak overshoot to 1.260V or 5.0% above 1.2V target



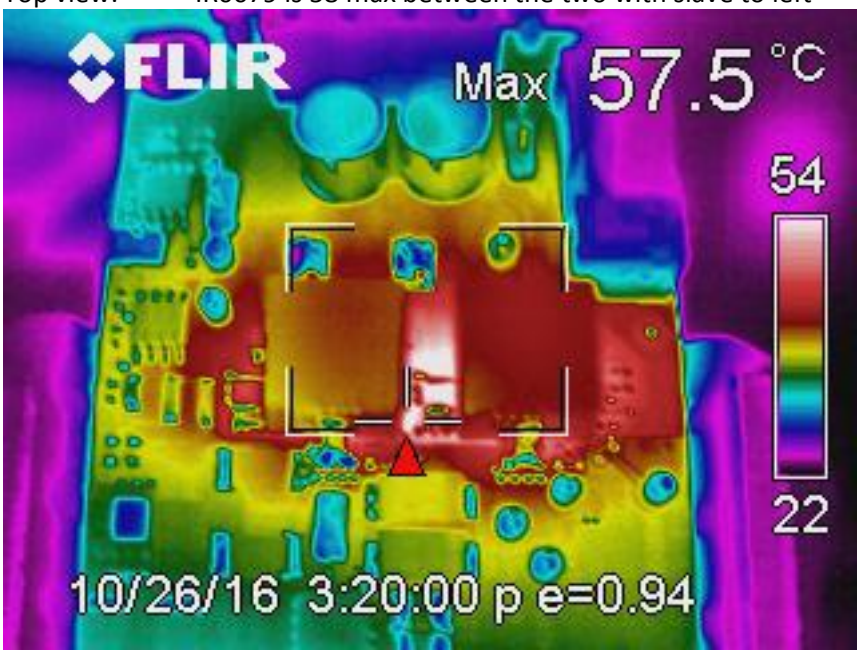
Q

Waveform across 300 mOhm dynamic load tied to Vout: 1.00V removed (maybe slightly more)
Close in tip & barrel on R505 (furthest of 11 parallel load resistors to drain of Q500)
200 MHz BW measurement: 1.00V/0.3 ohm = 3.33A times 11 resistors = 37A dump
10% to 90% rise time 134.6nsec or 29.3A/134.6nsec or -218A/usec rate



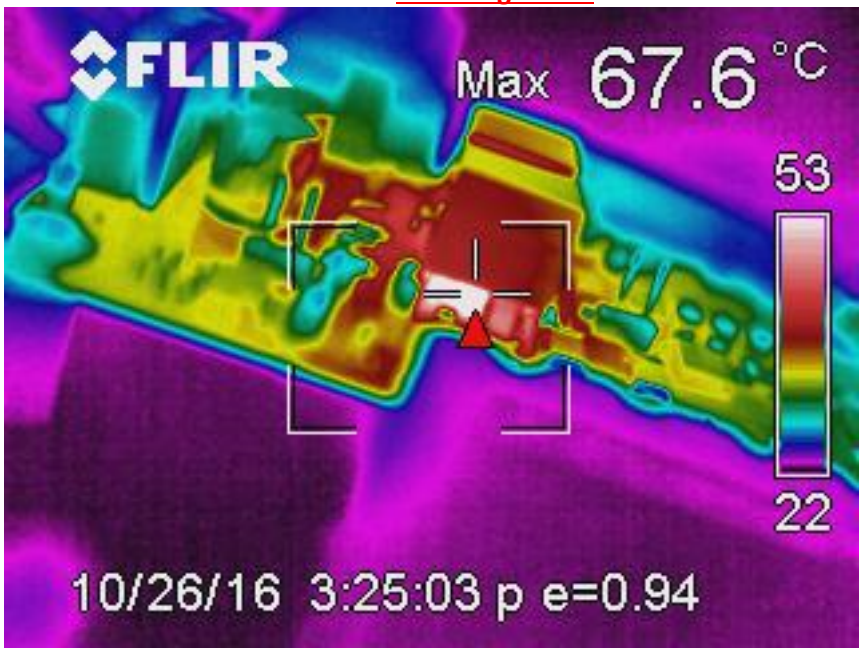
R529 now at 249 ohms sets speed of turn off and can be changed to get faster or slower turn off.

Thermal images: Full load with Fan: Model t3 with Wurth inductors
12.04Vin 6.83Ain 1.200Vout 60.00A 430kHz per phase actual Dec 21
Slave GUI 30.7A & 71.5 deg. C
Master GUI 29.6.0A & 70.5 deg. C
Top view: IR0079 is 58 max between the two with slave to left



Thermal camera showing wrong date

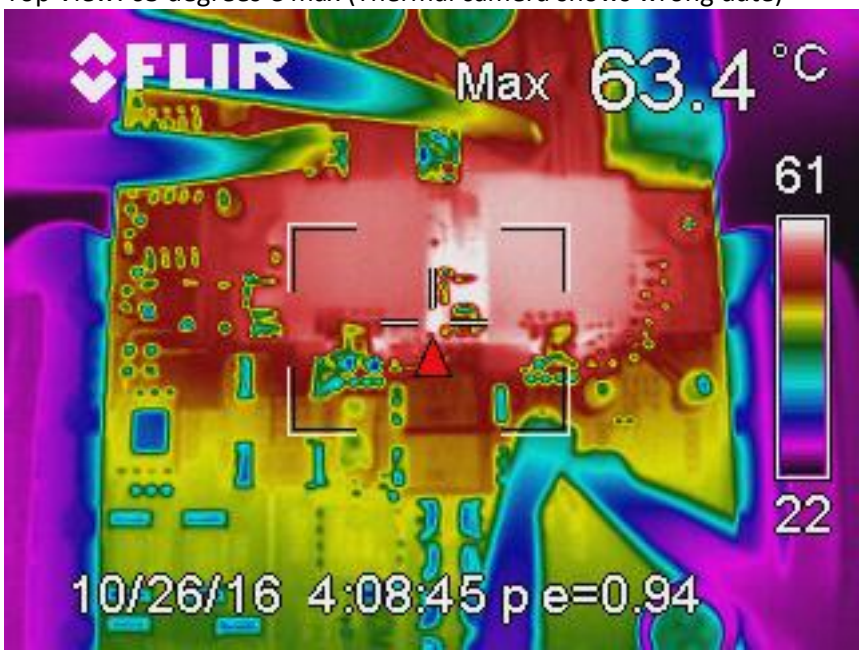
Now looking at slave edge vs. master edge to see which is hotter:
On master side with TPS546C23 deeper in from edge under inductor most I could see was ~63 deg. C
IR0081 at 68 max from below L2 **Slave Edge View**



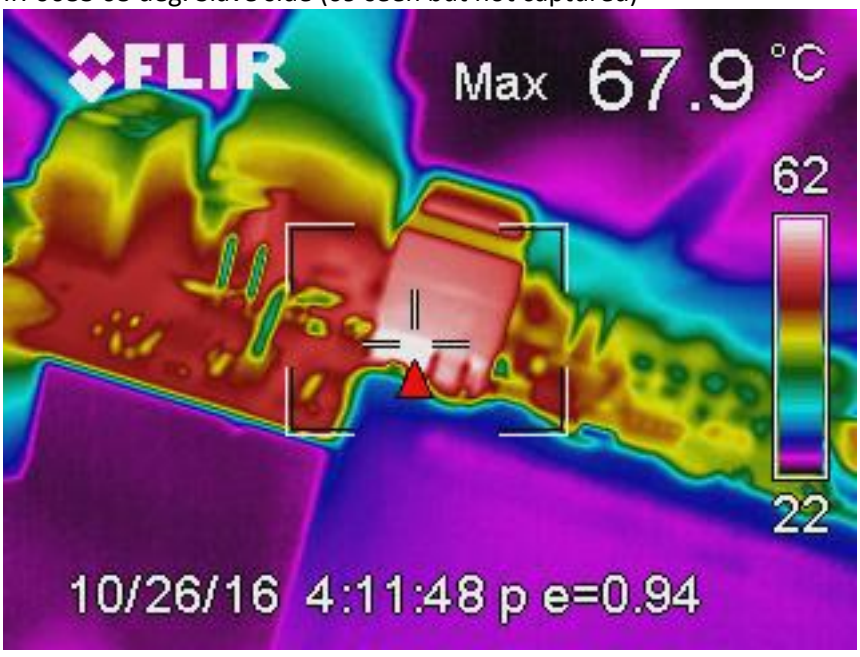
With fan and inductors on top GUI reading 4 degrees C hotter than what I can capture on edges.

Model t3 thermal images continued: Wurth Inductors Dec 21

No fan: 12.04Vin 3.8855Ain 1.200Vout 35.01A Dec 21 ½ hour run
35A load master 16.7A 73 deg. C
Slave 18.06A 74 deg. C
Top View: 63 degrees C max (Thermal camera shows wrong date)



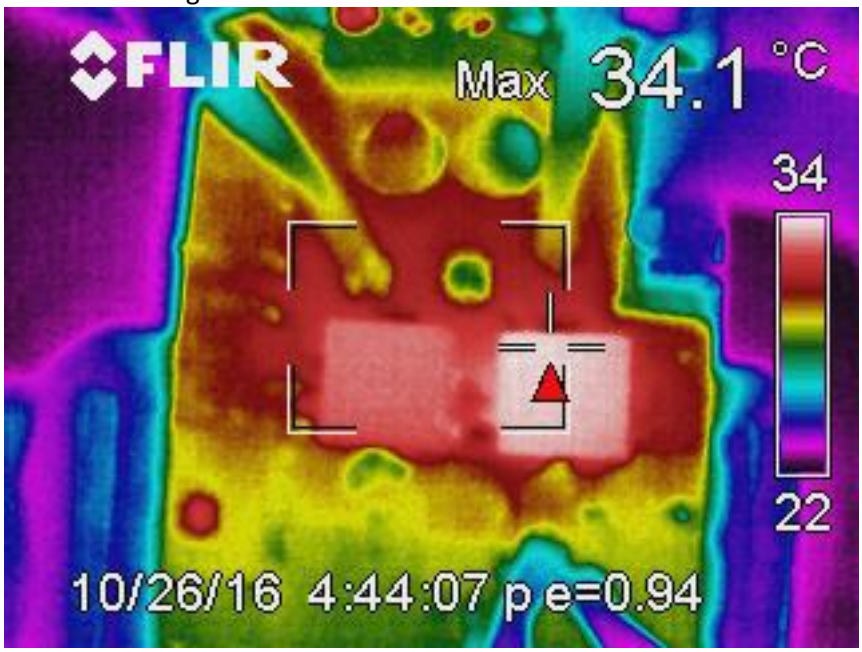
Now Slave side view:
IR-0083 68 deg. Slave side (69 seen but not captured)



Q

Model t3 thermal images continued: No fan & No load: Wurth inductors Dec 21

Finally, no load and no fan with 12.04Vin 107mA in 1.201Vout 432kHz/phase model t3
IR0084 is 34 deg. C with no load no fan Both FETs read 35 & 36 on GUI



Master inductor core about 2 degrees hotter than slave core
False date on thermal camera
Q

Efficiency data Model t2 5Vin

with ~1-2 Meter per second airflow model t2

Vin V	Iin A	Vout	Iout A	eff %	loss W
4.995	0.095	1.203	0.000	0.000	0.475
4.994	0.579	1.203	1.991	82.835	0.496
4.994	1.071	1.203	3.993	89.811	0.545
4.994	1.571	1.203	5.991	91.844	0.640
4.994	2.075	1.203	7.991	92.745	0.752
4.994	2.581	1.203	9.991	93.223	0.874
4.994	3.090	1.203	11.992	93.480	1.006
4.994	3.601	1.203	13.990	93.575	1.155
4.994	4.117	1.203	15.993	93.570	1.322
4.994	4.636	1.203	17.994	93.479	1.510
4.994	5.159	1.203	19.995	93.348	1.714
4.994	5.687	1.203	21.995	93.166	1.941
4.994	6.218	1.203	23.996	92.963	2.185
4.993	6.753	1.203	25.995	92.730	2.451
4.993	7.293	1.203	27.998	92.483	2.737
4.993	7.837	1.203	29.998	92.213	3.047
4.993	8.384	1.203	31.997	91.937	3.375
4.993	8.938	1.203	34.002	91.647	3.728
4.993	9.494	1.203	36.001	91.349	4.101
4.993	10.056	1.203	38.002	91.040	4.499
4.993	10.623	1.203	40.003	90.725	4.919
4.993	11.194	1.203	42.004	90.403	5.363
4.993	11.770	1.203	44.003	90.072	5.834
4.992	12.352	1.203	46.006	89.735	6.330
4.992	12.939	1.203	48.006	89.390	6.854
4.992	13.532	1.203	50.010	89.041	7.403
4.992	14.130	1.203	52.014	88.685	7.981
4.992	14.735	1.203	54.016	88.322	8.589
4.992	15.346	1.203	56.018	87.947	9.233
4.992	15.962	1.203	58.020	87.573	9.902
4.992	16.587	1.203	60.021	87.178	10.616

Q

Efficiency data continued:

Efficiency data Model t2 WE 8Vin

with ~1-2 Meter per second airflow model t2

Vin V	Iin A	Vout	Iout A	eff %	loss W
7.995	0.105	1.202	0.000	0.000	0.836
7.995	0.411	1.202	2.007	73.443	0.873
7.995	0.721	1.203	4.005	83.587	0.946
7.995	1.034	1.203	6.004	87.296	1.051
7.994	1.352	1.203	8.002	89.048	1.184
7.994	1.667	1.202	10.003	90.230	1.302
7.994	1.983	1.202	12.002	91.027	1.422
7.994	2.300	1.202	13.999	91.531	1.557
7.994	2.621	1.202	16.004	91.853	1.707
7.994	2.942	1.202	18.003	92.039	1.872
7.994	3.266	1.202	20.003	92.130	2.055
7.994	3.591	1.202	22.002	92.153	2.253
7.994	3.919	1.202	24.002	92.117	2.469
7.994	4.249	1.202	26.000	92.041	2.703
7.994	4.582	1.202	28.000	91.921	2.959
7.994	4.916	1.202	30.003	91.787	3.228
7.994	5.254	1.202	32.003	91.624	3.517
7.994	5.593	1.202	34.004	91.438	3.828
7.994	5.936	1.202	36.005	91.238	4.157
7.994	6.280	1.202	38.004	91.019	4.508
7.994	6.627	1.202	40.006	90.797	4.876
7.994	6.977	1.202	42.008	90.558	5.266
7.994	7.329	1.202	44.006	90.309	5.678
7.993	7.685	1.202	46.007	90.052	6.110
7.993	8.043	1.202	48.008	89.784	6.568
7.993	8.404	1.202	50.012	89.510	7.047
7.993	8.769	1.202	52.015	89.225	7.552
7.993	9.136	1.202	54.017	88.933	8.082
7.993	9.507	1.202	56.018	88.630	8.640
7.993	9.880	1.202	58.019	88.326	9.219
7.993	10.258	1.202	60.021	88.014	9.828

Q

Efficiency data continued:

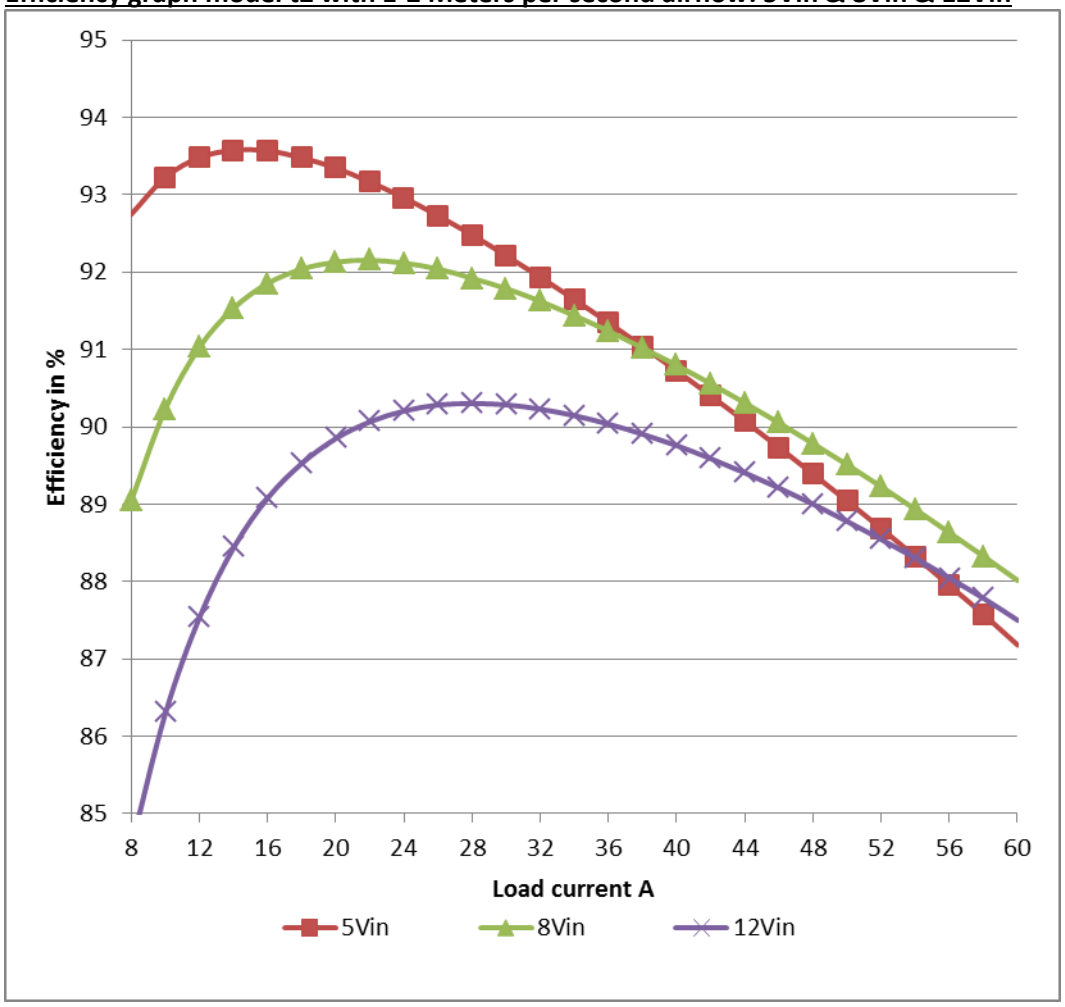
Efficiency data Model t2 WE inductors 12Vin

with ~1-2 Meter per second airflow model t2

Vin V	Iin A	Vout	Iout A	eff %	loss W
11.999	0.109	1.202	0.000	0.000	1.306
11.999	0.318	1.202	2.045	64.403	1.359
11.999	0.527	1.202	4.042	76.833	1.466
11.999	0.739	1.202	6.039	81.877	1.607
11.999	0.952	1.203	8.035	84.603	1.759
11.999	1.165	1.203	10.033	86.314	1.913
11.999	1.377	1.202	12.030	87.546	2.058
11.999	1.589	1.202	14.029	88.443	2.204
11.999	1.803	1.202	16.030	89.084	2.362
11.999	2.018	1.202	18.028	89.531	2.535
11.999	2.233	1.202	20.026	89.852	2.720
11.999	2.451	1.202	22.026	90.068	2.921
11.999	2.669	1.202	24.025	90.205	3.137
11.999	2.888	1.202	26.023	90.284	3.367
11.999	3.110	1.202	28.021	90.302	3.618
11.999	3.332	1.202	30.020	90.286	3.884
11.999	3.556	1.202	32.017	90.229	4.169
11.999	3.782	1.202	34.020	90.145	4.472
11.999	4.009	1.202	36.018	90.035	4.793
11.999	4.238	1.202	38.020	89.905	5.133
11.999	4.468	1.202	40.020	89.757	5.491
11.999	4.700	1.202	42.020	89.588	5.872
11.999	4.934	1.202	44.018	89.404	6.273
11.999	5.170	1.202	46.019	89.209	6.693
11.999	5.407	1.202	48.019	89.000	7.136
11.999	5.646	1.202	50.020	88.776	7.604
11.999	5.888	1.202	52.024	88.543	8.094
11.999	6.131	1.202	54.026	88.302	8.606
11.998	6.377	1.202	56.026	88.045	9.147
11.998	6.624	1.202	58.028	87.781	9.712
11.998	6.875	1.202	60.027	87.498	10.312

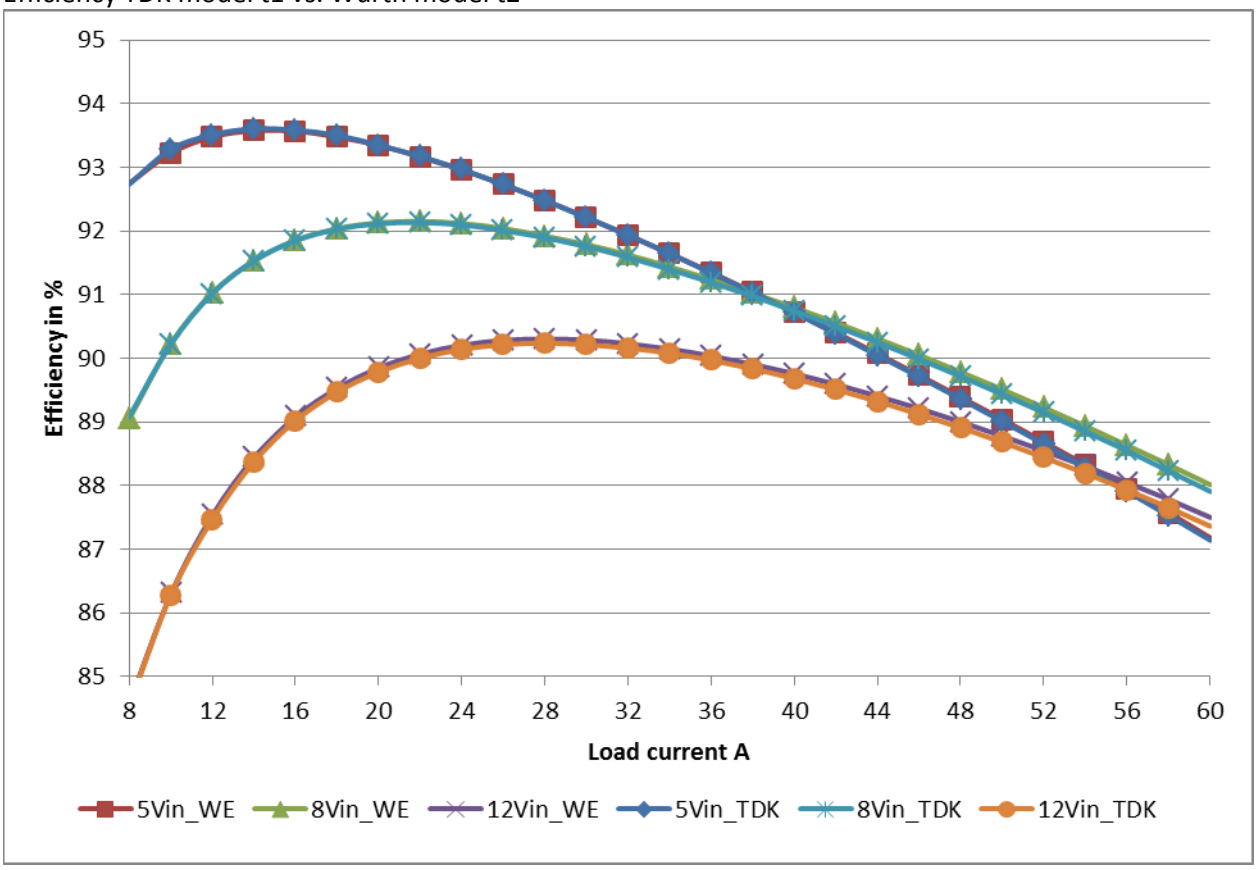
Q

Efficiency graph model t2 with 1-2 Meters per second airflow: 5Vin & 8Vin & 12Vin



Q

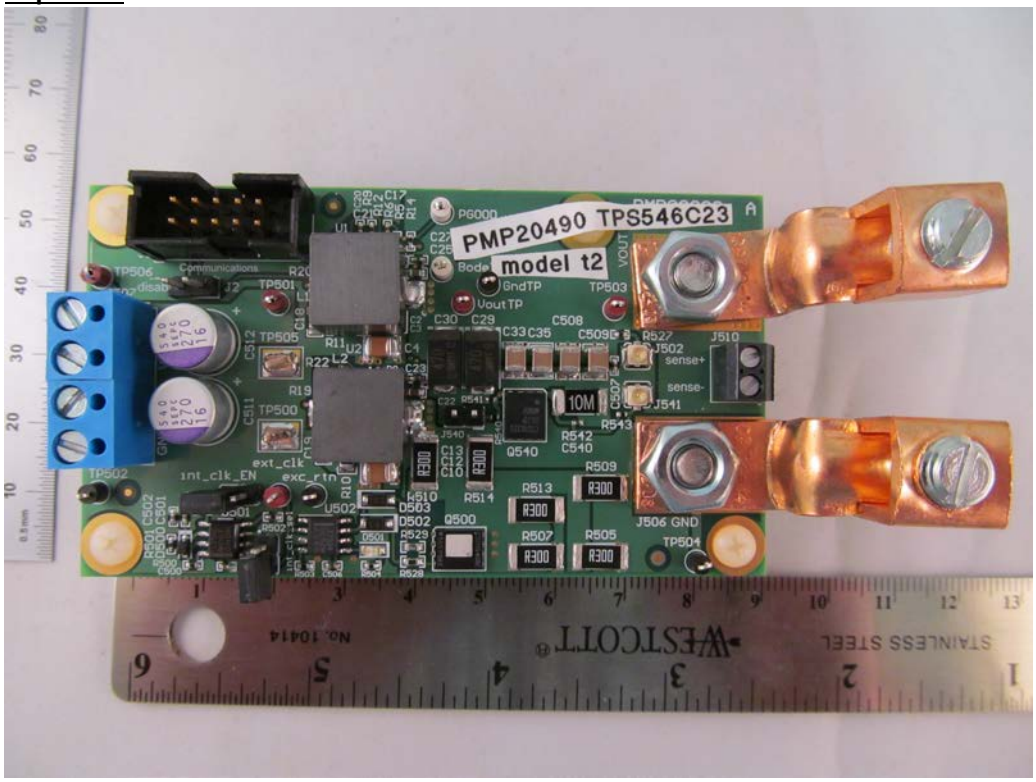
Efficiency TDK model t1 vs. Wurth model t2



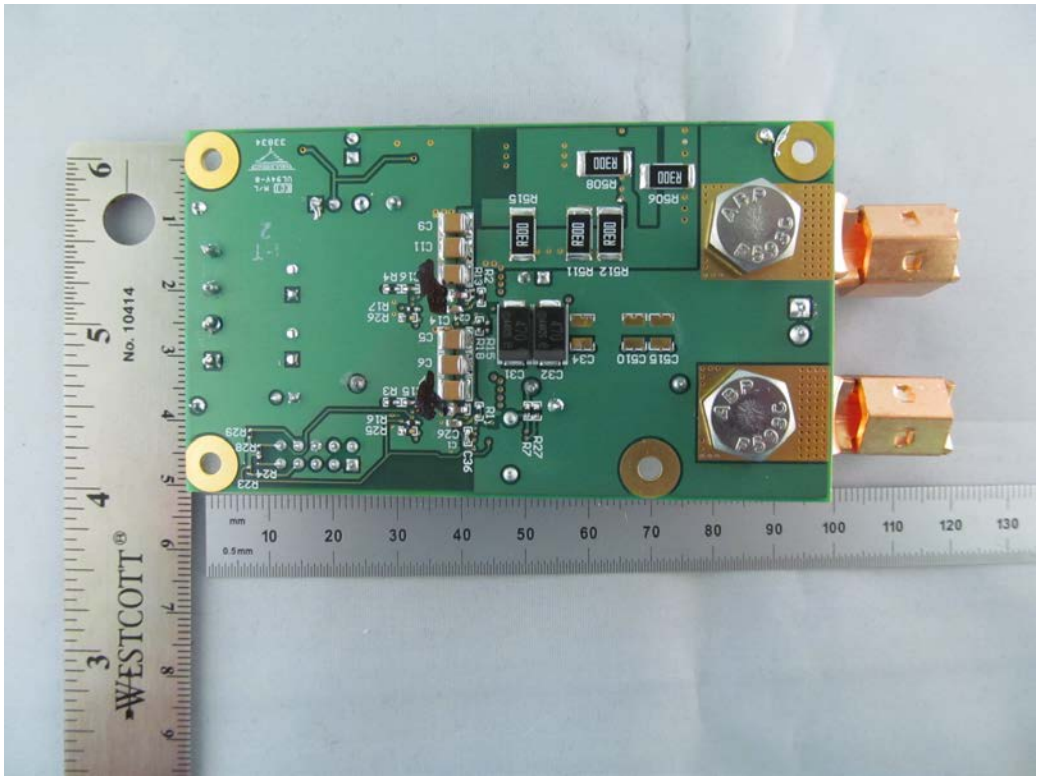
Conclusion: Effficiency variations are very small between the two type of inductors with greatest variation at max 60A load and 12Vin: Here efficiency for model t1 using TDK is 87.362% vs. model t2 with Wurth at 87.498% for a 0.138% difference. Model t3 with Wurth came in at 87.415%, or only 0.053% better than the TDK model.
However, saturation differences are significant. See pages 4-8 above.

Board assembly images:

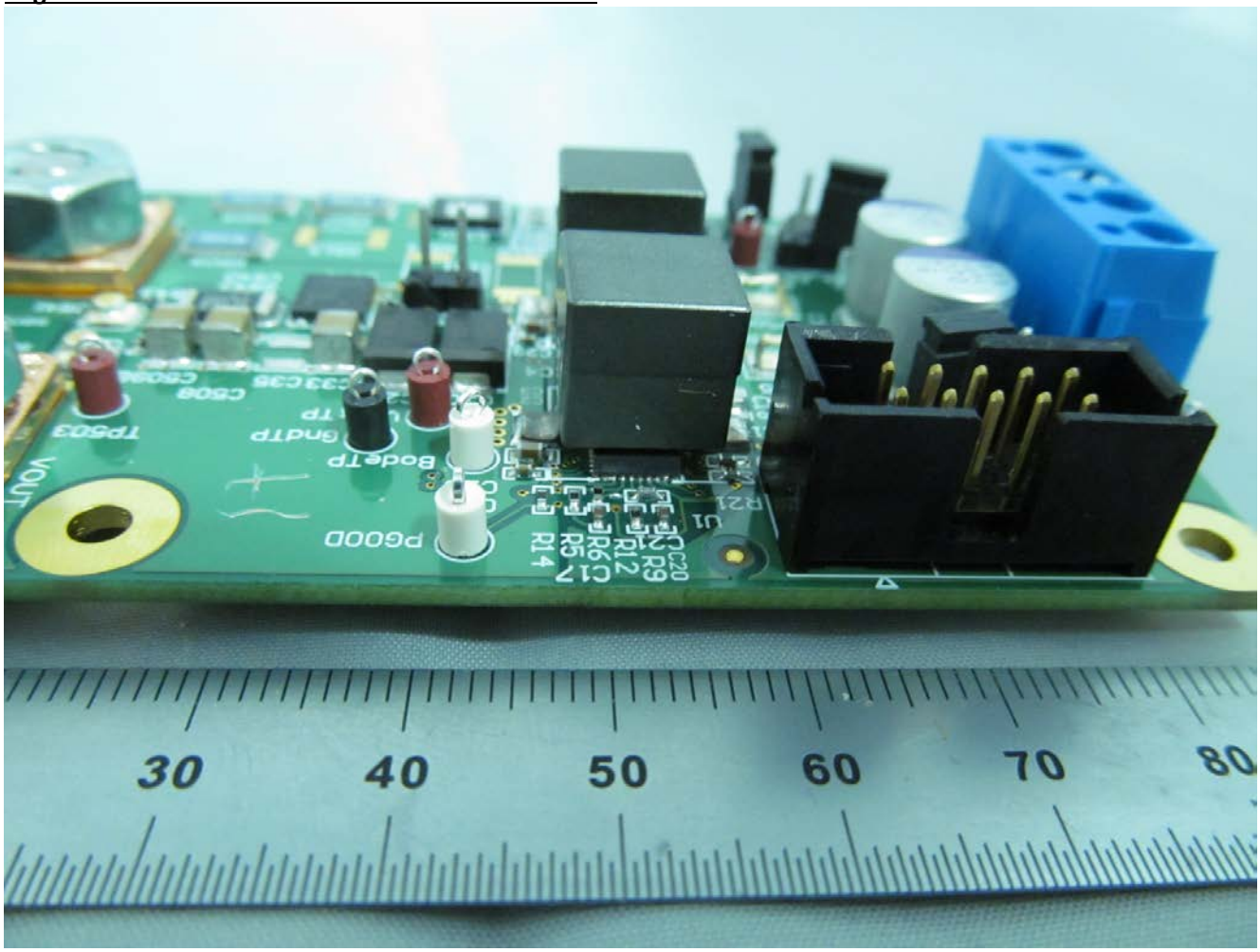
Top view:



Bottom view:



Board images continued:
Edge view to show controller U1 under inductor L1:



IMPORTANT NOTICE AND DISCLAIMER

TI PROVIDES TECHNICAL AND RELIABILITY DATA (INCLUDING DATASHEETS), DESIGN RESOURCES (INCLUDING REFERENCE DESIGNS), APPLICATION OR OTHER DESIGN ADVICE, WEB TOOLS, SAFETY INFORMATION, AND OTHER RESOURCES “AS IS” AND WITH ALL FAULTS, AND DISCLAIMS ALL WARRANTIES, EXPRESS AND IMPLIED, INCLUDING WITHOUT LIMITATION ANY IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE OR NON-INFRINGEMENT OF THIRD PARTY INTELLECTUAL PROPERTY RIGHTS.

These resources are intended for skilled developers designing with TI products. You are solely responsible for (1) selecting the appropriate TI products for your application, (2) designing, validating and testing your application, and (3) ensuring your application meets applicable standards, and any other safety, security, or other requirements. These resources are subject to change without notice. TI grants you permission to use these resources only for development of an application that uses the TI products described in the resource. Other reproduction and display of these resources is prohibited. No license is granted to any other TI intellectual property right or to any third party intellectual property right. TI disclaims responsibility for, and you will fully indemnify TI and its representatives against, any claims, damages, costs, losses, and liabilities arising out of your use of these resources.

TI’s products are provided subject to TI’s Terms of Sale (https:www.ti.com/legal/termsofsale.html) or other applicable terms available either on ti.com or provided in conjunction with such TI products. TI’s provision of these resources does not expand or otherwise alter TI’s applicable warranties or warranty disclaimers for TI products.

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265