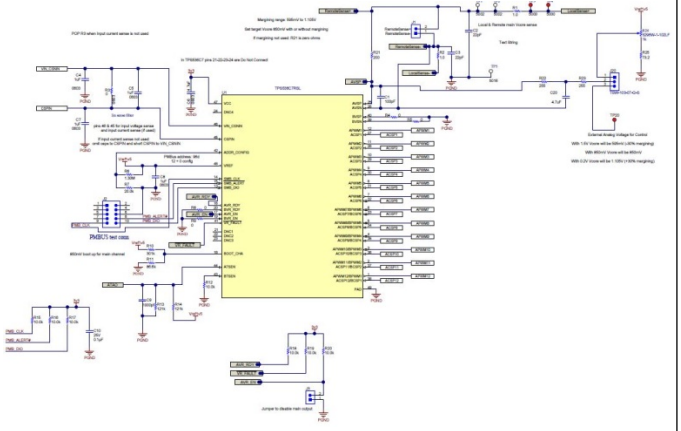
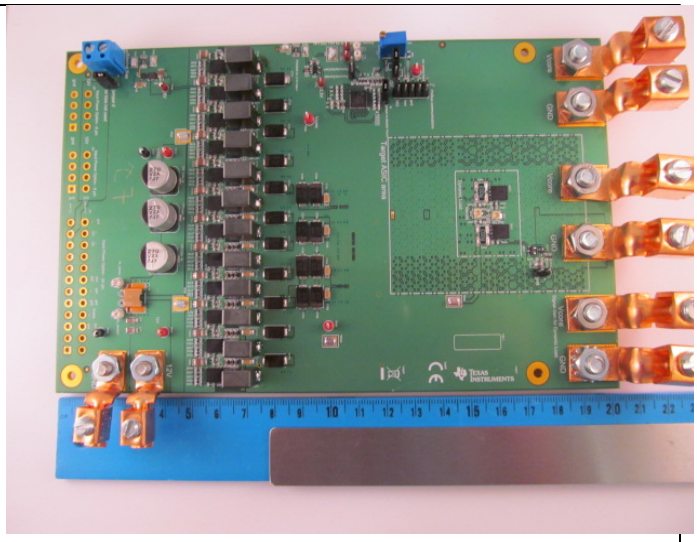
Test Report: PMP21887

High-Current 360-A Static / 600-A Peak Core PMBus Voltage 12-phase Reference Design for ASICs

Description

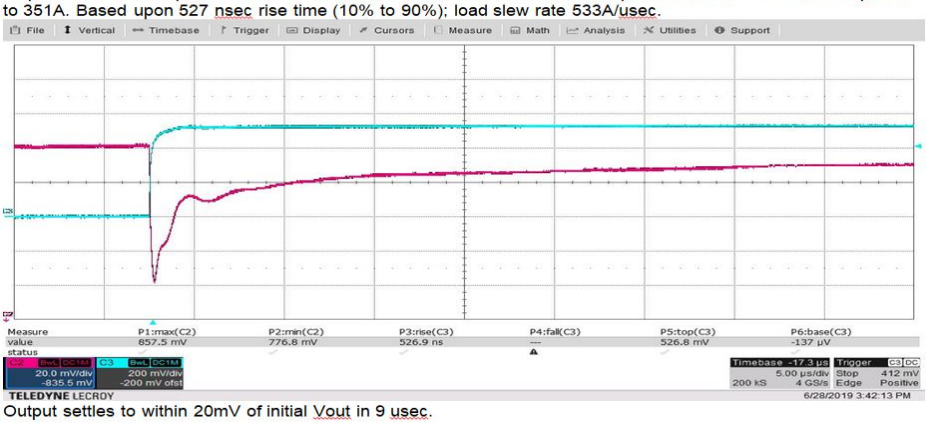
The PMP21887 is a 12-phase Power Management Bus (PMBus) buck converter powering Datacenter Hardware Accelerator, Enterprise Switch and Router application-specific integrated circuit (ASIC) core rails. It provides 360A of continuous current and 600A of peak current at 0.85-V nominal voltages. It uses twelve of TI's CSD95480 common footprint 70-A smart power stages. Design includes an on-board high speed dynamic load for testing to stringent dynamic load response requirements of high speed ASICs. The PMP21887 includes a Test Report showing these capabilities and enables a cut-and-paste design for powering high-current ASIC core rails with PMBus.





Testing with ~350A load step / dump on top of 300A static load for 650A peak

Model t2 as built with 12x 150 nH inductors and ~400 kHz per phase targeted 12Vin 300A static load and 350A dynamic load step on top of that at 50 Hz and 5% duty cycle: June 28, 2019
Step load response short term: Channel 2 red is Vout showing about 78mV peak undershoot from 856mV in response to 350A step load shown on channel 2 blue across 2x 3mOhms in parallel. Hence 527mV corresponds to 351A. Based upon 527 nsec rise time (10% to 90%); load slew rate 533A/usec.



Output settles to within 20mV of initial Vout in 9 usec.

1 Test Prerequisites

1.1 Voltage and Current Requirements

Table 1. Voltage and Current Requirements

PARAMETER	SPECIFICATIONS
Input Voltage	10-14 VDC
Output Voltage Range	0.8 to 1.2 VDC; tested at 0.85V setting
Max Load Current	360 A static / 600 A peak
Max Output Power (electrical peak / for thermal purposes)	~510W / 350W

1.2 Required Equipment

- Lab 12 V 50 A source
- Electronic loads rated to carry maximum static load
- Signal generator to drive on-board dynamic load. Example Tektronix AFG3102
- Loop stability analyzer such as Venable 3120 or Omricon Bode100
- Thermal camera
- Oscilloscope and voltage / current meters or current shunts

1.3 Considerations

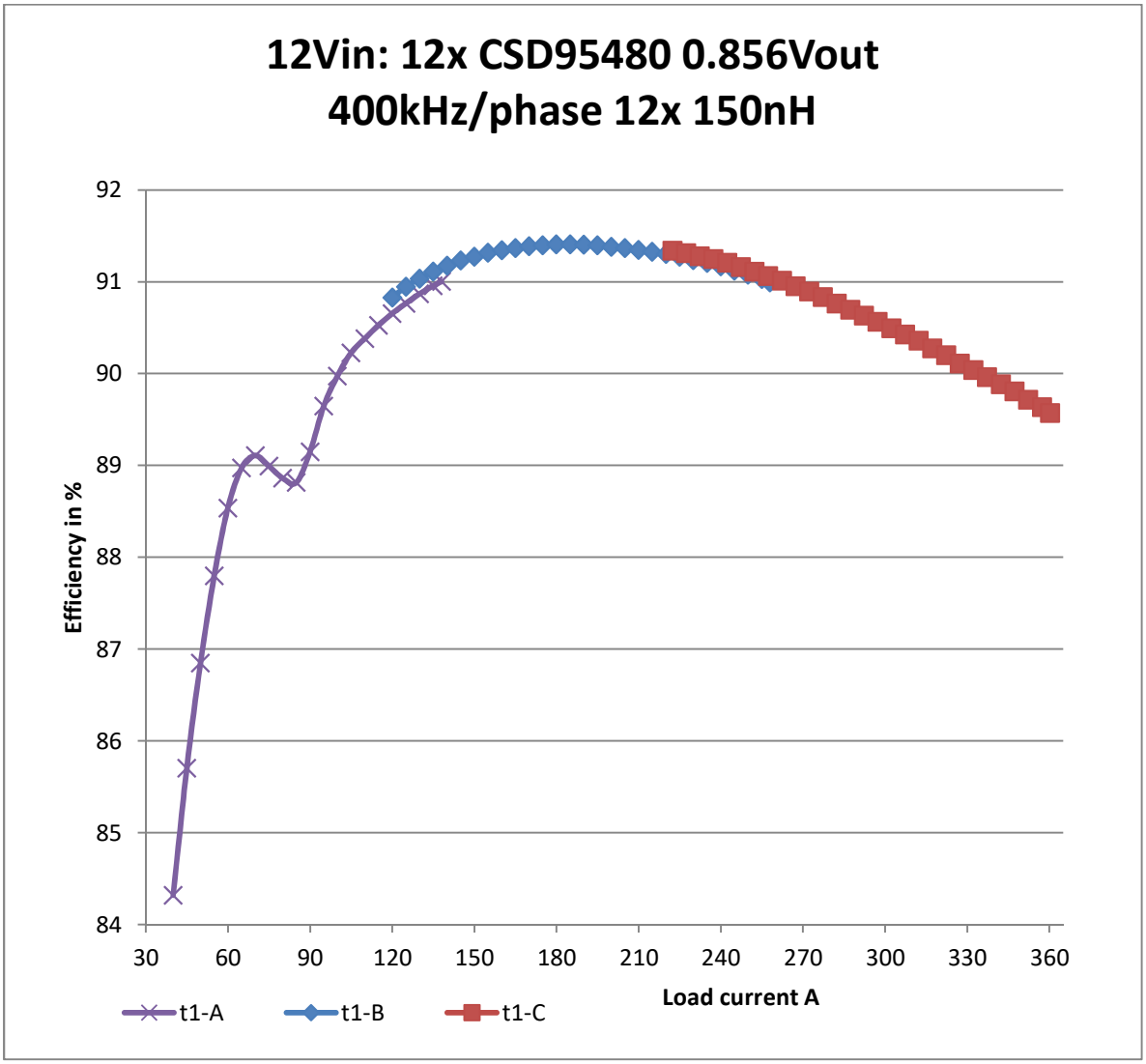
a) Fan cooling needed for > 150 A output.

Caution	Caution Hot surface. Contact may cause burns. Do not touch!

2 Testing and Results (Tests done by Josh Mandelcorn)

2.1 Efficiency Graph

From 12 Vin:



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2.2 Efficiency Data

Load stepped from zero A thru 135 in 5A increments, and then to 138A

No additional fixed loads

PMP21887 model t1: 12Vin to 856mV 300A max 400kHz / phase

12x CSD95480 WE 6x12x5 150nH inductors with fan

Vin V	Iin A	Vout	Iout A	eff %	loss W
11.999	0.516	0.856	0.000	0.00	6.19
11.998	0.872	0.856	4.989	40.85	6.19
11.998	1.229	0.857	9.982	58.01	6.19
11.998	1.587	0.858	14.978	67.44	6.20
11.997	1.947	0.858	19.974	73.38	6.22
11.997	2.308	0.859	24.970	77.44	6.24
11.997	2.669	0.859	29.964	80.38	6.28
11.996	3.033	0.860	34.961	82.60	6.33
11.996	3.398	0.860	39.958	84.32	6.39
11.996	3.763	0.861	44.953	85.70	6.45
11.995	4.129	0.861	49.952	86.85	6.52
11.995	4.496	0.862	54.947	87.80	6.58
11.994	4.867	0.862	59.946	88.54	6.69
11.994	5.250	0.863	64.944	88.97	6.95
11.994	5.650	0.863	69.944	89.11	7.38
11.993	6.065	0.864	74.944	88.99	8.01
11.993	6.484	0.864	79.941	88.86	8.66
11.992	6.897	0.865	84.944	88.81	9.25
11.992	7.281	0.865	89.944	89.15	9.47
11.992	7.649	0.866	94.945	89.64	9.50
11.991	8.027	0.867	99.947	89.97	9.65
11.991	8.411	0.867	104.949	90.23	9.86
11.991	8.803	0.868	109.954	90.38	10.15
11.990	9.195	0.868	114.958	90.53	10.44
11.990	9.588	0.869	119.960	90.65	10.74
11.989	9.982	0.869	124.965	90.76	11.05
11.989	10.377	0.870	129.969	90.87	11.36
11.989	10.773	0.870	134.972	90.96	11.68
11.988	11.011	0.871	137.977	91.00	11.88

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2.2 Efficiency data continued

120A additional fixed load
Iout is read Iout plus 59.98 / 0.4998 or 120A on fixed load
PMP21887 model t1: 12Vin to 856mV 300A max 400kHz / phase
12x CSD95480 WE 6x12x5 150nH inductors with fan

read I	Vin V	Iin A	Vout	Iout A	eff %	loss W
0.000	11.990	9.550	0.867	120.000	90.83	10.50
4.988	11.990	9.940	0.867	124.988	90.95	10.79
9.982	11.989	10.334	0.868	129.982	91.03	11.11
14.979	11.989	10.729	0.868	134.979	91.11	11.43
19.973	11.988	11.125	0.869	139.973	91.18	11.77
24.968	11.988	11.523	0.869	144.968	91.23	12.11
29.962	11.988	11.922	0.870	149.962	91.27	12.47
34.960	11.987	12.321	0.870	154.960	91.32	12.82
39.956	11.987	12.723	0.871	159.956	91.34	13.20
44.950	11.986	13.125	0.871	164.950	91.37	13.58
49.949	11.986	13.529	0.872	169.949	91.39	13.97
54.944	11.986	13.935	0.873	174.944	91.40	14.37
59.944	11.985	14.341	0.873	179.944	91.41	14.77
64.942	11.985	14.749	0.874	184.942	91.41	15.19
69.941	11.984	15.159	0.874	189.941	91.40	15.62
74.941	11.984	15.569	0.875	194.941	91.40	16.05
79.939	11.984	15.982	0.875	199.939	91.38	16.51
84.939	11.983	16.395	0.876	204.939	91.37	16.96
89.942	11.983	16.812	0.877	209.942	91.35	17.43
94.941	11.982	17.227	0.877	214.941	91.33	17.90
99.944	11.982	17.645	0.878	219.944	91.30	18.38
104.945	11.981	18.065	0.878	224.945	91.27	18.89
109.949	11.981	18.487	0.879	229.949	91.24	19.41
114.953	11.981	18.909	0.879	234.953	91.21	19.92
119.956	11.980	19.333	0.880	239.956	91.17	20.46
124.961	11.980	19.760	0.881	244.961	91.12	21.02
129.964	11.979	20.188	0.881	249.964	91.08	21.58
134.968	11.979	20.618	0.882	254.968	91.03	22.16
137.974	11.979	20.878	0.882	257.974	90.99	22.52

2.2 Efficiency data continued

222.31A additional fixed loads

Iout is read Iout plus 66.10 / 0.4998 plus 90.05 / 0.99985 or 132.25A plus 90.06A on fixed load

PMP21887 model t1: 12Vin to 856mV 300A max 400kHz / phase

12x CSD95480 WE 6x12x5 150nH inductors with fan

read I	Vin V	Iin A	Vout	Iout A	eff %	loss W
0.000	11.981	17.808	0.877	222.310	91.34	18.47
5.005	11.981	18.226	0.877	227.315	91.31	18.97
9.999	11.980	18.644	0.878	232.309	91.28	19.48
14.997	11.980	19.065	0.878	237.307	91.25	19.99
19.992	11.980	19.487	0.879	242.302	91.21	20.52
24.988	11.979	19.912	0.879	247.298	91.16	21.08
29.982	11.979	20.340	0.880	252.292	91.11	21.66
34.979	11.978	20.768	0.880	257.289	91.07	22.23
39.976	11.978	21.197	0.881	262.286	91.01	22.81
44.970	11.977	21.629	0.882	267.280	90.95	23.43
49.968	11.977	22.063	0.882	272.278	90.90	24.06
54.963	11.977	22.499	0.883	277.273	90.84	24.70
59.961	11.976	22.939	0.883	282.271	90.76	25.38
64.958	11.976	23.378	0.884	287.268	90.70	26.04
69.958	11.975	23.820	0.885	292.268	90.63	26.72
74.957	11.975	24.262	0.885	297.267	90.56	27.41
79.953	11.974	24.707	0.886	302.263	90.49	28.12
84.952	11.974	25.153	0.886	307.262	90.43	28.83
89.953	11.973	25.599	0.887	312.263	90.36	29.54
94.951	11.973	26.052	0.888	317.261	90.27	30.34
99.953	11.972	26.504	0.888	322.263	90.20	31.09
104.951	11.972	26.963	0.889	327.261	90.11	31.92
109.954	11.971	27.416	0.889	332.264	90.04	32.69
114.956	11.971	27.874	0.890	337.266	89.96	33.49
119.958	11.970	28.334	0.891	342.268	89.89	34.30
124.961	11.970	28.794	0.891	347.271	89.81	35.13
129.963	11.969	29.260	0.892	352.273	89.72	36.01
134.963	11.969	29.726	0.893	357.273	89.64	36.87
137.968	11.969	30.013	0.893	360.278	89.57	37.46

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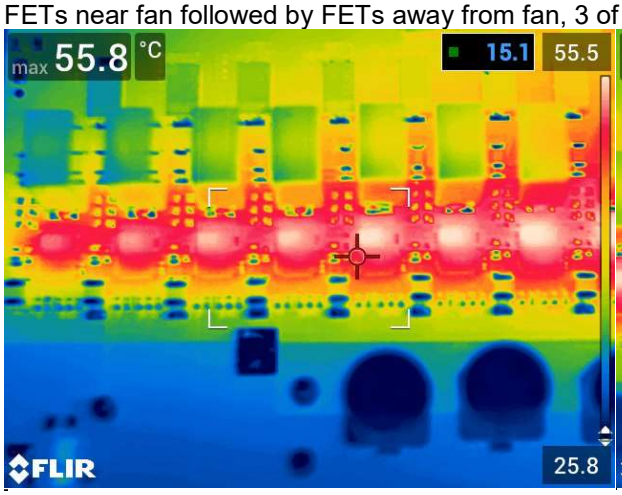
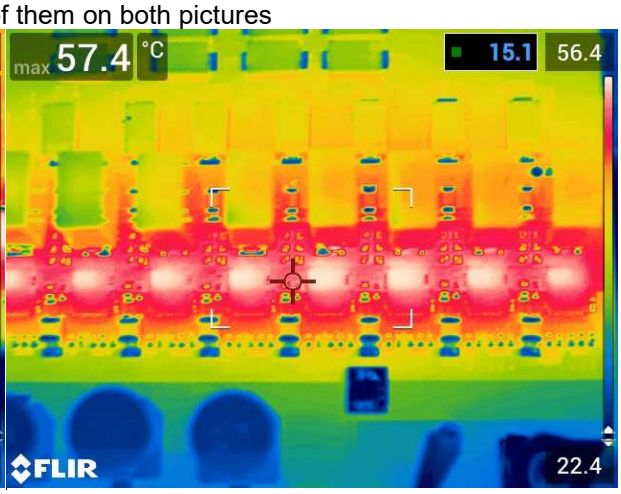
2.3 Thermal Images

300A loading
With fan: thermal images:
FETs near fan followed by FETs away from fan, 3 of them on both pictures





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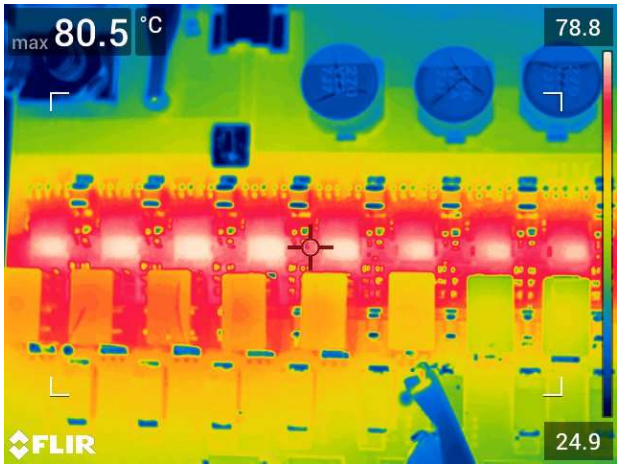
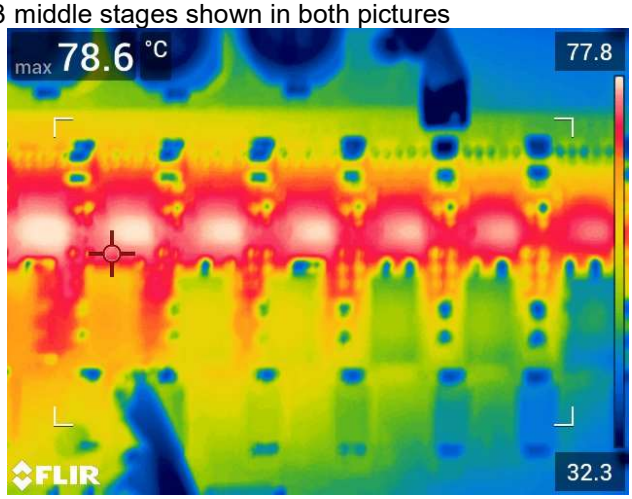
360A loading, also with Fan
Stages away from fan followed by stages near fan; 3 middle stages shown in both pictures





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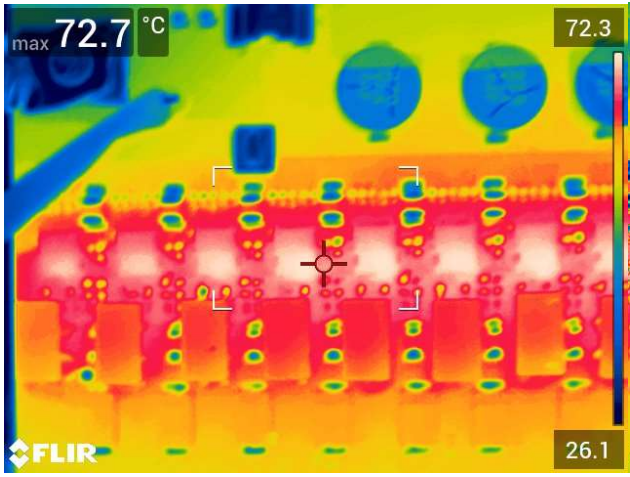
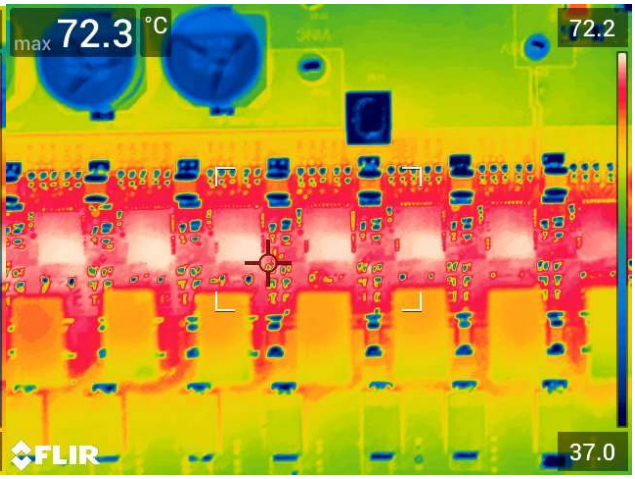
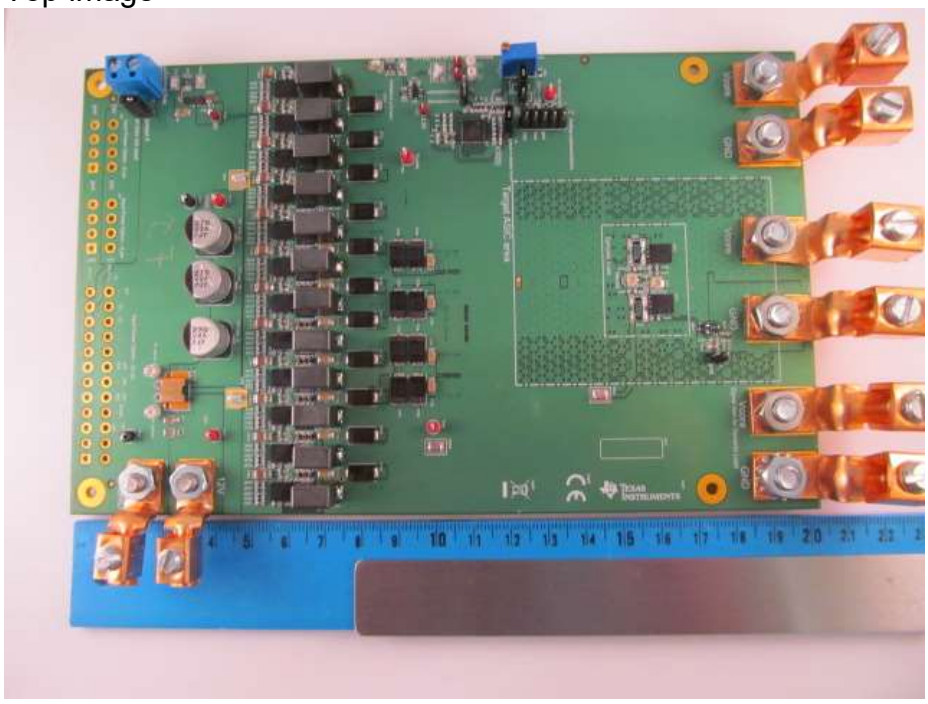
200A no fan model t2



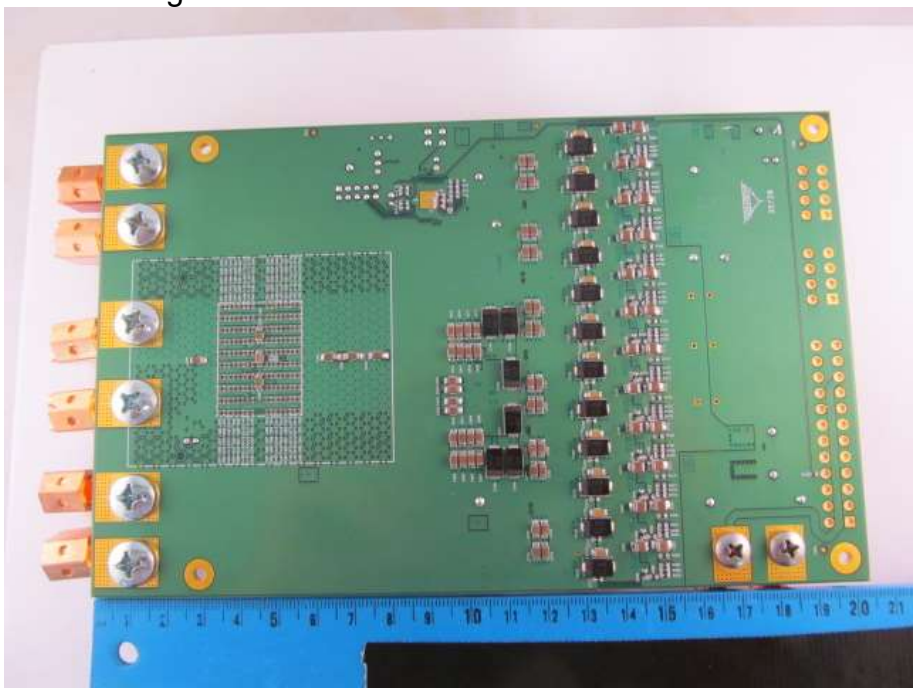


2.4 Dimensions

8 inches by 5 inches or 20.3 mm by 12.7 mm
Top image



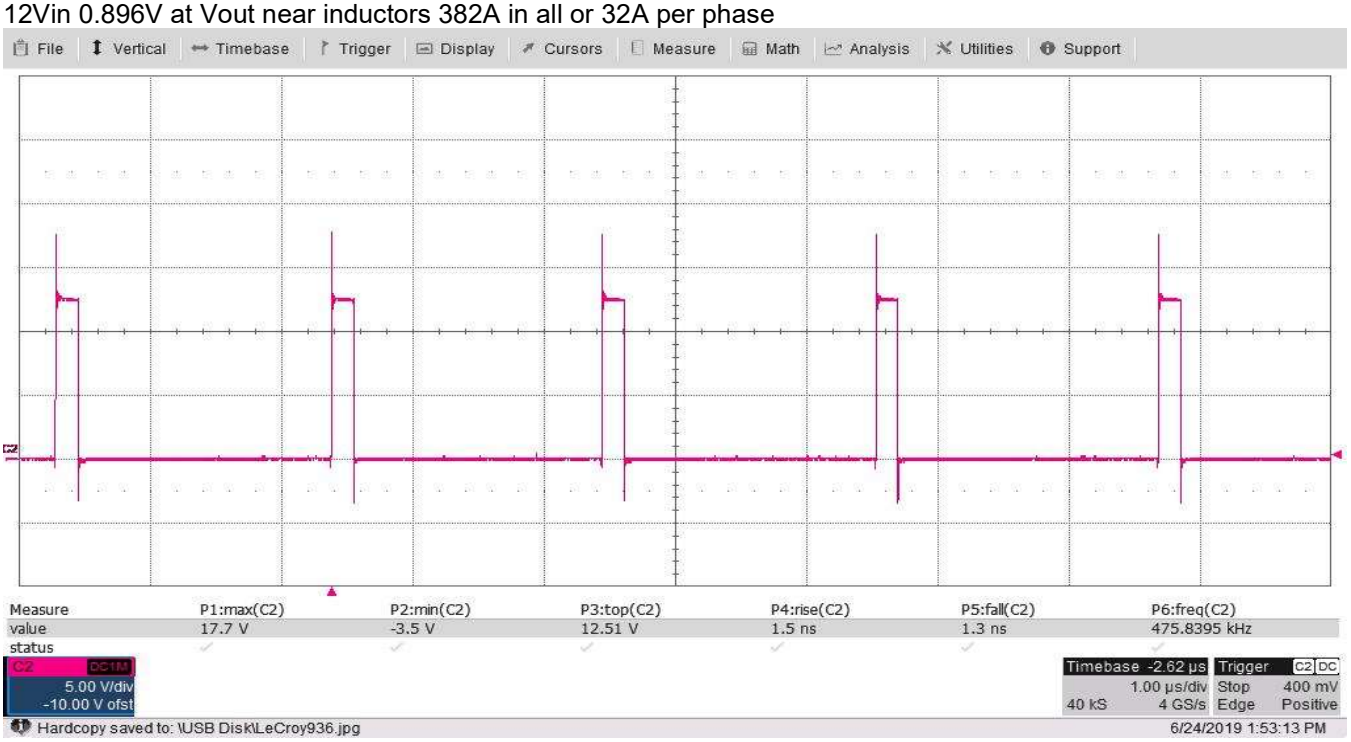
Bottom image



3 Waveforms

3.1 Switching

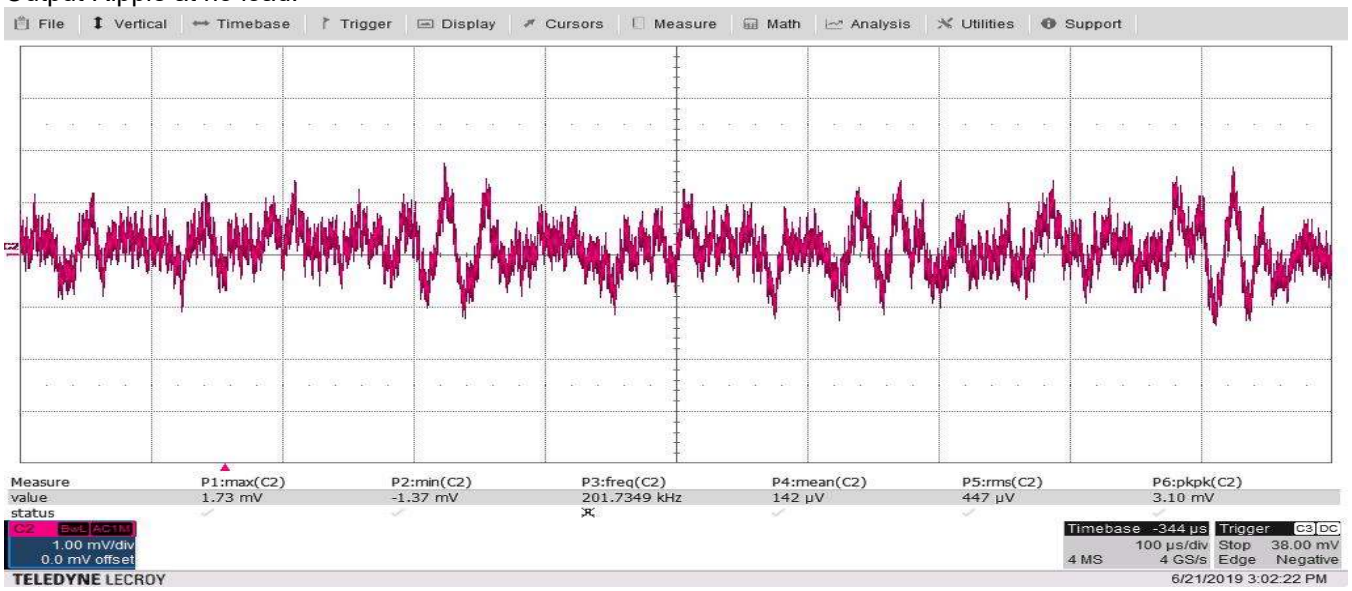
12Vin 0.896V at Vout near inductors 382A in all or 32A per phase



And one pulse in detail (snubber is 1.1 ohm plus 1000 pF; boot resistor is 1 ohm.)

3.2 Output Voltage Ripple

Output Ripple at no load:



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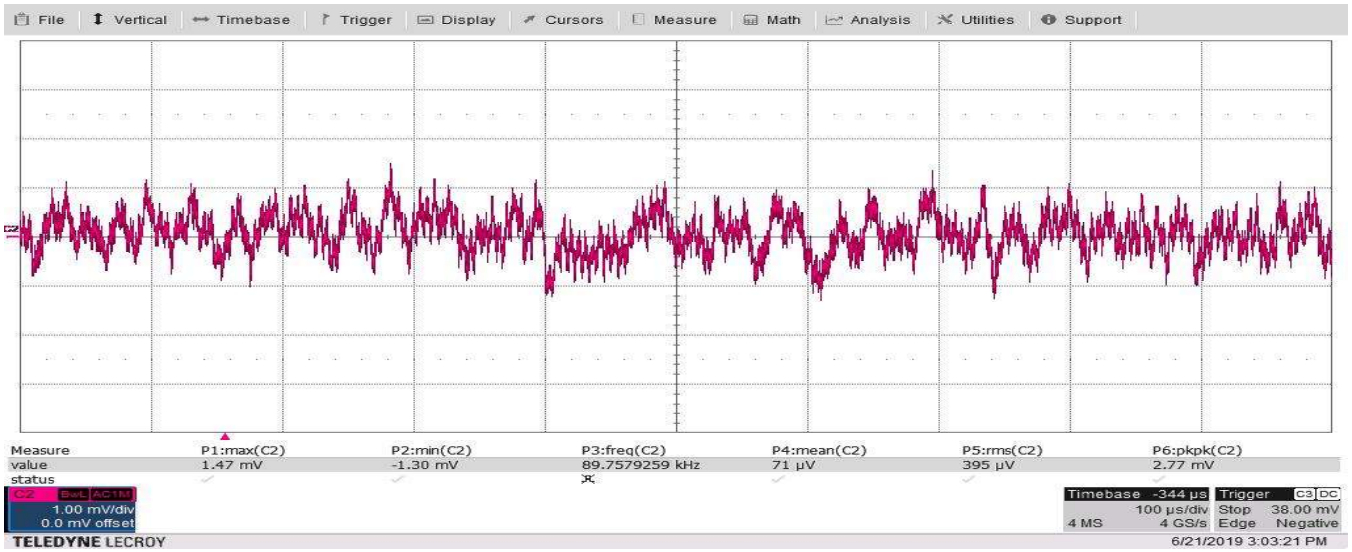
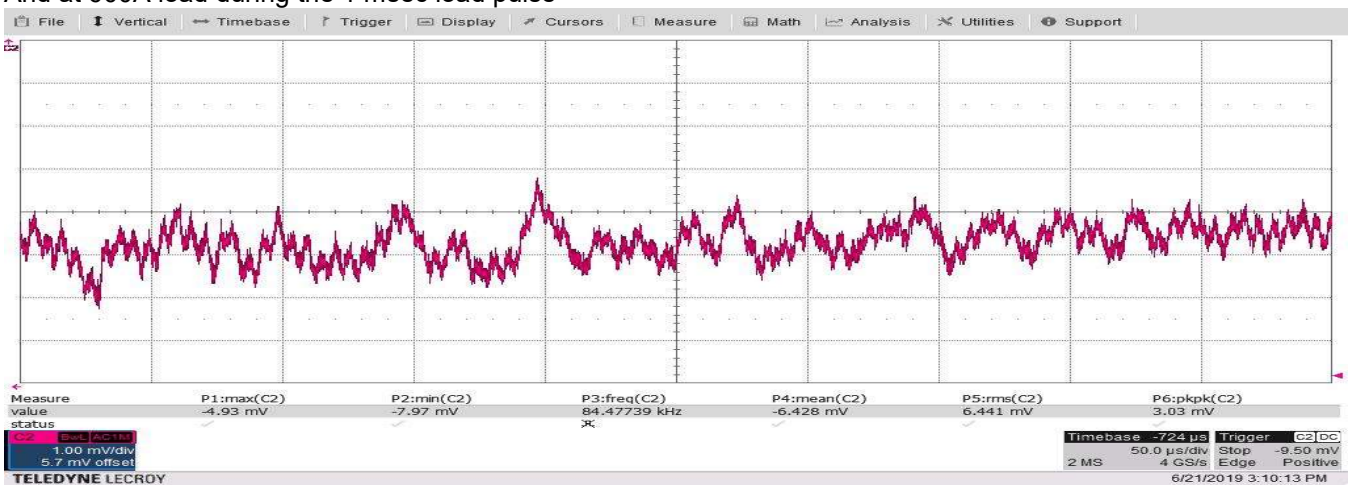
At 300A load

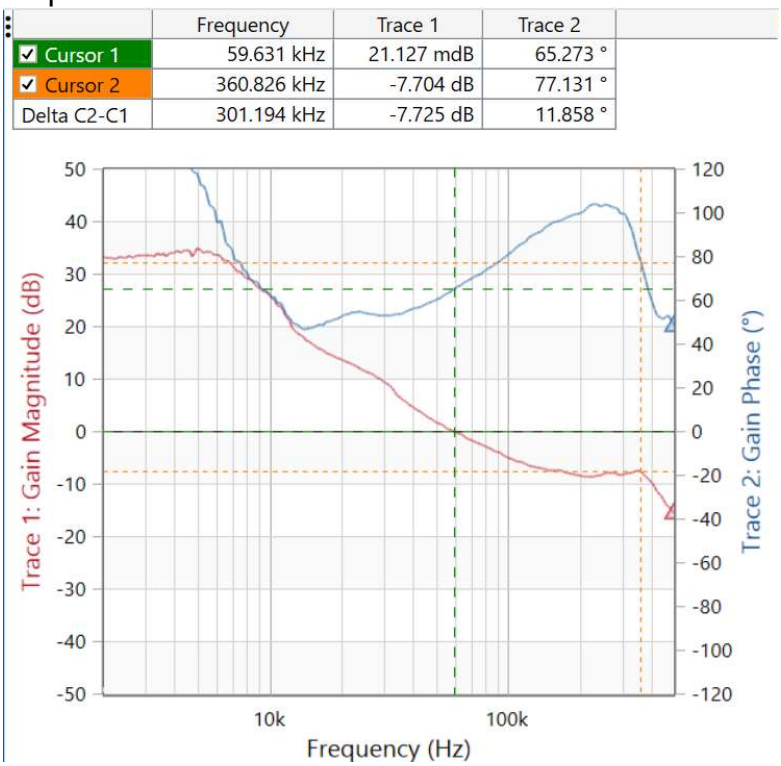


And at 600A load during the 1 msec load pulse

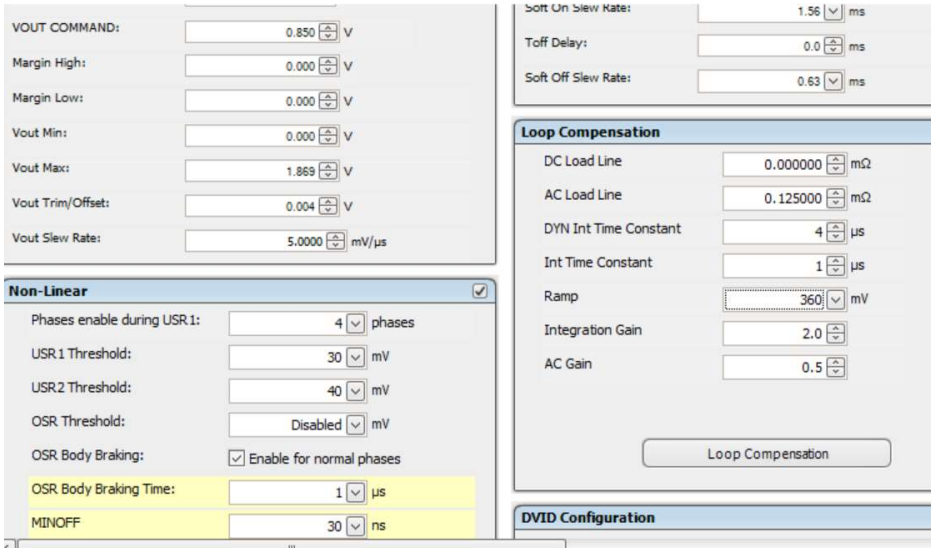


3.3 Bode Plot

0 dBm signal from 50 ohm source injected across 1 ohm on board between RS+ and LS+. Receiver BW at 100 Hz.
-10 dBm signal gave a “noisy plot, but similar; +10dBm gave a similar plot.
With “constant on-time controllers Bode plot can be used to predict stability, but not dynamic response.



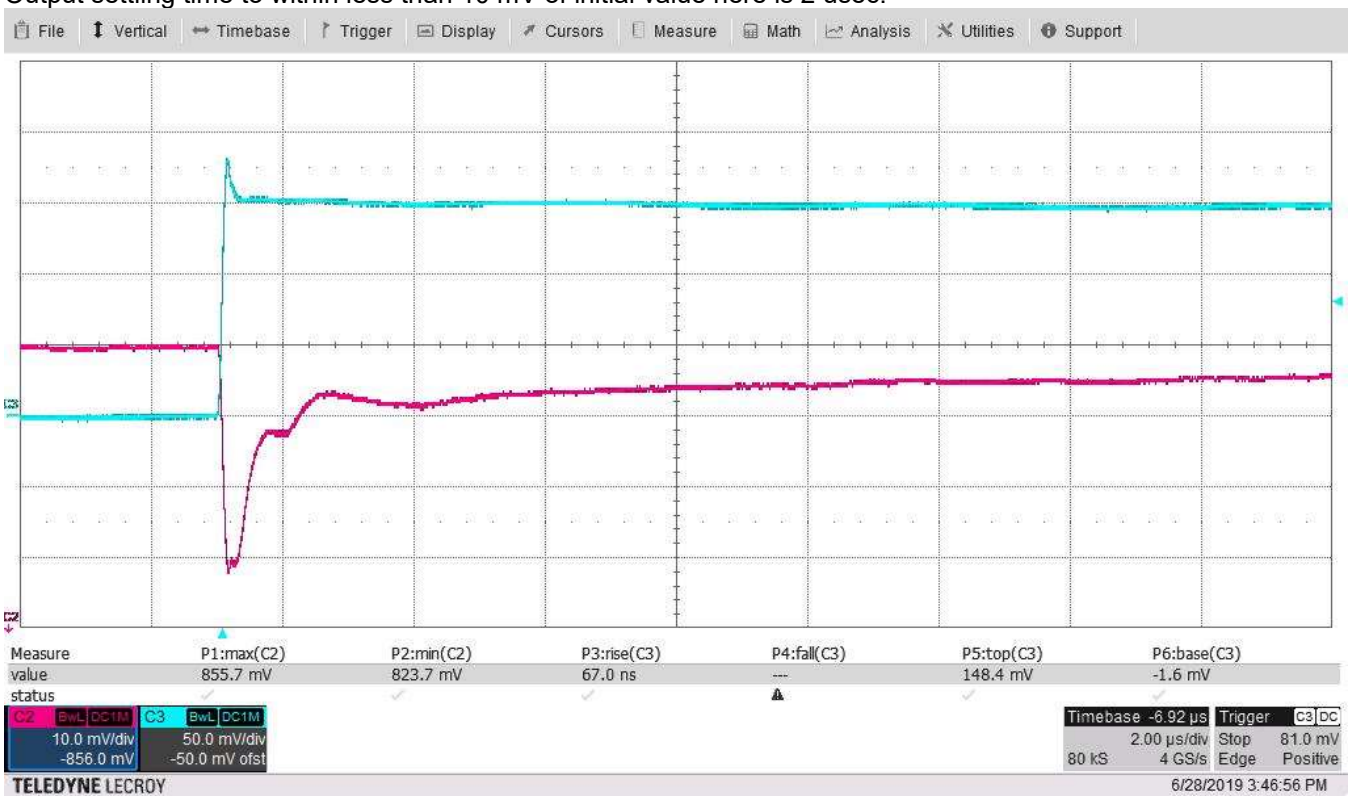
The 60kHz Bode plot crossover would predict maximum overshoot / undershoot at about 3 usec after load is switched. Dynamic responses show that time to be about ½ usec.



3.4 Dynamic Response

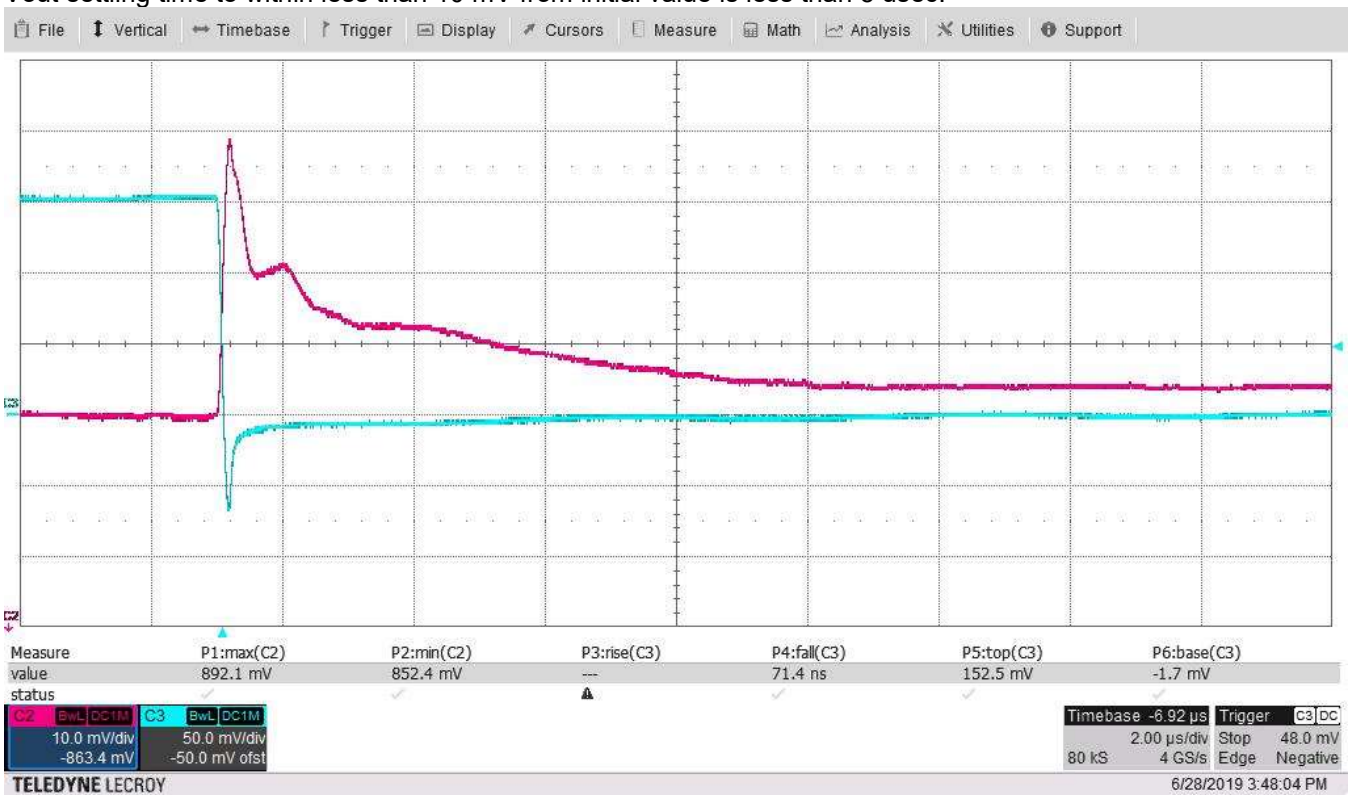
Testing with 100A load step from 300A static load

Model t2 as built with 12x 150 nH inductors and ~400 kHz per phase targeted 12Vin 300A static load and 100A dynamic load step on top of that at 50 Hz and 5% duty cycle: May 21, 2019
Step load response short term: Channel 2 red is Vout showing about 31mV peak undershoot in response to ~100A step load shown on channel 2 blue across 2x 3mOhms in parallel. Hence 150mV corresponds to 100A. Based upon 67 nsec rise time (10% to 90%); load slew rate ~1200A/usec.
Output settling time to within less than 10 mV of initial value here is 2 usec.



Testing with 100A load dump to 300A static load

Model t2 as built with 12x 150 nH inductors and ~400 kHz per phase targeted 12Vin 300A static load and 100A dynamic load step on top of that at 50 Hz and 5% duty cycle: June 28, 2019
Load dump response short term: Channel 2 red is Vout showing about 38mV peak overshoot in response to ~100A load dump shown on channel 2 blue across 2x 3mOhms in parallel. Hence 153mV corresponds to 102A. Based upon 71 nsec fall time (90% to 10%); load slew rate ~1140A/usec.
However, some of +38mV overshoot may be “inductive kick” from current waveform showing brief undershoot below zero A to almost -40A???
Vout settling time to within less than 10 mV from initial value is less than 5 usec.



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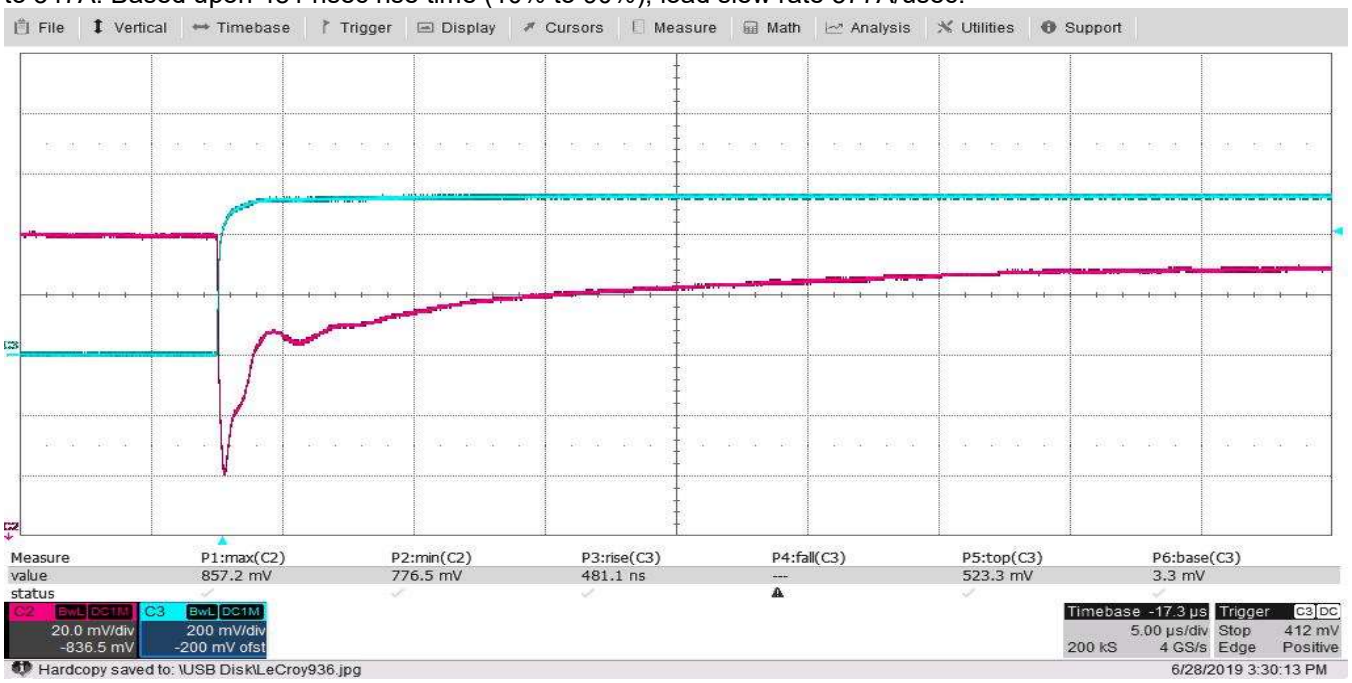
Testing with 347A load step / 353A load dump (0A static load)

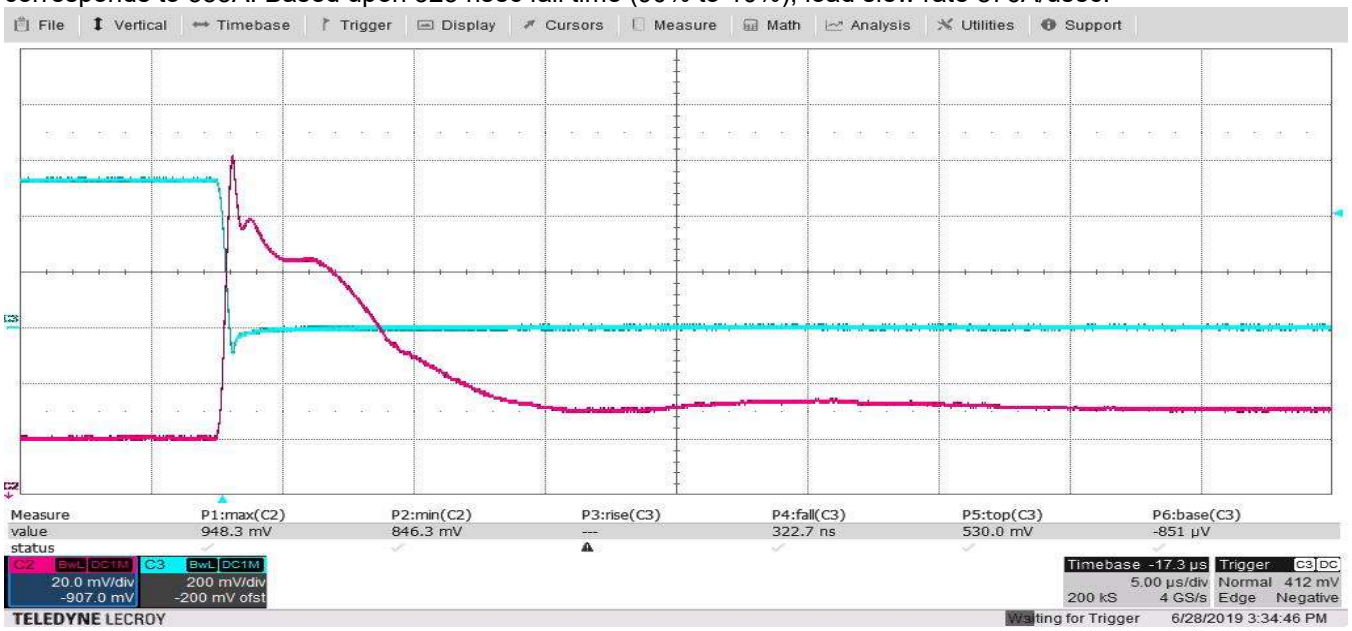
Model t2 as built with 12x 150 nH inductors and ~400 kHz per phase targeted 12Vin 0A static load and 345A dynamic load step on top of that at 50 Hz and 5% duty cycle: June 28, 2019

Step load response short term: Channel 2 red is Vout showing about 80mV peak undershoot from 856mV in response to ~300A step load shown on channel 2 blue across 2x 3mOhms in parallel. Hence 520mV corresponds to 347A. Based upon 481 nsec rise time (10% to 90%); load slew rate 577A/usec.



Output settles to within 20mV of initial Vout in 13 usec.

Load dump response 353 A to 0 ADC: Channel 2 red is Vout showing about 100mV peak overshoot from 847mV in response to 353A load dump shown on channel 2 blue across 2x 3mOhms in parallel. Hence 530mV corresponds to 353A. Based upon 323 nsec fall time (90% to 10%); load slew rate 876A/usec.



Output settles to within 20mV of initial Vout in 9 usec.

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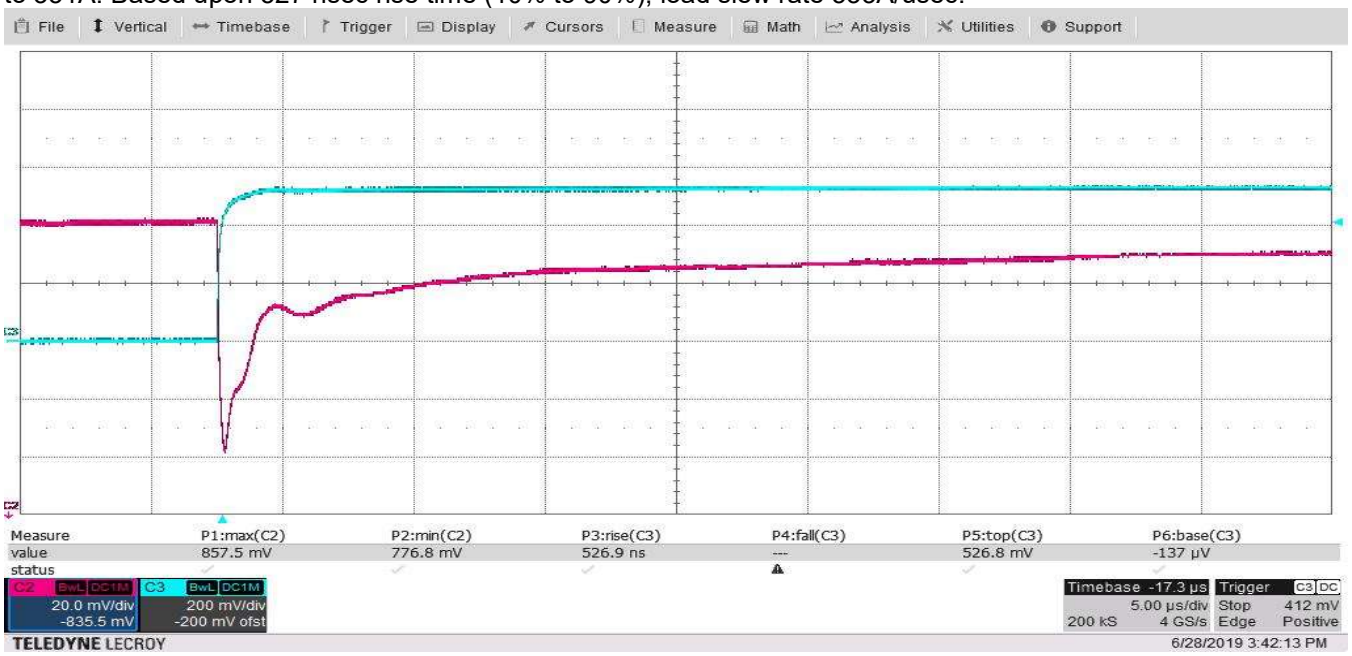
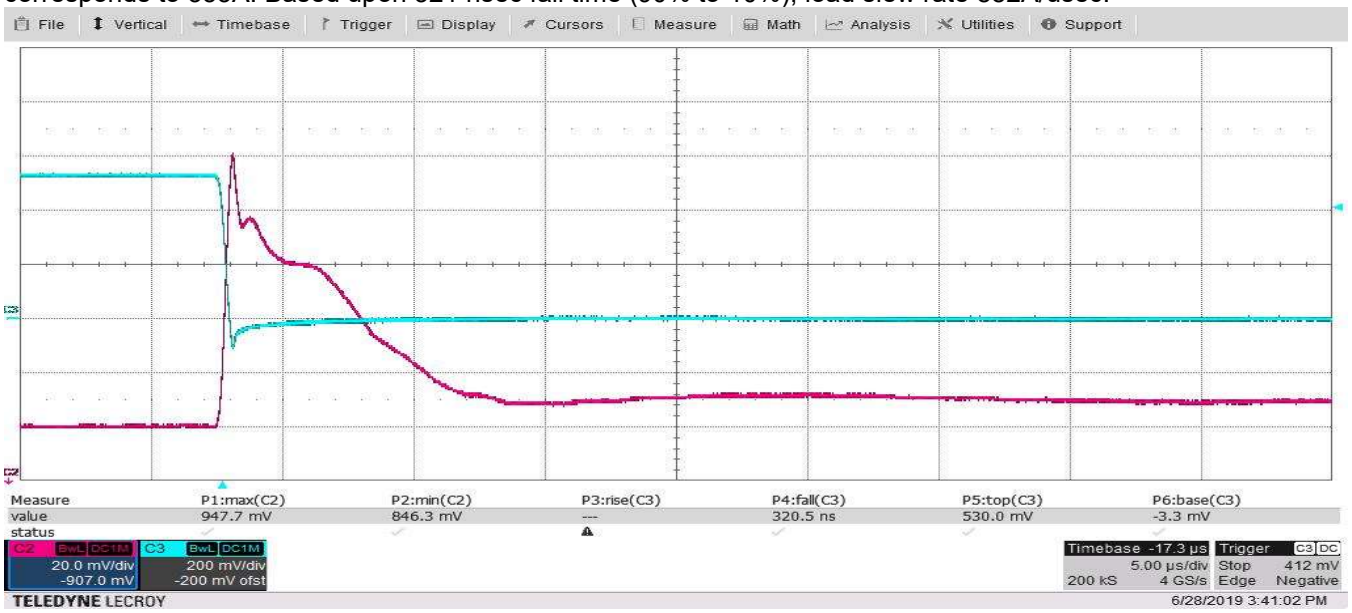
Testing with ~350A load step / dump on top of 300A static load for 650A peak

Model t2 as built with 12x 150 nH inductors and ~400 kHz per phase targeted 12Vin 300A static load and 350A dynamic load step on top of that at 50 Hz and 5% duty cycle: June 28, 2019
Step load response short term: Channel 2 red is Vout showing about 78mV peak undershoot from 856mV in response to 350A step load shown on channel 2 blue across 2x 3mOhms in parallel. Hence 527mV corresponds to 351A. Based upon 527 nsec rise time (10% to 90%); load slew rate 533A/usec.



Output settles to within 20mV of initial Vout in 9 usec.

Load dump response 353 A to 0 ADC: Channel 2 red is Vout showing about 100mV peak overshoot from 847mV in response to 353A load dump shown on channel 2 blue across 2x 3mOhms in parallel. Hence 530mV corresponds to 353A. Based upon 321 nsec fall time (90% to 10%); load slew rate 882A/usec.



Output settles to within 20mV of initial Vout in 8 usec.
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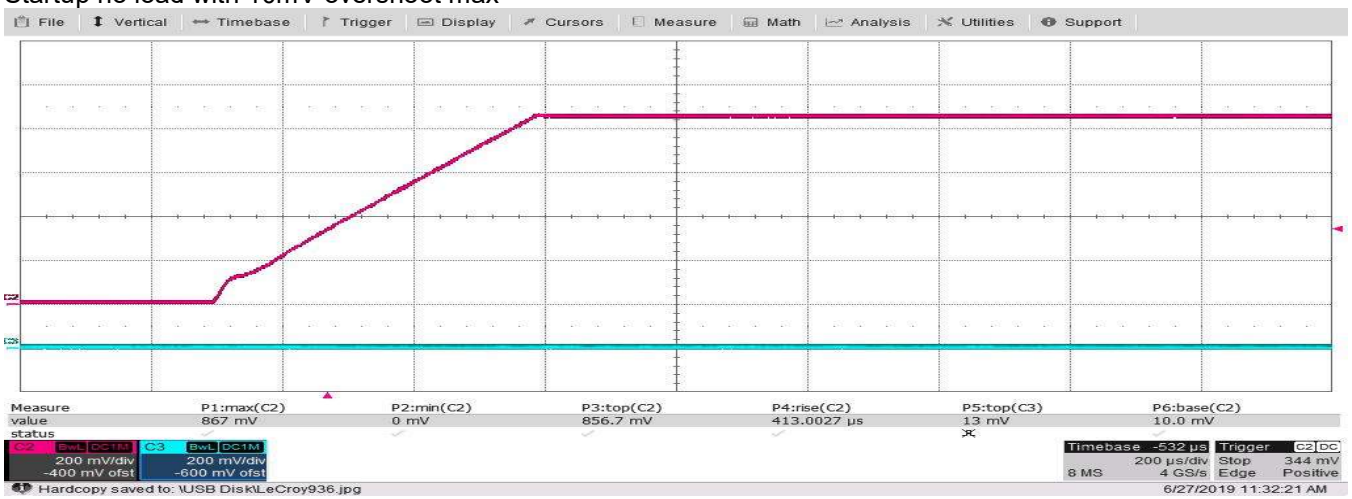
3.5

Start up from “enable”

With C20 for smoothing analog Vout adjusts in place startup is affected. Hence, C20 needs to be removed

Startup no load with 10mV overshoot max



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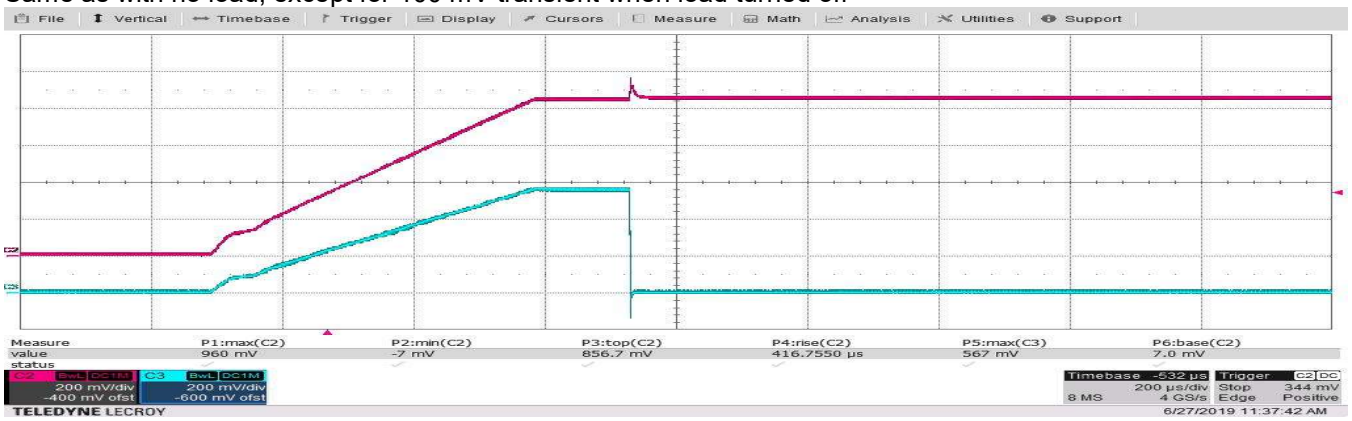
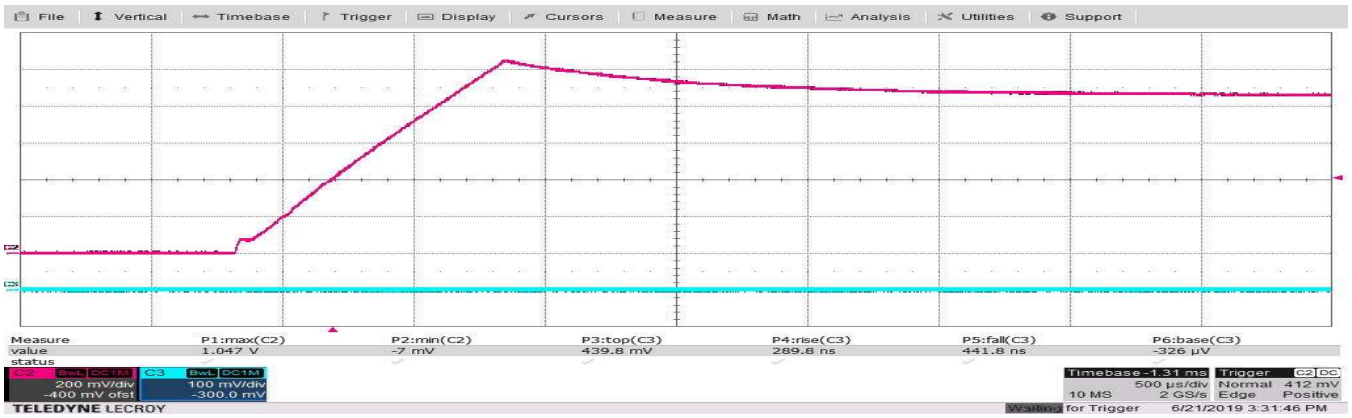
Startup with heavy pulse load with channel 3 green showing dynamic load across 1.5 mOhms for 370A max peak. Same as with no load, except for 100 mV transient when load turned off



Startup if C20 from analog Vout adjust is left on board

No load: overshoot to 1.05V and then back down to 860mV; slowing rise and / or reducing C20 from 0.47 uF should reduce this overshoot.



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