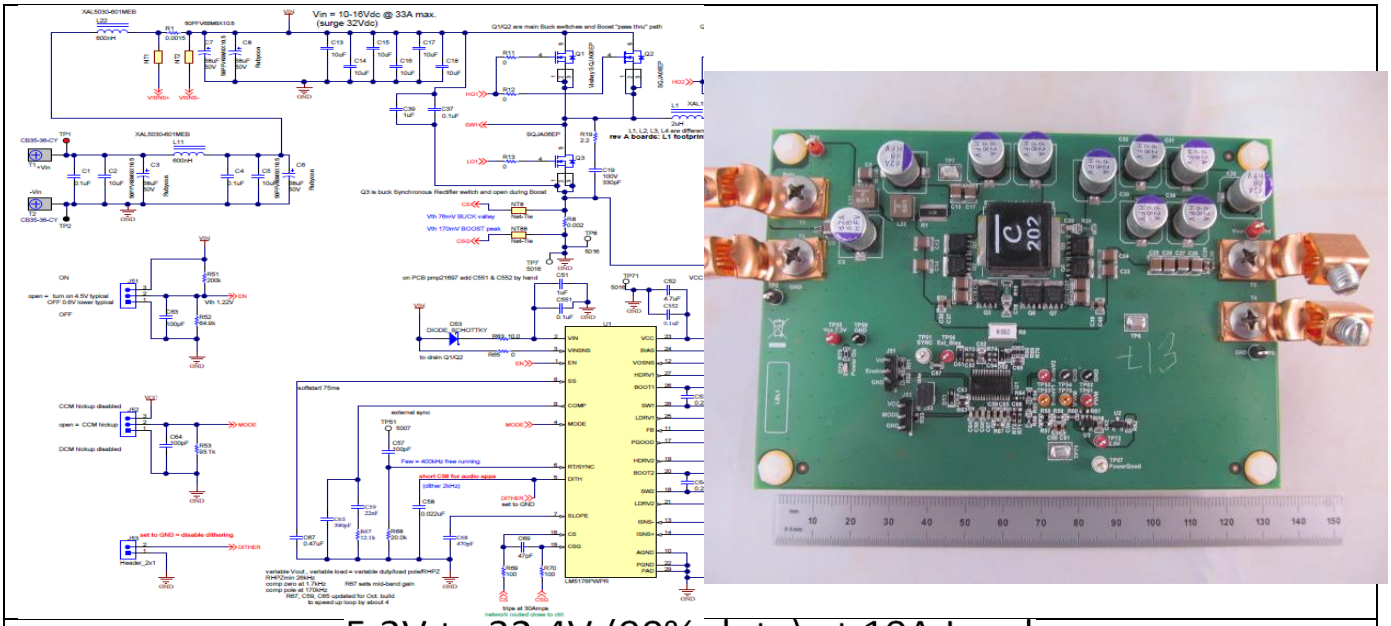
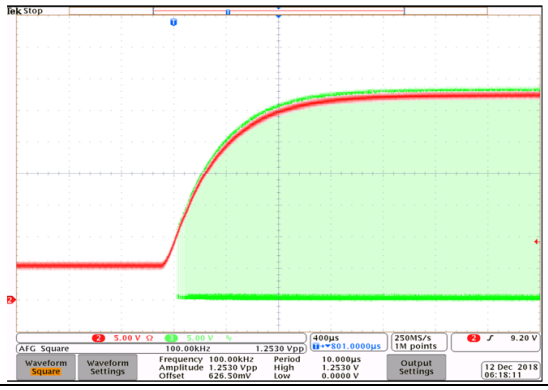
Test Report: PMP21697
Variable Voltage Power Converter 5-35 V 300 W Peak Reference Design for Automotive Audio Amplifiers

Description

This reference design provides a variable output power for audio amplifiers from 5 V to 35 V controllable by a Pulse Width Modulator signal. The output power capability of 75 W RMS and 300 W peak is suitable for high power automotive audio amplifiers. Conversion is 4-switch Buck-Boost for greater than 95% conversion efficiency. Output can be slewed over the 5 V to 35 V range with ~1 millisecond response time to maximize efficiency of the audio amplifier using this power. This design includes schematic, Bill of Materials, layout files and a test report.



5.3V to 32.4V (90% duty) at 10A Load
1.2ms, PWM @ 100kHz



1 Test Prerequisites

1.1 Voltage and Current Requirements

Table 1. Voltage and Current Requirements

PARAMETER	SPECIFICATIONS
Input Voltage	10-16 VDC
Output Voltage Range	5-35 VDC
Max Load Current	10 A
Max Output Power (electrical peak / for thermal purposes)	300W / 75W

1.2 Required Equipment

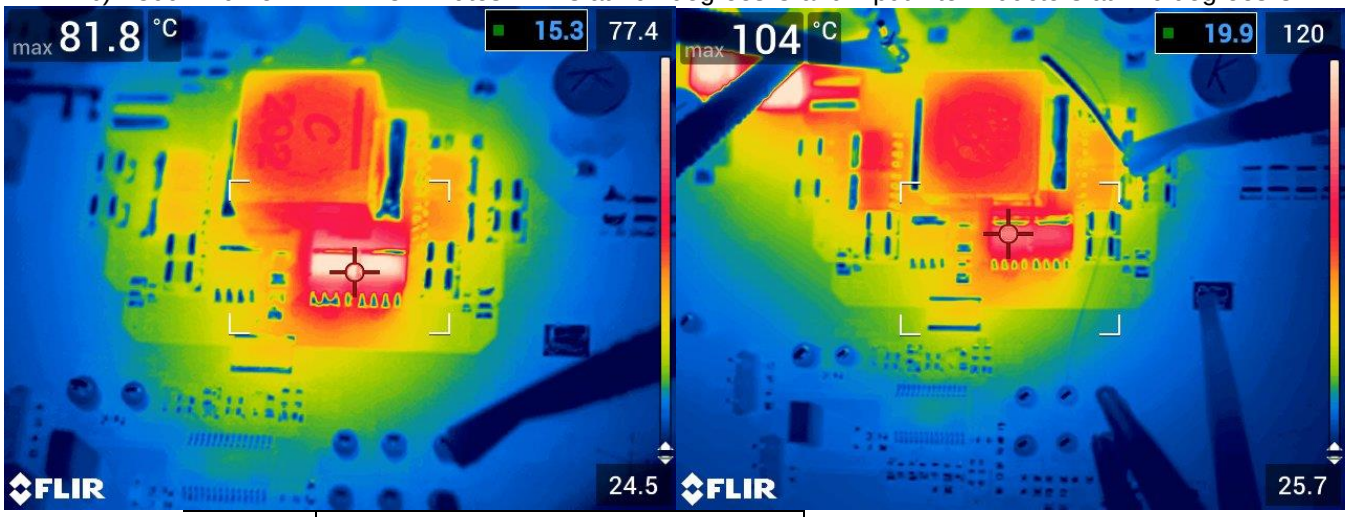
- Variable voltage source with >16 V max and at least 350 W
- Electronic load rated to at least 35 V, 10 A and 300 W
- Signal generator for Pulse Width Modulation control of Vout. Example Tektronix AFG3102
- Loop stability analyzer such as Venable 3120 or Omricon Bode100
- Thermal camera
- Oscilloscope and voltage / current meters or current shunts

1.3 Considerations

As peak output power and currents can be 4 times max steady state levels, and conduction losses follow the square of current for 16x heating; monitoring of heating on board during tests of peak power is needed to avoid destructive heating even with fan cooling. Below examples are with fan cooling.

a) run at 10Vin, 35Vout 4Aout 140W 82 degrees C max ~20 minute run

b) 300W run off 14Vin ~3 minutes: FETs at 104 degrees C and input filter inductors at 120 degrees C!!!



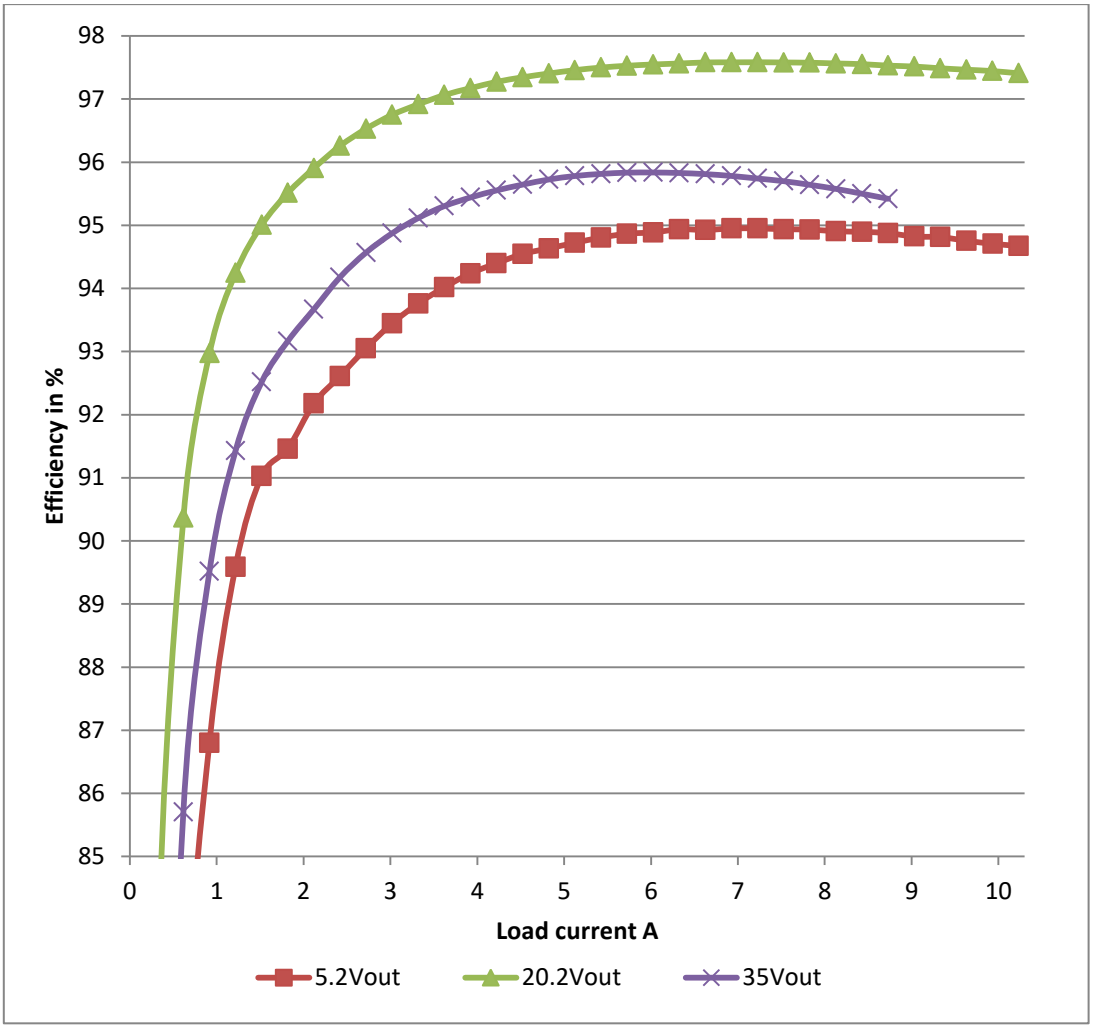
	Caution	
		Caution Hot surface. Contact may cause burns. Do not touch!

Testing was done by John Rice (sections 3.1 thru 3.4) and Josh Mandelcorn (all other sections).

2 Testing and Results

2.1 Efficiency Graph

From 14 Vin:



2.2 Efficiency Data

No airflow, 20 seconds per reading Vout set at 5.2V

Vin V	Iin A	Vout	Iout A	eff %	loss W
13.994	0.052	5.236	0.000	0.000	0.726
13.994	0.170	5.238	0.315	69.550	0.723
13.994	0.282	5.238	0.616	81.653	0.725
13.994	0.395	5.239	0.916	86.798	0.730
13.994	0.509	5.242	1.217	89.590	0.741
13.994	0.625	5.250	1.517	91.028	0.785
13.994	0.748	5.269	1.818	91.458	0.895
13.994	0.867	5.278	2.118	92.176	0.949
13.994	0.989	5.298	2.419	92.610	1.023
13.994	1.108	5.304	2.719	93.052	1.077
13.994	1.226	5.307	3.020	93.448	1.124
13.994	1.343	5.308	3.320	93.762	1.173
13.994	1.462	5.311	3.621	94.018	1.223
13.994	1.580	5.313	3.921	94.239	1.274
13.994	1.699	5.315	4.222	94.399	1.332
13.994	1.818	5.317	4.523	94.547	1.387
13.994	1.937	5.318	4.823	94.634	1.454
13.994	2.056	5.318	5.124	94.723	1.518
13.994	2.175	5.320	5.424	94.806	1.581
13.994	2.294	5.321	5.725	94.867	1.648
13.994	2.414	5.320	6.025	94.888	1.727
13.994	2.534	5.321	6.326	94.937	1.795
13.994	2.654	5.321	6.627	94.927	1.884
13.994	2.775	5.323	6.927	94.950	1.961
13.994	2.896	5.324	7.228	94.952	2.046
13.994	3.016	5.323	7.528	94.937	2.137
13.994	3.137	5.324	7.829	94.933	2.225
13.994	3.259	5.325	8.129	94.906	2.323
13.994	3.380	5.324	8.430	94.897	2.414
13.994	3.502	5.325	8.731	94.875	2.511
13.994	3.623	5.324	9.031	94.823	2.625
13.994	3.745	5.325	9.331	94.813	2.718
13.994	3.867	5.324	9.632	94.756	2.838
13.994	3.991	5.325	9.933	94.707	2.956
13.994	4.113	5.325	10.234	94.674	3.066

2.2 Efficiency data continued

No airflow, 20 seconds per reading Vout set at 20.2V

Vin V	Iin A	Vout	Iout A	eff %	loss W
13.994	0.094	20.242	0.000	0.000	1.316
13.994	0.557	20.253	0.318	82.469	1.368
13.994	0.991	20.287	0.618	90.370	1.336
13.994	1.433	20.295	0.919	92.977	1.408
13.994	1.875	20.294	1.219	94.249	1.509
13.994	2.319	20.293	1.519	95.006	1.620
13.994	2.762	20.293	1.819	95.513	1.734
13.994	3.204	20.291	2.119	95.906	1.836
13.994	3.645	20.290	2.420	96.258	1.909
13.994	4.087	20.292	2.720	96.530	1.984
13.994	4.528	20.292	3.021	96.751	2.058
13.994	4.969	20.290	3.321	96.917	2.144
13.994	5.410	20.289	3.622	97.064	2.223
13.994	5.851	20.287	3.922	97.173	2.315
13.994	6.293	20.286	4.222	97.273	2.402
13.994	6.735	20.285	4.523	97.346	2.502
13.994	7.177	20.282	4.823	97.405	2.606
13.994	7.619	20.280	5.124	97.459	2.710
13.994	8.062	20.279	5.424	97.500	2.821
13.994	8.505	20.278	5.725	97.529	2.942
13.994	8.949	20.276	6.025	97.549	3.070
13.994	9.394	20.274	6.326	97.564	3.202
13.994	9.839	20.274	6.626	97.581	3.331
13.994	10.284	20.273	6.927	97.582	3.479
13.994	10.729	20.273	7.227	97.584	3.628
13.994	11.175	20.272	7.528	97.580	3.784
13.994	11.622	20.272	7.828	97.576	3.941
13.994	12.069	20.271	8.129	97.565	4.113
13.994	12.517	20.272	8.430	97.554	4.285
13.994	12.966	20.271	8.730	97.530	4.481
13.994	13.415	20.272	9.030	97.516	4.663
13.994	13.864	20.271	9.331	97.488	4.874
13.994	14.316	20.273	9.631	97.466	5.077
13.994	14.765	20.273	9.932	97.444	5.281
13.994	15.217	20.272	10.232	97.408	5.519

Q

2.2 Efficiency data continued

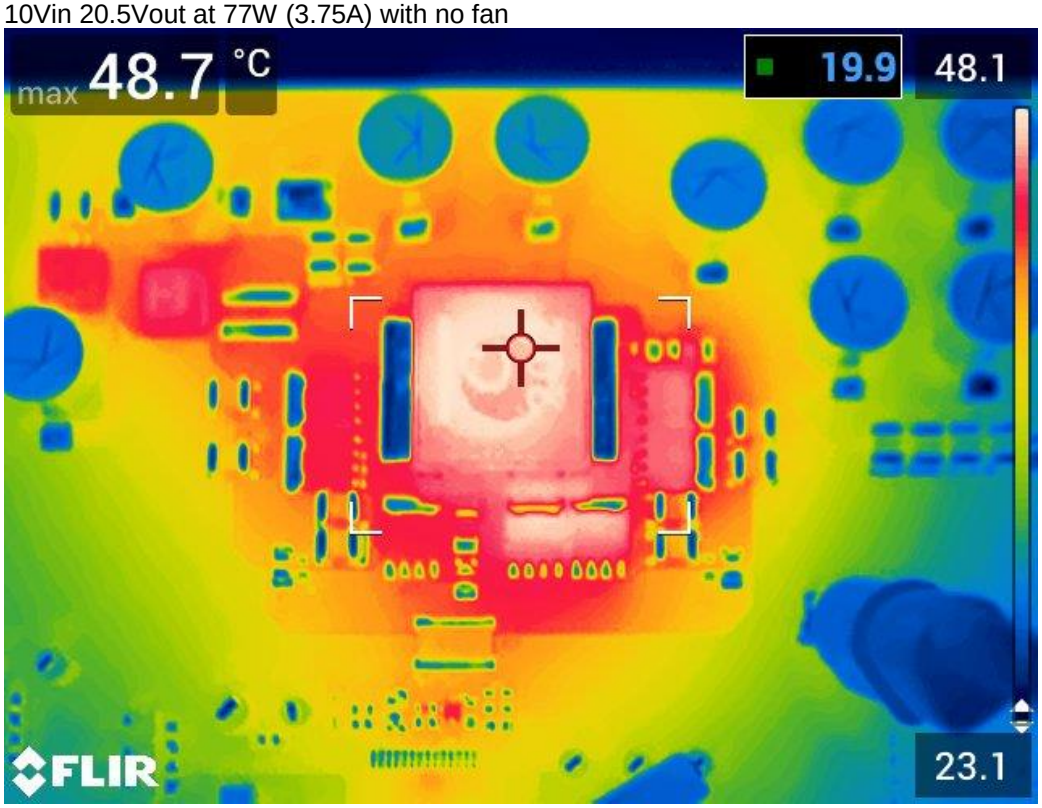
No airflow up to 148W, fans on up to 300W; 20 seconds per reading Vout set at 35V

Vin V	Iin A	Vout	Iout A	eff %	loss W
13.994	0.265	34.947	0.000	0.000	3.707
13.994	1.069	34.986	0.316	74.006	3.887
13.994	1.802	35.031	0.617	85.704	3.604
13.994	2.565	35.030	0.917	89.517	3.764
13.994	3.334	35.030	1.218	91.430	3.998
13.994	4.107	35.028	1.518	92.518	4.300
13.994	4.885	35.025	1.818	93.164	4.673
13.994	5.660	35.019	2.119	93.670	5.014
13.994	6.427	35.016	2.419	94.177	5.238
13.994	7.195	35.011	2.720	94.568	5.469
13.994	7.964	35.008	3.020	94.874	5.713
13.994	8.733	35.006	3.321	95.116	5.969
13.994	9.504	35.004	3.621	95.305	6.245
13.994	10.277	35.003	3.921	95.441	6.556
13.994	11.052	35.004	4.222	95.553	6.878
13.994	11.826	35.000	4.523	95.645	7.207
13.994	12.599	34.993	4.823	95.726	7.535
13.994	13.376	34.989	5.124	95.781	7.897
13.994	14.154	34.988	5.424	95.815	8.290
13.994	14.935	34.987	5.725	95.834	8.706
13.994	15.718	34.988	6.025	95.837	9.156
13.994	16.505	34.990	6.326	95.829	9.633
13.994	17.294	34.991	6.627	95.811	10.137
13.994	18.085	34.993	6.927	95.782	10.675
13.994	18.877	34.995	7.227	95.741	11.251
13.994	19.674	35.000	7.528	95.699	11.840
13.994	20.473	35.004	7.828	95.642	12.486
13.994	21.276	35.008	8.129	95.577	13.168
13.994	22.084	35.012	8.429	95.501	13.905
13.994	22.894	35.018	8.730	95.420	14.672

Q

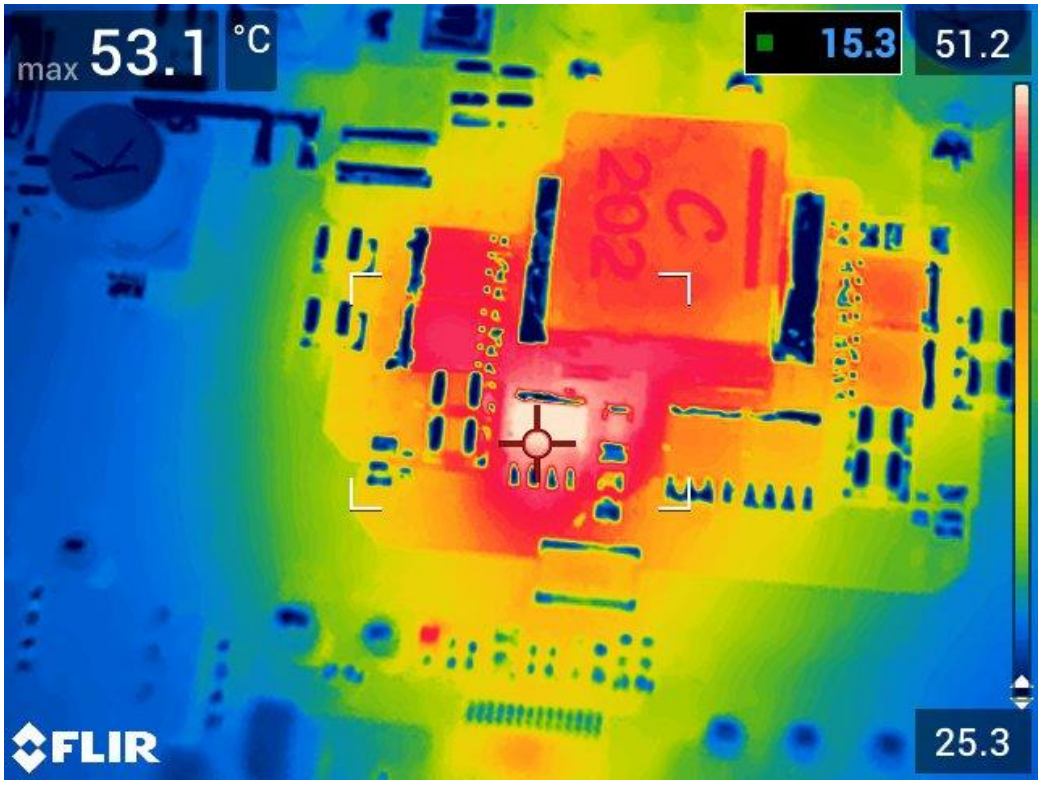
2.3 Thermal Image

10Vin 20.5Vout at 77W (3.75A) with no fan



Q

16Vin 5Vout 10A no fan

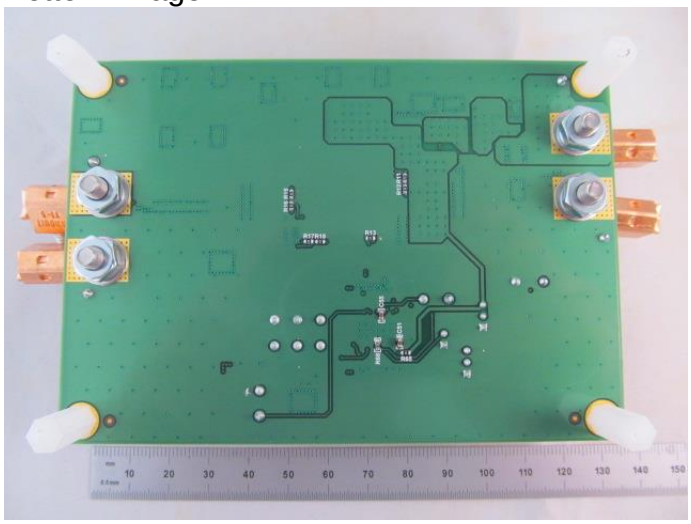


2.4 Dimensions

5 inches by 4 inches

Top image

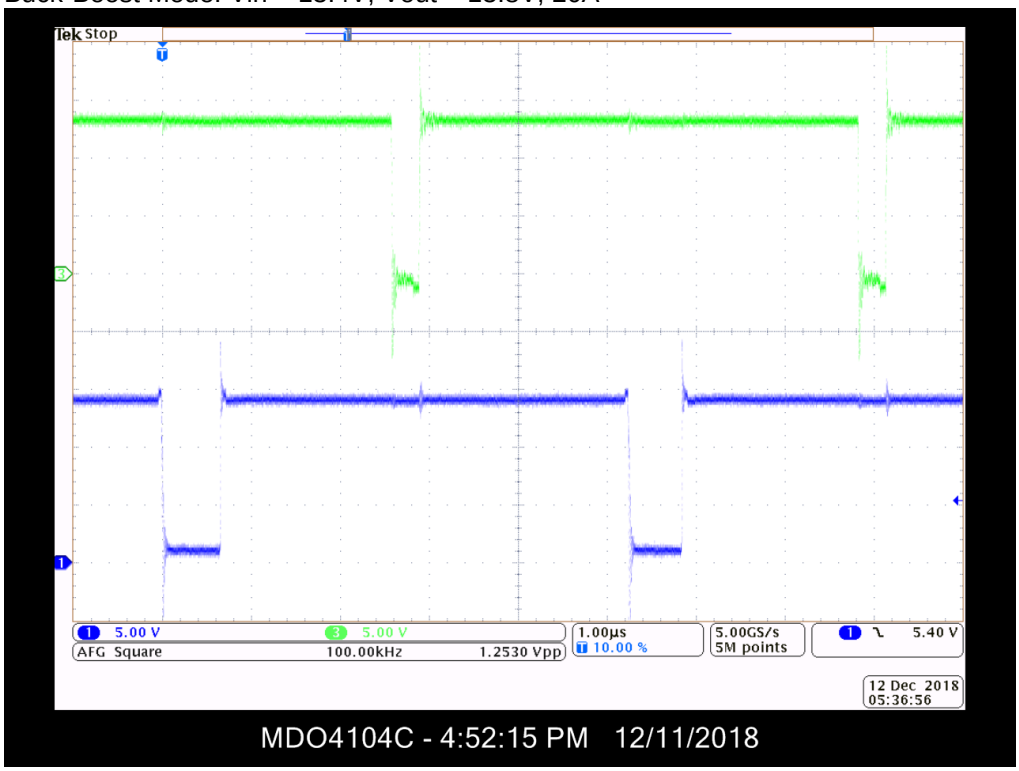
Bottom Image



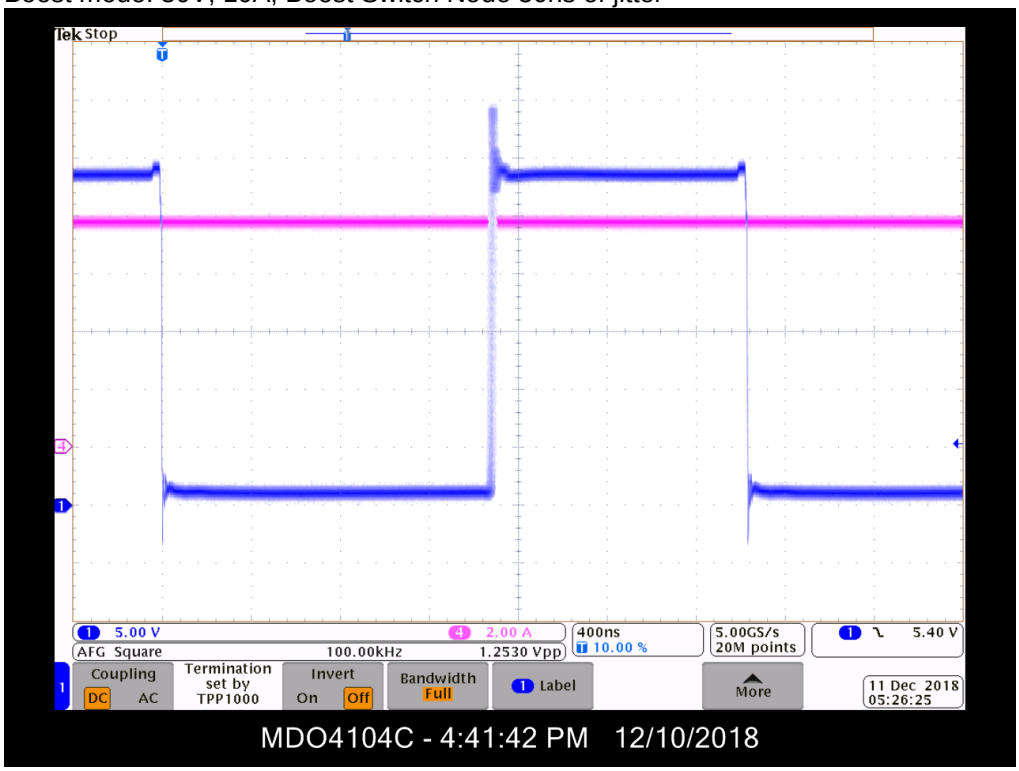
3 Waveforms

3.1 Switching

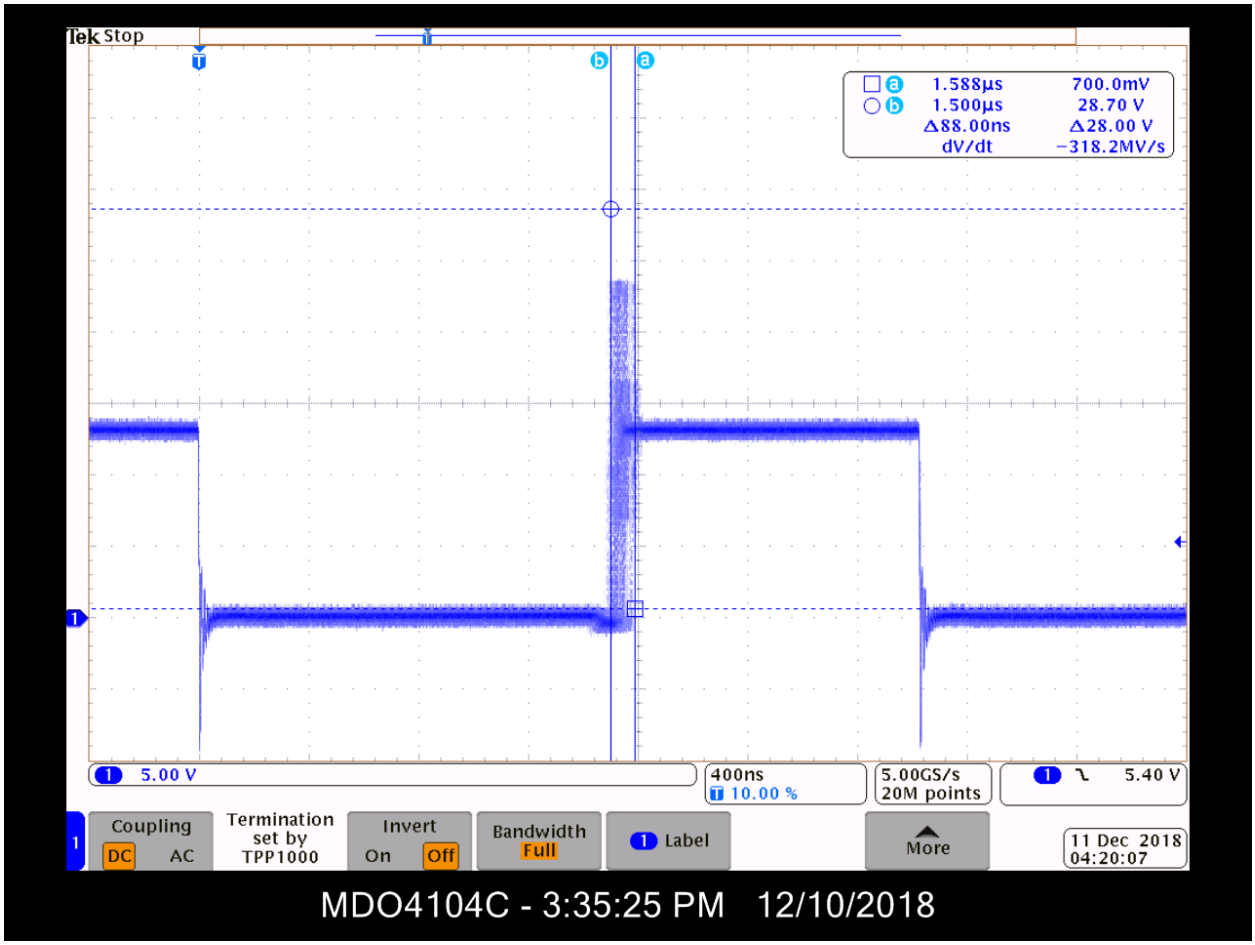
Buck-Boost Mode: Vin = 13.4V, Vout = 13.8V, 20A



Boost mode: 30V, 10A, Boost Switch Node 30ns of jitter



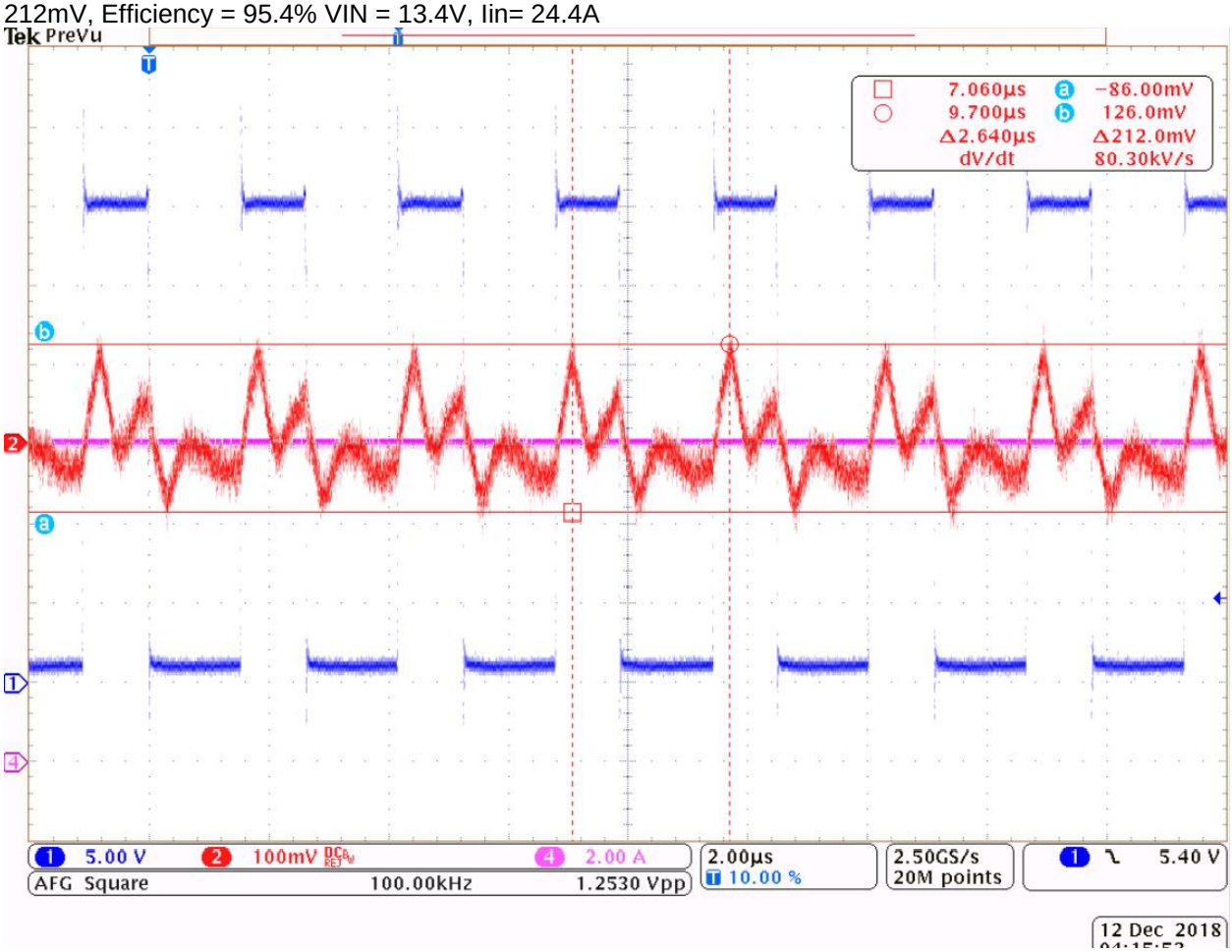
(3.1 switching waveforms continued)
Buck Mode: Switch Node Jitter14Vin: 5.33V/20A/99C SYNC FET



3.2 Output Voltage Ripple

Output Ripple at 31.2V/10A

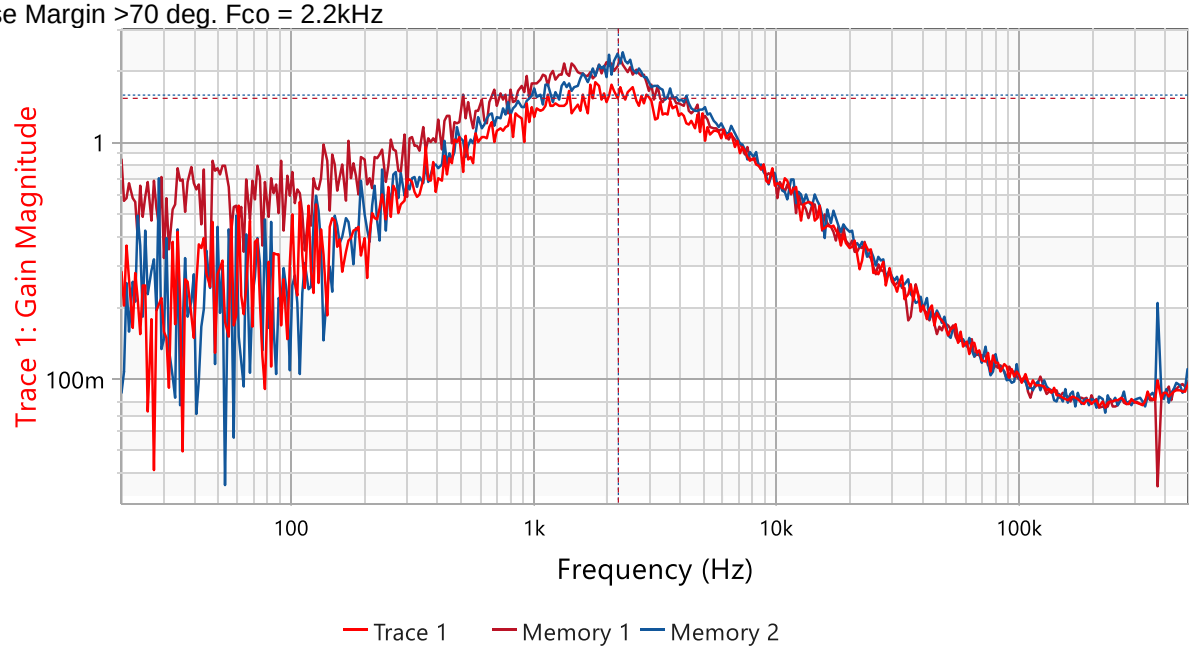
212mV, Efficiency = 95.4% VIN = 13.4V, Iin= 24.4A



3.3 Bode Plot

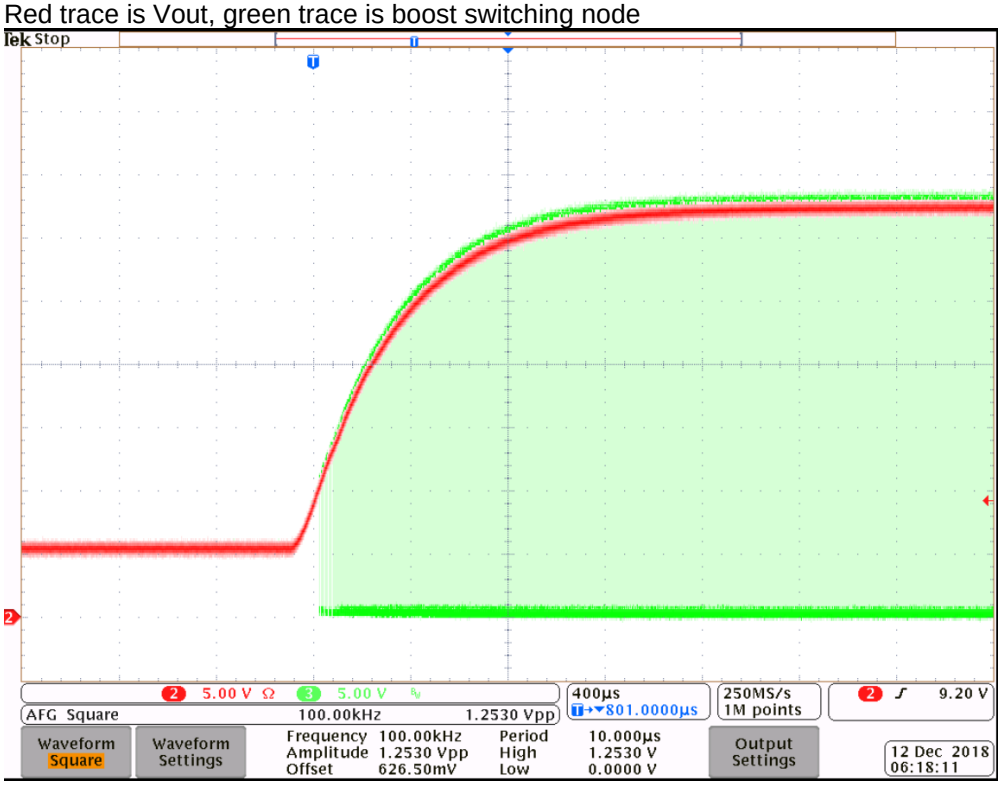
30V, 10A, 5A, 3A

Phase Margin >70 deg. Fco = 2.2kHz

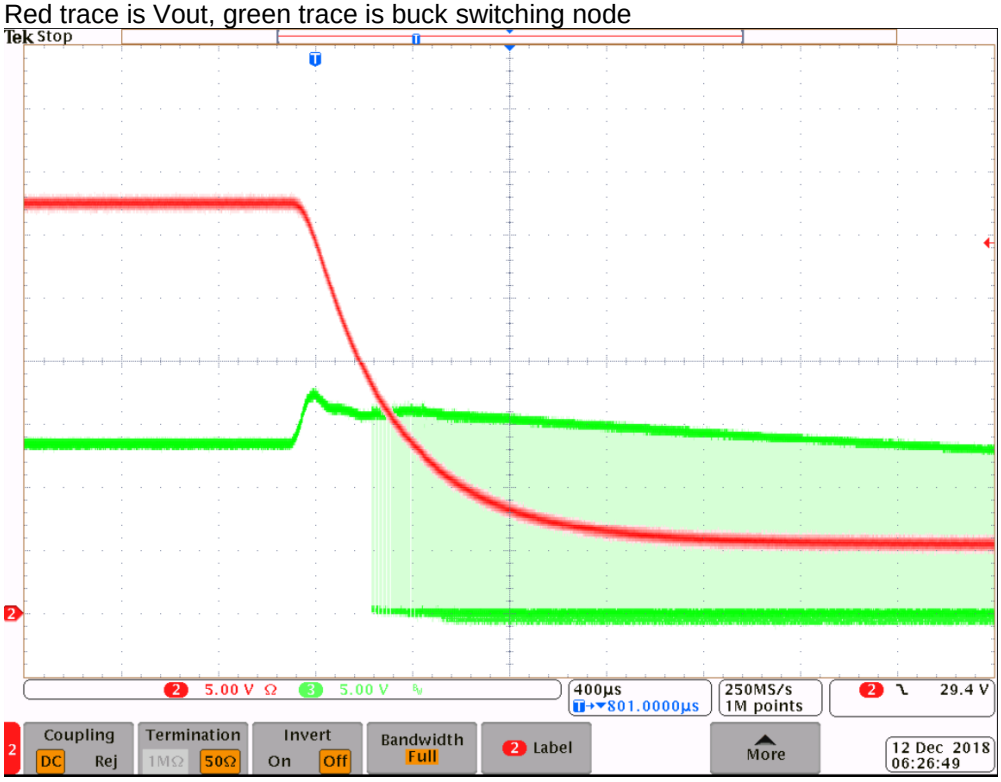


3.4 Dynamic Response

5.3V to 32.4V (90% duty) at 10A Load 1.2ms, PWM @ 100kHz
Red trace is Vout, green trace is boost switching node

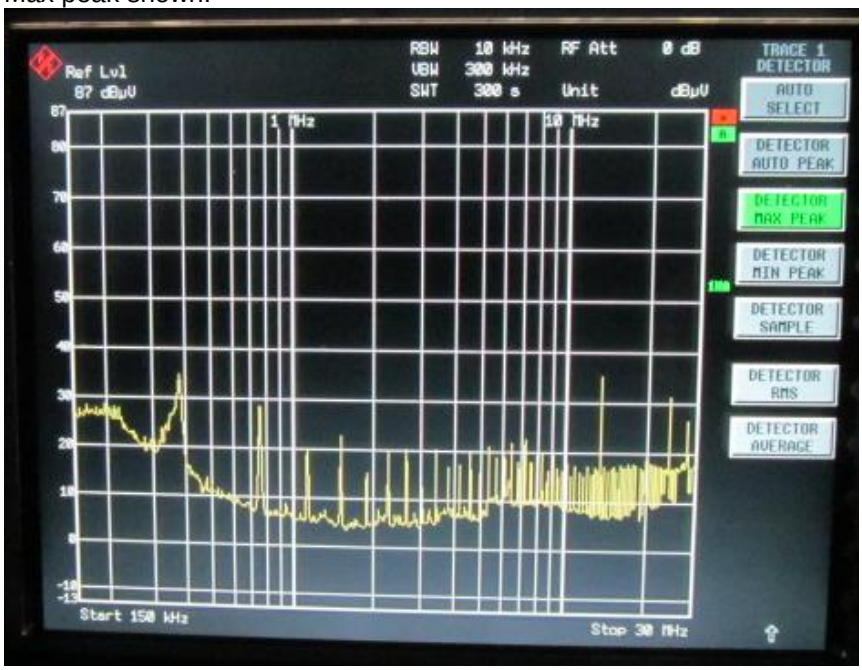


32.4V to 5.2V PWM @ 100kHZ
Red trace is Vout, green trace is buck switching node



3.5 Conducted Emissions

Tested in 150kHz to 30MHz range with 13.6Vin and loaded:
Buck mode: 5V 5A – Class 5 (CISPR 25)
Max peak shown:



Boost mode: 35Vin 77W ~Class 4
Max peak shown

Above 30 MHz will need to be evaluated in actual or representative enclosure.

3.6 Alternator Noise Study page 1 of 5

PMP21697 source immunity testing to simulate car alternator noise / pulses at 1 kHz and 2kHz:

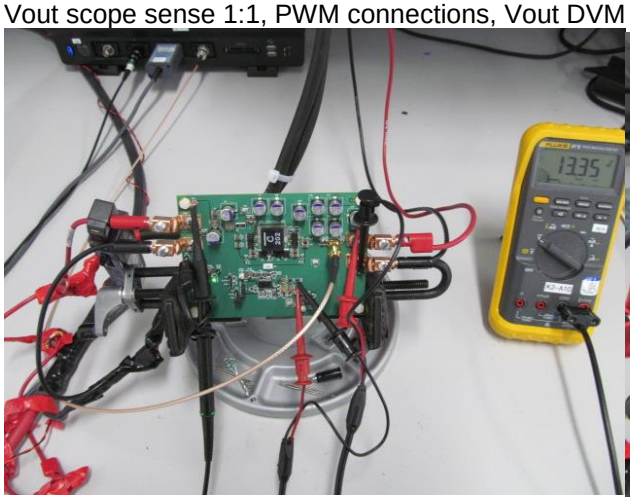
Lab source HP6032 set at 13.5Vout (30A current limit) with 10uH in series with positive output (except where shorted out) feeding PMP21697 model t11 at “battery input”. PMP21697 output loaded with 4A load and tested with Vout set to 5.35V (PWM duty at zero) for buck mode case; to 13.35V (PWM duty at 26%) for LM5176 to have both buck and boost sides active; and to 22.1V (PWM duty at 55%) for boost mode.

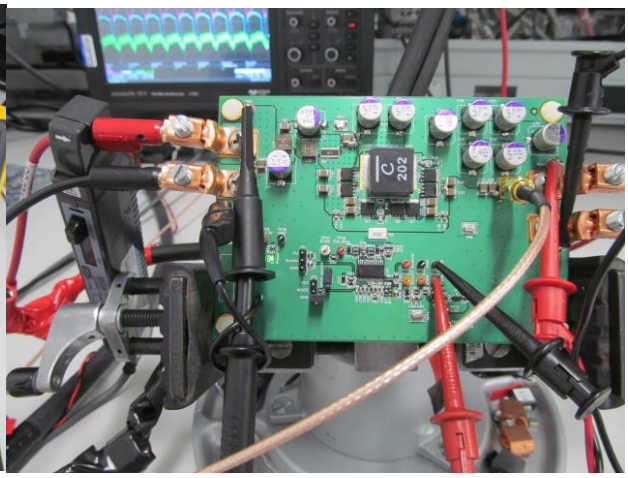
To simulate alternator noise, a Kikisui PLZ334 electronic load was connected across main PMP21697 input with constant current pulsed load at 20% duty cycle and rep rate of 1 kHz and 2 kHz. For the 2 kHz tests, a pulsed load of 4.0A at 20% duty was used (or 0.8A average) to induce alternator type ripple on the battery input of the PMP21697. The 10 uH inductor served to block these pulses from the lab source and force them into the PMP21697.

For the 1 kHz and with Vout at 5V, I used 2A, also at 20% duty for 0.4A average. But when I went to 13.35Vout and 22.1Vout, an input resonance occurred that destabilized the lab source. For the 13.35Vout case I was able to reduce the pulses to 1.3A and get the lab source stable. But for the 22.1Vout case, I had to remove the series inductor to avoid the lab source from going unstable. Here, I used a larger 5A pulse to get a reasonable input ripple voltage.

In all cases I monitored on the scope: Channel 2 red for input voltage directly to the PMP21697; channel 3 blue the input current to PMP21697 at battery plus; and channel 4 yellow the output voltage for 1 or 2kHz ripple out due to 1or 2kHz ripple in.

A rough attenuation was calculated based upon 20 time log base 10 of peak to peak input ripple divided by peak to peak output ripple, in which for both input and output the switching frequency ripple is ignored. Model t3 under test and model closeup: showing Input current probe & input power connections, Vin scope sense, Vout scope sense 1:1, PWM connections, Vout DVM & connections



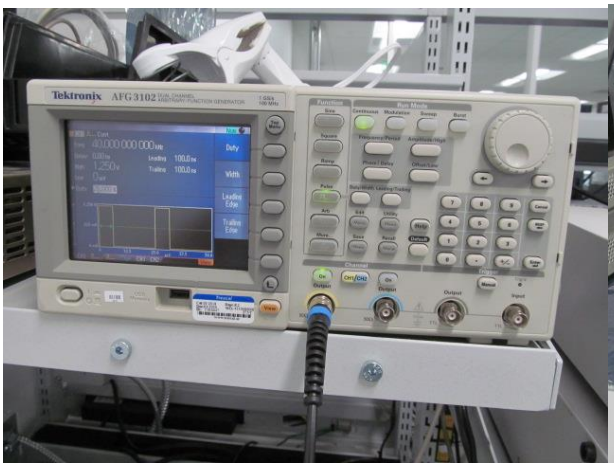


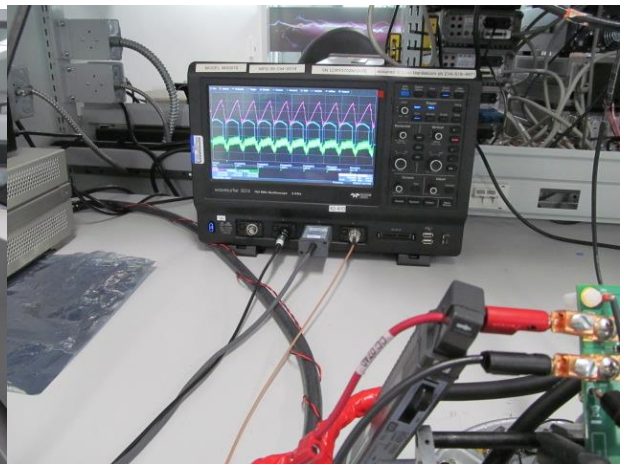
Q

(3.6 Alternator Noise Study page 2 of 5)

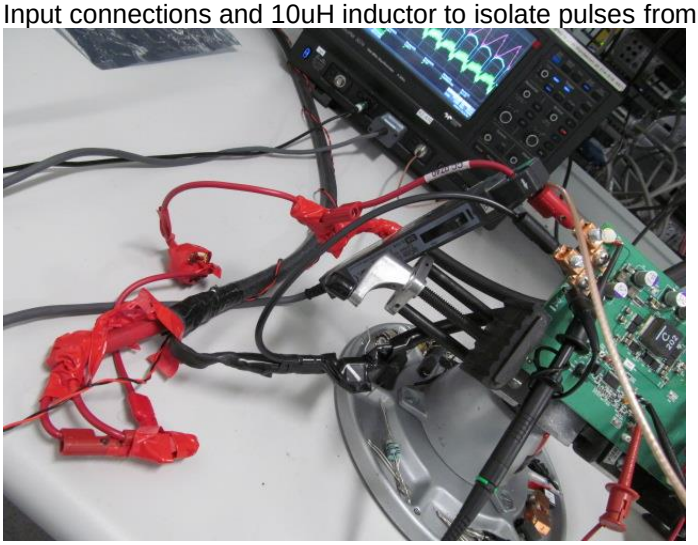
More setup pictures: Kikisui PLZ334 (above) for pulses; PLZ664WA for 4A DC load (below)

PWM generator : AFG3102 Tektronix scope LeCroy WS3074





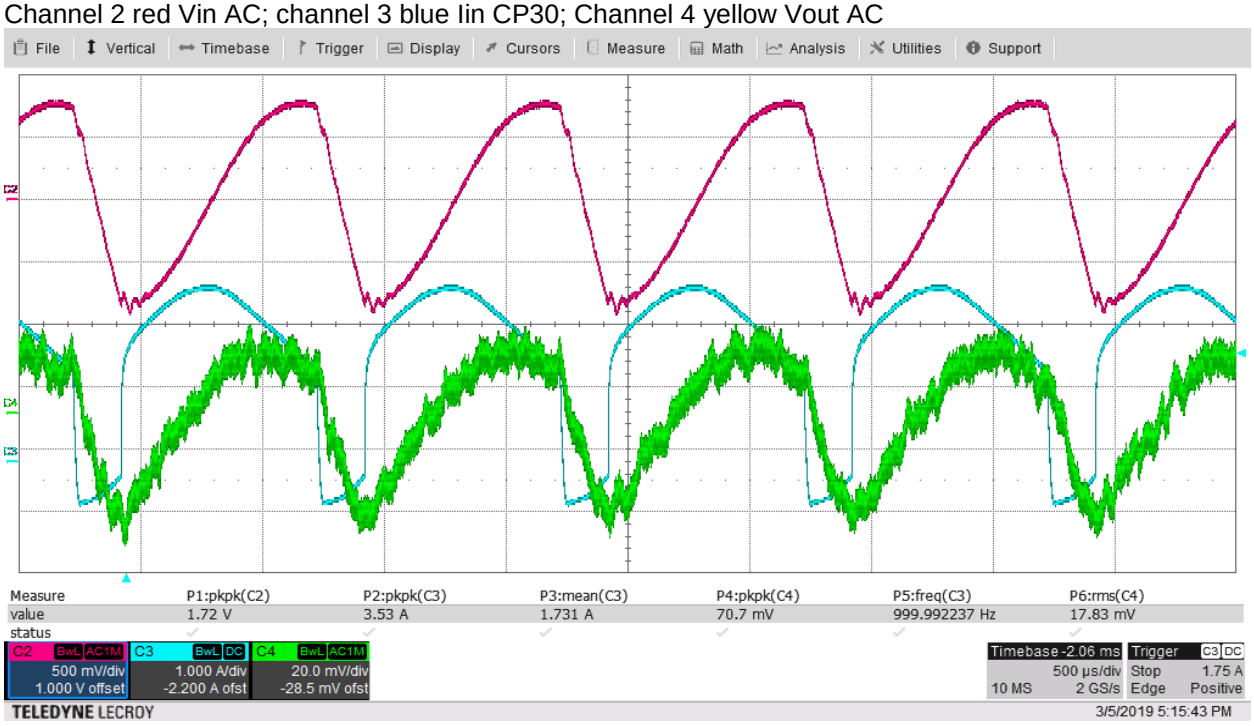
Input connections and 10uH inductor to isolate pulses from source



(3.6 Alternator Noise Study page 3 of 5)

5.35Vout at 4.0A 13.5Vin with 10uH inductor 1 kHz 2A 20% duty pulses Buck mode

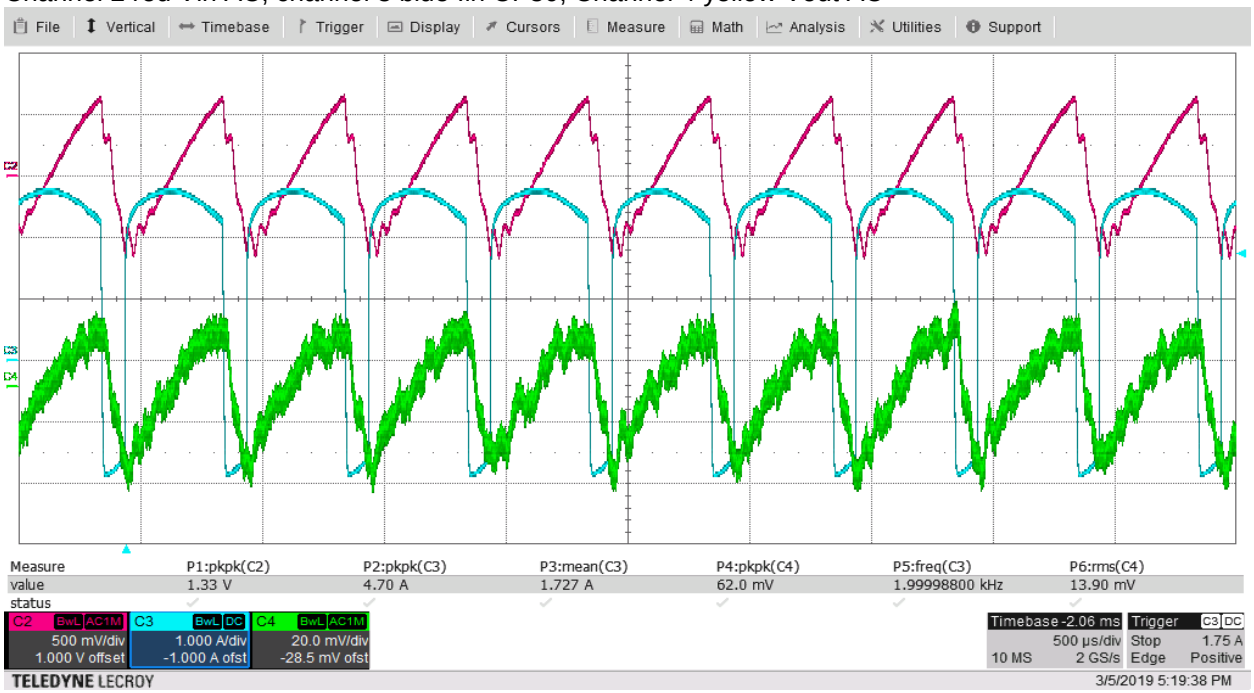
Channel 2 red Vin AC; channel 3 blue Iin CP30; Channel 4 yellow Vout AC



Input ripple 1kHz 1.7Vp-p output 1 kHz ripple (not including switching frequency ripple) 60mVp-p or 29dB attenuation

5.35Vout at 4.0A 13.5Vin with 10uH inductor 2 kHz 4A 20% duty pulses

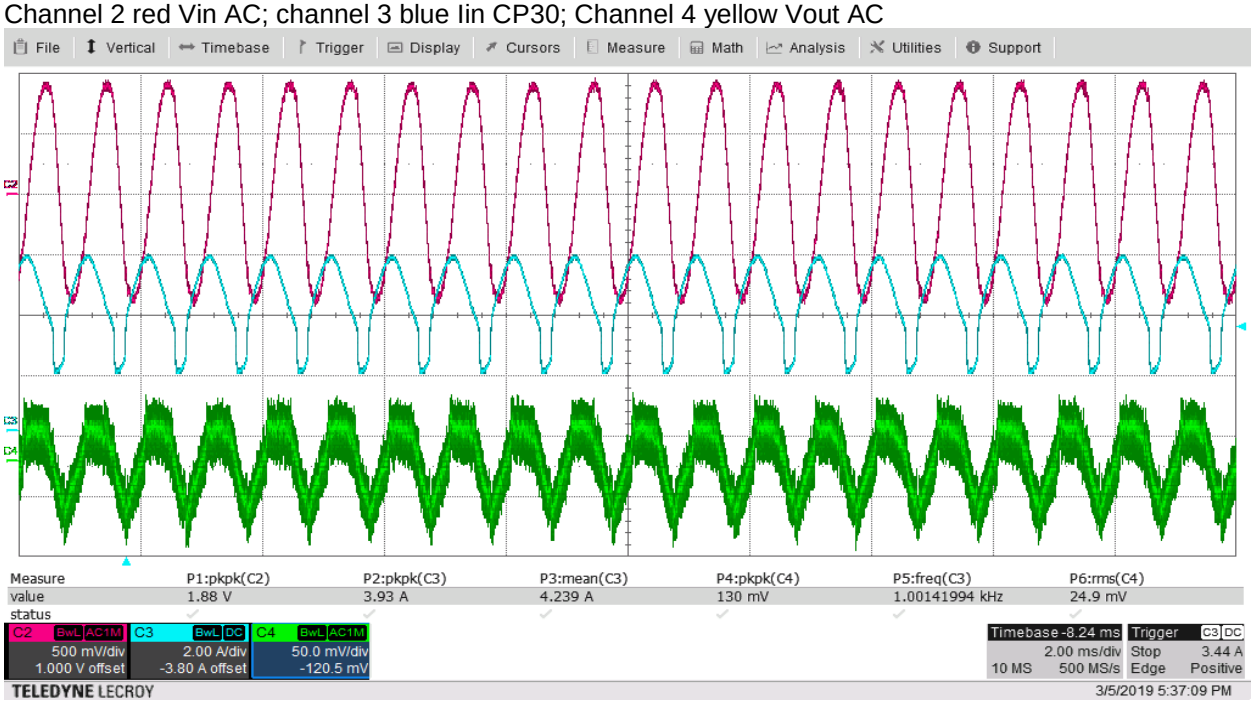
Channel 2 red Vin AC; channel 3 blue Iin CP30; Channel 4 yellow Vout AC



Input ripple 2kHz 1.25Vp-p output 2 kHz ripple (not including switching frequency ripple) 45mVp-p or 29dB attenuation

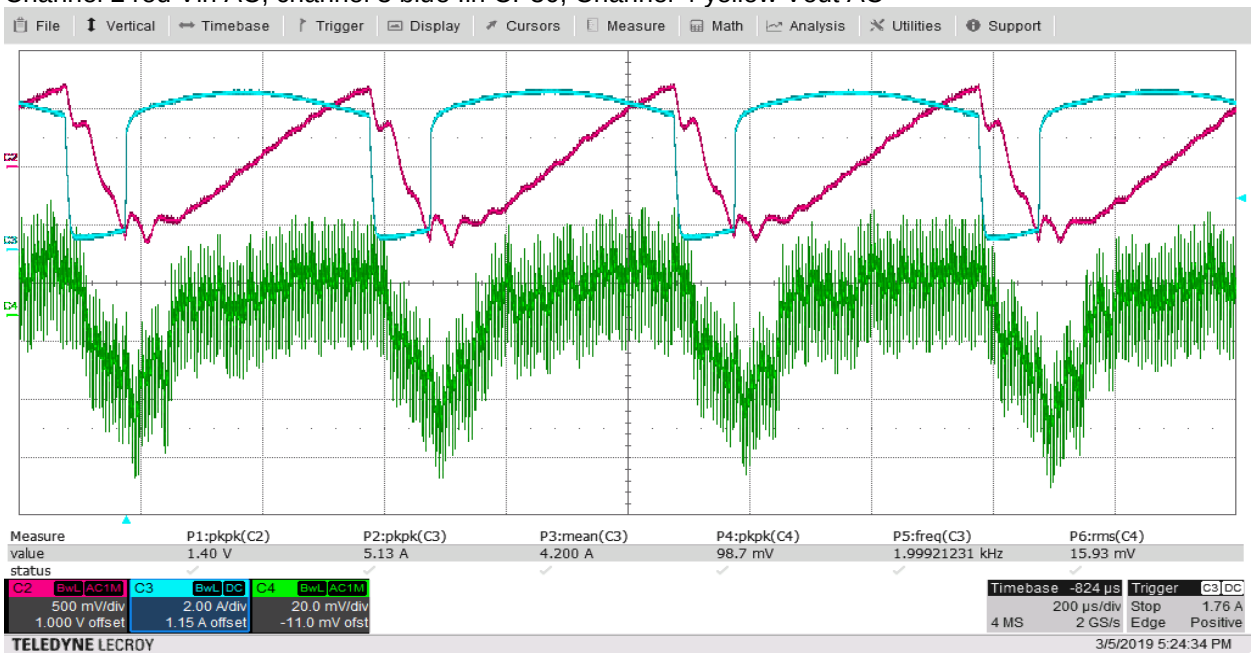
(3.6 Alternator Noise Study page 4 of 5)

13.35Vout at 4.0A 13.5Vin with 10uH inductor 1 kHz 1.3A 20% duty pulses
Buck-Boost mode
Channel 2 red Vin AC; channel 3 blue Iin CP30; Channel 4 yellow Vout AC



Input ripple 1kHz 1.8Vp-p output 1 kHz ripple (not including switching frequency ripple) 80mVp-p or 27dB attenuation

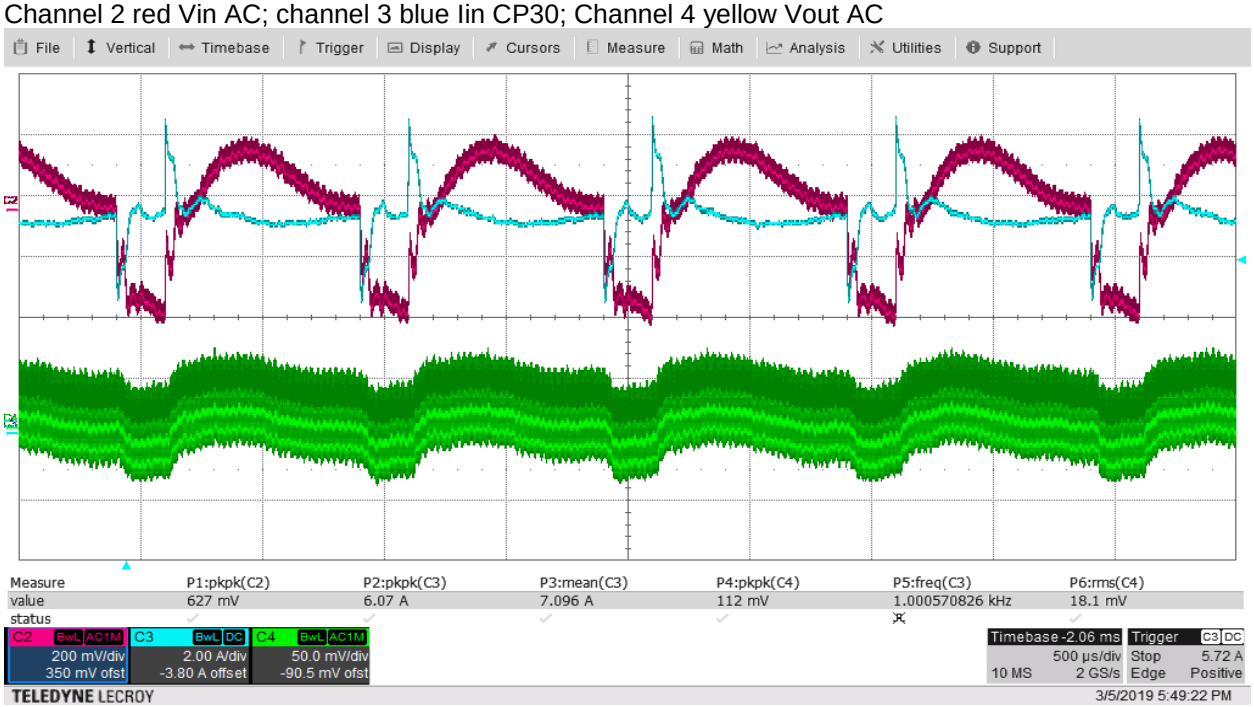
13.35Vout at 4.0A 13.5Vin with 10uH inductor 2 kHz 4A 20% duty pulses
Channel 2 red Vin AC; channel 3 blue Iin CP30; Channel 4 yellow Vout AC



Input ripple 2kHz 1.2Vp-p output 2 kHz ripple (not including switching frequency ripple) 55mVp-p or 27dB attenuation

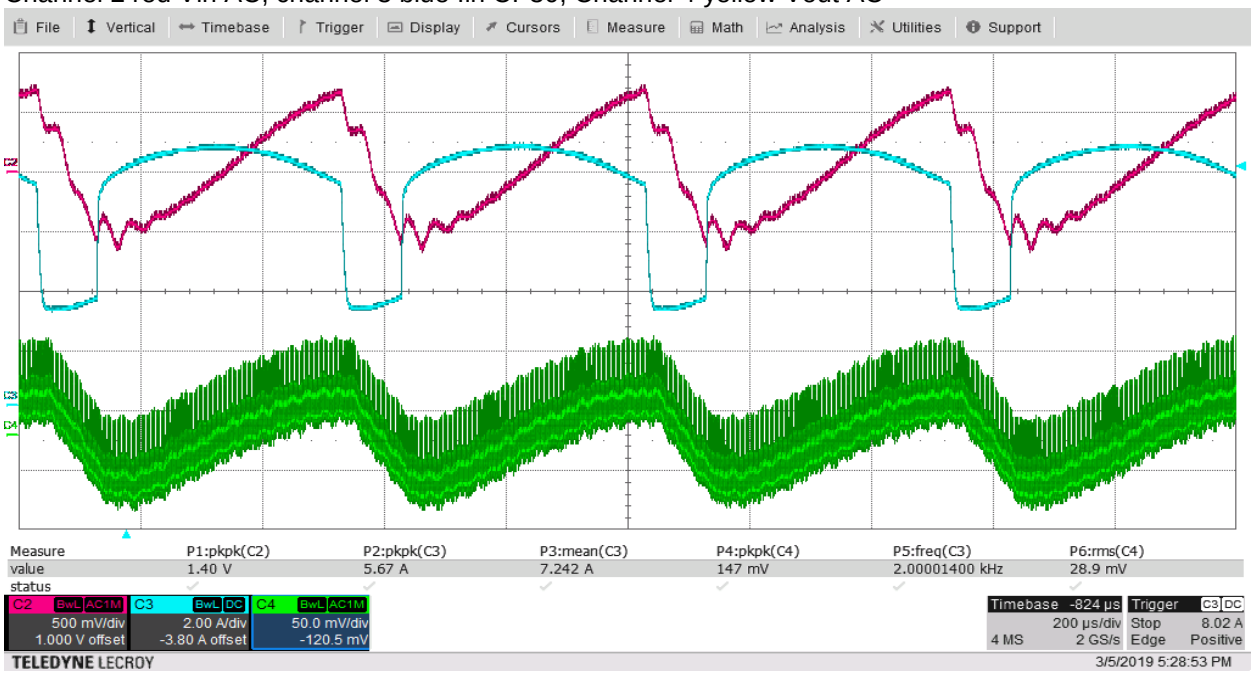
(3.6 Alternator Noise Study page 5 of 5)

22.1Vout at 4.0A 13.5Vin **without** 10uH inductor 1 kHz 5A 20% duty pulses
Boost mode
Channel 2 red Vin AC; channel 3 blue Iin CP30; Channel 4 yellow Vout AC



Input ripple 1kHz 530mVp-p output 1 kHz ripple (not including switching frequency ripple) 35mVp-p or 24dB attenuation

22.1Vout at 4.0A 13.5Vin with 10uH inductor 2 kHz 4A 20% duty pulses
Channel 2 red Vin AC; channel 3 blue Iin CP30; Channel 4 yellow Vout AC



Input ripple 2kHz 1.25Vp-p output 2 kHz ripple (not including switching frequency ripple) 70mVp-p or 25dB attenuation

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