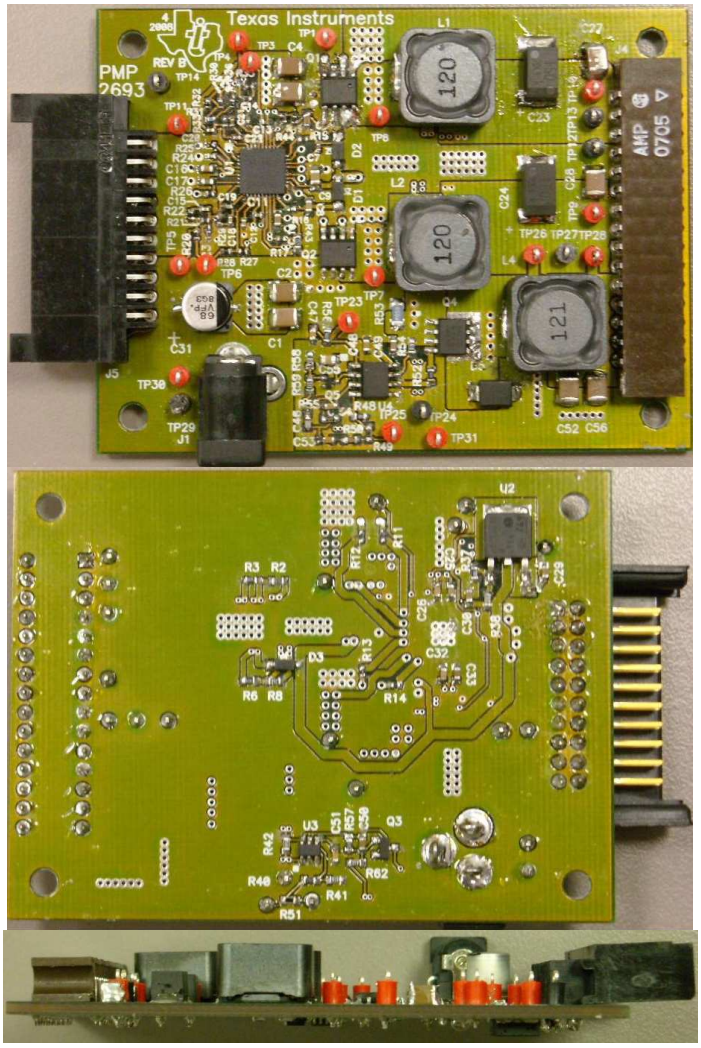
Introduction

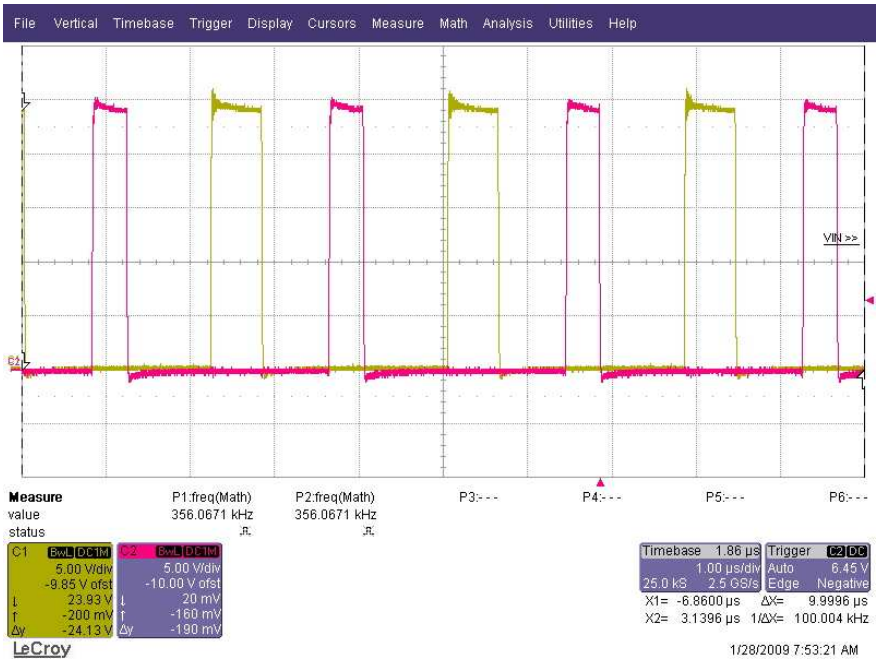
The converter board has been developed for a Spoerle (Arrow) embedded DC/DC platform. Therefore the mechanical and electrical specification are intended to satisfy or improve the request. Signals for Power Good and Enable are available to enable sequencing, voltage scaling, diagnosis.
It operates from DC 24V +/- 15% with three Buck topology to three different ouputs:
- 12V@1A, Buck controlled by TPS40200 (current limitation 2A)
- 5V@5A, Synch-Buck controlled by TPS40140 together with the 3.3V ouput (requested is 2A, actual current limitation 5.7A);
- 3.3V@5A, Synch-Buck controlled by TPS40140 together with the 5V ouput (requested is 2A, actual current limitation 5.7A)

Fot the 12V output (TPS40200) the switching frequency is 280kHz, for the other two outputs (TPS40140) the switching frequency is 350kHz.
Full MatchCad sheet of the three converters are also provided with complete calculation of power stage and control.

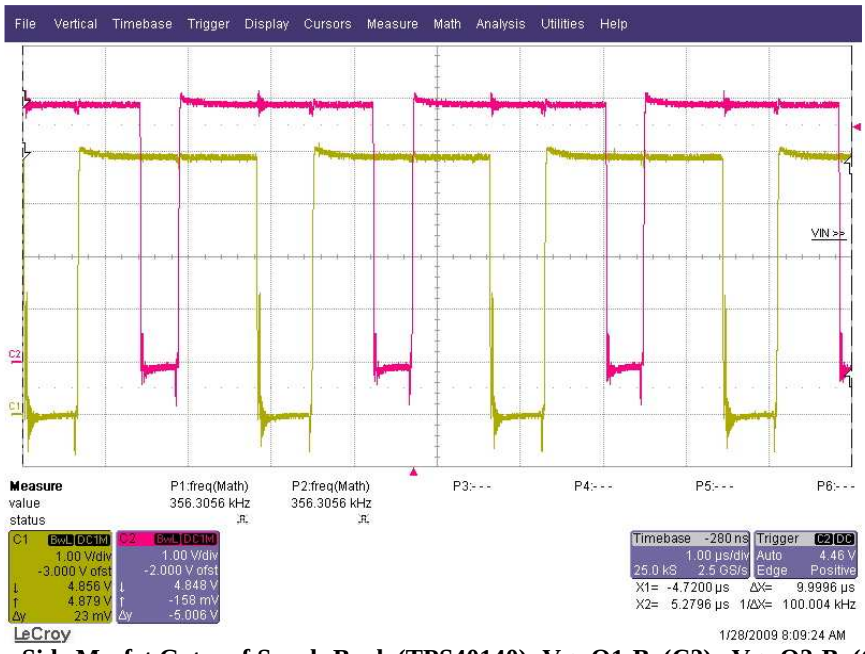
In the following the pictures (Top, Bottom, Side) of the realized board.



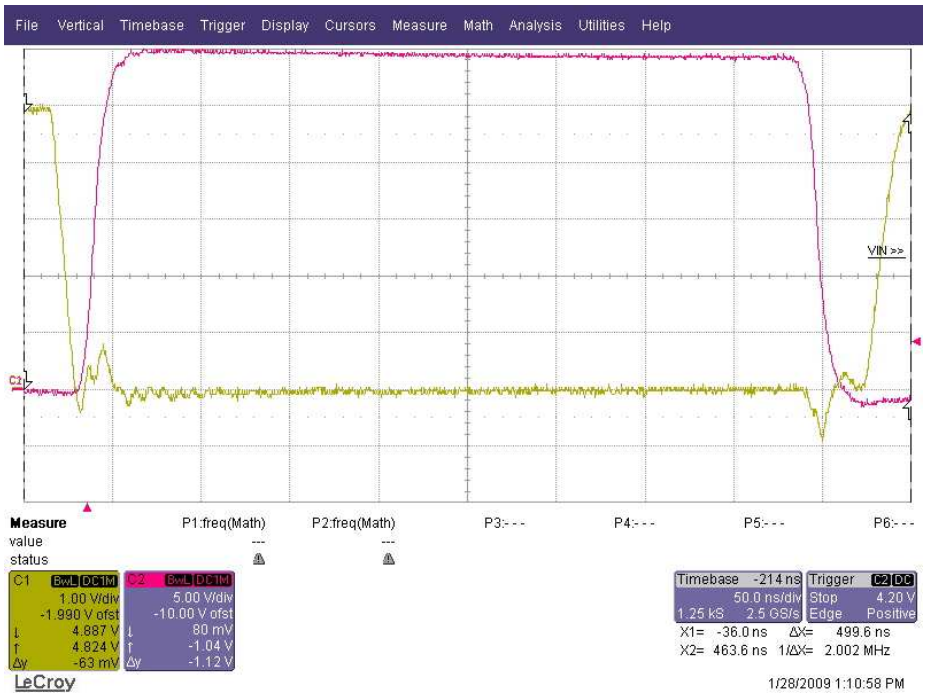
1 Main Waveforms



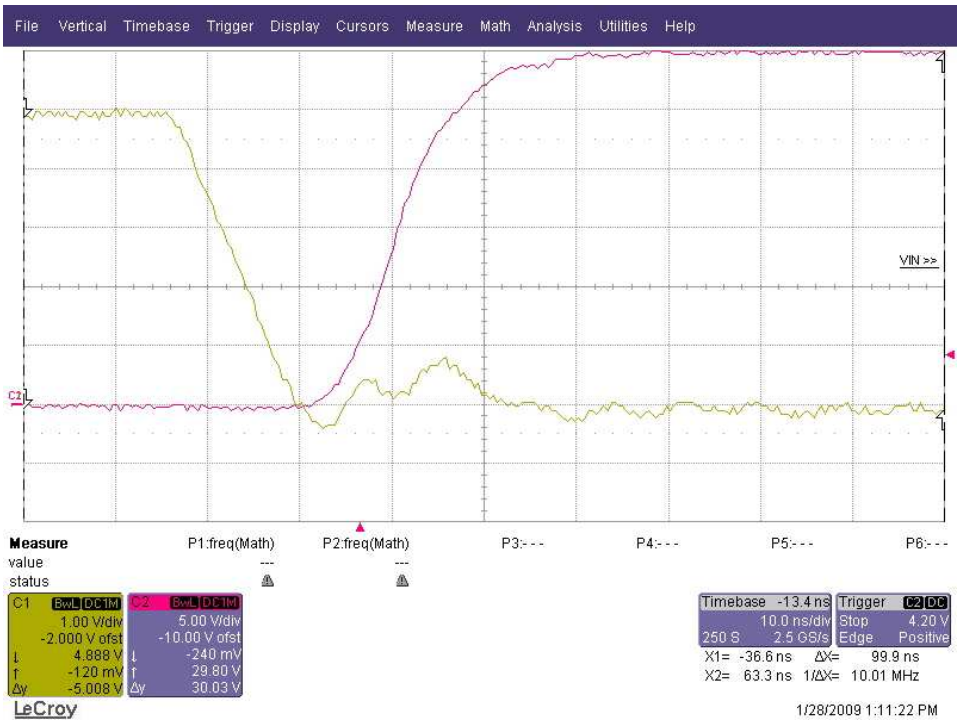
Switch Nodes of Synch-Buck (TPS40140): Vds Q1:B, TP8 (C2), Vds Q2:B, TP7 (C1)



Low Side Mosfet Gates of Synch-Buck (TPS40140): Vgs Q1:B, (C2), Vgs Q2:B, (C1)

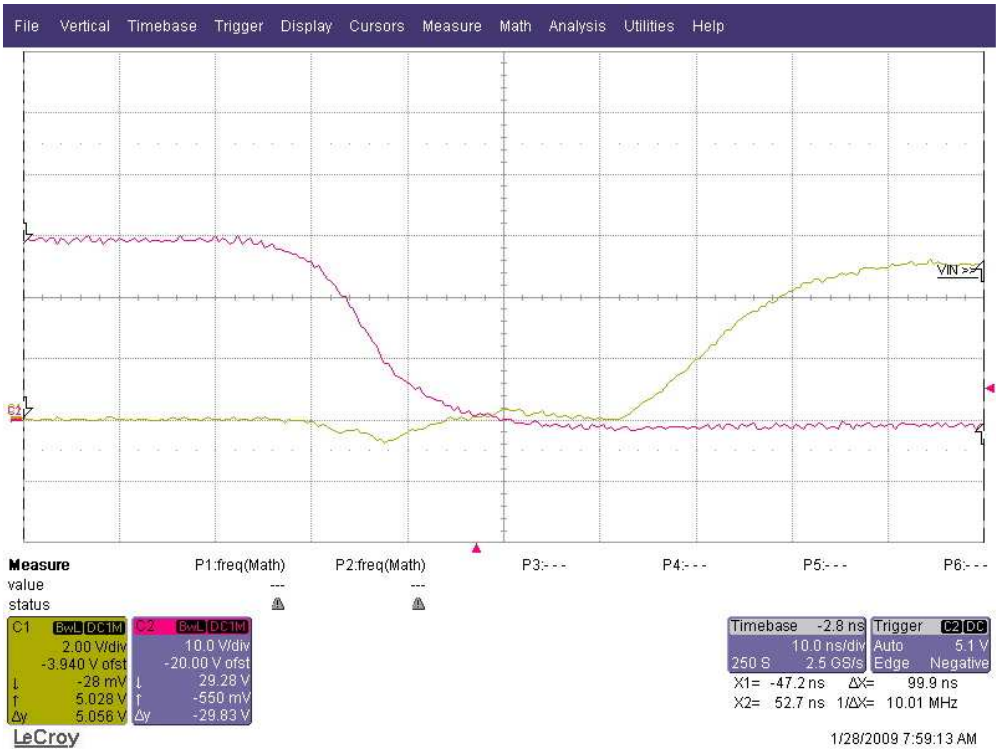


Gates of Synch-Buck for 5V output (TPS40140): VgGND Q2:A, (C2), VgGND Q2:B, (C1)

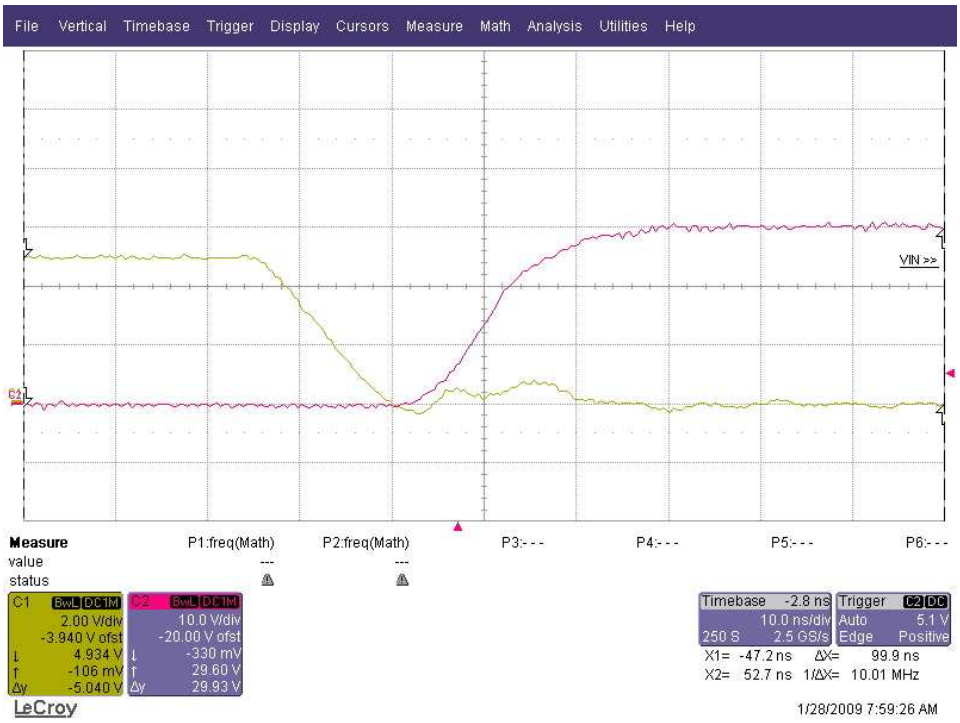


Gates of Synch-Buck for 5V output (TPS40140): VgGND Q2:A, (C2), VgGND Q2:B, (C1)

Gates of Synch-Buck for 5V output (TPS40140): VgGND Q2:A, (C2), VgGND Q2:B, (C1)



Gates of Synch-Buck for 3.3V output (TPS40140): VgGND Q1:A, (C2), VgGND Q1B, (C1)



Gates of Synch-Buck for 3.3V output (TPS40140): VgGND Q1:A, (C2), VgGND Q1B, (C1)

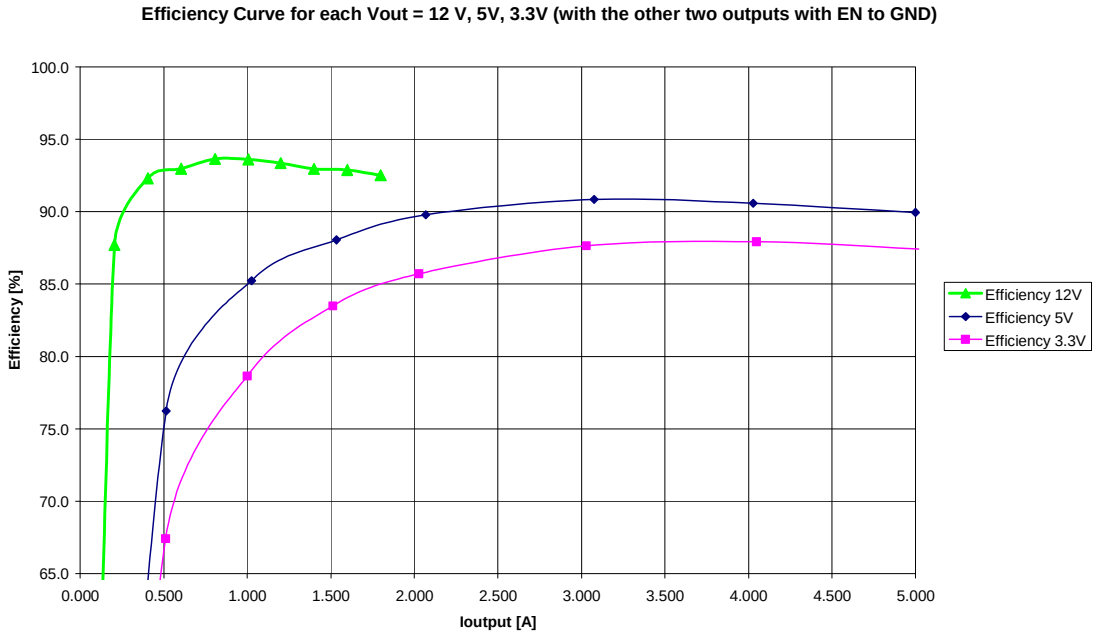
Switch Node and High Side Mosfet Gate of the 12V output Buck (TPS40200): VdGND Q4, TP26

2 Efficiency and Load Regulation

The efficiency diagrams are shown in the figure below for 6.5V, 9V, 12V input voltage, as a function of the output current.

The following table shows the measured values:

Vin[V]	Iin[mA]	Vout1[V]	Iout1[mA]	Vout2[V]	Iout2[mA]	Vout3[V]	Iout3[mA]	Pin[W]	Pout[W]	η%
24.26	0.027	**12.23**	**0.000**	**5.04**	**0.000**	**3.35**	**0.000**	0.655	0.000	**0.0**
24.18	0.346	**12.23**	**0.256**	**5.03**	**0.511**	**3.35**	**0.529**	8.366	7.472	**89.3**
24.09	0.656	**12.23**	**0.504**	**5.03**	**1.004**	**3.34**	**1.027**	15.803	14.648	**92.7**
24.08	0.978	**12.23**	**0.775**	**5.02**	**1.513**	**3.34**	**1.546**	23.550	22.237	**94.4**
24.01	1.313	**12.22**	**1.006**	**5.02**	**2.016**	**3.34**	**2.054**	31.525	29.266	**92.8**
20.08	0.028	**12.23**	**0.000**	**5.04**	**0.000**	**3.35**	**0.000**	0.562	0.000	**0.0**
20.68	0.397	**12.24**	**0.256**	**5.04**	**0.516**	**3.33**	**0.520**	8.210	7.468	**91.0**
20.60	0.764	**12.24**	**0.504**	**5.03**	**1.017**	**3.34**	**1.028**	15.738	14.717	**93.5**
20.55	1.129	**12.24**	**0.755**	**5.02**	**1.495**	**3.34**	**1.530**	23.201	21.861	**94.2**
20.44	1.518	**12.23**	**1.006**	**5.01**	**2.013**	**3.35**	**2.051**	31.028	29.253	**94.3**
27.79	0.028	**12.23**	**0.000**	**5.04**	**0.000**	**3.35**	**0.000**	0.770	0.000	**0.0**
27.68	0.307	**12.23**	**0.256**	**5.03**	**0.511**	**3.35**	**0.529**	8.498	7.473	**87.9**
27.67	0.582	**12.23**	**0.504**	**5.03**	**1.021**	**3.34**	**1.032**	16.104	14.746	**91.6**
27.65	0.856	**12.23**	**0.755**	**5.02**	**1.504**	**3.34**	**1.541**	23.668	21.931	**92.7**
27.59	1.140	**12.23**	**1.006**	**5.02**	**2.012**	**3.34**	**2.052**	31.453	29.257	**93.0**



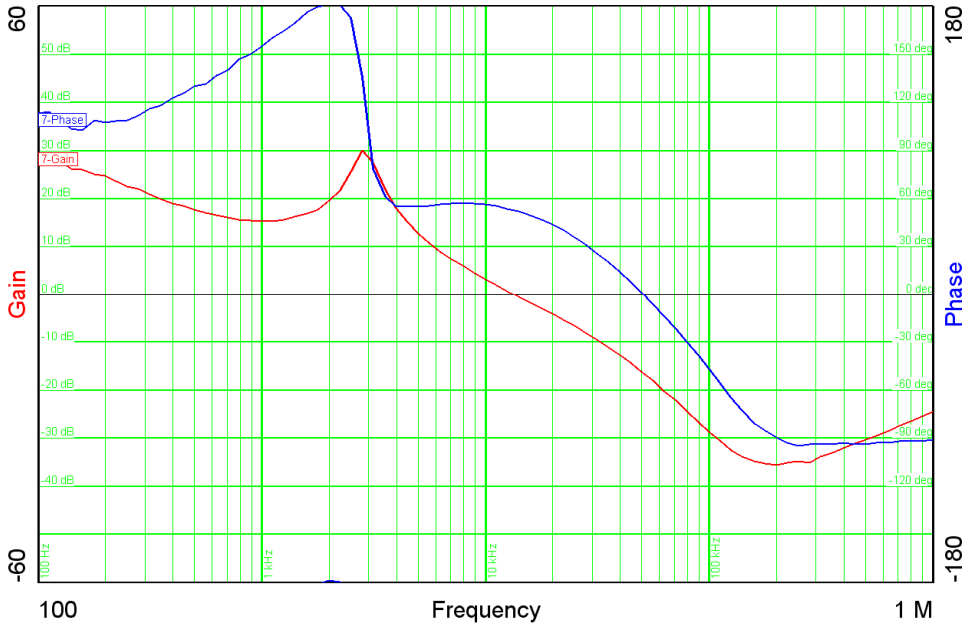
The following table shows the measured values, of each output power measured with the other two outputs shut-off by the Enable pin connected to Ground. The efficiency is effected however by the performance of the linear regulator, when the 5V output is shut-off, because in this condition the regulator provides the supply to the TPS40140.

Vin[V]	Iin[mA]	Vout1[V]	Iout1[mA]	Pin[W]	Pout2[W]	η%
24.44	0.013	**12.23**	**0.000**	0.318	0.000	**0.0**
24.41	0.117	**12.22**	**0.205**	2.856	2.505	**87.7**
24.37	0.220	**12.22**	**0.405**	5.361	4.949	**92.3**
24.35	0.326	**12.22**	**0.604**	7.938	7.381	**93.0**
24.32	0.433	**12.22**	**0.807**	10.531	9.862	**93.6**
24.32	0.540	**12.22**	**1.006**	13.133	12.293	**93.6**
24.24	0.648	**12.22**	**1.200**	15.708	14.664	**93.4**
24.26	0.758	**12.22**	**1.399**	18.389	17.096	**93.0**
24.22	0.868	**12.22**	**1.598**	21.023	19.528	**92.9**
24.21	0.981	**12.22**	**1.798**	23.750	21.972	**92.5**
24.43	0.029	**5.04**	**0.000**	0.708	0.000	**0.0**
24.40	0.139	**5.03**	**0.514**	3.392	2.585	**76.2**
24.39	0.248	**5.03**	**1.025**	6.049	5.156	**85.2**
24.36	0.359	**5.02**	**1.534**	8.745	7.701	**88.1**
24.34	0.475	**5.02**	**2.068**	11.562	10.381	**89.8**
24.26	0.699	**5.01**	**3.075**	16.958	15.406	**90.8**
24.20	0.917	**4.99**	**4.028**	22.191	20.100	**90.6**
24.13	1.147	**4.98**	**4.999**	27.677	24.895	**89.9**
24.44	0.032	**3.35**	**0.000**	0.770	0.000	**0.0**
24.42	0.104	**3.35**	**0.511**	2.540	1.712	**67.4**
24.41	0.174	**3.34**	**1.000**	4.247	3.340	**78.6**

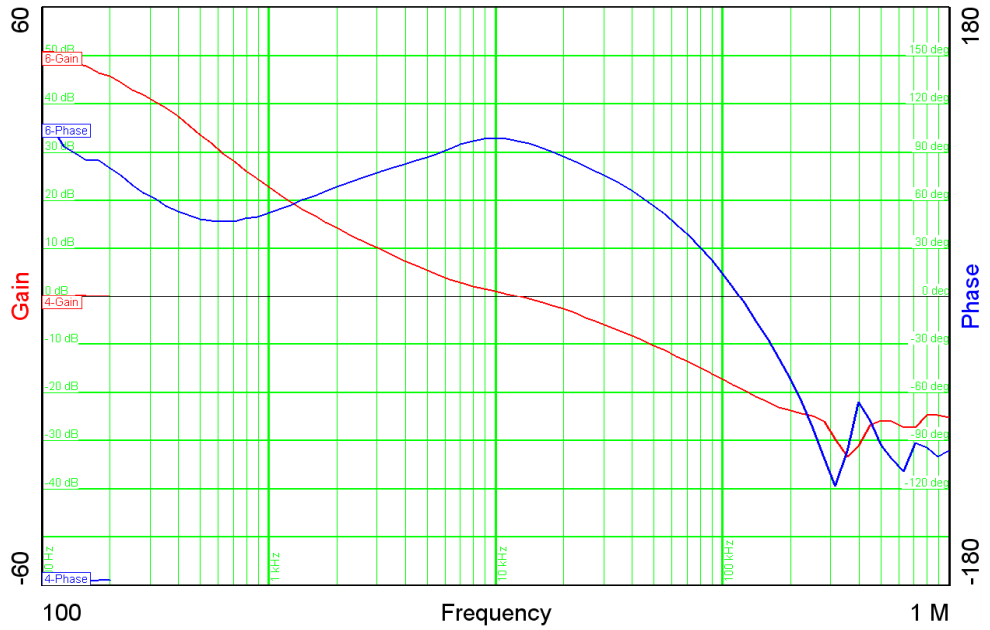
24.39	0.248	**3.34**	**1.512**	6.049	5.050	**83.5**
24.38	0.324	**3.34**	**2.027**	7.899	6.770	**85.7**
24.33	0.473	**3.33**	**3.029**	11.508	10.087	**87.6**
24.29	0.631	**3.33**	**4.047**	15.327	13.477	**87.9**
24.25	0.786	**3.32**	**5.019**	19.061	16.663	**87.4**

3 Control Loop Frequency Response

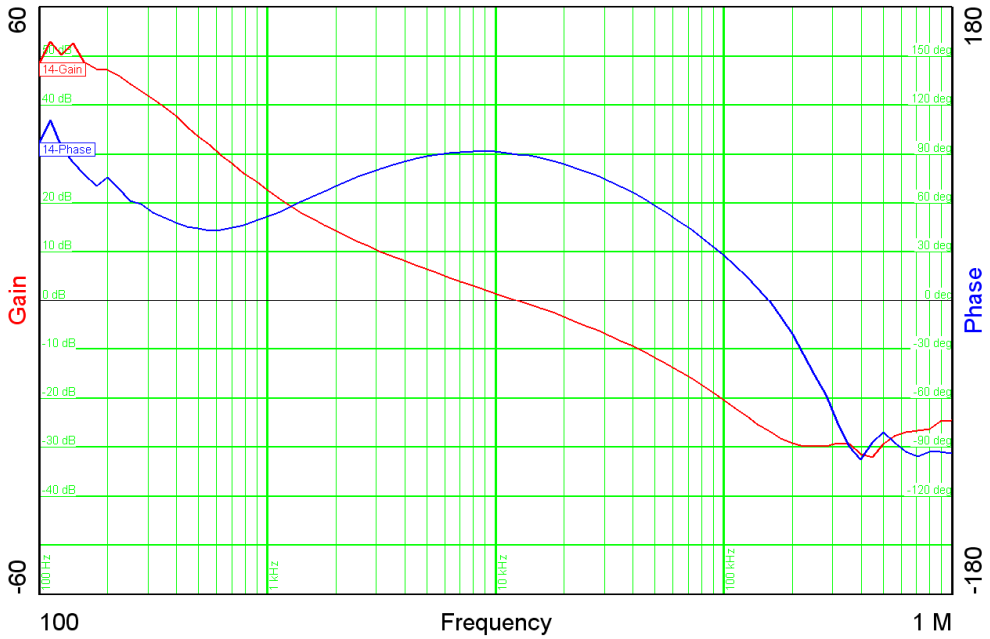
The figures below show the open loop response for Vout=12V, Vout=5V, and Vout=3.3V at full output load and Vin=24V.



Vout=12V (7-Gain and Phase)



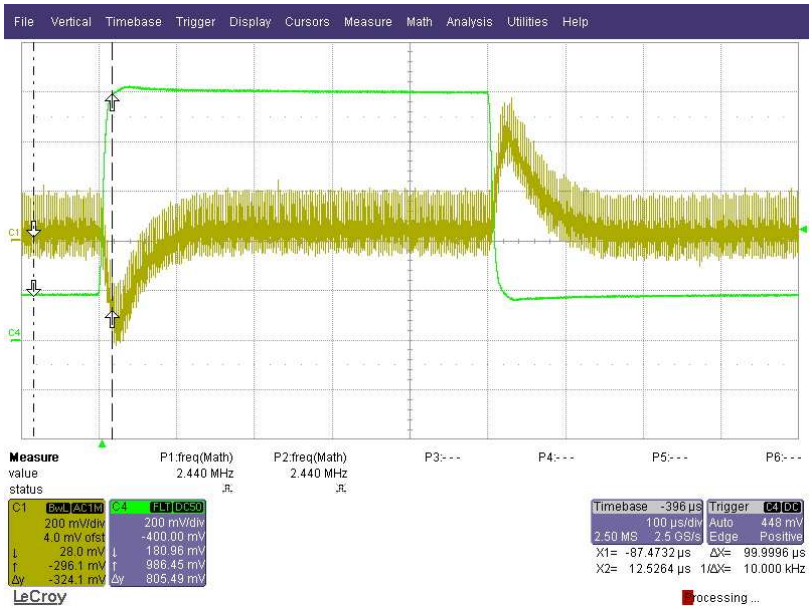
Vout=5V (6-Gain and Phase)



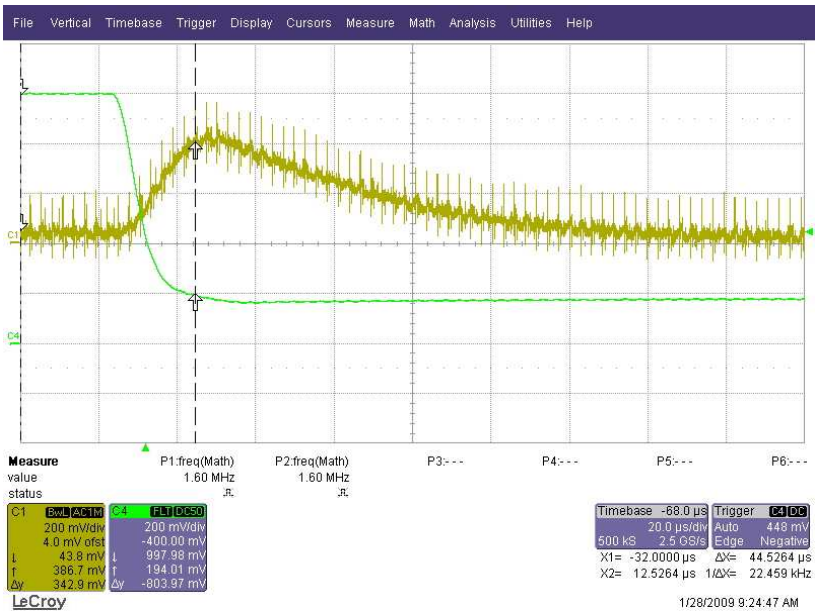
Vout=12V (14-Gain and Phase)

4 Load Transients

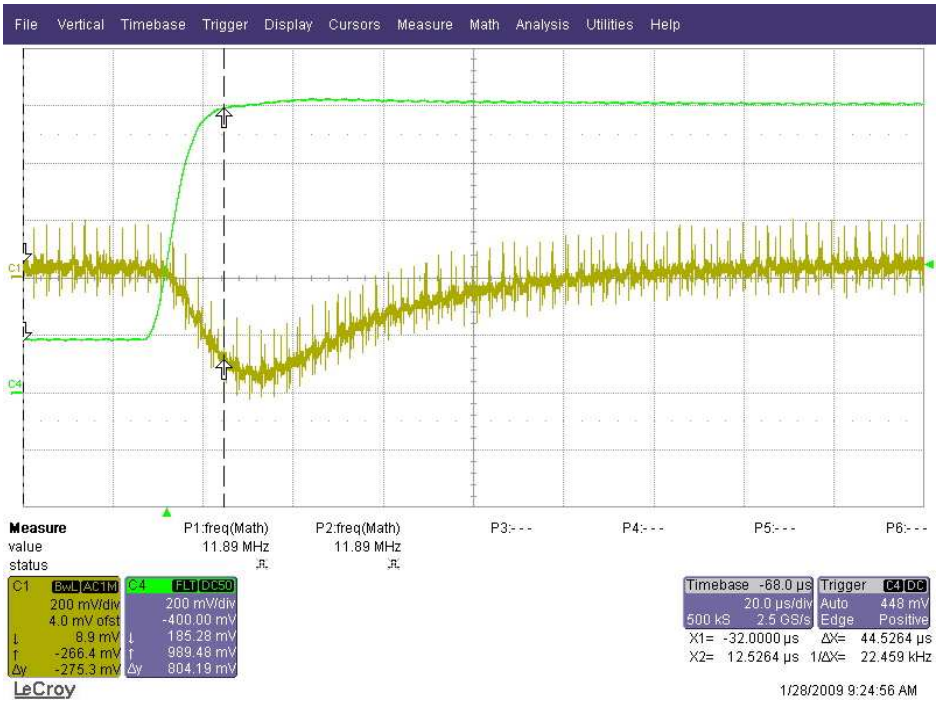
The figure below show the response to load transients applied to each output.
The current on the Output is stepping from minimum continous mode load to full load (1A for Vout=12V and 2A for Vout=5V and Vout=3.3V) and viceversa, with Vin=24V.



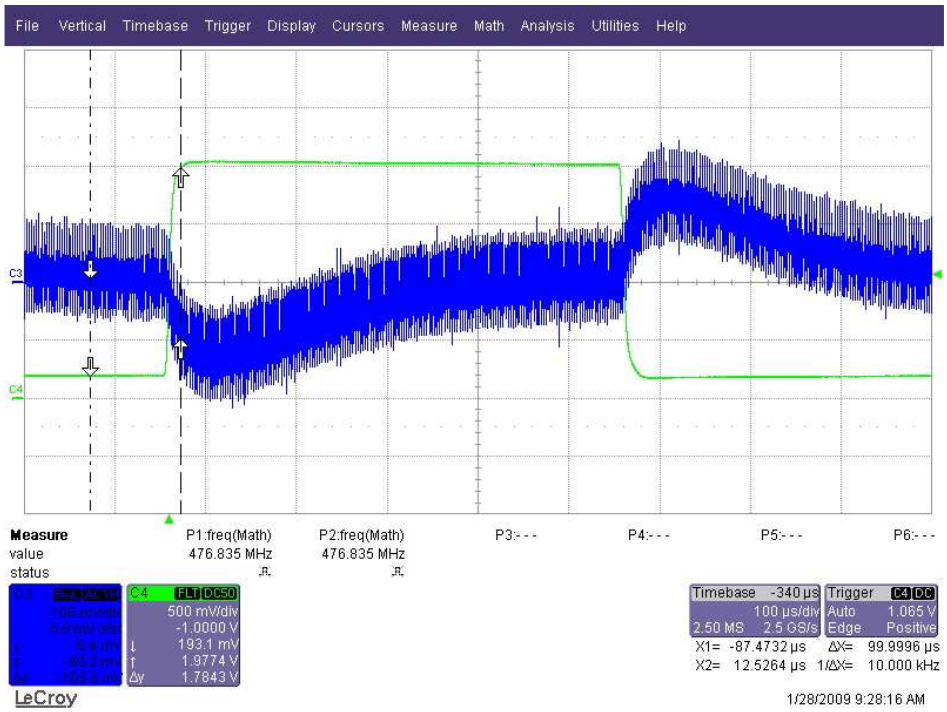
Vout=12V (C2), Iout (C4, 200mA/V current probe)



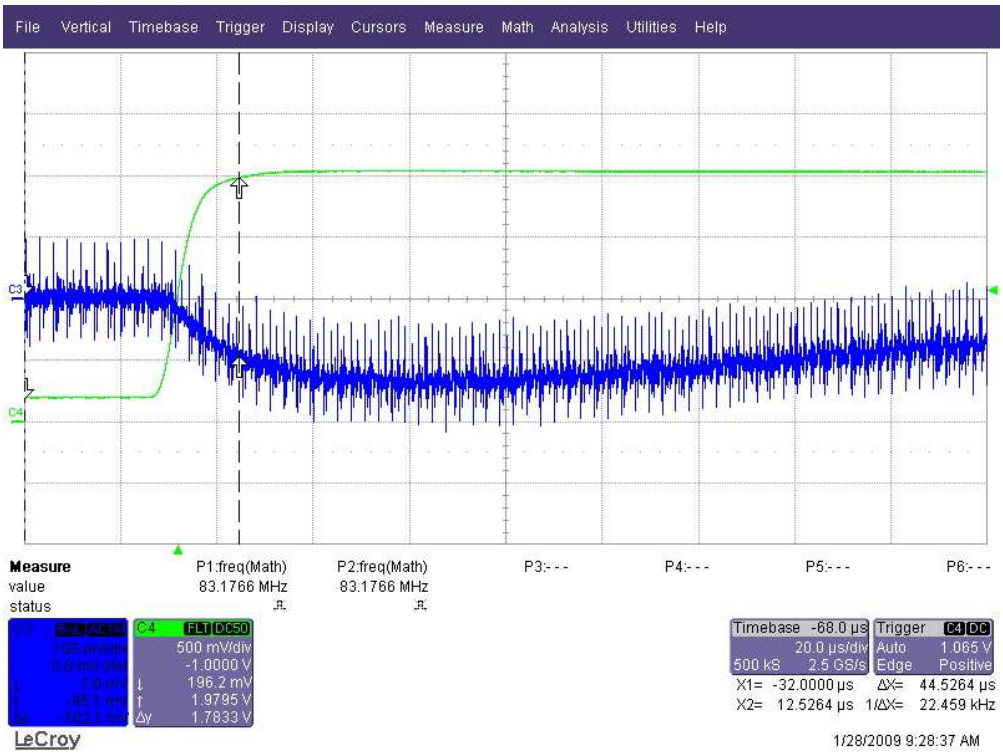
Vout=12V (C2), Iout (C4, 200mA/V current probe)



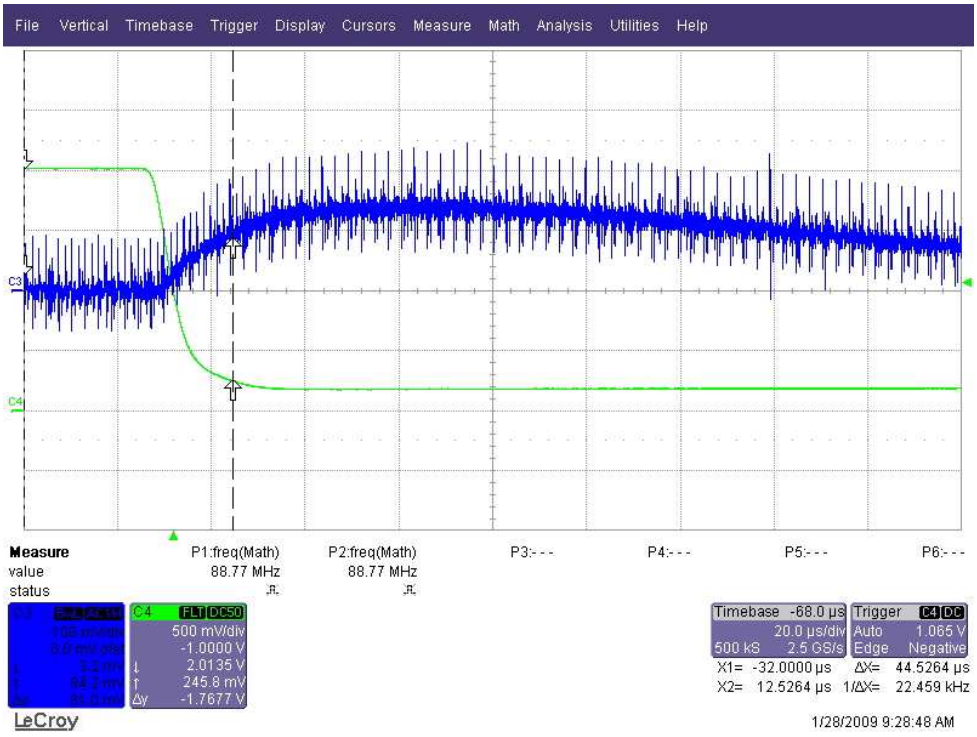
Vout=12V (C2), Iout (C4, 200mA/V current probe)



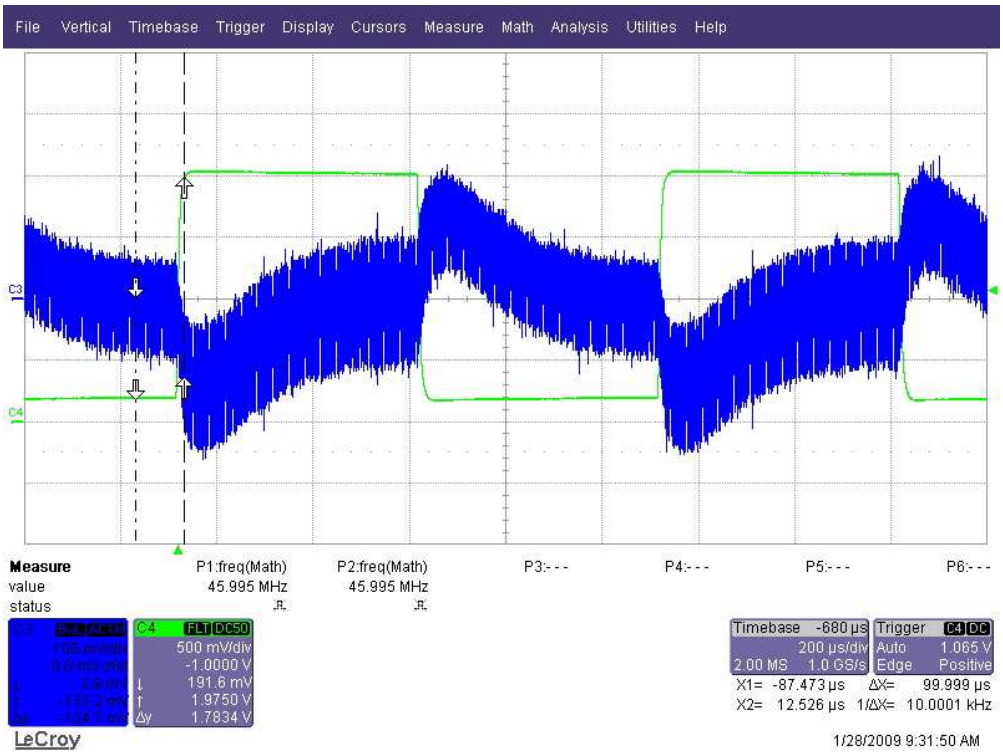
Vout=5V (C2), Iout (C4, 500mA/V current probe)



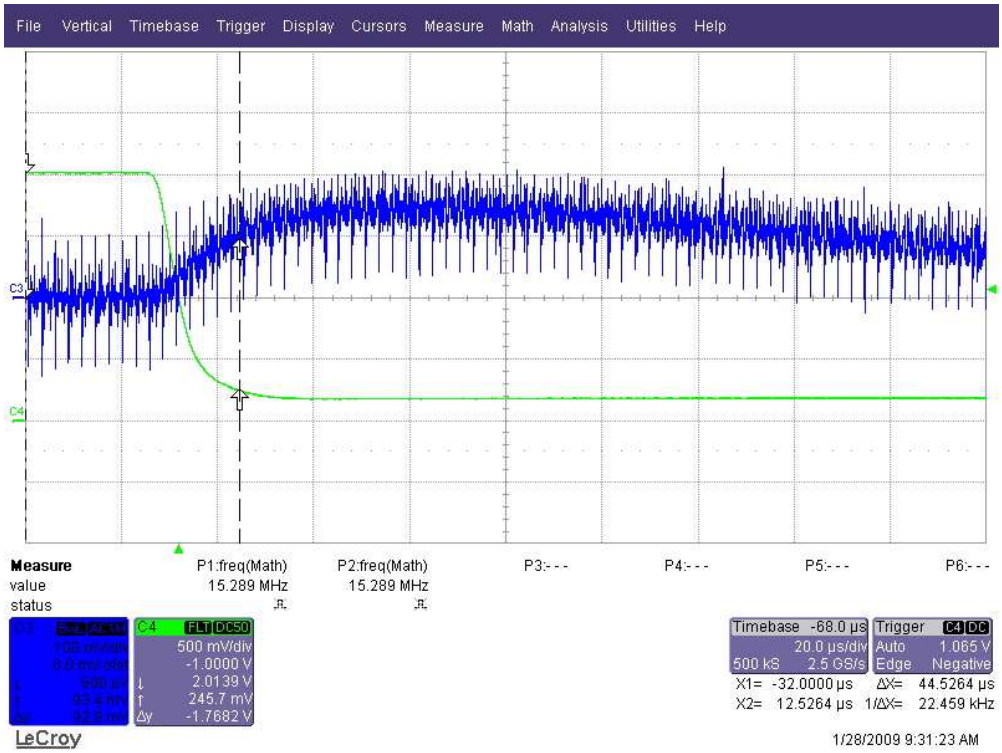
Vout=5V (C2), Iout (C4, 500mA/V current probe)



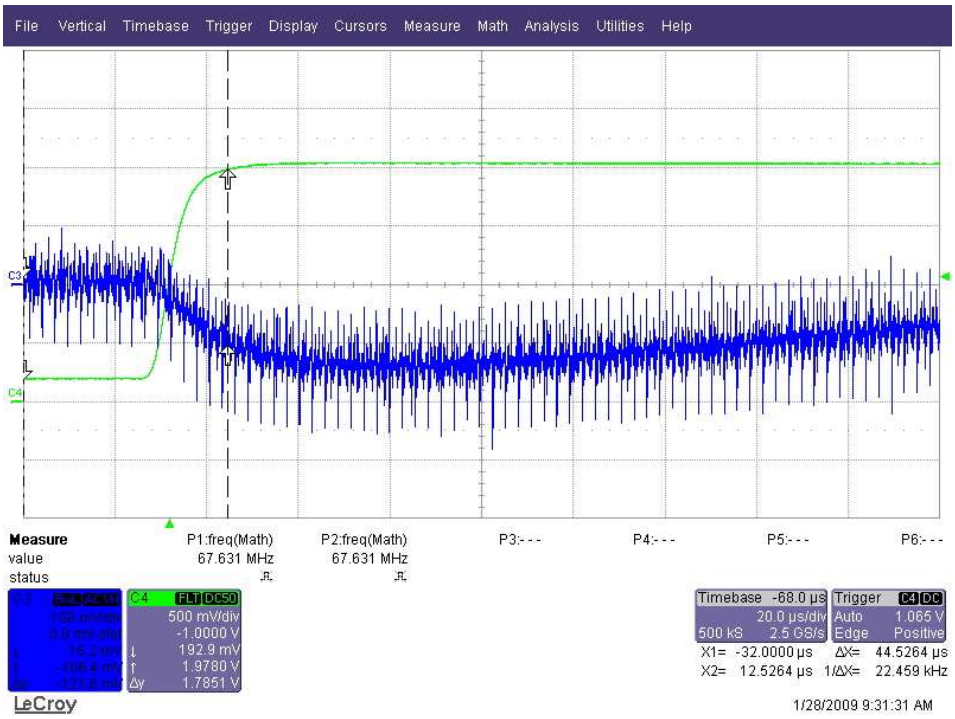
Vout=5V (C2), Iout (C4, 500mA/V current probe)



Vout=3.3V (C2), Iout (C4, 500mA/V current probe)



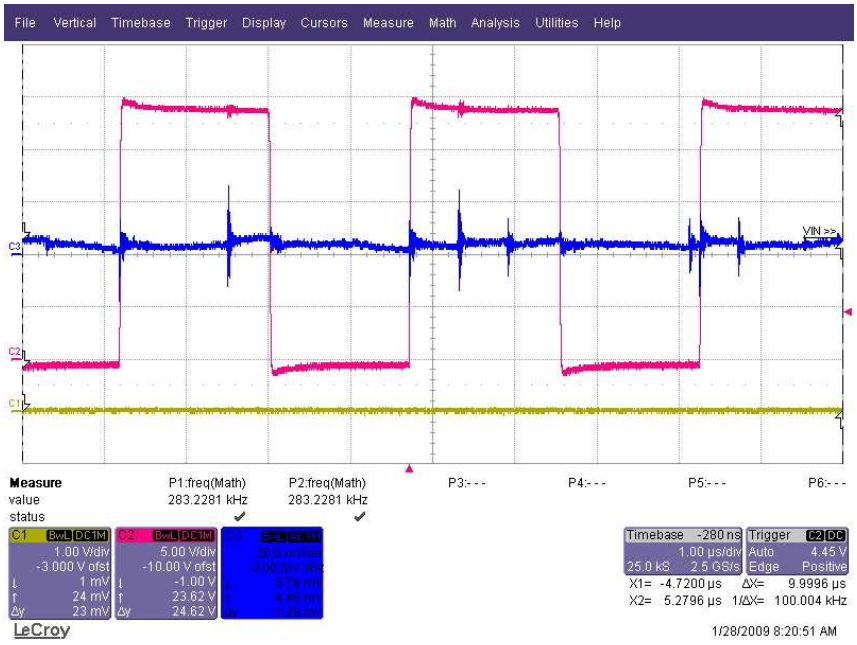
Vout=3.3V (C2), Iout (C4, 500mA/V current probe)



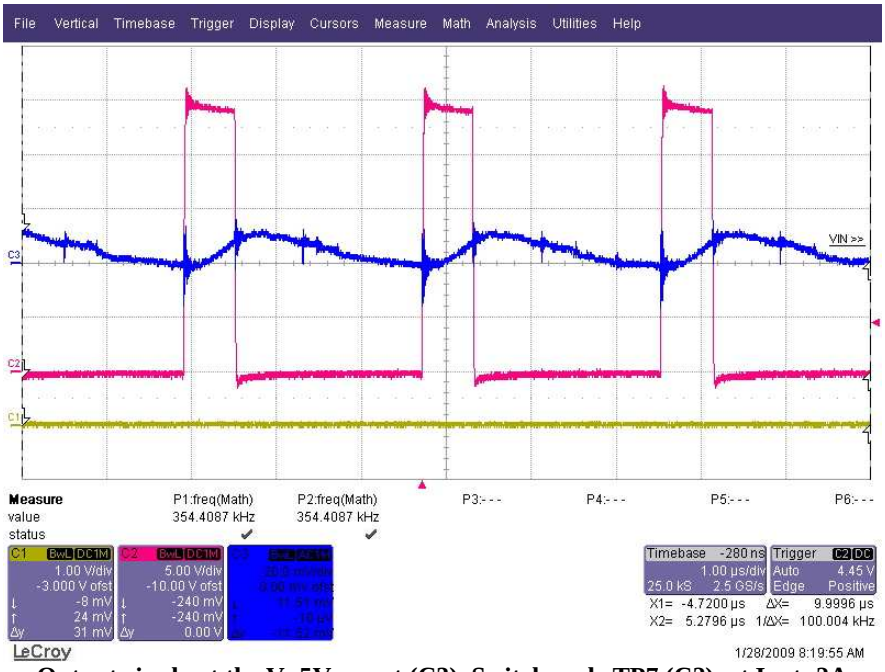
Vout=3.3V (C2), Iout (C4, 500mA/V current probe)

5 Output and Input Ripple Voltage

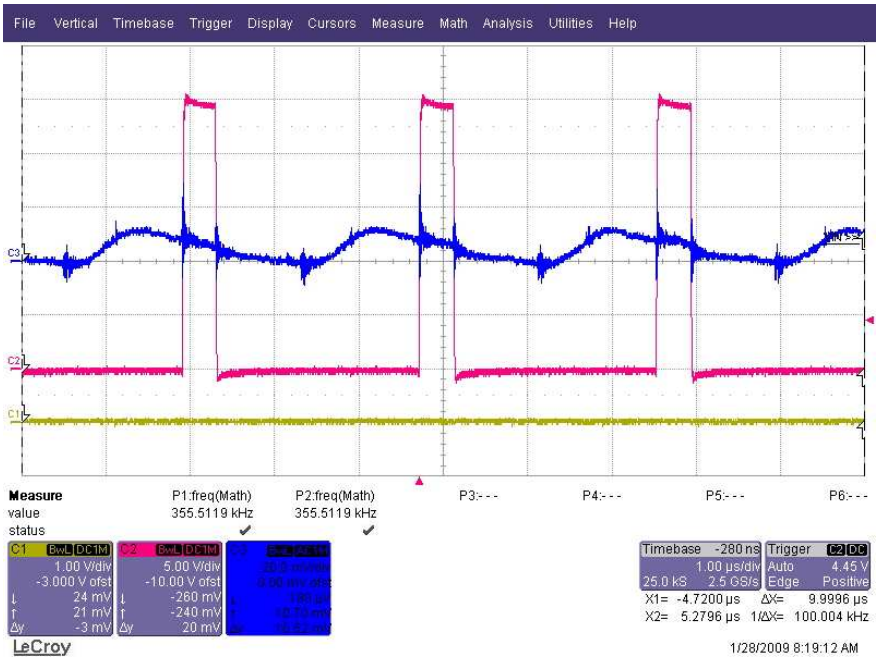
The output ripple voltage for the different output is shown in the figures below:



Output ripple at the V=12V ouput (C3), Switch node TP26 (C2), at Iout=1A

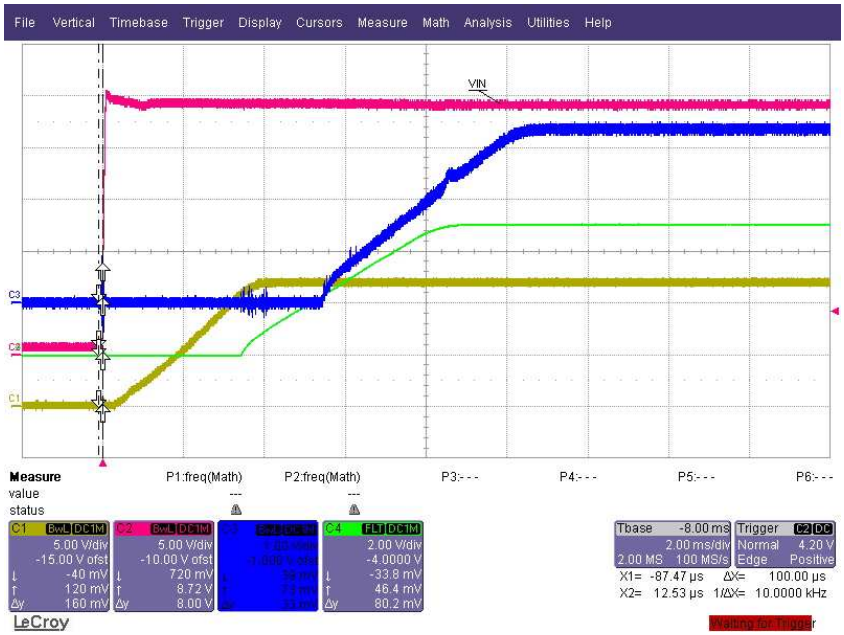


Output ripple at the V=5V ouput (C3), Switch node TP7 (C2), at Iout=2A



Output ripple at the V=3.3V ouput (C3), Switch node TP8 (C2), at Iout=2A

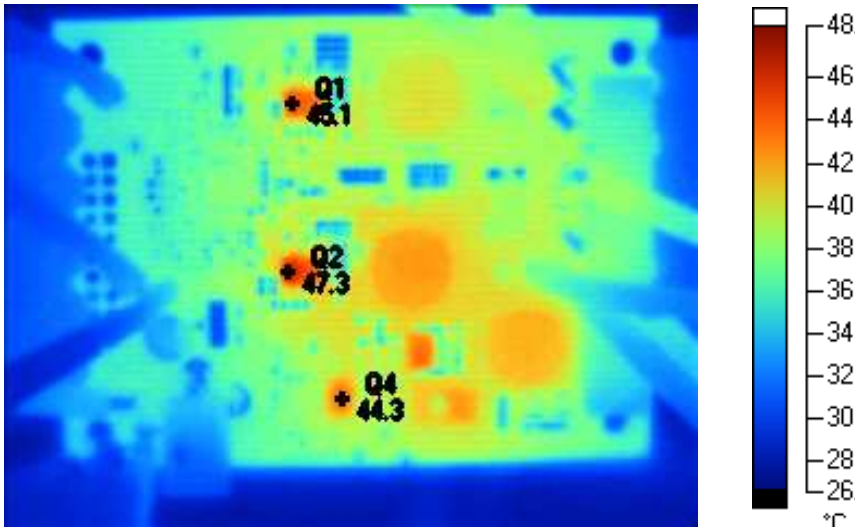
6 Start-up Waveforms



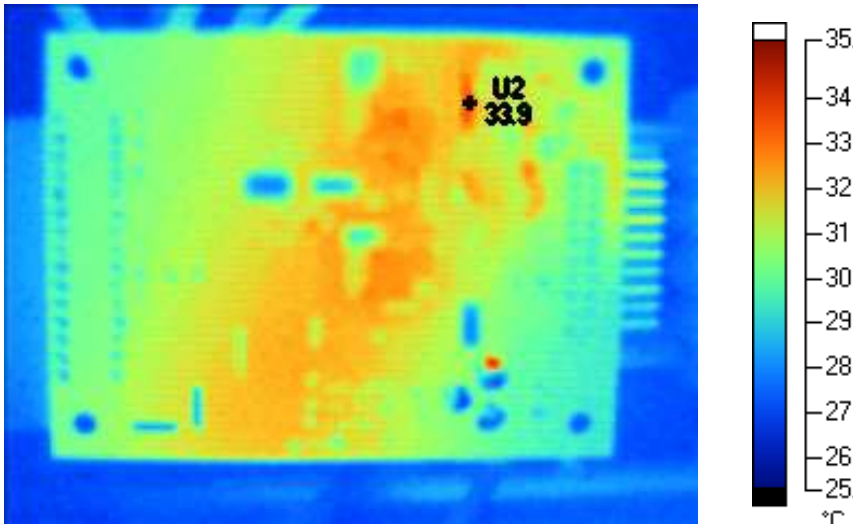
Input Voltage start Start-up Waveforms: Input voltage (C2), Output Voltage 12V (C1) @1A Output Voltage 5V (C4) @2A, output Voltage 3.3V (C3) @2A

7 Thermal Images

The thermal images of board are taken for the Top Side and Bottom side of the board at the temperature of T=25°C ambient, at output load Vout=12@1A Vout=5@2A Vout=3.3@2A.
In every picture the hottest spot is indicated, together with the temperature of the most significant components.



Top Side
Output Load Vout=12V@1A, Vout=5@2A, Vout=3.3V@2A, Output Power 30W



Bottom Side
Output Load Vout=12V@1A, Vout=5@2A, Vout=3.3V`@2A,Output Power=30W

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