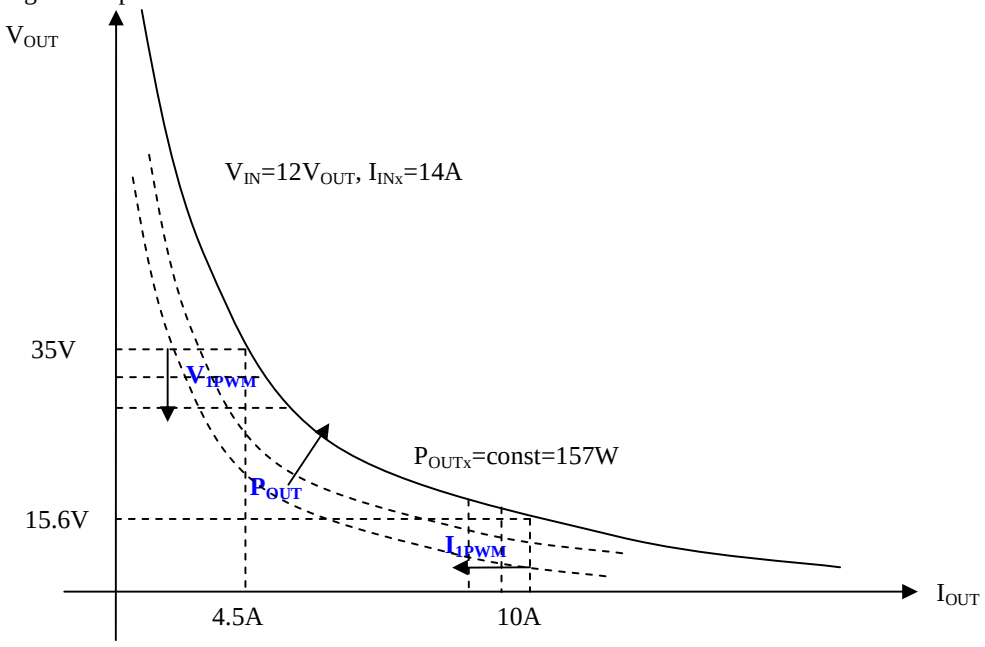
1 Operations

The Power supply system has been tested in all his functionalities, according to the specifications on Rev.1.0 dated 10th July 2007 and their update dated 1st November 2007.
The schematic and layout of the tested board including all the introduced modifications are in Rev.D.

Fixed Outputs (Specs Par.3.2) with current limitation, have been tested with the following results:

Vin[V]	Vout[V]	Iout[mA]	Pout[W]	η%
3.3	**3.078**	**3**	9.23	**93.27**
3.3	**3.012**	**3.69**	11.11	
3.3	**3.007**	**3.77**	11.34	
3.3	**2.994**	**3.82**	11.44	
3.3	**2.985**	**3.91**	11.67	
3.3	**1.7**	**2.4**	4.08	
3.3	**0.41**	**2.05**	0.84	
Vin[V]	**Vout[V]**	**Iout[mA]**	**Pout[W]**	**η%**
5.17	**5.03**	**3.04**	15.29	**97.29**
5.17	**4.89**	**3.36**	16.43	
5.17	**4.77**	**3.82**	18.22	
5.17	**4.66**	**3.95**	18.41	
5.17	**3.28**	**2.96**	9.71	
5.17	**3.07**	**2.72**	8.35	
5.17	**1.143**	**2.347**	2.68	

The second value for each output voltage gives the start of output current limitation, which follows a fold-back characteristic with tested possibility of OC reset form the micro (on the board also with manual switch.
For Variable Outputs (specs Par.3.1) the power stages test results are the object of the following paragraphs. They have been designed to satisfy the following summary operational characteristic curves, according to the specifications.



For simplicity and time reason in the following, all the results reported have been tested just on one Power stage (Sheet 1 of SCH, left side of PCB, left side of the board top side), because the two Power stages are symmetrical and identical. Complete characterization is performed at Vout=25V, while main eventual differences with other output voltage are reported.

The CV mode (Specs Par.5) has been tested with an external 0-5V 1kHz **20-80% duty cycle**, obtaining the Vout range from-to **8.53V - 34.40V** (not to the nominal 35V).

The CI mode has been tested with an external 0-5V 1kHz **20-80% duty cycle**, obtaining the range for reduced output current limitation from-to **2.1 A -8.4A**, (not to the maximum 10A).

The circuit implements two types of current limitation, input (**14A**) and output (**10A**) current.
The measured input current limitation takes place at **14.1A**.
A set of measured results useful in the next paragraphs, for Output Voltage and Output Current limitation as a function of $V_{1PWM,}$ of I_{1PWM} are the following:

Vout	V1PWM	Iout	I1PWM
8.5	20%	2.1	20%
14.5	35%	5.4	50%
25	60%	6.5	60%
34.5	80%	8.4	80%

Latch protection (cut-off) on Output current is implemented selecting manual switch S1 on the board, and it works with reset (switch S1 off) after its activation (overcurrent) when selected (switch S1 on).

1.2 Thermal considerations

All the Thermal measurement have been performed at Tamb=25°C, with a forced ventilation of 40CFM imposed through the entire section of the board. Further, some extra heatsinks have been applied to the board close to the primary mosfets to simulate the use of a thicker PCB with multiple layers.
According to the specifications, Tamb up to 85°C, achieved results on Rev.D (details in the following, last paragraph) evidence the need of reduce the power losses per input mosfet.
The proposed solution is to duplicate both input mosfets than their relative drives.
Details are shown in the schematic Rev.E.
Thermal resistance junction to amb for each mosfet has to be less than 40°C.
To achieve this performance, we propose the following points:
1) realize the new board with 70µm (2OZ) copper thickness, four layers (mandatory), maximizing the input traces
2) to devote to primary mosfet drain a PCB area of at least 2.5 square inches, for all the four layers, introducing an adequate number of thermal vias of proper section, among the layers (mandatory).
3) to maintain a forced ventilation of 40CFM on the board (eventual according to reduced maximum ambient temperature).
4) The PCB layout can be simply derived form the actual one, just increasing the mosfet area, both on drains according to point 2. that sources, after duplicating their number and drives. The input traces of the power stage has to be also maximized to allow power dissipation.

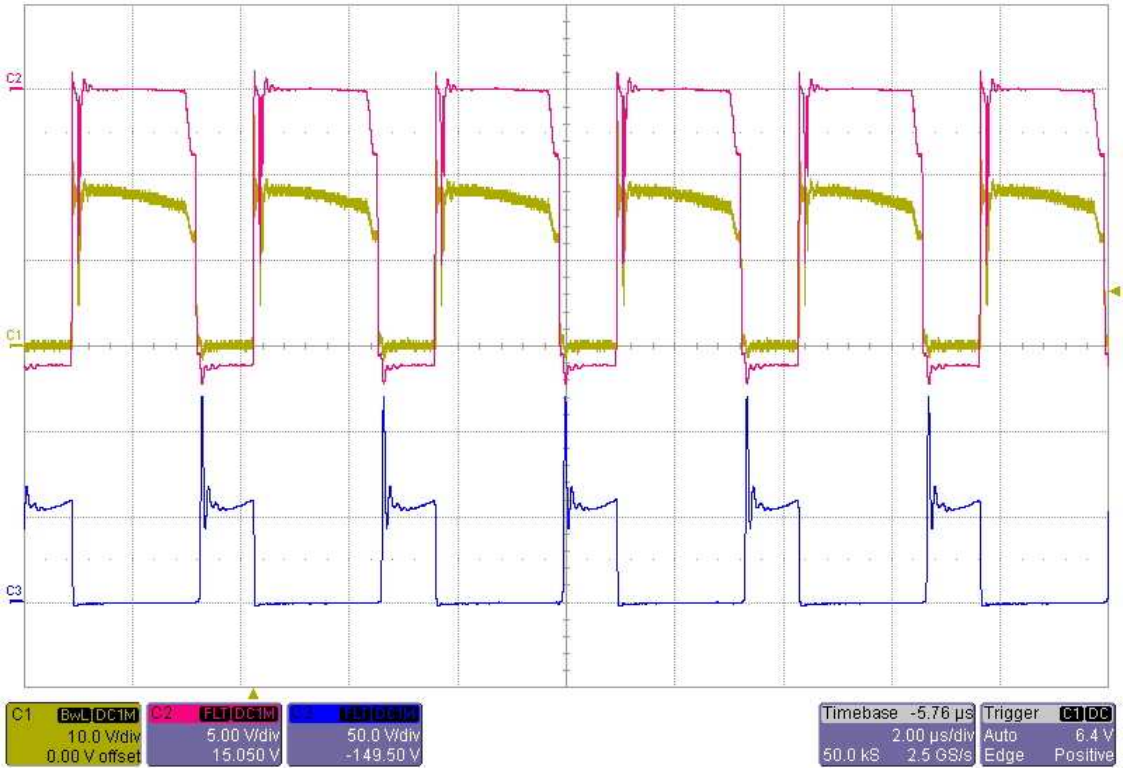
To allow maximum ambient temperature operations, the actual board built on Rev.D has been limited in input at output current, to guarantee an acceptable maximum operating temperature on the overall range. In particular, the output limitation has been set to **6.6A (I_{1PMW}=80%, V_{1PWM}=60%, Vout=25V)** (that's equivalent to 4.8A (I1PMW=80%, V1PWM=35%, Vout=14.5V). This has been implemented with the following changes of components values on the board:

- **R_{58}=R_{63}=24 kΩ,**
- **R_{17}=R_{16}=20 kΩ.**

This variation compared to the schematic in Rev.D has been implemented just before delivering the board, while the test report has been realized with the board fully in line with Rev.D.

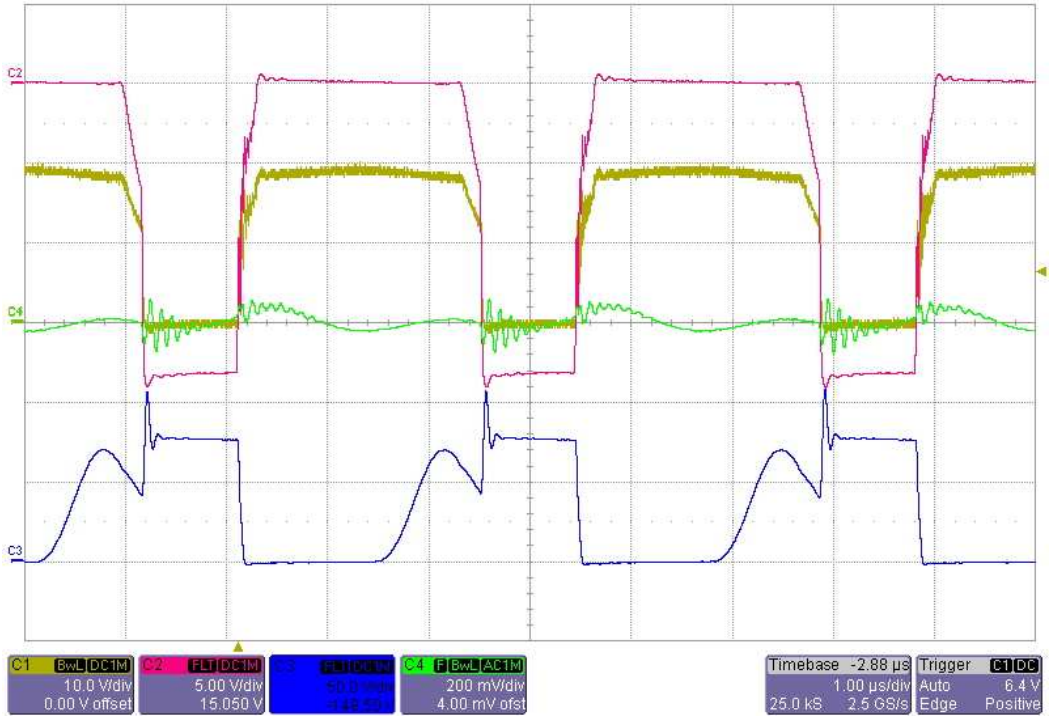
2 Main Waveforms

The converter is operating in Continuous Mode in most of its range of operation. At Vout=25V, the minimum current for Discontinuous current is Iout=0.3A. Switching frequency is fs=303kHz. Waveforms for the main switches in CCM are in the following picture.

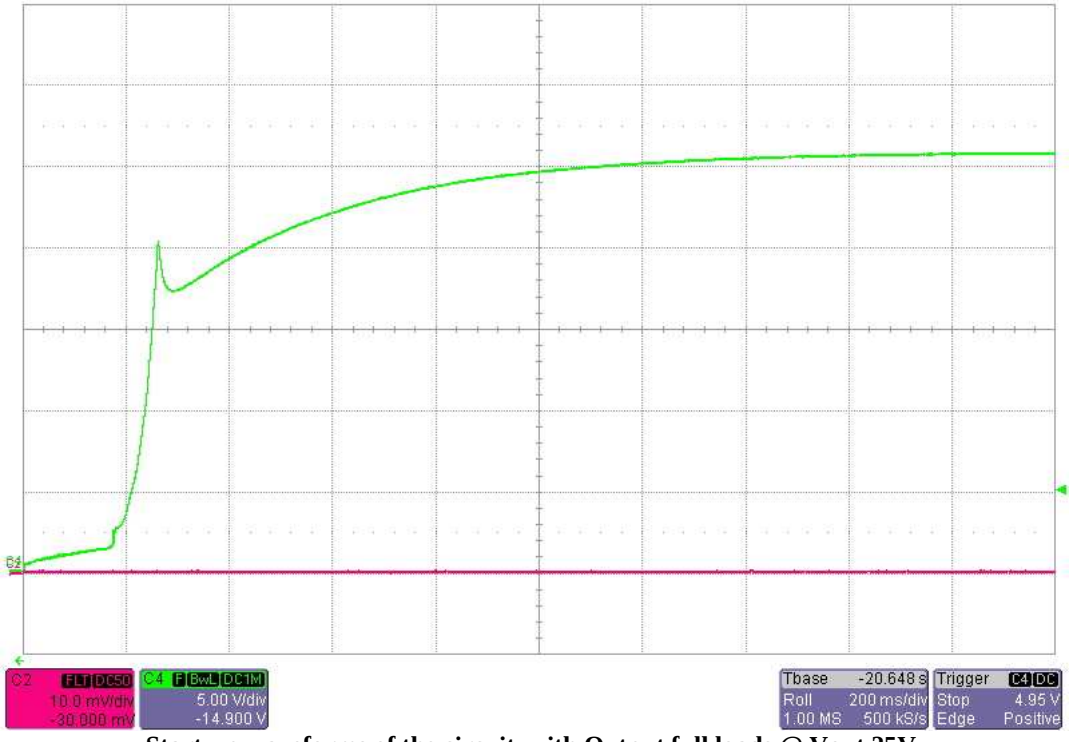


C1: Primary Mosfets Drain Voltage @ Vout=25V, Pout=156W
C2: Auxiliary (active clamp) Primary Mosfet Drain Voltage
C3: Output Diode Cathode Voltage

Same waveforms for the main switches in DCM are in the following picture.



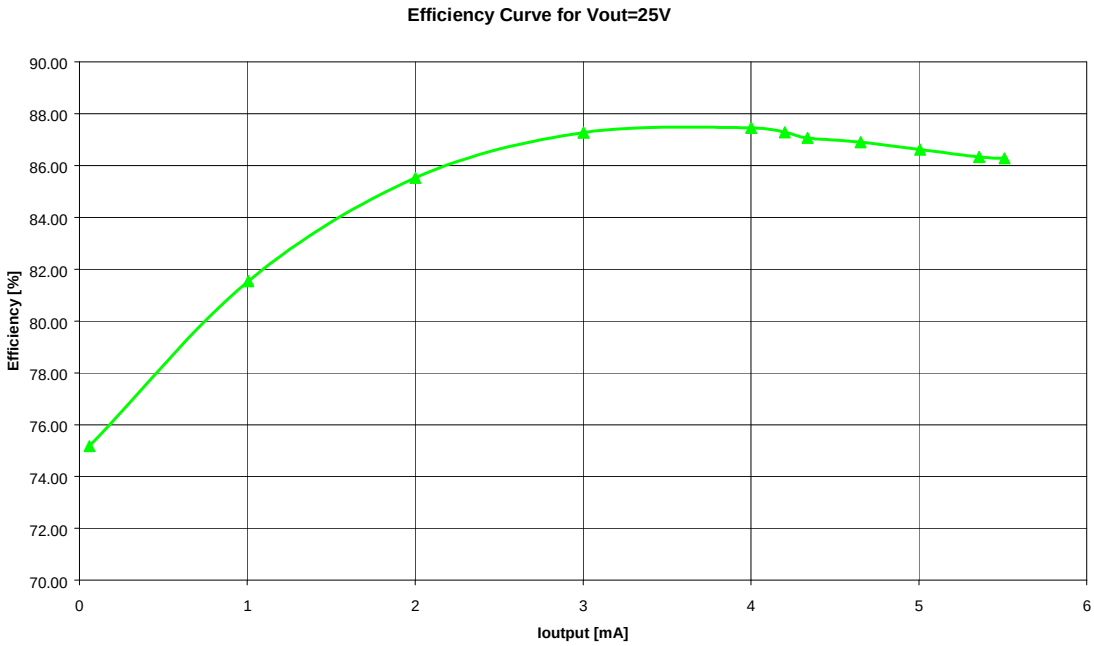
C1: Primary Mosfets Drain Voltage @ Vout=25V, Pout=156W
C2: Auxiliary (active clamp) Primary Mosfet Drain Voltage
C3: Output Diode Cathode Voltage



Start-up waveforms of the circuit, with Output full loads @ Vout 25V.

3 Efficiency

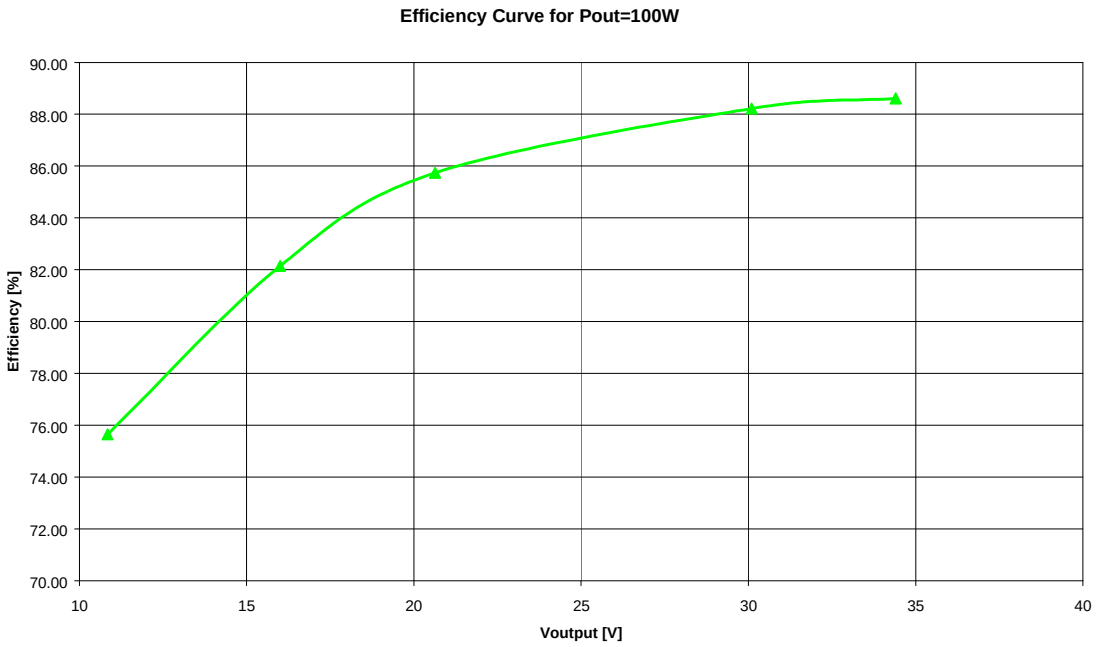
The efficiency diagram below as a function of the Output current.is derived for Vout=25V (V_{1PWM}=60%).



The following table shows the measured values for **Vin=12V, Vout=25V**:

Vin[V]	Iin[A]	Vout[V]	Iout[A]	Pin[W]	Pout[W]	η%
12.97	0.16	**26**	**0.06**	2.08	1.56	**75.17**
12.82	2.47	**25.64**	**1.007**	31.67	25.82	**81.54**
12.68	4.75	**25.73**	**2.002**	60.23	51.51	**85.52**
12.53	7.08	**25.78**	**3.003**	88.71	77.42	**87.27**
12.37	9.52	**25.74**	**4.001**	117.76	102.99	**87.45**
12.33	10.04	**25.72**	**4.201**	123.79	108.05	**87.28**
12.32	10.21	**25.25**	**4.337**	125.79	109.51	**87.06**
12.26	11.05	**25.3**	**4.653**	135.47	117.72	**86.90**
12.18	12.02	**25.33**	**5.006**	146.40	126.80	**86.61**
12.11	13	**25.36**	**5.359**	157.43	135.90	**86.33**
12.03	13.92	**26.22**	**5.51**	167.46	144.47	**86.27**

The efficiency diagram below as a function of the Output Voltage, is derived for a constant Output Power of about 100W, evidencing the different performances of the system with the different output voltages.

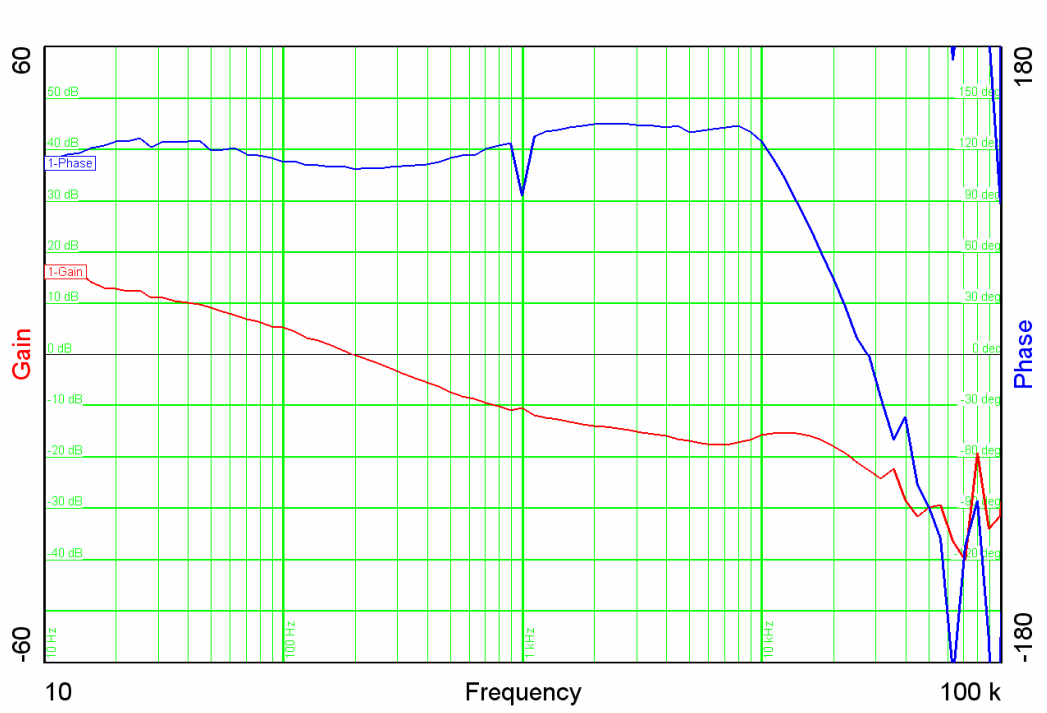


The following table shows the measured values for **Vin=12V, Pout=100W**:

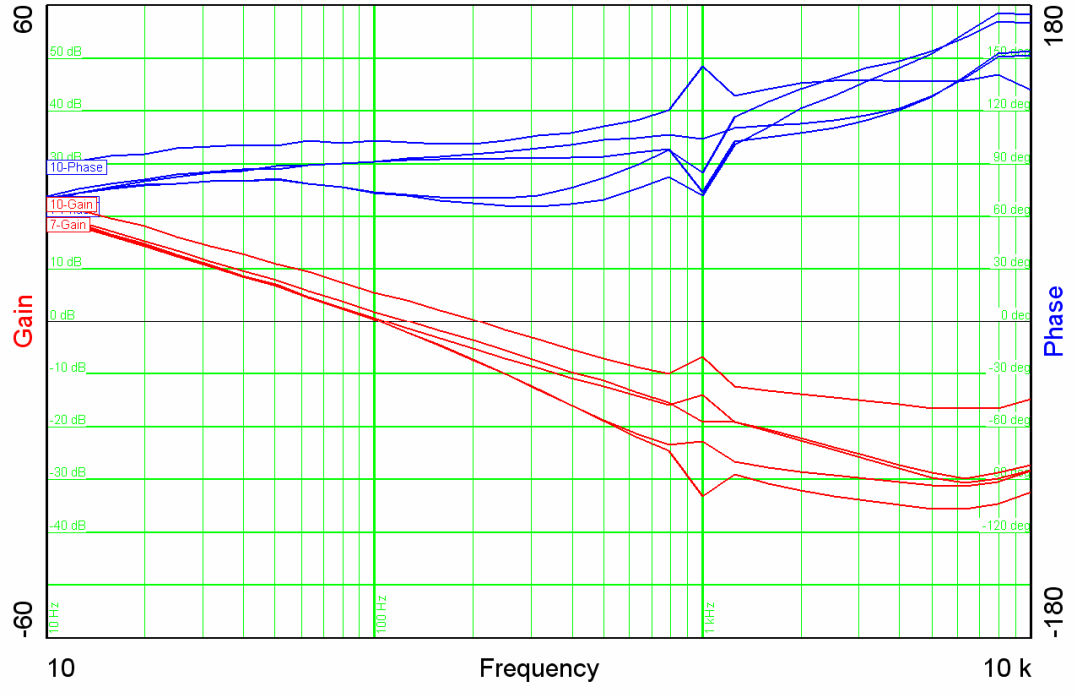
Vin[V]	Iin[A]	Vout[V]	Iout[A]	Pin[W]	Pout[W]	η%
12.32	10.11	**10.84**	**8.692**	124.56	94.22	**75.65**
12.31	10.28	**16**	**6.497**	126.55	103.95	**82.15**
12.35	9.74	**20.63**	**4.999**	120.29	103.13	**85.73**
12.33	10.1	**30.1**	**3.65**	124.53	109.87	**88.22**
12.32	10.09	**34.4**	**3.202**	124.31	110.15	**88.61**

4 Control Loop Frequency Response

The figures below show the open loop response at full load on Output with different Output Voltage



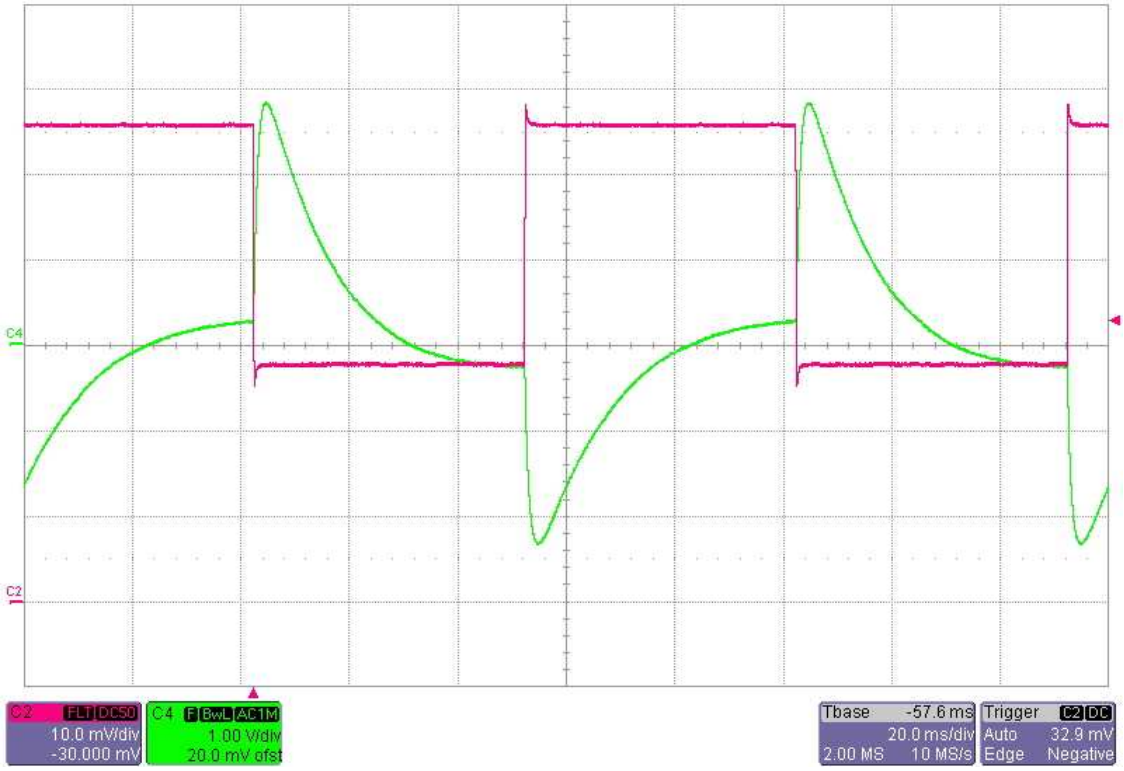
Vout=25V Iout=6A Output



Vout= 35, 20, 15, 10V ; Pout=150W

5 Load Transients

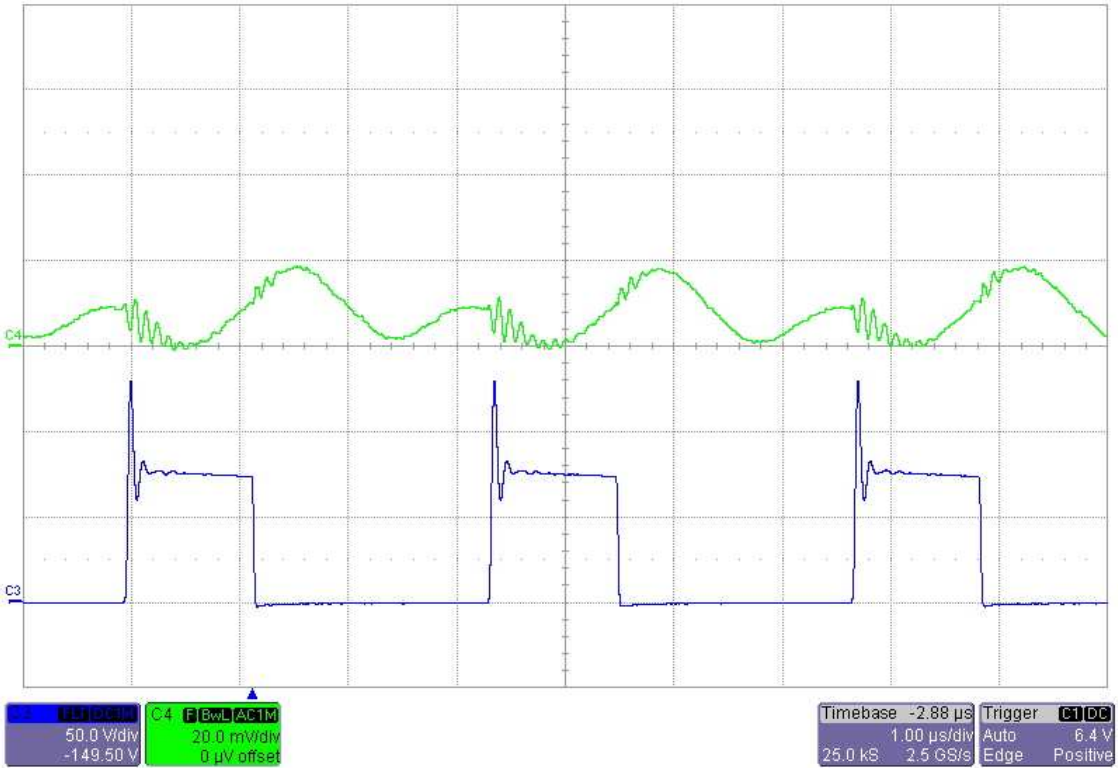
The figures below show the response to load transients. Vout=25V The current on Output is stepping from 3 to 6A output load and viceversa.



CH2 Output Current Step load (10mV/1A), CH4 Output Voltage Changes (AC)

6 Output Ripple Voltage

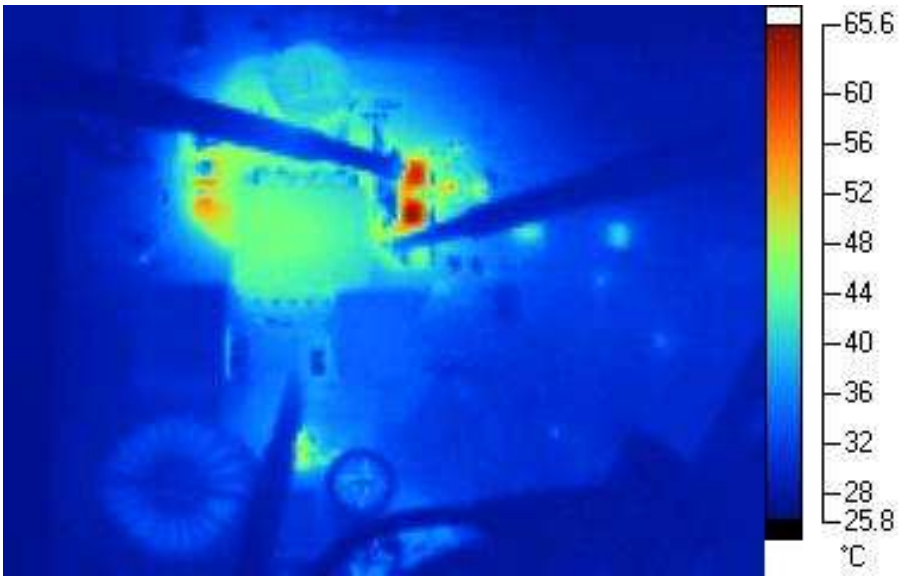
The output ripple voltage is shown in the figure below, for the 25V Output Voltage at full load.



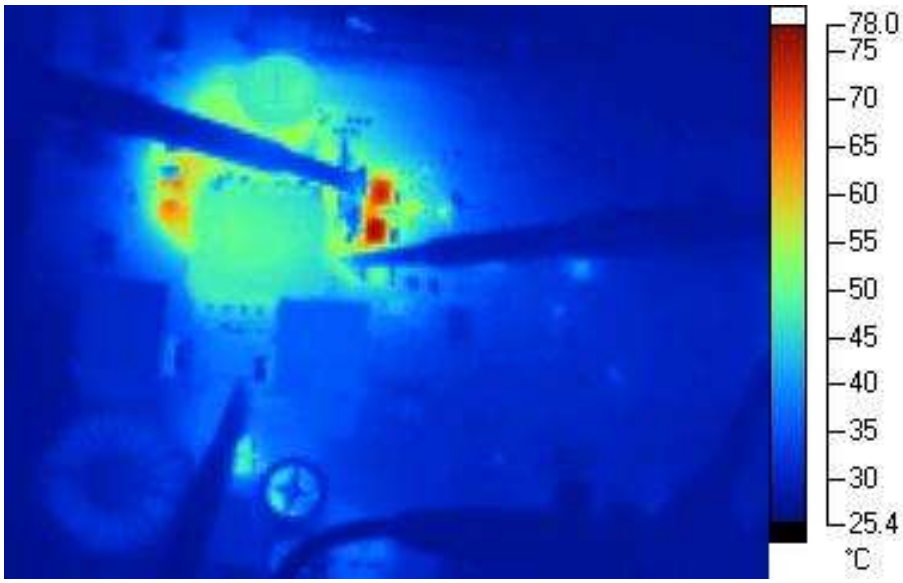
CH4: Output Voltage Ripple @ Vout=25V, Iout=6A

5 Thermal Images

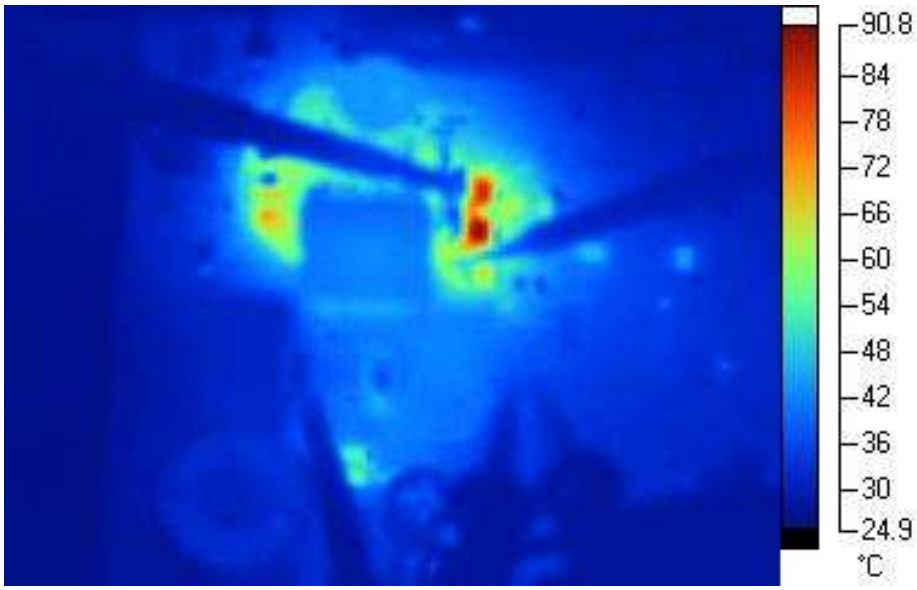
The thermal images of the board (top) are shown in particular for the left side of the board where the first power stage is located.
In the pictures, the two Fixed Outputs are turned off, because their thermal interaction is neglectable while their maximum reached temperature is lower than 60°C at full load, at Tamb=25°C. The different pictures show different performances with increasing output power to full power at Vout=25V, at Tamb=25°C, and the most stressful condition at lowest output voltage and increasing output current.



TOP Side Left side Power stage Pout=115W @ Vout=25V (V_{1PWM}=60%)



TOP Side Left side Power stage Pout=150W @ Vout=25V



TOP Side Left side Power stage Pout=100W @ Vout=14.5V (V_{1PWM}=35%), Iout=7A

IMPORTANT NOTICE

Texas Instruments Incorporated and its subsidiaries (TI) reserve the right to make corrections, modifications, enhancements, improvements, and other changes to its products and services at any time and to discontinue any product or service without notice. Customers should obtain the latest relevant information before placing orders and should verify that such information is current and complete. All products are sold subject to TI's terms and conditions of sale supplied at the time of order acknowledgment.

TI warrants performance of its hardware products to the specifications applicable at the time of sale in accordance with TI's standard warranty. Testing and other quality control techniques are used to the extent TI deems necessary to support this warranty. Except where mandated by government requirements, testing of all parameters of each product is not necessarily performed.

TI assumes no liability for applications assistance or customer product design. Customers are responsible for their products and applications using TI components. To minimize the risks associated with customer products and applications, customers should provide adequate design and operating safeguards.

TI does not warrant or represent that any license, either express or implied, is granted under any TI patent right, copyright, mask work right, or other TI intellectual property right relating to any combination, machine, or process in which TI products or services are used. Information published by TI regarding third-party products or services does not constitute a license from TI to use such products or services or a warranty or endorsement thereof. Use of such information may require a license from a third party under the patents or other intellectual property of the third party, or a license from TI under the patents or other intellectual property of TI.

Reproduction of TI information in TI data books or data sheets is permissible only if reproduction is without alteration and is accompanied by all associated warranties, conditions, limitations, and notices. Reproduction of this information with alteration is an unfair and deceptive business practice. TI is not responsible or liable for such altered documentation. Information of third parties may be subject to additional restrictions.

Resale of TI products or services with statements different from or beyond the parameters stated by TI for that product or service voids all express and any implied warranties for the associated TI product or service and is an unfair and deceptive business practice. TI is not responsible or liable for any such statements.

TI products are not authorized for use in safety-critical applications (such as life support) where a failure of the TI product would reasonably be expected to cause severe personal injury or death, unless officers of the parties have executed an agreement specifically governing such use. Buyers represent that they have all necessary expertise in the safety and regulatory ramifications of their applications, and acknowledge and agree that they are solely responsible for all legal, regulatory and safety-related requirements concerning their products and any use of TI products in such safety-critical applications, notwithstanding any applications-related information or support that may be provided by TI. Further, Buyers must fully indemnify TI and its representatives against any damages arising out of the use of TI products in such safety-critical applications.

TI products are neither designed nor intended for use in military/aerospace applications or environments unless the TI products are specifically designated by TI as military-grade or "enhanced plastic." Only products designated by TI as military-grade meet military specifications. Buyers acknowledge and agree that any such use of TI products which TI has not designated as military-grade is solely at the Buyer's risk, and that they are solely responsible for compliance with all legal and regulatory requirements in connection with such use.

TI products are neither designed nor intended for use in automotive applications or environments unless the specific TI products are designated by TI as compliant with ISO/TS 16949 requirements. Buyers acknowledge and agree that, if they use any non-designated products in automotive applications, TI will not be responsible for any failure to meet such requirements.

Following are URLs where you can obtain information on other Texas Instruments products and application solutions:

Products		**Applications**	
Audio	www.ti.com/audio	Communications and Telecom	www.ti.com/communications
Amplifiers	amplifier.ti.com	Computers and Peripherals	www.ti.com/computers
Data Converters	dataconverter.ti.com	Consumer Electronics	www.ti.com/consumer-apps
DLP® Products	www.dlp.com	Energy and Lighting	www.ti.com/energy
DSP	dsp.ti.com	Industrial	www.ti.com/industrial
Clocks and Timers	www.ti.com/clocks	Medical	www.ti.com/medical
Interface	interface.ti.com	Security	www.ti.com/security
Logic	logic.ti.com	Space, Avionics and Defense	www.ti.com/space-avionics-defense
Power Mgmt	power.ti.com	Transportation and Automotive	www.ti.com/automotive
Microcontrollers	microcontroller.ti.com	Video and Imaging	www.ti.com/video
RFID	www.ti-rfid.com		
OMAP Mobile Processors	www.ti.com/omap		
Wireless Connectivity	www.ti.com/wirelessconnectivity		
	TI E2E Community Home Page		e2e.ti.com

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