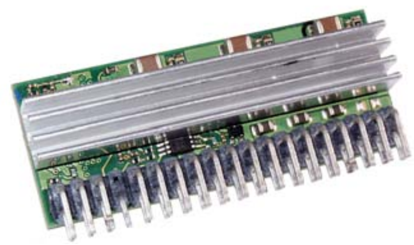
Technical Reference Note

Embedded Power for
Business-Critical Continuity

SIL60C2
Dual Row
60 Amp



Total Power: 240 W
Input Voltage: 4.5 - 13.8 VDC
# of Outputs: Single

Main Entry: **SIL60C2 Dual Row**
Function: **Single In-Line Power**
Usage: **LEDs, ASIC, Memory, FPGAs, Telecom and Networking Equipment, Servers, Industrial Equipment, POL Regulation**

Special Features

- 2 bit VID adjustable output voltage
- Phase shedding for power saving during light loads
- High power density design means reduced board space requirement
- Power good output signal
- Operating ambient temp up to +70 ˚C with suitable derating and forced air cooling
- Remote ON/OFF (active high)
- 0 A minimum load
- Input under-voltage lockout
- EU directive 2002/95/EC compliant for RoHS

Definition:
The SIL60C2 is a new high density open frame non-isolated converter series for space-sensitive applications. Each model has a wide input voltage range (4.5 - 13.8 V) and offers a wide 0.8 - 4.0 V output voltage range with a 60 A load. An external resistor in combination with the 2-bit VIDs allow you to set the output voltage from 0.8 V to 4.0 V. The SIL60C2 offers positive logic enable and over-current protection as standard.

Safety

Designed to meet:
- UL, cUL 60950-1
- (EN60950)

EMERSON
Network Power

General Description

Electrical Description

The SIL60C2 is implemented using a multi-phase synchronous buck topology. A block diagram of the converter is shown in Figure 1. The output is adjustable over a range of 0.8-4.0 V by using a resistor in series with the positive sense line.

The converter can be shut down via the enable pin. This input is run with positive logic that is compatible with popular logic devices. Positive logic implies that the converter is enabled if the input is high, and disabled if it is low (or floating).

The output is monitored for overtemperature, overcurrent and short-circuit conditions. When the PWM controller detects one of the above conditions, it forces the module into hiccup mode.

A typical application is shown in Figure 2.

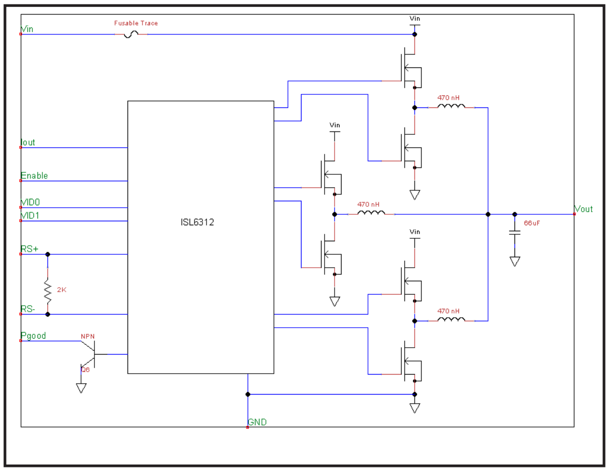


Figure 1 - Electrical Block Diagram

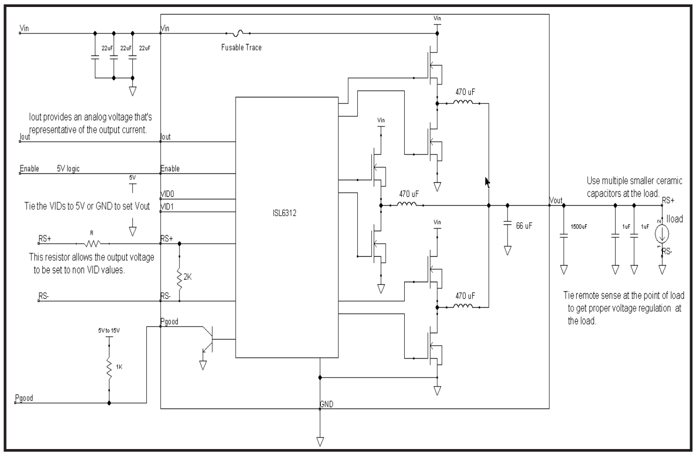


Figure 2 - Standard Application Drawing

Wide Operating Temperature Range

The SIL60C2's ability to accommodate a wide range of ambient temperatures is the result of its extremely high power conversion efficiency and resultant low power dissipation, combined with the excellent thermal performance of the PCB substrate. The maximum output power that the module can deliver depends on a number of parameters, primarily:

- Input voltage range
- Output load current
- Air velocity (forced or natural convection)
- Mounting orientation of target application PCB, i.e., vertical mount, or mechanically tied down (especially important in natural convection conditions).
- Target application PCB design, especially ground planes. These can be effective heatsinks for the converter.

The SIL60C2 module has an operating temperature range of 0 °C to 70 °C with suitable derating and/or forced air cooling.

Features and Functions

Output Voltage Adjustment

The output voltage on all models is adjustable from 0.8-4.0 V.

Setting Output Voltage

Default output voltage is set with the 2 bit VID as follows:

Vid1	Vid0	Vout
1	1	0.8 V
1	0	1.0 V
0	1	1.2 V
0	0	1.4 V

The output voltage may be optionally adjusted with a resistor placed in the series with the sense line, from 0.8 V to 4.0 V.

To trim the output voltage, place a resistor in series with pin 6 (RS+). The formula for calculating the value of this resistor is:

$$Rtrim = 2000 \times \left(\frac{V_{out} - VID\_SET}{VID\_SET} \right)$$

*When trimming output voltage always choose the nearest VID V_{out} setting.

Figure 3 - Setting Output Voltage

Undervoltage Lockout

The default undervoltage lockout is set at 4.5 V.

Current Limit and Short-Circuit Protection

The SIL60C2 model has a built-in non-latching current limit function and continuous short-circuit protection. When an overcurrent condition occurs, the module goes into hiccup mode, where it attempts to power up periodically to determine if the problem persists.

Note that none of the module specifications are guaranteed when the unit is operated in an overcurrent condition.

Features and Functions (cont'd)

Enable

The enable pin allows external circuitry to put the SIL60C2 converter into a low dissipation standby mode. Positive logic enable pin is available as standard.

The unit is turned on if the enable pin is high. Pulling the pin low will disable the unit. To guarantee turn-on, the enable voltage must be above 2.4 V. To disable, the enable voltage must be pulled below 0.8 V (or floating).

Figures 4 and 5 show various circuits for driving the Enable feature. The Enable input can be driven through a discrete device (i.e. a bipolar signal transistor) or directly from a logic gate output. The output of the logic gate may be an open-collector (or open-drain) device.

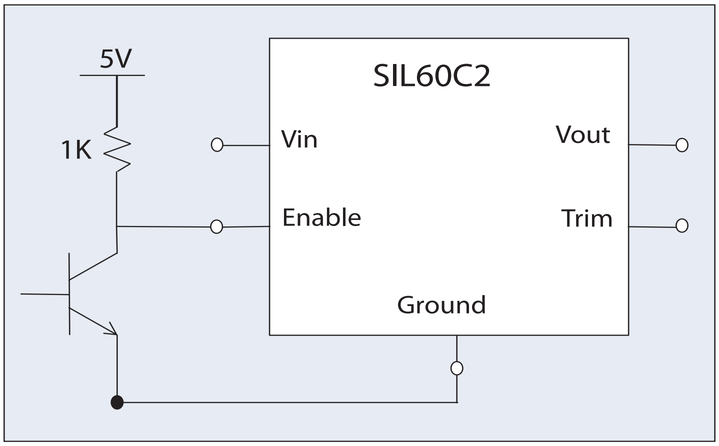


Figure 4 - Enable Input Drive Circuit for Non-Isolated Biopolar

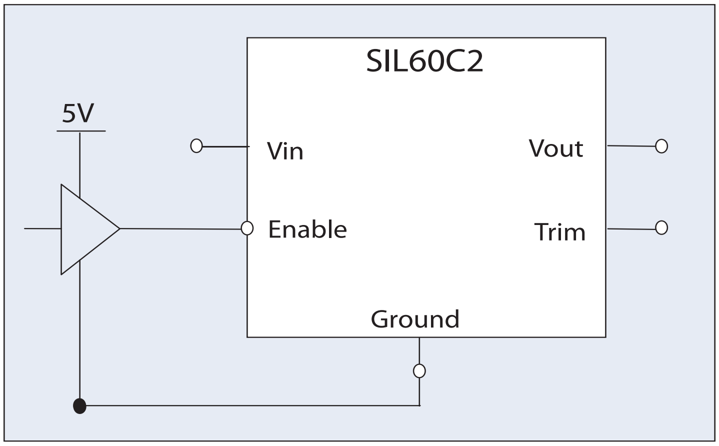


Figure 5 - Enable Input Drive Circuit for Logic Driver

Power Good

The SIL60C2 modules have a power good indicator output. This output pin uses positive logic and is open collector. Also, the power good output is able to sink 4 mA. The power good signal should not be pulled any higher than15 V.

When the output of the module is within ±10% of the nominal set point, the power good pin can be pulled high.

Features and Functions (cont'd)

Overtemperature Protection (OTP)

The SIL60C2 is equipped with non-latching overtemperature protection. A temperature sensor monitors the temperature of the PCB near one the main FETs. If the PCB temperature exceeds the 130 °C threshold the converter will shut down, disabling the output. When the PCB temperature has decreased to 100 °C the converter will automatically restart.

The converter might experience overtemperature conditions during a persistent overload on the output. Overload conditions can be caused by external faults. OTP might also be entered due to a loss of control of the environmental conditions (e.g. An increase in the converter's ambient temperature due to a failing fan).

Undervoltage Lockout

The SIL60C2 has built-in undervoltage lockout to ensure reliable output power. The lockout prevents the unit from operating when the input voltage is too low.

Remote Sense Compensation

The remote sense compensation feature minimizes the effect of resistance in the distribution system and facilitates accurate voltage regulation at the load terminals or another selected point. The remote sense lines will carry very little current and hence do not require a large cross-sectional area. However, if the sense lines are routed on a PCB, they should be located close to a ground plane in order to minimize any noise coupled onto the lines that might impair control loop stability. The module will compensate for a maximum drop of 400 mV. Remember that when using remote sense compensation all the resistance, parasitic inductance and capacitance of the distribution system are incorporated into the feedback loop of the power module. This can have an effect on the modules compensation capabilities, affecting its stability and dynamic response.

Output Capacitance

The SIL60C2 has output capacitors inside the converter. 1500 μF of capacitance is required for stabilization, as a minimum. When powering loads with large dynamic current requirements, improved voltage regulation is obtained by inserting low ESR capacitors as close as possible to the load. Low ESR ceramic capacitors will handle the short duration high frequency components of the dynamic current requirement. In addition, higher values of electrolytic capacitors should be used to handle the mid-frequency components.

Features and Functions (cont'd)

Output Capacitance (cont'd)
It is equally important to use good design practices when configuring the dc distribution system. Low resistance and low inductance PCB layout traces should be utilized, particularly in the high current output section. Remember that the capacitance of the distribution system and the associated ESR are within the feedback loop of the power capabilities, thus affecting the stability and dynamic response of the module. Note that the maximum rated value of output capacitance varies between models and for each output voltage setpoint. If there are additional concerns about output capacitance see your sales representative to schedule a test.

Parameter	Test Conditions	Min	Typ	Max	Units
Absolute Maximums					
Input Voltage		0		13.8	V
Enable Voltage		0		5	V
Operating Ambient Temperature		0		70	°C
Non-Operating Ambient Temperature		-40		125	°C
Input Specifications					
Input Voltage		4.5		13.8	V
Input Current	Minimum load		65		mA
	Remote ON/OFF			20	mA
Input Current	at Iout max			20	A
Start-up time	Power-up		<20		ms
	Remote ON/OFF		<20		ms
Output Specifications					
Output Voltage		0.8		4.0	V
Output Setpoint Accuracy	with VID	-1.0		+1.0	%
Output Regulation (Line)	Low line to High line	-0.3		+0.3	%
Output Regulation (Load)	Full load to minimum load	-0.2		+0.2	%
Load line			0.225 μΩ		
Output Current		0		60	A
Output Capacitance (Internal)			66		uF
Output Capacitance (External)			1500		uF
Output Ripple/Noise (Peak/Peak)	5 Vin, 0.8 Vout, 0 uF Cout			40	mV
	12 Vin, 2.5 Vout, 0 uF Cout			40	mV
	12 Vin, 5 Vout, 0 uF Cout			40	mV
Efficiency	12 Vin, 1.2 Vout, 60 Aout		88.5		%
	12 Vin, 1.5 Vout, 60 Aout		90.5		%
	12 Vin, 1.8 Vout, 60 Aout		91.5		%
Dynamic Load Response (Peak Deviation)	12 Vin, 1.5 Vout, 4.5-6.0 at 25 A/us, 1500 uF Cout		38		mV
	12 Vin, 1.8 Vout, 4.5-6.0 at 20 A/us, 1500 uF Cout		43		mV
Dynamic Load Response (Settling Time)	12 Vin, 1.5 Vout, 4.5-6.0 at 25 A/us, 1500 uF Cout		40		us
	12 Vin, 1.8 Vout, 4.5-6.0 at 20 A/us, 1500 uF Cout		40		us

Parameter	Test Conditions	Min	Typ	Max	Units
Turn On Specifications					
Turn On Delay (with Vin)			3		ms
Turn On Delay (with Enable)			3		ms
Output Rise Time	10% - 90%			300	ms
Enable Specifications					
Signal Low (Unit Off)		0		0.8	V
Signal Low Current	12 Vin	0		0.5	mA
Signal High (Unit On)			2.4		V
Signal High Current				0.5	µA
Protection Specifications					
Over Current Protection	Hiccup Mode		102		A
Input Under Voltage (Rising)			4.5		V
Input Under Voltage (Falling)			4		V
General Specifications					
MTBF	Telcordia SR-332		TBD		Hours
Weight			27.1		g
Switching Frequency	Per Phase		300		kHz
Material Ratings					
Flammability			UL94V-0		
Material Type			FR4 PCB		

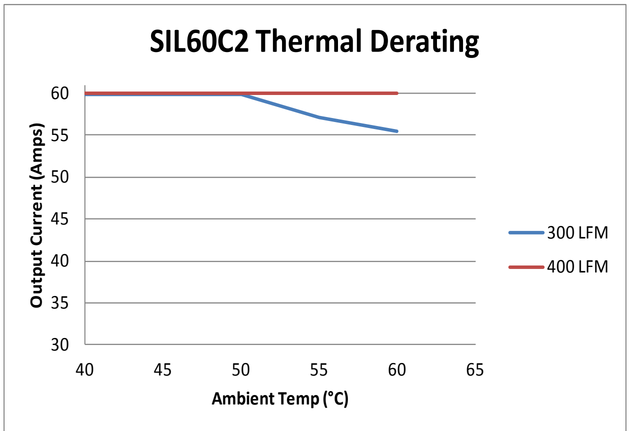


Figure 6: Thermal Derating Curve

Figure 7 Efficiency

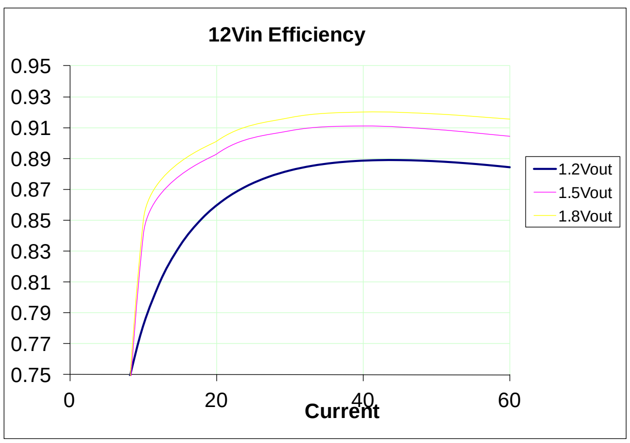


Figure 8: Efficiency

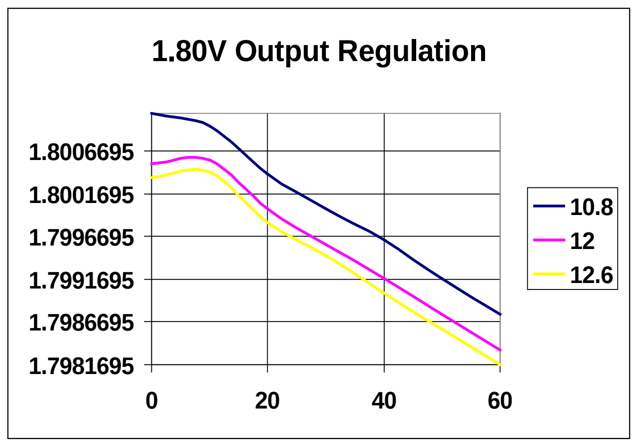


Figure 9: Regulation

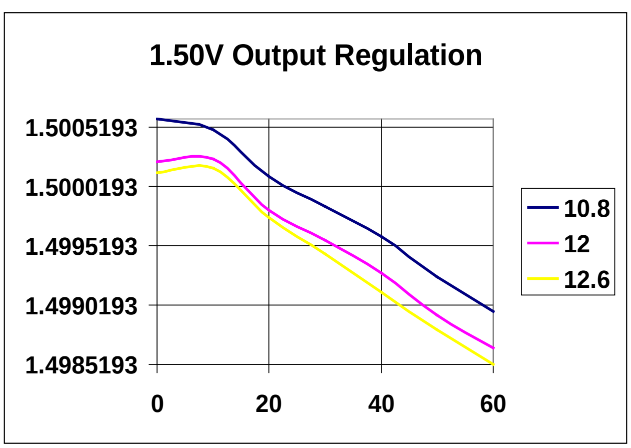


Figure 10: Regulation

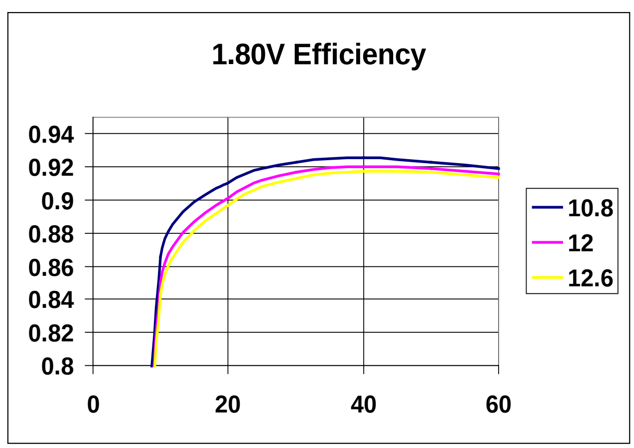


Figure 11: Efficiency

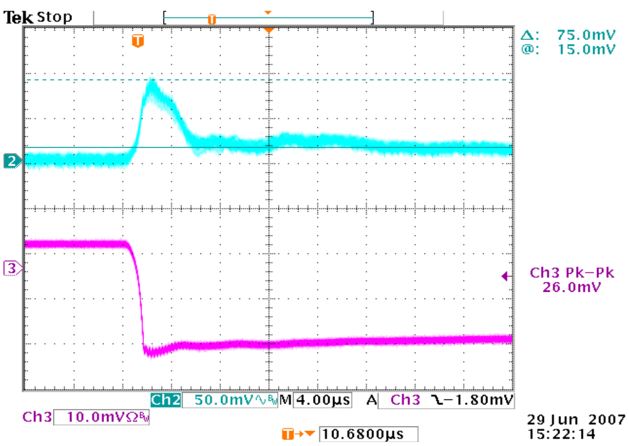


Figure 12: 1.5 Vout Transient Response with 25A step
(with 3x560uF Oscon capacitors on output)

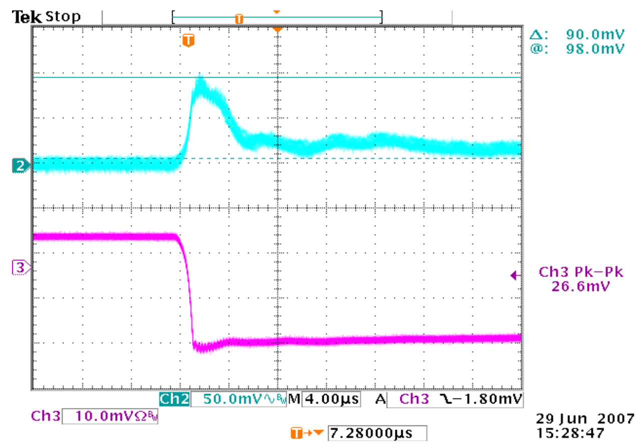


Figure 13: 1.8 Vout Transient Response with 20A step
(with 3x560uF Oscon capacitors on output)

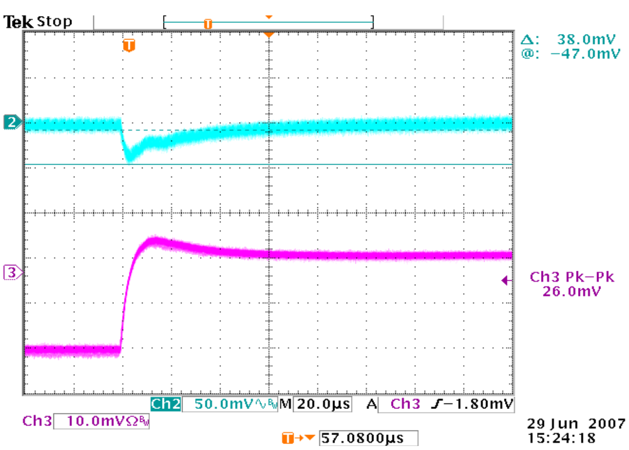


Figure 14: 1.5 Vout Transient Response with 25A step
(with 3x560uF Oscon capacitors on output)

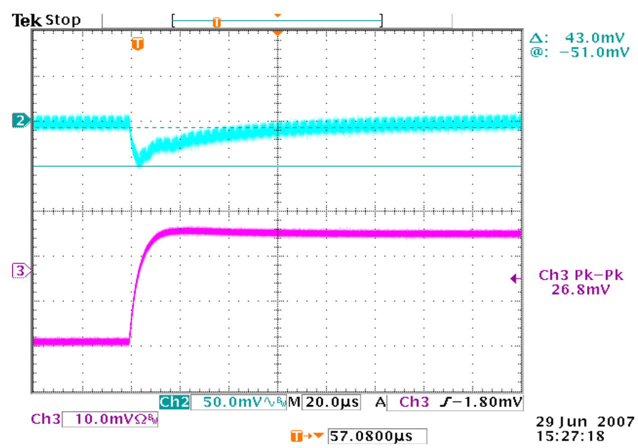


Figure 15: 1.8 Vout Transient Response with 20A step
(with 3x560uF Oscon capacitors on output)

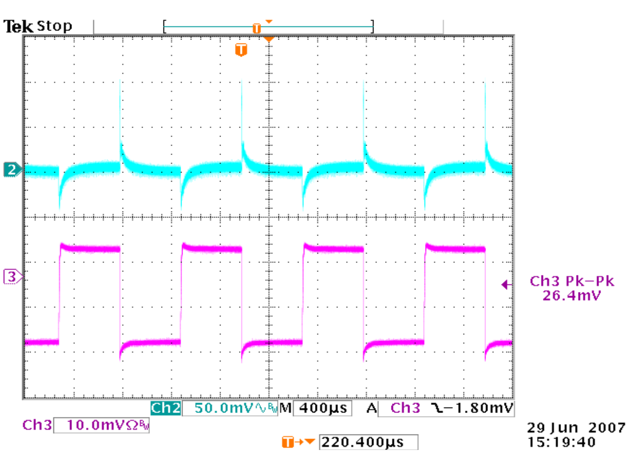


Figure 16: 1.5 Vout Transient Response with 25A step
(with 3x560uF Oscon capacitors on output)

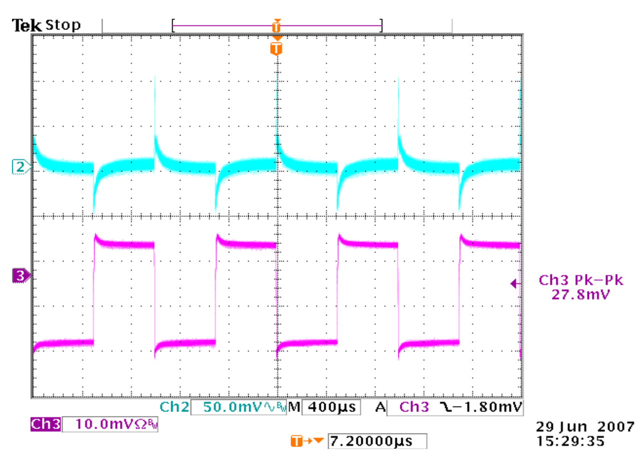


Figure 17: 1.8 Vout Transient Response with 20A step
(with 3x560uF Oscon capacitors on output)

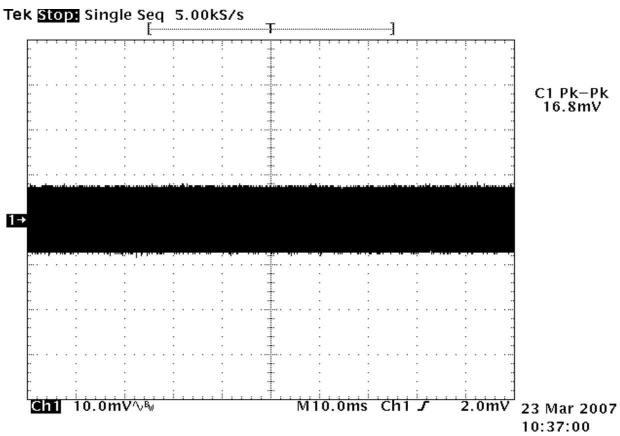


Figure 18 : Output Noise Vin 11, Vout 1.8 Iin 0.3, Iout 0.06

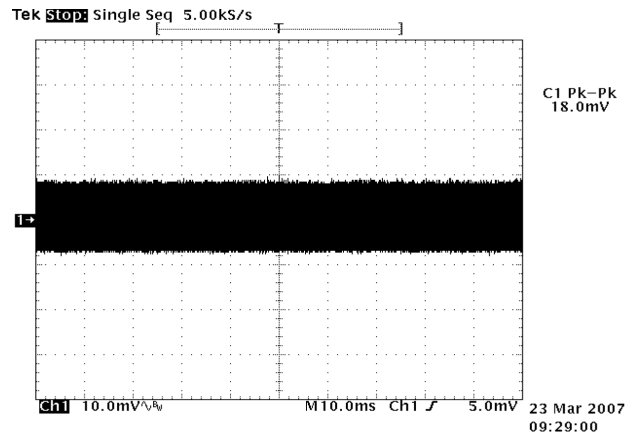


Figure 19: Output Noise Vin 11, Vout 1.5 Iin 0.22, Iout 0.06

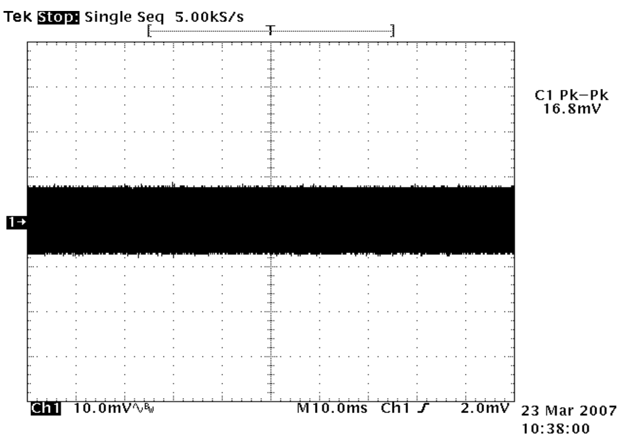


Figure 20: Output Noise Vin 11, Vout 1.8, Iin 3.7, Iout 20

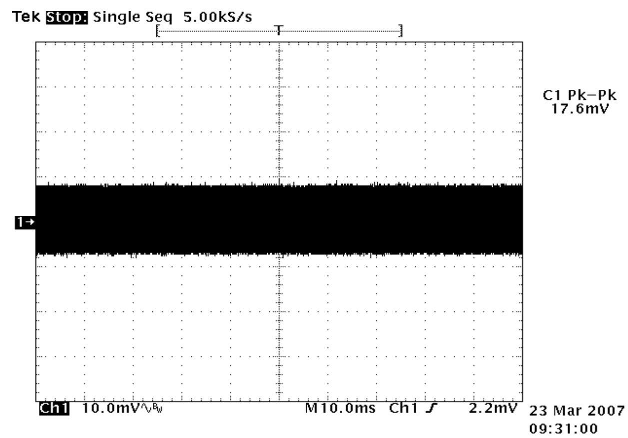


Figure 21: Output Noise Vin 11, Vout 1.5, Iin 3.1, Iout 20

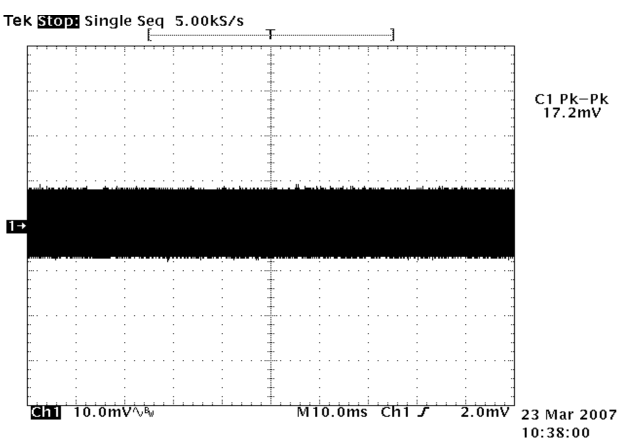


Figure 22: Output Noise Vin 11, Vout 1.9, Iin 7.4, Iout 40

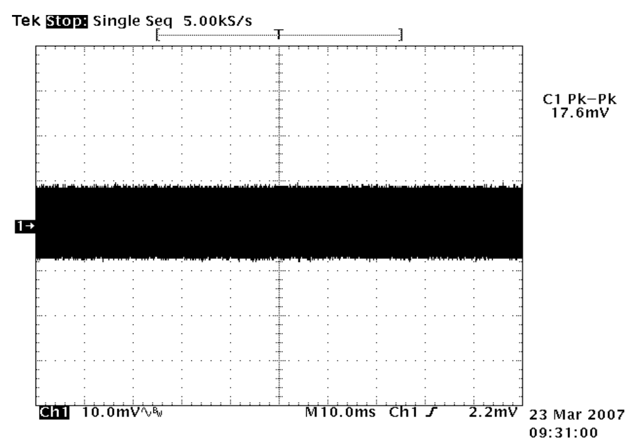


Figure 23: Output Noise Vin 11, Vout 1.6, Iin 6.3, Iout 40

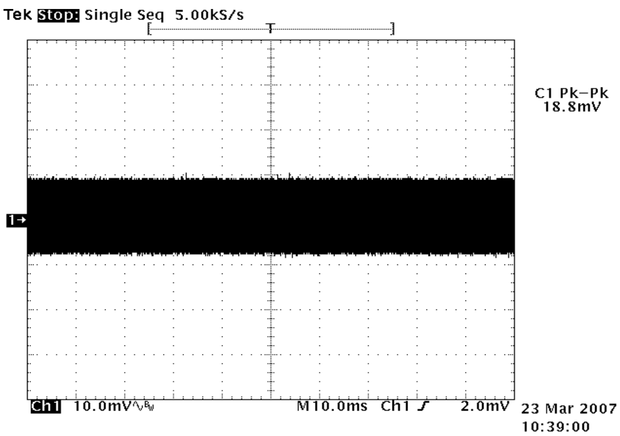


Figure 24: Output Noise Vin 11, Vout 1.9, Iin 11.4, Iout 60

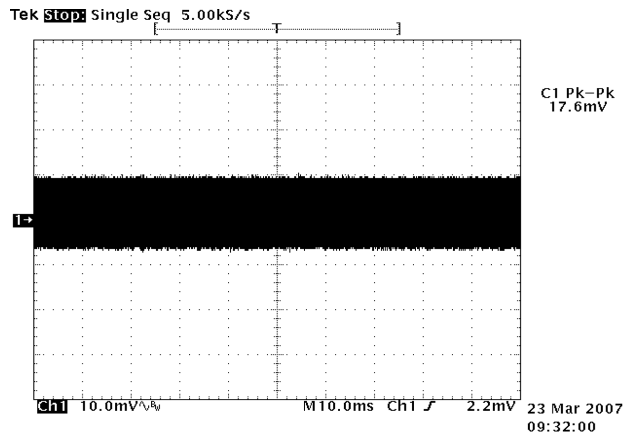


Figure 25: Output Noise Vin 11, Vout 1.6, Iin 9.7, Iout 60

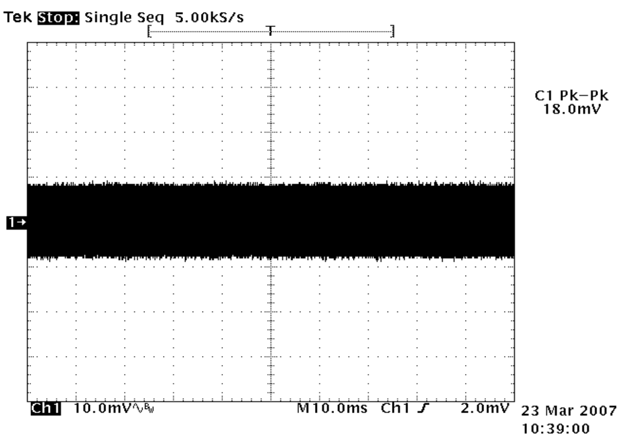


Figure 26: Output Noise Vin 12, Vout 1.8 ,Iin 0.3, Iout 0.06

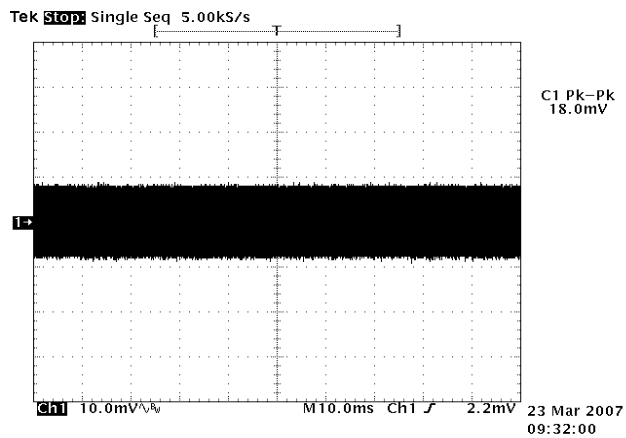


Figure 27: Output Noise Vin 12, Vout 1.5 ,Iin 0.2, Iout 0.06

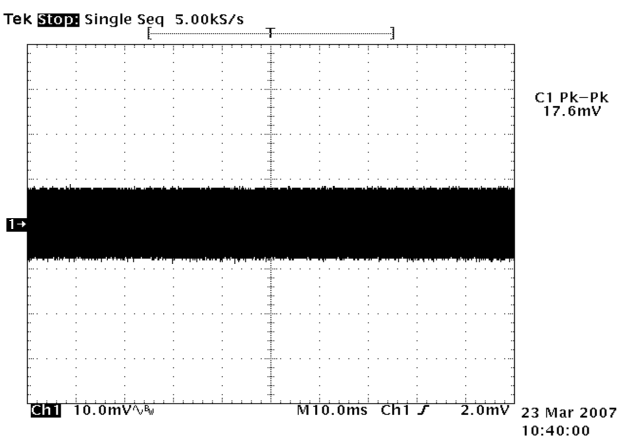


Figure 28: Output Noise Vin 12, Vout 1.8 ,Iin 3.4, Iout 20

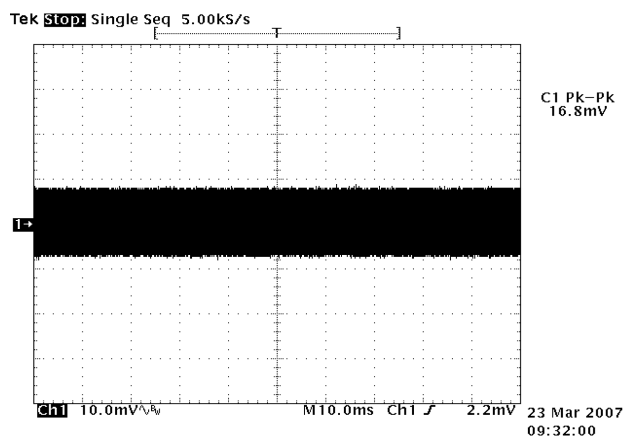


Figure 29: Output Noise Vin 12, Vout 1.5 ,Iin 0.3, Iout 20

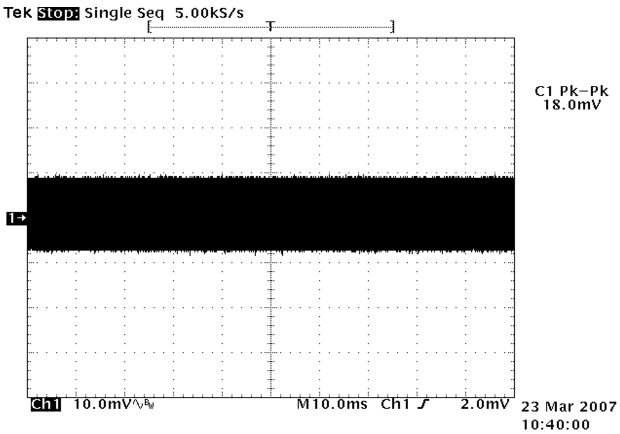


Figure 30: Output Noise Vin 12, Vout 1.9 ,Iin 6.7, Iout 40

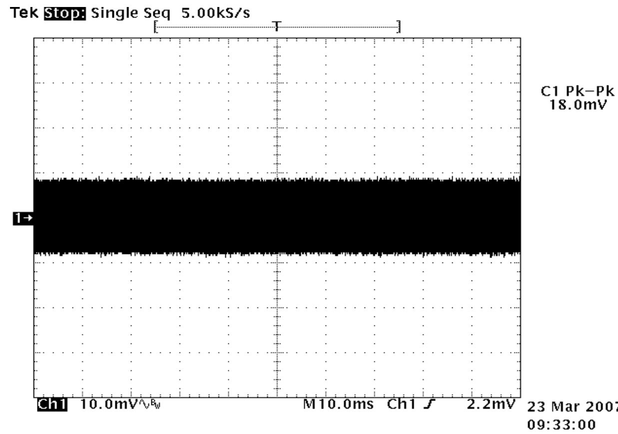


Figure 31: Output Noise Vin 12, Vout 1.5 ,Iin 3, Iout 20

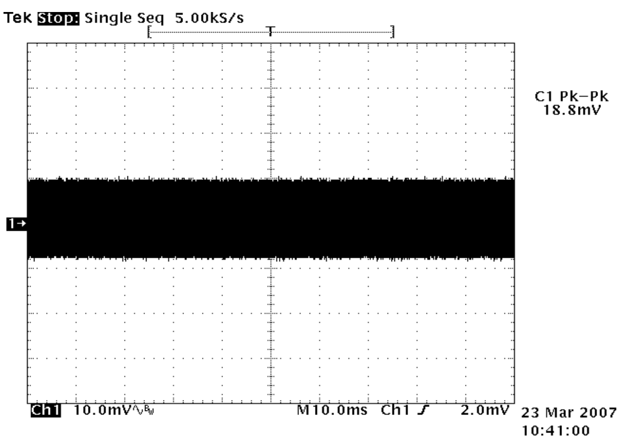


Figure 32: Output Noise Vin 12, Vout 1.9 ,Iin 10, Iout 60

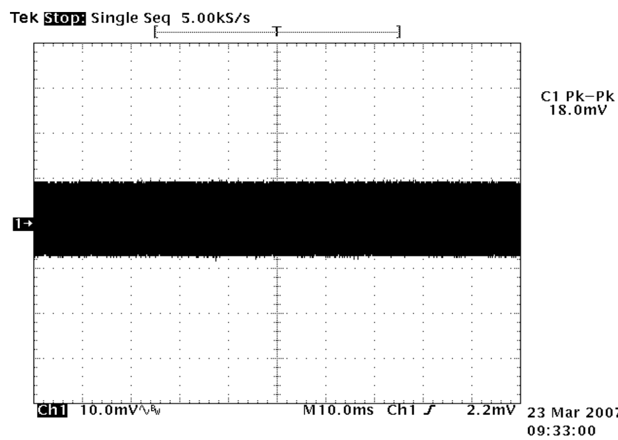


Figure 33: Output Noise Vin 12, Vout 1.6 ,Iin 8.7, Iout 60

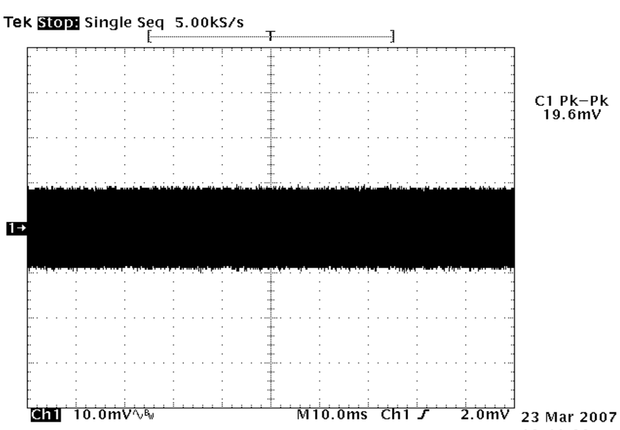


Figure 34: Output Noise Vin 13, Vout 1.9 ,Iin 0.3, Iout 0.06

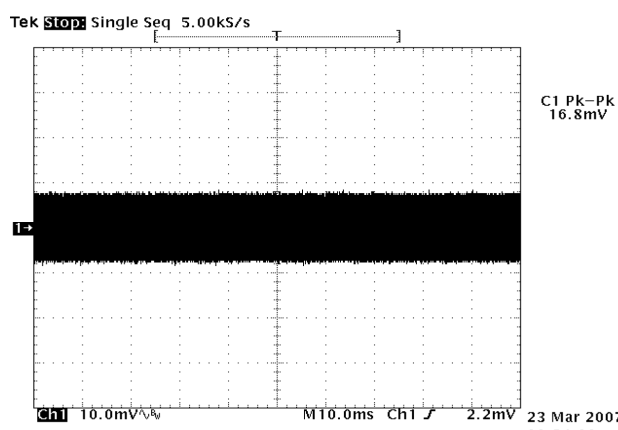


Figure 35: Output Noise Vin 13, Vout 1.5 ,Iin 0.23, Iout 0.06

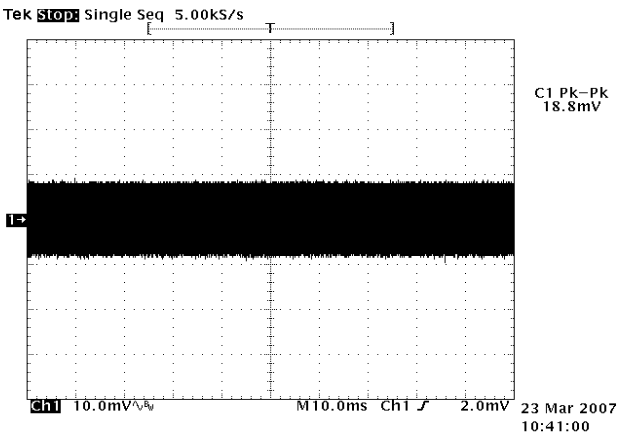


Figure 36: Output Noise Vin 13, Vout 1.8 ,Iin 0.3, Iout 20

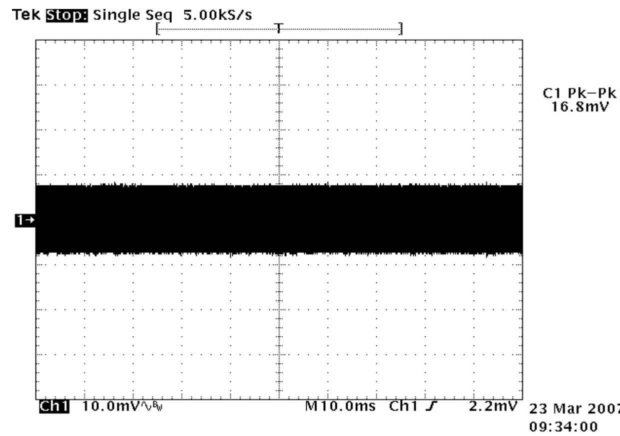


Figure 37: Output Noise Vin 13, Vout 1.5 ,Iin 2.7 Iout 20

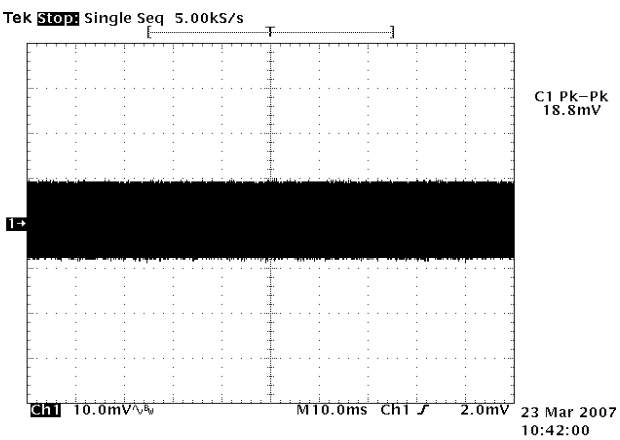


Figure 38: Output Noise Vin 13, Vout 1.9 ,Iin 6.4, Iout 40

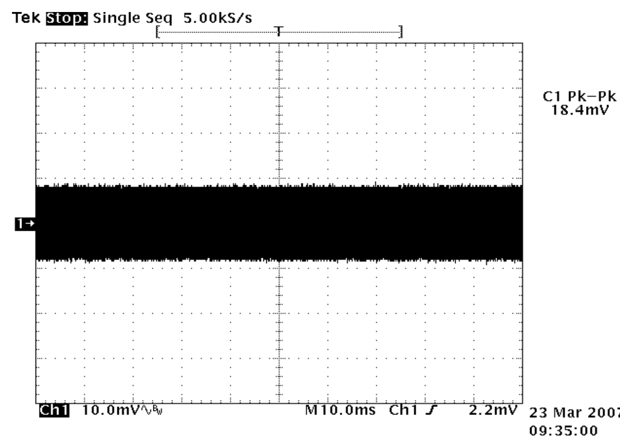


Figure 39: Output Noise Vin 13, Vout 1.6 ,Iin 5.4, Iout 40

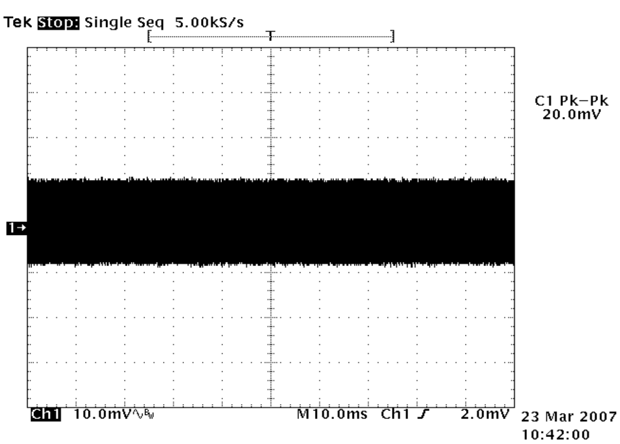


Figure 40: Output Noise Vin 13, Vout 1.9 ,Iin 9.8, Iout 60

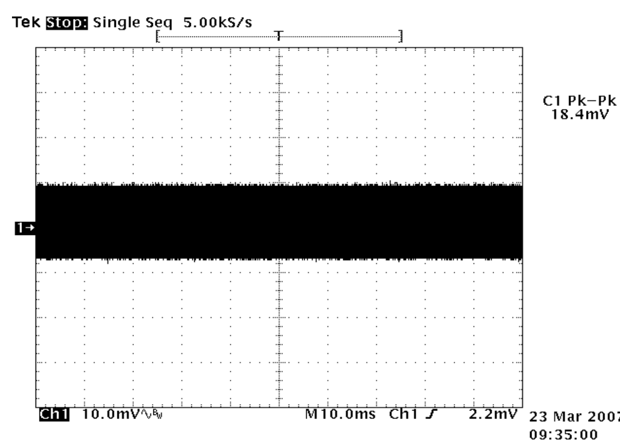


Figure 41: Output Noise Vin 13, Vout 1.6 ,Iin 8.3, Iout 60

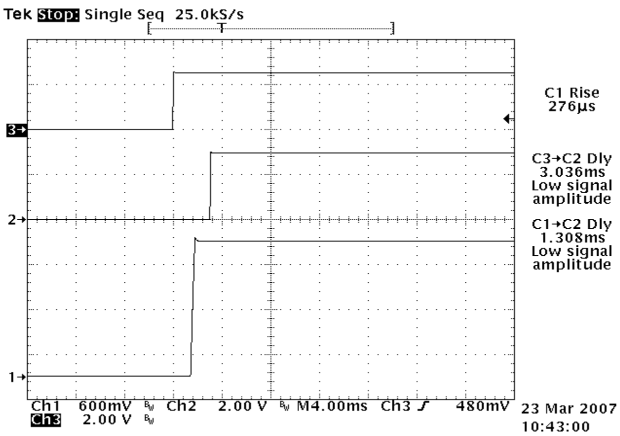


Figure 42: Turn On Vin 10.8, Vout 1.8, Iin 0.3, Iout 0.6

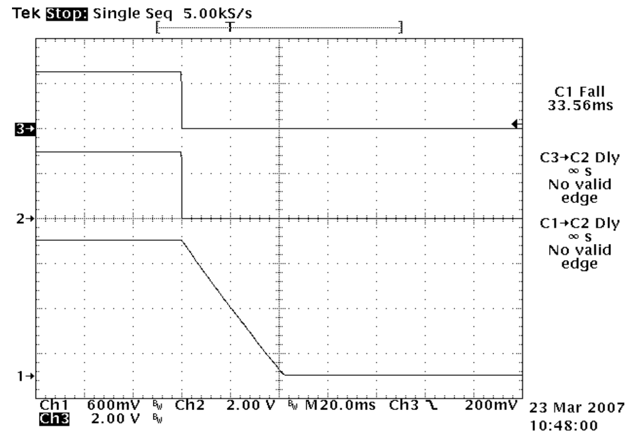


Figure 43: Turn Off Vin 10.8, Vout 1.8, Iin 0.3, Iout 0.6

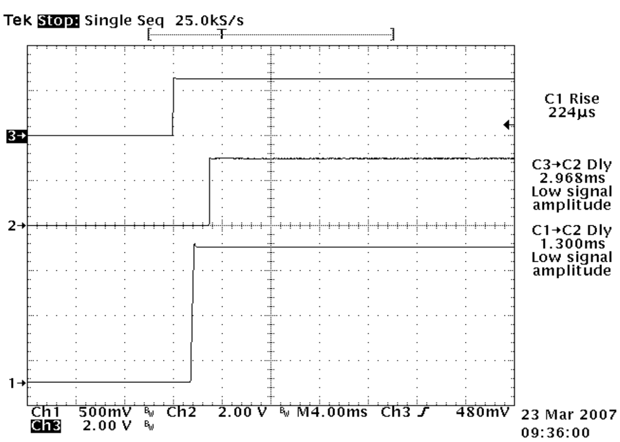


Figure 44: Turn On Vin 11, Vout 1.5, Iin 0.03, Iout 0.6

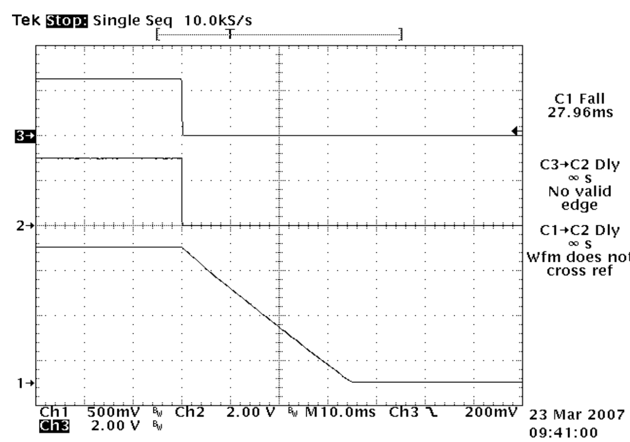


Figure 45: Turn Off Vin 11, Vout 1.5, Iin 0.03, Iout 0.6

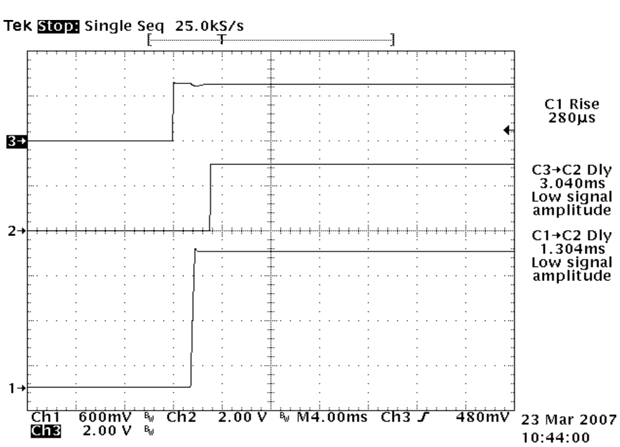


Figure 46: Turn On Vin 10.8, Vout 1.8, Iin 3.7, Iout 20

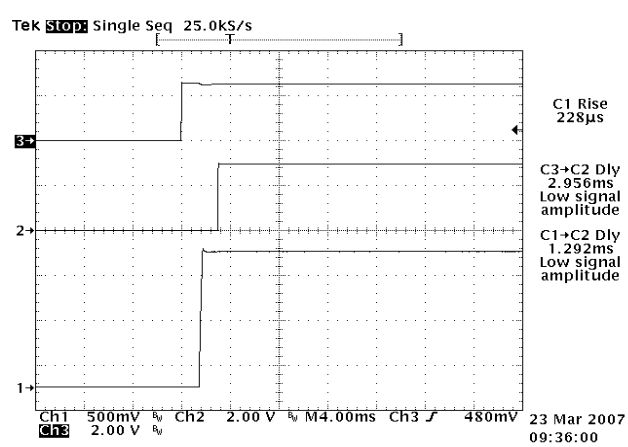


Figure 47: Turn On Vin 11, Vout 1.5, Iin 3, Iout 20

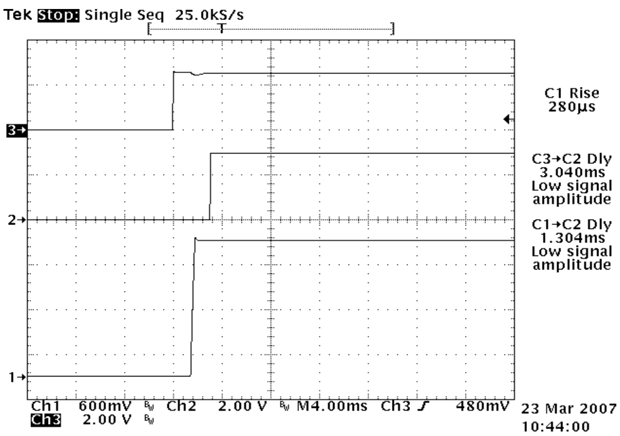


Figure 48: Turn On Vin 11, Vout 1.9, Iin 7, Iout 40

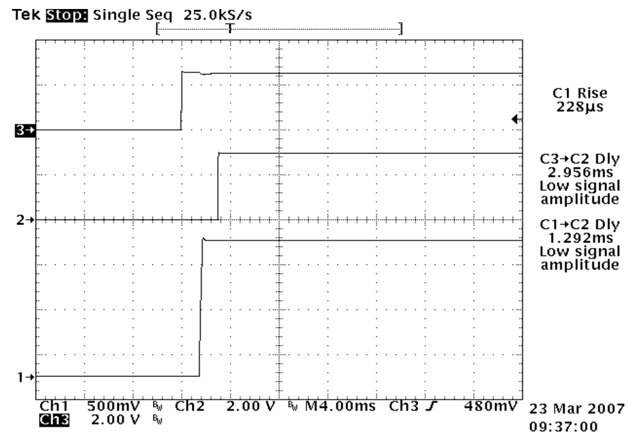


Figure 49: Turn On Vin 11, Vout 1.6, Iin 6, Iout 40

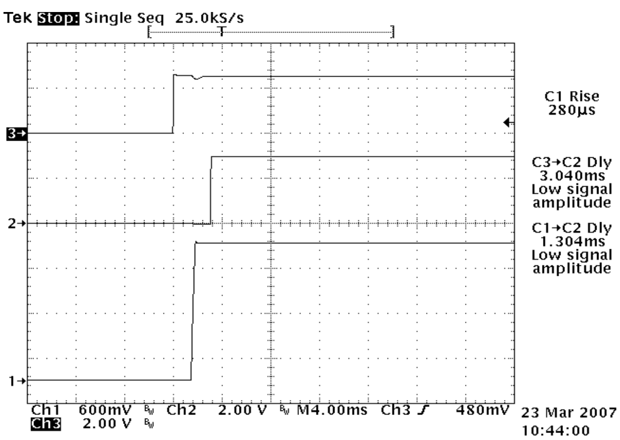


Figure 50: Turn On Vin 11, Vout 1.9, Iin, 11, Iout 60

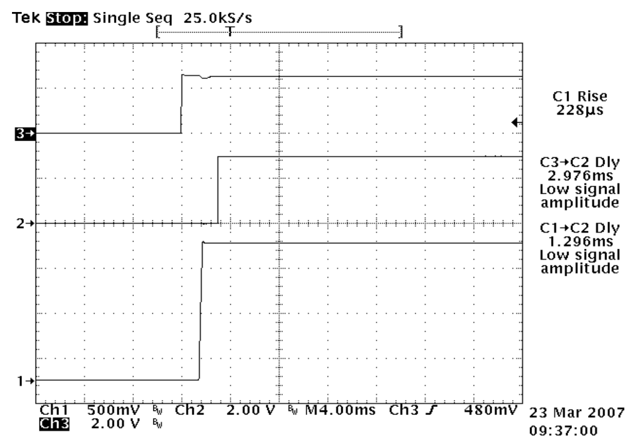


Figure 51: Turn On Vin 11, Vout 1.6, Iin 10, Iout 60

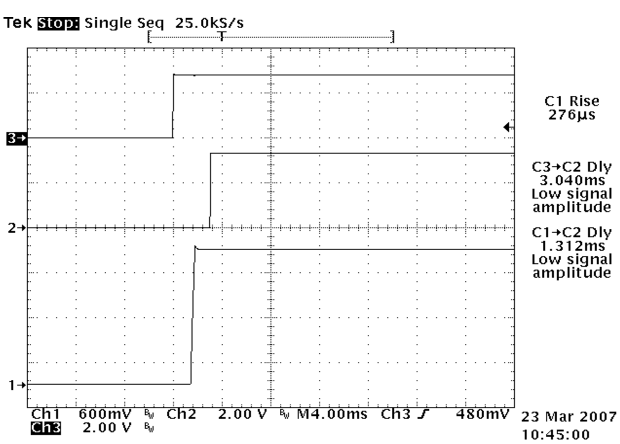


Figure 52: Turn On Vin 12, Vout 1.8, Iin 0.3, Iout 0.06

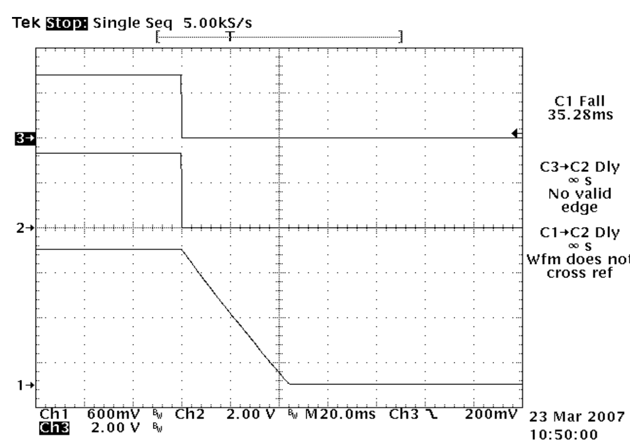


Figure 53: Turn Off Vin 12, Vout 1.8, Iin 0.3, Iout 0.06

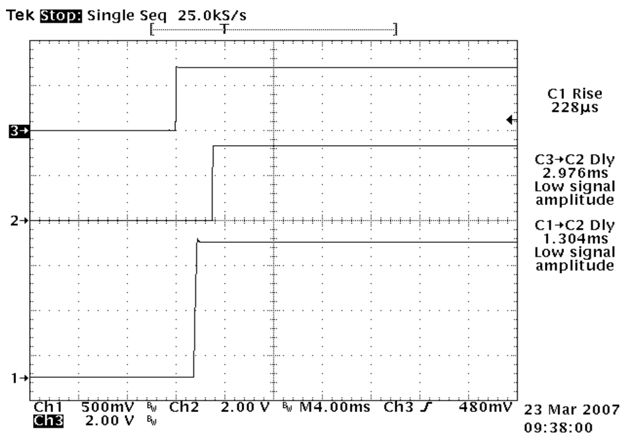


Figure 54: Turn On Vin 12, Vout 1.5, Iin 0.3, Iout 0.06

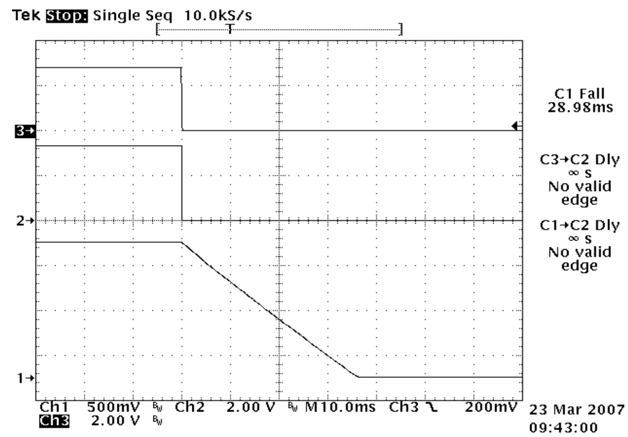


Figure 55: Turn Off Vin 12, Vout 1.5, Iin 0.3, Iout 0.06

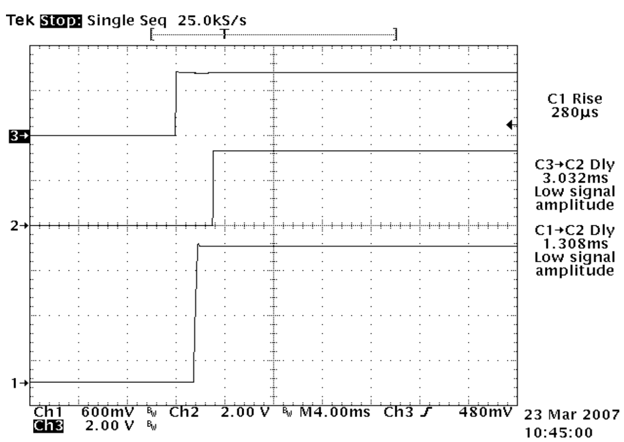


Figure 56: Turn On Vin 12, Vout 1.9, Iin 3, Iout 20

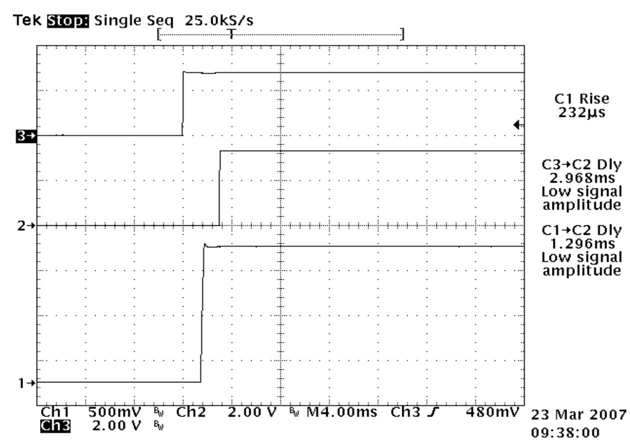


Figure 57: Turn On Vin12, Vout 1.5, Iin 3, Iout 20

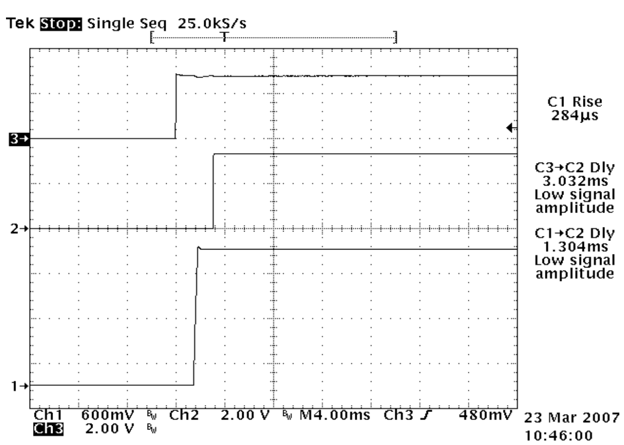


Figure 58: Turn On Vin 12, Vout 1.9, Iin 7, Iout 40

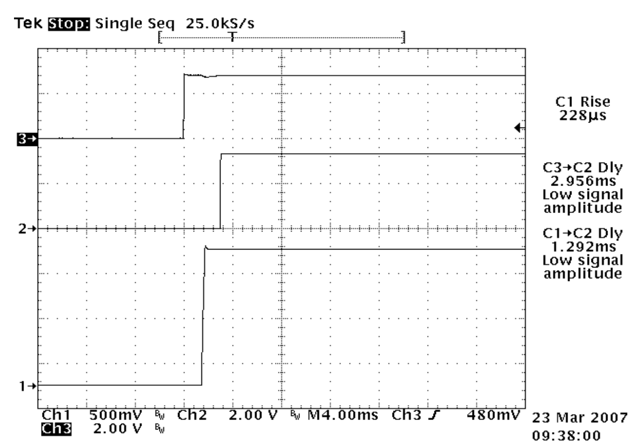


Figure 59: Turn On Vin 12, Vout 1.6, Iin 6, Iout 40

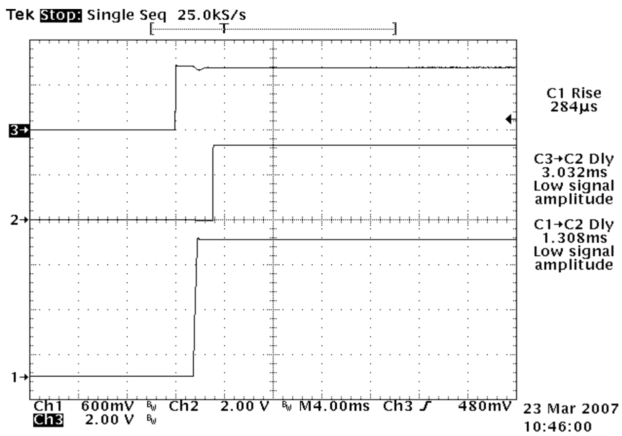


Figure 60: Turn On Vin 12, Vout 1.9, Iin 10, Iout 60

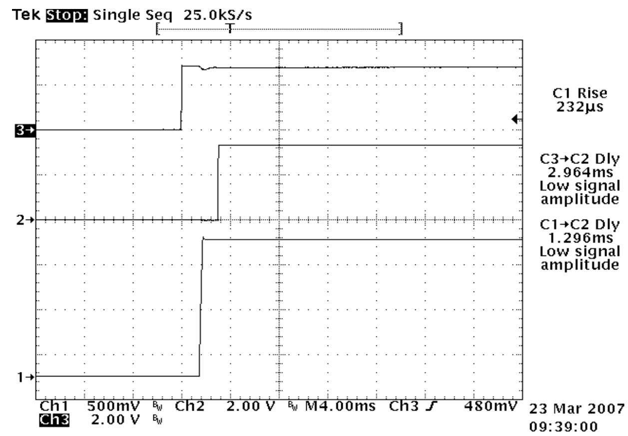


Figure 61: Turn On Vin 12, Vout 1.6, Iin 9, Iout 60

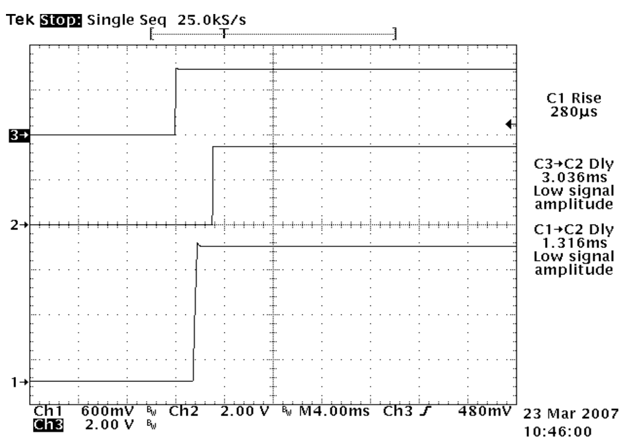


Figure 62: Turn On Vin 13, Vout 1.8, Iin 0.3, Iout 0.06

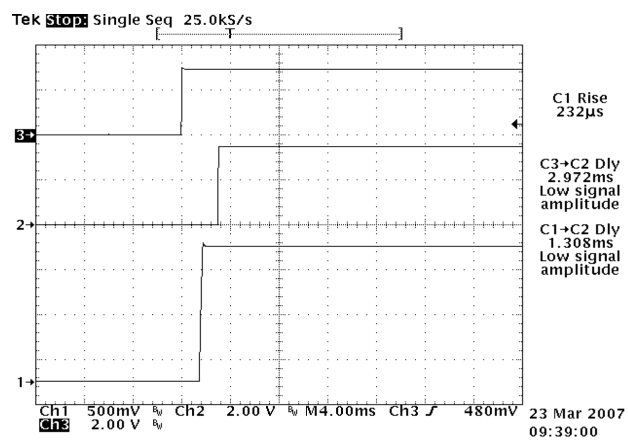


Figure 63: Turn On Vin 13, Vout 1.5, Iin 0.03, Iout 0.06

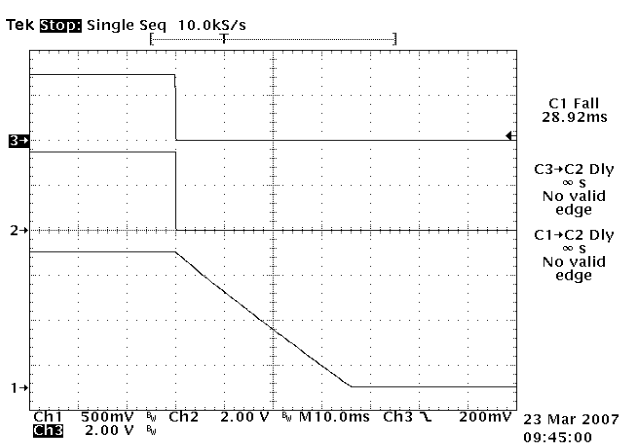


Figure 64: Turn Off Vin 13, Vout 1.5, Iin 0.03, Iout 0.06

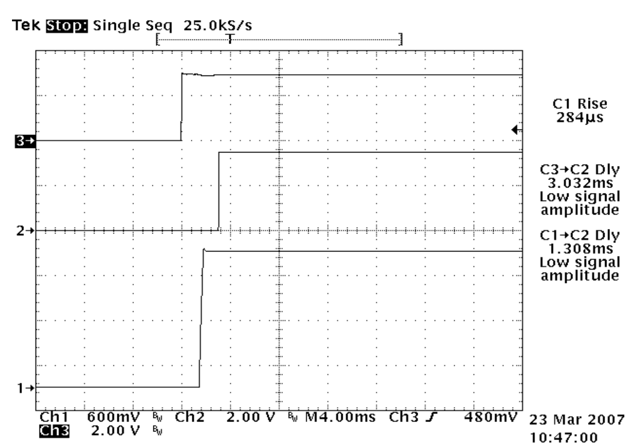


Figure 65: Turn On Vin 13, Vout 1.5, Iin 3, Iout 20

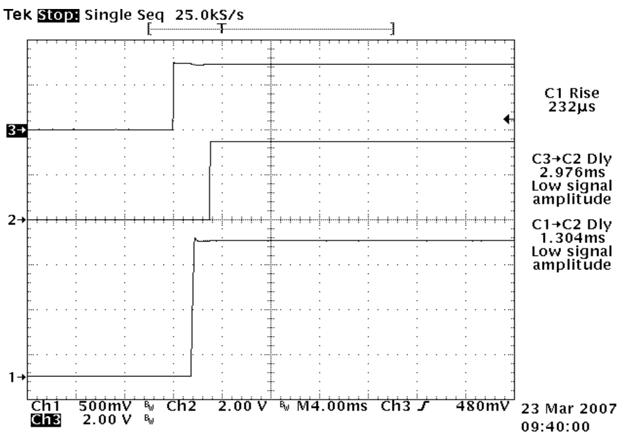


Figure 66: Turn On Vin 13, Vout 1.9, Iin 7, Iout 40

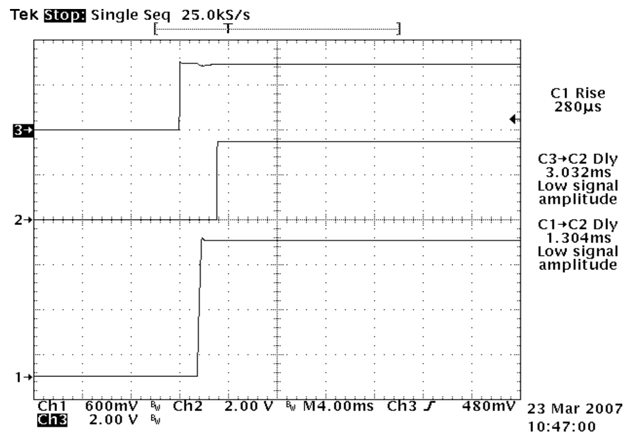


Figure 67: Turn On Vin 13, Vout 1.9, Iin 10, Iout 60

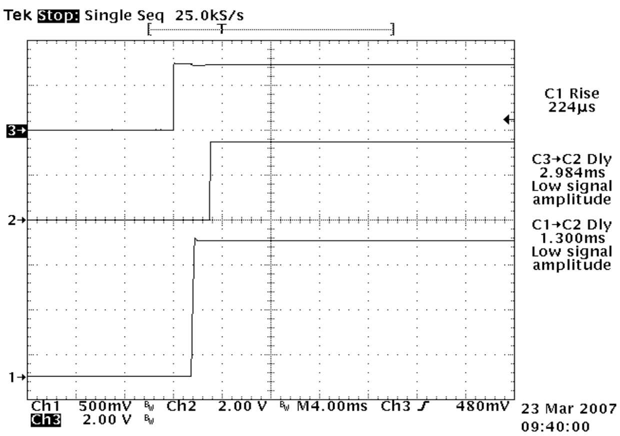


Figure 68: Turn On Vin 13, Vout 1.6, Iin 8, Iout 60

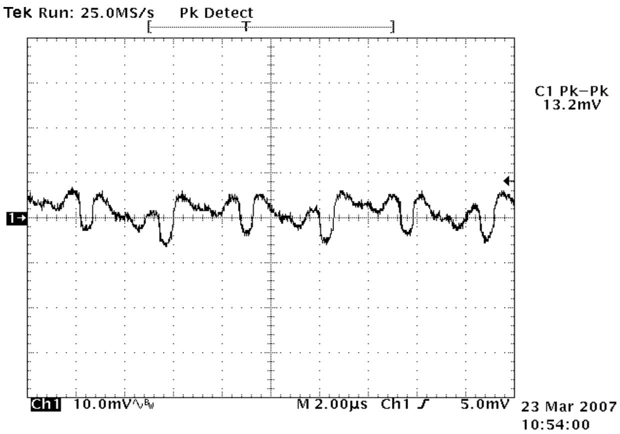


Figure 63: Voltage Ripple Vin 11, Vout 1.8, Iin 0.26, Iout 0.06

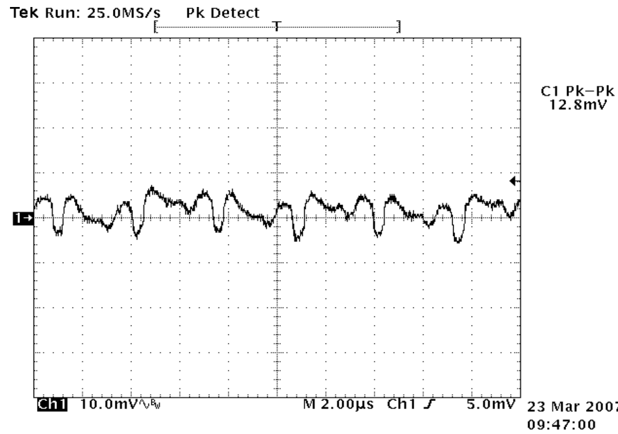


Figure 64: Voltage Ripple Vin 11, Vout 1.5, Iin 0.22, Iout 0.06

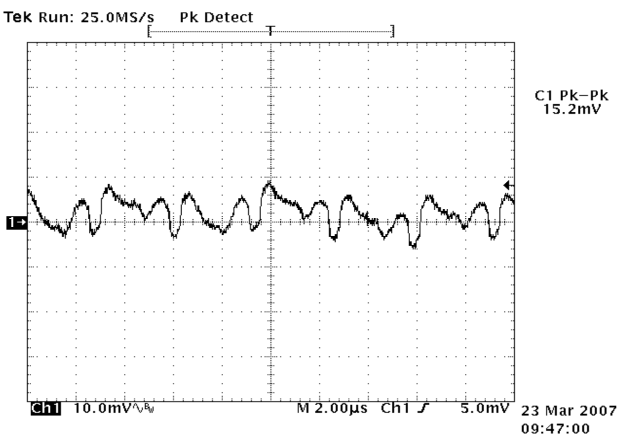


Figure 65: Voltage Ripple Vin 11, Vout 1.5, Iin 3.2, Iout 20

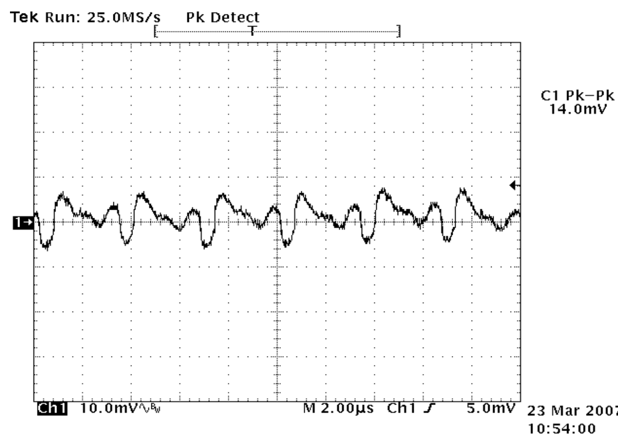


Figure 66: Voltage Ripple Vin 11, Vout 1.89 Iin 7.4, Iout 40

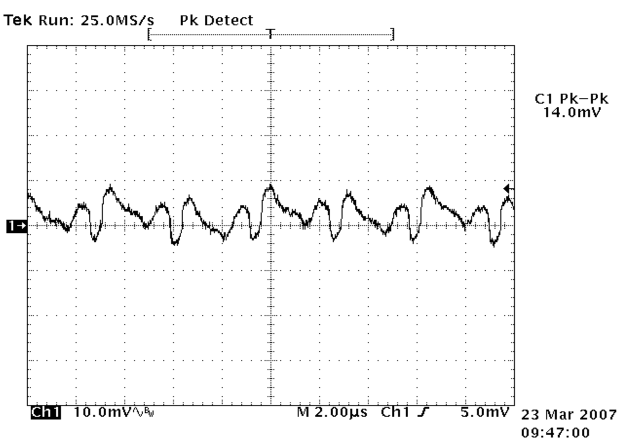


Figure 67: Voltage Ripple Vin 11, Vout 1.6, Iin 6.2, Iout 40

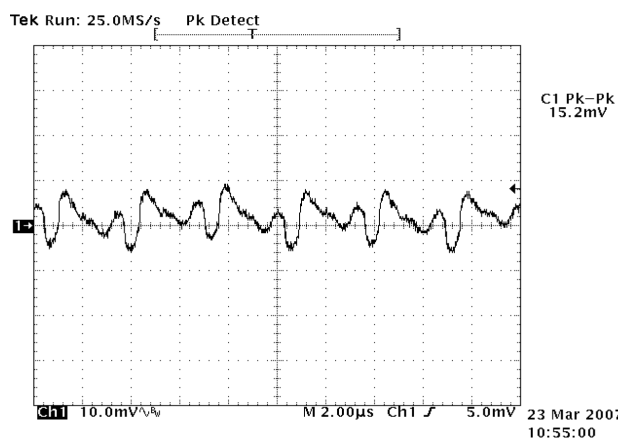


Figure 68: Voltage Ripple Vin 11, Vout 1.9, Iin 11.4, Iout 60

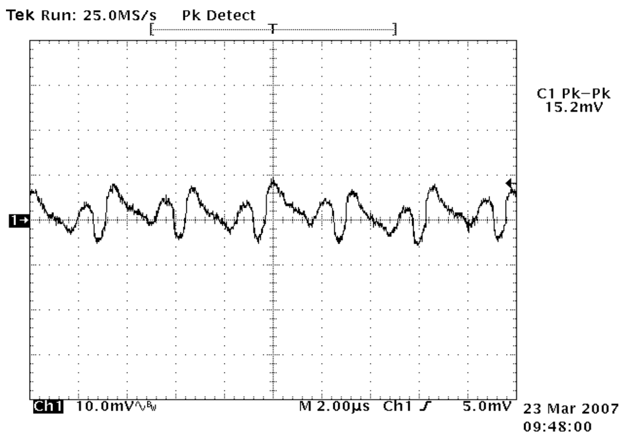


Figure 69: Voltage Ripple Vin 11, Vout 1.6, Iin 9.6, Iout 60

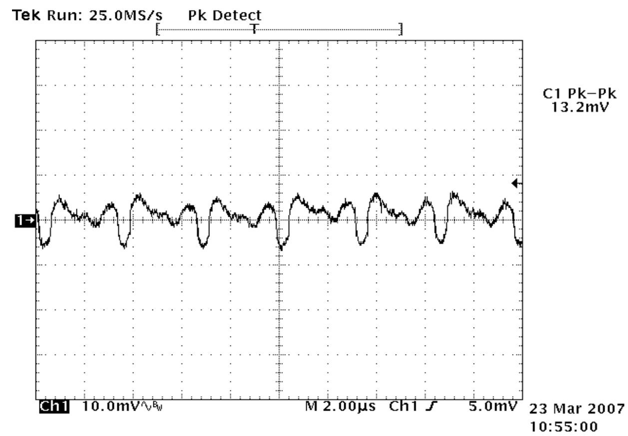


Figure 70: Voltage Ripple Vin 12, Vout 1.8, Iin 3.4, Iout 20

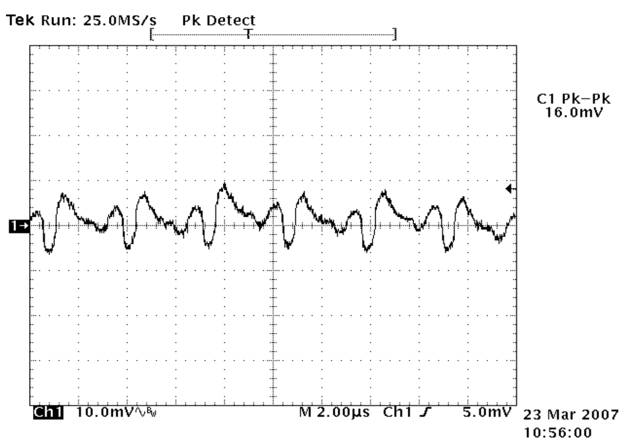


Figure 71: Voltage Ripple Vin 12, Vout 1.9, Iin 7.4, Iout 40

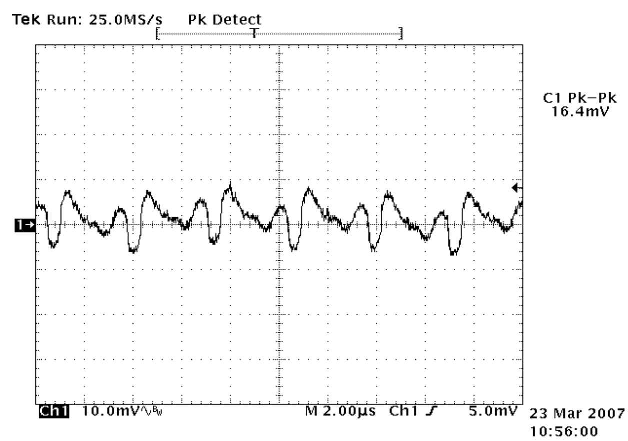


Figure 72: Voltage Ripple Vin 12, Vout 1.9, Iin 10.3, Iout 60

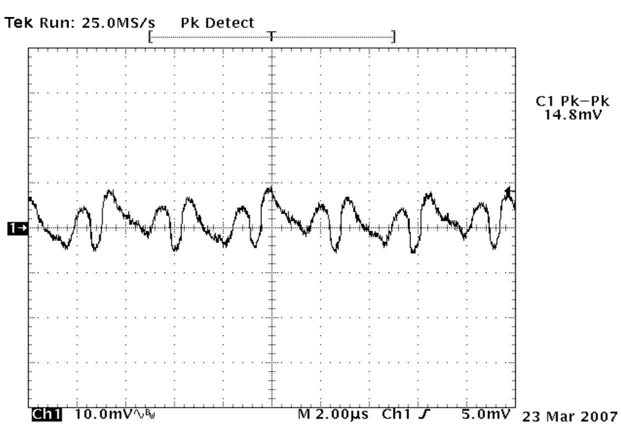


Figure 73: Voltage RIpple Vin 12, Vout 1.6, Iin 8.7, Iout 60

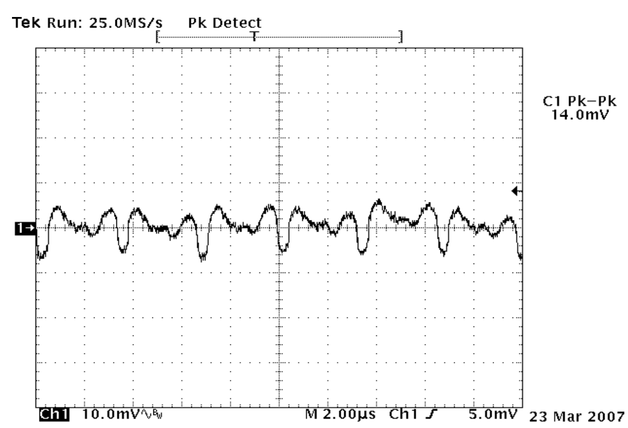


Figure 74: Voltage Ripple Vin 13, Vout 1.8, Iin 0.3, Iout 0.06

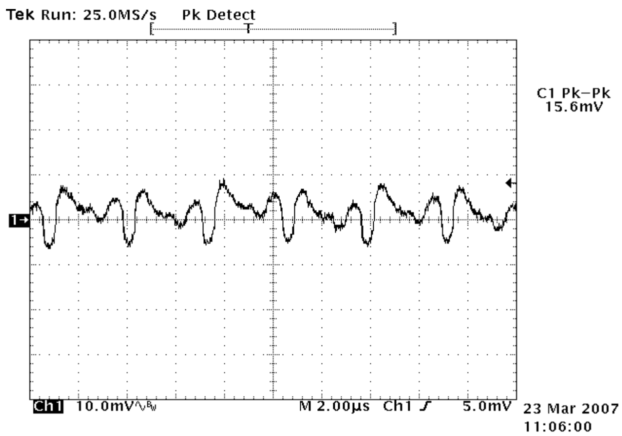


Figure 75: Voltage Ripple Vin 13, Vout 1.9, Iin 6.4, Iout 40

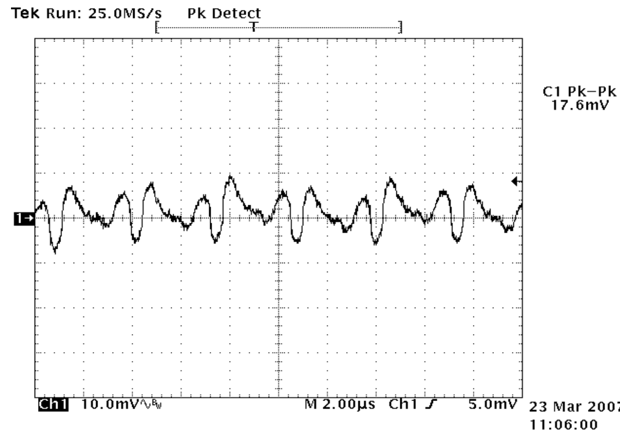


Figure 76: Voltage Ripple Vin 13, Vout 1.9, Iin 9.8, Iout 60

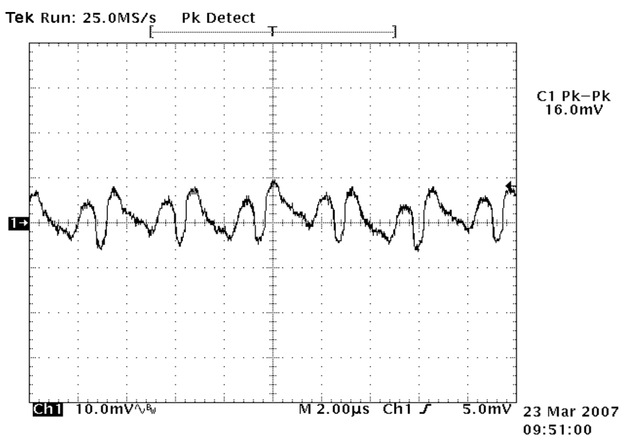


Figure 77: Voltage Ripple Vin 13, Vout 1.6, Iin 8.3, Iout 60

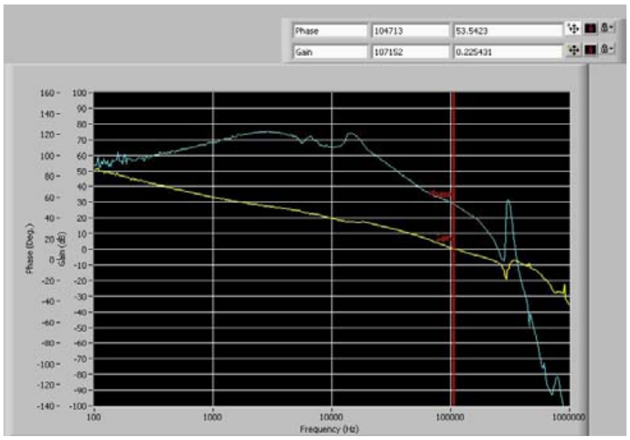


Figure 78: 0 A load 1.8 Vout

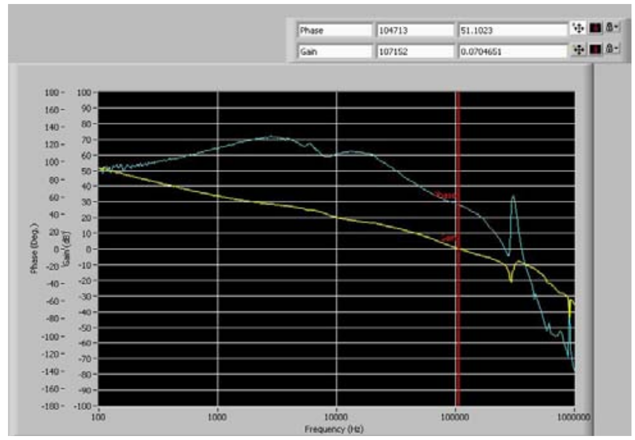


Figure 79: Phase Gain 0 A load 1.5 Vout

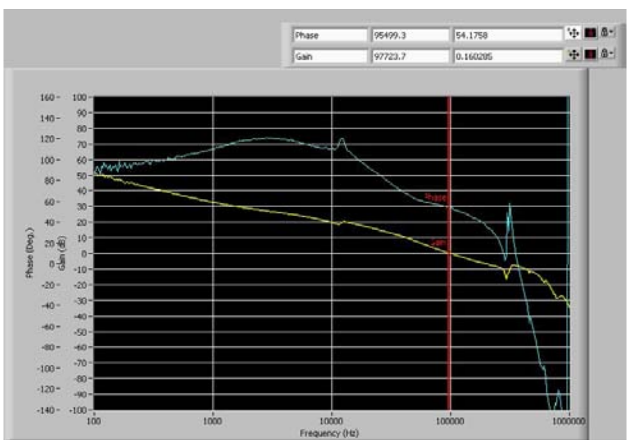


Figure 80: 0 A load 1.8 Vout

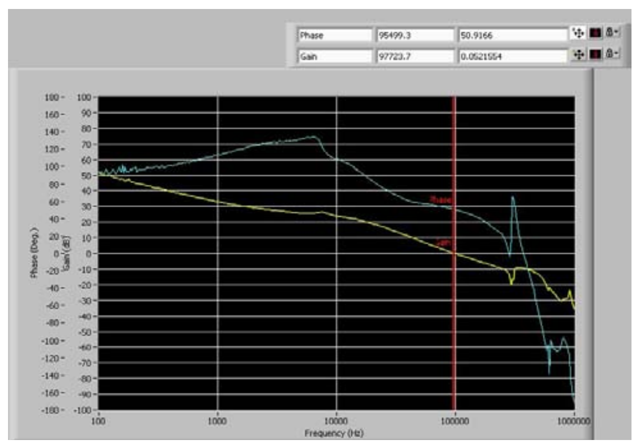


Figure 81: Phase Gain 0 A load 1.5 Vout

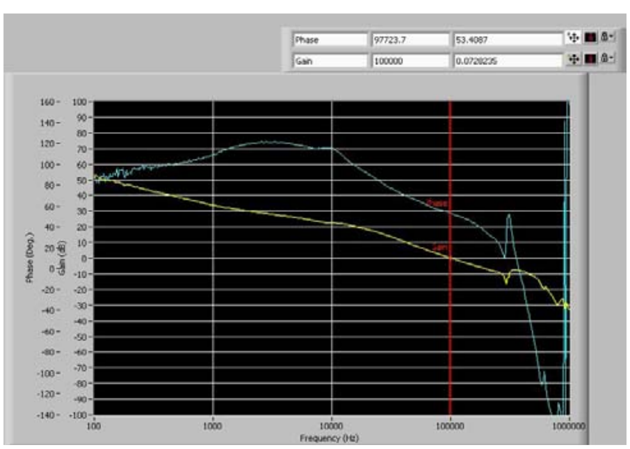


Figure 82: 0 A load 1.8 Vout

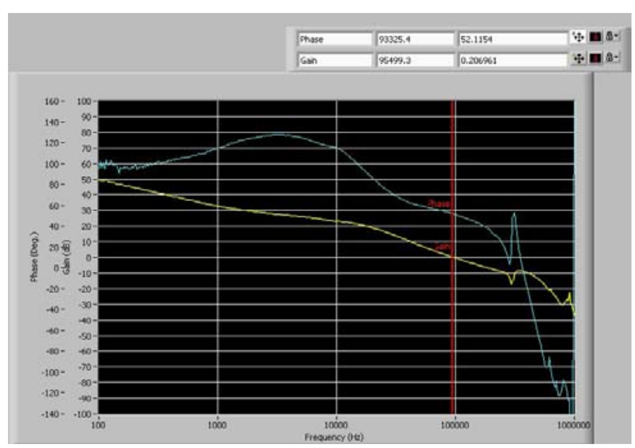


Figure 83: Phase Gain 0 A load 1.5 Vout

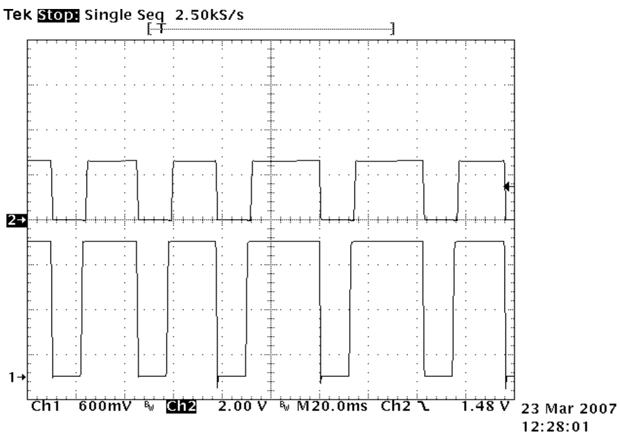


Figure 84: Overcurrent Vin 11, Vout 1.9, Iin 20, Iout 102

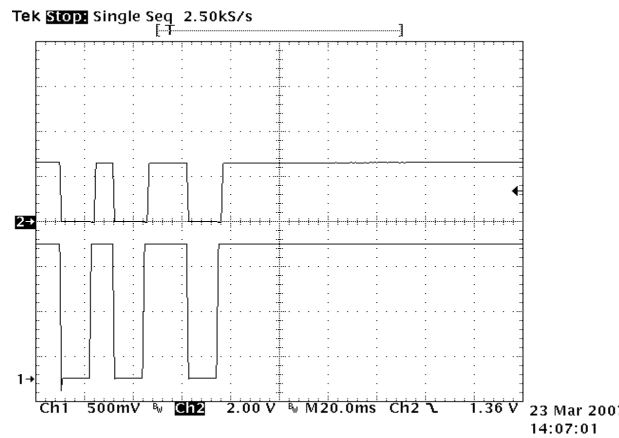


Figure 85: Overcurrent Vin 11, Vout 1.5, Iin 17, Iout 102

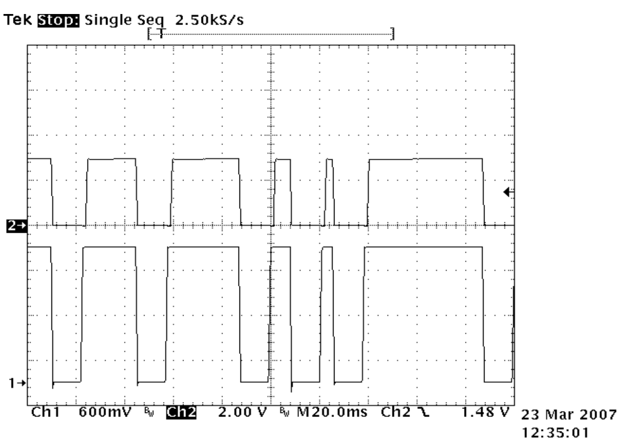


Figure 86: Overcurrent Vin 12, Vout 1.9, Iin 18, Iout 102

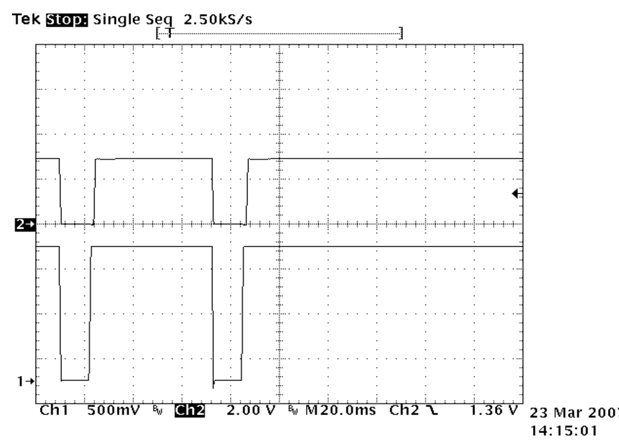


Figure 87: Overcurrent Vin 12, Vout 1.5, Iin 16, Iout 102

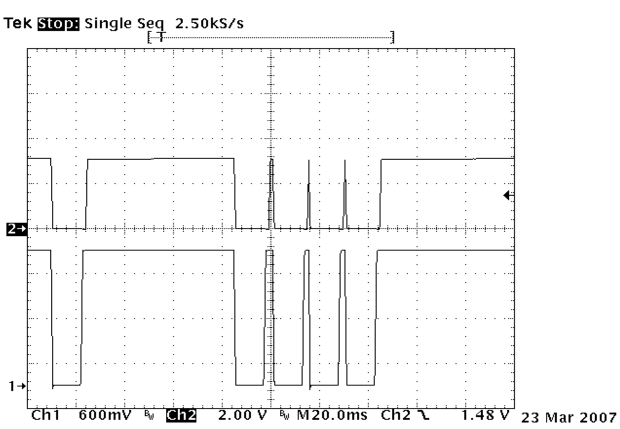


Figure 88: Overcurrent Vin 13, Vout 1.9, Iin 17, Iout 102

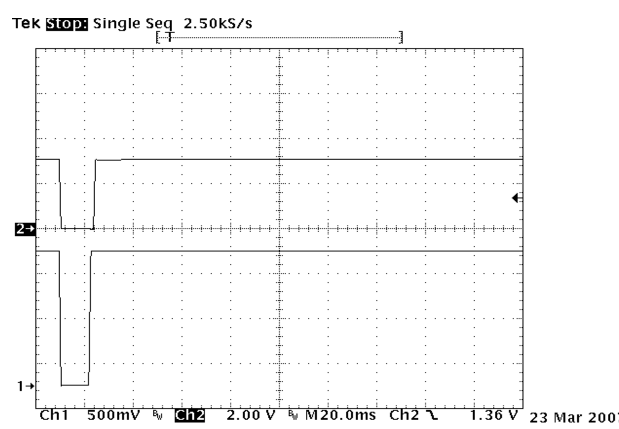


Figure 89: Overcurrent Vin 13, Vout 1.5, Iin 16, Iout 103

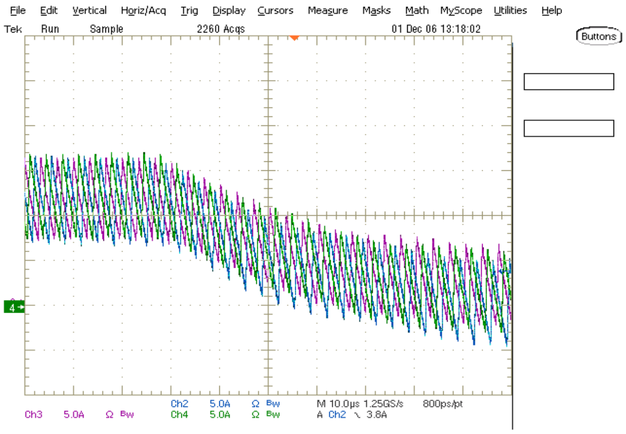


Figure 90: Phase Sharing during transient - 35 A step

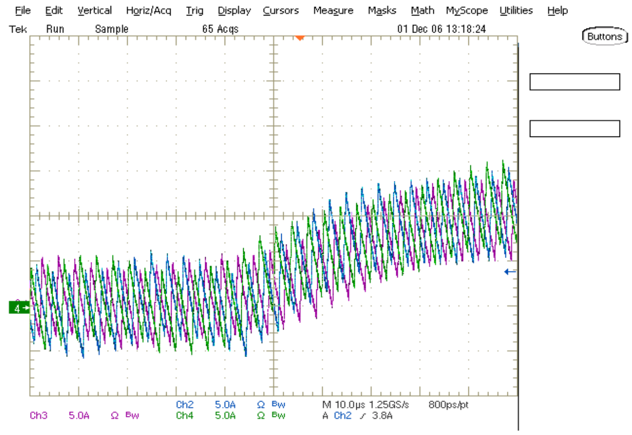


Figure 91: Phase Sharing during transient - 35 A step

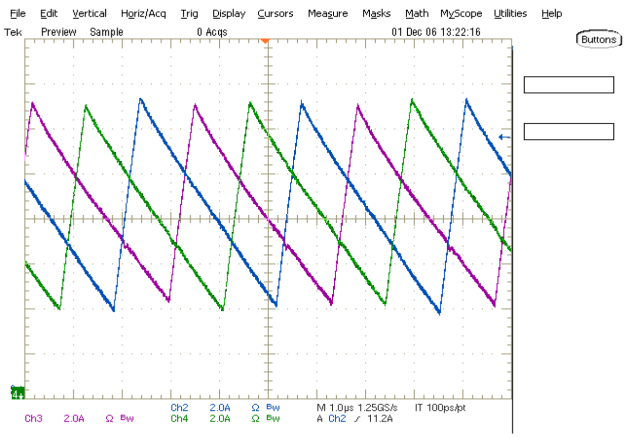


Figure 92: Phase Sharing during transient - 35 A step

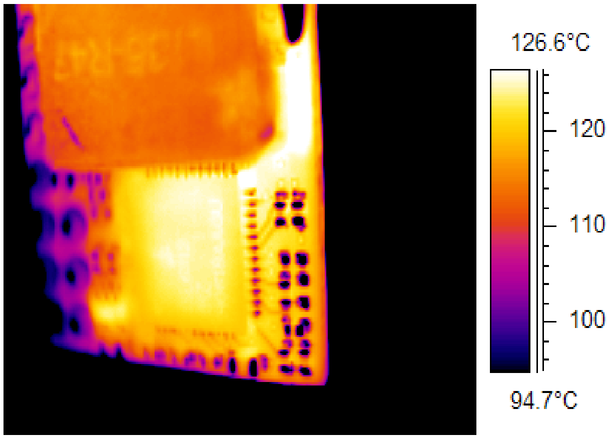


Figure 93: Thermal Shutdown Enable Pin rising threshold 0.85, Enable Pin hysteresis 110 mV

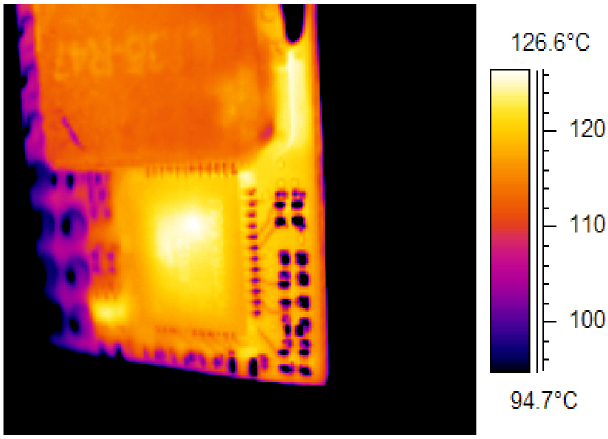


Figure 94: Thermal Shutdown Enable Pin rising threshold 0.85, Enable Pin hysteresis 110 mV

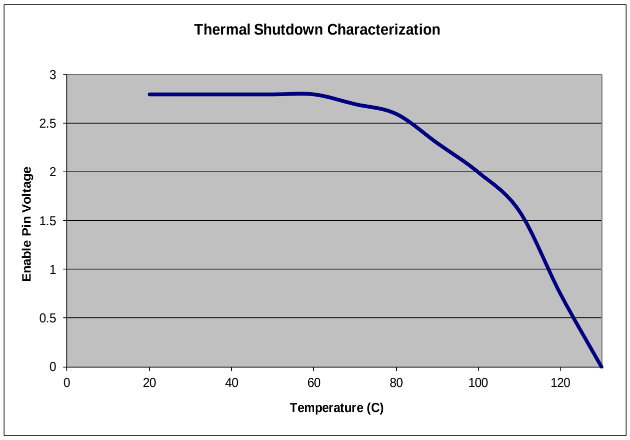


Figure 95: Thermal Shutdown

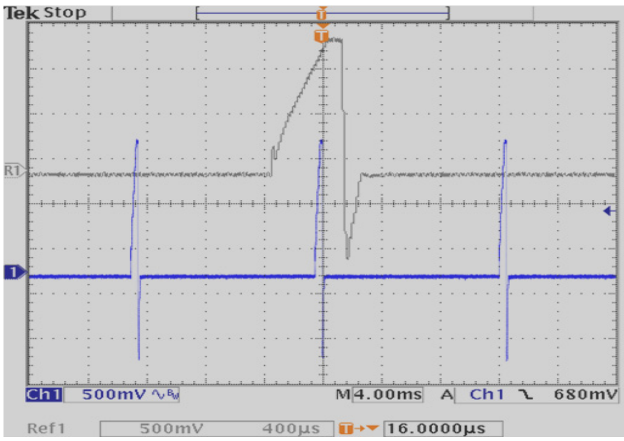


Figure 96: Short Circuit

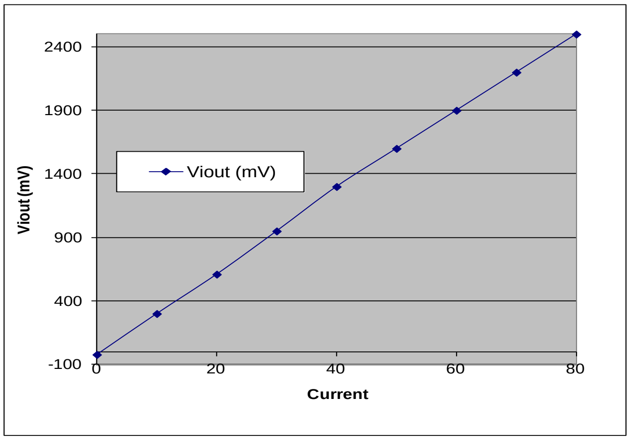
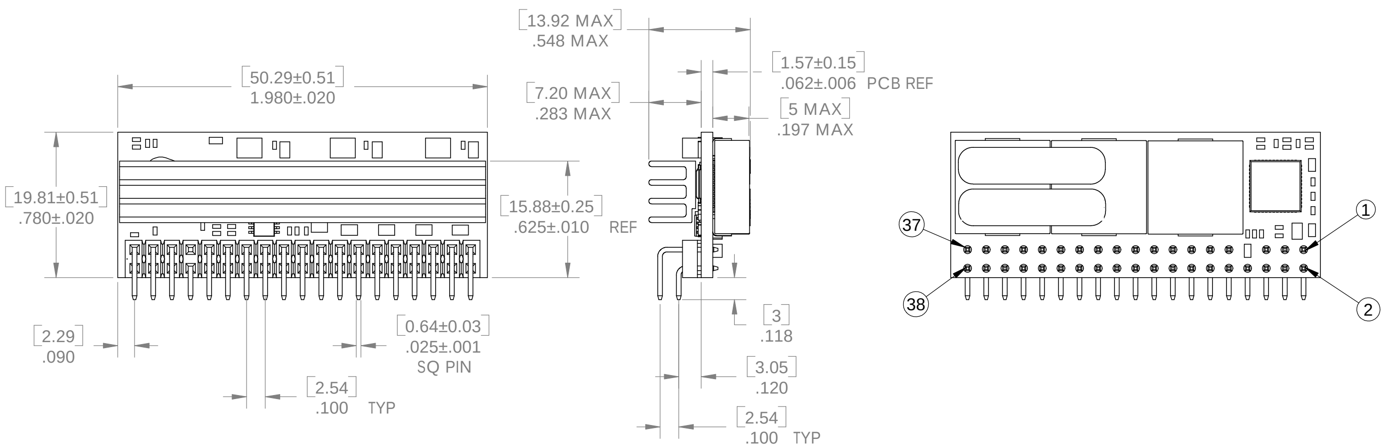


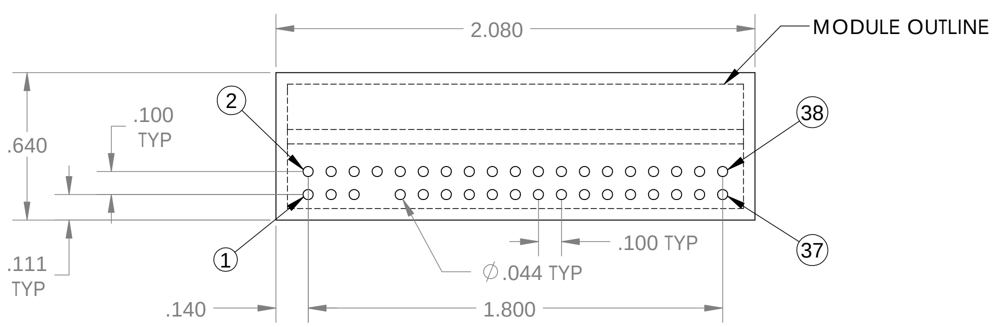
Figure 97: Viout

Mechanical Drawings

Vertical Surface Mount



Footprint



Pin Assignments

Single Output

1. VID0	11. VIN	20. Vout	30. Ground
2. Viout*	12. VIN	21. Ground	31. Ground
3. VID1	13. VIN	22. Ground	32. Ground
4. PGood	14. VIN	23. Ground	33. Vout
5. RS-	15. Ground	24. Ground	34. Vout
6. RS+	16. Ground	25. Vout	35. Vout
7. Open	17. Vout	26. Vout	36. Vout
8. Enable	18. Vout	27. Vout	37. Ground
9. Ground	19. Vout	28. Vout	38. Ground
10. Ground		29. Ground	

*Vi_{out} is a current monitoring pin. 31mV / A , ±15% tolerance.

Operating Information

Ordering Information										
Output Power (Max.)	Input	Output	Output Current (Min.)	Output Current (Max.)	Efficiency (Typical)	Regulation Line	Regulation Load	Orientation	Model Number
240 W	4.5 - 13.8 V	0.8 - 4.0 Vdc	0 A	60 A	89%	±0.3%	±0.5%	Vertical	SIL60C2-00SADJ-VDJ

Ordering Information

Product Family	Rated Output Current	Performance	Generation		Input Voltage	Output Voltage		Mounting Option	Pins	RoHs Compliance
SIL	60	C	2	-	00	SADJ	-	X	D	J
Product Family SIL = Single In Line SMT = Surface Mount	**Rated Output Current** 60 = 60 A	**Performance** C = Cost Optimized	**Generation** 2 = Increased Current Density		**Input Voltage** 00 = 4.5-13.8 V	**Output Voltage** Single Adjustable Output		**Mounting Option** H =Horizontal V = Vertical	**Pin** D = Dual Row	**RoHS Compliance** J = Pb-free (RoHS 6/6 compliant)

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