ON Semiconductor

Design Note – DN06041/D

NCP1034 Buck Converter

Device	Input Voltage	Output Voltage	Output Current	Voltage ripple	Topology	I/O Isolation
NCP1034	48 V ±20 %	5 V	5 A	< 30 mV	Buck	None

Description

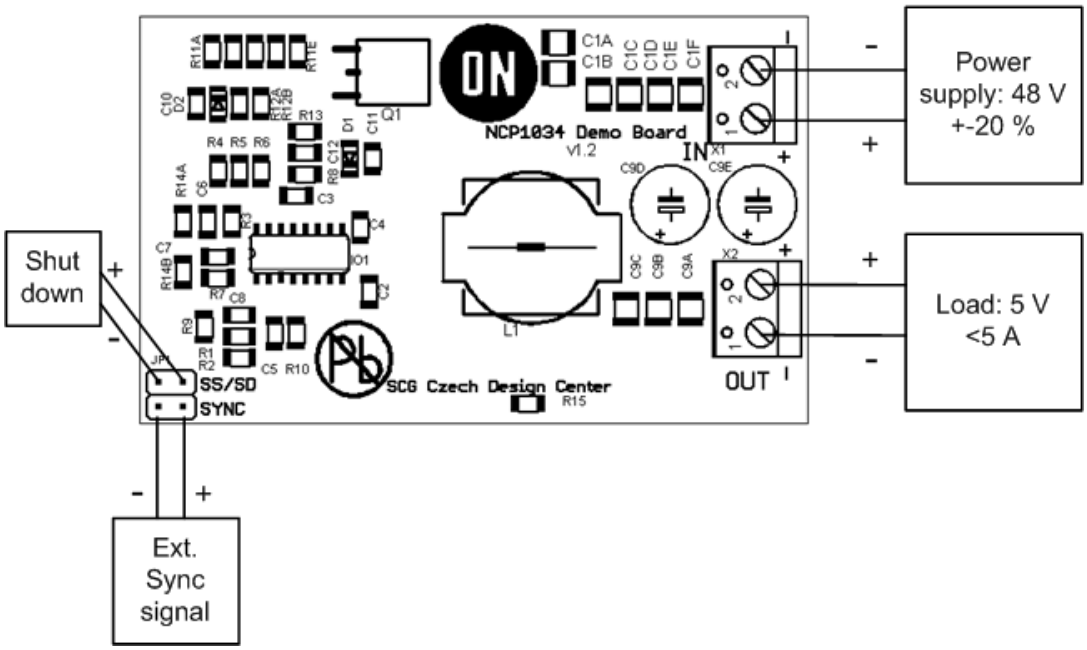
This Design Note describes high voltage, high power and high efficiency DC/DC buck converter featuring the NCP1034.

The NCP1034 is voltage mode PWM controller for a high voltage synchronous buck. The controller drives two external N-Mosfets with programmable frequency up to 500 kHz for wide applications range. The IC is able to be synchronized by external signal or is able to synchronize other ICs that simplify design of system level filter. The output voltage can be set as low as 1.25 V. Besides system and drivers UVLO there is an external UVLO that can be set to user value. Over current protection uses low side MOSFET R_{DSON} as sensing resistor, which has no impact on efficiency. Current limit protection uses a hiccup mode. These protections provide application additional security level.

Key Features

- High input voltage
- High operation frequency
- High efficiency
- Low output voltage ripple
- Ceramic capacitors only
- Over current protection
- Under voltage protection
- Start to pre-biased output
- Small size

Connection diagram



Schematic

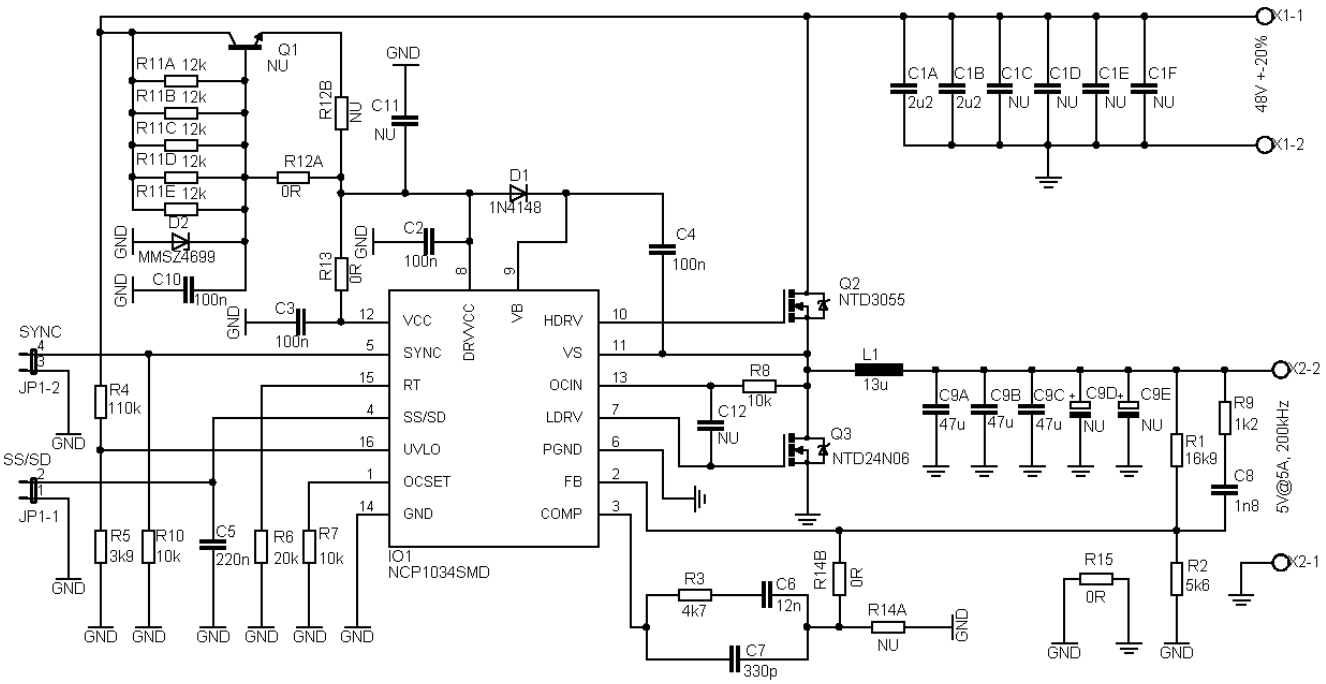


Figure 1 – Schematic of the NCP1034 demo board

The demo board was designed as board with many options. There is linear regulator for powering the IC only with Zener diode or with high voltage transistor (R12A and R12B selected one of these regulators), compensation circuit of second or third type (R14A and R14B), ceramic or electrolytic output capacitors (C9A – C9E) and various input capacity (C1A – C1F). For additional filtering there are R13 and C11 which is not currently used. There are two headers pins for easy connection to external synchronization pulse source or to direct connection to the other NCP1034 demo board and the SS/SD pin that can be used to shut down the controller by connecting it to the ground.

Circuit layout

Circuit is designed on two layer FR4 board with 72 μm copper cladding. Except connectors all components are surface mounted types and almost all of them are on the top layer. On the bottom side there are power MOSFETs because it can be easy put on cooler (if demo board is used on prescribed operations conditions and at room temperature it is not needed).

Some components must be placed very carefully. Blocking capacitors C2, C3 and bootstrap capacitor C4 have to be placed close to the IC. Low side MOSFET's source have to be connected to the IC's power ground with minimum resistance and inductance of connection so two layers connection between them is needed. Feedback and compensation network should be near the IC to minimize noise on them. Using signal and power ground connected in one point near the output connector improves load regulation. Inductor and output capacitors are placed close to the MOSFETs and output connector.

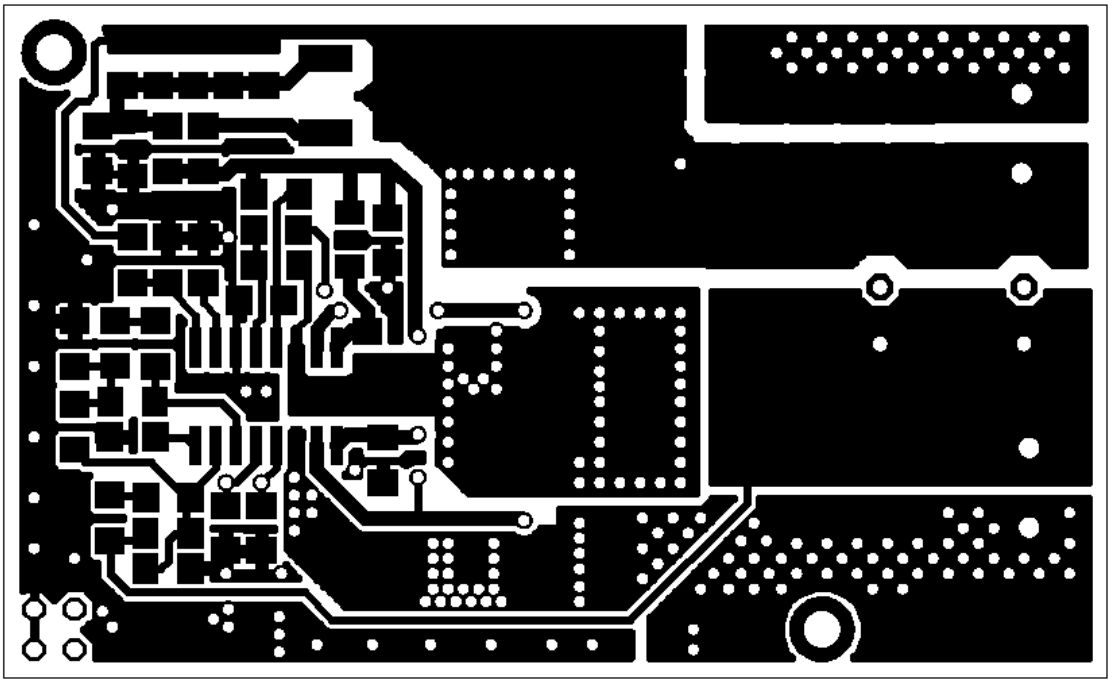


Figure 2 – Top layer

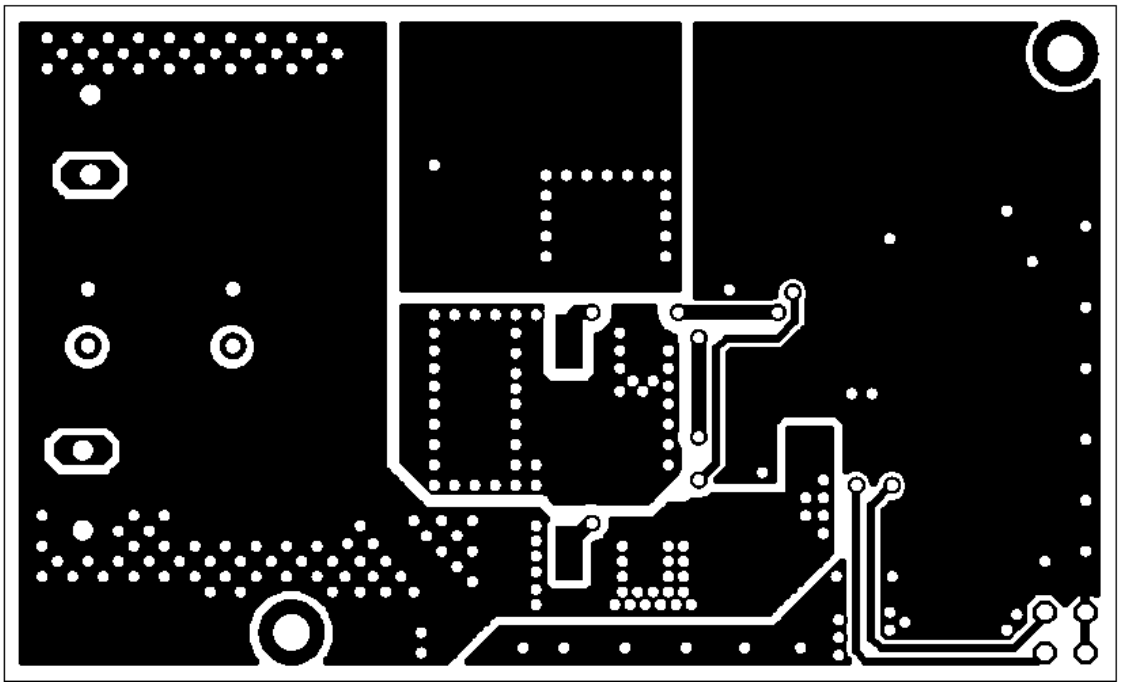


Figure 3 – Bottom layer

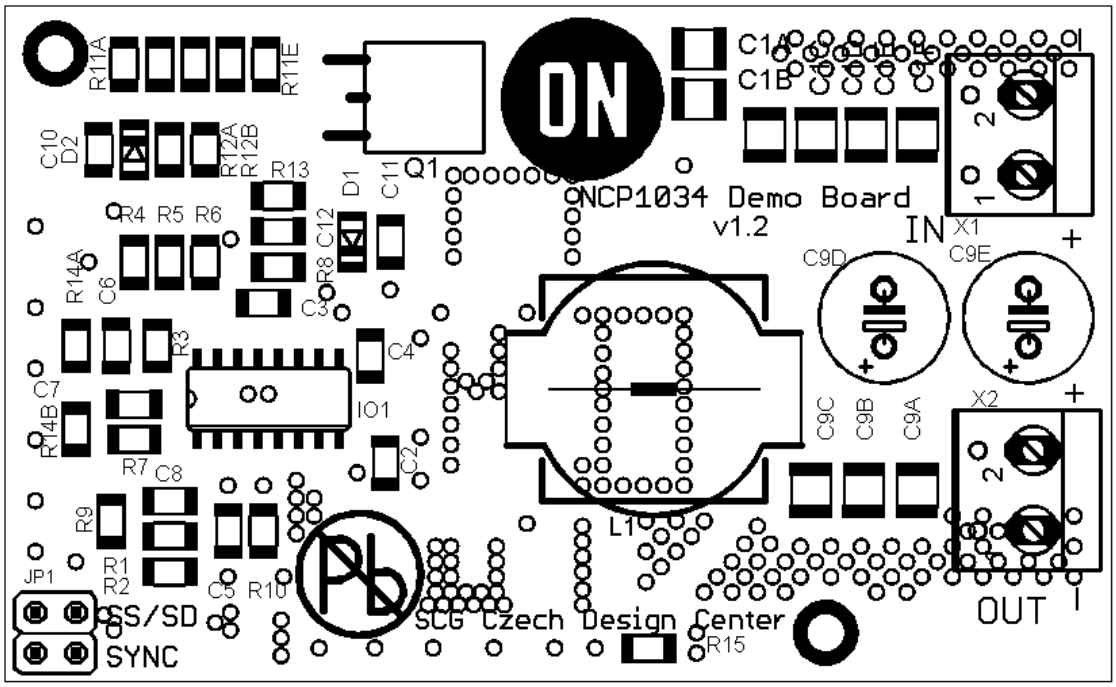


Figure 4 – Top side components

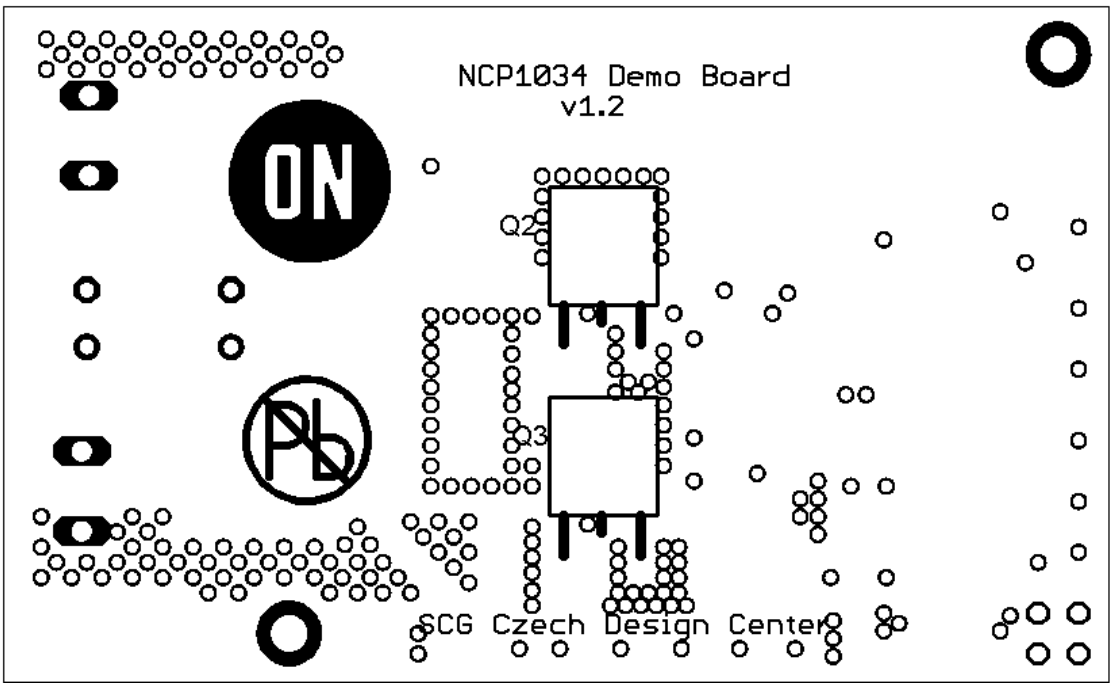


Figure 5 – Bottom side components

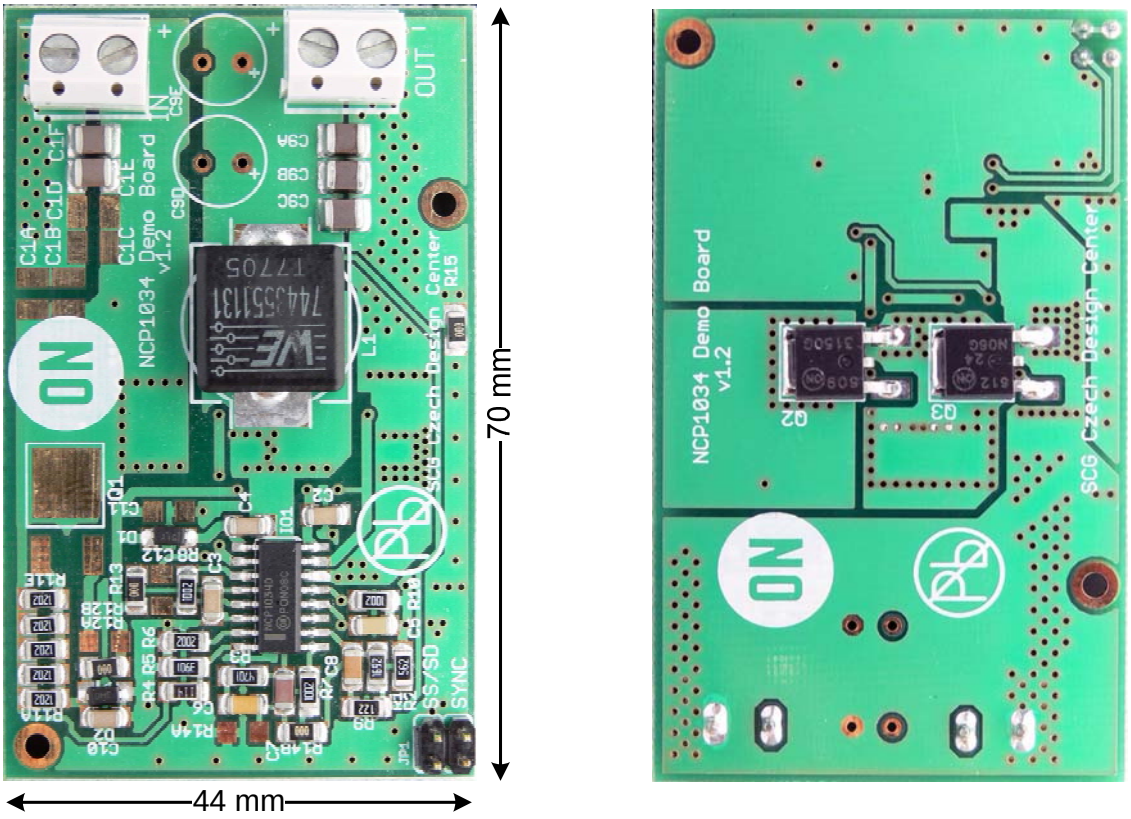


Figure 6 – Demo board photos

Measurement

Table 1: Output parameters

Characteristic	Typ	Unit
Output voltage	5.02	V
Maximum output current	5	A
Oscillator frequency	200	kHz
Output voltage ripple		
I_{OUT} = 0.1 A	16.5	mV_{pk-pk}
I_{OUT} = 5 A	20.5	
Load regulation		
I_{OUT} = 0–5 A, V_{IN} = 48 V	-0.34	mV/A
Line regulation V_{IN} = 38 – 58 V		
I_{OUT} = 0.1 A	0.004	%
I_{OUT} = 5 A	0.011	%

Start up sequence

Dark blue – Output voltage
Light blue – SS voltage
Green – Output current

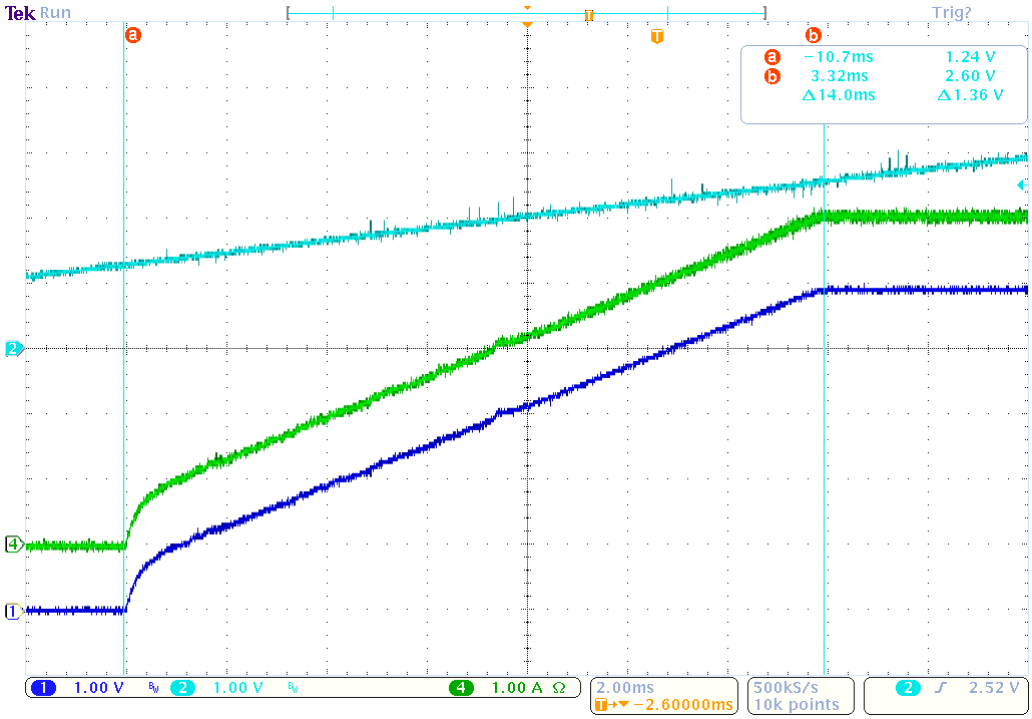


Figure 7 - Start to nominal load

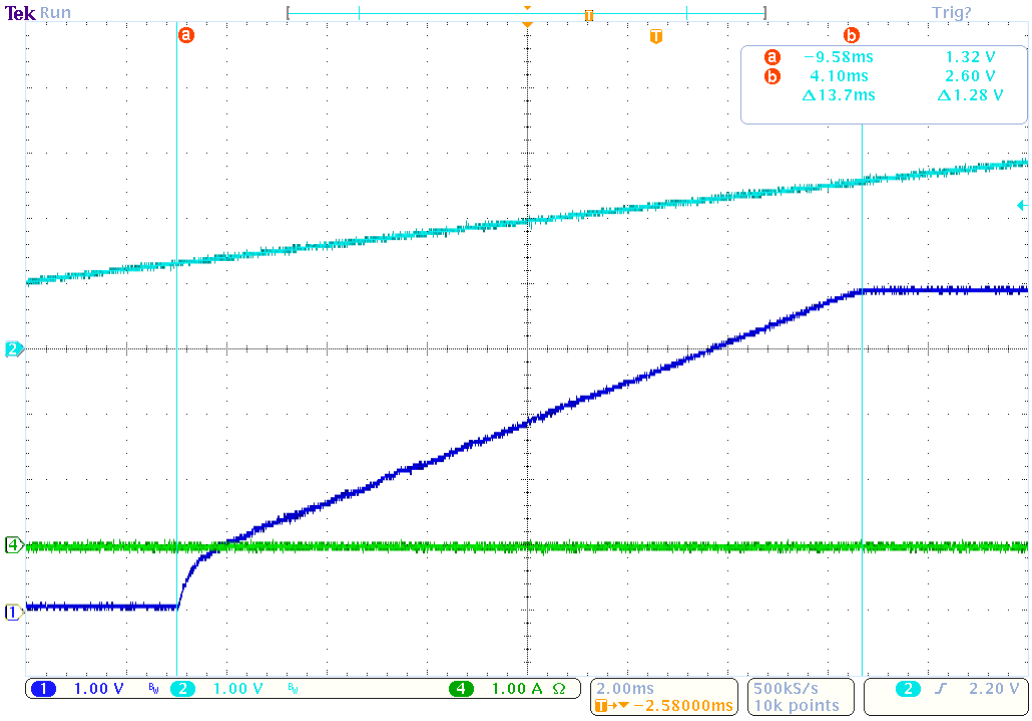


Figure 8 - Start to light load

Pink – Bridge voltage

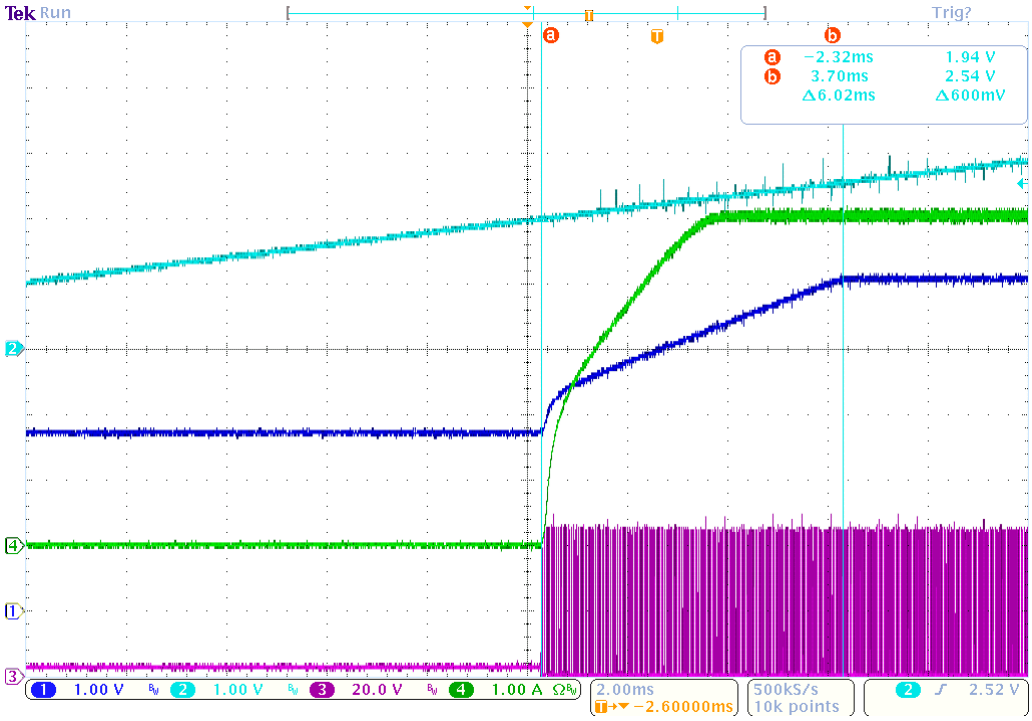


Figure 9 - Start to pre-biased output

Over Current Protection

Dark blue – Output voltage
Light blue – SS voltage
Pink – Bridge voltage
Green – Inductor current

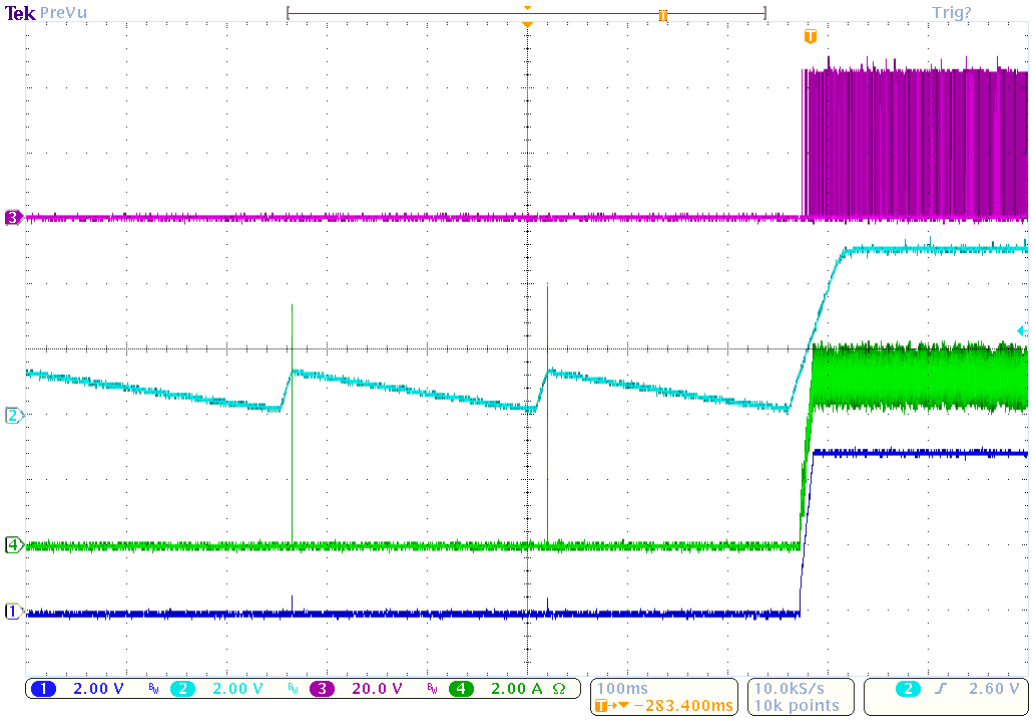


Figure 10 - Shorted output and release

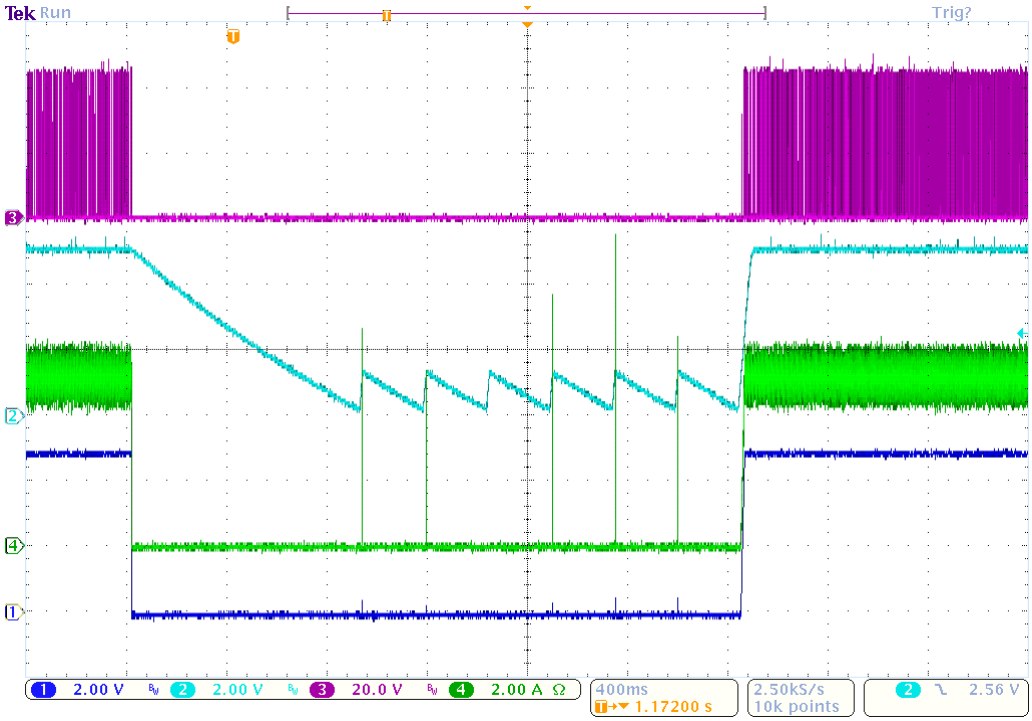


Figure 11 - Overload from nominal load and released

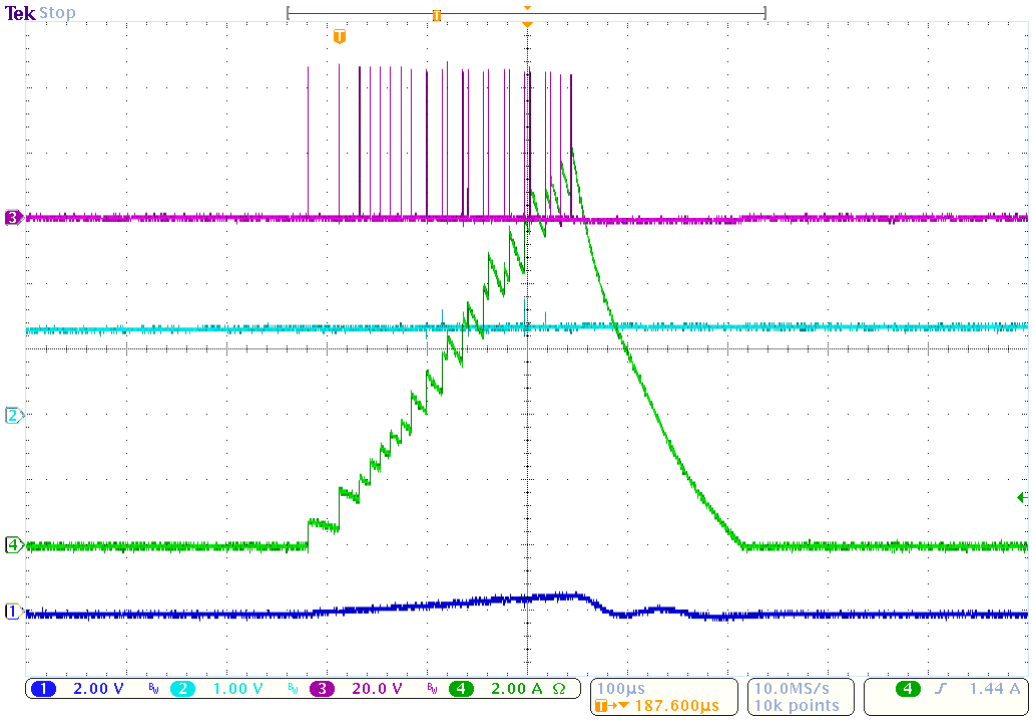


Figure 12 - Hicup pulse detail

Shutdown

Dark blue – Output voltage
Light blue – SS voltage
Pink – Input voltage
Green – Output current

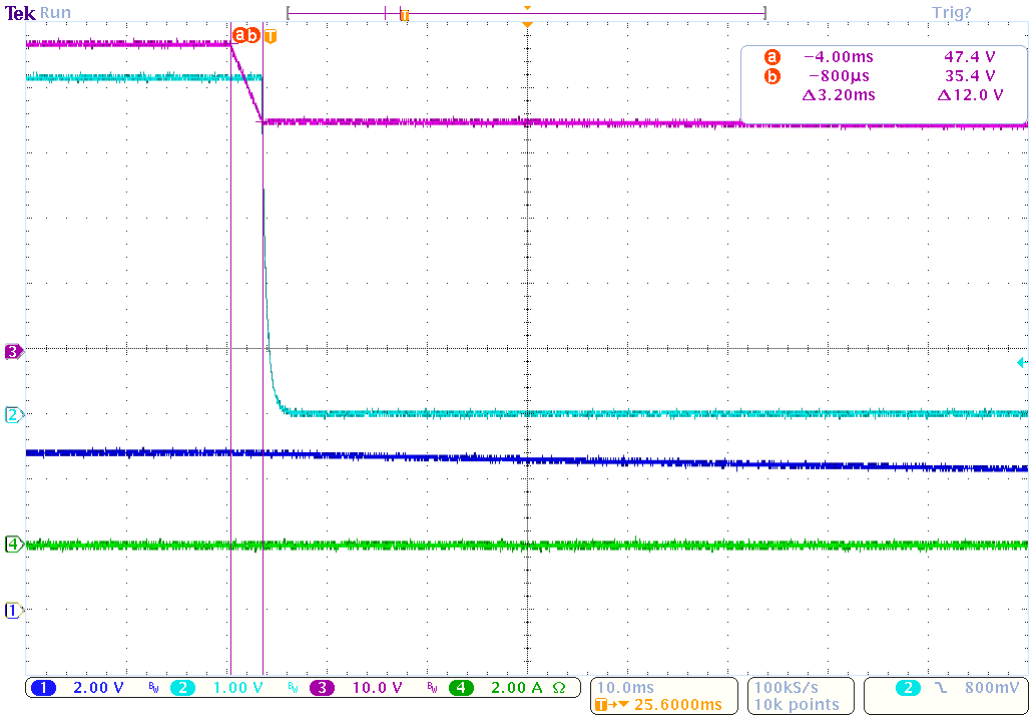


Figure 13 - Switch off input voltage to light load

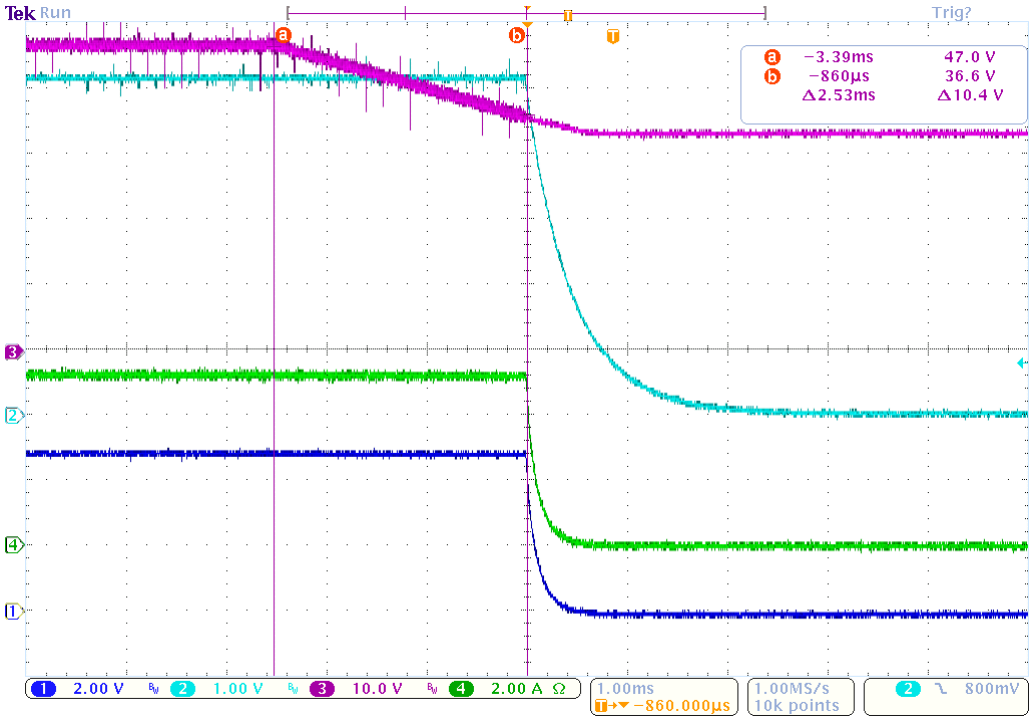


Figure 14 - Switch off input voltage to nominal load

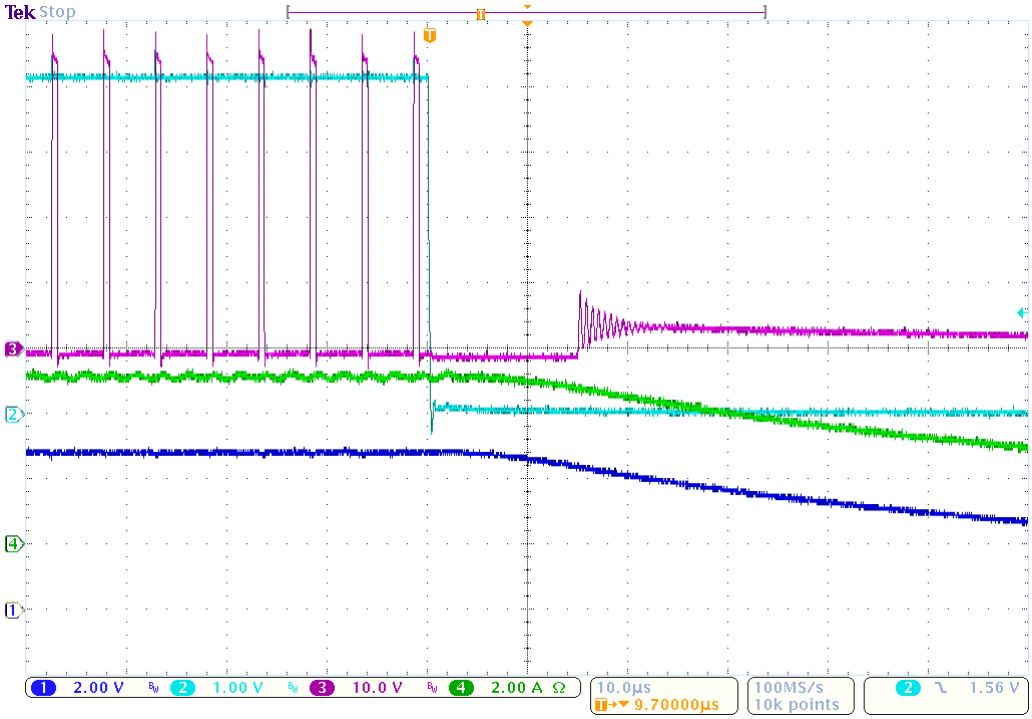


Figure 15 - Shut down through SS/SD pin

Step response and output voltage ripple

Dark blue – Output voltage
Pink – Bridge voltage
Green – Output current

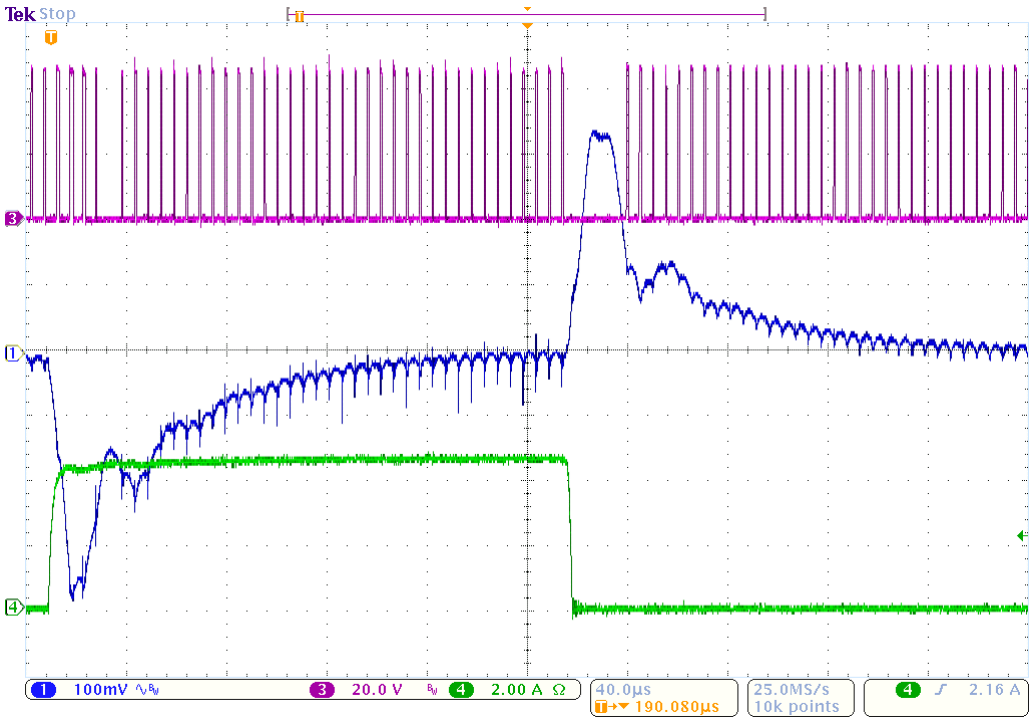


Figure 16 - Load step response

Green – Inductor current

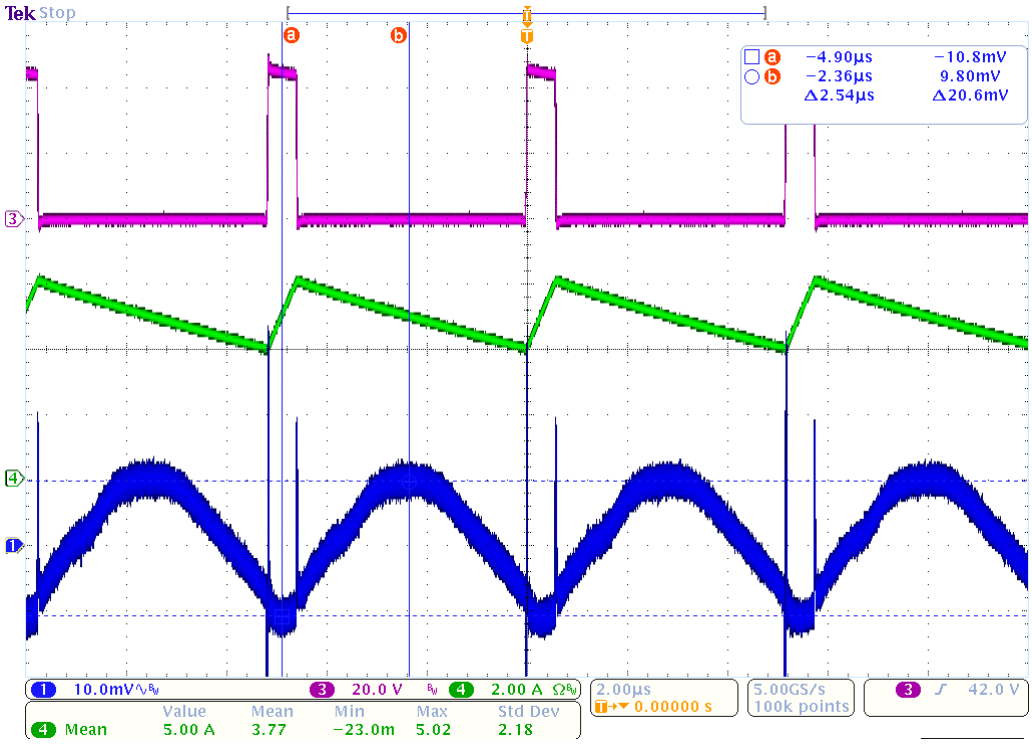


Figure 17 - Output voltage ripple I_{OUT} = 5 A

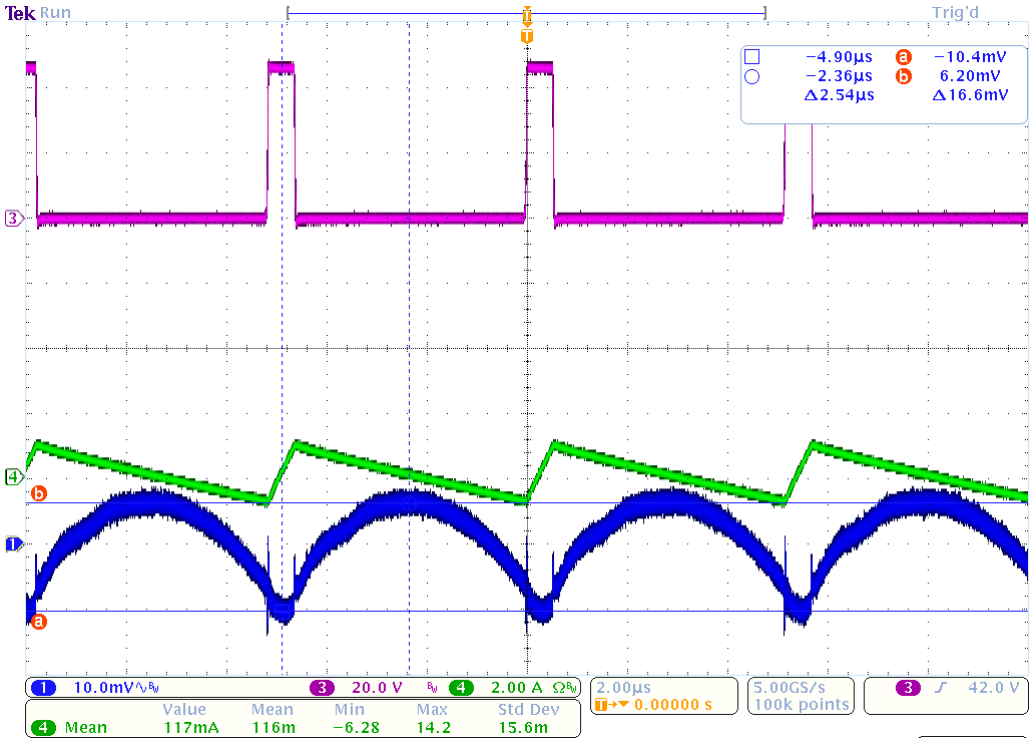


Figure 18 - Output voltage ripple I_{OUT} = 0.1 A

Synchronization

Two independent boards connected (or not) via Sync pin and ground.
Dark blue – First demoboard Sync pin voltage
Light blue – Second demoboard Sync pin voltage
Green – First demoboard bridge voltage
Pink – Second demoboard bridge voltage

Figure 19 – No synchronization

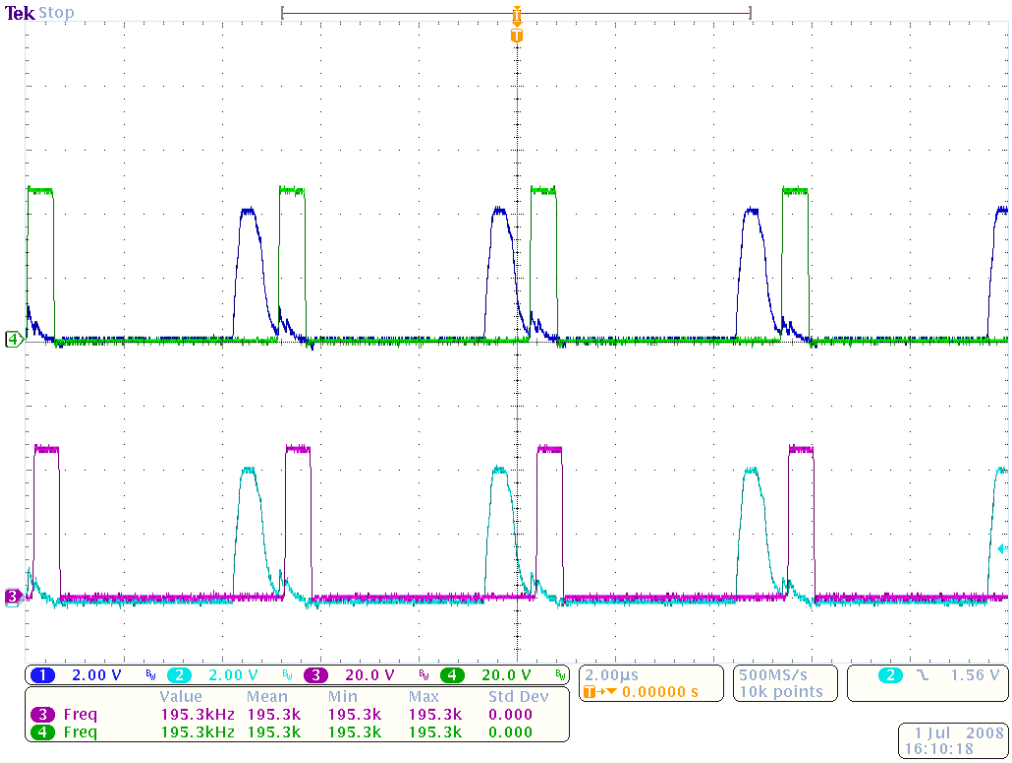


Figure 20 – Synchronized – Sync pins connected

Line and load regulation

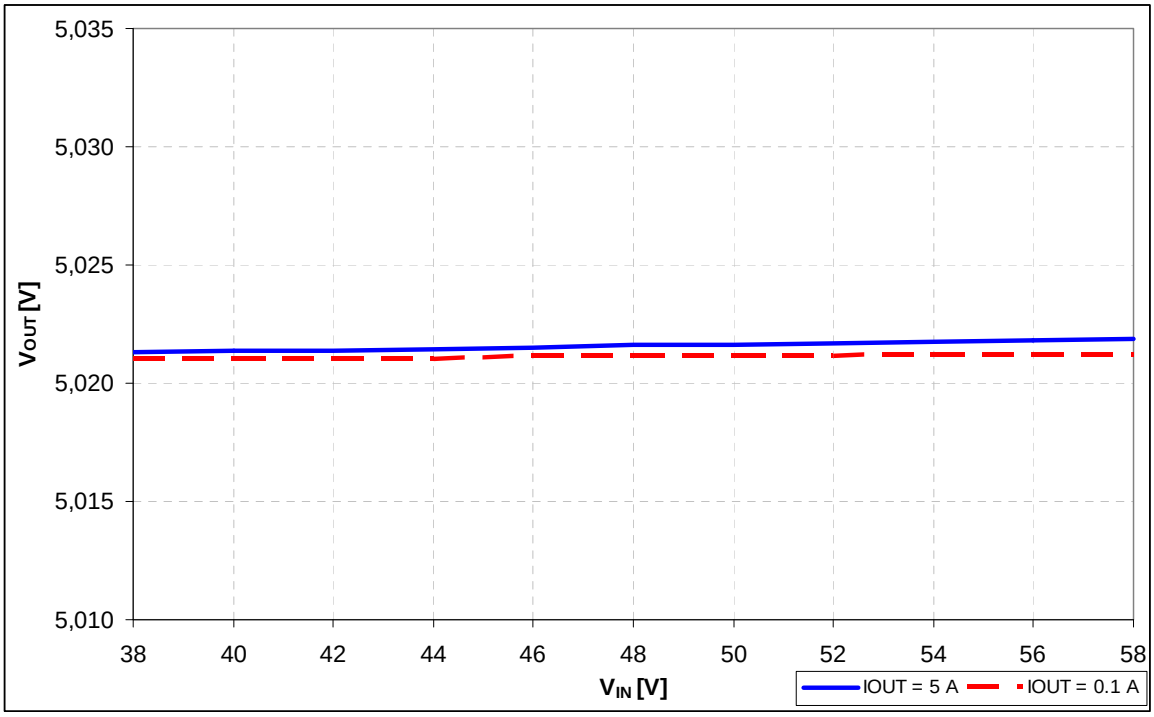


Figure 21 – Line regulation

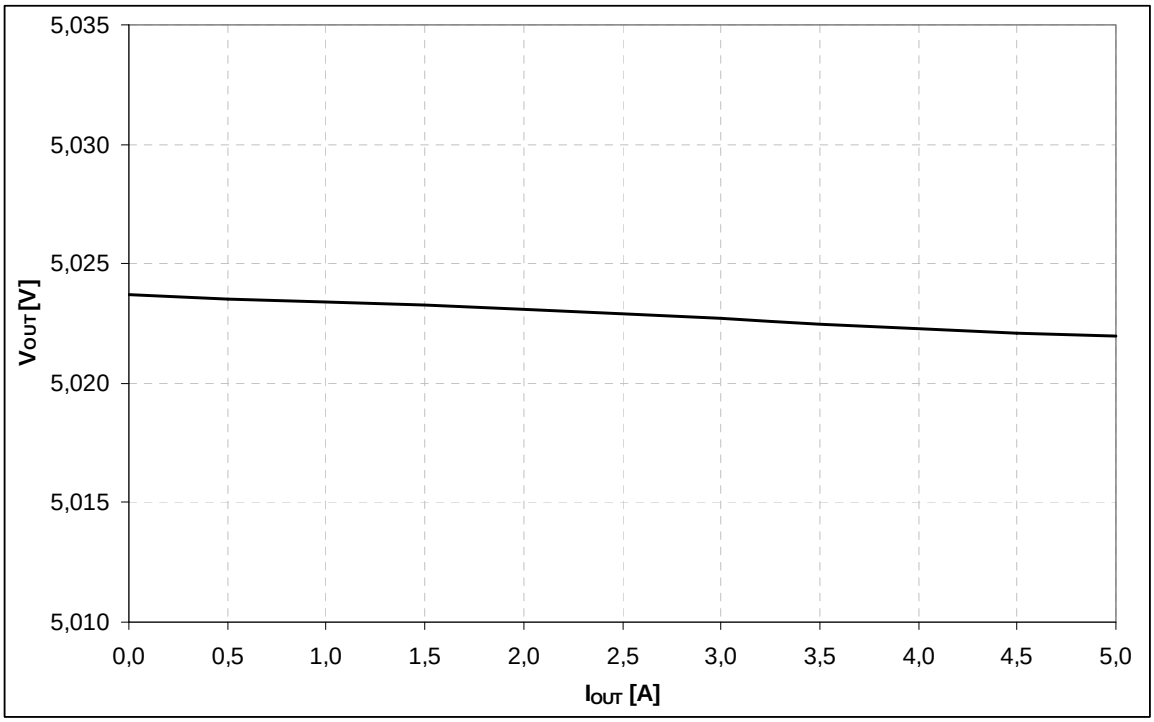


Figure 22 – Load regulation V_{IN} = 48 V

Efficiency

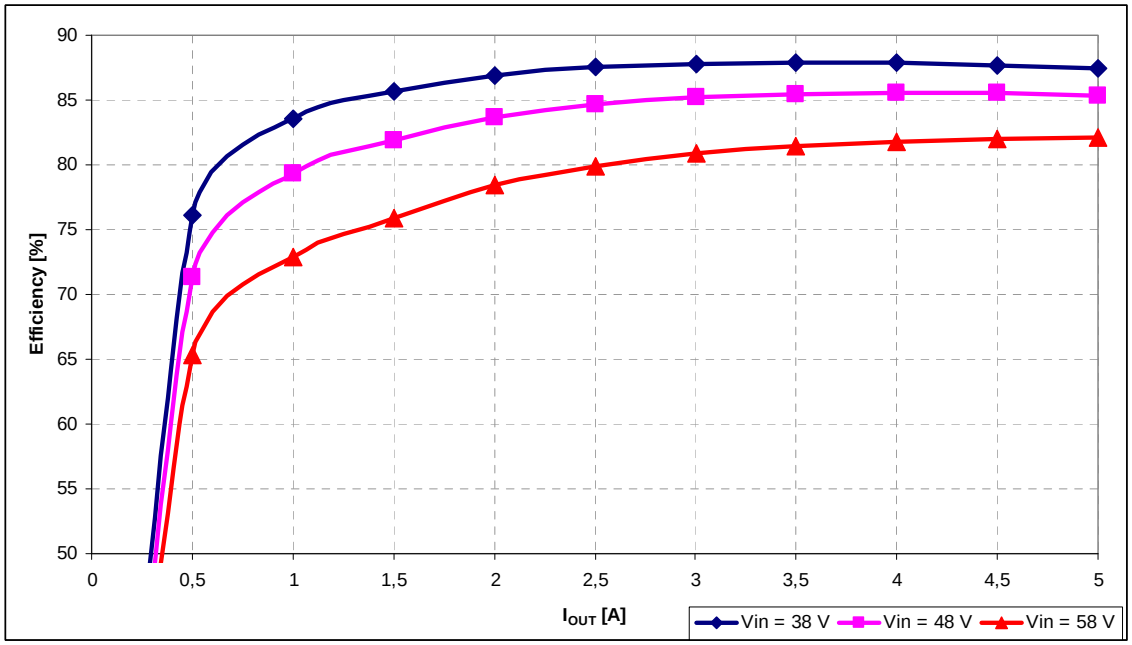


Figure 23 - Efficiency

		Unit	
Pind, winding	0,32	W	<-- Inductor Winding Loss
Pcore	1,20	W	<-- Core Loss in Inductor. Available in Inductor Data Sheet.
Pstatic, IC	0,03	W	<-- Static Power Loss of the IC
Phigh_gate	0,02	W	<-- Power Loss of High Power Switch Gate Charge
Plow_gate	0,06	W	<-- Power Loss of Low Power Switch Gate Charge
Pdynam, IC	0,07	W	<-- Dynamic Power Loss of the IC
Phigh_switch, cond	0,32	W	<-- Conduction Loss of High Power Switcher
Plow_switch, cond	0,72	W	<-- Conduction Loss of Low Power Switcher
Phigh_switch, sw	0,21	W	<-- Switching Loss of High Power Switcher
Plow_switch, sw	0,00	W	<-- Switching Loss of Low Power Switcher
Plow_switch, body	0,92	W	<-- Body Diode Recovery Charge Loss
Plow_dead_time	0,11	W	<-- Body Diode Conduction Loss
P_switch_capacit	0,07	W	<-- Switchers Capacitance Loss
P preregulator	0,31	W	<-- Power Loss of Linear Preregulator VIN --> VCC
Ploss, total	4,37	W	<-- Total Loss
Pout	25,00	W	<-- Output Power
Pin	29,37	W	<-- Input Power = Output Power + Total Loss
Efficiency	85	%	<-- Efficiency of Converter (Est: +/- 5%)

Figure 24 – Power loss review from spreadsheet

Bode plot

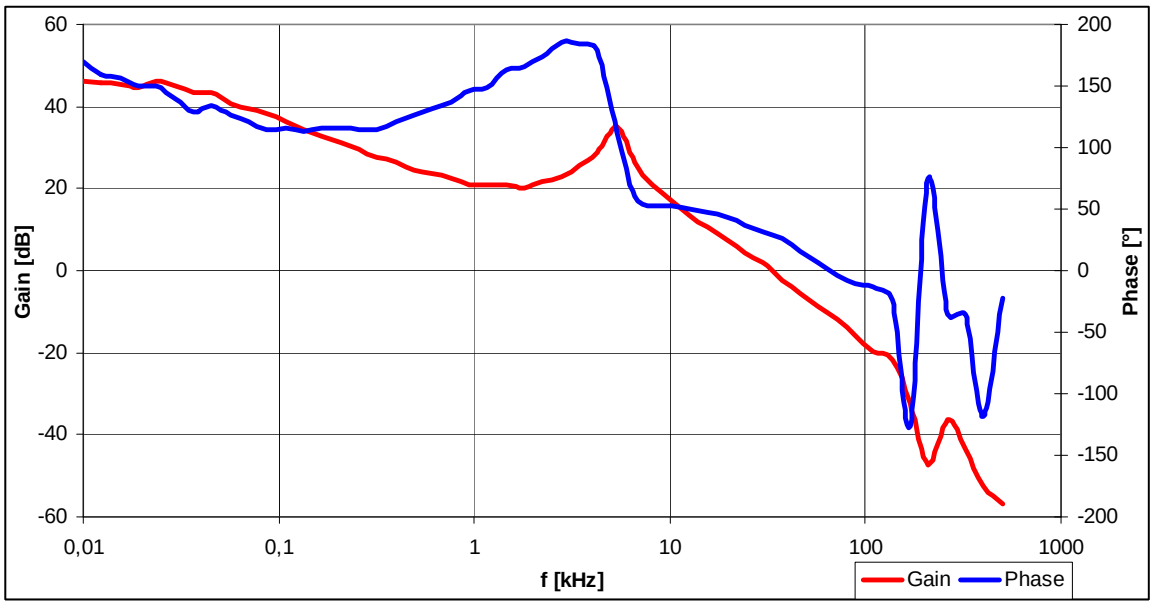


Figure 25 – Bode plot V_{IN} = 48 V, I_{OUT} = 5 A

Bill of materials

Bill of Materials for the NPC1034 Demoboard

Designator	Quantity	Description	Value	Tolerance	Footprint	Manufacturer	Manufacturer Part Number	Substitution Allowed	Lead Free	Comments
R9	1	Resistor SMD	1k2	1%	1206	Vishay	CRCW12061K20FKEA	Yes	Yes	
R5	1	Resistor SMD	3k9	1%	1206	Vishay	CRCW12063K90FKEA	Yes	Yes	
R3	1	Resistor SMD	4k7	1%	1206	Vishay	CRCW12064K70FKEA	Yes	Yes	
R2	1	Resistor SMD	5k6	1%	1206	Vishay	CRCW12065K60FKEA	Yes	Yes	
R1	1	Resistor SMD	16k9	1%	1206	Vishay	CRCW120616K9FKEA	Yes	Yes	
R6	1	Resistor SMD	20k	1%	1206	Vishay	CRCW120620K0FKEA	Yes	Yes	
R11A, R11B, R11C, R11D, R11E	1	Resistor SMD	12k	1%	1206	Vishay	CRCW120612K0FKEA	Yes	Yes	
R4	1	Resistor SMD	110k	1%	1206	Vishay	CRCW1206110KFKEA	Yes	Yes	
R7, R8, R10	3	Resistor SMD	10k	1%	1206	Vishay	CRCW120610K0FKEA	Yes	Yes	
R12A, R13, R14B, R15	4	Resistor SMD	0R	1%	1206	Vishay	CRCW120600R0FKEA	Yes	Yes	
R12B, R14A	2	Resistor SMD	NU	-	1206	-	-	-	-	
C8	1	Ceramic Capacitor SMD	1n8	10%	1206	Kemet	C1206C182K5RAC-TU	Yes	Yes	
C6	1	Ceramic Capacitor SMD	12n	10%	1206	Kemet	C1206C123K5RACTU	Yes	Yes	
C5	1	Ceramic Capacitor SMD	220n	10%	1206	Kemet	C1206C224K5RACTU	Yes	Yes	
C7	1	Ceramic Capacitor SMD	330p	10%	1206	Yageo	CC1206KRX7R9BB331	Yes	Yes	
C11, C12	2	Ceramic Capacitor SMD	NU	-	1206	-	-	Yes	Yes	
C2, C3, C4, C10	4	Ceramic Capacitor SMD	100n	10%	1206	Kemet	C1206F104K1RACTU	Yes	Yes	
C9A, C9B, C9C	3	Ceramic Capacitor SMD	47u/6.3V	20%	1210	Kemet	C1210C476M9PAC7800	Yes	Yes	
C1A, C1B	2	Ceramic Capacitor SMD	2.2u/100V	10%	1210	Murata	GRM32ER72A225KA35L	Yes	Yes	
C1C, C1D,C1E, C1F	4	Ceramic Capacitor SMD	NU	-	1210	-	-	Yes	Yes	
C9D, C9E	2	Electrolytic Capacitor	NU	-	8x15	-	-	Yes	Yes	
L1	1	Inductor SMD	13u	20%	13.2x12.8	Würth	7443551131	Yes	Yes	
D1	1	Switching Diode	MMSD4148	-	SOD123	ON Semiconductor	MMSD4148T1G	Yes	Yes	
D2	1	Zener Diode 500mW 12V	MMSZ4699	-	SOD123	ON Semiconductor	MMSZ4699T1G	Yes	Yes	
Q1	1	NPN Tranzistor	NU	-	DPAK	-	-	Yes	Yes	
Q2	1	Power N-MOSFET	NTD3055	-	DPAK	ON Semiconductor	NTD3055-150G	Yes	Yes	
Q3	1	Power N-MOSFET	NTD24N06	-	DPAK	ON Semiconductor	NTD24N06T4G	Yes	Yes	
IO1	1	High voltage synchronous PWM buck controler	NCP1034	-	SOIC16	ON Semiconductor	NCP1034DR2G	No	Yes	
X1	1	Inlet Terminal Block	PCB 2 WAY	-	Pitch: 5mm	Lumberg	KRM 02	Yes	Yes	
X2	1	Outlet Terminal Block	PCB 2 WAY	-	Pitch: 5mm	Lumberg	KRM 02	Yes	Yes	

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