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100 W Automotive Pre-Regulator, Non-Isolated, Synchronous Buck, NCV881930-Based Reference Design

TND6290/D

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REFERENCE DESIGN

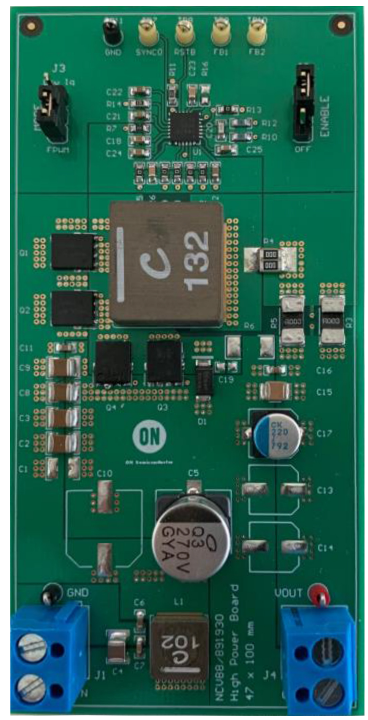

Figure 1. Reference Design Board Image

Overview

This reference design describes the operation and the performance of a 100 W non−isolated synchronous buck automotive pre−regulator, based on the NCV881930 synchronous buck controller with four NVMFS5C460NL 40 V N−channel MOSFET. The reference design shows a complete design for an automotive pre−regulator for a broad range of applications, and highlights the capabilities of the NCV881930 controller.

It is intended for the power supply designer to adopt the circuit directly into a typical system design, making only minimal component changes based on the system requirements.

The design is meant to be a complete solution, but it also provides access to key features of the NCV881930. These include integrated compensation, low I_Q and continuous synchronous mode, wide input range, overcurrent protection, external synchronization, adaptive non−overlap drivers, integrated spread−spectrum, and under voltage lockout.

Key Features

- Complete Automotive Reference Design
- Synchronous Buck Converter with an Input Voltage Range between 6.0 to 16.0 V, Handles Peaks Up to 40 V
- 410 kHz Switching Frequency for Maximum Efficiency
- NCV881930 Low Quiescent Current Automotive Synchronous Buck Converter and Four NVMFS5C460NL 40 V N−channel MOSFET
- Small Form Factor PCB with Four Layers

Specifications

Table 1. SPECIFICATIONS TABLE

Device	NCV881930
Application	Automotive Pre-Regulator
Input Voltage	6 V to 16 V DC, 40 V Peak
Output Power	Up to 100 W
Topology	Synchronous Buck
Isolation	Non-Isolated
Output Voltage	5.0 V
Nominal Current	15.0 A 20.0 A (Peak)

SCHEMATICS

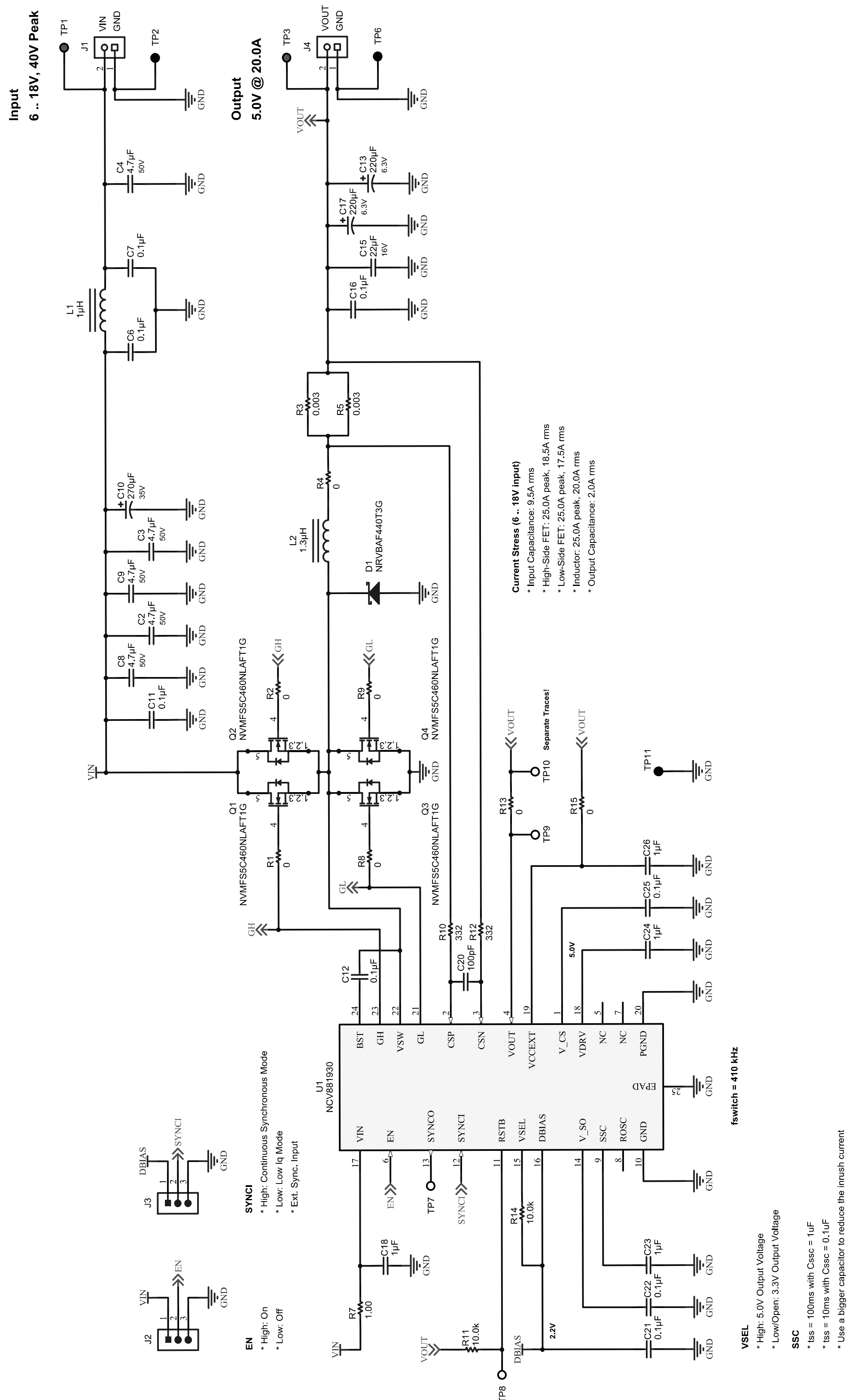

Figure 2. NCV881930 Synchronous Buck Schematic

BOARD LAYOUT

Figure 3, 4, 5 and 6 shows the top and bottom assembly and the four layers of the PCB. The PCB is 47 mm × 100 mm (length × width) where the height of the PCB is approximately 12.5 mm.

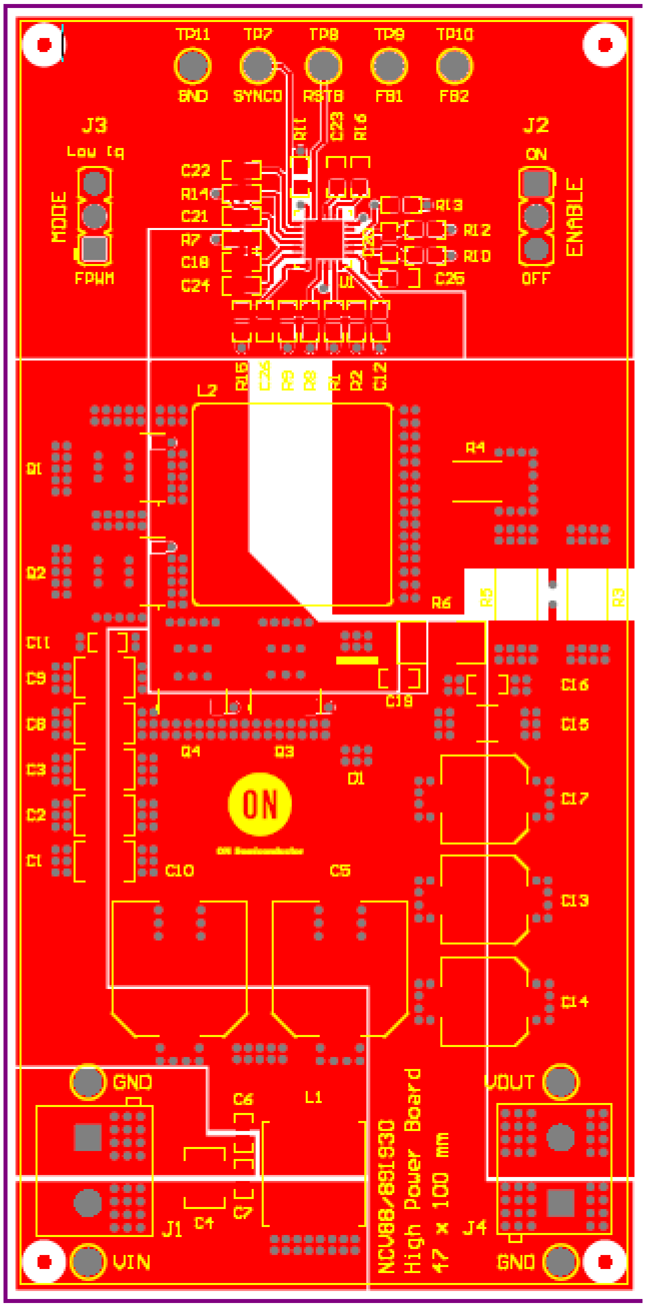

Figure 3. Top Layer and Assembly Drawing

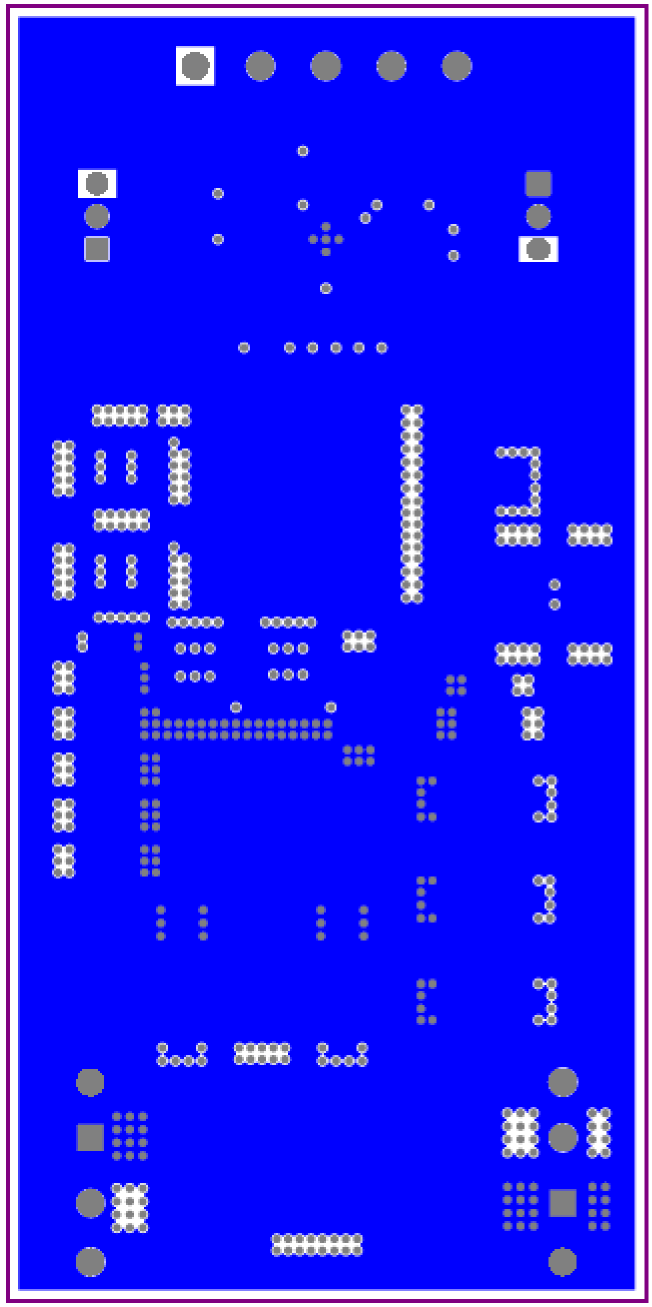

Figure 4. Bottom Layer and Assembly Drawing

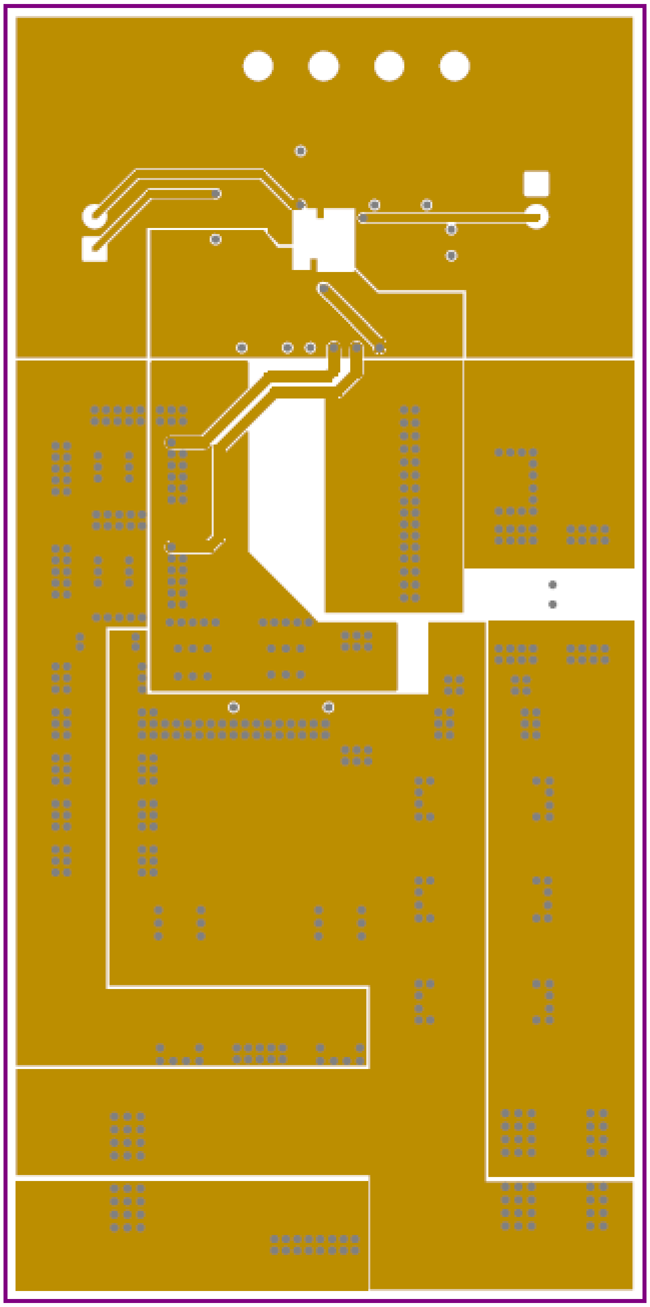

Figure 5. Inner Top Layer

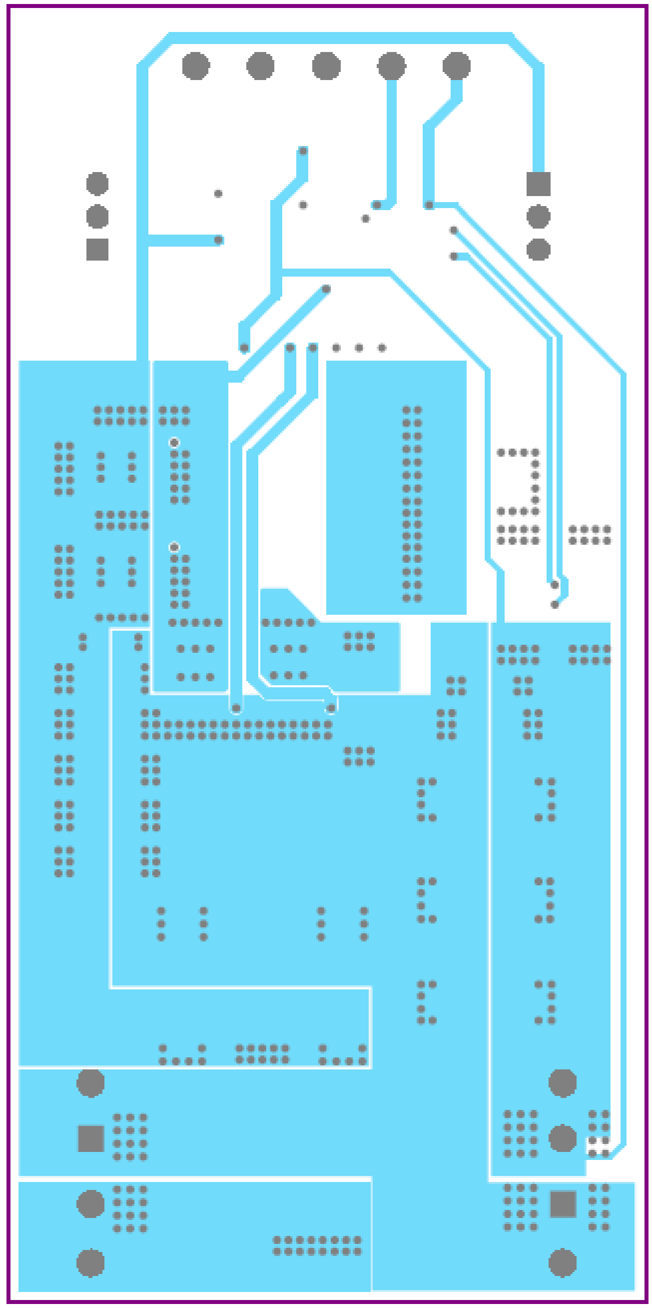

Figure 6. Inner Bottom Layer

PERFORMANCE SUMMARY

Output Voltage

NCV881930 has two fixed output voltage options, 3.3 V and 5.0 V. By pulling VSEL pin to DBIAS using a 10 kΩ resistor, the output voltage is set to 5.0 V. Leaving VSEL floating or connecting it to GND, sets the output voltage to 3.3 V.

Depending on the output current, a modification of the power stage (inductor, shunt, and output capacitance) might be necessary. Therefore please refer to Table 6 in the datasheet.

Efficiency

The efficiency for continuous synchronous mode is shown in Figure 7. This measurement does take into account the losses in the input filter (inductor L1).

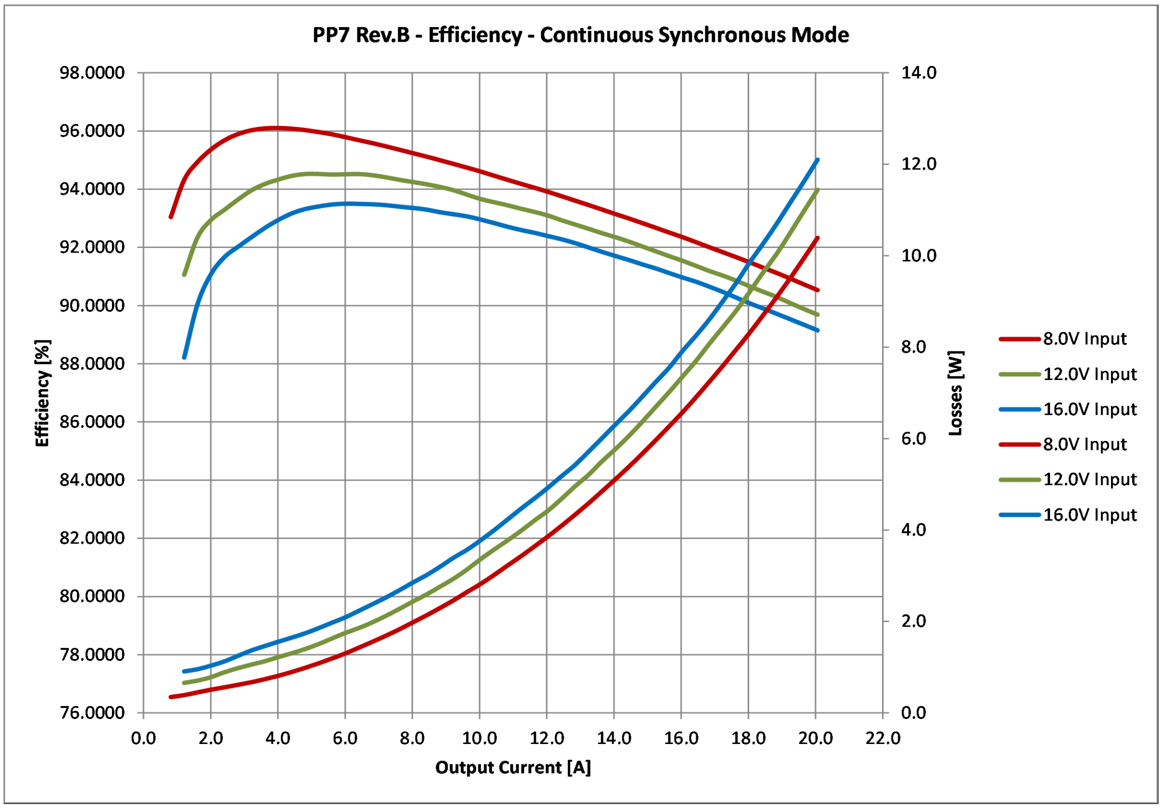

Figure 7. Efficiency for 8.0, 12.0 and 16.0 V Input Voltage

Thermal Image

The thermal images show the board at an ambient temperature of 21°C with an input voltage of 12.0 V, 10.0 A (Figure 8) and 15.0 A (Figure 9) load.

Component	VIN = 12.0 V @ 10.0 A	VIN = 12.0 V @ 15.0 A
Controller	51.2°C	61.0°C
Upper FETs	74.4°C	87.4°C
Lower FETs	66.7°C	85.3°C
Inductor	58.0°C	80.5°C

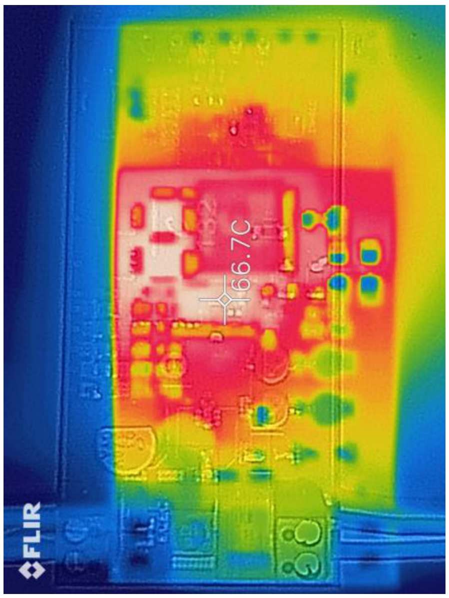

Figure 8. Thermal Image at 10.0 A Load

Figure 9. Thermal Image at 15.0 A Load

Transient Response

The response to a load step from 10.0 A to 20.0 A and vice versa at 12.0 V input voltage is shown in Figure 10.

Channel 1

- Output voltage, −147 mV (−2.94%) undershoot, +147 mV (+2.94%) overshoot
- 100 mV/div, 100 μs/div, AC coupled

Channel 2

- Output current, load step 20.0 to 10.0 A and vice versa
- 10 A/div, 100 μs/div

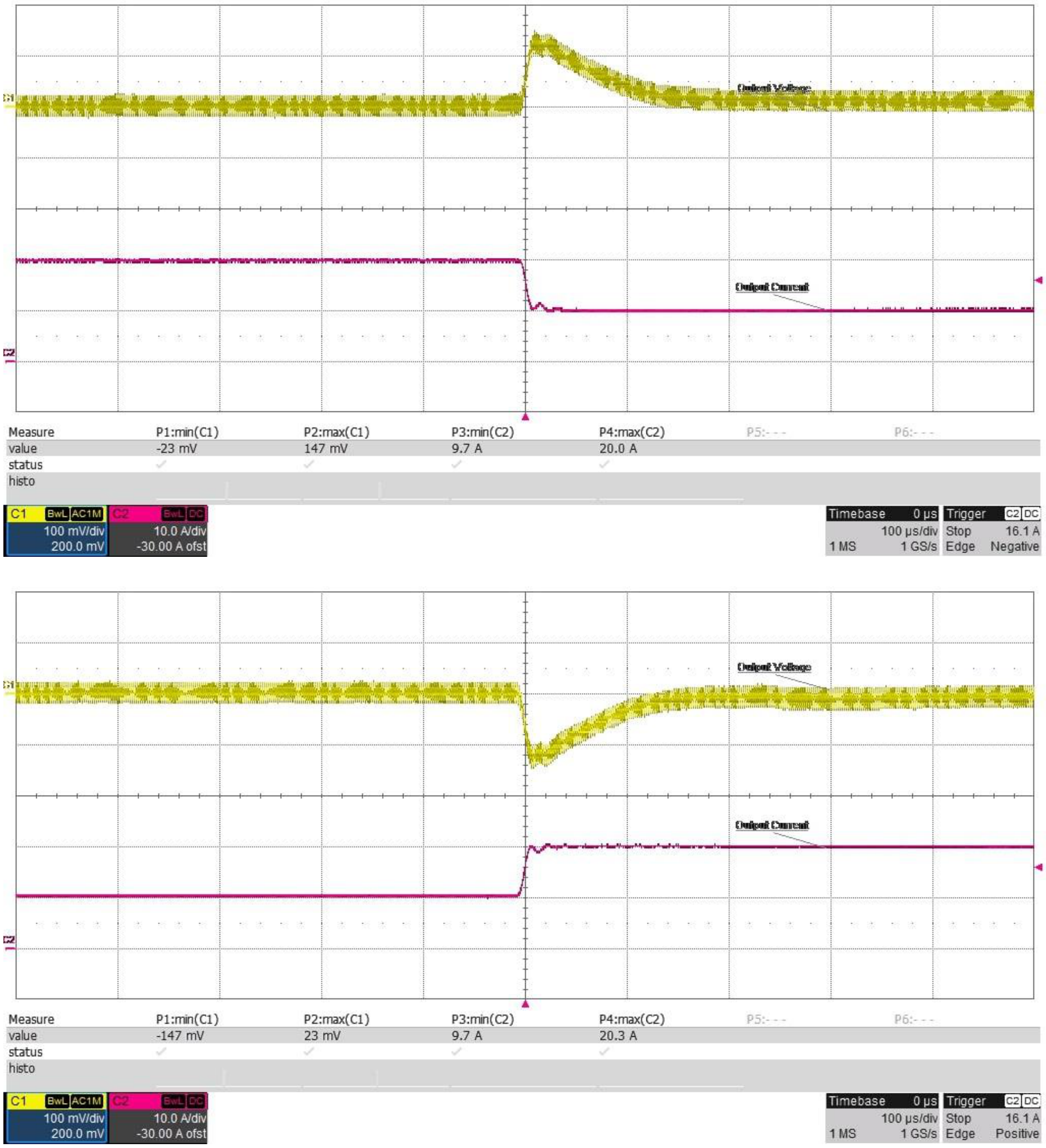

Figure 10. Transient Response on 20.0 A to 10.0 A Load Step Down and 10.0 A to 20.0 A Load Step Up

Frequency Response

The frequency response at 12.0 V input voltage and 10.0 A and 20.0 A load is shown in Figure 11 and Figure 12.

FREQUENCY RESPONSE

Input Voltage	Output Current	Bandwidth	Phase Margin	Gain Margin
12.0 V	10.0 A	39.2 kHz	90.1°	−17.2 dB
12.0 V	20.0 A	38.1 kHz	92.8°	−15.3 dB

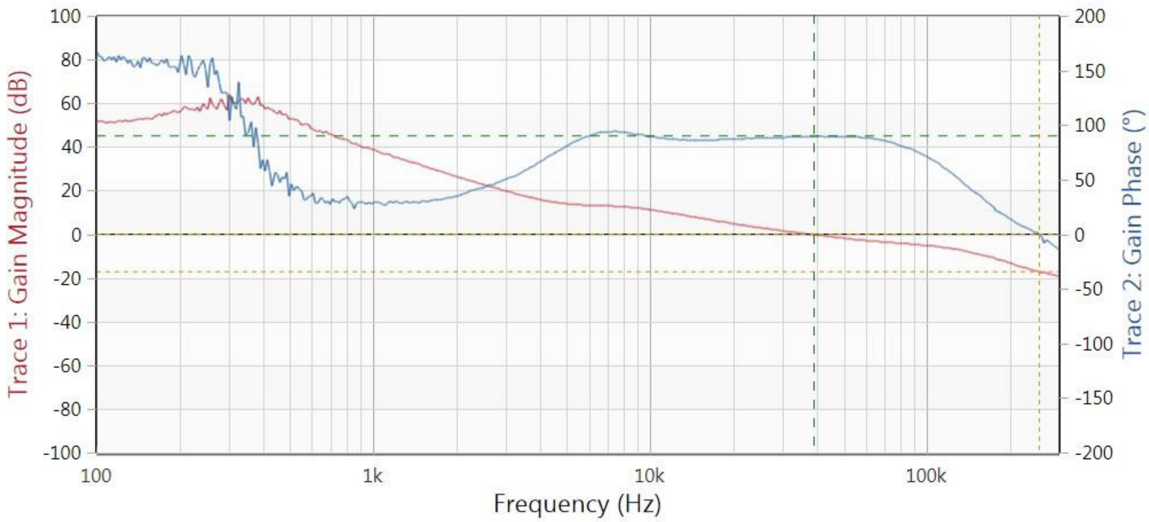

Figure 11. Frequency Response at 10.0 A Load

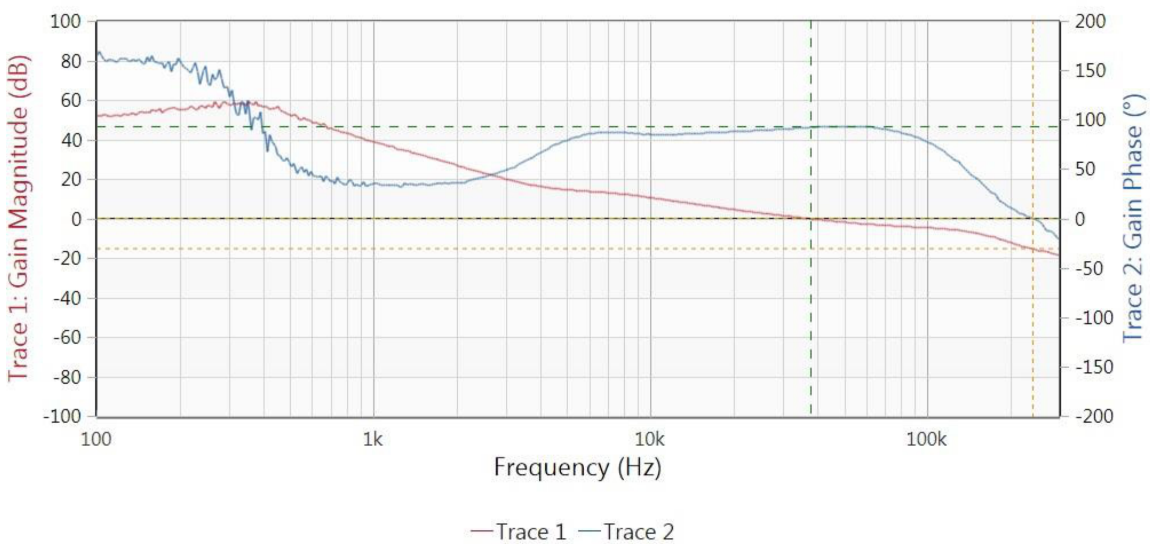

Figure 12. Frequency Response at 20.0 A Load

Impact of Output Capacitance Configuration on Performance

The datasheet of the NCV881930 gives detailed recommendations for the output filter configuration (inductance, shunt resistance, and output capacitance) dependent on the output voltage and current.

Table 2 shows the measurement results for various output capacitor configurations and their corresponding performance regarding ripple, transient response and phase margin.

Different sets of high capacitance ceramic and polymer capacitors were used for the measurements.

- 1x 100 nF, 50 V, 0603, X7R, always populated
  muRata GCJ188R71H104KA12D
- 22 μF ceramic, 16 V, 1210, X7R
  muRata GCM32ER71C226ME19L
  18 μF @ 5.0 Vdc, 2 mΩ ESR @ 410 kHz
- 120 μF polymer
  Nichicon PCJ0J121MCL1GS
  24 mΩ ESR @ 100 kHz
- 220 μF polymer
  Nichicon PCJ0J221MCL1GS
  15 mΩ ESR @ 100 kHz

Table 2. MEASUREMENT RESULTS FOR VARIOUS OUTPUT CAPACITOR CONFIGURATIONS

Polymer: 220 μF, 6.3 V	2	1	0	# of caps
Polymer: 120 μF, 6.3V	0	0	3	# of caps
Ceramic: 22 μF, 16 V	1	1	1	# of caps
Output Ripple, peak−peak	145	162	96	[mV]
Output Ripple, peak−peak	2.90	3.24	1.92	[%]
Transient Response, peak−peak	±147	−183 / +157	−153 / +137	[mV]
Transient Response, peak−peak	2.94	3.66 / 3.14	3.06 / 2.74	[%]
Bandwidth	38.1	66.6	34.5	[kHz]
Phase Margin	92.8	69.4	80.3	[°]

BILL OF MATERIALS (BOM)

Table 3. BILL OF MATERIALS

Designator	Qty.	Value	Part Number	Manufacturer	Description	Package
C2, C3, C4, C8, C9	5	4.7 μF	GCJ32ER71H475KA12	MuRata	CAP, CERM, 4.7 μF, 50 V, ±10%, X7R, 1210	1210
C6, C7, C11, C12, C16, C21, C22, C25	8	0.1 μF	GCJ188R71H104KA12	MuRata	CAP, CERM, 0.1 μF, 50 V, ±10%, X7R, AEC−Q200 Grade 1, 0603	0603
C10	1	270 μF	GYA1V271MCQ1GS	Nichicon	CAP, Conductive Polymer Hybrid Aluminum Electrolytic, 270 μF, 35 V, ±20%, 0.020 Ω, 10x10.3 SMD	10.3x10.3x10.3
C13, C17	2	220 μF	PCJ0J221MCL1GS	Nichicon	CAP, Conductive Polymer Aluminum Capacitor 220 μF, 6.3 V, ±20%, 0.015 Ω, AEC−Q200 Grade 2, SMD	D6.3xL6.Ω
C15	1	22 μF	GCM32ER71C226KE19L	MuRata	CAP, CERM, 22 μF, 16 V, ±10%, X7R, 1210	1210
C18, C23, C24, C26	4	1 μF	GCJ188R71E105KA01D	MuRata	CAP, CERM, 1 μF, 25 V, ±10%, X7R, AEC−Q200 Grade 1, 0603	0603
C20	1	100 pF	GRM1885C1H101JA01D	MuRata	CAP, CERM, 100 pF, 50 V, ±5%, C0G/NP0, 0603	0603
D1	1	40 V	NRVBAF440T3G	ON Semiconductor	Diode, Schottky, 40 V, 4 A, SMA−FL	SMA−FL
FID1, FID2, FID3, FID4	4		N/A	N/A	Fiducial mark. There is nothing to buy or mount.	N/A
J1, J4	2		ED120/2DS	On−Shore Technology	Terminal Block, 5.08 mm, 2x1, Brass, TH	2x1 5.08 mm Terminal Block
J2, J3	2		61300311121	Wurth Elektronik	Header, 2.54 mm, 3x1, Gold, TH	Header, 2.54 mm, 3x1, TH
L1	1	1.5 μH	XAL7030−102MEB	Coilcraft	Inductor, Shielded, Composite, 1 μH, 21.8 A, 0.00455 Ω, SMD	XAL7030
L2	1	1.3 μH	XAL1580−132MEB	Coilcraft	Inductor, Shielded, Composite, 1.3 μH, 46.7 A, 0.00115 Ω, SMD	15.2x8x16.2 mm
Q1, Q2, Q3, Q4	4	40	NVMFS5C460NLAFT1G	ON Semiconductor	MOSFET, N−CH, 40 V, 78 A, DFN5 5x6 mm	DFN5 5x6 mm
R1, R2, R8, R9, R13, R15	6	0	CRCW06030000Z0EA	Vishay−Dale	RES, 0, 5%, 0.1 W, 0603	0603
R3, R5	2	0.003	ERJ−M1WTF3M0U	Panasonic	RES, 0.003, 1%, 1 W, 2512	2512
R4	1	0	CRCW25120000Z0EG	Vishay−Dale	RES, 0, 5%, 1 W, AEC−Q200 Grade 0, 2512	2512
R7	1	1.00	CRCW06031R00FKEA	Vishay−Dale	RES, 1.00, 1%, 0.1 W, 0603	0603
R10, R12	2	332	CRCW0603332RFKEA	Vishay−Dale	RES, 332, 1%, 0.1 W, 0603	0603

Table 3. BILL OF MATERIALS (continued)

Designator	Qty.	Value	Part Number	Manufacturer	Description	Package
R11, R14	2	10.0k	CRCW060310K0FKEA	Vishay−Dale	RES, 10.0 k, 1%, 0.1 W, 0603	0603
TP1, TP3	2		5000	Keystone	Test Point, Miniature, Red, TH	Red Miniature Testpoint
TP2, TP6, TP11	3		5001	Keystone	Test Point, Miniature, Black, TH	Black Miniature Testpoint
TP7, TP8, TP9, TP10	4		5002	Keystone	Test Point, Miniature, White, TH	White Miniature Testpoint
U1	1		NCV881930MW00R2G	ON Semiconductor	Low Quiescent Current 410 kHz Automotive Synchronous Buck Controller	QFNW−24

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