

50 W Automotive 410 kHz Pre-Regulator, Non-Isolated, Synchronous Buck, NCV881930-Based Reference Design

TND6426/D

Overview

This reference design describes the operation and performance of a 50 W non-isolated synchronous buck automotive pre-regulator, based on the NCV881930 synchronous buck controller with two NVTYS005N04CL 40 V N-channel MOSFETs in 3.3 × 3.3 LPAK package. 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 system requirements. The design is meant to be a complete solution, providing 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 undervoltage lockout.

Key Features

- Complete Automotive Reference Design
- Synchronous Buck Converter with an Input Voltage Range of 5.0 to 16.0 V, Handles Peaks up to 40 V
- 410 kHz Switching Frequency for Maximum Efficiency
- onsemi [NCV881930](#) Low Quiescent Current Automotive Synchronous Buck Converter and [NVTYS005N04CL](#) 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 50 W
Topology	Synchronous Buck
Isolation	Non-Isolated
Output Voltage	3.3 V, 5.0 V
Nominal Current	10.0 A

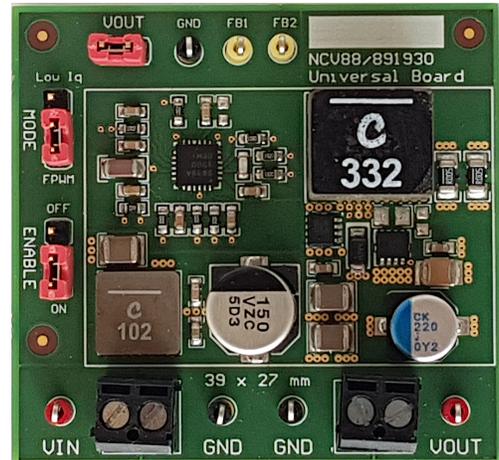


Figure 1. Reference Design Board Image

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SCHEMATIC

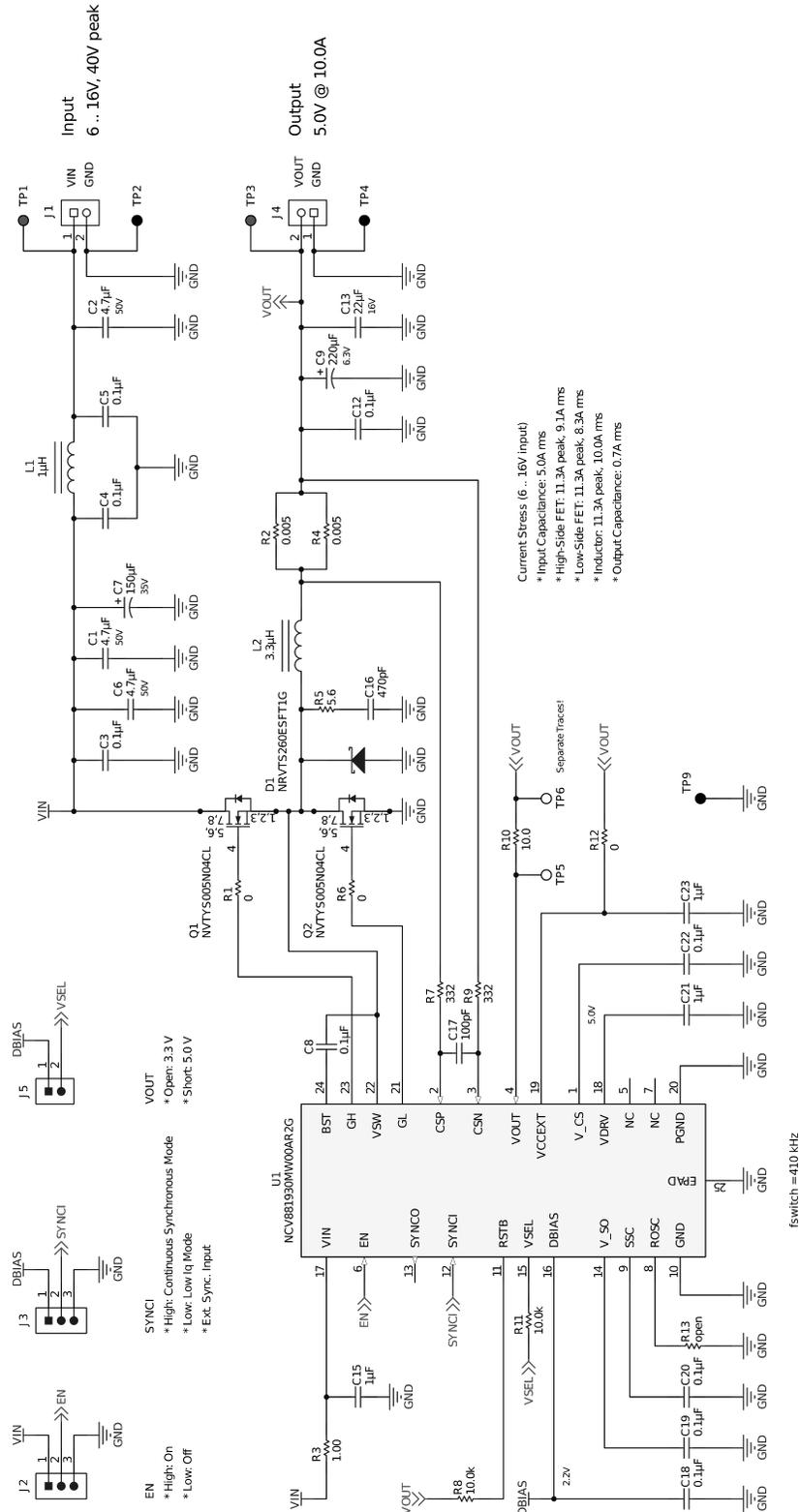


Figure 2. NCV881930 Synchronous Buck Schematic

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BOARD LAYOUT

Figure 3, 4, 5 and 6 shows the top and bottom assembly and the four layers of the PCB, which measures 47 mm × 44 mm × 11 mm (length × width × height).

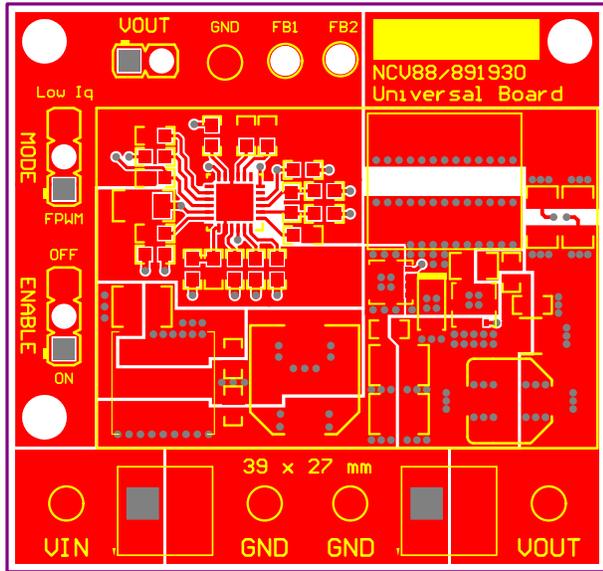


Figure 3. Top Layer and Assembly Drawing

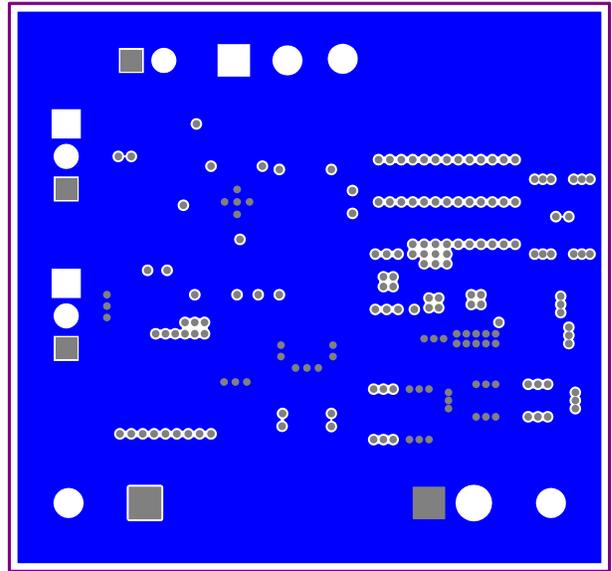


Figure 4. Bottom Layer and Assembly Drawing

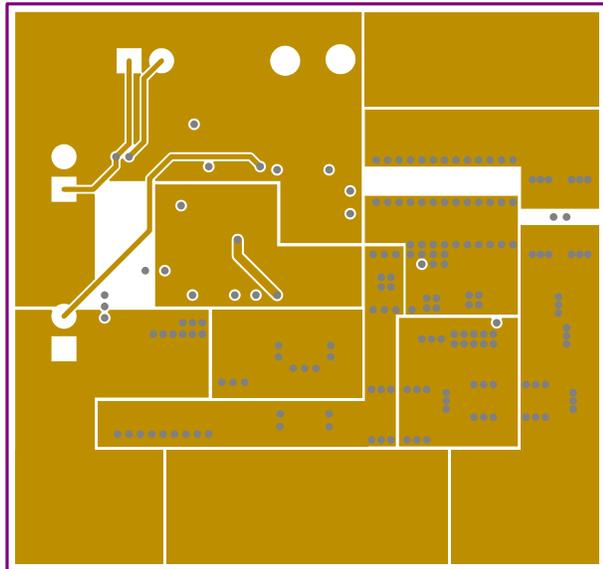


Figure 5. Inner 1 Layer

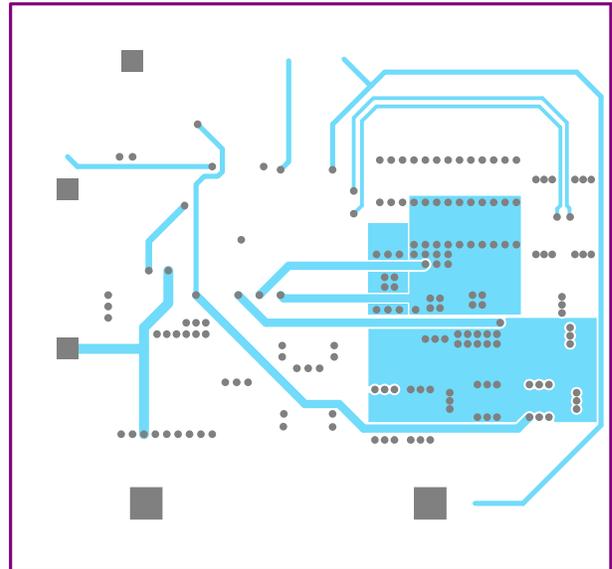


Figure 6. Inner 2 Layer

PERFORMANCE SUMMARY

Output Voltage

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

Dependent on the output voltage and current, a modification of the power stage (inductor, shunt, output capacitance) may be required. Please consult therefore Table 6 in the [NCV881930](#) datasheet.

Efficiency

The efficiency for continuous synchronous mode with 3.3 V and 5.0 V output voltage is shown in Figure 7 and 8. The measurement was done “plug-to-plug”, therefore the losses of the input filter are included.

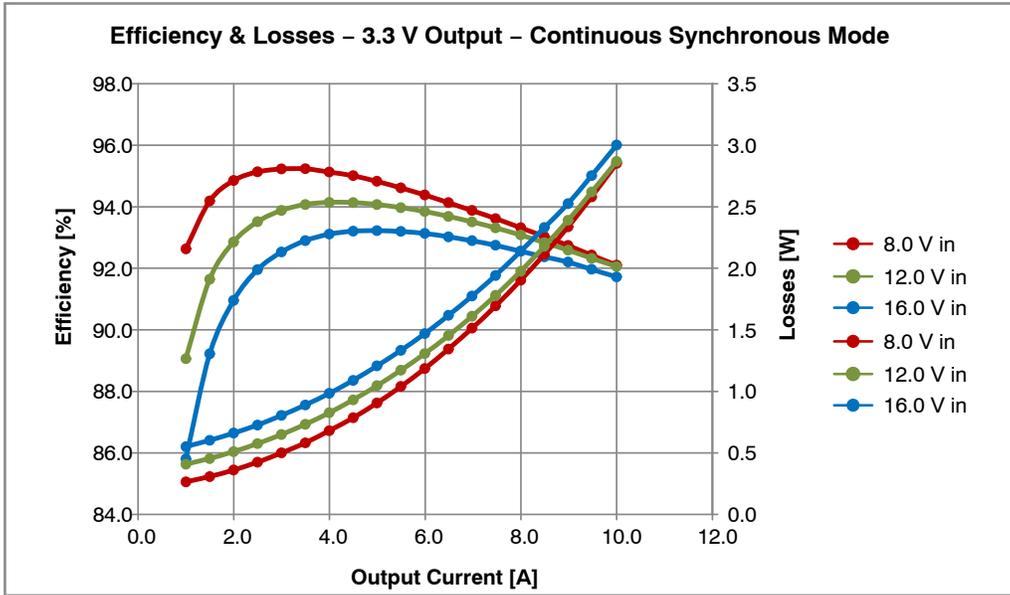


Figure 7. Efficiency at 3.3 V Output Voltage

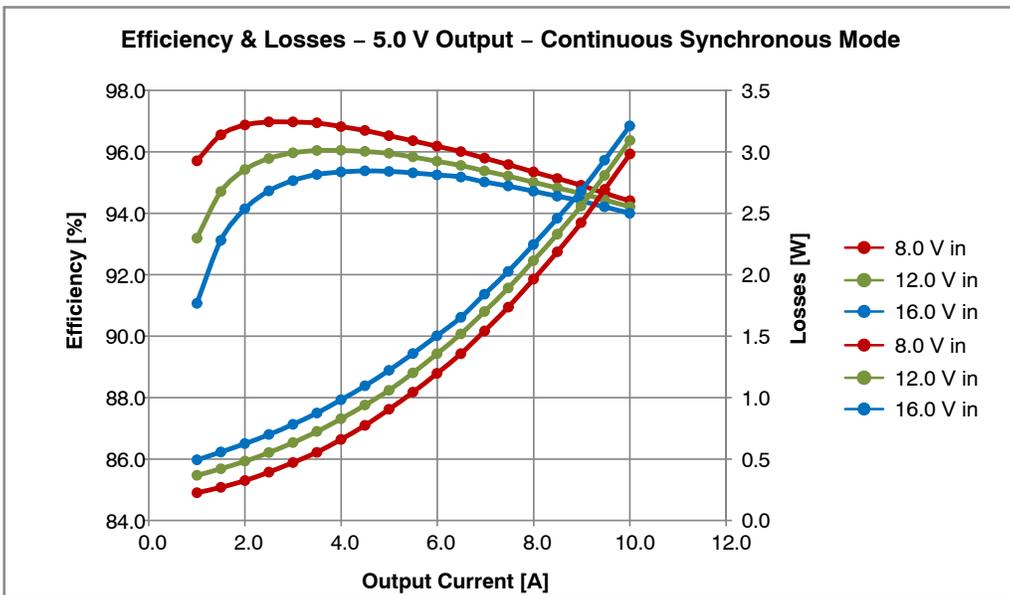


Figure 8. Efficiency at 5.0 V Output Voltage

Thermal Image

The thermal images show the circuit at an ambient temperature of 22°C with an input voltage of 12.0 V.

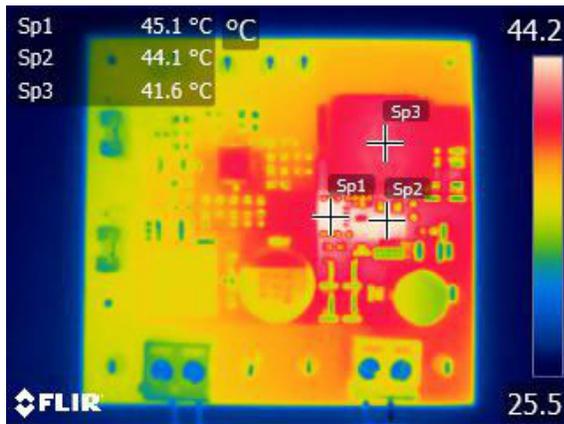


Figure 9. Thermal Image at 3.3 V Output Voltage and 5.0 A Load

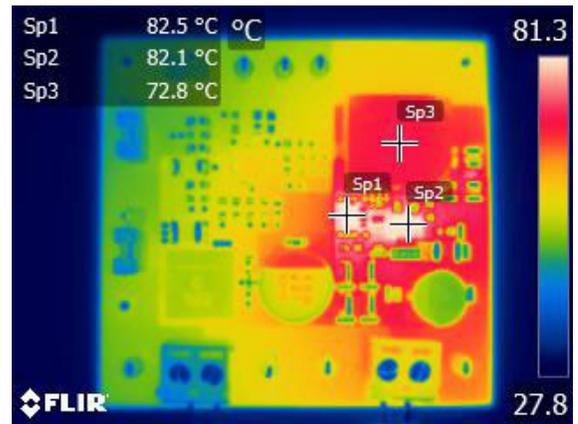


Figure 10. Thermal Image at 3.3 V Output Voltage and 10.0 A Load

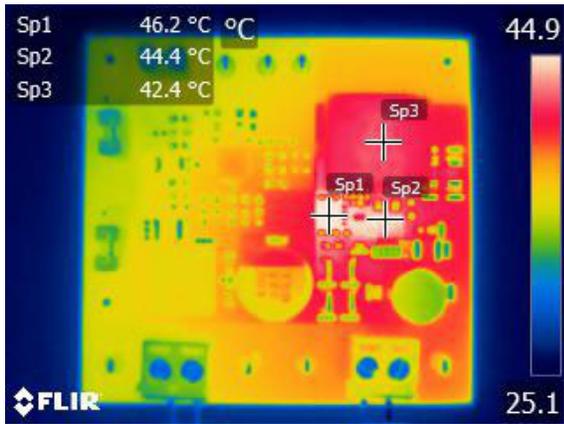


Figure 11. Thermal Image at 5.0 V Output Voltage and 5.0 A Load

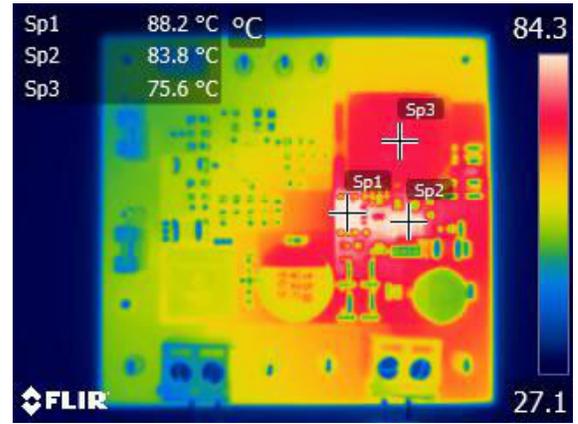


Figure 12. Thermal Image at 5.0 V Output Voltage and 10.0 A Load

Table 2. COMPONENT TEMPERATURES

Component	3.3 V Output Voltage		5.0 V Output Voltage	
	Temperature @ 5.0 A Load	Temperature @ 10.0 A Load	Temperature @ 5.0 A Load	Temperature @ 10.0 A Load
SP1: Q1	45.1°C	82.5°C	46.2°C	88.2°C
SP2: Q2	44.1°C	82.1°C	44.4°C	83.8°C
SP3: L1	41.6°C	72.8°C	42.4°C	75.6°C

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Transient Response

The response to a load step from 5.0 A to 10.0 A and vice versa at 12.0 V input voltage and 5.0 V output voltage is shown in Figure 13.

Channel 1

- ◆ Output current, load step 5.0 to 10.0 A and vice versa 5 A/div, 1 ms/div

Channel 2

- ◆ Output voltage, -97 mV (-1.9%) undershoot, +93 mV (1.9%) overshoot 100 mV/div, 1 ms/div, AC coupled

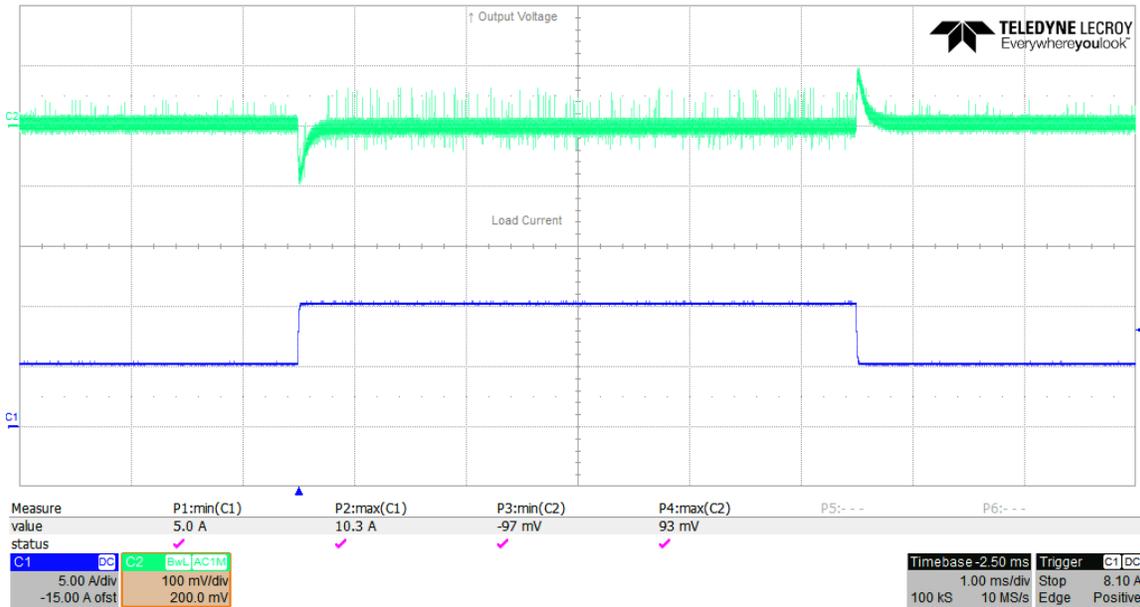


Figure 13. Transient Response on 5.0 A Load Step

Frequency Response

The frequency response at 12.0 V input voltage, 5.0 V output voltage and 10.0 A load is shown in Figure 14.

Trace 1

- ◆ 35 kHz bandwidth
- ◆ -23 dB gain margin

Trace 2

- ◆ 66° phase margin

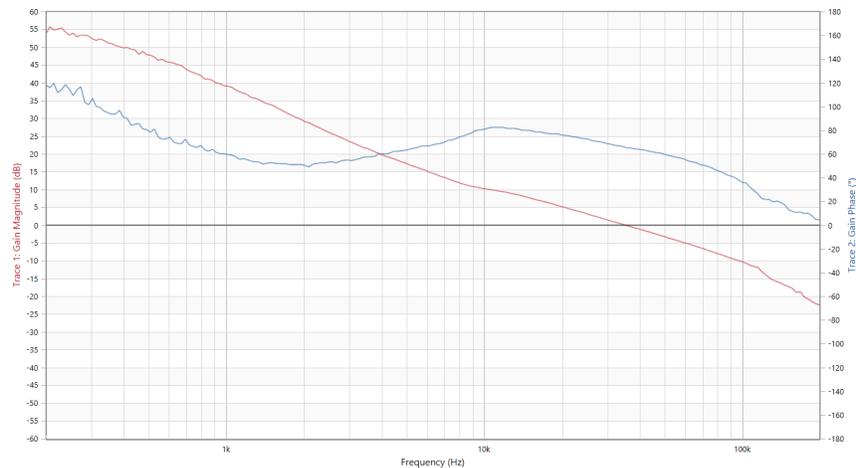


Figure 14. Frequency Response at 10.0 A Load

Impact of Output Capacitance Configuration on Performance

The [NCV881930](#) datasheet gives detailed recommendations for the output filter configuration (inductance, shunt resistance, output capacitance) dependent on the output voltage and current. A test series

with three different output capacitance configurations were conducted and the results show that different configurations are possible without decreasing performance or causing stability issues by the integrated compensation.

The following configurations for the output capacitance are evaluated:

Table 3. TEST CONFIGURATIONS

	Ceramic Capacitor 1	Ceramic Capacitor 2	Polymer Capacitor
Configuration 1	100 nF, 50 V, 0603, X7R muRata GCJ188R71H104KA12D	22 μF, 16 V, 1210, X7R muRata GCM32ER71C226ME19L 18 μF @ 5.0 V DC, 2 mΩ ESR @ 410 kHz	120 μF, 6.3 V, 24 mΩ Nichicon PCJ0J121MCL1GS
Configuration 2			220 μF, 6.3 V, 10 mΩ Nichicon PCK0J221MCO1GS
Configuration 3			330 μF, 6.3 V, 9 mΩ Nichicon PCK0J331MCO1GS

Table 4 shows the measurement results for the different output capacitor configurations and their corresponding performance regarding transient response and phase/gain margin.

The input voltage is 12.0 V, the output voltage is 5.0 V, the load current for the frequency response measurement is 10.0 A and the load step is 5.0 A to 10.0 A and vice versa.

Table 4. MEASUREMENT RESULTS

	Configuration 1 – 120 μF	Configuration 2 – 220 μF	Configuration 3 – 330 μF
Bandwidth	63 kHz	35 kHz	25 kHz
Phase Margin	53°	66°	78°
Gain Margin	-11 dB	-23 dB	-28 dB
Transient Response	-97 / -94 mV ±1.9%	-97 / +93 mV ±1.9%	-97 / +93 mV ±1.9%

Summary

- The phase and gain margin show good values over a broad range of output capacitance. Only with 120 μF of output capacitance the phase margin is below the typically recommended value of minimum 60° for a robust automotive design.
- Generally, higher output capacitance leads to higher phase and gain margin.
- The transient response is basically the same for all measurements and independent of the output capacitance. The voltage drop / overshoot is around ±1.9 % for all measurements.

- With low output capacitance the bandwidth increases and with higher output capacitance it decreases. Therefore, a lower bandwidth is compensated by larger capacitance and vice versa.
- As the device is internally compensated, the reason for that behavior is the shift of the load pole:

$$f_{\text{Pole, Load}} = \frac{1}{2 \cdot \pi \cdot C_{\text{out}} \cdot R_{\text{load}}} = \frac{1}{2 \cdot \pi \cdot C_{\text{out}} \cdot \frac{V_{\text{out}}}{I_{\text{out}}}} \quad (\text{eq. 1})$$

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BILL OF MATERIALS (BOM)

Table 5. BILL OF MATERIALS

Designator	Qty.	Value	Part Number	Manufacturer	Description	Package
C1, C2, C6	3	4.7 μ F	GCM32ER71H475KA55	MuRata	CAP, CERM, 4.7 μ F, 50 V, \pm 10%, X7R, 1210	1210
C3, C4, C5, C8, C12, C18, C19, C20, C22	9	0.1 μ F	GCM155R71H104KE02D	MuRata	CAP, CERM, 0.1 μ F, 50 V, \pm 10%, X7R, 0603	0603
C7	1	150 μ F	EEHZC1V151P	Panasonic	CAP, Hybrid Polymer, 150 μ F, 35 V, \pm 20%, 0.027 Ω , SMD	D8xL10 mm
C9	1	220 μ F	PCK0J221MCO1GS	Nichicon	CAP, Aluminum Polymer, 220 μ F, 6.3 V, \pm 20%, 0.010 Ω , SMD	D5.0xL6.0 mm
C13	1	22 μ F	GCM32ER71C226KE19L	MuRata	CAP, CERM, 22 μ F, 16 V, \pm 10%, X7R, 1210	1210
C15	1	1 μ F	GCM21BR71H105KA03	MuRata	CAP, CERM, 1 μ F, 50 V, \pm 10%, X7R, 1206	1206
C16	1	470 pF	GCM155R71H471KA37D	MuRata	CAP, CERM, 470 pF, 50 V, \pm 10%, X7R, 0603	0603
C17	1	100 pF	GCM1555C1H101JA16	MuRata	CAP, CERM, 100 pF, 50 V, \pm 5%, COG/NPO, 0603	0603
C21, C23	2	1 μ F	GCM188R71E105KA64D	MuRata	CAP, CERM, 1 μ F, 25 V, \pm 10%, X7R, 0603	0603
D1	1	60 V	NRVTS260ESFT1G	onsemi	Diode, Schottky, 60 V, 2 A, AEC-Q101, SOD-123FL	SOD-123FL
J1, J4	2		ED555/2DS	On-Shore Technology	Terminal Block, 3.5 mm Pitch, 2x1, TH	7.0x8.2x6.5 mm
J2, J3	2		61300311121	Würth Elektronik	Header, 2.54 mm, 3x1, Gold, TH	2.54mm, 3x1, TH
J5	1		61300211121	Würth Elektronik	Header, 2.54 mm, 2x1, Gold, TH	2.54mm, 2x1, TH
L1	1	1 μ H	XAL7030-102MEB	Coilcraft	Inductor, Shielded, Composite, 1 μ H, 21.8 A, 0.00455 Ω , SMD	7.5x7.5x3.1 mm
L2	1	3.3 μ H	XAL1010-332MEB	Coilcraft	Inductor, Shielded, Composite, 3.3 μ H, 25 A, 0.0037 Ω , SMD	11.3x10x10 mm
Q1, Q2	2	40 V	NVTYS005N04CLTWG	onsemi	MOSFET, N-CH, 40 V, 75 A, FET, 3.3x3.3	LFPAK8, 3.3x3.3
R1, R6, R12	3	0 Ω	CRCW06030000Z0EA	Vishay-Dale	RES, 0, 5%, 0.1 W, 0603	0603
R2, R4	1	0.005 Ω	ERJ-8CWFR005V	Panasonic	RES, 0.005, 1%, 1 W, 1206	1206
R3	1	1.00 Ω	CRCW06031R00FKEA	Vishay-Dale	RES, 1.00, 1%, 0.1 W, 0603	0603
R5	1	5.6 Ω	CRCW08055R60JNEA	Vishay-Dale	RES, 5.6, 5%, 0.125 W, 0805	0805
R7, R9	2	332 Ω	CRCW0603332RFKEA	Vishay-Dale	RES, 332, 1%, 0.1 W, 0603	0603
R8, R11	2	10.0 k Ω	CRCW060310K0FKEA	Vishay-Dale	RES, 10.0 k, 1%, 0.1 W, 0603	0603
R10	1	10.0 Ω	CRCW060310R0FKEA	Vishay-Dale	RES, 10.0, 1%, 0.1 W, 0603	0603
TP1, TP3	2		5000	Keystone	Test Point, Miniature, Red, TH	Miniature Testpoint
TP2, TP4, TP9	3		5001	Keystone	Test Point, Miniature, Black, TH	Miniature Testpoint
TP5, TP6	2		5002	Keystone	Test Point, Miniature, White, TH	Miniature Testpoint
U1	1		NCV881930MW00AR2G	onsemi	Low Quiescent Current 410 kHz Automotive Synchronous Buck Controller	QFNW24

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