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TND6323/D

Automotive Start-Stop Power Supply Reference Design

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REFERENCE DESIGN

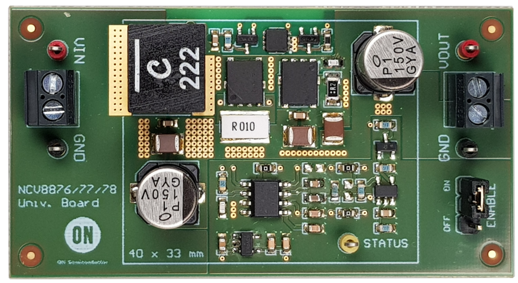

Figure 1. Reference Design Board Image

Overview

This automotive start−stop power supply reference design describes the operation and performance for a typical pre−boost application needed in various automotive applications like ADAS, gateway and infotainment. It ensures proper supply of all subsequent regulators and therefore uninterrupted operation of the application, even at significant input voltage drops down to 1.5 V caused by cold cranking.

The design demonstrates the NCV887801 controller capabilities and incorporates a NVMFS5C442NL 40 V N−channel FET and a NRVB460MFS 60 V Schottky diode for the power stage.

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, but it also provides access to key features of the NCV887801. These include automatic wake up, status pin diagnostic function, low I_Q, ±2% output accuracy over temperature range, peak current mode control with integrated slope compensation and cycle−by−cycle current limit protection with hiccup−mode overcurrent protection.

Key Features

- Complete Automotive Reference Design
- Non−synchronous Boost Converter with an Input Voltage Range of Nominal 3.0 to 7.0 V, Capable to Operate Temporary Down to 1.5 V, Withstands Peaks Up to 40 V
- 450 kHz Switching Frequency for High Efficiency
- ON Semiconductor NCV887801 Start−Stop Non−synchronous Boost Controller, NVMFS5C442NL 40 V N−channel FET and NRVB460MFS 60 V Schottky Diode
- Optional Bypass Circuit with a NVTFS5116PL −60 V P−FET to Minimize Losses while the Converter is Not Switching
- Small Form Factor PCB with Four Layers

Specifications

Table 1. SPECIFICATIONS TABLE

Device	NCV887801
Application	Automotive Start−Stop Boost Converter
Input Voltage	3 V to 7 V DC Nominal, 1.5 V Temporary, 40 V Peak
Output Power	20 W
Topology	Non−synchronous Boost
Isolation	Non-Isolated
Output Voltage	6.8 V
Nominal Current	3.0 A

December, 2019 − Rev. 1

Publication Order Number:
TND6323/D

SCHEMATICS

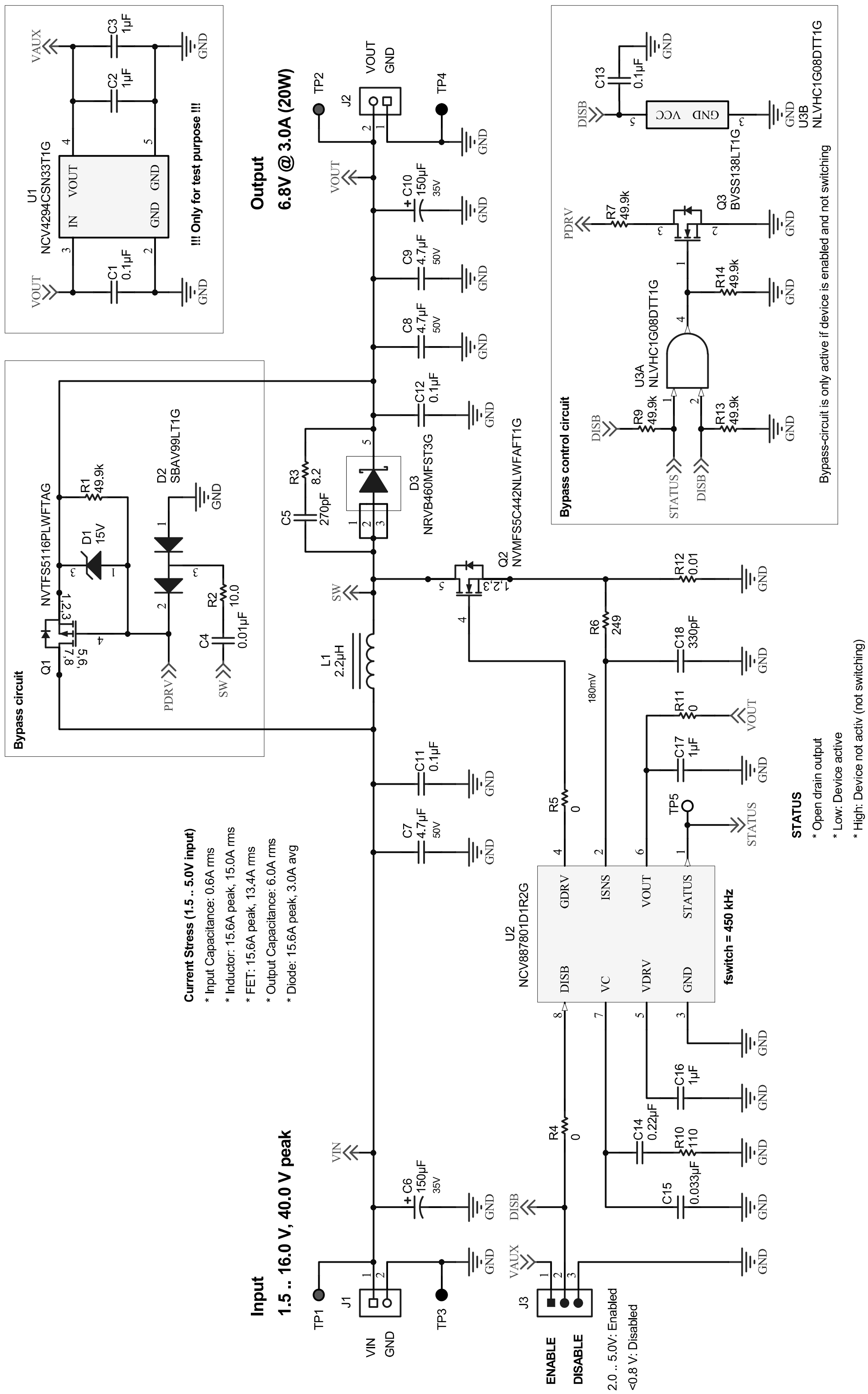

Figure 2. NCV887801 Non−synchronous Boost Schematic

BOARD LAYOUT

Figure 3, 4, 5 and 6 shows the top and bottom assembly and the four layers of the PCB. The converter size is 39 mm × 27 mm (length × width) where the height of the PCB is approximately 11 mm.

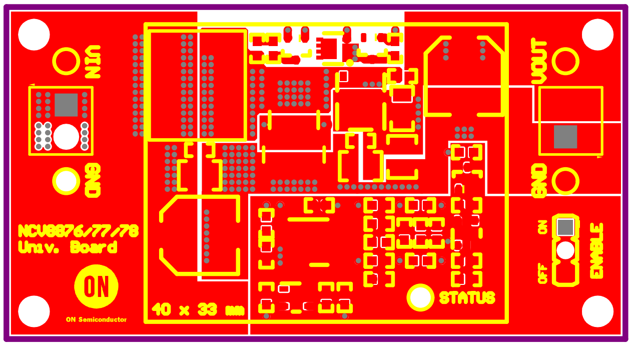

Figure 3. Top Layer and Assembly Drawing

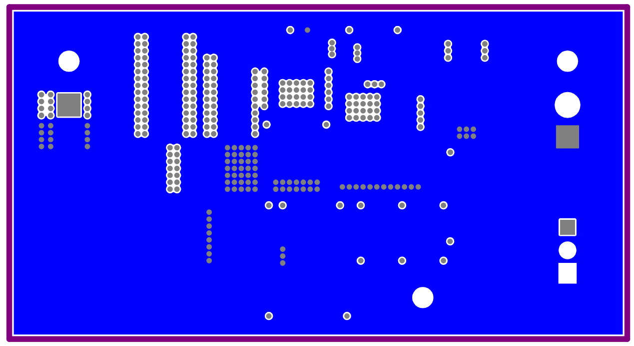

Figure 4. Bottom Layer and Assembly Drawing

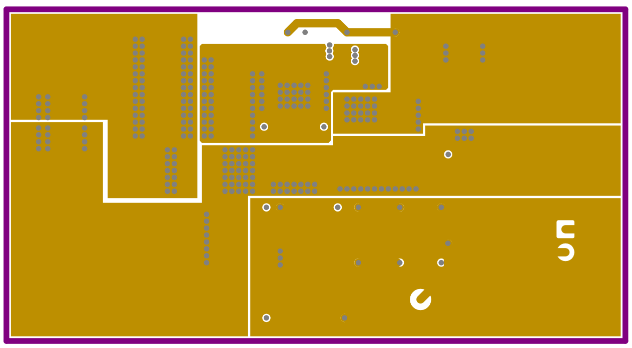

Figure 5. Inner 1 Layer

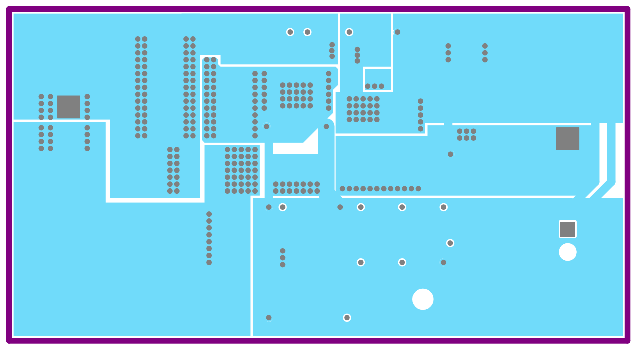

Figure 6. Inner 2 Layer

PERFORMANCE SUMMARY

Output Voltage

The feedback voltage divider is integrated in the device to minimize losses, therefore the output voltage of NCV887801 is fixed to 6.8 V. This voltage is selected to provide enough margin to maintain a 5.0 V output of a pre−regulator which is supplied by the boost converter.

Efficiency

The efficiency for 4.0 and 6.0 V input voltage is shown in Figure 7.

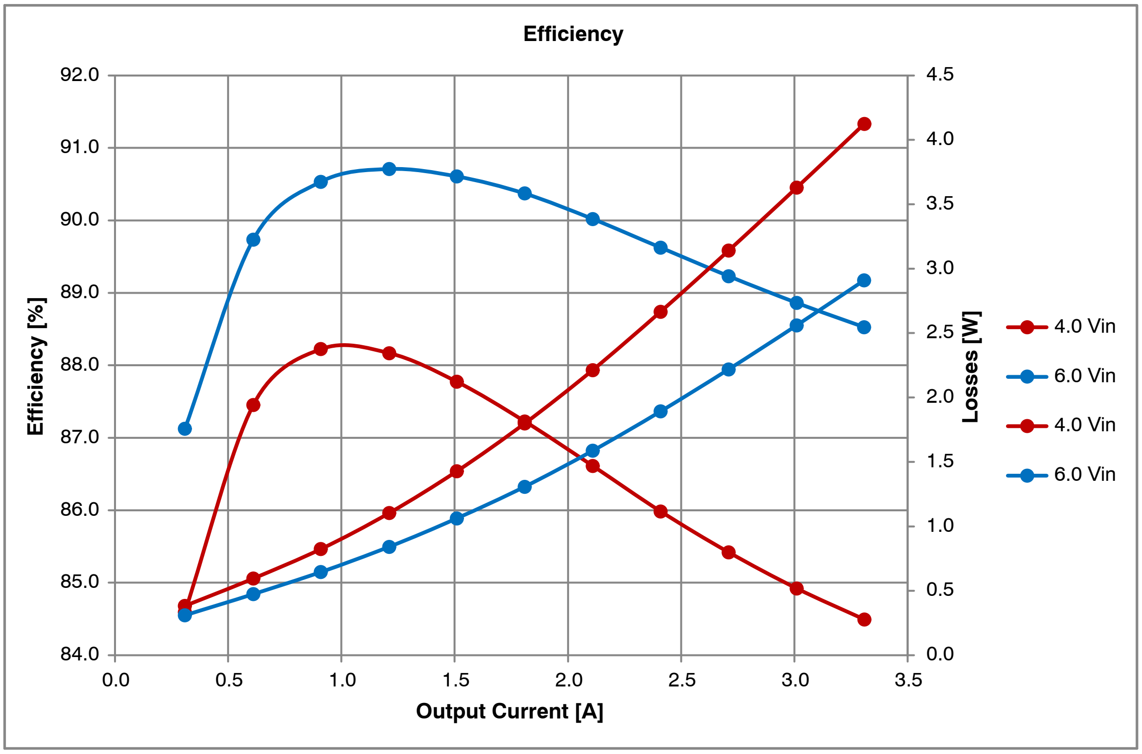

Figure 7. Efficiency for 4.0 and 6.0 V Input Voltage

Thermal Image

The thermal performance of the circuit at an ambient temperature of 21°C with an input voltage of 4.0 V and 1.5 A load is shown in Figure 8.

- Diode D3 58.4°C
- FET Q2 48.6°C
- Inductor L1 43.7°C
- Shunt R12 46.0°C
- Snubber R3 52.1°C

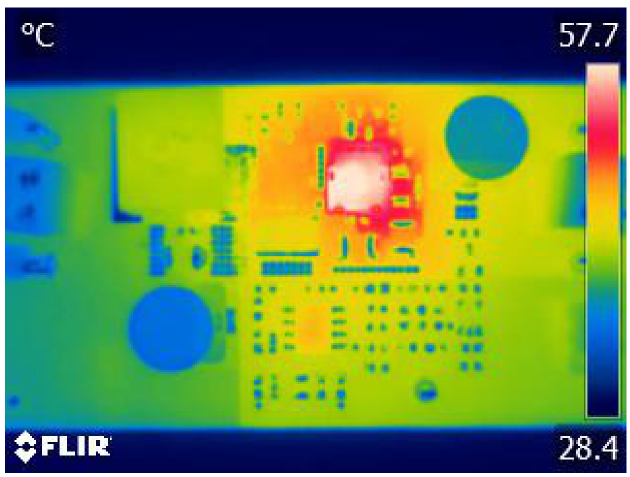

Figure 8. Thermal Image at 1.5 A Load

Transient Response

The response to a load step from 1.5 A to 3.0 A and vice versa at 3.0 V input voltage is shown in Figure 9.

Channel 1

- Output current, load step 1.5 to 3.0 A
- 2 A/div, 1 ms/div

Channel 2

- Output voltage, −471 mV (−6.9%) undershoot, +400 mV (5.9%) overshoot
- 500 mV/div, 1 ms/div, AC coupled

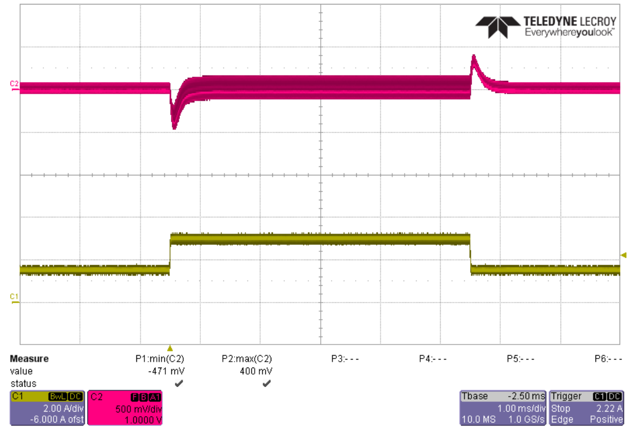

Figure 9. Transient Response on 1.5 A Load Step

Frequency Response

The frequency response at 3.0 V input voltage and 3.0 A load is shown in Figure 10.

- 3.8 kHz bandwidth
- 65° phase margin
- −13 dB gain margin

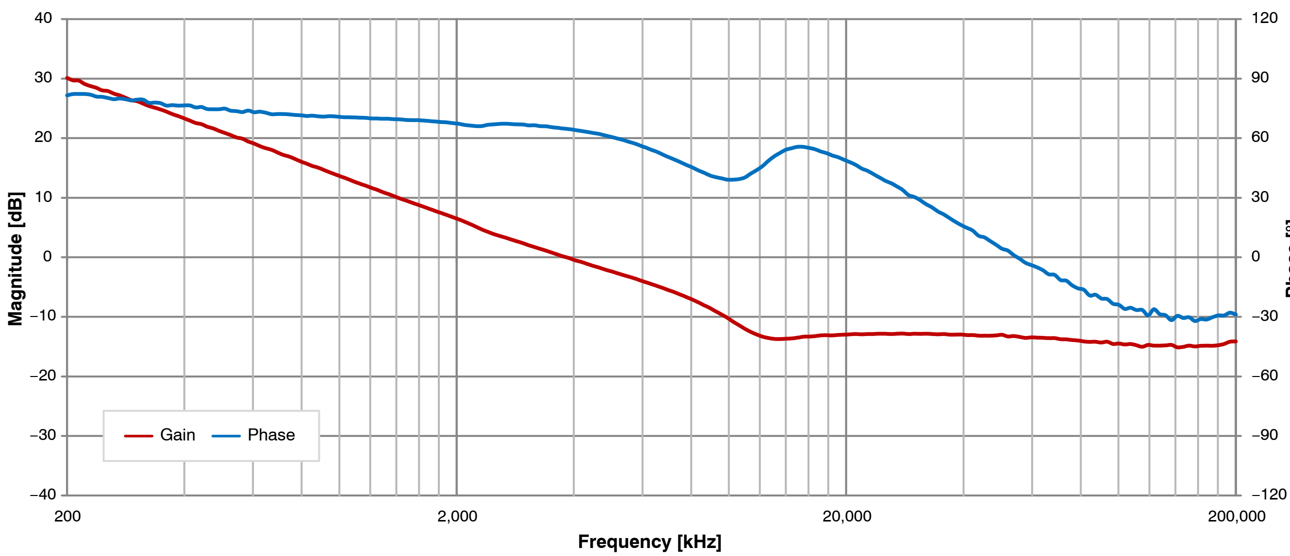

Figure 10. Frequency Response at 3.0 A Load

Table 2.

Input Voltage	Load	Bandwidth	Phase Margin	Gain Margin
2.5 V	6.8 V @ 3.0 A	2.9 kHz	53°	−11 dB
3.0 V	6.8 V @ 3.0 A	3.8 kHz	65°	−13 dB
4.0 V	6.8 V @ 3.0 A	5.4 kHz	76°	−16 dB
5.0 V	6.8 V @ 3.0 A	6.9 kHz	81°	−16 dB
6.0 V	6.8 V @ 3.0 A	6.9 kHz	87°	−18 dB

Bypass Circuit

As long as the battery voltage is high enough (6.8 V plus approx. 0.6 V for the diode forward voltage drop), the boost converter is not switching. Because the boost converter is connected between the battery and the load, the complete load current flows through the inductor and diode of the boost converter. The forward voltage of the diode, in particular, causes significant losses.

At 20 W load, 12 V input voltage and 0.6 V diode forward voltage drop the input current is 1.75 A. This causes 1 W losses on the diode and is equal to only 95% efficiency of the circuit without the converter even switching.

To reduce the losses a bypass circuit was developed which is shown in Figure 11. The P−FET NVTFS5116PL has an on−resistance of 51 mΩ (typ. @ 4.5 V_{GS}) and causes only around 140 mW losses. And at higher loads the usage of the bypass circuit is even more advantageous.

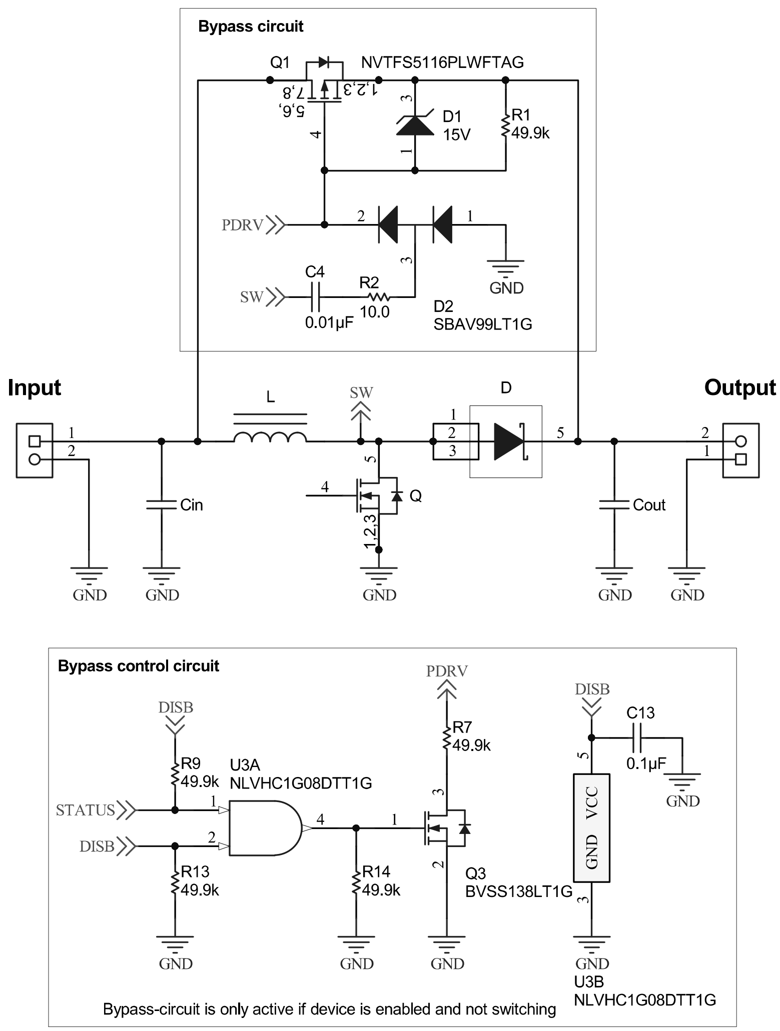

Figure 11. Bypass Circuit

The bypass circuit shown on the top consists of three different parts:

- P−FET Q1 in parallel to the inductor and diode of the power stage.
- Diode D1 and resistor R1 to limit the gate−source voltage to 15 V and to provide a discharge path.
- A type of charge pump circuit based on C4, R2 and D2. C4 provides an AC coupling of the switching node, R2 limits the current and D2 rectifies the positive part of the AC voltage respectively shorts the negative voltage to GND.

The bypass control circuit on the bottom is based on a 2−input AND gate and uses two signals to enable and disable the bypass circuit:

- DISB
  - External disable signal for the NCV887801 comes, for instance, from a microcontroller
  - High (2.0−5.0 V): NCV887801 enabled, but not necessarily switching as long as the input voltage is higher than approx. 7.4 V as mentioned above
  - Low (< 0.8 V): NCV887801 disabled
  - Is used to supply also the AND gate

- STATUS
  - Open drain output of NCV887801
  - Indicates if the boost converter is switching or not
  - Low: converter is switching
  - High: converter is not switching

Dependent on the state of DISB and STATUS, the bypass circuit is active or not:

Table 3.

	Behavior	NCV887801	Bypass and Control Circuit	Description
DISB low & STATUS undefined	• Boost converter is not switching • Load current flows through inductor and diode	Disabled and not switching → STATUS is undefined	• Bypass control circuit is not active • Bypass circuit is in off state	• AND gate is not supplied → Q3 is off • Signal PDRV is pulled high by R1 → P−FET Q1 is off
DISB high & STATUS low	• Boost converter is switching • Input voltage is boosted	Enabled and switching → STATUS is low	• Bypass control circuit is active • Bypass circuit is in off state	• AND gate is supplied and its output is low → Q3 is off • Signal PDRV is pulled high by R1 → P−FET Q1 is off • Charge pump circuit C4/R2/D2 generates a positive voltage and ensures that Q1 keeps in off state
DISB high & STATUS high	• Boost converter is not switching • Load current flows through P−FET	Enabled and not switching → STATUS is high	• Bypass control circuit is active • Bypass circuit is in on state	• AND gate is supplied and its output is high → Q3 is on • Signal PDRV is pulled low → P−FET Q1 is on

BILL OF MATERIALS (BOM)

Table 4. BILL OF MATERIALS

Designator	Qty.	Value	Part Number	Manufacturer	Description	Package
C1, C11, C12, C13	4	0.1 μF	GCJ188R71H104KA12	MuRata	CAP, CERM, 0.1 μF, 50 V, ±10%, X7R, AEC−Q200 Grade 1, 0603	0603
C2, C3, C16, C17	4	1 μF	GCM188R71E105KA64D	MuRata	CAP, CERM, 1 μF, 25 V, ±10%, X7R, AEC−Q200 Grade 1, 0603	0603
C4	1	0.01 μF	GCJ188R71H103KA01	MuRata	CAP, CERM, 1 μF, 50 V, ±10%, X7R, AEC−Q200 Grade 1, 0603	0603
C5	1	270 pF	GCG1885G1H271JA01	MuRata	CAP, CERM, 270 pF, 50 V, ±5%, X8G, AEC−Q200 Grade 1, 0603	0603
C6, C10	2	150 μF	GYA1V151MCQ1GS	Nichicon	CAP, Hybrid Polymer, 150 μF, 35 V, ±20%, 0.027 Ω, SMD	D8 × L10 mm
C7, C8, C9	3	4.7 μF	GCJ32ER71H475KA12	MuRata	CAP, CERM, 4.7 μF, 50 V, ±10%, X7R, AEC−Q200 Grade 1, 1210	1210
C14	1	0.22 μF	GCM188R71H224KA64	MuRata	CAP, CERM, 0.22 μF, 50 V, ±10%, X7R, AEC−Q200 Grade 1, 0603	0603
C15	1	0.033 μF	GCM188R91H333KA37	MuRata	CAP, CERM, 0.033 μF, 50 V, ±10%, X8R, AEC−Q200 Grade 1, 0603	0603
C18	1	330 pF	GCM1885G2A331JA16	MuRata	CAP, CERM, 330 pF, 100 V, ±5%, C0G, AEC−Q200 Grade 1, 0603	0603
D1	1	15 V	SZBZX84C15LT1G	ON Semiconductor	Diode, Zener, 15 V, 225 mW, SOT−23	SOT−23
D2	1	100 V	SBAV99LT1G	ON Semiconductor	Diode, Standard Recovery Rectifier, 100 V, 0.715 A, AEC−Q101, SOT−23	SOT−23
D3	1	60 V	NRVB460MFST3G	ON Semiconductor	Diode, Schottky, 60 V, 4 A, SO−8FL	SO−8FL
J1, J2	2		ED555/2DS	On−Shore Technology	Terminal Block, 3.5 mm Pitch, 2x1, TH	7.0 × 8.2 × 6.5 mm
J3	1		61300311121	Wurth Elektronik	Header, 2.54 mm, 3x1, Gold, TH	Header, 2.54 mm, 3x1, TH
L1	1	2.2 μH	XAL1010−222MEB	Coilcraft	Inductor, Shielded, Composite, 2.2 μH, 32 A, 0.00255 Ω, SMD	Inductor, 11.3 × 10 × 10 mm
Q1	1	−60 V	NVTFS5116PLWFTAG	ON Semiconductor	MOSFET, P−CH, −60 V, −14 A, μ8FL	μ8FL
Q2	1	40	NVMFS5C442NLWFAFT1G	ON Semiconductor	MOSFET, N−CH, 40 V, 130 A, SO−8FL	DFN5 5 × 6 mm
Q3	1	50 V	BVSS138LT1G	ON Semiconductor	MOSFET, N−CH, 50 V, 0.2 A, AEC−Q101, SOT−23	SOT−23
R1, R7, R9, R13, R14	5	49.9 kΩ	CRCW060349K9FKEA	Vishay−Dale	RES, 49.9 kΩ, 1%, 0.1 W, 0603	0603
R2	1	10.0 Ω	CRCW060310R0FKEA	Vishay−Dale	RES, 10.0 Ω, 1%, 0.1 W, 0603	0603
R3	1	8.2 Ω	CRCW12068R20JNEA	Vishay−Dale	RES, 8.2 Ω, 5%, 0.25 W, 1206	1206
R4, R5, R11	3	0 Ω	CRCW06030000Z0EA	Vishay−Dale	RES, 0 Ω, 5%, 0.1 W, 0603	0603
R6	1	249 Ω	CRCW0603249RFKEA	Vishay−Dale	RES, 249 Ω, 1%, 0.1 W, 0603	0603
R10	1	110 Ω	CRCW0603110RFKEA	Vishay−Dale	RES, 110 Ω, 1%, 0.1 W, 0603	0603
R12	1	0.01 Ω	FCSL64R010FER	Ohmite	RES, 0.01 Ω, 1%, 2 W, 2512 WIDE	2512 WIDE
TP1, TP2	2		5000	Keystone	Test Point, Miniature, Red, TH	Red Miniature Testpoint
TP3, TP4	2		5001	Keystone	Test Point, Miniature, Black, TH	Black Miniature Testpoint
TP5	1		5002	Keystone	Test Point, Miniature, White, TH	White Miniature Testpoint
U1	1		NCV4294CSN33T1G	ON Semiconductor	45 V, 30 mA, Low−Dropout Linear Regulator, SOT−23−5	DBV0005A
U2	1		NCV887801D1R2G	ON Semiconductor	Automotive Grade Start−Stop Non−Synchronous Boost Controller	SOIC−8
U3	1		NLVHC1G08DTT1G	ON Semiconductor	Single 2−Input Positive−AND Gate, TSOP−5	TSOP−5

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