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AND90079/D

Automotive Pre-Regulator Reference Design and Evaluation Board Overview

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APPLICATION NOTE

Overview

ON Semiconductor provides several reference designs for automotive synchronous buck pre−regulators covering a broad range of applications such as ADAS, cluster, body and infotainment. The purpose of this application note is to provide an overview of the various reference designs / EVBs, as well as compares them based on the technical and the application aspects. For more information about the individual reference, design the corresponding application note should be consulted.

Applications

ADAS applications like driver assist camera, surround view camera ECU as well as other applications such as cluster and infotainment generally share a common power architecture. The structure of such an automotive power tree is very similar to Figure 1.

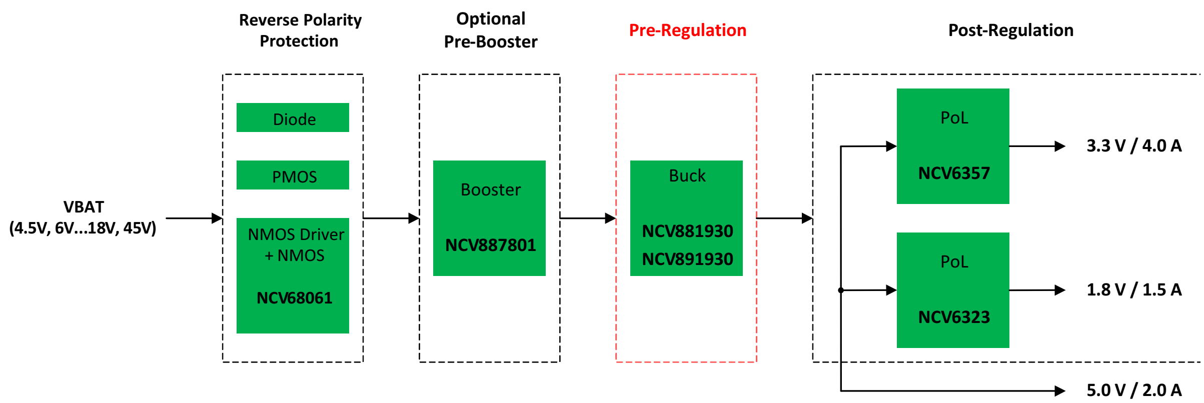

Figure 1. Automotive Power Tree

The power tree compromises of four stages/sub−circuits. The first stage/sub−circuit is known as reverse polarity protection. Its main purpose is to protect all ECUs connected to the battery from damage in case a car's battery is reversely connected to the wrong terminals. Several protection techniques are available such as a diode, a PMOS, and an NMOS + Driver.

The next sub−circuit is a pre−booster mainly used to boost the battery's voltage during cold cranking to a level such that the pre−regulator is able to maintain its nominal output voltage. The pre−booster is not always needed, it depends if the system needs to be operable during cold cranking or not and how low and long the battery voltage collapses.

Subsequently a pre−regulator is placed, which converts the battery voltage down to an output voltage of typically 5.0 V or 3.3 V. Similar to the pre−booster, the pre−regulator is directly connected to the board net and has to operate within the specified operation range and as well as withstanding load dump which is typically around 40 V. The input voltage range depends on the application and for a 5 V pre−regulator it could be around 6 V to 16 V continuous operation range without any derating.

The final stage is often used to directly supply loads, such as CAN TxRx, as well as to provide the supply voltage for low voltage point−of−load (PoL) regulators. These are also known as post−regulators.

The two−step architecture using pre−regulation and post−regulation is a well−established approach as it provide several benefits:

- Only the pre−regulator needs to be capable to handle load dump. This requires a 40 V (automotive) / 60 V (truck) technology, which has naturally lower performance and higher cost compared to a low voltage technology used for post−regulation. Therefore this architecture limits the usage of 40 V technology to a single device (or two, if a pre−booster is needed).
- Due to the low input voltage, post−regulators with a low voltage technology can be used, which generally offer higher performance and lower cost compared to 40 V technology.
- With typical input voltages of 3.3 V or 5.0 V, post−regulators can operate with switching frequencies of 2 MHz and above, which enables small solution size, high bandwidth and still good efficiency due to moderate switching losses.
- As the output voltages are relatively low, a 3.3 V or 5.0 V input voltage results in reasonable duty cycles even at output voltages below 1.0 V and with no issues with minimum on−time limitations.

Reference Designs

ADAS applications like front camera, surround view camera, radar and Lidar as well as cluster, infotainment and gateway have in most cases a power consumption up to 30 W. Higher power for the pre−regulation is seen especially in sensor fusion ECUs for autonomous driving of level 2 and above.

Based on these power ranges ON Semiconductor developed different reference designs in addition to the existing evaluation board to address the majority of the requirements of the automotive pre−regulators:

Table 1.

Reference Design / EVB	Controller	Switching Frequency	FETs	Input	Output	
TND6286/D	NCV881930	410 kHz	1x NVMFD5C478NL (Dual FET)	6 V to 16 V DC, 40 V peak	Up to 30 W	5.0 V / 6.0 A Avg.
TND6287/D	NCV891930	2 MHz	1x NVMFD5C478NL (Dual FET)		Up to 15 W Avg. up to 30 W Peak	5.0 V / 3.0 A Avg. 5.0 V / 6.0 A Peak
TND6290/D	NCV881930	410 kHz	4x NVMFS5C460NL (2xHS/LS)		Up to 75 W Avg. up to 100 W Peak	5.0 V / 15.0 A Avg. 5.0 V / 20.0 A Peak
NCV881930MW00−50GEVB	NCV881930	410 kHz	2x NVMFS5C460NL	6 V to 35 V, 37 V surge	Up to 50 W	5.00 V / 10 A
NCV881930MW00−33GEVB	NCV881930	410 kHz	2x NVMFS5C460NL	6 V to 35 V, 37 V surge	Up to 20 W	3.30 V / 6.00 A
NCV891930MW00−50GEVB	NCV891930	2 MHz	2x NVMFS5C468NL	6 V to 35 V, 37 V surge	Up to 30 W	5.00 V / 6.00 A
NCV891930MW01−40GEVB	NCV891930	2 MHz	2x NVMFS5C468NL	6 V to 35 V, 37 V surge	Up to 24 W	4.00 V / 6.00 A
NCV891930MW01−365GEVB	NCV891930	2 MHz	2x NVMFS5C468NL	6 V to 35 V, 37 V surge	Up to 22 W	3.65 V / 6.00 A
NCV891930MW00−33GEVB	NCV891930	2 MHz	2x NVMFS5C468NL	6 V to 35 V, 37 V surge	Up to 20 W	3.30 V / 6.00 A

NCV881930 and NCV891930 are state of the art low quiescent current automotive synchronous buck controllers supporting fixed 3.30 V, 3.65 V, 4.00 V and 5.00 V output voltage. They are capable of 45 V load dump, have spread spectrum, UVLO, adjustable soft start and integrated compensation to ease and simplify the design.

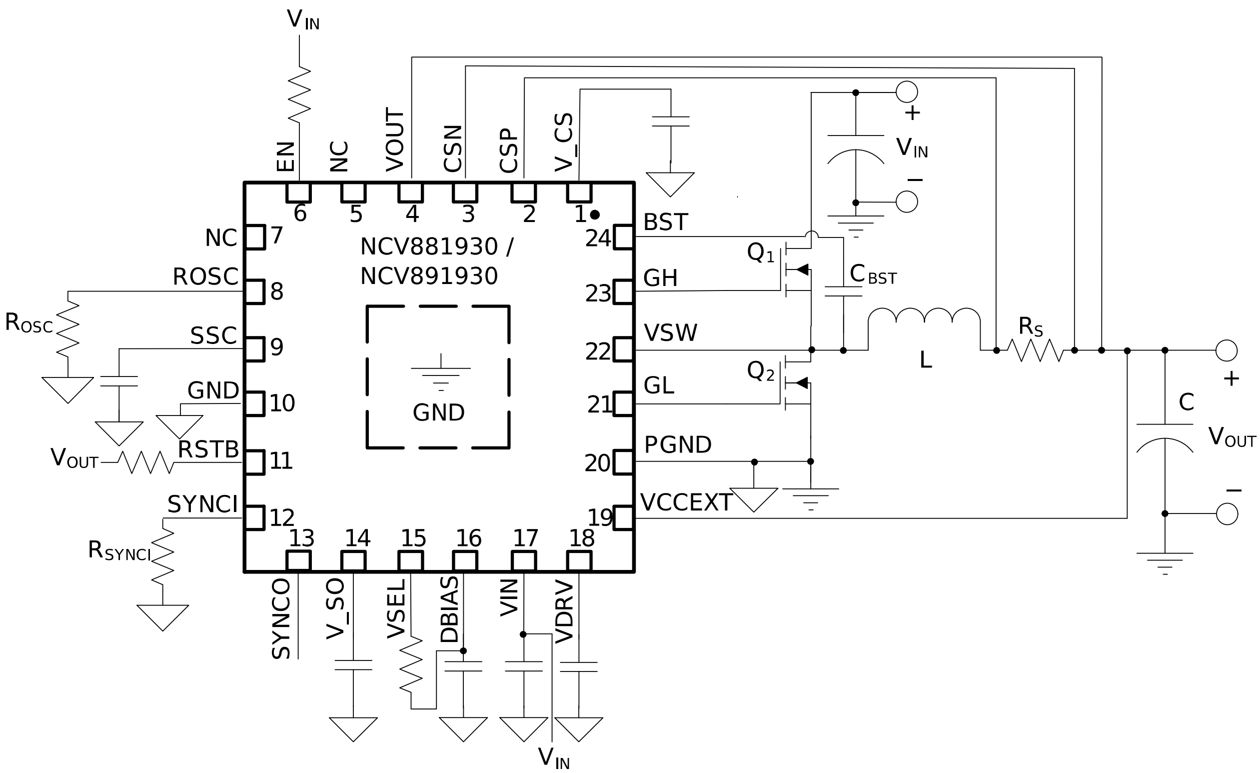

Figure 2. NCV88/891930 Application Schematic

Switching Frequency

The buck controllers are available as derivatives with 410 kHz and 2 MHz switching frequency. Therefore depending on the output power and the design's focus (efficiency vs. size), a higher or lower switching frequency could be chosen. Generally, a lower switching frequency offers higher efficiency due to lower switching and inductor core losses. On the other hand, the inductance can become a quite large component. Higher switching frequency offers also higher bandwidth, thus the output capacitance can be lower for the same load transient performance compared to the lower switching frequency.

Efficiency and FET Selection

To be able to compare the efficiency of the different reference designs with each other, a nominal input voltage of 12.0 V and an output voltage of 5.0 V was selected. The controller was set into continuous synchronous mode (SYNCI = 1) as the efficiency at higher load ranges is more important than low I_q performance.

Further measurement results like for 3.3 V output voltage and different input voltages can be found in the respective reference design documentation and datasheets.

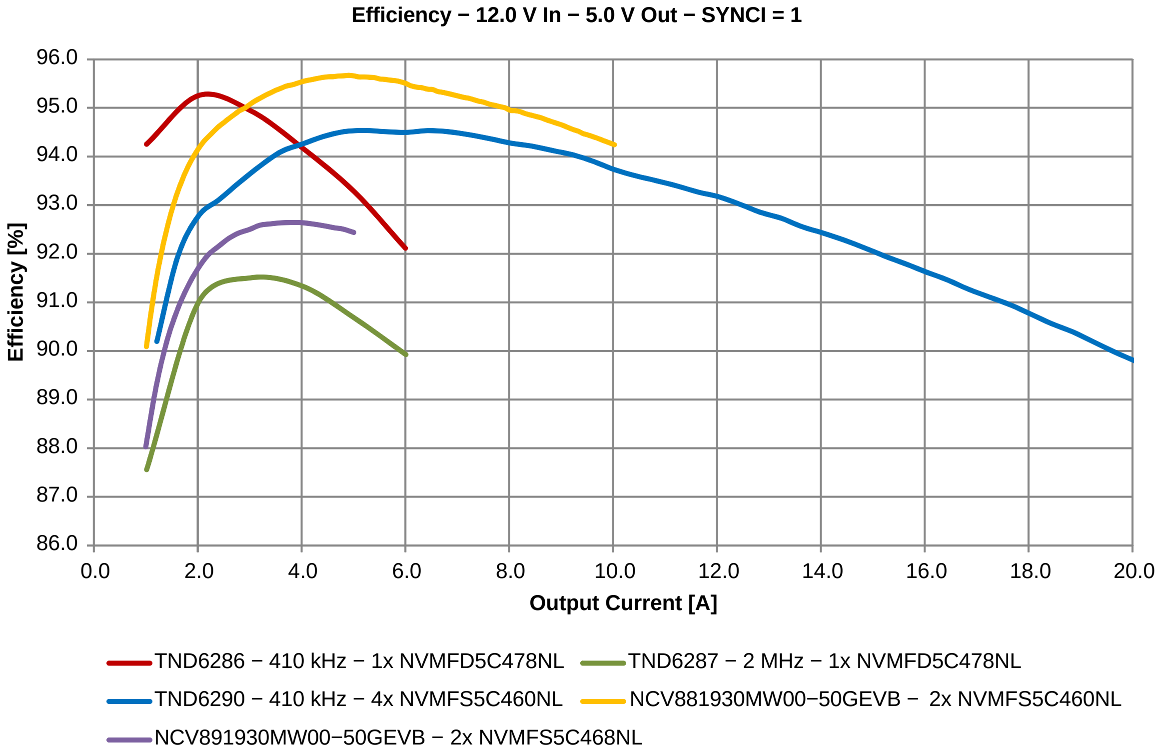

Figure 3. Efficiency Comparison

Figure 3 shows that reference designs and evaluation boards cover the full power range from a few Watts up to one hundred Watts. Based on the power supply's focus; efficiency, cost or size, ON Semiconductor offers various options in the range up to 30 W with switching frequencies of 410 kHz and 2 MHz.

- Reference design TND6286/D with NCV881930 (410 kHz) and NVMFD5C478NL (dual FET) is a high efficient and cost effective pre−regulator with a small solution size providing up to 30 W continuous.
- Reference design TND6287/D with NCV891930 (2 MHz) and NVMFD5C478NL (dual FET) is a cost effective pre−regulator with an even smaller solution size compared to the 410 kHz version due to potential space savings for the inductor and output capacitance. The efficiency is naturally lower due to the higher switching losses at 2 MHz, thus the maximum output power is up to 15 W continuous and 30 W peak.
- Evaluation board NCV891930MW00−50GEVB (2 MHz) uses NVMFS5C468NL single FETs. This allows a better spread of the heat and power dissipation, therefore it can deliver up to 25 W continuous. With high switching frequency fast FETs like NVMFS5C468NL are needed to keep the switching losses in a reasonable range.
  For high switching frequency, fast rise and fall time of the high−side FET is generally more important than on−resistance. For lower output voltages with a low duty cycle the efficiency can be further optimized by selecting a slow−switching but lower resistive FET for the low−side.
- Evaluation board NCV881930MW00−50GEVB (410 kHz) uses NVMFS5C460NL single FETs. The low switching frequency allows usage of lower resistive FETs compared to 2 MHz which boosts the efficiency significantly. Therefore it provides up to 50 W continuous on the output.
- Reference design TND6290/D with NCV881930 (410 kHz) uses four NVMFS5C460NL FETs in total. Due to the high power two FETs are in parallel for the high−side as well as for the low−side. This is needed to reduce the on−resistance as well to spread the power losses. It provides up to 15 A continuous and 20 A peak.

Links

Reference Designs

- TND6286/D − 30 W Automotive 410 kHz Pre−Regulator, Non−Isolated, Synchronous Buck, NCV881930−Based Reference Design
- TND6287/D − 30 W Automotive 2 MHz Pre−Regulator, Non−Isolated, Synchronous Buck, NCV891930−BasedReference Design
- TND6290/D − 100 W Automotive Pre−Regulator, Non−Isolated, Synchronous Buck, NCV881930−Based Reference Design

Evaluation Boards

- NCV881930 Low Quiescent Current 410 kHz Automotive Synchronous Buck Controller
  Evaluation boards with 3.3 V and 5.0 V available.
- NCV891930 Low Quiescent Current 2 MHz Automotive Synchronous Buck Controller
  Evaluation boards with 3.3 V, 3.65V, 4.0 V and 5.0 V available.

Application Notes

- AND9824/D − NCV881930/NCV891930 −Mixed Capacitor Technology Filtering
- NCV88/891930 IC Power Dissipation Design Tool
- AND90078/D − Selecting Power MOSFETs for the NCV881930 andNCV891930 Automotive Synchronous Buck Controllers

Product Page

- NCV881930 Low Quiescent Current 410 kHz Automotive Synchronous Buck Controller
- NCV891930 Low Quiescent Current 2 MHz Automotive Synchronous Buck Controller

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