

## ISL85403

Achieving a Regulated Supply (5V or 12V) from an Input Range of 3V to 40V

### Abstract

In voltage regulation applications, where input voltage can fluctuate or drop to a voltage lower than the required output voltage (such as a battery powered system), for a buck converter to provide a well-regulated output voltage, it is critical to detect the change in the input voltage and respond to it fast. Respond by either boosting up the input voltage first when it is too low, or running in buck-only mode when input is high enough for regular buck conversion. A conventional 2-stage boost buck converter can implement this functionality, but it typically requires two controller ICs. This application note introduces using a single ISL85403 to output most of the commonly seen voltage rails while accommodating, at a reasonable BOM cost, a wide range of operating input voltage from 3V to 40V. Two 12W evaluation boards for 5V and 12V outputs are also demonstrated.

### Contents

<b>1. Theory of Operation</b> .....	<b>2</b>
<b>2. Design Considerations for Low Input Operation</b> .....	<b>3</b>
2.1 2.1 Selecting the Boost MOSFET .....	3
2.2 2.2 Setting the On/OFF Threshold for the Boost Stage .....	3
<b>3. Application Examples</b> .....	<b>4</b>
<b>4. Conclusion</b> .....	<b>9</b>
<b>5. Revision History</b> .....	<b>9</b>

### List of Figures

Figure 1. Boost Buck Converter using ISL85403 .....	2
Figure 2. Component Network to Adjust Threshold Voltages for EXT_BOOST .....	3
Figure 3. ISL85403EVAL1Z Board .....	4
Figure 4. ISL85403EVAL3Z Board .....	4
Figure 7. ISL85403EVAL3Z Efficiency vs Load .....	5
Figure 8. ISL85403EVAL3Z Output Voltage vs Load .....	5
Figure 5. ISL85403EVAL1Z Efficiency vs Load .....	5
Figure 6. ISL85403EVAL1Z Output Voltage vs Load .....	5
Figure 9. ISL85403EVAL1Z Schematic .....	6
Figure 10. ISL85403EVAL3Z Schematic .....	7

### Related Literature

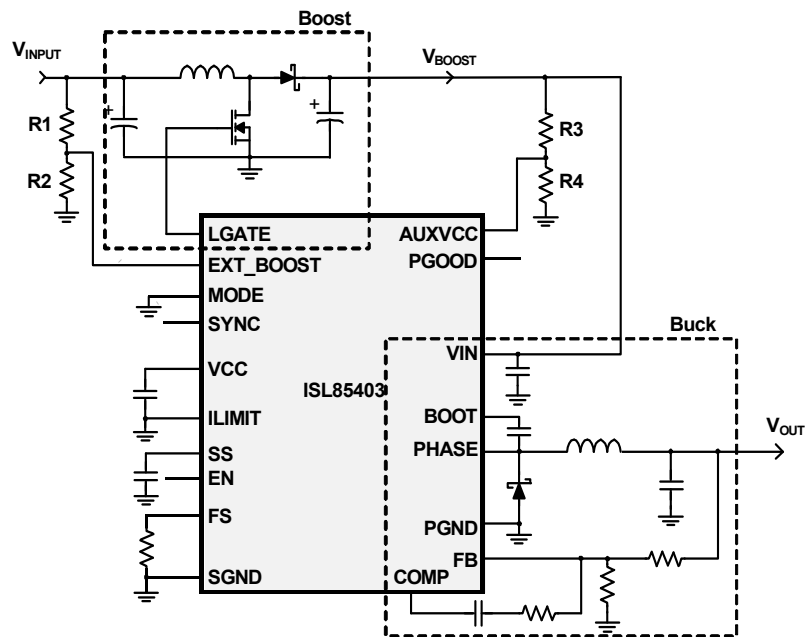
For a full list of related documents, visit our website:

- [ISL85403](#) device page

## 1. Theory of Operation

When the input voltage for a power supply varies or decreases significantly, it is necessary to boost it up whenever needed by turning on a boost converter, so that output regulation can be maintained. However, when the input voltage is adequate or resumes back to normal, the boost is not needed and therefore should be disabled. This can be achieved with a single control IC in the ISL85403. The ISL85403 is a synchronous buck controller integrated with a high-side MOSFET and both high-side and low-side drivers. However, it can be configured to control a boost buck converter as well. The low-side driver can drive a boost converter preceding a buck stage controlled by the same IC. This allows the IC to control a 2-stage boost buck converter. When the system input voltage drops to a level too low for the second stage buck converter to maintain regulation, the first stage boost converter can boost the input voltage up to keep the output voltage in regulation. This provides a reliable converter solution in applications that warrant support for a very wide input voltage range.

[Figure 1](#) shows a typical application circuit of a 2-stage boost buck converter. The EXT\_BOOST pin is connected to the system input (oftentimes a battery) through a resistor divider. The EXT\_BOOST pin monitors the boost input voltage to turn on and off the boost stage. When the input is high enough for the buck stage to regulate the output voltage, either at startup, or after the input recovers to normal from a decline, the boost stage is disabled. Select the threshold voltage to turn on the boost PWM (from low-side gate drive LGATE) with enough margin to cover the voltage drop of the boost inductor and diode, and the buck's maximum duty cycle and conduction drop, so that the buck converter is still in regulation before the boost kicks in and input voltage can be boosted up. The values of R1 and R2 set the boost turn-on threshold and hysteresis. The AUX VCC pin monitors the boost output voltage in a similar way. More detailed information can be found in the [ISL85403](#) datasheet.



**Figure 1. Boost Buck Converter using ISL85403**

The steady stage DC transfer functions for the output voltage of the boost stage ( $V_{\text{BOOST}}$ ) and the output of the buck stage ( $V_{\text{OUT}}$ ) are:

$$\text{(EQ. 1)} \quad V_{\text{BOOST}} = \frac{1}{1-D} V_{\text{INPUT}}$$

$$\text{(EQ. 2)} \quad V_{\text{OUT}} = D V_{\text{BOOST}} = \frac{D}{1-D} V_{\text{INPUT}}$$

where  $V_{\text{INPUT}}$  is the system, or boost, input voltage.

The steady stage boost output voltage can be derived using [Equations 1](#) and [2](#) as follows:

$$(EQ. 3) \quad V_{\text{BOOST}} = (1 - D)V_{\text{BOOST}} + DV_{\text{BOOST}} = V_{\text{INPUT}} + V_{\text{OUT}}$$

$V_{\text{OUTBST}}$  is connected to the VIN pin of the IC, which is internally connected to a bias LDO to generate VCC; therefore, the IC can keep operating even when  $V_{\text{INPUT}}$  drops to a very low level.

Although a 2-stage configuration, this boost buck converter only requires one controller IC and one external MOSFET. Therefore, compared with the conventional ones, this configuration has lower BOM cost while supporting an equally wide input voltage range.

## 2. Design Considerations for Low Input Operation

The ISL85403 supports a 2-stage boost buck converter with an input voltage as low as 3V. However, there are some issues associated with this operating condition that need to be addressed.

### 2.1 2.1 Selecting the Boost MOSFET

When starting up at 3V, it is critical that the switching MOSFET of the boost stage can be fully turned on. Therefore, the gate charge waveforms and the output characteristics charts of a MOSFET need to be examined carefully when selecting the MOSFET. It is preferred to choose one with a gate charge chart where the plateau occurs at a voltage lower than 3V, although MOSFETs that meet this specification are limited. As a recommendation, the BSZ025N04LS by Infineon is a good choice. Not only can it switch on at 3V, it also has a low ON-resistance when fully turned on, which helps improve system efficiency in steady-state operation.

### 2.2 2.2 Setting the On/OFF Threshold for the Boost Stage

Another issue that needs to be considered is that, depending on the output voltage, the simple resistor divider on the EXT\_BOOST pin may not be adequate to ensure proper turn-on and turn-off of the boost converter.

When powering up at a low input voltage, the voltage into the EXT\_BOOST pin must be greater than 200mV for the boost converter to start up. When the input is high enough and the voltage into EXT\_BOOST is greater than 800mV, the boost converter is disabled and only the buck stage operates.

If the boost converter needs to start at an input voltage of 3V, the lowest voltage the EXT\_BOOST pin needs to see is 200mV. Then an 800mV voltage (4 times of the 200mV threshold) into this pin would mean an input voltage of 12V (4 times of 3V), which means only the buck stage can switch at 12V. However, if the targeted output voltage is 12V (or 9V to 10V considering all the overhead), regulation cannot be maintained. Therefore, a resistor divider is not sufficient for this kind of specification.

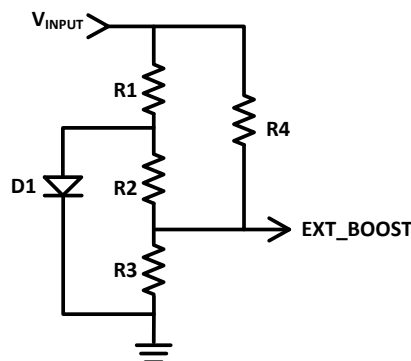


Figure 2. Component Network to Adjust Threshold Voltages for EXT\_BOOST

[Figure 2](#) shows a component network that can be adjusted to ensure proper thresholds to turn on or turn off the boost converter. It replaces the resistor divider R1 and R2 in [Figure 1 on page 2](#). At power-up from the input, current flows through the resistor divider and forward biases the diode, which sets the voltage on the EXT\_BOOST pin. Choose values for R1, R2, and R3 to ensure a greater than 200mV voltage on EXT\_BOOST at

the low end of the input voltage range. R4 is a large value resistor that pulls minimum current when the input voltage is low. As input goes up, R4 pulls more current and voltage on EXT\_BOOST increases. Therefore, R4 can be adjusted to set the input voltage where EXT\_BOOST sees 800mV and the boost converter is disabled.

**Note:** The forward voltage of the diode changes across temperature; therefore, the resistor values need to yield proper threshold voltages over the entire operating temperature range specified for the application, based on the characteristics of the diode. Detailed instruction about how to design such a network can be seen in the [R16ZZ0001](#) *Tips for Using the ISL85403 in Boost-Buck Mode.*

### 3. Application Examples

As examples, two evaluation boards using the ISL85403 in the 2-stage boost buck configuration are provided, one for a 5.0V output voltage (ISL85403EVAL1Z) and the other for a 12.0V output voltage (ISL85403EVAL3Z). Both examples support an input range from 3V to 40V and an output power up to 12W.

Pictures for the two evaluation boards, ISL85403EVAL1Z and ISL85403EVAL3Z, can be seen in [Figures 3](#) and [4](#). They are designed for the specifications listed below:

Specification	ISL85403EVAL1Z	ISL85403EVAL3Z
Input Voltage (V <sub>IN</sub> )	3V to 40V	3V to 40V
Output Voltage (V <sub>OUT</sub> )	5.0V	12.0V
Maximum Output Current (I <sub>OUT_MAX</sub> )	2.5A	1A

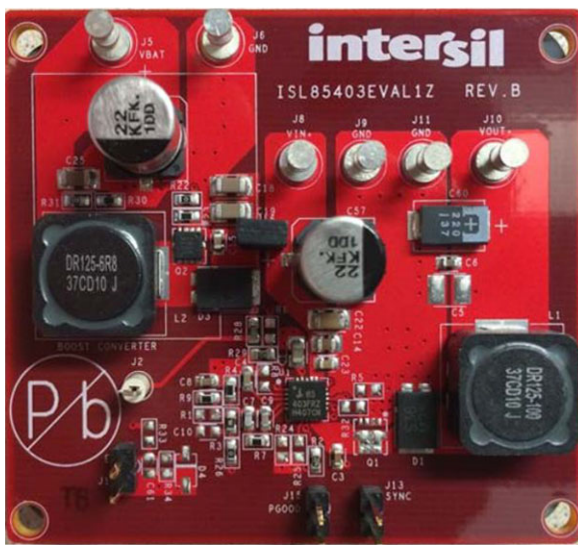


Figure 3. ISL85403EVAL1Z Board

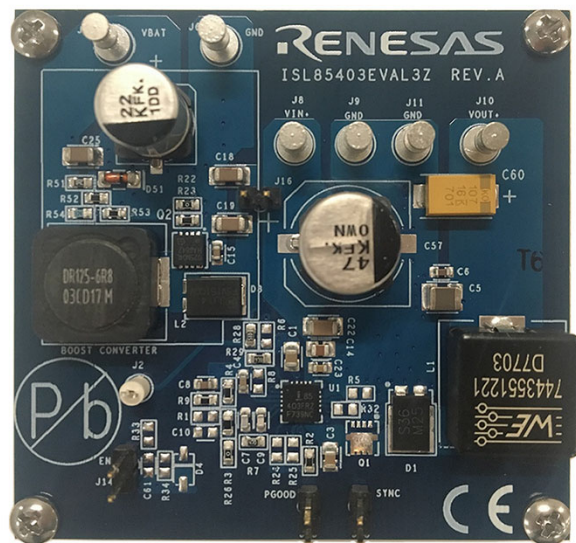


Figure 4. ISL85403EVAL3Z Board

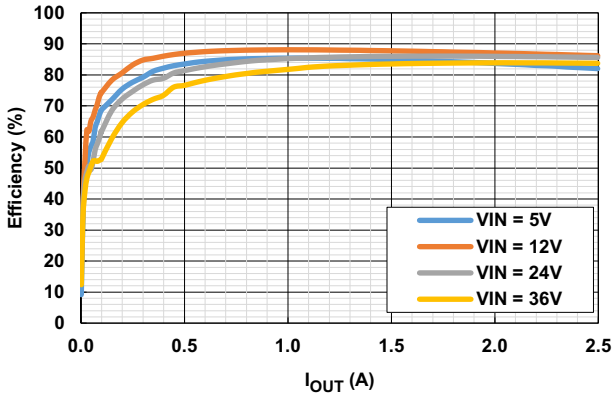


Figure 5. ISL85403EVAL1Z Efficiency vs Load

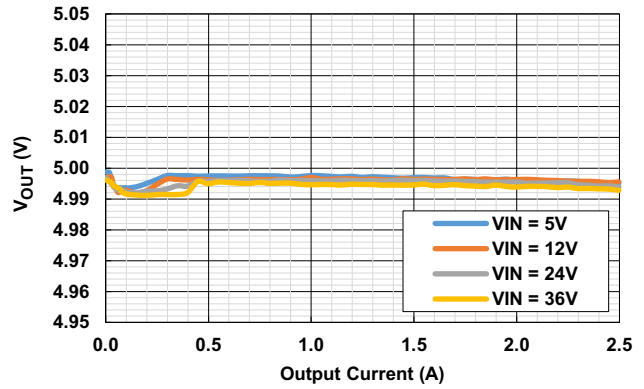


Figure 6. ISL85403EVAL1Z Output Voltage vs Load

Figures 5 and 6 show efficiency and regulation performance of the 5V converter on ISL85403EVAL1Z. Figures 7 and 8 show efficiency and regulation performance of the 12V converter on ISL85403EVAL3Z.

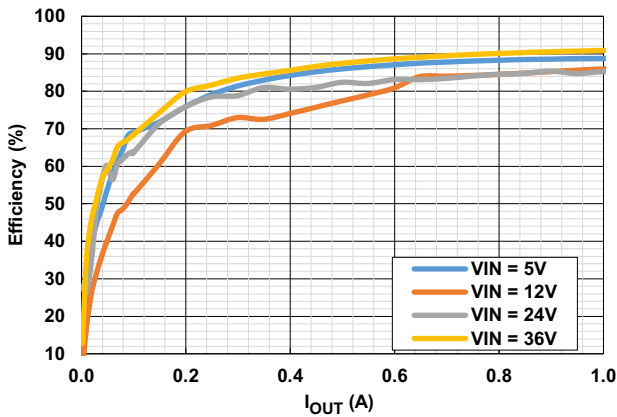


Figure 7. ISL85403EVAL3Z Efficiency vs Load

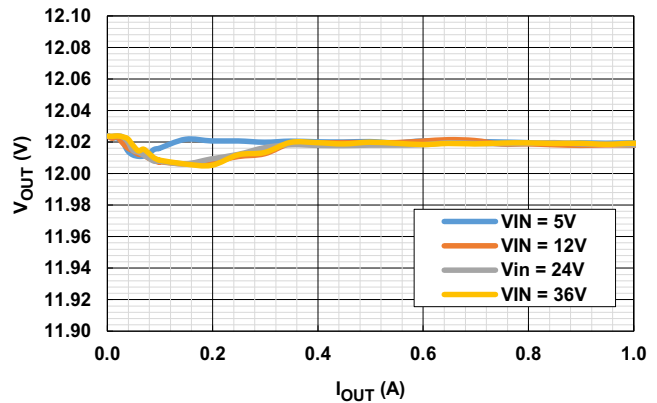


Figure 8. ISL85403EVAL3Z Output Voltage vs Load

Figure 9 shows the schematic of the ISL85403EVAL1Z, and Figure 10 shows the schematic of ISL85403EVAL3Z.

In ISL85403EVAL1Z, it can be seen that a simple resistor divider sets the voltage on the EXT\_BOOST pin. This is sufficient in this application where the output voltage is 5V and the minimum input voltage is 3V. At 3V input, EXT\_BOOST sees 293mV, which is well above the required 200mV to start up the boost stage. When the voltage at EXT\_BOOST is 800mV, the corresponding input voltage is 8.2V, where enough headroom is present to allow the converter to run in Buck mode only.

In the ISL85403EVAL3Z where the output voltage is 12V, the component network illustrated in Figure 2 on page 3 needs to be included in this application. The LL4148 by On Semiconductors is used as the diode in the network, and based on its characteristics, the resistor values are chosen as follows:

R1	R2	R3	R4
45.3k	4.02k	4.99k	120k

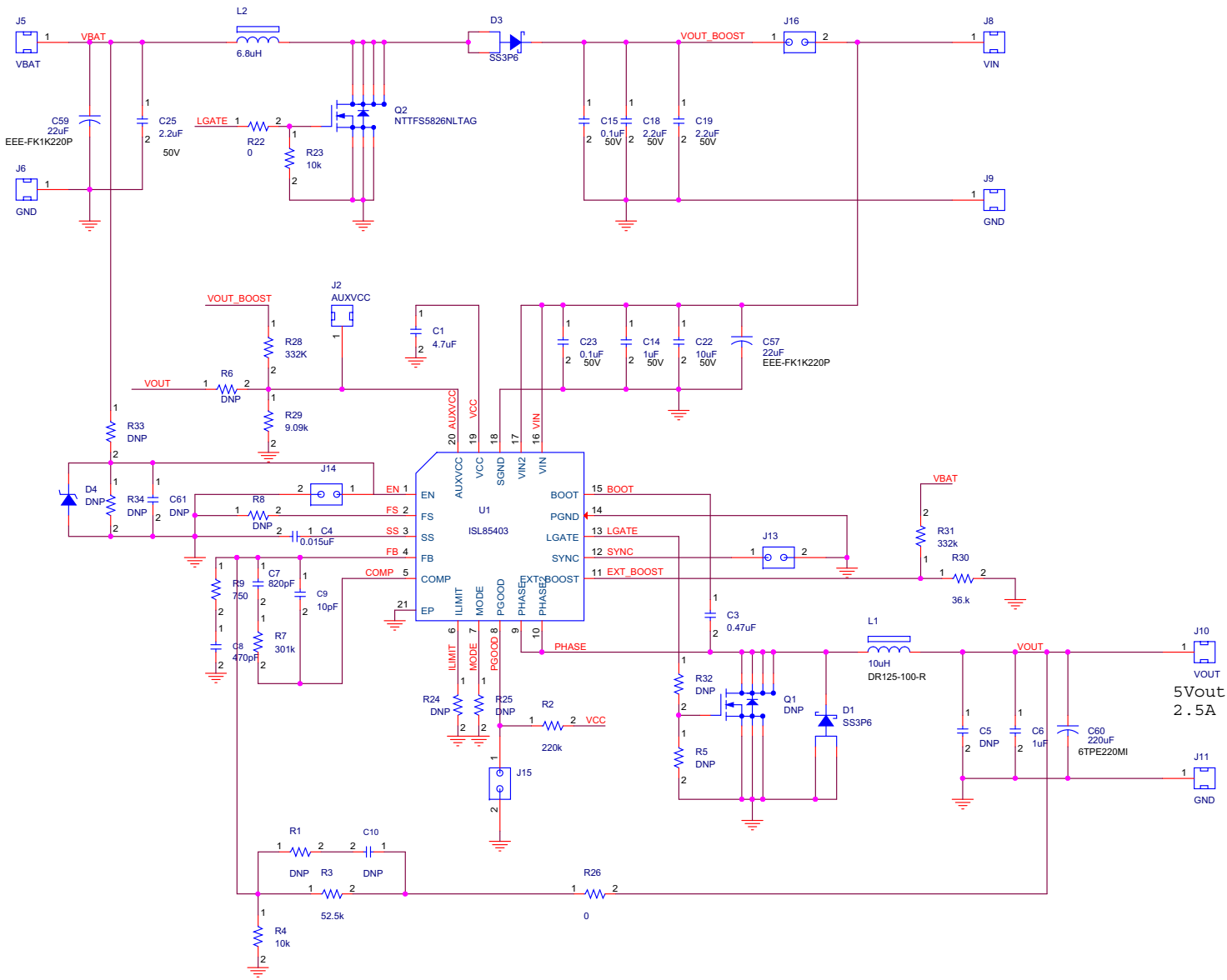


Figure 9. ISL85403EVAL1Z Schematic

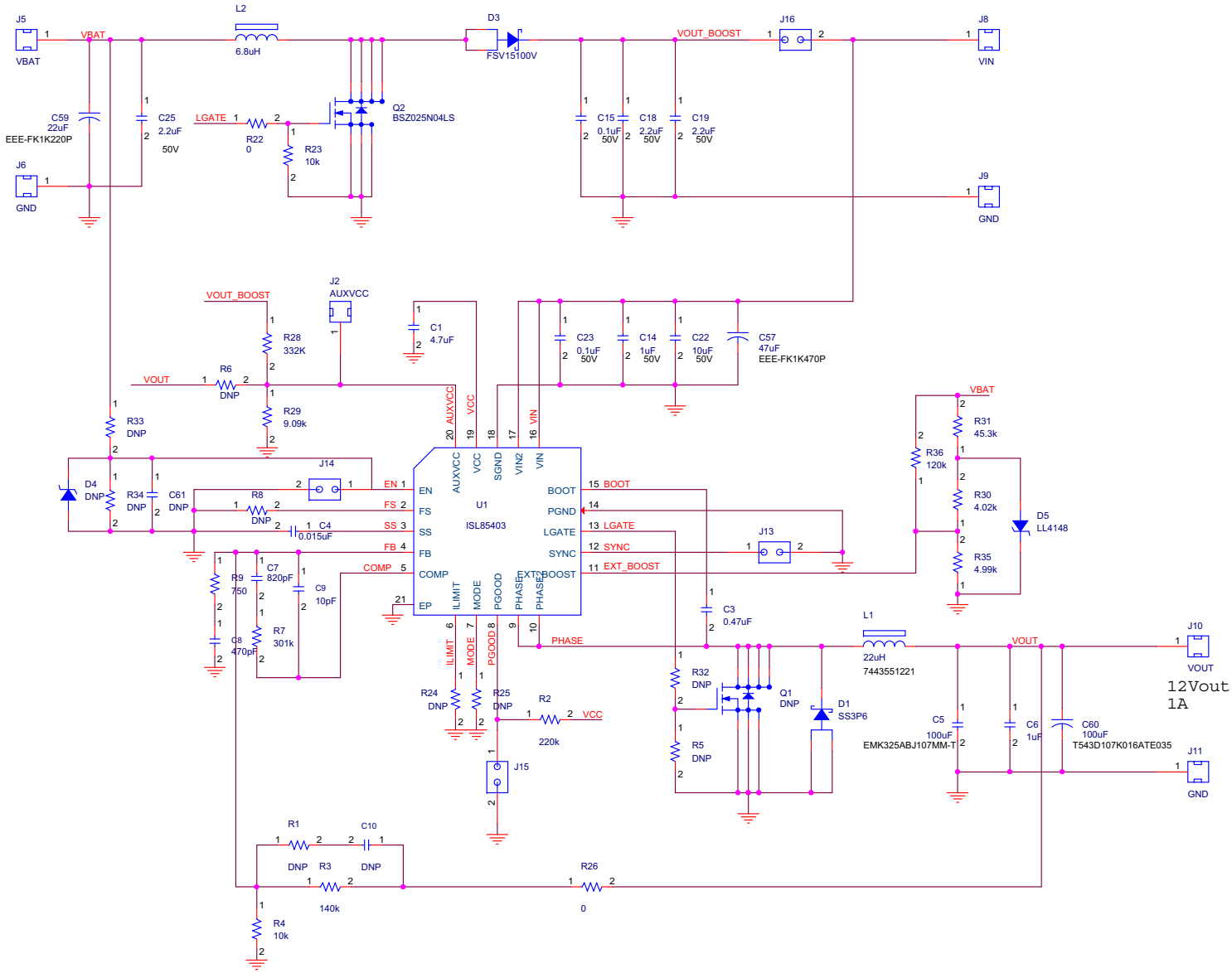


Figure 10. ISL85403EVAL3Z Schematic

As a result, the voltage thresholds to turn on and off the boost stage are set as the following:

Temperature	V <sub>Battery</sub> (V)	EXT_BOOST (mV)
25°C	3	286
	16.38	800
65°C	3	260
	16.125	800

**Note:** The input voltage at which the boost converter is disabled is set above 16V to account for the maximum duty cycle of the buck converter and to cover voltage drop from components such as the boost diode and inductor.

The following are the bill of materials for these two boards.

**Table 1. ISL85403EVAL1Z Bill of Materials**

Ref Des	Part Number	Qty	Description	Manufacturer
C6	C1608X7R1C105K	1	CAP, SMD, 0603, 1.0µF, 16V, 10%, X7R, ROHS	TDK
C57, 59	EEE-FK1K220P	2	CAP, SMD, 8X10.2, 22µF, 80V, 20%, ALUM.ELEC., ROHS	Panasonic
C9	Various	1	CAP, SMD, 0603, 10pF, 50V, 5%, C0G, ROHS	Various
C15, C23	Various	1	CAP, SMD, 0603, 0.1µF, 50V, 10%, X7R, ROHS	Various
C4	Various	1	CAP, SMD, 0603, 0.015µF, 50V, 10%, X7R, ROHS	Various
C8	Various	1	CAP, SMD, 0603, 470pF, 50V, 5%, NP0, ROHS	Various
C3	C1608X7R1H474K	1	CAP, SMD, 0603, 0.47µF, 50V, 10%, X7R, ROHS	TDK
C7	Various	1	CAP, SMD, 0603, 820pF, 50V, 5%, C0G, ROHS	Various
C14	Various	1	CAP, SMD, 0805, 1.0µF, 50V, 10%, X7R, ROHS	Various
C1	0805ZD475KAT2A	1	CAP, SMD, 0805, 4.7µF, 10V, 10%, X5R, ROHS	AVX
C22	Various	1	CAP, SMD, 1206, 10µF, 50V, 10%, X5R, ROHS	Various
C18, C19, C25	GRM31CR71H225KA88L	3	CAP, SMD, 1206, 2.2µF, 50V, 10%, X7R, ROHS	Murata
C60	6TPE220MI	1	CAP-POSCAP, SMD, 7.3x4.3x1.8, 220µF, 6.3V, 20%, 18mΩ, ROHS	Sanyo
L1	DR125-100-R	1	COIL-PWR INDUCTOR, SMD, 12.5mm, 10µH, 20%, 5.35A, ROHS	Coiltronics
L2	DR125-6R8-R	1	COIL-PWR INDUCTOR, SMD, 12.5mm, 6.8µH, 20%, 6.64A, ROHS	Coiltronics
D1, D3	SS6P3LHM3/86A	2	DIODE-SCHOTTKY RECTIFIER, SMD, SMPC, 60V, 3A, ROHS	Vishay
U1	ISL85403IRZ	1	IC-SWITCHING REGULATOR, 20P, QFN, 4X4, ROHS	Renesas
Q2	BSZ100N06LS3G	1	TRANSIST-MOS, N-CHANNEL, 8P, PG-TSDSON-8, 60V, 20A, ROHS	Infineon
R2	Various	1	RES, SMD, 0603, 220k, 1/10W, 1%, TF, ROHS	Various
R3	Various	1	RES, SMD, 0603, 52.3k, 1/10W, 1%, TF, ROHS	Various
R4, R23	Various	2	RES, SMD, 0603, 10k, 1/10W, 1%, TF, ROHS	Various
R7	Various	1	RES, SMD, 0603, 301k, 1/10W, 1%, TF, ROHS	Various
R9	Various	1	RES, SMD, 0603, 750Ω, 1/10W, 1%, TF, ROHS	Various
R22, R26	Various	2	RES, SMD, 0603, 0Ω, 1/10W, TF, ROHS	Various
R28, R31	Various	2	RES, SMD, 0603, 332k, 1/10W, 1%, TF, ROHS	Various
R29	Various	1	RES, SMD, 0603, 9.09k, 1/10W, 1%, TF, ROHS	Various
R30	Various	1	RES, SMD, 0603, 36k, 1/10W, 1%, TF, ROHS	Various



**Table 1. ISL85403EVAL1Z Bill of Materials (Continued)**

Ref Des	Part Number	Qty	Description	Manufacturer
R1, R5, R6, R8, R24, R25, R32, R33, R34, C5, C10, C61, D4, Q1	N/A	0	Do not populate	N/A

**Table 2. ISL85403EVAL3Z Bill of Materials**

Ref Des	Part Number	Qty	Description	Manufacturer
C5	EMK325ABJ107MM-T	1	CAP, SMD, 1210, 100µF, 16V, 20%, X5R, ROHS	
C6	C1608X7R1C105K	1	CAP, SMD, 0603, 1.0µF, 16V, 10%, X7R, ROHS	TDK
C57	EEE-FK1K470P	1	CAP, SMD, 10X10.2, 47µF, 80V, 20%, ALUM.ELEC., ROHS	Panasonic
C59	EEE-FK1K220P	1	CAP, SMD, 8X10.2, 22µF, 80V, 20%, ALUM.ELEC., ROHS	Panasonic
C9	Various	1	CAP, SMD, 0603, 10pF, 50V, 5%, C0G, ROHS	Various
C15, C23	Various	1	CAP, SMD, 0603, 0.1µF, 50V, 10%, X7R, ROHS	Various
C4	Various	1	CAP, SMD, 0603, 0.015µF, 50V, 10%, X7R, ROHS	Various
C8	Various	1	CAP, SMD, 0603, 470pF, 50V, 5%, NP0, ROHS	Various
C3	C1608X7R1H474K	1	CAP, SMD, 0603, 0.47µF, 50V, 10%, X7R, ROHS	TDK
C7	Various	1	CAP, SMD, 0603, 820pF, 50V, 5%, C0G, ROHS	Various
C14	Various	1	CAP, SMD, 0805, 1.0µF, 50V, 10%, X7R, ROHS	Various
C1	0805ZD475KAT2A	1	CAP, SMD, 0805, 4.7µF, 10V, 10%, X5R, ROHS	AVX
C22	Various	1	CAP, SMD, 1206, 10µF, 50V, 10%, X5R, ROHS	Various
C18, C19, C25	GRM31CR71H225KA8 8L	3	CAP, SMD, 1206, 2.2µF, 50V, 10%, X7R, ROHS	Murata
C60	T543D107K016ATE035	1	CAP-TANTALUM, SMD, 2917, 100µF, 16V, 10%, 35mΩ, ROHS	Kemet
L1	7443551221	1	22uH SHIELDED WIREWOUND INDUCTOR, 6A,24.7mOhm	Würth
L2	DR125-6R8-R	1	COIL-PWR INDUCTOR, SMD, 12.5mm, 6.8µH, 20%, 6.64A, ROHS	Coiltronics
D1	SS6P3LHM3/86A	1	DIODE-SCHOTTKY RECTIFIER, SMD, SMPC, 60V, 3A, ROHS	Vishay
D3	FSV15100V	1	DIODE-SCHOTTKY, 100V, 15A, TO-277-3	ON Semi
D5	LL4148	1	DIODE, 100V, 200mA, SOD80	ON Semi
U1	ISL85403IRZ	1	IC-SWITCHING REGULATOR, 20P, QFN, 4X4, ROHS	Renesas
Q2	BSZ100N06LS3G	1	TRANSIST-MOS, N-CHANNEL, 8P, PG-TSDSON-8, 60V, 20A, ROHS	Infineon
R2	Various	1	RES, SMD, 0603, 220k, 1/10W, 1%, TF, ROHS	Various
R3	Various	1	RES, SMD, 0603, 140k, 1/10W, 1%, TF, ROHS	Various
R4, R23	Various	2	RES, SMD, 0603, 10k, 1/10W, 1%, TF, ROHS	Various
R7	Various	1	RES, SMD, 0603, 301k, 1/10W, 1%, TF, ROHS	Various
R9	Various	1	RES, SMD, 0603, 750Ω, 1/10W, 1%, TF, ROHS	Various
R22, R26	Various	2	RES, SMD, 0603, 0Ω, 1/10W, TF, ROHS	Various
R28	Various	1	RES, SMD, 0603, 332k, 1/10W, 1%, TF, ROHS	Various
R29	Various	1	RES, SMD, 0603, 9.09k, 1/10W, 1%, TF, ROHS	Various
R30	Various	1	RES, SMD, 0603, 4.02k, 1/10W, 1%, TF, ROHS	Various
R31	Various	1	RES, SMD, 0603, 45.3k, 1/10W, 1%, TF, ROHS	Various
R35	Various	1	RES, SMD, 0603, 4.99k, 1/10W, 1%, TF, ROHS	Various

**Table 2. ISL85403EVAL3Z Bill of Materials (Continued)**

Ref Des	Part Number	Qty	Description	Manufacturer
R36	Various	1	RES, SMD, 0603, 120k, 1/10W, 1%, TF, ROHS	Various
R1, R5, R6, R8, R24, R25, R32, R33, R34, C10, C61, D4, Q1	N/A	0	Do not populate	N/A

## 4. Conclusion

The ISL85403 by Renesas is a versatile regulator IC that can be used not only as a conventional buck controller, but also as a boost buck controller, which accommodates a wide range of input voltage while reliably maintaining output regulation. It also has comprehensive protections against various faults including overcurrent, overvoltage and over-temperature, which makes it a robust solution in a large variety of applications.

## 5. Revision History

Rev.	Date	Description
1.00	Aug.29.19	Initial release

## Notice

1. Descriptions of circuits, software and other related information in this document are provided only to illustrate the operation of semiconductor products and application examples. You are fully responsible for the incorporation or any other use of the circuits, software, and information in the design of your product or system. Renesas Electronics disclaims any and all liability for any losses and damages incurred by you or third parties arising from the use of these circuits, software, or information.
2. Renesas Electronics hereby expressly disclaims any warranties against and liability for infringement or any other claims involving patents, copyrights, or other intellectual property rights of third parties, by or arising from the use of Renesas Electronics products or technical information described in this document, including but not limited to, the product data, drawings, charts, programs, algorithms, and application examples.
3. No license, express, implied or otherwise, is granted hereby under any patents, copyrights or other intellectual property rights of Renesas Electronics or others.
4. You shall not alter, modify, copy, or reverse engineer any Renesas Electronics product, whether in whole or in part. Renesas Electronics disclaims any and all liability for any losses or damages incurred by you or third parties arising from such alteration, modification, copying or reverse engineering.
5. Renesas Electronics products are classified according to the following two quality grades: "Standard" and "High Quality". The intended applications for each Renesas Electronics product depends on the product's quality grade, as indicated below.
  - "Standard": Computers; office equipment; communications equipment; test and measurement equipment; audio and visual equipment; home electronic appliances; machine tools; personal electronic equipment; industrial robots; etc.
  - "High Quality": Transportation equipment (automobiles, trains, ships, etc.); traffic control (traffic lights); large-scale communication equipment; key financial terminal systems; safety control equipment; etc.Unless expressly designated as a high reliability product or a product for harsh environments in a Renesas Electronics data sheet or other Renesas Electronics document, Renesas Electronics products are not intended or authorized for use in products or systems that may pose a direct threat to human life or bodily injury (artificial life support devices or systems; surgical implantations; etc.), or may cause serious property damage (space system; undersea repeaters; nuclear power control systems; aircraft control systems; key plant systems; military equipment; etc.). Renesas Electronics disclaims any and all liability for any damages or losses incurred by you or any third parties arising from the use of any Renesas Electronics product that is inconsistent with any Renesas Electronics data sheet, user's manual or other Renesas Electronics document.
6. When using Renesas Electronics products, refer to the latest product information (data sheets, user's manuals, application notes, "General Notes for Handling and Using Semiconductor Devices" in the reliability handbook, etc.), and ensure that usage conditions are within the ranges specified by Renesas Electronics with respect to maximum ratings, operating power supply voltage range, heat dissipation characteristics, installation, etc. Renesas Electronics disclaims any and all liability for any malfunctions, failure or accident arising out of the use of Renesas Electronics products outside of such specified ranges.
7. Although Renesas Electronics endeavors to improve the quality and reliability of Renesas Electronics products, semiconductor products have specific characteristics, such as the occurrence of failure at a certain rate and malfunctions under certain use conditions. Unless designated as a high reliability product or a product for harsh environments in a Renesas Electronics data sheet or other Renesas Electronics document, Renesas Electronics products are not subject to radiation resistance design. You are responsible for implementing safety measures to guard against the possibility of bodily injury, injury or damage caused by fire, and/or danger to the public in the event of a failure or malfunction of Renesas Electronics products, such as safety design for hardware and software, including but not limited to redundancy, fire control and malfunction prevention, appropriate treatment for aging degradation or any other appropriate measures. Because the evaluation of microcomputer software alone is very difficult and impractical, you are responsible for evaluating the safety of the final products or systems manufactured by you.
8. Please contact a Renesas Electronics sales office for details as to environmental matters such as the environmental compatibility of each Renesas Electronics product. You are responsible for carefully and sufficiently investigating applicable laws and regulations that regulate the inclusion or use of controlled substances, including without limitation, the EU RoHS Directive, and using Renesas Electronics products in compliance with all these applicable laws and regulations. Renesas Electronics disclaims any and all liability for damages or losses occurring as a result of your noncompliance with applicable laws and regulations.
9. Renesas Electronics products and technologies shall not be used for or incorporated into any products or systems whose manufacture, use, or sale is prohibited under any applicable domestic or foreign laws or regulations. You shall comply with any applicable export control laws and regulations promulgated and administered by the governments of any countries asserting jurisdiction over the parties or transactions.
10. It is the responsibility of the buyer or distributor of Renesas Electronics products, or any other party who distributes, disposes of, or otherwise sells or transfers the product to a third party, to notify such third party in advance of the contents and conditions set forth in this document.
11. This document shall not be reprinted, reproduced or duplicated in any form, in whole or in part, without prior written consent of Renesas Electronics.
12. Please contact a Renesas Electronics sales office if you have any questions regarding the information contained in this document or Renesas Electronics products.

(Note1) "Renesas Electronics" as used in this document means Renesas Electronics Corporation and also includes its directly or indirectly controlled subsidiaries.

(Note2) "Renesas Electronics product(s)" means any product developed or manufactured by or for Renesas Electronics.

(Rev.4.0-1 November 2017)

## Corporate Headquarters

TOYOSU FORESIA, 3-2-24 Toyosu,  
Koto-ku, Tokyo 135-0061, Japan  
[www.renesas.com](http://www.renesas.com)

## Contact Information

For further information on a product, technology, the most up-to-date version of a document, or your nearest sales office, please visit:  
[www.renesas.com/contact/](http://www.renesas.com/contact/)

## Trademarks

Renesas and the Renesas logo are trademarks of Renesas Electronics Corporation. All trademarks and registered trademarks are the property of their respective owners.