150W BUCK-BOOST

- **Four Switches Synchronous BUCK-BOOST**

  Input voltage 12Vdc-24Vdc, output 3.3V~19.2V/12A, maximum output power 150W, switching frequency up to 1200kHz, peak efficiency up to 98.1%.

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- **Highlighted Products**
  - INN040FQ043A

- **Target Applications**
  - Ultra-Books, Notebooks, Tablet PCs
  - Car Charger

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- **Test Results**

- **Photo**

Vin=20V, Vout=13.5V
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1. Overview

1.1. Description

The INNDDD150A1 is a four switches synchronous BUCK-BOOST DC/DC module, which supports 150W output. The evaluation board features InnoGaN INN040FQ043A. The INNDDD150A1 operates from 12V to 24V input voltage range and generates adjustable 3.3V to 19.2V, 12Amax output. The switching frequency and dead time is adjustable for different evaluation scenario.

1.2. Features

- **Main features and Advantages**
  > High efficiency: 98.10% @ 24Vin, 19.2Vout/6A, 600KHz
  > Adjustable switching frequency: 400KHz~1200KHz
  > Adjustable output voltage: 3.3V~19.2V

- **Protection Function**
  > Input over voltage protection
  > Input over current protection
  > Input over current protection

1.3. Applications

- **Ultra-Books, Notebooks, Tablet PCs**
- **Car Charger**
2. Parameters

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Parameter</th>
<th>Conditions</th>
<th>Min</th>
<th>Nom</th>
<th>Max</th>
<th>Units</th>
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<td>VIN</td>
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<td>24</td>
<td>Vdc</td>
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<tr>
<td>Fs</td>
<td>Switching frequency</td>
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<td>-</td>
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<td>VOUT</td>
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<td>-</td>
<td>19.2</td>
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<tr>
<td>POUT</td>
<td>Output power</td>
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<td>W</td>
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**Table 1 Electrical characteristics (Ta=25°C)**

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<tr>
<td>Eff,pk</td>
<td>Peak efficiency</td>
<td>Measured @Vin=24V, Output=19.2V/6A,600KHz</td>
<td>98.1</td>
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<td></td>
<td>%</td>
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<tr>
<td>Eff</td>
<td>Full load efficiency</td>
<td>Measured @Vin=20V, Output=13.5V/12A,600KHz</td>
<td>96.75</td>
<td></td>
<td></td>
<td>%</td>
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</tbody>
</table>
3. Demo Solutions

3.1. System Solutions

![Diagram of 150W Demo board topology](image)

*Figure 1 150W Demo board topology*

The 150W BUCK-BOOST demo board adopts the solution of synchronous 4-switch BUCK-BOOST topology.

3.2. Value of GaN

Four GaN field effect transistors INN040FQ043A with FCQFN package, drain-source voltage 40V, and the maximum conduction resistance of 4.3mΩ are adopted in the schematic.

- **Lower Driver Losses**

  The gate charge (Qg) of GaN is smaller, when the driver voltage is same, the driver loss for our GaN will be lower. Also, with same driver loss, GaN will allow higher frequency, which will reduce the size of another device.

- **Lower Switching Losses**

  The capacitance (C) determines the amount of charge (Q) that needs to be supplied to various terminals of the device to change the voltage across those terminals (Q = C*V). The parasitic capacitance of GaN is smaller, where Ciss and Crss are much smaller than Si MOSFET. The faster this charge is supplied, the faster the device will change voltage, and the less the switching time will be. So GaN has lower switching loss.
- Zero Reverse Recovery

The reverse recovery charge QRR is a charge related to this reverse conduction mechanism, representing the amount of charge dissipated when a body diode is turned off. Reverse recovery charge does not directly relate to the device capacitances for an enhancement-mode GaN transistor. This charge comes from the minority carriers left over during diode conduction in a p-n junction of a MOSFET. Because there are no minority carriers involved in conduction in an enhancement-mode GaN transistor, there is no reverse recovery charge. Therefore, QRR is zero, which is a significant advantage compared with power MOSFET.

3.3. Highlighted Products

3.3.1. InnoGaN Device INN040FQ043A.

![InnoGaN device INN040FQ043A](image)

Figure 2 InnoGaN device INN040FQ043A

InnoGaN Device INN040FQ043A has FCQFN 3mm x 4mm package size, drain-source voltage 40V, and the maximum conduction resistance of 4.3mΩ, compared with Si MOSFET 5mm x 6mm DFN package, INN040FQ043A has about 1/3 Ciss, 1/4 package size.
4. Hardware Implementation

4.1. Photos

4.2. Design Considerations

4.2.1. Control IC

The control IC for the demo board is SC8886S from Southchip. SC8886S is a synchronous buck-boost charger controller, which supports buck mode, boost mode and buck-boost mode. SC8886S adopts Narrow-VDC power path management, which automatically regulates the current and voltage and controls the flow of power. SC8886S has 5.3V driver voltage which is suitable for GaN driving. Also, it supports different switching frequency from 400 KHz to 1200 KHz. Besides, it supports adjustable dead time from 10ns to 80ns.
4.2.2. PCB Layout for Minimizing Parasitic Inductance

During PCB layout, great attention should be paid to the parasitic inductance, which includes CSI, power loop inductance and driver loop inductance as shown in Figure 5. The longer the trace, the greater the parasitic inductance will be. When a rapidly changing current flows through the device, an induced voltage will be generated across the common source inductor due to the blocking effect of the inductance. The induced voltage will cause the source and gate to ring, causing unexpected losses. As a result, we must minimize the parasitic inductance by optimized PCB layout.

For the power loop, place the high frequency bus capacitor as close to the two power switching devices as possible; for the driver loop, place the driver or controller close to the switching device so that the driver loop will be smaller. Besides, we can allocate the source pads closest to the gate to act as the “star” connection point for both the gate loop and power loop. The layout of the gate and power loops are then separated by having the currents flow in opposite or orthogonal directions, as shown in Figure 6.

![Figure 3 Schematic of half bridge power stage](image)
Figure 6  Minimize the common source inductance
5. Testing & Results

5.1. Test Setup

The 150W Buck-Boost demonstration board is easy to set up to evaluate the performance of INN40FQ043A. Before the test, we need to get all the equipment prepared, which includes DC source, electronic load, digital multimeter, and digital oscilloscope with 1 GHz bandwidth. Refer to Figures 4 and follow the procedure below for proper connection and measurement setup:

a) With power off, connect the input power supply, load, digital multimeter and I2C interface according to figure 7 correctly;

b) Turn on the input power supply to required value, make sure that input voltage does not exceed 26V.

c) The default output voltage is 12.5V, and it can be set by host through the I2C interface, for more detailed operation instructions, see Simple operation instruction.

5.2. Test Results

5.2.1. Efficiency curve
Figure 8 Efficiency Curve
Vin=20V, Vo=13.5V

Figure 9 Efficiency Curve
Vin=24V, Fs=600KHz

Figure 10 Efficiency curve
Vin=24V, Fs=800KHz

Figure 11 Efficiency curve
Vin=24V, Fs=1200KHz

Figure 12 Efficiency Curve
Vin=12V, Fs=600KHz

Figure 13 Efficiency Curve
Vin=12V, Fs=800KHz
5.2.2. Switching Waveforms

**Test conditions**
- Vin: 20Vdc
- Vo: 13.5V
- Io: 12A
- Fs: 800KHz

**Test Result**
- Vgsmax: 5.2V
- Vdsmx: 21.5V

**Test conditions**
- Vin: 20Vdc
- Vo: 13.5V
- Io: 12A
- Fs: 800KHz

**Test Result**
- Tf_gs: 8.49ns
- Tr_sw: 5.606ns
- TDHL: 9.233ns
5.2.3. Thermal Test

**Test conditions**
- \( \text{Vin}=20\text{Vdc} \)
- \( \text{Vout}=13.5\text{V} \)
- \( \text{Iout}=12\text{A} \)
- \( \text{Fs}=800\text{KHz} \)
- Ambient temp 25°C
- Run for 1h

**Result**
- Q2: 92.6°C
- Q3: 78.3°C
- Q4: 70.7°C
- Q1: 75.3°C
- \( \text{SC8886S}: 69.1°C \)
- Inductance: 93.4°C
Appendix

Appendix A. Schematics

Figure 16 Schematic
## Appendix B. BOM

<table>
<thead>
<tr>
<th>Comment</th>
<th>Description</th>
<th>Designator</th>
<th>Quantity</th>
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<td>C1</td>
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<tr>
<td>CL108102KB8NNNC</td>
<td>1nF 0603 ±10% 50V X7R</td>
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<td>DT5524L</td>
<td>40V 2A 420mV@2A</td>
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<td>MW5A100035-1R5MT</td>
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<td>M3X5.56X1.53</td>
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<td>INN0R0FO43A</td>
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<td>AONR21357</td>
<td>30V PMOS</td>
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<td>STE1206M1W0RO05FS</td>
<td>0.005R (5mR) 1206 ±1%</td>
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<td>Q5</td>
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<td>U1</td>
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</table>
Appendix C. PCB Layouts

(a) Top Layer

(b) Mid Layer 1

(c) Mid Layer 2

(d) Mid Layer 3
Note:
There is a dangerous voltage on the demo board, and exposure to high voltage may lead to safety problems such as injury or death.
Proper operating and safety procedures must be adhered to and used only for laboratory evaluation demonstrations and not directly to end-user equipment.

Reminder:
This product contains parts that are susceptible to electrostatic discharge (ESD). When using this product, be sure to follow antistatic procedures.

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