REFERENCE DESIGN OF 15A POL Using IR3447

DESCRIPTION

The IR3447 is a synchronous buck converter, providing a compact, high performance and flexible solution in a small 5mmx6mm QFN package.

Key features offered by the IR3447 include internal Digital Soft Start, precision 0.6V reference voltage, Power Good, thermal protection, programmable switching frequency, Enable input, input under-voltage lockout for proper start-up, enhanced line/load regulation with feed forward, external frequency synchronization with smooth clocking, internal LDO, true differential remote sensing and pre-bias start-up.

A thermally compensated output over-current protection function is implemented by sensing the voltage developed across the on-resistance of the synchronous rectifier MOSFET for optimum cost and performance.

This document provides the design recommendation for the feedback loop compensation, input and output capacitors to meet Huawei’s applications. The design is tested on a standard IR3447 demo board to verify the loop stability and input/output voltage ripple. Switching node spike, efficiency and thermal performance are also tested for customer’s reference.

APPLICATION INFORMATION

• $V_{in} = 6V-19V$ (12V, Nominal), No Vcc required.
• $V_{out} = 0.9V @ 0-15A/ 1.8V@0-5.5A$, Refer to Table 1 for details
• $F_s=300kHz \sim 350kHz$
• $L= 0.6uH$, Pulse PG0702 601NL, $0.91m\Omega$, $I_{sat} = 32A$
• Input/Output voltage ripple = 1% of $V_{in}/V_{out}$
• Transient load response = 3% of $V_{out} @ 50\%$ step load current
• Efficiency $>90\% @ V_{in} = 12V$, $V_{out} = 0.9V$, $I_o=15A$
• Max ambient temperature: 100ºC, 0.5m/s
APPLICATION INFORMATION

Feedback Loop Compensation Design
The IR3447 employs voltage mode control with a proprietary PWM scheme, allowing the closed loop bandwidth as high as 1/5th of the switching frequency. The input voltage feedforward ensures the cross-over frequency independent of the input voltage, which simplifies the design effort. Please note that as Vin is approaching to 6V, the performance of input voltage feedforward may be degraded slightly due to the nonlinearity of the internal circuit. As a result, the cross-over frequency is lower at Vin of 6V.

The loop compensation is designed for a 60kHz cross-over frequency, with a phase margin higher than 50° and gain margin larger than 10dB to accommodate the component variations and noise/jittering. Since SP caps are used for the output capacitors, type III-A compensation is used. Please refer to the application note AN-1162 “Compensator Design Procedure for Buck Converter with Voltage-Mode Error-Amplifier” for more information. SupiRBuck excel design tool is a very useful tool to create the design without going through the complicated math calculations.

Output Capacitor Selection
The selection of the output capacitors are determined by the requirements of the output voltage ripple and transient load response. For this application, the low switching frequency limits the highest achievable control bandwidth. To meet the transient response requirement, two SP capacitors, 470uF/2.5V/6mΩ (Panasonic EEFSX0E471XE), are used. Please note that EEFSX0E471XE is rated for -40ºC~105ºC operating temperature. Voltage derating may be required depending on the operating temperature over 105ºC. The capacitors rated for 125ºC operating temperature may be used for better long-term reliability.

Additional ceramic capacitors are needed to meet the output voltage ripple requirement. For the bench test, ten ceramic capacitors, 47uF/X5R/6.3V/0805 (TDK C2012X5R0J476M125AC), are used along with the SP capacitors. However, for 100ºC ambient operating temperature, the capacitors with X7R temperature coefficient should be selected (eg.TDK CGA5L1X7R0J226M160AC). It should be pointed out that the capacitance value changes significantly with the DC bias voltage. This parameter also varies a lot among different capacitor vendors. It is important to check the DC-bias characteristics in the datasheet. In addition, the AC ripple voltage also has some effect on the capacitance.

<table>
<thead>
<tr>
<th>Vout (V)</th>
<th>Iomax (A)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.9V</td>
<td>15A</td>
</tr>
<tr>
<td>1.0V</td>
<td>10A</td>
</tr>
<tr>
<td>1.15V</td>
<td>7A</td>
</tr>
<tr>
<td>1.5V</td>
<td>9A</td>
</tr>
<tr>
<td>1.8V</td>
<td>5.5A</td>
</tr>
</tbody>
</table>

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This evaluation board is a preliminary version meant for the engineering evaluation of the IR3447. Based on the results of the continuing evaluation, this board can evolve and change without notice.
Input Capacitor Selection

The selection of the input capacitors are determined by the requirement of the input voltage ripple. Ceramic capacitors are selected for its low ESR and ESL. At the minimum input voltage, the input ripple current is maximum. At the maximum input voltage, the capacitance value decreases most due to the DC bias. So the input voltage ripple should be tested under these two conditions. For the bench test, ten ceramic capacitors, 22μF/X5R/25V/1206 (Murata GRM31CR61E226KE15L), are used. However, for 100°C ambient operating temperature, the capacitors with X7R temperature coefficient should be selected (e.g. 10μF/X7R/25V/1206, TDK C3216X7R1E106K160AB).

Switch Node Spike

The switching node voltage spike can be reduced by a good PCB layout design, such as minimize the loop inductance, placing the input capacitors close to the input and GND pads. In addition, adding a boot resistor can help to slow down the switching speed and therefore to reduce the switch node spike, at the expense of the reduction of the efficiency.

For this application, the max input voltage is 19V. To ensure a reliable operation, it is recommended to use a 2Ω resistor in series with the boot capacitor. The max switch node voltage is reduced to 25.5V from 31V. The resulting effect on the efficiency is negligible. Please refer to test results for more information.
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**Fig. 1: Schematic of the 15A POL using IR3447, fsw=300kHz**

Bench test used: 10x 22uF/X5R/25V/1206 (Murata GM031CR61E226KE15L)
For 100°C operating ambient temp, select capacitors with X7R temperature coefficient.

Bench test used: 10x 47uF/X5R/6.3V/0805 (TDK C2012X5R0J476M125AC)
For 100°C operating ambient temp, select capacitors with X7R temperature coefficient.
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TYPICAL OPERATING WAVEFORMS
Vin=6V-19V, Vo=0.9V, Io=0-15A, 300kHz, Room Temperature, no airflow

Step Load Response, Vin=12V, Vo=0.9V, Io=7.5A-0A-7.5A, Ch3:Vout, Ch4:Io, Overshoot=12.6mV, Undershoot=-22.4mV

Step Load Response, Vin=12V, Vo=0.9V, Io=15A-7.5A-15A, Ch3:Vout, Ch4:Io, Overshoot=13.6mV, Undershoot=-24mV

Step Load Response, Vin=6V, Vo=0.9V, Io=7.5A-0A-7.5A, Ch3:Vout, Ch4:Io, Overshoot=17.6mV, Undershoot=-24.8mV

Step Load Response, Vin=6V, Vo=0.9V, Io=15A-7.5A-15A, Ch3:Vout, Ch4:Io, Overshoot=18.4mV, Undershoot=-27.2mV

Step Load Response, Vin=19V, Vo=0.9V, Io=7.5A-0A-7.5A, Ch3:Vout, Ch4:Io, Overshoot=12.8mV, Undershoot=-21.6mV

Step Load Response, Vin=19V, Vo=0.9V, Io=15A-7.5A-15A, Ch3:Vout, Ch4:Io, Overshoot=13.6mV, Undershoot=-22.4mV

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TYPICAL OPERATING WAVEFORMS
Vin=6V-19V, Vo=0.9V, Io=0-15A, 300kHz, Room Temperature, no airflow

Vin Ripple Vin=12V, Vo=0.9V, Io=15A
Ch3: V_in, V_in-ripple=92mV

Vin Ripple Vin=6V, Vo=0.9V, Io=15A
Ch3: V_in, V_in-ripple=100.0mV

Vin Ripple Vin=19V, Vo=0.9V, Io=15A
Ch3: V_in, V_in-ripple=104mV

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TYPICAL OPERATING WAVEFORMS
Vin=6V-19V, Vo=0.9V, Io=0-15A, 300kHz, Room Temperature, no airflow

Bode Plot: Vin=12V, Vout = 0.9V and 15A load: bandwidth of 59 kHz; PM= 54°, GM=-15dB

Bode Plot: Vin=19V, Vout = 0.9V and 15A load: bandwidth of 58 kHz; PM= 56°, GM=-15dB
TYPICAL OPERATING WAVEFORMS
Vin=6V-19V, Vo=0.9V, Io=0-15A, 300kHz, Room Temperature, no airflow

Bode Plot: Vin=6V, Vout = 0.9V and 15A load: bandwidth of 43 kHz; PM= 63°, GM=-18dB

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**TYPICAL OPERATING WAVEFORMS**

Vin=6V-19V, Vo=0.9V, Io=0-15A, 300kHz, Room Temperature, no airflow
This evaluation board is a preliminary version meant for the engineering evaluation of the IR3447. Based on the results of the continuing evaluation, this board can evolve and change without notice.
TYPICAL OPERATING WAVEFORMS

Vin=6V-19V, Vo=1.8V, Io=0-15A, 300kHz, Room Temperature, no airflow

Vout Ripple Vin=12V, Vo=1.8V, Io=5.5A
Ch2:Vin, Ch3:Vo, Vo-ripple=17.2mV

Vout Ripple Vin=6V, Vo=1.8V, Io=5.5A
Ch2:Vin, Ch3:Vo, Vo-ripple=16mV

Vout Ripple Vin=19V, Vo=1.8V, Io=5.5A
Ch2:Vin, Ch3:Vo, Vo-ripple=18mV
TYPICAL OPERATING WAVEFORMS
Vin=6V-19V, Vo=1.8V, Io=0-5.5A, 300kHz, Room Temperature, no airflow

Step Load Response, Vin=12V, Vo=1.8V, Io=2.5A-0A-2.5A, Ch3:Vout, Ch4:Io, Overshoot=14.4mV, Undershoot=-15.2mV

Step Load Response, Vin=12V, Vo=1.8V, Io=5.5A-2.5A-5.5A, Ch3:Vout, Ch4:Io, Overshoot=14.4mV, Undershoot=-18.4mV

Step Load Response, Vin=6V, Vo=1.8V, Io=2.5A-0A-2.5A, Ch3:Vout, Ch4:Io, Overshoot=14.4mV, Undershoot=-16.8mV

Step Load Response, Vin=6V, Vo=1.8V, Io=5.5A-2.5A-5.5A, Ch3:Vout, Ch4:Io, Overshoot=15.2mV, Undershoot=-18.4mV

Step Load Response, Vin=19V, Vo=1.8V, Io=2.5A-0A-2.5A, Ch3:Vout, Ch4:Io, Overshoot=12.8mV, Undershoot=-15.2mV

Step Load Response, Vin=19V, Vo=1.8V, Io=5.5A-2.5A-5.5A, Ch3:Vout, Ch4:Io, Overshoot=16mV, Undershoot=-20mV
TYPICAL OPERATING WAVEFORMS
Vin=6V-19V, Vo=1.8V, Io=0-5.5A, 300kHz, Room Temperature, no airflow

Bode Plot: Vin=12V, Vout = 1.8V and 5.5A load: bandwidth of 53 kHz; PM= 60°, GM=-15dB

Bode Plot: Vin=19V, Vout = 1.8V and 5.5A load: bandwidth of 60 kHz; PM= 59°, GM=-14dB
TYPICAL OPERATING WAVEFORMS
Vin=6V-19V, Vo=0.9V, Io=0-15A, 300kHz, Room Temperature, no airflow

Bode Plot: Vin=6V, Vout = 1.8V and 5.5A load: bandwidth of 38 kHz; PM= 65º, GM=-19dB