APPLICATION NOTE 3539

A 50 Watt Internal Bus Architecture (IBA) Power Supply

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Abstract: This article discusses a 12V/50W bus-converter that provides a well-regulated, efficient, isolated 12 volts from a 48V bus. The topology used is a single-switch forward converter with synchronous rectification. The MAX5003 is the PWM controller used in this design, which is optimized for the narrow input-voltage range of 48V, ±5%.

Introduction

An Internal Bus Architecture (IBA) includes two power-conversion stages. The first stage uses a bus converter to obtain an intermediate bus voltage. The second stage uses point-of-load (POL) converters to convert the intermediate bus voltage to one or several low, well-regulated voltages to power the nearby loads. In this article we describe a 12V/50W bus converter that provides a well-regulated, isolated 12V from a 48V bus.

Power Supply Specification

- Input voltage: 48VDC, ±5% regulation
- Output voltage: 12V at 4.2A
- Minimum load: zero amps
- Ripple: ±1% peak-to-peak
- Isolation: 1500VAC
- Low cost
- Efficiency: > 90%
- Output should be short-circuit and overload protected

Power Conversion Topology

There are several power conversion topologies to choose among for this design. The chosen topology must be low cost and efficient. Due to the low cost requirement we have to choose a direct-driven, single-switch topology. The high-efficiency goal requires synchronous rectification in the secondary. The choices most suitable for this design are:

- Single-switch flyback with synchronous rectification on the secondary (Figure 1)
Single-switch forward with primary reset winding and synchronous rectification on the secondary (Figure 2).

For Larger Image

Figure 1. A flyback converter with synchronous rectification.

For Larger Image

Figure 2. Forward converter with reset winding and synchronous rectification.

The single-switch flyback topology has the advantage over the forward in the absence of an output inductor. We must add the extra drive transformer, T2, with the additional circuitry that transfers the primary drive signal from the PWM controller, U1, to the secondary stage. This signal is then used to turn off the synchronous MOSFET Q2 in the secondary stage just prior to turning off the primary MOSFET Q1. In addition, the Q3, Q5, C6, R3, D3, and R4 circuitry is added to delay the turn on of MOSFET Q1, thereby guaranteeing that secondary MOSFET Q2 turns off before Q1 turns on. Without this circuitry, there would be a short circuit across the transformer secondary until MOSFET Q2 turns off, causing, in turn, current spikes in MOSFET Q1 when it turns on.

In the single-switch forward-converter topology we need an extra inductor, but the output capacitance could be smaller than in the flyback design. We can also avoid the extra drive transformer (T2 above) by ensuring that the transformer T1 has been completely reset, and that the voltage across the transformer is at zero prior to the turn on of the primary switch.

Since the IBA power supply has a narrow input voltage range, we can maximize the operating duty cycle. The MAX5003 PWM controller will be used in the design described below. Figure 3 is the schematic of the actual power supply.
Component list for the power supply

<table>
<thead>
<tr>
<th>Designator</th>
<th>Qty</th>
<th>Description</th>
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</table>
| C1         | 1   | Ceramic capacitor 470pF, X7R, 50V, 10% (0402)  
TDKC1005X7R1H471K |
| C10        | 1   | Ceramic capacitor 0.33µF, X5R, 6.3V, 10% (0402)  
TDKC1005X5R0J334K |
| C11        | 1   | Ceramic capacitor 1µF, X5R, 6.3V, 20% (0402)  
TDKC1005X5R0J105M |
| C12        | 1   | Ceramic capacitor 2200µF, X7R, 50V, 10% (0402)  
TDKC1005X7R1H222K |
| C13        | 1   | Ceramic capacitor 0.1µF, X5R, 25V, 20% (0603)  
TDKC1608X7R1E104M |
| C14, C17   | 2   | Ceramic capacitor 0.068µF, 16V, 10% (0402)  
TDKC1005X5R1C683Kex |
| C15        | 1   | Ceramic capacitor 4700µF, 250VAC, X7R (2220)  
Murata GA355DR7GC472KY02 |
| C2, C3, C4 | 3   | Polymer tantalum chip capacitor 47µF, 16V, 20%  
Kemet T520D476M016ASE070 |
| C5         | 1   | Ceramic capacitor 1µF, 100V, X7R, 10% (1210)  
TDKC3225X7R2A105K |
| C6         | 2   | Ceramic capacitor 1µF, 16V, X7R, 20%, (0805)  
TDKC2012X7R1C105M |
| C8         | 1   | SMT Electrolytic capacitor 22µF, 50V, 20%  
Panasonic EEVFK1H220P |
| D1         | 1   | Zener diode 6.2V, 200mW (SOD323)  
Diodes Inc 1N4148W |
| D2-D5, D7-D10, D12 | 9 | Switching diode 75V, 150ma (SOD323)  
Diodes Inc 1N4148W |
| D11        | 1   | Silicon Epitaxial Planar Rectifier 200V, 200ma (SMINI2P)  
Panasonic MA115 |
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| D5 | 1 | Schottky diode 3A, 40A (SMA)  
Diodes Inc B340A |
| L1 | 1 | Inductor 3.3mH  
Coilcraft DO1608C-335 |
| L2 | 1 | Inductor 12µH  
Coilcraft DO5022P-103ML |
| Q3 | 1 | Transistor PNP 60V SOT23 MMBT2907  
Diodes Inc MMBT2907 |
| Q4 | 1 | N channel MOSFET, 80V, 15mΩ, SO8  
International Rectifier IRF7493 |
| Q5 | 1 | N channel MOSFET 30V, 13.8mΩ, SO8  
International Rectifier IRF7807Z |
| Q7 | 1 | N channel MOSFET 200V, 79mΩ, SO8  
International Rectifier IRF7892 |
| Q6 | 1 | N channel MOSFET, 30V, 1.2A, SOT23  
Fairchild Semiconductor NDS351AN |
| R1 | 1 | Resistor 27k, 5% (1206) |
| R10, R20 | 2 | Resistor 20.0k, 1% (0402) |
| R11-R14 | 4 | Resistor 1Ω 5% (0603) |
| R15 | 1 | Resistor 66.5k, 1% (0402) |
| R16 | 1 | Resistor 1.24k, 1% (0402) |
| R17 | 1 | 1.24k, 1% |
| R18 | 1 | Resistor 562Ω, 1% (1206) |
| R19 | 1 | Resistor 1k, 1% (1206) |
| R21 | 1 | Resistor 100Ω, 1% (0402) |
| R22 | 1 | Resistor 60.4k, 1% (0402) |
| R23 | 1 | Resistor 0.025Ω, 1% (0805) |
| R27 | 1 | Resistor 2.32k, 1% (0402) |
| R3 | 1 | Resistor 261k, 1% (0402) |
| R4 | 1 | Resistor 5.1k, 1% (0402) |
| R5 | 1 | Resistor 490Ω, 1% (0402) |
| R6 | 1 | Resistor 221k, 1% (0402) |
| R7 | 1 | Resistor 22Ω, 1% (1206) |
| R8 | 1 | Resistor 15k, 1% (0402) |
| R9 | 1 | Resistor 453k, 1% (0805) |
| T1 | 1 | Custom transformer (EFD20-12)  
Delta 2004D-535A |
| U1 | 1 | High Voltage PWM Power Supply Controller  
MAXIM MAX5003ESE |
| U2, U4 | 2 | Adjustable shunt regulator SOT23-5 |
Table 1. Texas Instruments TLV431IDB
U3 1 SMD Optoisolator 1channel HiCTR
NEC PS2911-1

Figure 4. Ripple and noise at 12V/4.2A (input is 48VDC).
Note: The Bandwidth used in the ripple and noise measurement is 20MHz. The peak-to-peak ripple at full load and 48V input is 110mV.
Figure 5. VDS and ID in Q7 at 50W output and 48VDC input.

Note: The peak voltage on Q7 is 152V at an input of 48V input. This is because the reset winding does not clamp and the transformer gets reset by the LC resonance formed by the transformer magnetizing inductance and the total reflected capacitance across the Q7 (D-S). This includes the transformer primary capacitance, the MOSFET Q7 capacitance, and the reflected capacitance from Q5 (D-S). Also note that the transformer voltage has reached zero just prior to the turn on of Q7. Reducing the conduction time interval for diode D5 thus optimizes the efficiency.
Figure 6. Current in Q7 and VGS on Q5 at full load and 48VDC input.

Note: The synchronous freewheeling MOSFET Q5 has been turned off before Q7 turns on, thus preventing current spikes in Q7. These current spikes would reduce the efficiency.
Figure 7. Current in Q7 and VDS on Q5 at full load and 48VDC input.

Figure 8. Current in Q7 and VGS on Q5 at full load and 48VDC input.

Note: The measured efficiency of this power supply at 50W at an input of 48V was 93%. The power supply met all the requirements specified for the design. Under short circuit, the supply would go into hiccup current limit, which would recover into full load when the short was removed.

Related Parts

<table>
<thead>
<tr>
<th>Part</th>
<th>Description</th>
<th>Free Samples</th>
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<tbody>
<tr>
<td>MAX5003</td>
<td>High-Voltage PWM Power-Supply Controller</td>
<td>Free Samples</td>
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<td>Free Samples</td>
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</tbody>
</table>

More Information

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