

TI Designs

24 V_{IN}, 5 V_{OUT} for Factory Automation and Industrial Robotics Reference Design



Description

This TI Design uses the TPS40170 synchronous buck controller to provide a well regulated 5-V rail from a 24-V industrial bus. In conjunction with the controller, a pair of CSD18504Q5A N-channel power FETs are used in the design to provide high efficiency across the entire 4-A load range.

Resources

- | | |
|-----------------------------|--------------|
| PMP15025 | Design Page |
| TPS40170 | Product Page |
| CSD18504Q5A | Product Page |

Features

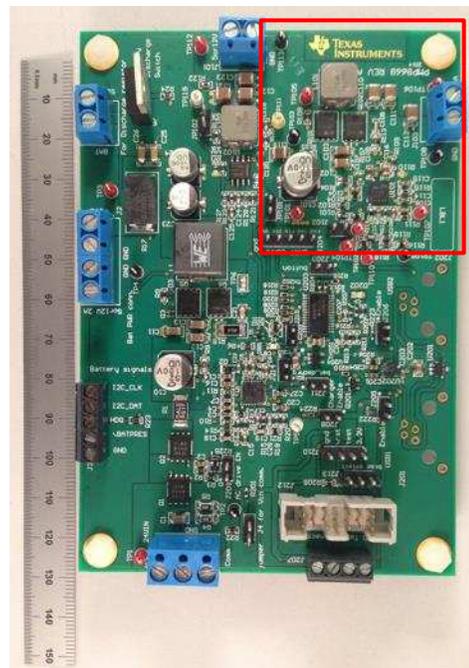
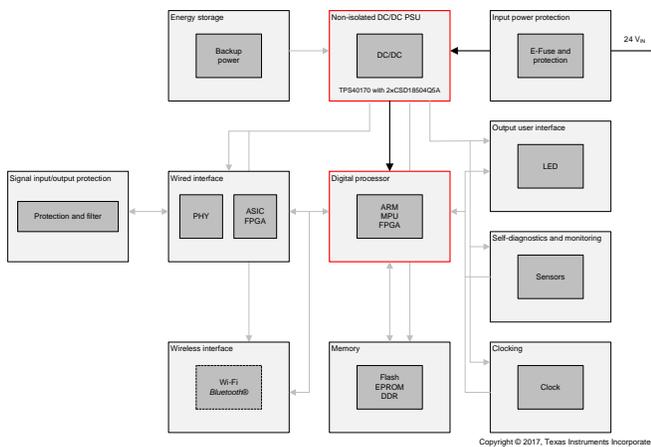
- 24-V_{IN} to 5-V_{OUT} Synchronous Buck Regulator
- I_{MAX} = 4 A
- 390-kHz Efficiency
- 90% Full Load Efficiency
- Minimal Phase Ringing at Full Load Current
- 30-kHz Loop Bandwidth With 75° of Phase Margin for Fast, Stable Transient Response

Applications

- Powering Processors, ASICs, FPGAs, and Other Equipment for Industrial Automation Applications
- Factory Automation
- Industrial Robotics Applications



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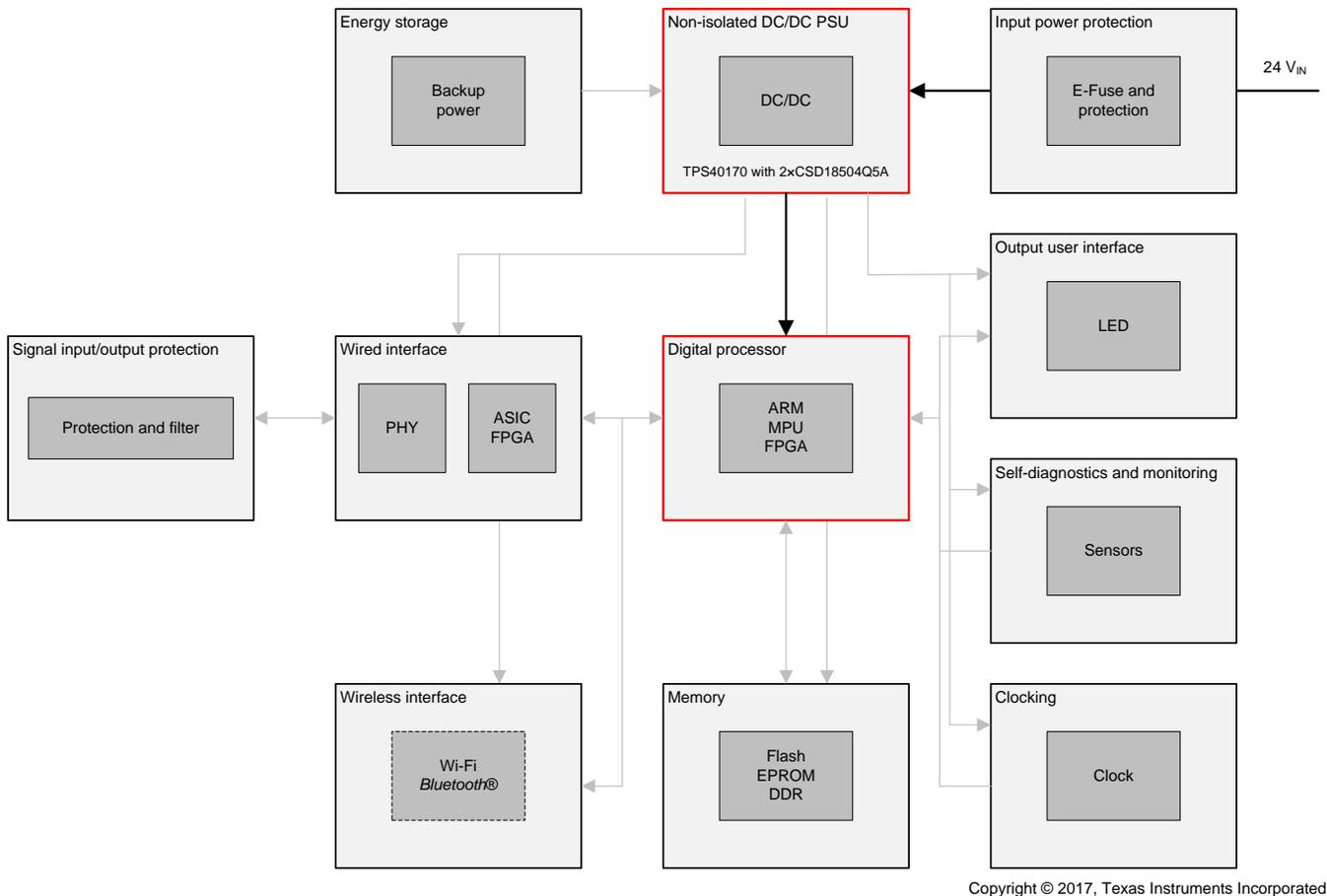
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1 System Overview

1.1 System Description

This TI Design features a single phase, synchronous buck converter that can take in a 24-V industrial bus and supply a stable 5-V, 4-A solution capable of powering Sitara™ processor PMICs. With the CPU, PMIC, and 5-V buck regulator coming from a single vendor, a successful first-time power-up becomes much easier to achieve. The design features both high efficiency and power density, making it suitable for industrial automation applications such as robotics and motor drives.

1.2 Block Diagram



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Figure 1. PMP15025 Block Diagram

1.3 Highlighted Products

1.3.1 TPS40170 4.5- to 60-V Wide Input Synchronous PWM Buck Controller

Key features include:

- Wide input voltage range from 4.5 to 60 V
- 600-mV reference voltage with 1% accuracy
- Programmable undervoltage lockout (UVLO) and hysteresis
- Programmable switching frequency between 100 and 600 kHz
- Low-side FET sensing overcurrent protection
- High-side FET short-circuit protection with integrated thermal compensation
- Integrated bootstrap diode
- 20-pin, 3.5-mm×4.5-mm VQFN package

1.3.2 CSD1804Q5A 40-V N-Channel NexFET Power MOSFET

Key features include:

- $Q_G = 7.7 \text{ nC}$ ($V_{GS} = 4.5 \text{ V}$)
- $R_{DS(ON)} = 7.5 \text{ m}\Omega$ ($V_{GS} = 4.5 \text{ V}$)
- Avalanche rated
- Pb free terminal plating
- RoHS compliant
- 5-mm×6-mm SON package

2 System Design Theory

A high-efficiency, power dense synchronous buck controller and FETs for factory automation applications (for example, industrial robotics and motor drives) provide a stable 5-V output from a 24-V bus. A 390-kHz switching frequency is chosen to minimize the size and number of output filter components while maintaining a peak efficiency of 90.0%. The voltage mode control scheme with input feedforward offers a simple, low-cost solution to be implemented that can be stabilized using standard Type III compensation.

The TPS40170 controller and CSD18504Q5A FETs are rated for input voltages of 60 V and 40 V, respectively, making them a good fit for 24-V input applications as there is sufficient margin for transients and variations without risking damage to the ICs. Additionally, the TPS40170 also offers frequency synchronization features to help cut down on noise and EMI in the overall system making it more robust.

Further design optimizations or modifications to allow for higher output current can be done in WEBENCH® Designer.

3 Getting Started Hardware

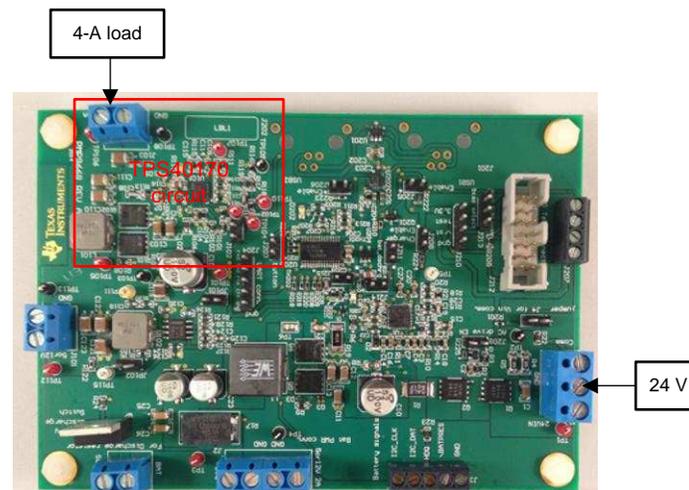


Figure 2. Connection Guide

3.1 Hardware

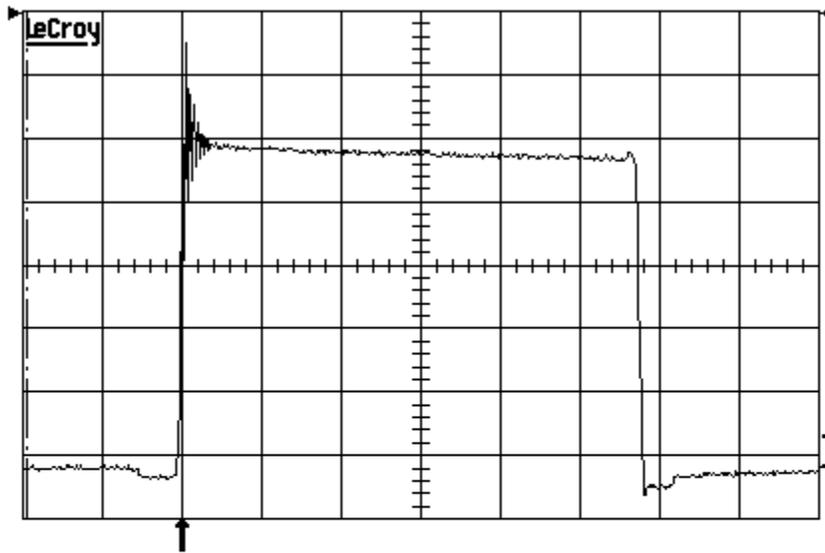
To test this TI Design, gather the following equipment:

- 24-V power supply: provides input power to TPS40170
- Digital multimeter: measures the DC value of V_{OUT} , V_{IN} , and other nodes of interest
- Oscilloscope: monitors the phase node, V_{OUT} , V_{IN} , COMP, and so on
- Electronic load: loads the output of the regulator and provides transient waveforms

4 Testing and Results

9-May-14
16:39:19

1
.1 μ s
5.0 V



Freq(1) - - -
maximum(1) 34.34 V
rise(1) 4.7 ns
Fall(1) 7.9 ns
minimum(1) -2.38 V

.1 μ s

1 .5 V DC $\times 10$
2 1 V DC $\times 10$
3 50 mV AC
4 50 mV AC



1 DC 35.6 V

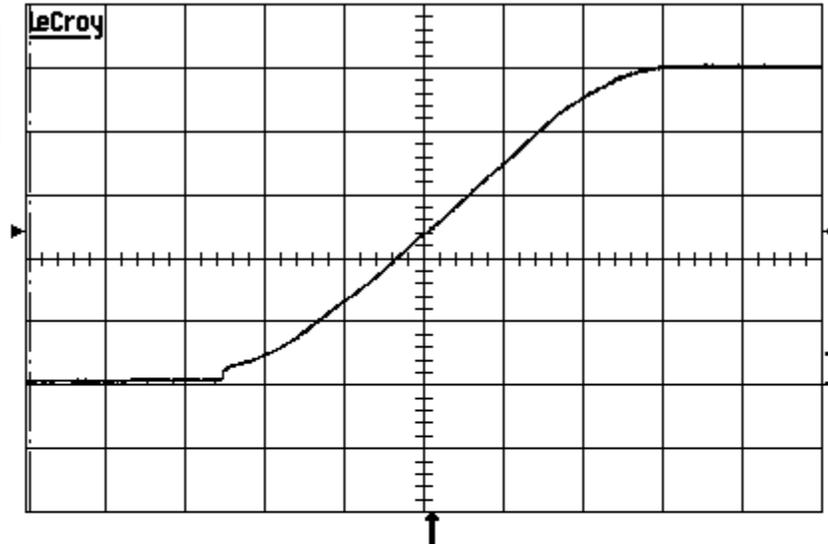
1 GS/s

STOPPED

Figure 3. Switch Node, 4-A Load

9-May-14
16:15:46

2 ms
1.00 V



Freq(1) - - -
maximum(1) 5.01 V
rise(1) 7.53426 ms
Fall(1) - - -
minimum(1) -0.02 V

2 ms BWL
1 .1 V DC $\times 10$
2 1 V DC $\times 10$
3 50 mV AC
4 50 mV AC



1 DC 2.40 V

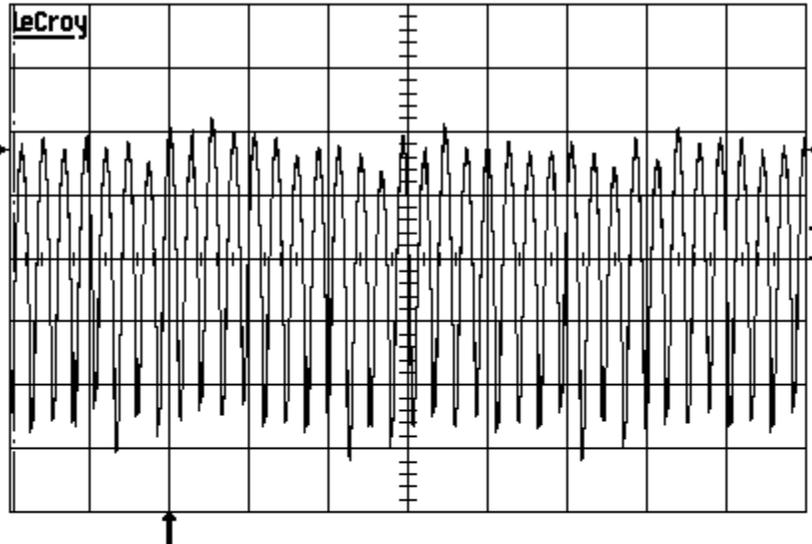
5 MS/s

STOPPED

Figure 4. Startup Waveform, No Load

9-May-14
16:51:30

10 μ s
2.00mV



Freq(1) μ s 376.482 kHz
 maximum(1) 4.44mV
 rise(1) μ s 663.8 ns
 Fall(1) μ s 579.3 ns
 minimum(1) -6.38mV

10 μ s BWL
 1 2 mV AC
 2 1 V DC $\times 10$
 3 50 mV AC
 4 50 mV AC



1 DC 3.44mV

1 GS/s

STOPPED

Figure 5. Output Ripple, 4-A Load

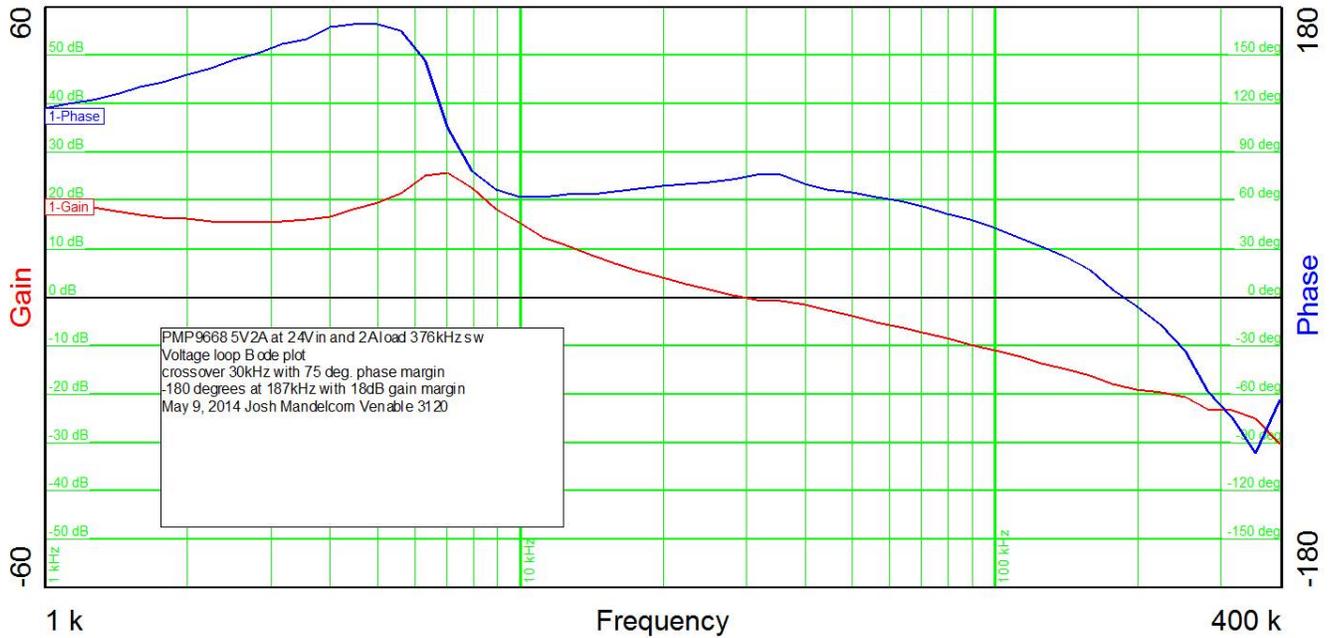


Table 1. Efficiency and Power Loss Data, No Cooling

V _{IN} (V)	I _{IN} (A)	V _{OUT} (V)	I _{OUT} (A)	EFFICIENCY	P _{LOSS} (W)
24.08	0.9327	4.928	4.084	89.6	2.333
24.05	0.6832	4.924	3.000	89.9	1.659
24.07	0.4587	4.918	2.001	89.1	1.200
24.09	0.2413	4.920	1.001	84.7	0.888
24.10	0.1342	4.957	0.500	76.6	0.756
24.11	0.0252	4.960	0	0	0.608

5 Design Files

To download the schematics, BOM, and other documentation, see the design files at <http://www.ti.com/tool/PMP15025>.

6 Related Documentation

1. Texas Instruments, [TPS40170 4.5 V to 60 V Wide Input Synchronous PWM Buck Controller](#) , TPS40170 Datasheet (SLUS970)
2. Texas Instruments, [CSD18504Q5A 40-V N-Channel NexFET™ Power MOSFET](#), CSD18504Q5A Datasheet (SLPS366) <http://www.ti.com/lit/ds/symlink/csd18504q5a.pdf>
3. Texas Instruments, WEBENCH Design Center (<http://www.ti.com/webench>)

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