参考資料

TI Designs: PMP15040
サイズの制限が厳しい産業用センサ向けの、Vin範囲の広い電源のリファレンス・デザイン

概要

このリファレンス・デザインでは、スペースの制限が最も重要な問題であるようなセンサ・アプリケーションで、FPGA、ASIC、MCUに給電する方法の例を紹介します。この設計は入力電圧範囲が6V～60Vと広く、超小型で効率の高いDC/DCコンバータを使用しているため、産業用センサ、フィールド・トランスミッタ、モータ・ドライブ、PLCモジュールなどのアプリケーションに適しています。出力電圧は可変で、ユーザーの特定の要求に適応可能です。

リソース

PMP15040	デザイン・フォルダ
LMR36006	プロダクト・フォルダ
LMR36015	プロダクト・フォルダ

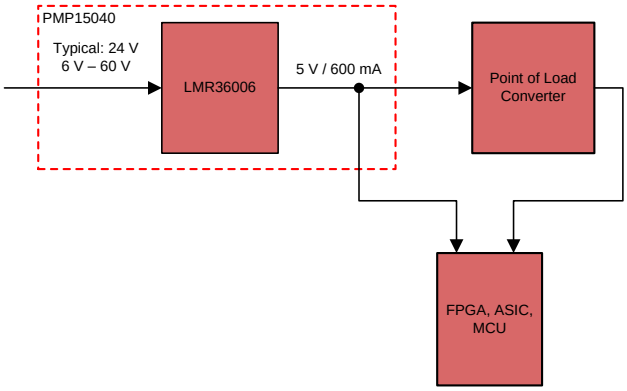
TI E2E™ Community　E2E エキスパートに質問

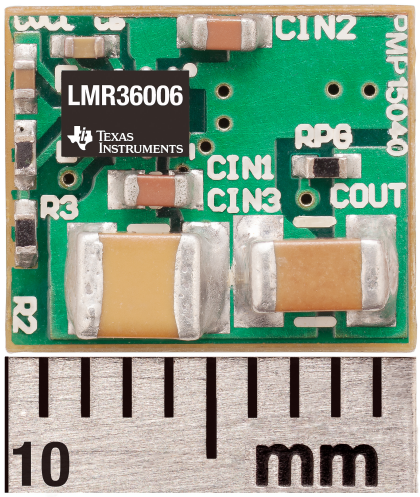
特長

- ソリューション・サイズの最適化 - 8.3mm×10mm
  - 少ない部品点数
  - 両面実装基板
  - スイッチング周波数: 1MHz
  - 厳密な電流制限
- 広い入力電圧範囲(6V～60V)により、ラインの差異に適合
- 低いノイズ・シグネチャと、静かなスイッチ・ノード
- 出力レール
  - 600mAで5V (±1.5%精度)
  - ユーザー固有の要件に適応するため電圧を調整可能

アプリケーション

- ファクトリ・オートメーション– 変位トランスミッタ
- ファクトリ・オートメーション - 流量トランスミッタ
- ファクトリ・オートメーション - マシン・ビジョン
- モータ・ドライブ - ACドライブ - AC位置フィードバック





1 System Description

The PMP15040 is optimized for size-sensitive sensor applications, specifically Field Transmitters and AC Drive Feedback systems. The standard power stage uses a Wide Vin DC/DC converter that enables peak efficiency > 90% as shown in 図 18.

A displacement transmitter uses an analog front-end to convert a signal of a sensor to an electrical representation and digital processor to convert this signal to a digital representation. A standard displacement transmitter uses a non-isolated Wide Vin DC/DC converter as the primary power stage. 図 1 highlights the PMP15040 standard placement within the field transmitter system.

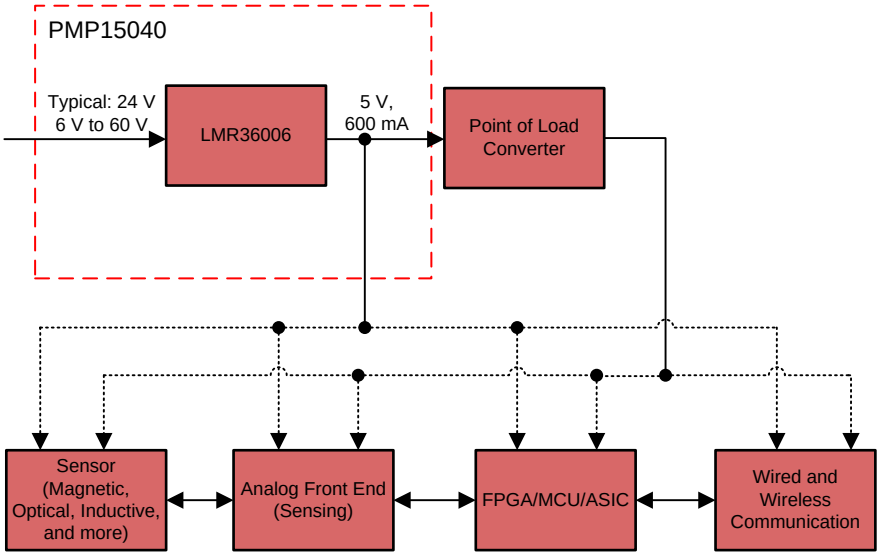


図 1. PMP15040 Field Transmitter Block Diagram

An AC Drive Feedback system converts SIN/COS differential inputs from the resolver or encoder to digital outputs, which enables accurate rotor position feedback of AC drives. AC Drive Position Feedback uses a non-isolated Wide Vin DC/DC converter as the primary power stage paired with a Point-of-Load DC/DC converter. These two power rails are necessary to power the Digital Processing component of the system. 図 2 highlights PMP15040 standard placement within the AC Drive Position Feedback system.

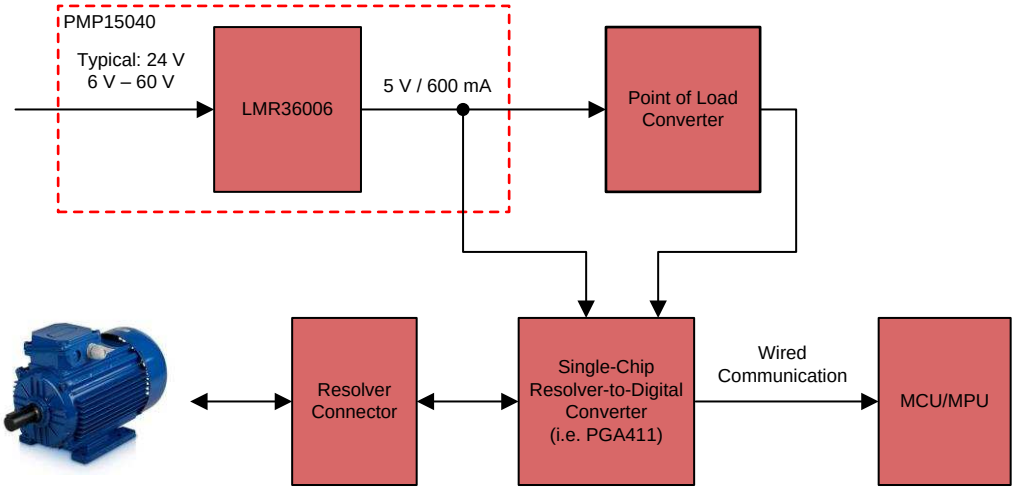


図 2. PMP15040 Rotary Encoder Block Diagram

1.1 Key System Specifications

表 1. Key System Specifications

PARAMETER	SPECIFICATIONS
V_{IN} minimum	6-V
V_{IN} maximum	60-V
V_{IN} nominal	24-V
V_{OUT}	5-V
I_{OUT}	600-mA
F_{SW}	1-MHz
X - Dimension	8.3-mm
Y - Dimension	10-mm

2 System Overview

2.1 Block Diagrams

図 3 shows the PMP15040 block diagram.

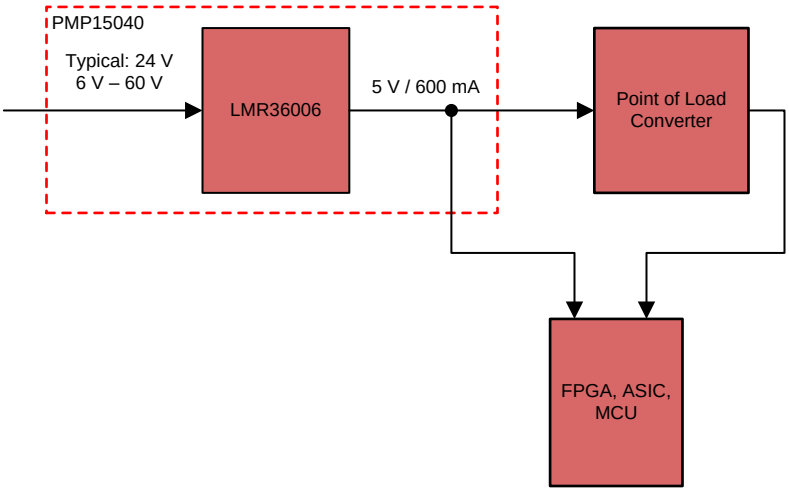


図 3. PMP15040 General Block Diagram

2.2 Highlighted Products

2.2.1 LMR36006

Features:

- Synchronous buck converter
- Wide operation input voltage: 4.2 V to 60 V (with transient protection up to 66 V)
- 1-MHz switching frequency
- Low quiescent current: 25 μA
- –40°C to +150°C junction temperature range
- Adjustable 1-V to 28-V output
- Maximum current load: 600 mA for LMR36006 and 1.5 A for LMR36015
- QFN package: 3 mm × 2 mm

2.3 System Design Theory

The PMP15040 highlights the 8.3 mm × 10 mm optimized solution size of the LMR36006. The synchronous buck converter, LMR36006, is a wide-input voltage range, low-quiescent current, high performance regulator with internal compensation. The LMR36006 is optimal for size-constraint applications because the LMR36006 has a 3-mm × 2-mm QFN package size, 1-MHz switching frequency, and a tight current limit. 図 6 shows the schematic of the front-end DC/DC converter. 図 4 and 図 5 show the images of the front and back side of PMP15040 board.

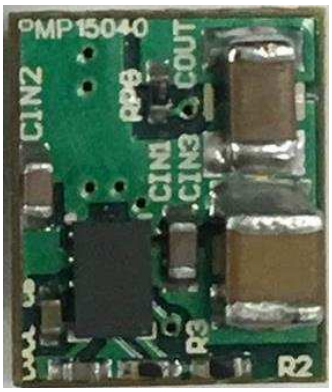


図 4. Front of the PMP15040 Board

図 5. Back of the PMP15040 Board

The operating frequency for the LMR36006 regulator is 1 MHz, and the device implements a precise current limit. Consequently, the output filter size and component values are minimized. The LMR36006 offers three operating switching frequency variants: 400 kHz, 1 MHz, and 2.1 MHz. The 1-MHz switching frequency provides peak efficiency greater than 90% at 12 V_{IN}, and peak efficiency greater than 80% at 24 V_{IN}. When the user selects the 1-MHz variant, the inductance range can be decreased from 40 µH – 50 µH to 10 µH – 25 µH. When the user selects an inductor with an inductance of 18 µH, the inductor should be capable of handling a maximum current of 1.2 A. Ultimately, inductor manufacturers have a wide selection of 18-µH inductors in a 4-mm × 4-mm package size. The PMP15040 uses a 18-µH inductor with a C_{OUT} of 22 µF.

For the PMP15040, the LMR36006 output voltage is set to 5 V with a resistor divider from FB to V_{OUT}. The top feedback resistor (R_{FBT}) is set to 100 kΩ, and the bottom resistor (R_{FBB}) is calculated using 式 1. V_{REF} is nominally 1 V.

$$R_{FBB} = \frac{R_{FBT}}{\left[\frac{V_{OUT}}{V_{REF}} - 1\right]} \quad (1)$$

For this 5-V example, values are R_{FBT} = 100 kΩ and R_{FBB} = 24.9 kΩ. Depending on the power requirement of the downstream digital component, the output voltage can be adjusted. For example, for a MCU which require a typical power rail of 3.3 V, the output voltage can be adjusted.

To scale the output voltage for specific system requirements, the output feedback resistors can be resized. For example, if a MCU requires a typical power rail of 3.3-V, the output voltage can be adapted by recalculating R_{FBB}. For this 3.3-V example values would be R_{FBT} = 100 kΩ and R_{FBB} = 43.5 kΩ. Furthermore, the PMP15040 output filter (L1 and C_{OUT}) will support the output voltage adjustment.

When scaling the output voltage from 5 V to 3.3 V, the corresponding output power capability of the LMR36006 will decrease from 3 W to 2 W. To increase the power capability of the PMP15040 to 7.5 W at 5 V_{OUT} and 5 W at 3.3 V_{OUT}, the pin-compatible LMR36015 offers a 1.5-A maximum output load current. To adapt the design to the LMR36015, the output filter (L1 and C_{OUT}) must be modified appropriately. TI recommends to modify the L1 to 4.7 µH and modify the C_{OUT} to 33 µF. Also, the saturation current of the inductor must support the increased current capability and peak current limit of 3 A. Powered iron cores exhibit a soft saturation current, allowing some relaxation in the current rating of the inductor.

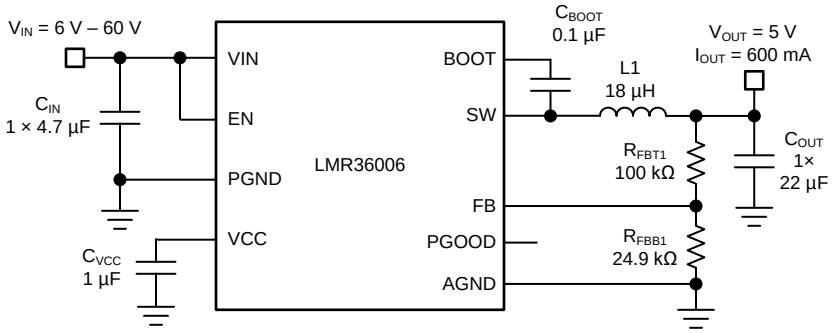


図 6. LMR36006 Schematic

The LMR36006 and LMR36015 devices are designed with a flip-chip or HotRod technology, which greatly reduces the parasitic inductance of the pins. Package lead inductance substantially increases the switch node ringing and the corresponding EMI performance. A wire-bond package, 図 7, has significant lead inductance compared to a flipped-chip, on-lead (FCOL) package, 図 8. HotRod technology eliminates wire bonds by attaching the silicon die directly the lead frame. Consequently HotRod technology lowers R_{DS_ON}, parasitic lead inductance, and dramatically reduces switch node ringing. The switch node waveforms of a wire bond package and a HotRod package can be seen in 図 9 and 図 10.

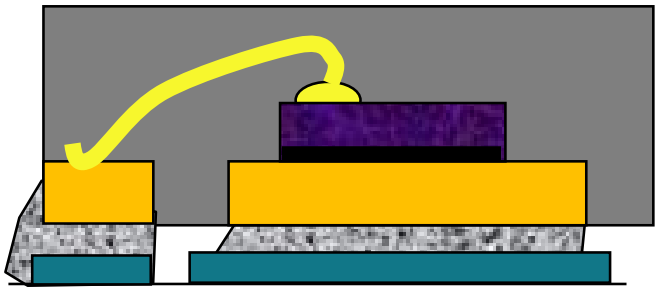


図 7. Standard QFN Package

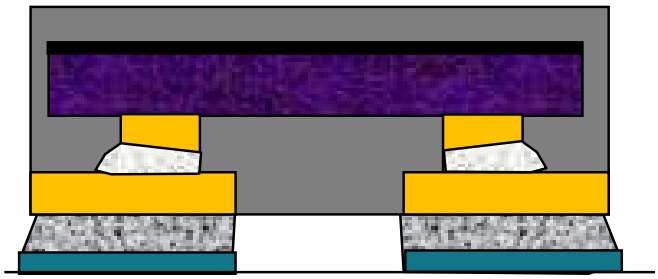


図 8. FCOL QFN Package

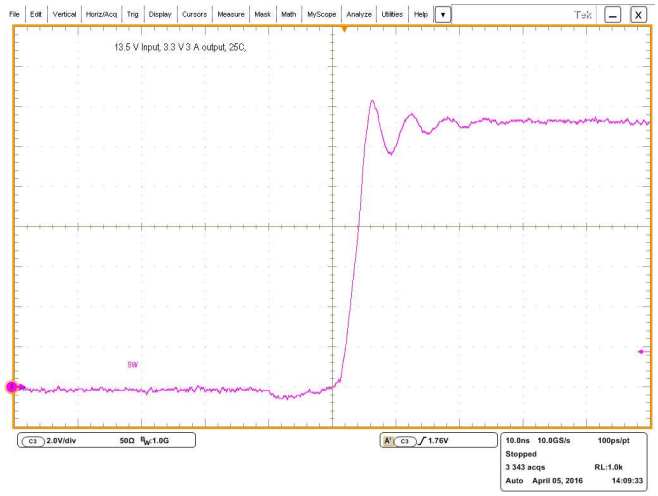


図 9. Wirebond Device Switch Node Signal

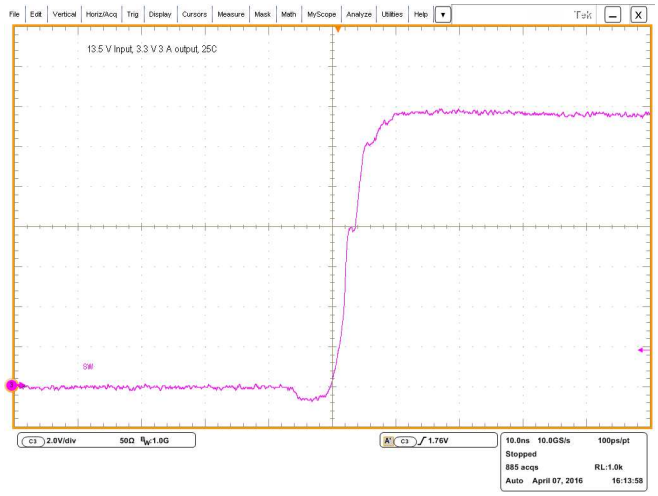


図 10. FCOL QFN Device Switch Node Signal

The LMR36006 HotRod package enables the smallest die to package ration and ultimately enables an optimized layout and total solution size of 8.3 mm × 10 mm shown in 図 11. The optimized layout is highlighted in 図 12 and 図 13.

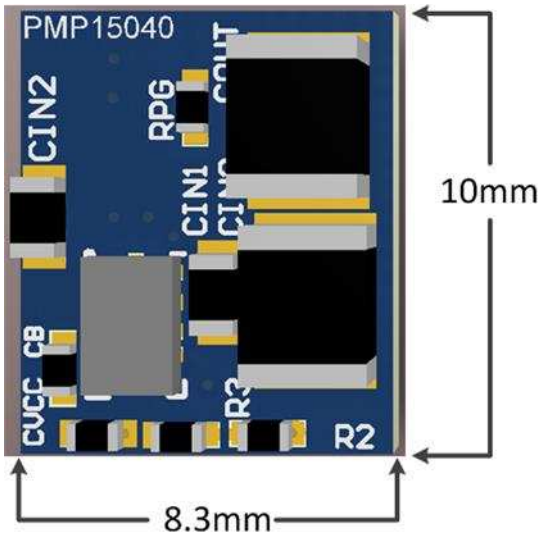


図 11. PMP15040 Board Dimensions

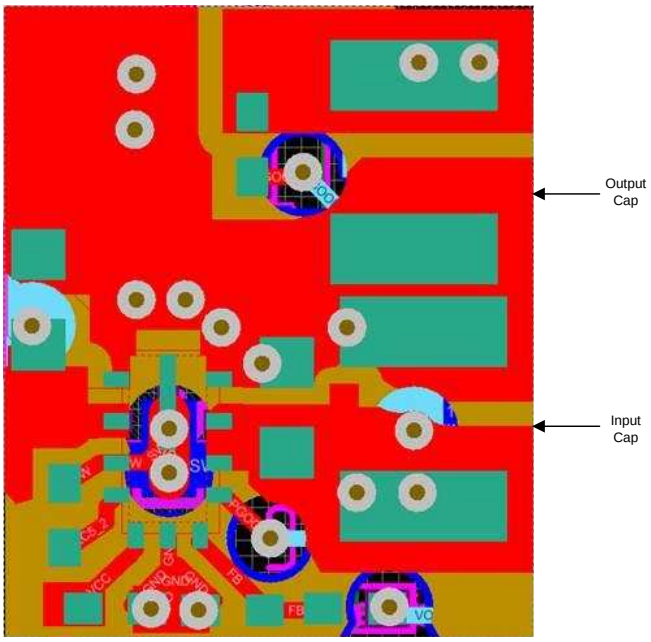


図 12. PMP15040 PCB Layout: Top Layer

図 13. PMP15040 PCB Layout: Bottom Layer

For design calculations and layout examples, see the relevant data sheet for the devices:

- *LMR36006 4.2-V to 60-V, 0.6-A Synchronous Step-Down Converter in HotRod™ Package* (SNVSB48)
- *LMR36015 4.2-V to 60-V, 1.5-A Synchronous Step-Down Converter in HotRod™ Package* (SNVSB49)

3 Hardware, Testing Requirements, and Test Results

3.1 Required Hardware

3.1.1 Hardware

These steps outline the hardware setup:

1. Connect a DC power supply to the board input as shown in 図 14.
2. Connect an electronic or resistive load to the LMR36006 output (V_{OUT}), as shown in 図 14, to imitate the typical load.

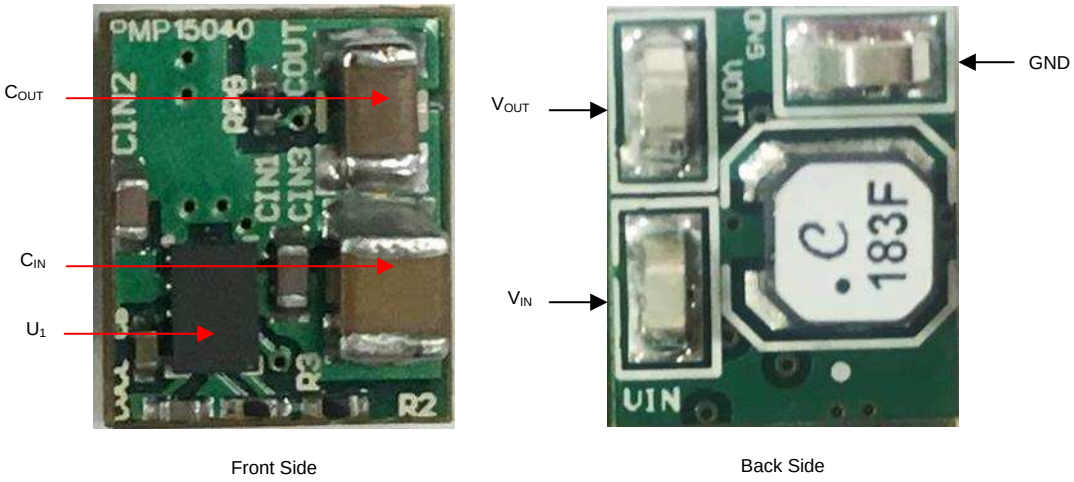


図 14. PMP15040 Board Setup

3.2 Testing and Results

The following diagrams show the design performance.

3.2.1 Thermal Data

The infrared (IR) thermal image in 図 15 was taken at steady state with 24 V_{IN} and the LMR36006 output at a load of 10 mA (no airflow). The ambient temperature is approximately 22°C. The maximum IC temperature is 28.4°C.

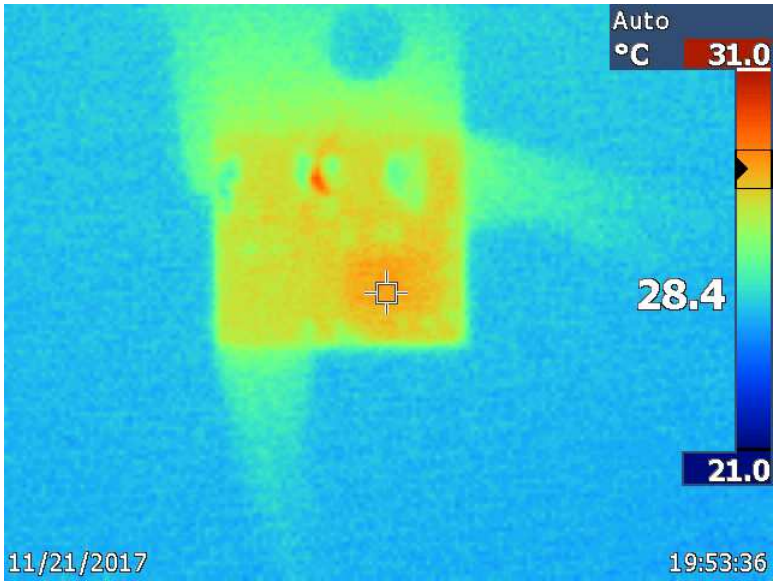


図 15. Thermal Image at 24 V_{IN}, 5 V_{OUT}, 10 mA I_{OUT}

The infrared (IR) thermal image in 図 16 was taken at the steady state with 24 V_{IN} and the LMR36006 output at a load of 300 mA (no airflow). The ambient temperature is approximately 22°C. The maximum IC temperature is 68°C.

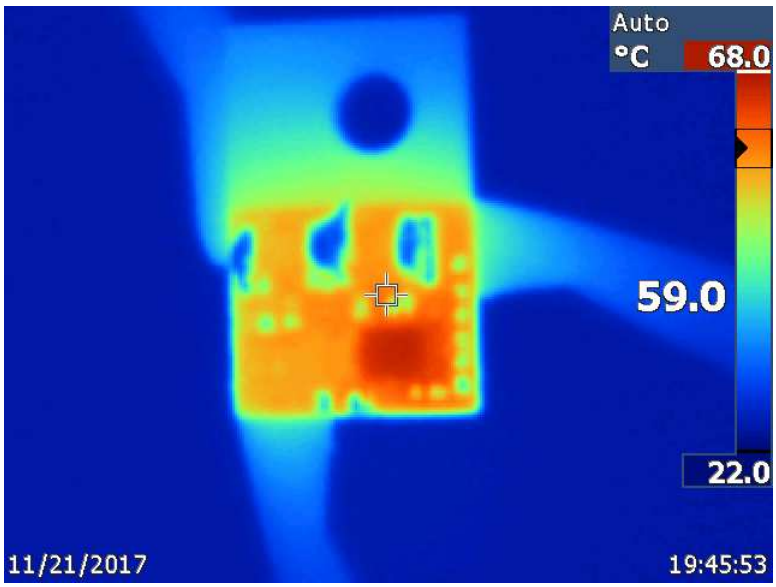


図 16. Thermal Image at 24 V_{IN}, 5 V_{OUT}, 300 mA I_{OUT}

The infrared (IR) thermal image in 図 17 was taken at the steady state with 24 V_{IN} and the LMR36006 output at a load of 600 mA (no airflow). The ambient temperature is approximately 22°C. The maximum IC temperature is 85°C.

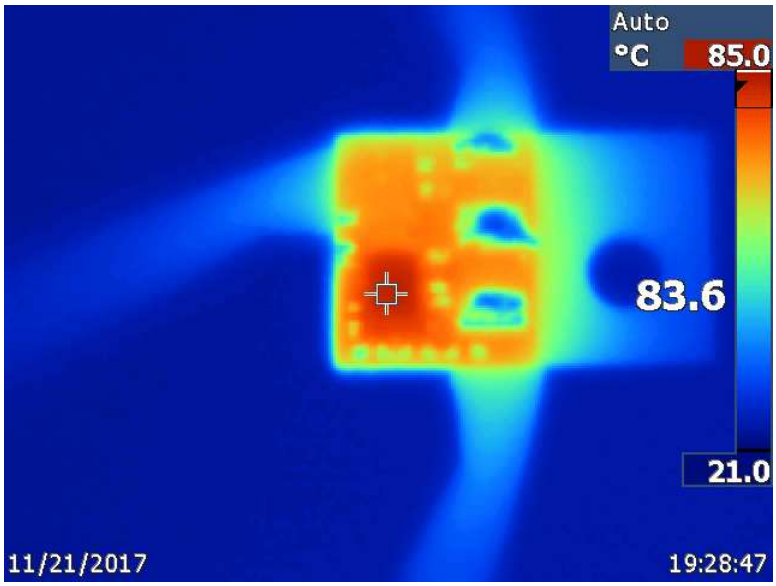


図 17. Thermal Image at 24 V_{IN}, 5V_{OUT}, 600 mA I_{OUT}

3.2.2 Efficiency Data

図 18 shows the PMP15040 efficiency data versus a load current.

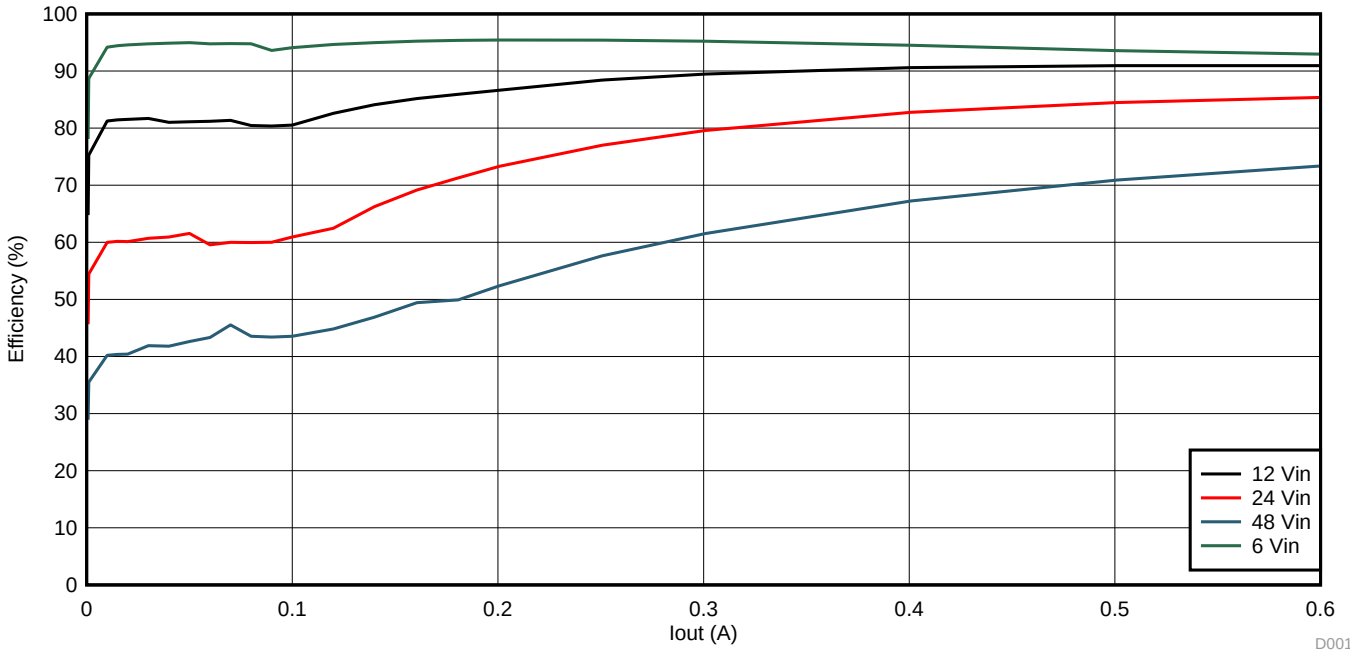


図 18. Efficiency vs. Output Current

3.2.3 Start-Up Waveforms

図 19 shows the start-up waveform at 24-V input and no load. 図 20 shows the start-up waveform at 24-V input and 600-mA load.

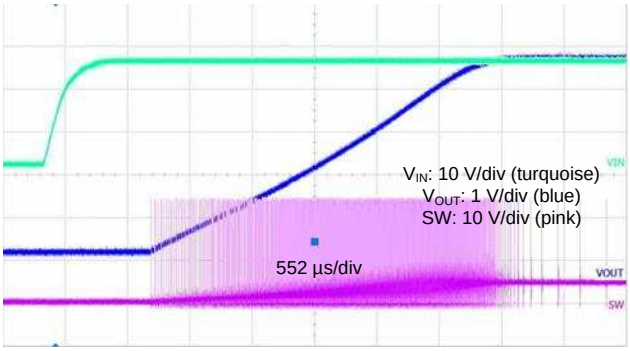


図 19. Start-Up Waveform: V_{IN} = 24 V, I_{OUT} = 0 A

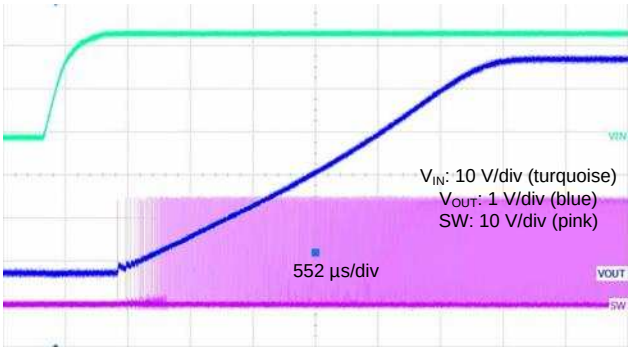


図 20. Start-Up Waveform: V_{IN} = 24 V, I_{OUT} = 600 mA

3.2.4 Switch Node and Output Voltage Ripple

図 21 shows the steady-state switch-node voltage and output voltage ripple at 24 V_{IN} and 0-A load. 図 22 shows the steady-state, switch-node voltage and output voltage ripple at 24 V_{IN} and 600-mA load. 図 23 shows the steady-state switch-node voltage and output voltage ripple at 60 V_{IN} and 0-A load. 図 24 shows the steady-state, switch-node voltage and output voltage ripple at 60 V_{IN} and 600-mA load.

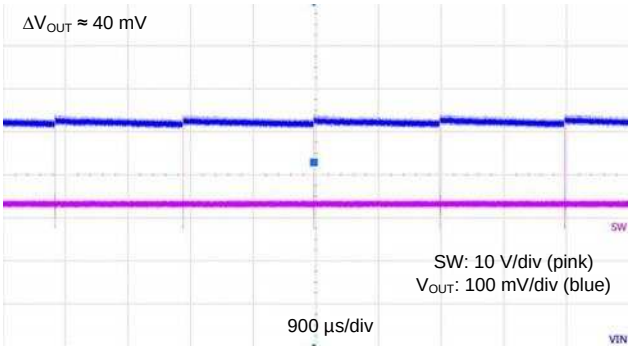


図 21. Steady-State Waveform: V_{IN} = 24 V, I_{OUT} = 0 A

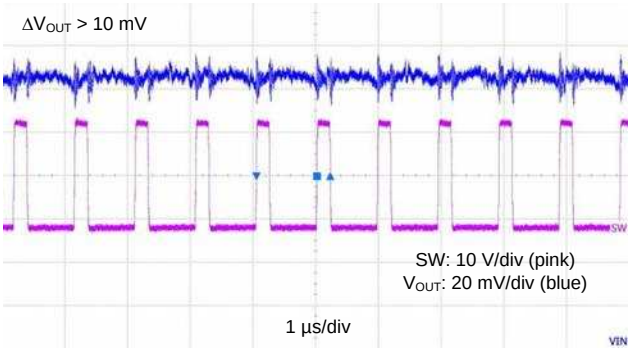


図 22. Steady-State Waveform: V_{IN} = 24 V, I_{OUT} = 600 mA

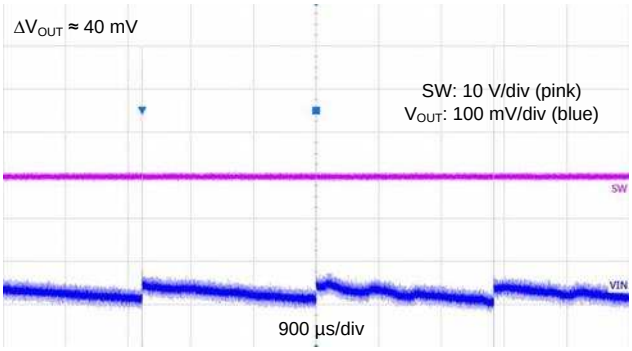


図 23. V_{IN} = 60 V, I_{OUT} = 0 A

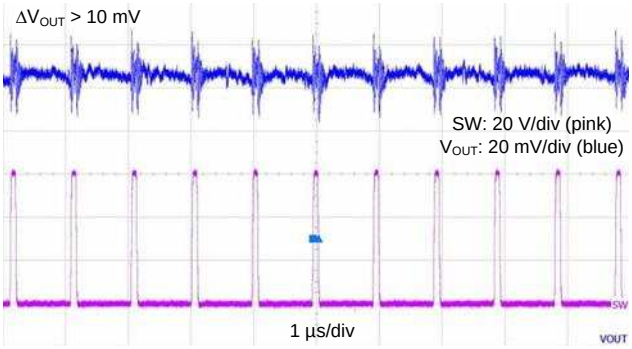


図 24. V_{IN} = 60 V, I_{OUT} = 600 mA

3.2.5 Load Transient

The load transient waveforms monitor the output voltage and the load current. Channel 1 (blue) shows the output current of the LMR36006 (I_{OUT}). Channel 2 (purple) shows the output voltage of the LMR36006 (V_{OUT}). 図 25 and 図 26 show the load transient results.

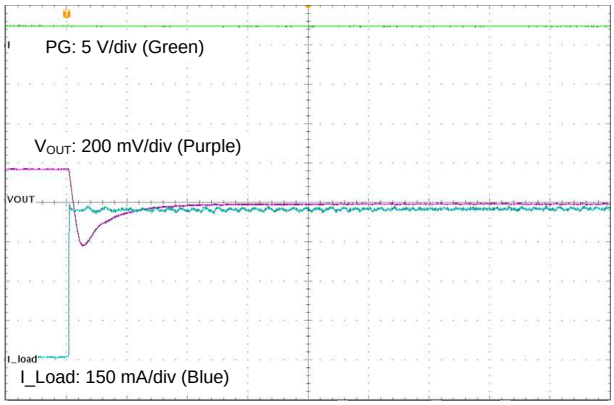


図 25. Load Transient: I_{OUT} = 0 A to 600 mA, V_{IN} = 24 V, t_R=1 A/µs

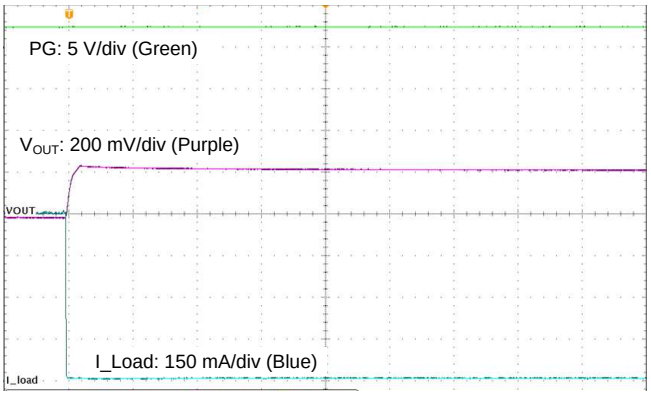


図 26. Load Transient: I_{OUT} = 600 mA to 0 A , V_{IN} = 24 V, t_F=1 A/µs

4 Design Files

4.1 Schematics

To download the schematics, see the design files at PMP15040.

4.2 Bill of Materials

To download the bill of materials (BOM), see the design files at PMP15040.

4.3 PCB Layout Recommendations

4.3.1 Layout Prints

To download the layer plots, see the design files at PMP15040.

4.4 Altium Project

To download the Altium project files, see the design files at PMP15040.

4.5 Gerber Files

To download the Gerber files, see the design files at PMP15040.

4.6 Assembly Drawings

To download the assembly drawings, see the design files at PMP15040.

5 Related Documentation

1. *LMR36006 4.2-V to 60-V, 0.6-A Synchronous Step-Down Converter in HotRod™ Package* (SNVSB48)
2. *LMR36015 4.2-V to 60-V, 1.5-A Synchronous Step-Down Converter in HotRod™ Package* (SNVSB49)
3. *Powering up the Performance of Sensitive Test and Measurement Systems*, blog

5.1 商標

改訂履歴

資料番号末尾の英字は改訂を表しています。その改訂履歴は英語版に準じています。

2018年**6**月発行のものから更新	**Page**
• Changed *Efficiency vs. Output Current* graph	10

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