Test Report: PMP23486

1.2W LLC Isolated Bias Supply Reference Design Using Sector Wound Planar Transformer

Description

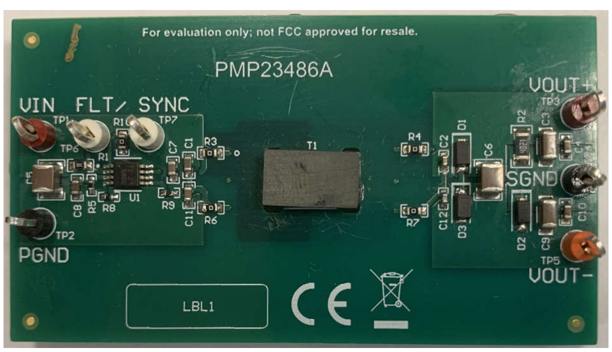
This 1.2W isolated reference design provides approximately 24V out at 50mA from a 12V automotive power source. The output voltage is split using a Zener regulator to +18V, –5V for an insulated-gate bipolar transistor (IGBT) gate drive. The circuit uses the UCC25800-Q1 half-bridge LLC transformer driver operating at a nominal switching frequency of 500kHz. The secondary-side resonant tank frequency is set slightly above the switching frequency to produce a flat gain. For this open-loop design, the output voltage is proportional to the input voltage by the transformer turns ratio. The transformer windings are integrated into the printed circuit board and sector wound for no overlap. The result is very low interwinding capacitance and common-mode current, along with high isolation voltage.

Features

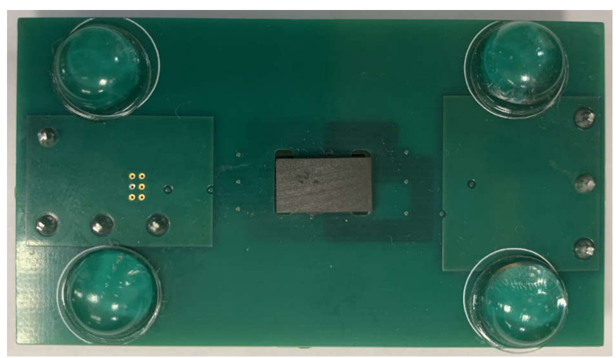
- Sector wound planar transformer integrated into the PCB
- Low-profile 6.3mm overall height set by transformer core
- Output voltage is proportional to input voltage
- 500kHz switching frequency for small size
- Fixed frequency LLC for low EMI
- Functional safety capable

Applications

- Traction inverter



Top of Board


Bottom of Board

1 Test Prerequisites

1.1 Voltage and Current Requirements

Table 1-1. Voltage and Current Requirements

Parameter	Specifications
Input Voltage	12V DC
Output Voltage	+18V, –5V
Load Current	50mA
Switching Frequency	500kHz
Isolation	3600V peak

1.2 Required Equipment

- DC power supply
- Electronic load
- Oscilloscope
- Current probe
- Current shunt
- Digital voltmeters
- Thermal camera

1.3 Considerations

All tests were performed at room temperature on an open bench.

1.4 Dimensions

This design was built on a 6-layer board with 1oz copper on all layers. The overall board dimensions are 38.1mm × 68.6mm. The overall design height is set by the transformer core at 6.3mm. Top and bottom layers are used for signal routing and ground. Layers 2 and 4 are used for the primary transformer winding. Layers 3 and 5 are used for the secondary transformer winding.

2 Testing and Results

2.1 Efficiency and Regulation Graphs

The following figures show the converter efficiency and regulation. The Zener regulator used to split the output voltage draws 4mA, which lowers the overall efficiency by about 8% at full load. Regulation is determined by the output impedance, which is set by the characteristic impedance of the secondary side resonant tank.

$$Z = \sqrt{\frac{14\mu H}{6.6nF}} = 46\Omega \quad (1)$$

The output voltage droop is then 46Ω × 50mA = 2.3V

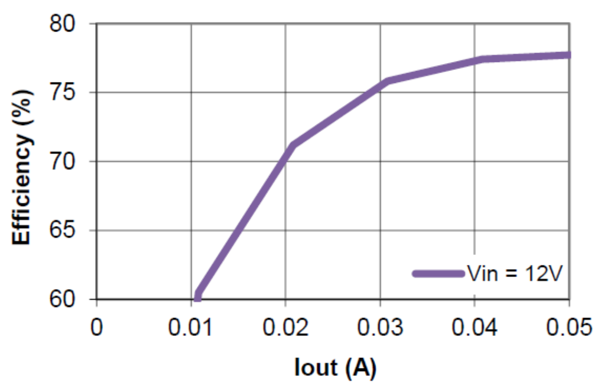


Figure 2-1. Efficiency Graph

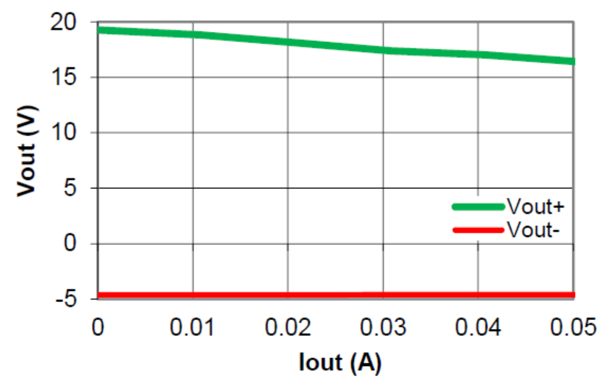


Figure 2-2. Regulation Graph

2.2 Efficiency Data

Efficiency data is shown in the following table.

V_{IN} (V)	I_{IN} (A)	V_{OUT+} (V)	V_{OUT-} (V)	I_{OUT} (A)	P_{IN} (W)	P_{OUT} (W)	P_{LOSS} (W)	Efficiency (%)
11.999	0.0159	19.295	–4.635	0.0000	0.191	0.000	0.191	0.00
11.999	0.0349	18.833	–4.622	0.0108	0.419	0.253	0.165	60.49
12.000	0.0554	18.131	–4.619	0.0208	0.665	0.473	0.192	71.18
12.000	0.0745	17.404	–4.608	0.0308	0.894	0.678	0.216	75.84
12.000	0.0950	17.032	–4.602	0.0408	1.140	0.883	0.257	77.43
12.000	0.1141	16.408	–4.593	0.0507	1.369	1.065	0.304	77.76

2.3 Thermal Images

Thermal performance is shown in the following figure at 12V input, 50mA load. The image was taken at thermal equilibrium with no airflow.

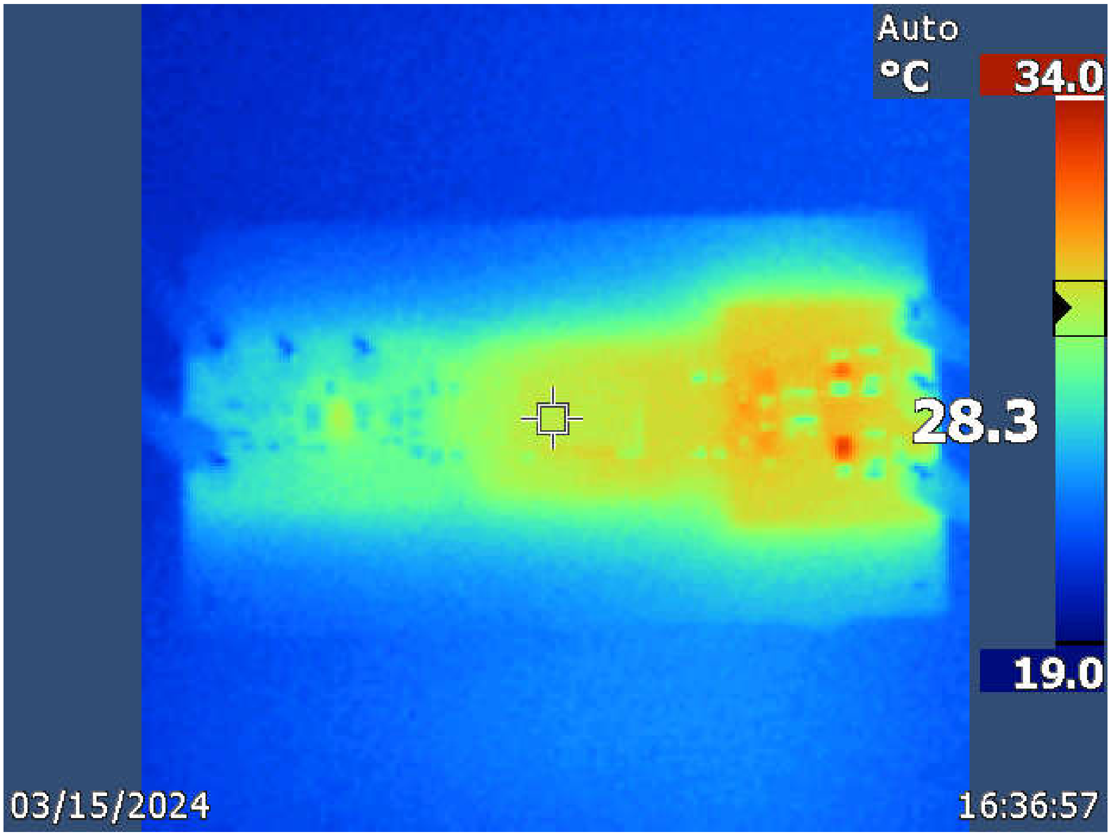


Figure 2-3. Thermal Image

3 Waveforms

3.1 Switching

Switching behavior waveforms are shown in the following figures.

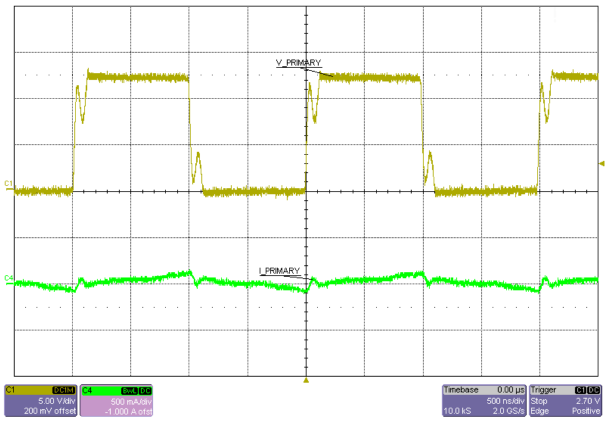


Figure 3-1. 12V Input, 0mA Load

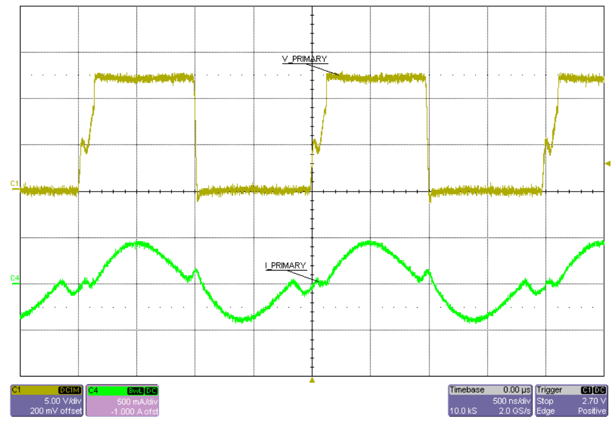


Figure 3-2. 12V Input, 50mA Load

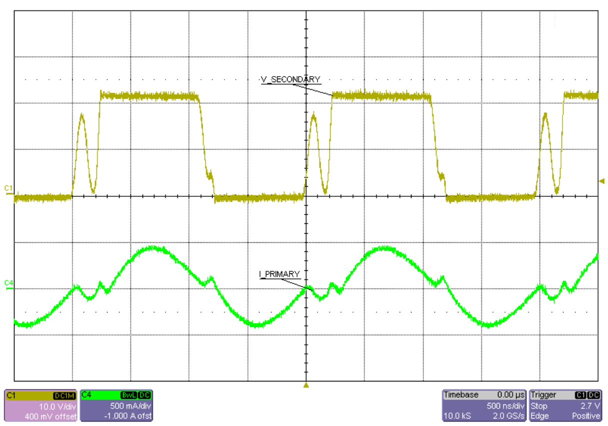


Figure 3-3. 12V Input, 50mA Load

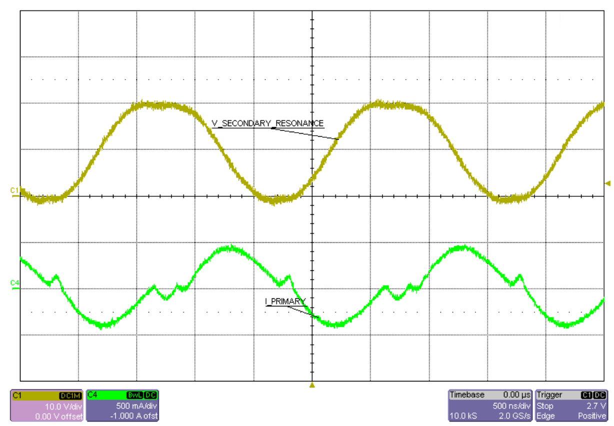


Figure 3-4. 12V Input, 50mA Load

3.2 Output Voltage Ripple

Output voltage ripple waveforms are shown in the following figures.

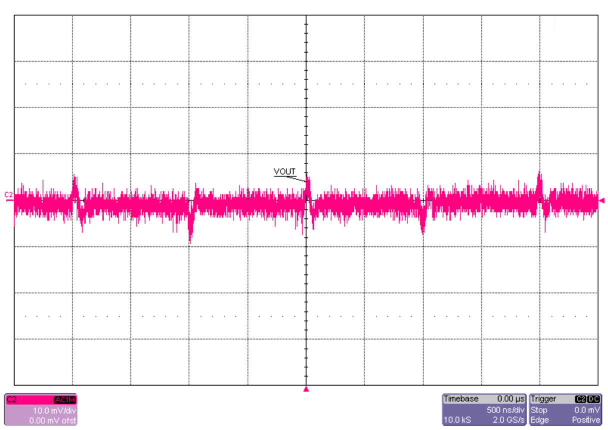


Figure 3-5. 12V Input, 0mA Load

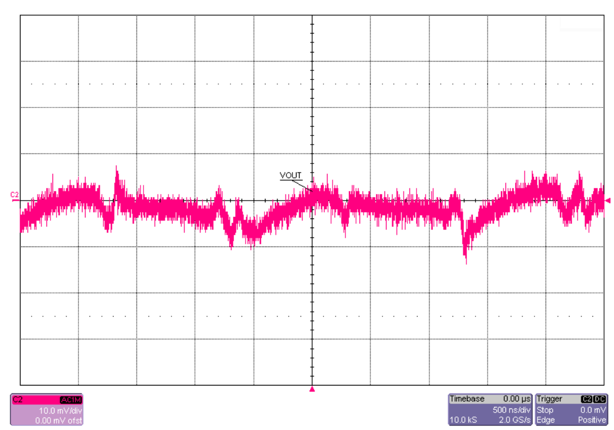


Figure 3-6. 12V Input, 50mA Load

3.3 Current Limit Protection

Current limit protection waveforms are shown in the following figures.

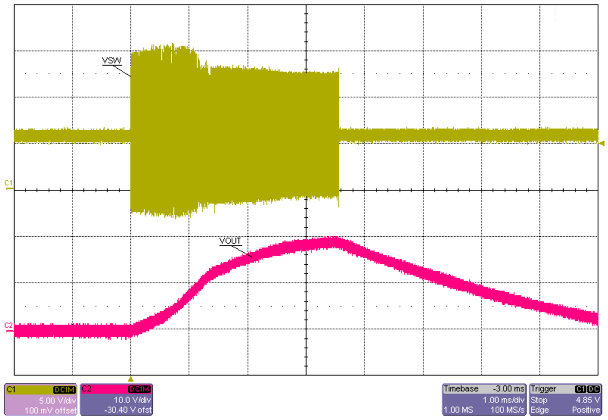


Figure 3-7. 12V Input, 66mA Load

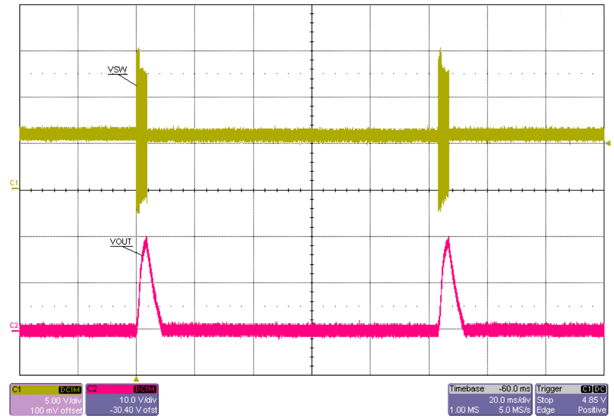


Figure 3-8. 12V Input, 66mA Load

3.4 Start-up

Start-up waveforms are shown in the following figures.

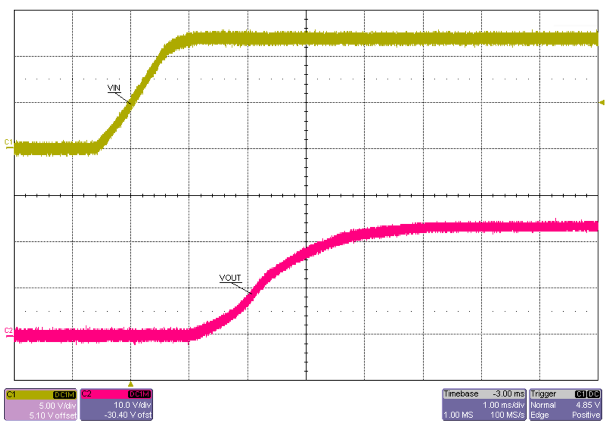


Figure 3-9. 12V Input, 0mA Load

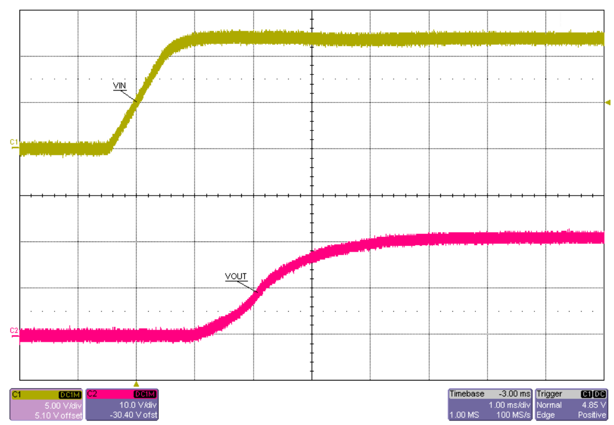


Figure 3-10. 12V Input, 50mA Load

IMPORTANT NOTICE AND DISCLAIMER

TI PROVIDES TECHNICAL AND RELIABILITY DATA (INCLUDING DATA SHEETS), DESIGN RESOURCES (INCLUDING REFERENCE DESIGNS), APPLICATION OR OTHER DESIGN ADVICE, WEB TOOLS, SAFETY INFORMATION, AND OTHER RESOURCES “AS IS” AND WITH ALL FAULTS, AND DISCLAIMS ALL WARRANTIES, EXPRESS AND IMPLIED, INCLUDING WITHOUT LIMITATION ANY IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE OR NON-INFRINGEMENT OF THIRD PARTY INTELLECTUAL PROPERTY RIGHTS.

These resources are intended for skilled developers designing with TI products. You are solely responsible for (1) selecting the appropriate TI products for your application, (2) designing, validating and testing your application, and (3) ensuring your application meets applicable standards, and any other safety, security, regulatory or other requirements.

These resources are subject to change without notice. TI grants you permission to use these resources only for development of an application that uses the TI products described in the resource. Other reproduction and display of these resources is prohibited. No license is granted to any other TI intellectual property right or to any third party intellectual property right. TI disclaims responsibility for, and you will fully indemnify TI and its representatives against, any claims, damages, costs, losses, and liabilities arising out of your use of these resources.

TI’s products are provided subject to TI’s Terms of Sale or other applicable terms available either on ti.com or provided in conjunction with such TI products. TI’s provision of these resources does not expand or otherwise alter TI’s applicable warranties or warranty disclaimers for TI products.

TI objects to and rejects any additional or different terms you may have proposed.

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265