Application Report
Topology Selection for Isolated Power Supplies in Patient Monitor

TEXAS INSTRUMENTS

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ABSTRACT

Multiparameter Patient Monitors measure vital signs and use isolated modules for achieving the patient safety. These modules are small in size as they are inserted into the main monitor and support up to 5kV isolation. The data and power both are isolated using digital isolators and isolated power supplies, respectively. This application report talks about different topologies for isolated power and data. It dwells deeper into the critical design challenges associated with isolated power and data such as output regulation, feedback mechanism, input voltage range, output power and size considerations along with suitable power architectures. Finally, it compares the topologies on the basis of all these different parameters.

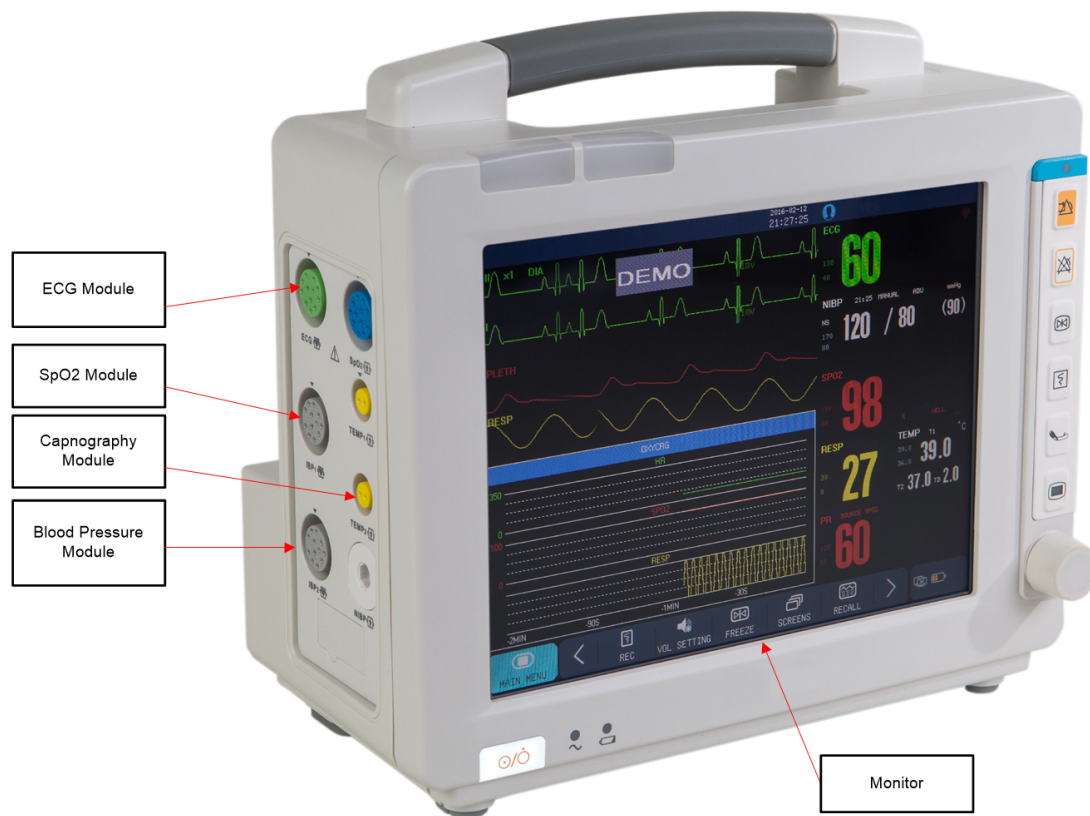## Table of Contents

List of Figures

List of Tables

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1 Introduction

Patient safety is a global health priority. Recalling resolution WHA55.18 (2002), which urged Member States to "pay the closest possible attention to the problem of patient safety and to establish and strengthen science-based systems, necessary for improving patients' safety and the quality of health care", the seventy-second World Health Assembly (WHA72), in May 2019, adopted WHA72.6, a resolution on 'Global action on patient safety'. (Source: https://www.who.int/patientsafety/en/)

Multiparameter Patient Monitors measure human vital signs like Electrocardiogram (ECG), Blood Oxygen Concentration (% SpO2), blood pressure, temperature, and so forth(see Figure 1-1).

Figure 1-1. Multi-Parameter Patient Monitor Showing How Modules are Connected to Main Monitor

Figure 1-2 shows a generic block diagram of the ECG module. It highlights the isolation between the analog circuit and the digital processing unit. Medical standards (like IEC60601-1) specify that multiparameter patient monitors need to have isolation up to 5kV to separate the grounds, prevent any ground loop currents, and prevent leakage currents flowing from the patient's body. While isolating data, it also needs the same level of isolation as on the power supply.
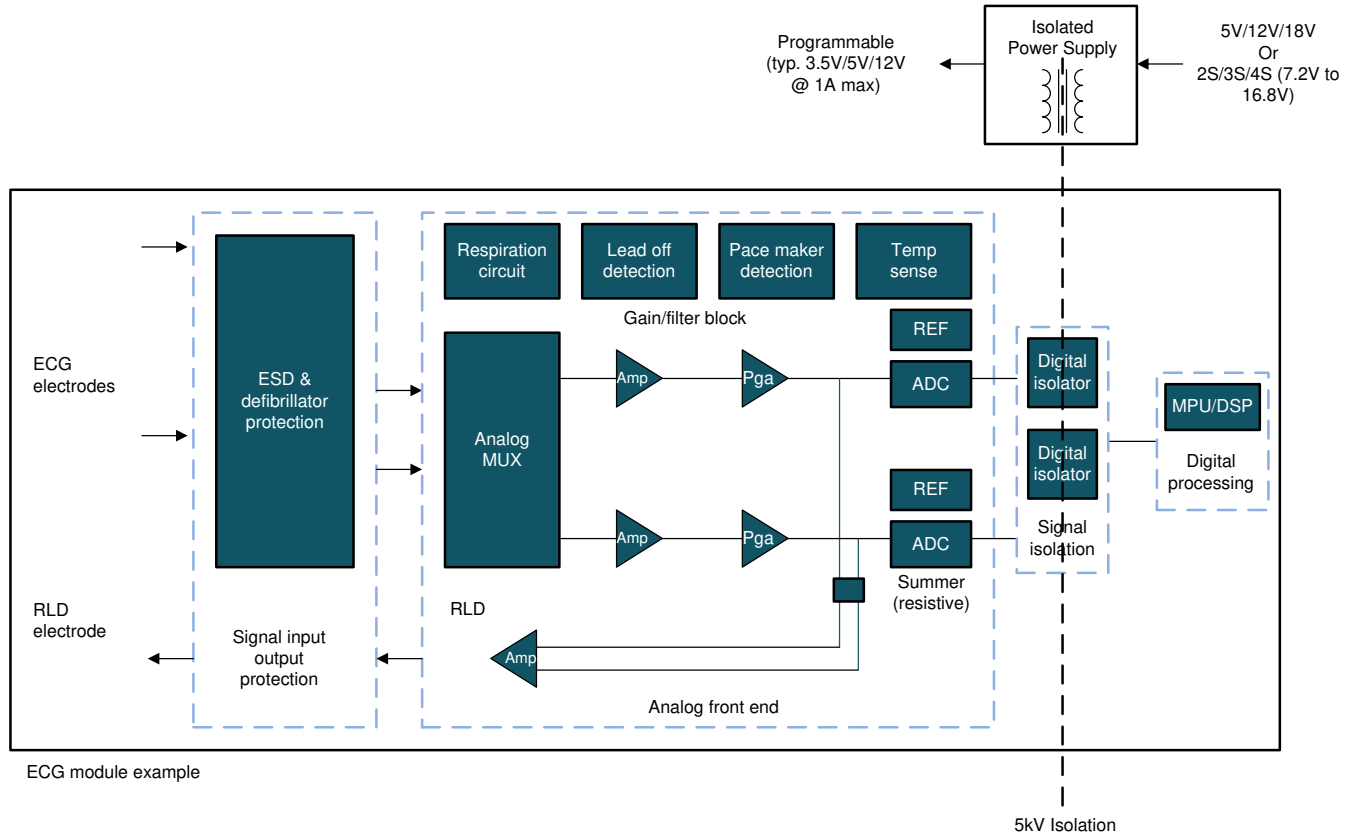

Figure 1-2. Isolated ECG Module Block Diagram (showing isolation)

The data isolation can be done using simple digital isolators but the isolated power topology needs a thoughtful analysis. Table 1-1 shows the typical specs for such isolated power supplies.

Table 1-1. Technical Specifications of Typical Isolated Power Supply

Characteristic	Value
Input voltage range	Option – 1: 3.3 V to 24 V from AC/DC power supply
	Option – 2: From 1S-4S battery (i3.7 V to 16 V)
Output Voltage	Option – 1: 3.3 V or 5 V
	Option – 2: 3.5 V or 5.5 V to be followed by an Low Drop-out Regulator (LDO)
Output power	Typical 5 watts to 7 watts
Isolation	5 kV and above

This application report dwells deeper into critical design challenges associated with isolated power and data such as output regulation, feedback mechanism, input voltage range, output power and size considerations along with suitable power architectures given below:

- Conventional and PSR Flyback – Wide input voltage (Vin) and adjustable output power (Pout)
- Open-loop and Closed-loop Push-Pull – Feedback mechanism and output regulation
- Integrated isolated power and data – form-factor constraint designs with limited Pout

2 Flyback Topology

A typical conventional Flyback converter is a buck-boost converter with the inductor split to form a transformer, so that the voltage ratios are multiplied with an additional advantage of isolation. It can generate voltages below or above the input voltage and can support output power levels easily up to 10s of watts (depending upon the transformer design). To get the isolated output information back to the Flyback controller (aka PWM controller) device in order to accurately regulate the output, the output is fed back using either an opto-coupler based circuit or a tertiary winding as shown in Figure 2-1. In such cases, the component count and the solution size is fairly large. In fact, reliability can be a concern with opto-coupler based feedback and an additional winding (for tertiary winding based feedback) adds to the cost of the transformer.

It is important to properly design the Flyback transformer for best performance. The transformer should be very well coupled with low leakage inductance for highest efficiency and best regulation (especially in multiple outputs). The parasitic capacitance from the primary to secondary must also be limited to prevent excessive Electro-magnetic Interference (EMI).
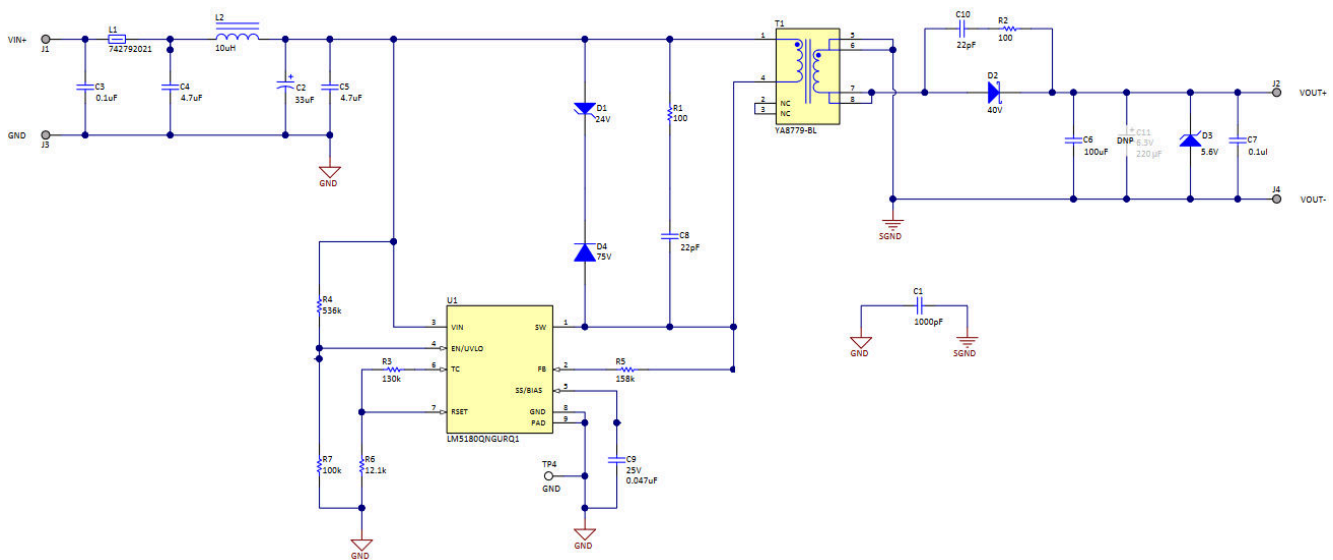

(a)   (b)

Figure 2-1. Conventional Flyback Feedback Mechanism (a) Using Opto-Coupler (b) Using Tertiary Winding

3 Primary Side Regulated (PSR) Flyback Topology

The PSR Flyback topology eliminates the need of an opto-coupler or tertiary winding and provides extremely tight load regulation using the feature of the resonant ring caused by the magnetizing inductance and the switch node capacitance. Compared to conventional Flyback, it operates in Discontinuous Conduction Mode (DCM) or Boundary conduction Mode (BCM) depending on the load. It, in turn, eliminates any errors from the transformer DC resistance (DCR) or secondary side diode to provide tight regulation.

The PSR Flyback operates in BCM/DCM with lower inductance (given the higher peak-to-peak ripple current) and lower switching losses compared to Continuous Conduction Mode (CCM) because the MOSFET turn-on and diode turn-off are at zero current. However, higher primary and secondary-side RMS currents in PSR Flyback result in conduction losses in the magnetic and semiconductors.

Figure 3-1 shows an example schematic for PSR Flyback topology using LM5180 device. It shows how transformer has only two windings and overall number of components is also less compared to conventional Flyback.

Figure 3-1. PSR Flyback Configuration Showing Very Less Number of Total Components and Single Transformer

4 Open-Loop Push-Pull Topology

A push-pull transformer driver is a popular solution for low-noise, small form factor isolated power supplies. It is supplied from a tightly regulated input rail and operates open loop at a fixed 50% duty cycle. For instance, SN6505 is a low-noise, low-EMI push-pull transformer driver specifically designed for small form factor, isolated power supplies. It drives center-tapped transformer from a DC power supply. Ultra-low noise and EMI are achieved by slew rate control of the output switch voltage and through Spread Spectrum Clocking (SSC). SN6505 includes a soft-start feature that prevents high inrush current during power up with large load capacitors.
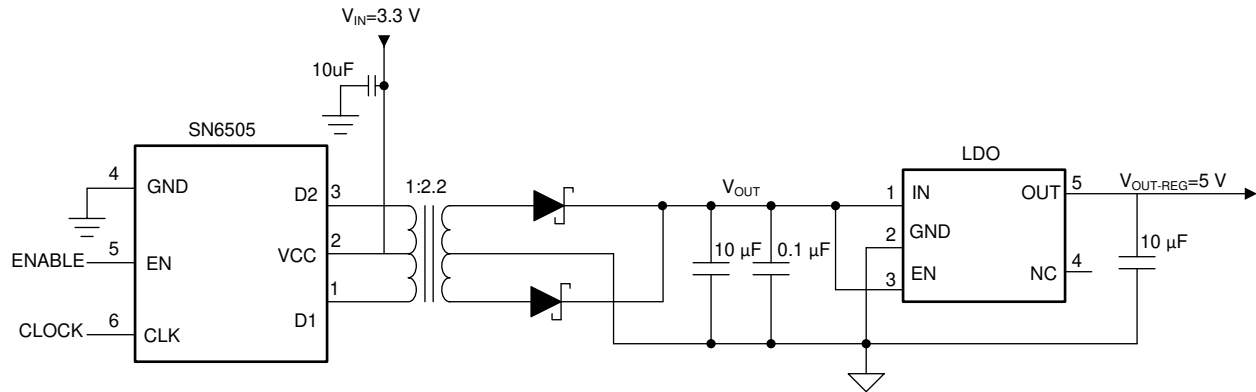

Figure 4-1. Open-Loop Push-Pull Topology Using SN6505

Figure 4-1 shows the schematic for open-loop push-pull topology using SN6505. This topology provides design simplicity by eliminating the feedback loop. The push-pull transformer offers lower primary-secondary capacitance that enables a reduction in common-mode noise compared to Flyback. Additionally, the push-pull topology utilizes the transformer core magnetizing current more efficiently, which results in a smaller magnetic solution compared to the conventional Flyback. The total component count is also very less (close to six excluding the output LDO in Figure 4-1).

The transformer driver (without any feedback) cannot support a wide input voltage range and instead requires a tightly regulated input voltage. Being an open-loop topology, there is always a concern on output regulation. The typical load regulation for SN6505 is shown in Figure 4-2. Depending on the requirement, an LDO can be used at the output for regulated output.
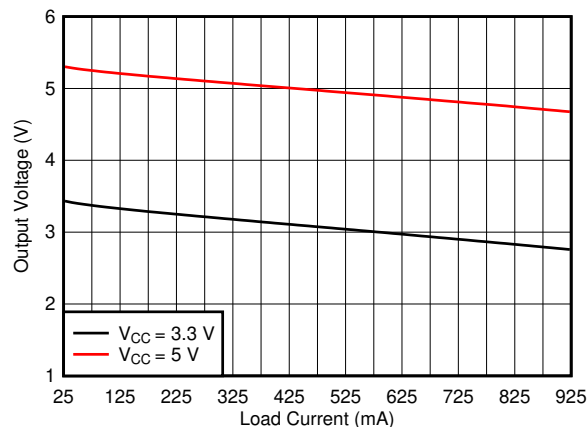

Figure 4-2. Output Regulation for SN6505A With Pulse Transformer (Wurth 750315240)

5 Closed Loop Push-Pull Topology

Meeting output voltage regulation requirements can be challenging due to the absence of closed loop feedback in open-loop Push pull topology. For higher power levels and tighter output regulation, closed-loop push-pull topology can also be used. Similar to a conventional Flyback, this topology needs an isolated feedback using opto-coupler. An example schematic for such topology using LM25037 is shown in Figure 5-1. Though the power level is approximately 5W here, the overall component count and size is huge compared to open-loop push-pull topology using SN6505.
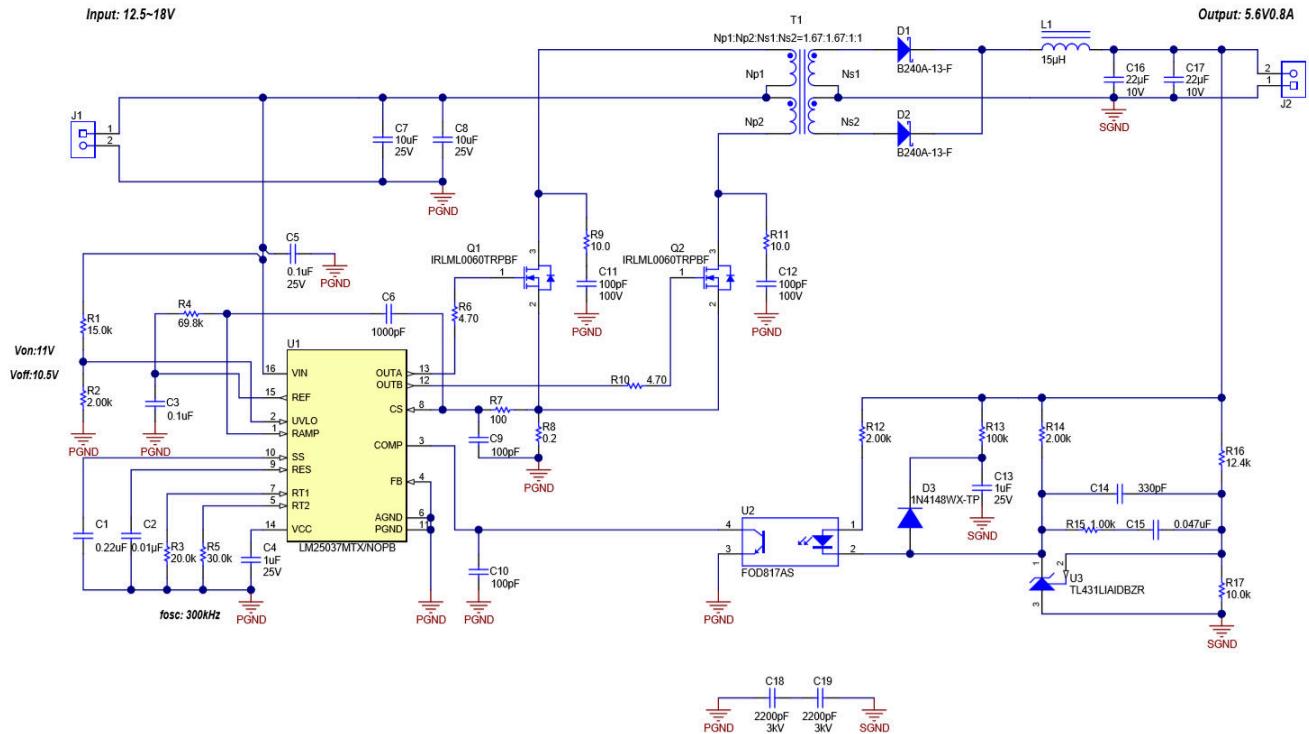

Figure 5-1. Closed Loop Push-Pull Topology Using LM25037
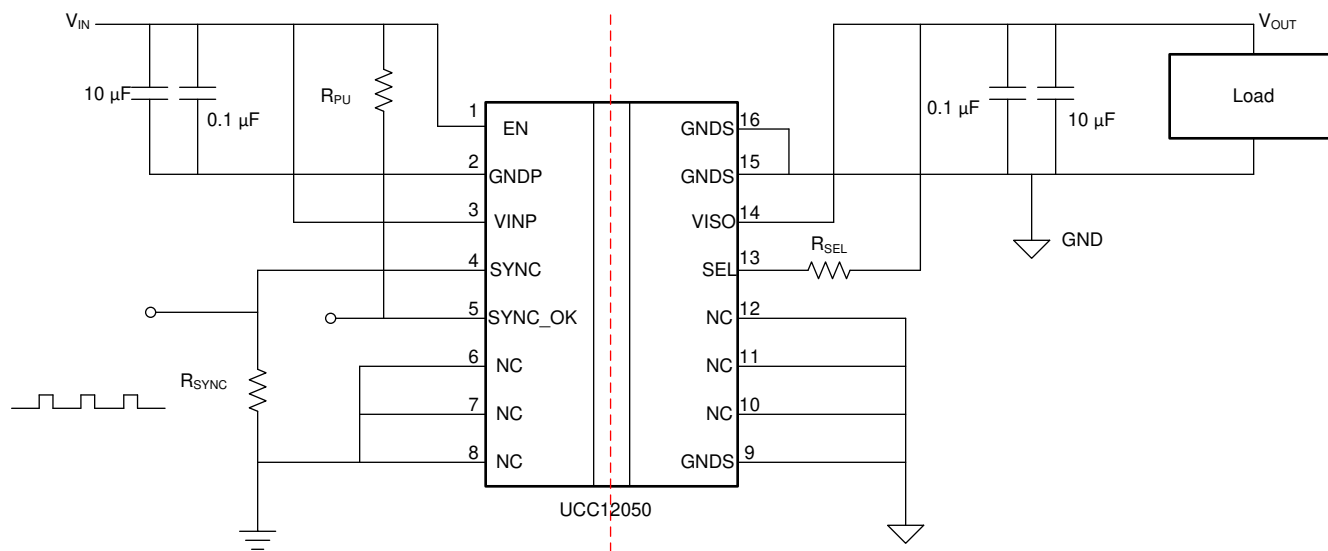
6 Integrated Isolated Power Solution

The traditional approaches to generate isolated power use a DC/DC converter to drive a transformer in Flyback, Flybuck or push-pull topologies. Pulsating signals on the secondary side are rectified and filtered to generate an isolated DC supply. Opto-coupler-based feedback to the primary side achieves line and load regulation. In certain cases where the DC/DC converter runs in an open-loop configuration, an LDO is used to post-regulate the converter output. The drawback with this discrete approach is that the complete solution – the transformer and other components – occupies a lot of space on the board. Also, designing a stable and efficient isolated power supply can be challenging.

Various latest solutions, integrate a DC/DC converter with a micro-transformer, along with signal-isolation channels, in a single package. Such solutions solve several design challenges faced by system engineers, including:

- Board-area reduction: The first benefit of an integrated solution is a reduction in board area. The solution size reduces significantly since the power stage, transformer, rectifier diodes, isolated feedback (and sometimes, the digital data-isolation channels) are integrated in one single chip. In addition to the surface-area reduction, the use of planar transformers enables the z-dimension or height of the integrated solution to be lower than discrete transformers, which could be two to three times thicker.
- Simplicity and robust design: System design becomes much simpler with an integrated solution, since user can integrate the feedback for line/load regulation and all protection mechanisms for the power supply (such as overload and short-circuit protection, thermal shutdown and soft start) on the chip. Boards with bulky transformers perform poorly in vibration tests. Thus, board-level reliability can also improve with an integrated solution.

The Texas Instruments UCC12050 is part of a family of reinforced isolated DC/DC bias converters and modules. It integrates a transformer and DC/DC controller with a proprietary architecture to achieve high efficiency with very low emissions. It provides 500 mW (typical) of isolated output power at peak efficiency of 60%. The UCC12050 device is suitable for applications that have limited board space and desire more integration.

UCC12050 integrates a highly innovative transformer to enable a package size of 10.3 x 10.3 mm with only 2.65 mm height. The integrated thermal shutdown and tolerance to short-circuit at the output enables very robust applications. This device is also suitable for modules where transformers meeting the required isolation specifications are bulky and expensive. Figure 6-1 shows an example schematic.

Figure 6-1. UCC12050 Schematic Showing Low Component Count

Compared to similar competition products in this category, UCC12050 provides almost 30% higher efficiency, 30°C lower temperature rise at full load and can pass CISPR 32 Class B emissions testing on a two-layer PCB without LDOs or ferrite beads (see Figure 6-2). In an apples-to-apples comparison with competition UCC12050 has over 20dB of emissions improvement.
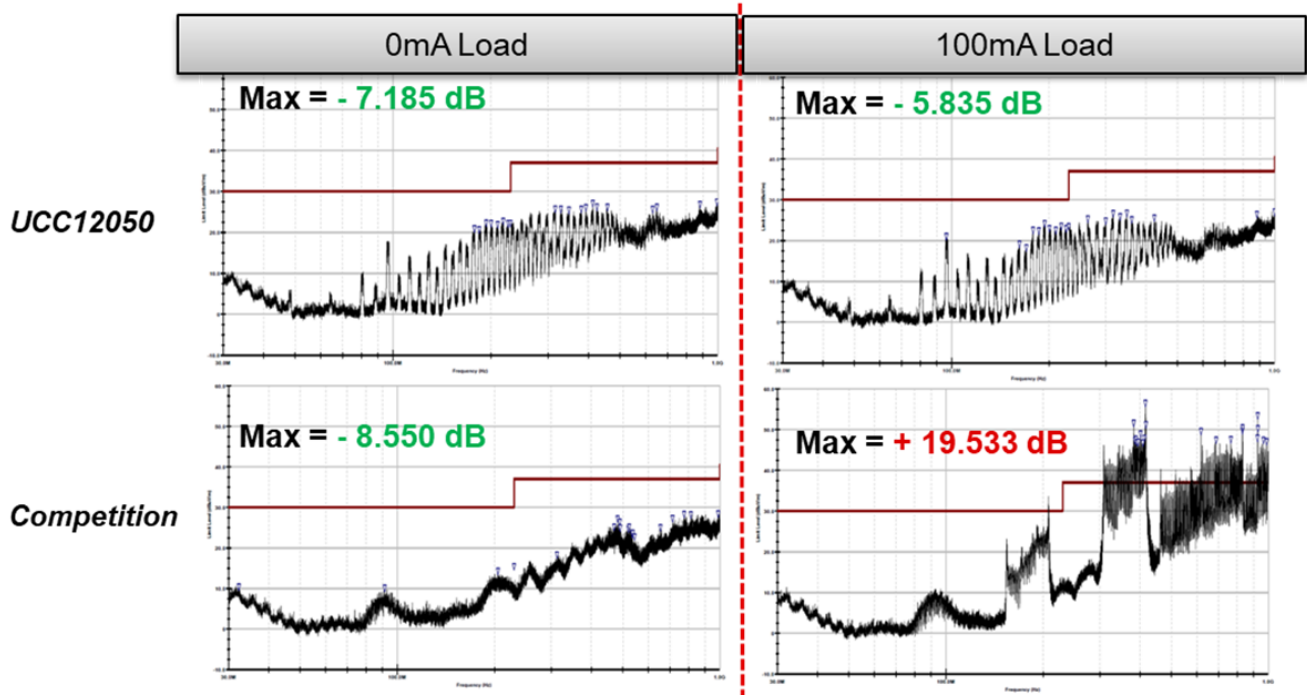

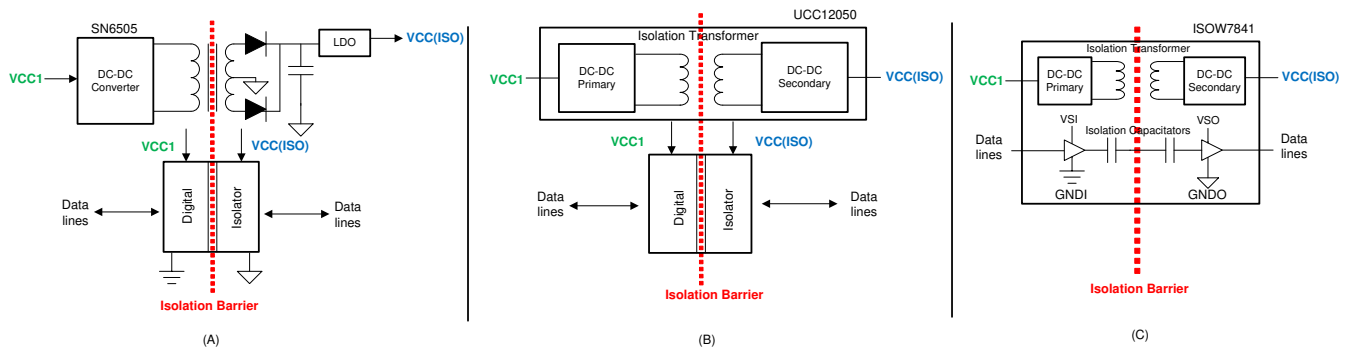**Figure 6-2. UCC12050 Shows Lower Radiated Emissions Than Competitive Integrated Device**

7 Isolated Power and Data Into Single Device

The Texas Instruments ISOW7841 is part of a family of reinforced quad-channel high-performance digital isolators that integrate a high-efficiency, low-emissions DC/DC converter. The digital isolators operate up to 100-Mbps, with a propagation delay less than 16-ns. The integrated DC/DC switch-mode converter uses advanced circuit techniques to reduce power losses and boost efficiency, supporting 130-mA of load current with 5-V input and 75-mA of load current with 3.3-V input. Integrated closed-loop feedback provides excellent line and load regulation. Special emissions-reduction techniques have been implemented to help meet emissions standards.

However, designers lose some flexibility with integrated power and data solutions, for instance, configuration for the number of outputs, and isolation levels.
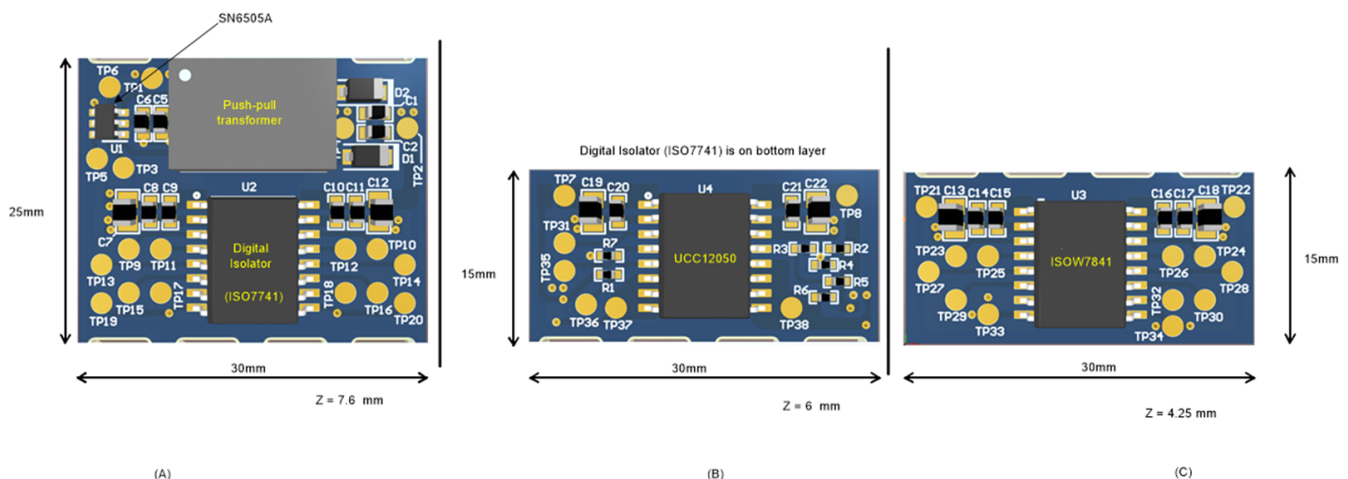
For a high-level block diagram comparison of three solutions, see Figure 7-1.

- SN6505 based open-loop push-pull power supply with separate digital isolator
- Integrated power module UCC12050 with separate digital isolator
- ISOW7841 with integrated digital isolators

Figure 7-1. Comparing Discrete and Integrated Solutions

For all the three approaches shown in Figure 7-1, the layout comparison is highlighted in Figure 7-2. The integrated solutions show how overall size can be reduced.

Figure 7-2. Layout Size Comparison for (A) SN6505 + Digital Isolator (B) UCC12050 + Digital Isolator (on bottom layer) and (C) ISOW7841

8 Summary

Table 8-1 shows the comparison of all the topologies in terms of different parameters.

Table 8-1. Comparison of Isolated Power Topologies

Parameter	Conventional Flyback	PSR Flyback (LM25180)	Open-Loop Push-Pull (SN6505)	Closed-Loop Push-Pull (LM25037)	Isolated Power Module (UCC12050)	Isolated Power With Digital Isolator (ISOW7841)
Output power level	Flexible (Transformer and PWM controller dependent)	5W to 7W	5W	Flexible (Transformer and PWM controller dependent)	0.5W	0.65W
Input Voltage Range	Up to 42 V/65 V	Up to 42 V/65 V	Up to 5.5 V	Up to 75 V	Up to 5.5 V	Up to 5.5 V
Output Regulation	1% or less	1%	5 to 10%	1% or less	1.5%	1%
No. of discrete components	More than 30	21	10	46	Less than 10	Less than 10
Isolation Rating	Flexible (Transformer dependent)	Flexible (Transformer dependent)	Flexible (Transformer dependent)	Flexible (Transformer dependent)	5000 Vrms Reinforced	5000 Vrms Reinforced
Emission	High	High	Low	High	Low	Moderate to high

9 Revision History

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

Changes from Revision * (October 2019) to Revision A (October 2020)   **Page**

- Updated the numbering format for tables, figures and cross-references throughout the document...................2
- The title of the document was changed...2

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