

Passing CISPR 32 Class-B Radiated Emissions With Ease Using ISOW6441



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1 Introduction - Digital Isolator with Integrated DC/DC Converter

Modern isolated systems such as industrial automation, motor drives, and communication interfaces consist of multiple subsystems operating in different power domains. For these domains to work together, signal isolation is necessary for signal communication and isolated power is needed to power the secondary side components.

While a discrete isolated power design can be cost effective, this method can be more complex. This method requires various external components consuming a lot of PCB space, especially the external transformer which is bulky and occupies space not only in the X and Y dimension but also in the Z dimension (height). Engineers must navigate multiple discrete components including isolation transformers, driver circuits, rectification stages, and feedback networks to achieve a successful design.

Texas Instruments' ISOW product family addresses these challenges through combining isolated DC-DC conversion and digital isolation in an integrated single-package solution.

The ISOW6441 is the latest generation in ISOW portfolio which consists of digital isolator that integrates an isolated DC/DC converter including a power transformer into a single SOIC package, as shown in [Figure 1-1](#). The integrated DC/DC converter generates the isolated power to the secondary (isolated) side of device. Integration of the isolated DC/DC converter along with the power transformer into a single package makes the device a very compact design. The device also significantly reduces the complexity involved in designing the overall power supply compared to a discrete design. Such devices are widely used in many industrial applications some of which include PLCs, communication modules, industrial transport, medical instruments, and energy meters.

The DC/DC converter in ISOW6441 switches at about 60MHz to reduce the size of the power transformer and enable integration in a small SOIC package. At this switching frequency, the spectral components of the switching converter fall into a spectrum that can be subjected to regulatory restrictions by some electromagnetic interference (EMI) standards like CISPR 32.

In a market where a majority of the integrated DC/DC converter solution devices possess an inherent challenge in meeting stringent international and OEM emission standard requirements even with a bunch of system level fixes, the ISOW6441 stands out as a champion by having the capability of meeting the same emissions requirements on a bare-minimum 2-Layer PCB using simple SMD components and no complex layout constraints, making it the most cost effective solution. This document will discuss in detail about how ISOW6441 on simple cost effective 2-layer PCB is sufficient to meet stringent CISPR32 class-B limits

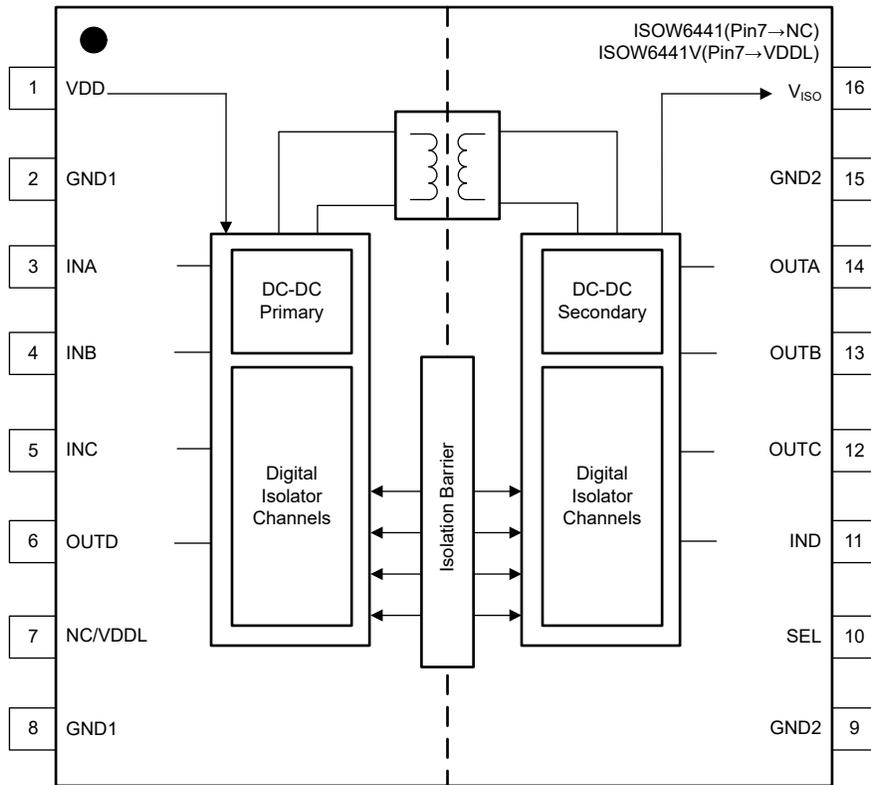


Figure 1-1. ISOW6441 Internal Block Diagram

2 CISPR 32 Radiated Emissions Standard Overview

CISPR 32 is an international radio disturbance standard for multimedia equipment (MME). The standard establishes requirements that provide an adequate level of protection for the radio spectrum and specifies procedures to maintain the reproducibility of measurement and the repeatability of results. Most industrial end-equipment certification agencies require the compliance of the end-equipment to CISPR 32 as one of the requirements for the end-equipment to be certified to the relevant end-equipment standard. Hence, product designers must consider these EMC requirements while designing products.

The standard defines two classes of equipment associated with two types of end-user environments.

- Class B requirements are intended to offer adequate protection to broadcast services within the residential environment. Equipment intended primarily for use in a residential environment shall meet the Class B limits. Class B limits are more stringent than the below mentioned Class A
- Class A requirements are for all non-Class B equipment; Class A equipment shall comply with the more relaxed Class A limits.

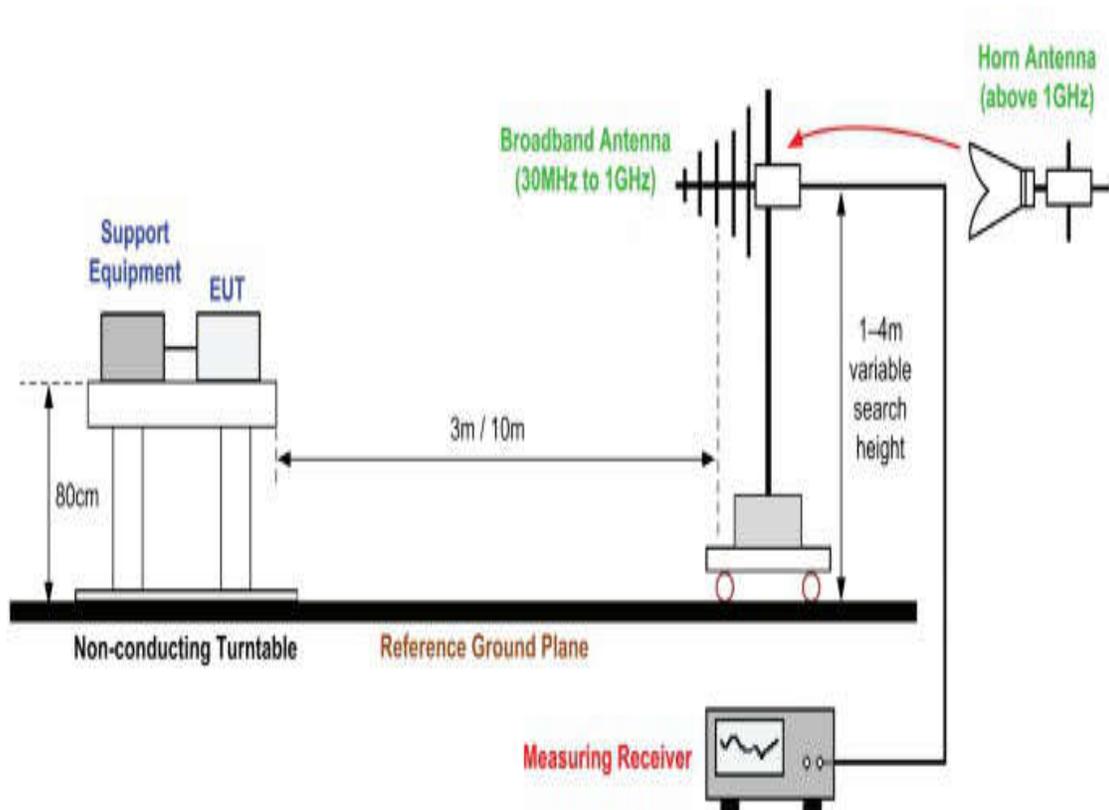


Figure 2-1. CISPR32 test setup

CISPR32 specifies an Equipment Under Test (EUT) placed on a nonconductive turntable in an anechoic chamber as depicted in [Figure 2-1](#). The EUT is placed 10 meters and 3 meters away from the receiving antenna for 30MHz-1GHz and 1GHz-6GHz range, respectively. The antenna is configured for both horizontal as well as vertical polarizations and adjusted in height between 1m-4m for 30MHz-1GHz scan and 1m-2m for 1GHz-6GHz scan. For each antenna height and polarization, the EUT on a turntable is rotated from 0 to 360 degrees to find the maximum field-strength readings. The worst-case emission readings among the different polarizations and heights are recorded for both 30MHz-1GHz range as well as 1GHz-6GHz range.

3 Understanding the Source of Radiated Emissions

Electromagnetic radiations can emit from a switching isolator on a given PCB in the form of either common-mode current loop or differential-mode current loop as shown in Figure 3-1. The fast transients in the DC/DC converter couple through the parasitic capacitance between the isolated grounds on the PCB, creating a common-mode current between side 1 and side 2 of the isolated system. Because the two sides are completely isolated, the current forms a large return loop through air as well as board-level parasitic capacitances. This large current loop is a major contributor to radiated emissions in isolated systems. Another way to understand this emissions mechanism is that the two isolated parts of the board form a dipole antenna transmitter. The differential-mode current loop can be formed due to high voltage ripple on both input supply (VDD) as well as isolated out supply (VISO).

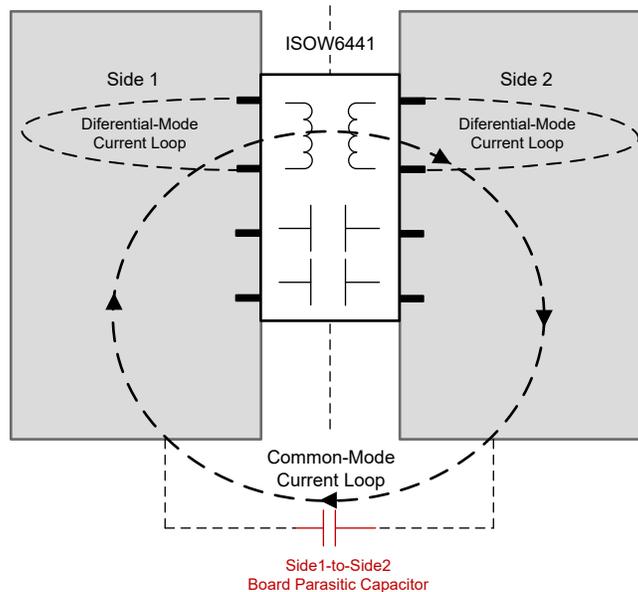


Figure 3-1. Common-Mode and Differential-Mode Current Loops Formation on PCB

4 Achieving Lower Radiated Emissions with ISOW6441

ISOW6441 is specifically designed to meet CISPR32 Class B standards with more than 10dB margin using a cost-effective, two-layer board with simple layout with minimal external components. TI uses a patented symmetric design architecture in the design and layout of ISOW6441 to provide low emissions, and this helps in achieving the best cost to performance ratio in the market.

The ISOW6441 device uses high-frequency switching to compensate for low transformer coil inductance, and also duty-cycles the power-converter to provide the required output DC load while maintaining regulation. Whenever the converter is on, a high current draw from the input supply, V_{DD} , occurs. This current has low-frequency content (roughly proportional to the closed-loop regulation bandwidth) and high-frequency content at the switching frequency (60MHz) and harmonics of the DC/DC converter.

To achieve best emissions performance from ISOW6441, following measures need to be taken on the designed PCB to attenuate the supply noise efficiently as shown in [Figure 4-1](#).

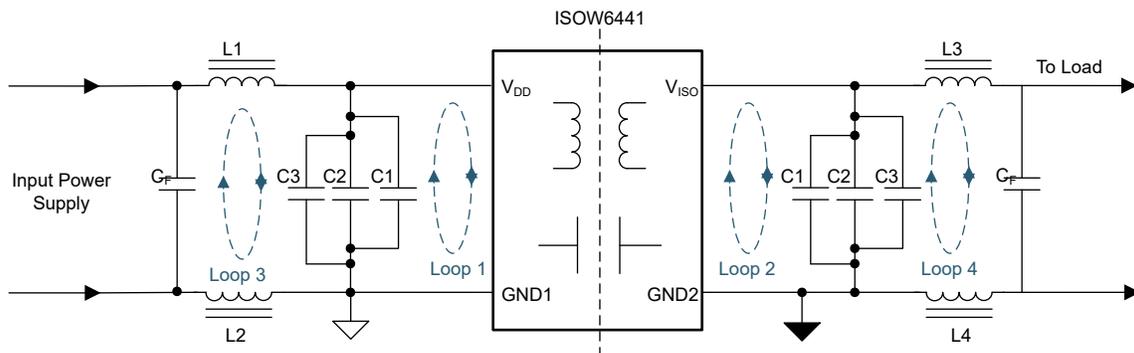


Figure 4-1. Supply Decoupling Capacitors and Ferrite Beads

1. Supply Decoupling Capacitors - Must Have for ISOW6441

Decoupling capacitors play an important role in filtering differential noise and keeping the voltage ripple to a minimum value. These capacitors also provide the instantaneous peak currents needed by various functional blocks in the DC/DC converter of ISOW6441. The ISOW6441 requires an input and output capacitor bank of different capacitors ($C1 = 0.1\mu\text{F}$, $C2 = 1\mu\text{F}$, $C3 = 10\mu\text{F}$) to filter out a lot of the high-frequency content and prevent propagating to input supply routing as well as to the output load. Placing these capacitors as close to the pins as possible is critical to limit the area of loop 1 and loop 2. The $0.1\mu\text{F}$ capacitor ($C1$) must be placed within 2mm distance from the DC/DC converter supply pins ($V_{DD}/GND1$ and $V_{ISO}/GND2$). Use a capacitor with the lowest equivalent series resistance (ESR) for frequencies from 10MHz to 100MHz. The ISOW6441 also requires a bulk capacitor of at least $10\mu\text{F}$ placed after the $0.01\mu\text{F}$ capacitor. Use an optional $1\mu\text{F}$ capacitor just before the $10\mu\text{F}$ for better noise filtering.

Important: Place all these capacitors on the same PCB layer as the ISOW6441 device. [Figure 4-2](#) shows an example PCB layout with the suggested decoupling capacitor placements on ISOW6441DWEEVM.

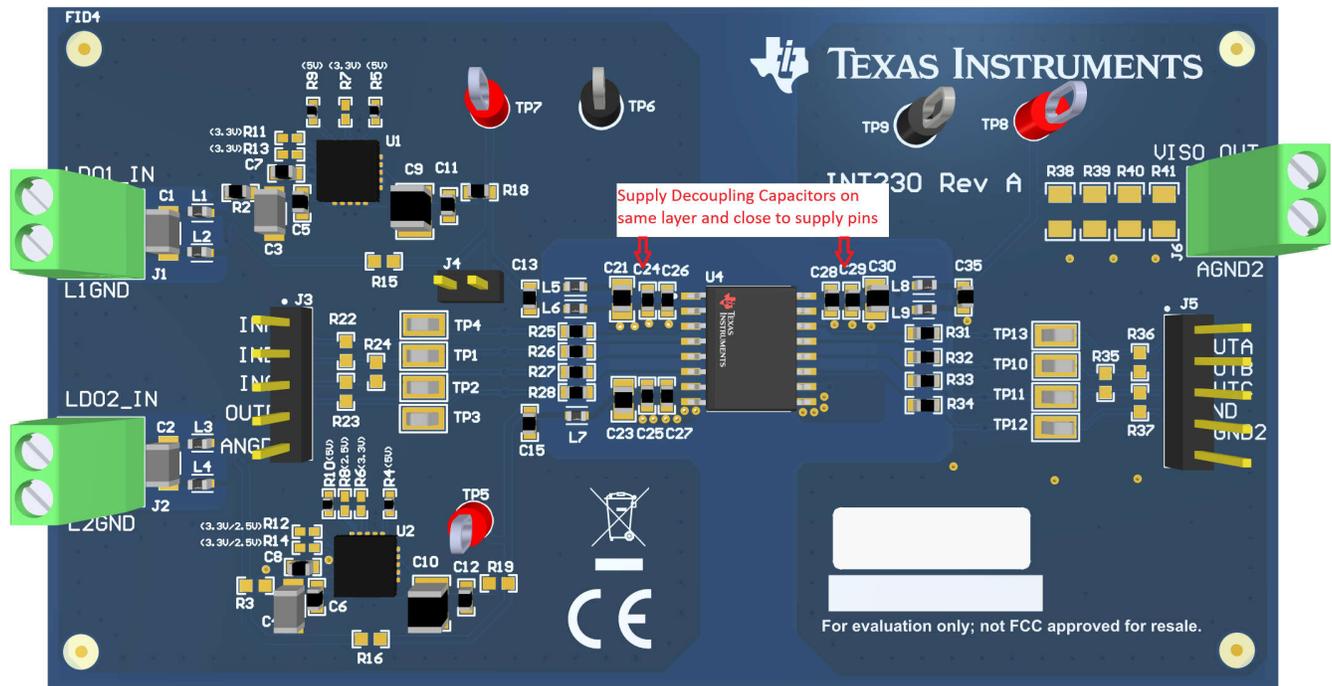


Figure 4-2. Example Decoupling Capacitor Placement for ISOW6441 on ISOW6441DWEVM

2. Further Improvements with Ferrite Beads

Although supply decoupling capacitors take care of reducing loop 1 and loop 2 currents closer to the device, additional ferrite beads (FB) can be used along with a capacitor (C_F) to contain the high frequency noise on supply routings of VDD-GND1 and VISO-GND2 from further spreading on the larger PCB area by reducing the loop 3 and loop 4 currents. FBs L1-L2 for VDD-GND1 and L3-L4 for VISO-GND2 as shown in [Figure 4-1](#) offer high attenuation to select frequencies thereby blocking the switching noise to spread in the larger routings in the PCB. Choose these FBs to offer the highest impedance ($> 1k\Omega$) at the switching frequency and harmonic frequencies, such as BLM18HE152SH1D.

For getting effective results from usage of FBs, a minimum Keep-Out-Zone (KOZ) needs to be maintained. Maintain all the power and ground planes before and after FBs stay separated throughout all PCB Layers. Make sure this separation space in planes before and after FB is greater than the length of the FB. This maintains there are no alternate current loops formed which are created through capacitive coupling between the planes, bypassing FBs.

Refer to [ISOW6441DWEM](#) for all the PCB design measures discussed for meeting best emissions performance from ISOW6441.

5 Radiated Emissions Testing Guidelines

The primary reason for radiations is the formation of antennae on the board. Long cables used to power up the system or probes used to measure any parameter can act like antennae and cause a higher emission reading. Make sure the setup used for emissions closely mimics the final system conditions of operation. Achieve this by keeping the cables connected to and originating from the system as short as possible or according to the actual system usage conditions. Any direct or capacitive connections of the board or metal shields to protected earth (PE) that are eventually planned for use in the final system must be present during EMI testing as well.

If the supply connections are long wires coming from a power supply placed far away from the DUT, then common-mode chokes (CMC) are recommended near the DUT so that the emissions are not unnecessarily aggravated by the long wires. In place of CMCs, use ferrite core clamp filters on the cables to minimize impact on emissions measurement. By using these filters, emissions of the actual setup are measured, and the effect of the long cables is nullified. Solder any extra components required on the board, such as load resistors, directly to the board rather than connecting them to the board using long wires.

Another way to avoid such long wires is to power equipment under test (EUT) using batteries with very short wires if the EUT is DC powered. [Figure 5-1](#) shows the evaluation module ISOW6441DWEEVM powered using a 9V alkaline battery with very short connecting wires.

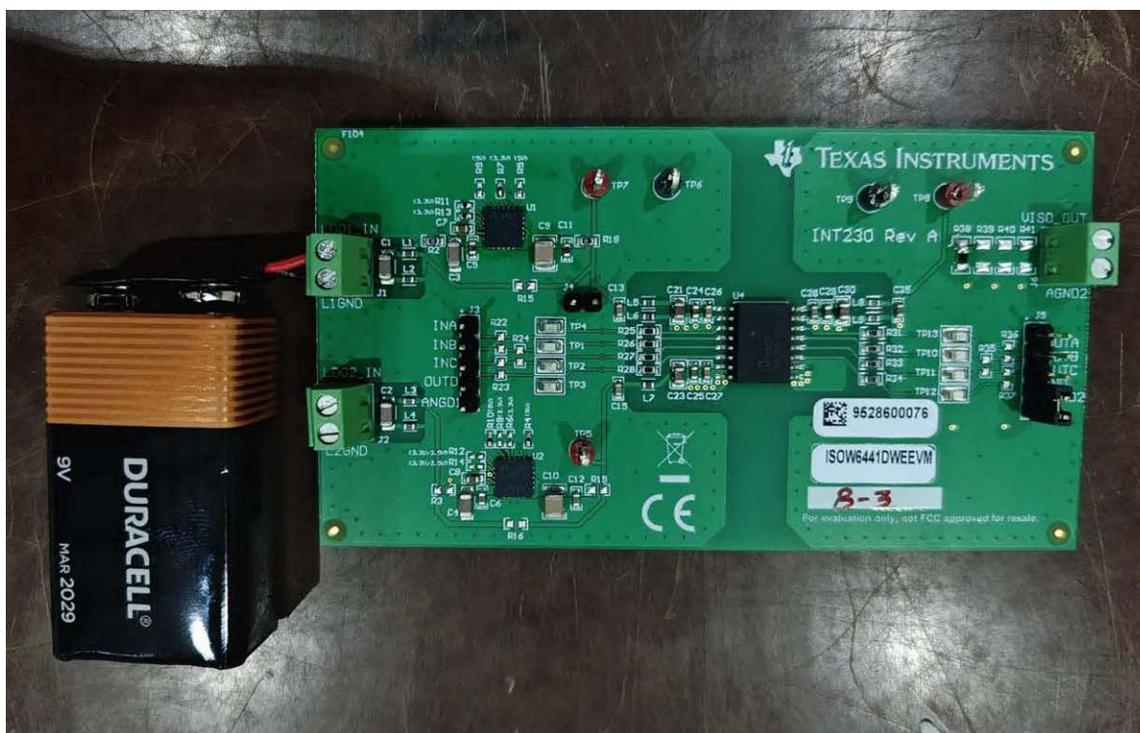


Figure 5-1. ISOW6441DWEEVM Emissions Test Setup Using a Battery

According to the CISPR 32 standard, the radiated emissions limits are specified as quasi-peak limits, although the peak-detector measurement is typically used to get a quick result. The device ISOW6441 uses spread spectrum clocking to change the switching frequency across a small band of frequencies instead of concentrating all the power at one single frequency. Techniques such as this show significantly better results when subjected to quasi-peak scans.

Take peak-detector measurements first to find out the frequencies for the worst-case measurements. Follow this with the quasi-peak measurements at the select worst-case frequencies to estimate the true margin from the CISPR 32 quasi-peak limit line.

6 Radiated Emissions Test Results

Table 6-1 presents ISOW6441DWEEVM CISPR 32 test results with the test setup shown in Figure 5-1 for all the VDD and VISO voltage configurations and at max ILOAD for each configuration. The results clearly show that the ISOW6441 radiated emissions have >10dB margin from class B limit lines and comfortably meet CISPR 32 Class B, even with peak emissions measurements.

Table 6-1. Device configurations and results for CISPR32 Class-B radiated emission tests

	V _{DD} (V)	V _{ISO} (V)	V _{ISO} load (mA)	Frequency Range	Emissions Spectrum Results
Test-1	5	5	110	30MHz-1GHz	Figure 6-1
Test-2	5	5	110	1GHz-6GHz	Figure 6-2
Test-3	5	3.3	140	30MHz-1GHz	Figure 6-3
Test-4	5	3.3	140	1GHz-6GHz	Figure 6-4
Test-5	3.3	3.3	60	30MHz-1GHz	Figure 6-5
Test-6	3.3	3.3	60	1GHz-6GHz	Figure 6-6

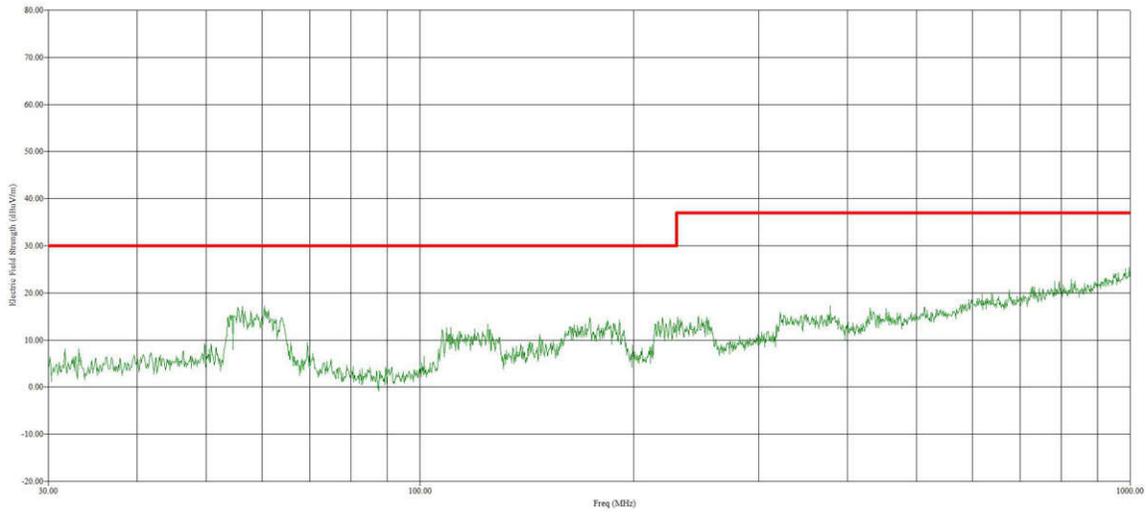


Figure 6-1. Radiated Emissions Result for CISPR32 Class-B with 5V Input, 5V Output, 110mA Load (30MHz to 1GHz)

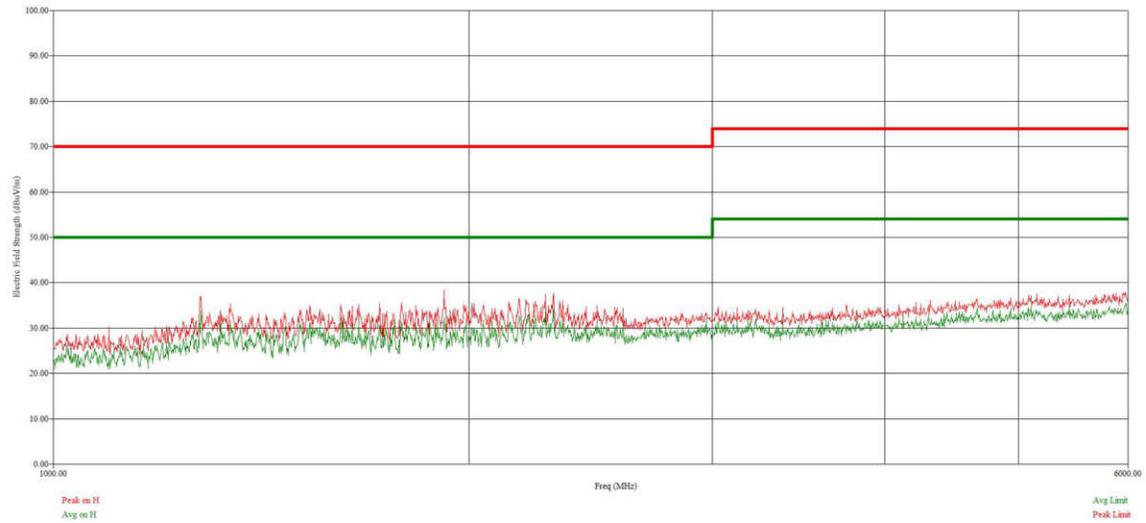


Figure 6-2. Radiated Emissions Result for CISPR32 Class-B with 5V Input, 5V Output, 110mA Load (1GHz to 6GHz)

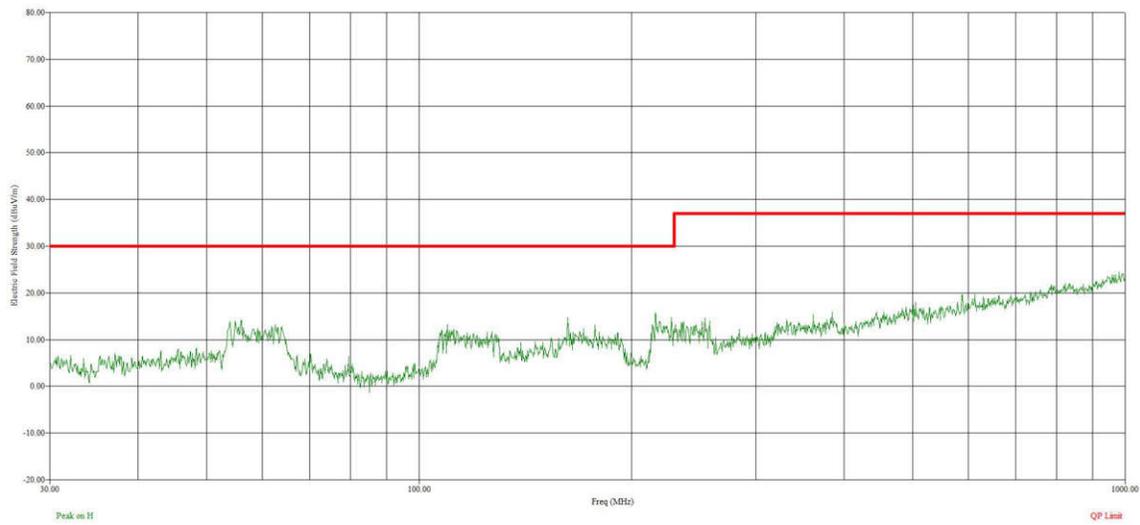


Figure 6-3. Radiated Emissions Result for CISPR32 Class-B With 5V Input, 3.3V Output, 140mA Load (30MHz to 1GHz)

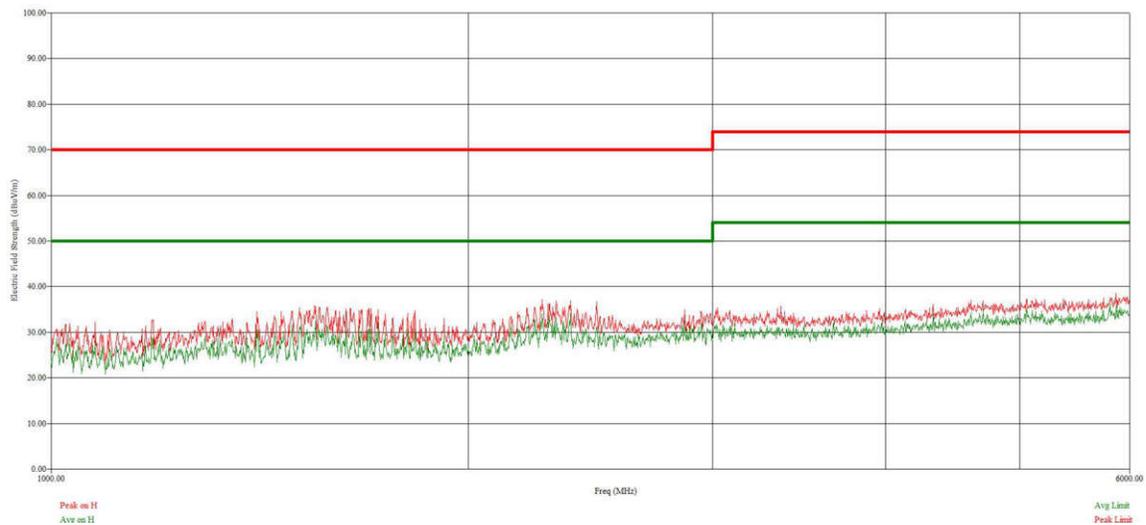


Figure 6-4. Radiated Emissions Result for CISPR32 Class-B with 5V Input, 3.3V Output, 140mA Load (1GHz to 6GHz)

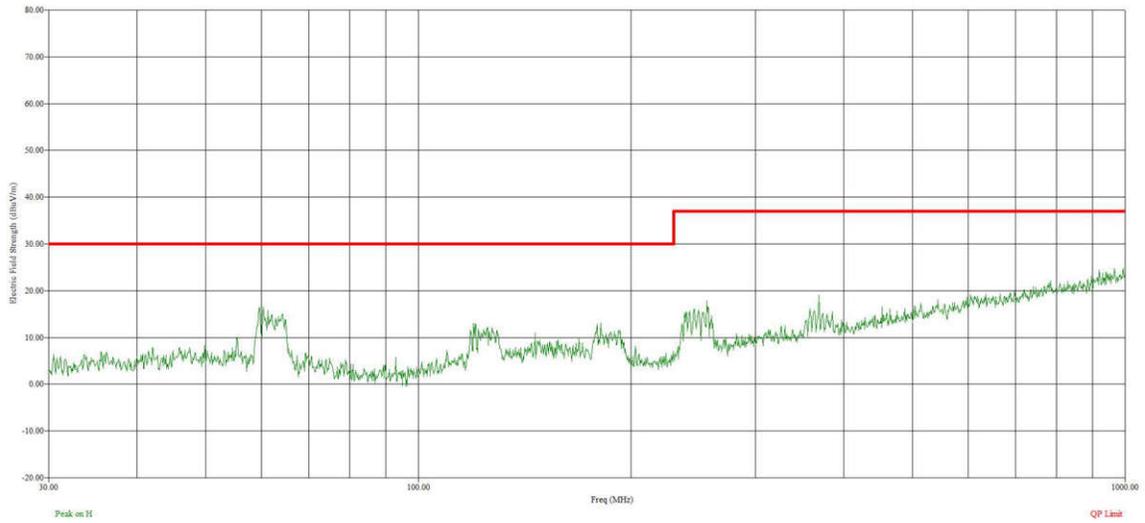


Figure 6-5. Radiated Emissions Result for CISPR32 Class-B with 3.3V Input, 3.3V Output, 60mA Load (30MHz to 1GHz)

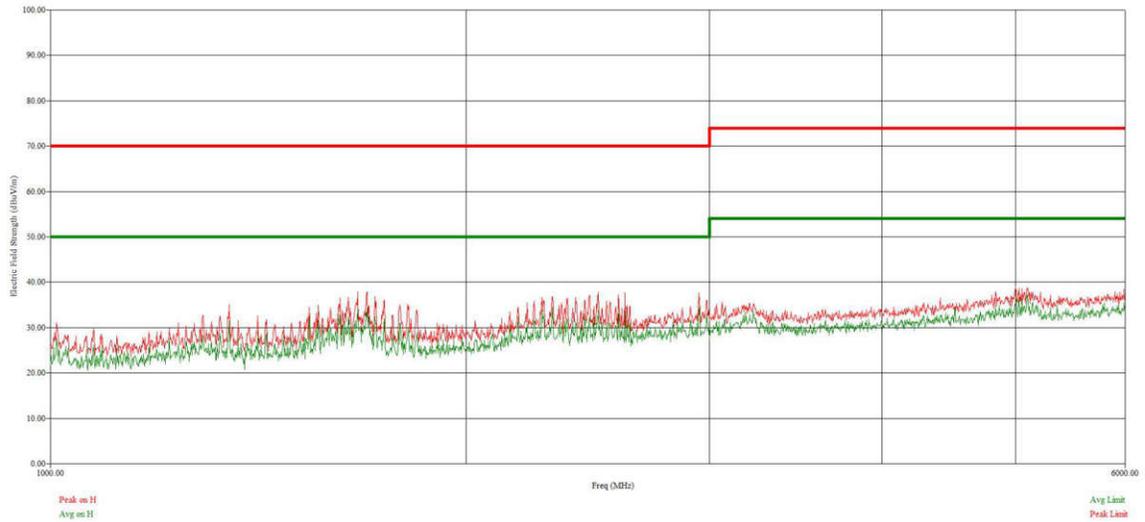


Figure 6-6. Radiated Emissions Result for CISPR32 Class-B with 3.3V Input, 3.3V Output, 60mA Load (1GHz to 6GHz)

7 Conclusion

TI's latest generation solution for digital isolators with integrated DC/DC converters, the ISOW6441, have switching frequencies of the converters in the 60MHz range to keep the size of the transformer small. This high-frequency switching can cause radiated emissions of the integrated device to appear in the band of CISPR 32 frequency spectrum. Large PCBs and long connected cables aggravate the overall radiations of the DC/DC converter integrated isolated power solutions. The ISOW6441 has optimized radiated emissions performance due to the patented symmetric design architecture and spread spectrum clocking. To achieve further improvements in emissions follow the placement guidelines for suggested decoupling capacitors and ferrite beads to meet CISPR32 Class B limits with >10dB margin at full load capability for input/output voltage configurations. These recommendations reduce the impact of large PCBs and long cables on radiated emissions results and enable the end-equipment to comply to CISPR 32 standard emissions limits.

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