Application Note

Best Practices to Attenuate AMC3301 Family Radiated Emissions EMI

TEXAS INSTRUMENTS

ABSTRACT

This document demonstrates how printed circuit board (PCB) input trace or cable design affects radiated emissions electromagnetic interference (EMI) performance for Texas Instruments' AMC3301 precision isolated amplifier with integrated DC/DC converter. The AMC3301 family as shown in Table 6-1 does not produce excessive radiated emissions by themselves and are capable of passing CISPR 11 class B without additional components as shown in Figure 2-2 if the length of the input traces connected to the device are short. For designs requiring additional radiated emissions attenuation, ferrite bead and common-mode choke selection and placement recommendations are provided.

Several industrial and automotive applications require some type of isolation to protect the digital circuitry from the high-voltage circuit performing a function. Texas Instruments has an extensive portfolio of isolated amplifiers and converters featuring a SiO_2 isolation barrier to help customers address their isolated data conversion needs. Texas instruments' SiO_2 isolation barrier allows for exceptional reliability, often over 100 years of operation. For more information on TI's SiO_2 isolation barrier, please review the Isolation link. EMI testing is common in these applications to verify the system does not produce radiated emissions that exceed the defined levels which may negatively impact other components or circuits in the system. Please see this application note for a more in-depth description of EMI. The magnitude of acceptable radiation and testing procedure for radiated emissions is put in place by the Comité International Spécial des Perturbations Radio, also known as CISPR. Industrial applications measure according to the CISPR 11 standard, while automotive applications measure to the CISPR 25 standard. For more information on the CISPR standards and their respective magnitudes over frequency, please see this application note.

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Trademarks

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1 Introduction

The AMC3301 family of devices has two sources of radiated emissions, as shown in Figure 1-1, the capacitive data path shown below in red and the integrated DC/DC converter shown in blue. The radiated emissions performance of the data path is the same as the AMC1300B-Q1 and contributes very little radiated emissions as shown in this Best in Class Radiated Emissions EMI Performance with the AMC1300B-Q1 Isolated Amplifier technical write paper. The second and largest source of radiated emissions for the AMC3301 family is the integrated DC/DC converter that operates at a frequency of 30 MHz with spread spectrum modulation. The coils of the internal DC/DC converter have a parasitic capacitance from the primary (user) side to the secondary (high) side of the isolation barrier. The primary driver generates a common-mode voltage between the isolated grounds, HGND and GND that has a quasi-resonant nature and generates harmonics to higher frequencies. Because of the nature of the isolation barrier, the energy is unable to find a conductor to return to the source. With no path back to the source, the energy radiates from the device pins (and any traces or PCB planes they are connected to) in the form of radiated emissions.

Input traces and cables that are connected to the isolated amplifier or converter act as antennas for the electro-magnetic energy injected between HGND and GND. The size and shape of the traces and cables directly affect the magnitude of the radiated emissions over frequency. As a general rule, shorter antennas radiate more effectively at higher frequencies, while longer antennas radiate more effectively at lower frequencies. When designing with the AMC3301 family, input traces and cables should be kept as short as possible to limit the magnitude of radiated emissions.

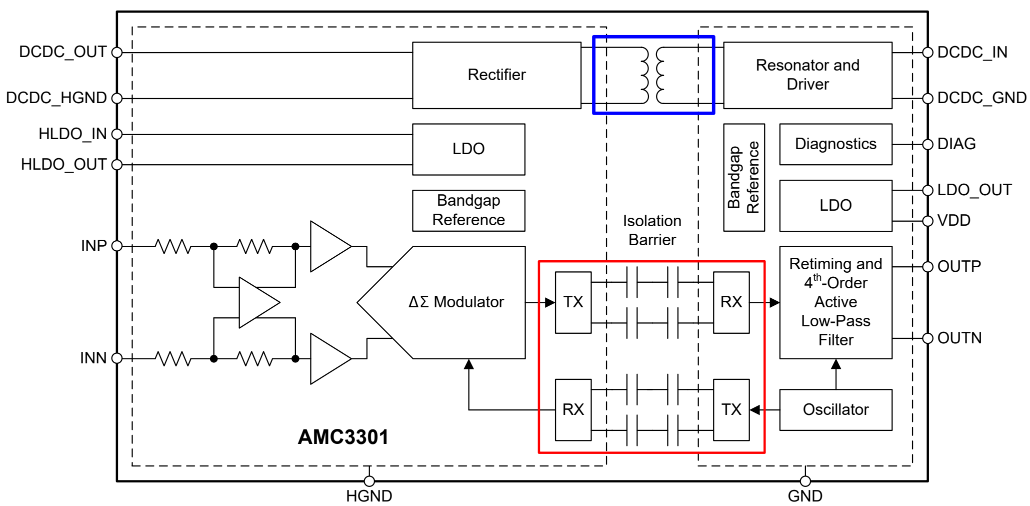

Figure 1-1. AMC3301 Isolated Amplifier Block Diagram

2 Effects of Input Connections on AMC3301 Family Radiated Emissions

CISPR 11 peak measurements were performed with various input cable lengths and Texas Instruments' AMC3301. The input cable lengths tested are a 1.5 m input, a 30 cm input and an input shorted at the input terminal of the evaluation module (EVM). The same AMC3301EVM was used for all tests and powered from an external battery. All measurements shown are in the horizontal, or worst-case, orientation. Refer to the test setups in Figure 2-1 and CISPR 11 radiated emissions EMI plots in Figure 2-2 and Figure 2-3.

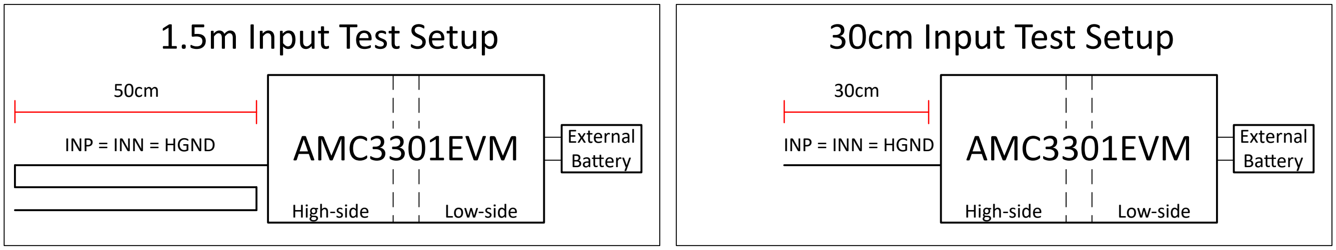

Figure 2-1. Test setup with AMC3301EVM and Input Lengths

Figure 2-2 shows the radiated emissions performance of the AMC3301 with an input short shown in blue. The AMC3301 shows very little radiated emissions above the noise floor in red – demonstrating that the AMC3301 does not produce excessive radiated emissions if the input traces or cables to the device are short.

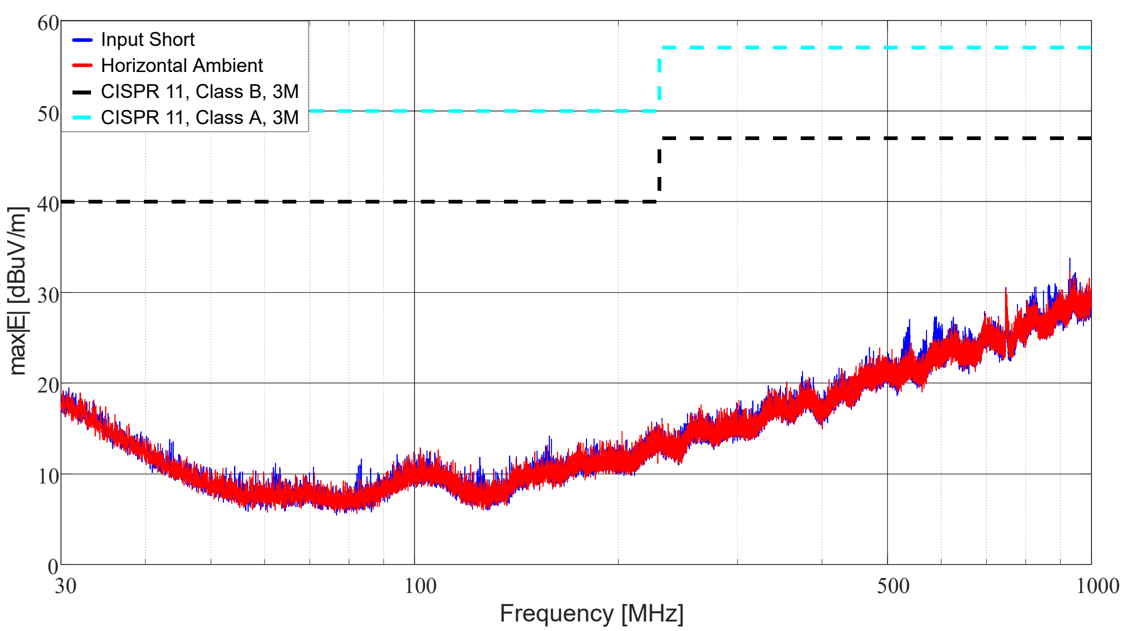

Figure 2-2. AMC3301EVM Input Short and Horizontal Ambient CISPR 11 Measurement

Figure 2-3 shows the radiated emissions measurement for the 1.5 m input in blue, 30 cm in red and input short in green. Longer input traces and cables connected to the AMC3301 increase the magnitude of radiated emissions as shown by the 1.5 m input and 30 cm input test cases compared to the input short.

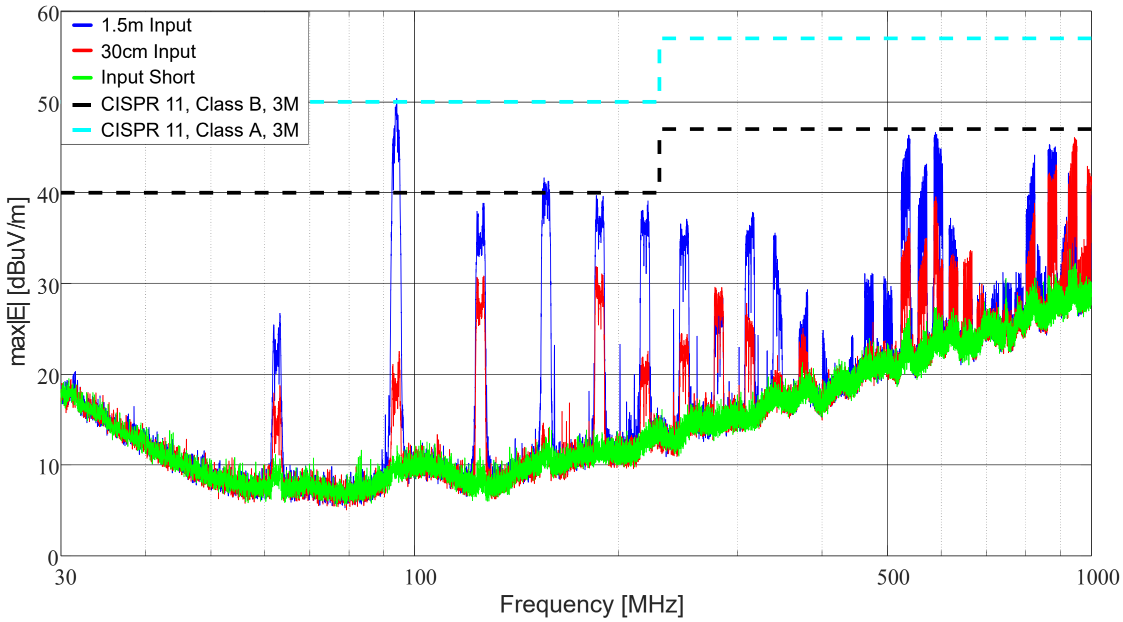

Figure 2-3. AMC3301EVM with Different Input Lengths CISPR 11 Measurement

3 Attenuating AMC3301 Family Radiated Emissions

3.1 Ferrite Beads and Common Mode Chokes

Designers need to limit the length of the input traces or cables connected to the AMC3301 family. However, some applications will require longer input traces or cables which will lead to excessive radiated emissions. This radiation can be attenuated by using ferrite beads or a common-mode choke in series with the input connections. When selecting a ferrite bead or common-mode choke, refer to the impedance over frequency plot in the components' data sheet. A minimum of 1 kΩ ohm impedance (z) is recommended over the frequency range of interest, 150 MHz to 800 MHz for CISPR 11, with higher impedances attenuating radiated emissions more effectively. Table 3-1 lists recommended ferrite beads and a common-mode choke.

Table 3-1. Ferrite Bead and Common-mode Choke Recommendations

Type	Manufacturer	Part Number
Ferrite Bead	Wurth Elektronik	74269244182
Ferrite Bead	Murata	BLM15HD182SH1
Ferrite Bead	Taiyo Yuden	BKH1005LM182-T
Common-mode Choke	Murata	DLW31SN222SQ2

To demonstrate the benefits of adding the ferrite beads or a common-mode choke for the 1.5 m input and 30 cm input, refer to Figure 3-1 and Figure 3-2 respectively. The 74269244182 ferrite bead from Wurth Elektronik and DLW31SN222SQ2 common-mode choke from Murata were added in series to the input connections for these tests.

Figure 3-1 shows the radiated emissions of the 1.5 m input. Without ferrite beads or a common-mode choke is shown in blue and the CISPR 11 class B limit is violated. The attenuating benefit of the ferrite beads is shown in red and the common-mode choke in green. Both the ferrite beads and common-mode choke significantly attenuate the radiated emissions, allowing the AMC3301EVM to pass the CISPR 11 class B test.

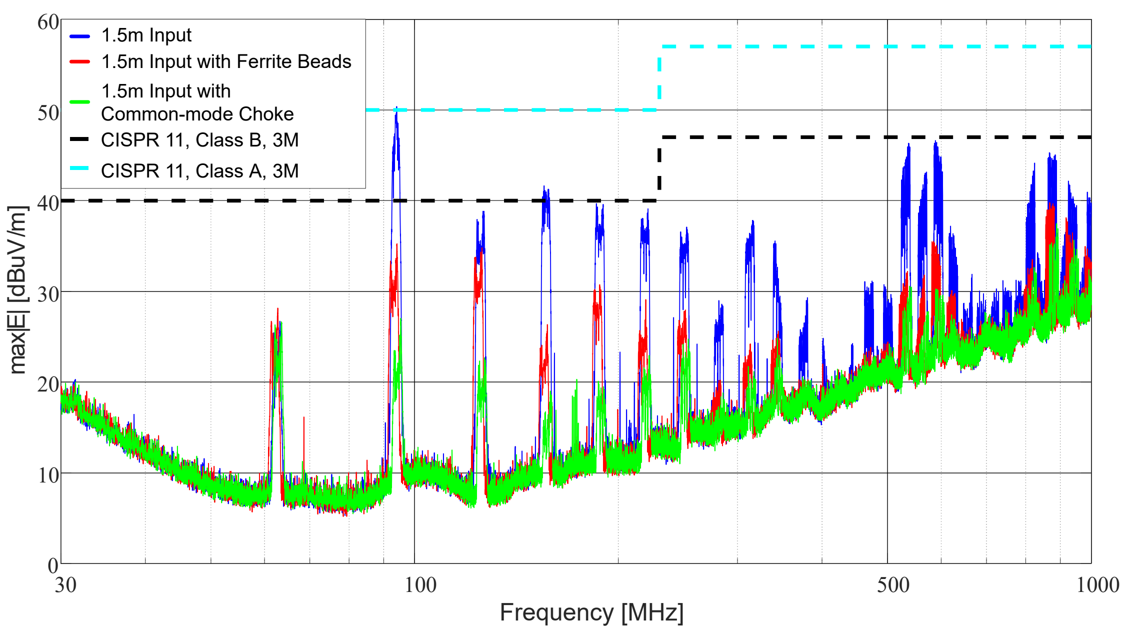

Figure 3-1. AMC3301EVM CISPR 11 Measurements with 1.5 m Input

Figure 3-2 shows the radiated emissions of the 30 cm input. All test cases pass the CISPR 11 class B test, including without ferrite beads or a common-mode choke as shown in blue. This indicates that additional components are not necessary to pass the test, but to demonstrate the attenuating benefits, the measurements with ferrite beads are shown in red and the common-mode choke in green.

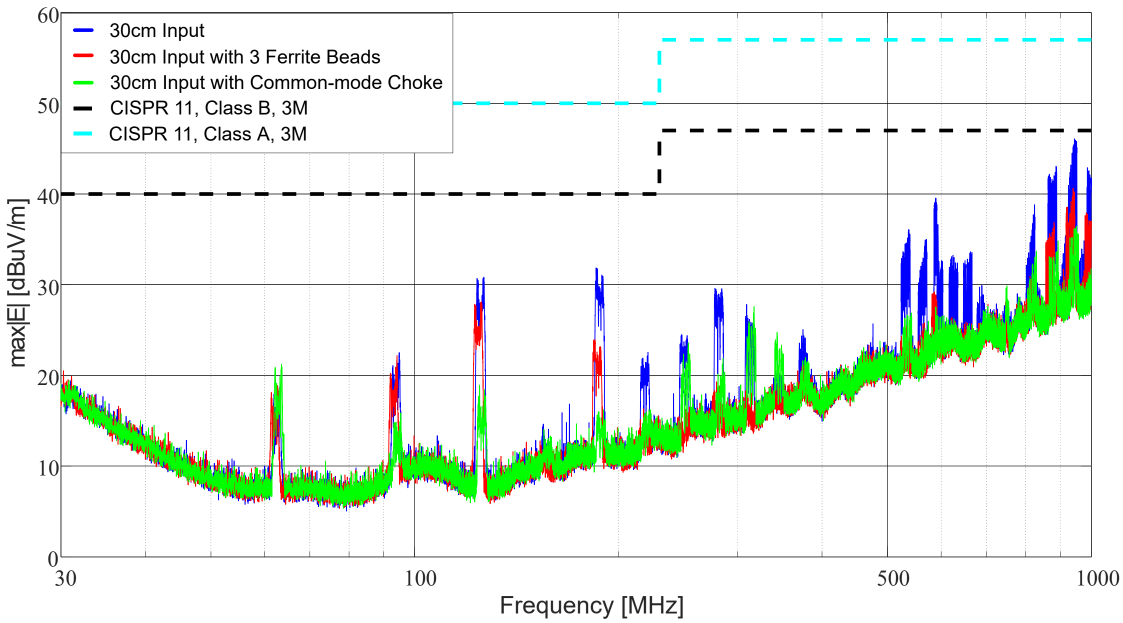

Figure 3-2. AMC3301EVM CISPR 11 Measurements with 30 cm Input

3.2 PCB Schematics and Layout Best Practices for AMC3301 Family

Figure 3-3 shows the schematic for the ferrite beads on the left and the common-mode choke on the right. Note that three ferrite beads are required, one for each input as well as one for the HGND trace to the shunt resistor. The common-mode choke has two channels and terminating the HGND connection to VINN near the common-mode choke is necessary. The differential RC filter created by R2, R4 and C12 is placed between the ferrite beads or common-mode choke and the AMC3301. Refer to the layout guidelines section in the device's data sheet for additional detail.

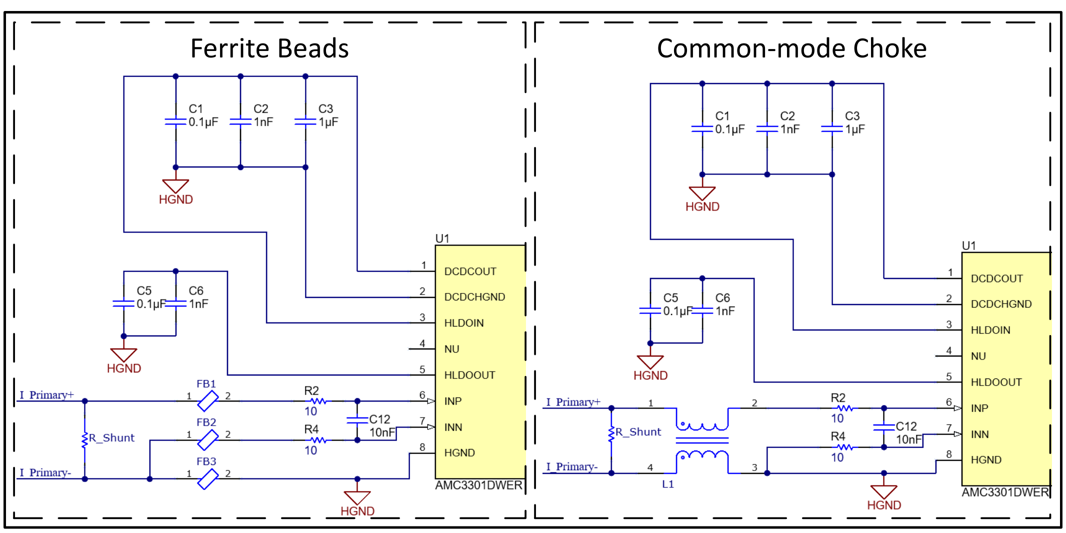

Figure 3-3. AMC3301 Ferrite Bead and Common-mode Choke Schematics

The ferrite beads or common-mode choke should be placed as close to the device as possible to limit the amount of copper area that will act as an antenna. A direct and low inductance connection should be made from pin 2 (DCDC_HGND) to pin 8 (HGND). Figure 3-4 shows the recommended layouts for the ferrite beads on the left and the common-mode choke on the right.

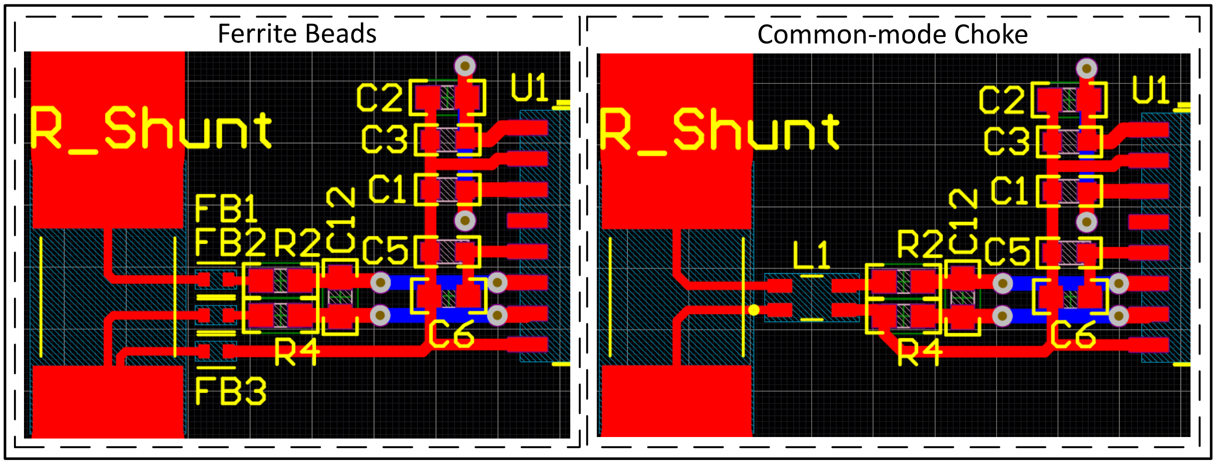

Figure 3-4. AMC3301 Ferrite Bead and Common-mode Choke Layouts

4 Using Multiple AMC3301 Devices

4.1 Device Orientation

As mentioned previously, the coils of the internal DC/DC converter have a parasitic capacitance from the primary side to the secondary side of the isolation barrier, and the energy radiates from the device pins, and traces connected to pins. As a result, it is important to consider how the AMC3301 family will radiate and affect other devices along the isolation barrier, including other AMC3301's.

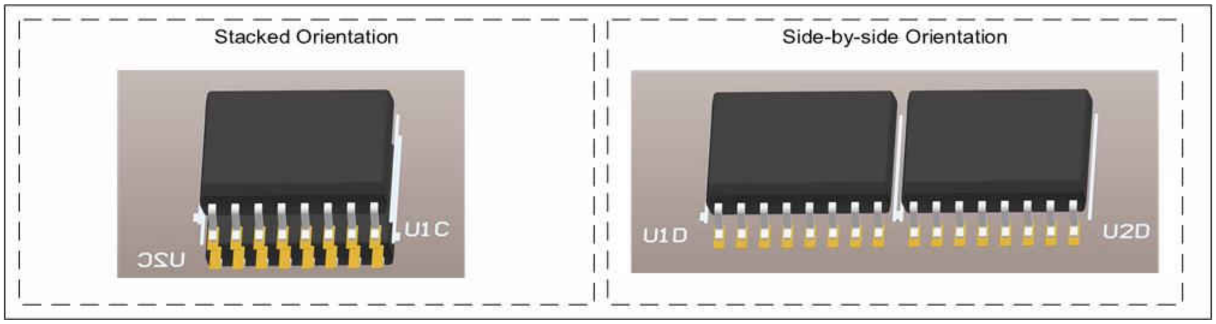

Figure 4-1. Device orientation examples

To demonstrate the effects of device orientation, a stacked orientation and side-by-side orientation are tested. The schematic used in testing is the same as the ferrite section of Figure 4-1. The input ferrite beads part number is 74269244182, and they were tested with 1.5 m input shorted together.

Figure 4-2 shows the orientations will meet the CISPR 11 class B limit as a result of the ferrite beads discussed previously. The stacked orientation is in red while the side-by-side orientation is in blue. In addition, the orientations fall within 5 dBuV/m of each other. However, placing both devices right on top of each other-in a stacked orientation-shows the best performance.

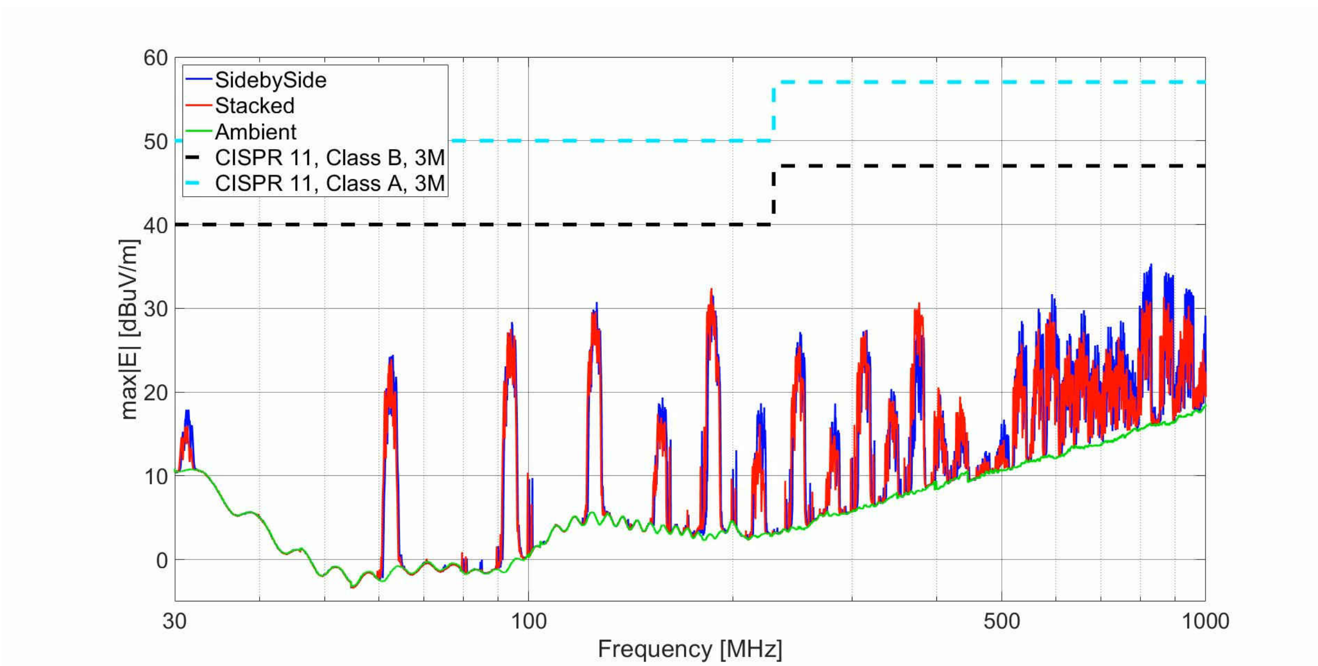

Figure 4-2. Multiple AMC3301 CISPR 11 Measurements with 1.5 m Input

4.2 PCB Layout Best Practices for Multiple AMC3301

The schematic used in testing is the same as the ferrite section of Figure 4-3. However, layout for stacking the AMC3301's is shown in Figure 4-3.

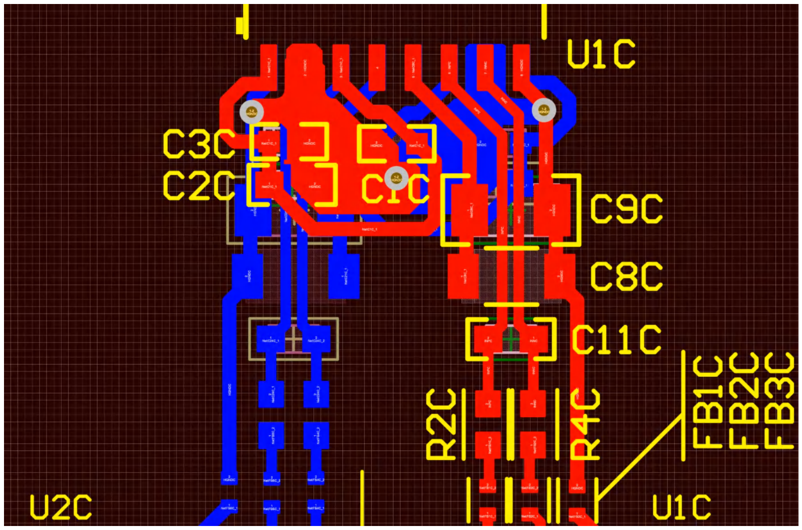

Figure 4-3. Recommended Multiple AMC3301 Devices Layout

In general, the same layout principles described in Section 3.2 are followed with a two layer board design.

However, a direct and low inductance path from pin 2 (DCDC_HGND) to pin 8 (HGND) of each device is achieved differently. Instead of a trace, a star connection connects both devices between the top and bottom layers at pins 4 and 5. In addition, a pool of copper is used to connect the DC/DC capacitors to DCDC_HGND on the same layer.

Finally, the LDO_OUT capacitors are scaled up to a 1206 package to allow direct and uninterrupted path for the positive and negative inputs underneath the capacitors.

5 Conclusion

Over the past several years, SiO_2 isolation has been a popular choice for many customers in need of isolated amplifiers. Texas Instruments continues to innovate and recently released the AMC3301 precision isolated amplifier with integrated DC/DC converter. The AMC3301 family does not produce excessive radiated emissions by itself and is capable of passing CISPR 11 class B without additional components if the length of input traces or cables are short. Ferrite beads or a common-mode choke can be used to further attenuate radiated emissions if desired. AMC3301 devices can be stacked on top of each other on the top and bottom layers if multiple are used. When designing with the AMC3301 family, customers can confidently create designs featuring the high reliability and high analog performance that capacitive isolation brings, while enjoying the convenience of an integrated DC/DC converter and best in class radiated emissions performance.

6 AMC3301 Family Table

The content discussed in this application note is applicable to all isolated amplifiers and isolated converters with integrated DC/DC converter in the AMC3301 family, listed in Table 6-1.

Table 6-1. AMC3301 Family Table

Device	Type	Description
AMC3301	Reinforced Isolated Amplifier	Current Sensing, ±250-mV Input
AMC3301-Q1	Reinforced Isolated Amplifier	Current Sensing, ±250-mV Input, Automotive
AMC3302	Reinforced Isolated Amplifier	Current Sensing, ±50-mV Input
AMC3302-Q1	Reinforced Isolated Amplifier	Current Sensing, ±50-mV Input, Automotive
AMC3330	Reinforced Isolated Amplifier	Voltage Sensing, ±1-V Input
AMC3330-Q1	Reinforced Isolated Amplifier	Voltage Sensing, ±1-V Input, Automotive
AMC3306M25	Reinforced Isolated Modulator	Current Sensing, ±250-mV Input
AMC3306M05	Reinforced Isolated Modulator	Current Sensing, ±50-mV Input
AMC3336	Reinforced Isolated Modulator	Voltage Sensing, ±1-V Input
AMC3336-Q1	Reinforced Isolated Modulator	Voltage Sensing, ±1-V Input, Automotive

7 Revision History

Changes from Revision * (June 2021) to Revision A (September 2022)	**Page**
• Updated the numbering format for tables, figures, and cross-references throughout the document	2
• Added *Using Multiple AMC3301 Devices* section with Device Orientation data and Layout Recommendations	8