Keywords: RS-485, RS-422, Isolated transceiver, transceiver module, isolated module, MAXM22511, isolated power, EMI, EMC, stitch capacitor, stitch capacitance

APPLICATION NOTE 6835

HOW TO DESIGN AND LAYOUT AN EMI-OPTIMIZED PCB FOR THE MAXM22511 ISOLATED RS-485 TRANSCEIVER MODULE

Abstract: Maxim has integrated both data and power isolation in a tiny module. This application note discusses guidelines to meet industry standards for an EMI-optimized design and layout and shows measurements for radiated noise taken on the MAXM22511. Results shown in this application note compare the MAXM22511 with two competitor ICs (tested on the competitor EMI-optimized evaluation boards).

Introduction

The MAXM22511 isolated RS-485/RS-422, full-duplex, transceiver module delivers a complete isolation solution for data and power channels and provides 2500V_{RMS} (60s) of galvanic isolation between the cable-side (RS-485/RS-422 driver/receiver side) and the UART-side of the device. An integrated DC-DC converter powers the cable-side of the module without requiring an external transformer, saving board space and improving system performance. With no external components required, these modules offer a significant amount of functionality in a very small footprint. An integrated high-frequency switching DC-DC can be a concern for designers who need to meet strict electromagnetic compatibility (EMC) guidelines. Maxim has designed an EMI-optimized board and has performed in-house measurements for radiated noise on the MAXM22511. This application note discusses design techniques and compares the results to two competitor ICs (tested on the competitor EMI-optimized evaluation boards). Guidelines for the MAXM22511 EMI-optimized layout are also included.

Evolution of Integration

Getting Started: The Discrete Solution

The original ANSI/EIA/TIA-485-A-1998 (RS-485) standard was created to address the shortcomings of RS-232 and RS-422. The RS-485 is a bidirectional standard that features multiple drivers and receivers on a single bus, in which each driver can relinquish or drive the bus. RS-485 incorporates the specifications of the point-to-point RS-422 standard but is more robust, which makes the RS-485 ideal for industrial applications.

For robust communication in harsh environments, a typical RS-485 communication block requires a microcontroller, an isolation barrier (i.e., the optocouplers in **Figure 1**), a transceiver (half or full-duplex) and a cable. Power is required for both the logic and isolated sides of the circuit. Historically, each of these components was accomplished discretely (Figure 1). Discrete circuits, although optimal in some special circumstances, tend to be large and expensive. The use of many components requires a large amount of board space and additional BOM and assembly costs. While still used in some limited applications, discrete building block circuits have been increasingly replaced with high-level integrated solutions over the years. For example, optocouplers can be replaced with Maxim's digital isolators, which

offer higher data rates, lower power consumption, and a smaller footprint. Integrated solutions (ICs or modules) have several advantages including a smaller size/footprint, lower cost, high reliability, and low power dissipation.

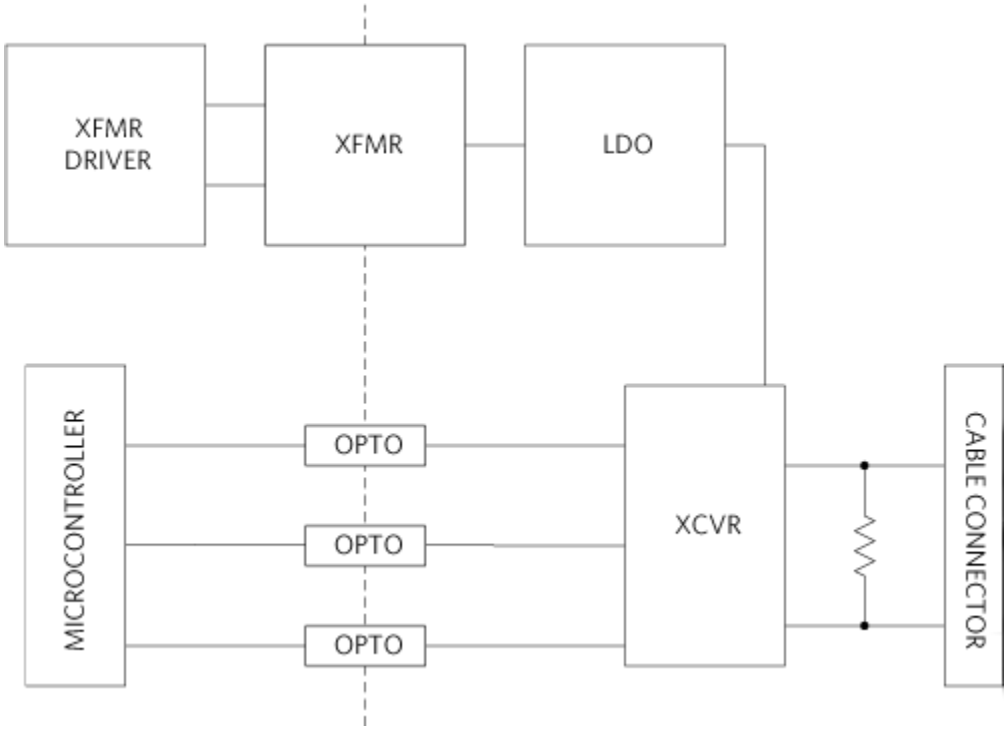


Figure 1. Discrete RS-485/RS-422 communication blocks.

First Level Integration: Integrated Transceiver and Transformer Driver
Maxim introduced a family of isolated RS-485/RS-422 transceivers for robust communications, which include the standard RS-485 features common across the industry (e.g., data rates up to 25Mbps and slew rate limited transceivers for better EMI performance). These transceivers integrate a 2.5kV or 5kV isolation boundary, a half- or full-duplex RS-485 transceiver, and a transformer driver to power the isolated (or RS-485 communication) side of the device (**Figure 2**).

By integrating the data and power-controller blocks, these transceivers reduce the overall footprint for robust communication applications.

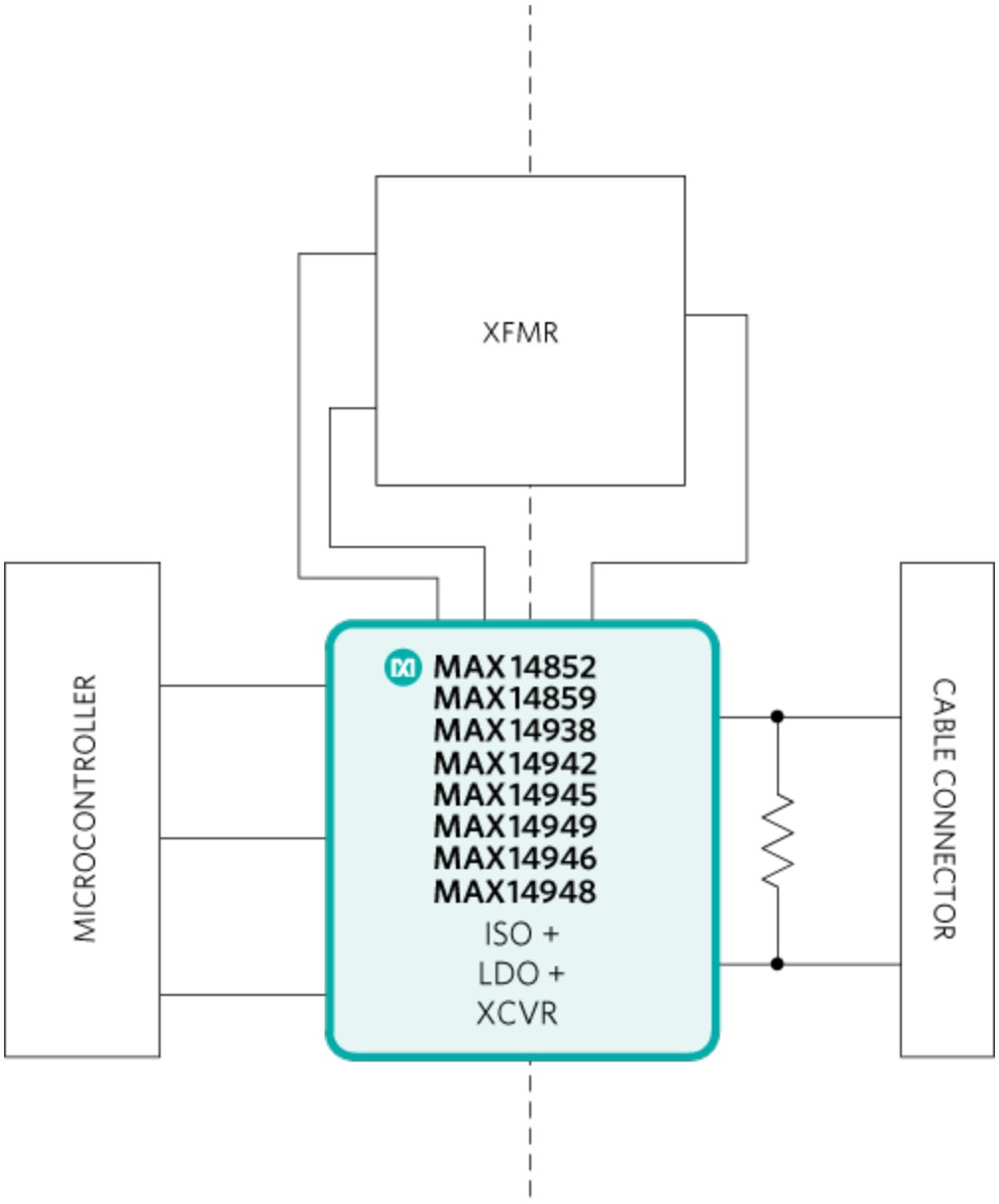


Figure 2. Integrated RS-485/RS-422, isolation, and transformer driver communication block.

The Final Frontier: Fully Integrated Module Maxim's most recent robust communication device, the MAXM22511, is a fully integrated, isolated RS-485/RS-422, full-duplex, transceiver module. This transceiver requires no external components and builds on Maxim's proven leadership in RS-485, pairing communication and power for the smallest robust high-performance communication solution available (**Figure 3**).

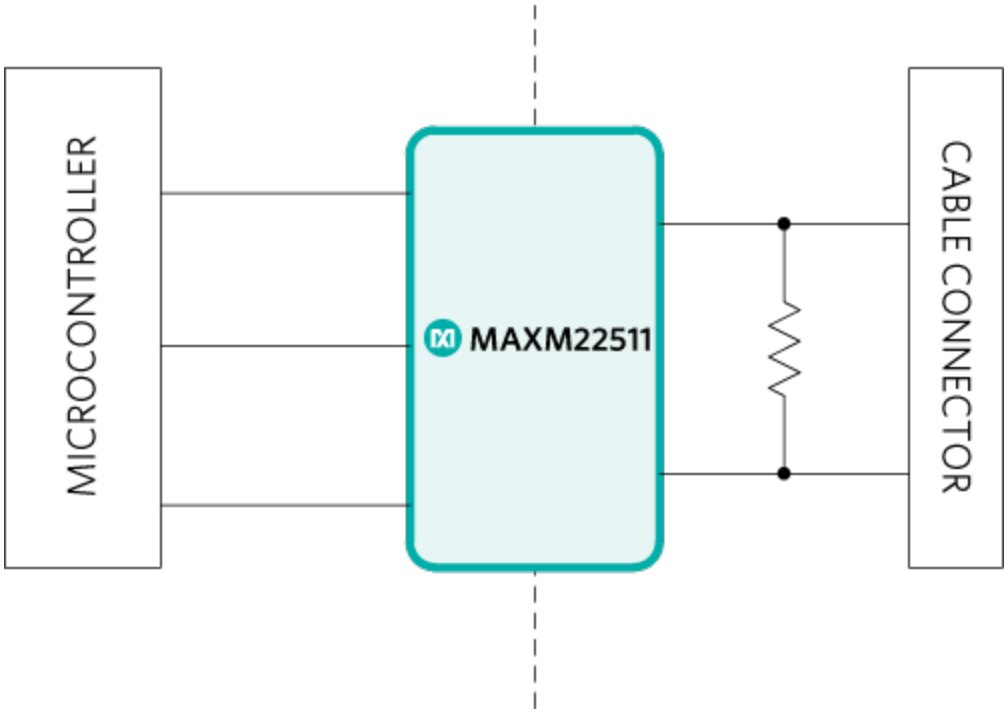


Figure 3. Fully integrated RS-485/RS-422 with the MAXM22511.

The MAXM22511 integrates all required blocks of an industrial RS-485 system (e.g., isolation barrier, transceiver, and isolated power supply). Data isolation is achieved using Maxim's proprietary capacitive isolation technology. An integrated DC-DC and LDO provide regulated power for the isolated side of the circuit (**Figure 4**). The internal transformer is based on a ferrite core to help reduce unwanted EMI emissions. Key features of this module include the integrated transformer (completing the isolated power supply), 60% DC-DC efficiency, $2.5kV_{RMS}$ isolation and ±35kV ESD protection on the RS-485 I/Os.

The MAX22511 solution has a 9.35mm x 11.5mm footprint (no external components are needed), reduced power dissipation, and a high level of ESD protection. This transceiver is a robust one-component solution that addresses both the data and power needs of an isolated industrial interface.

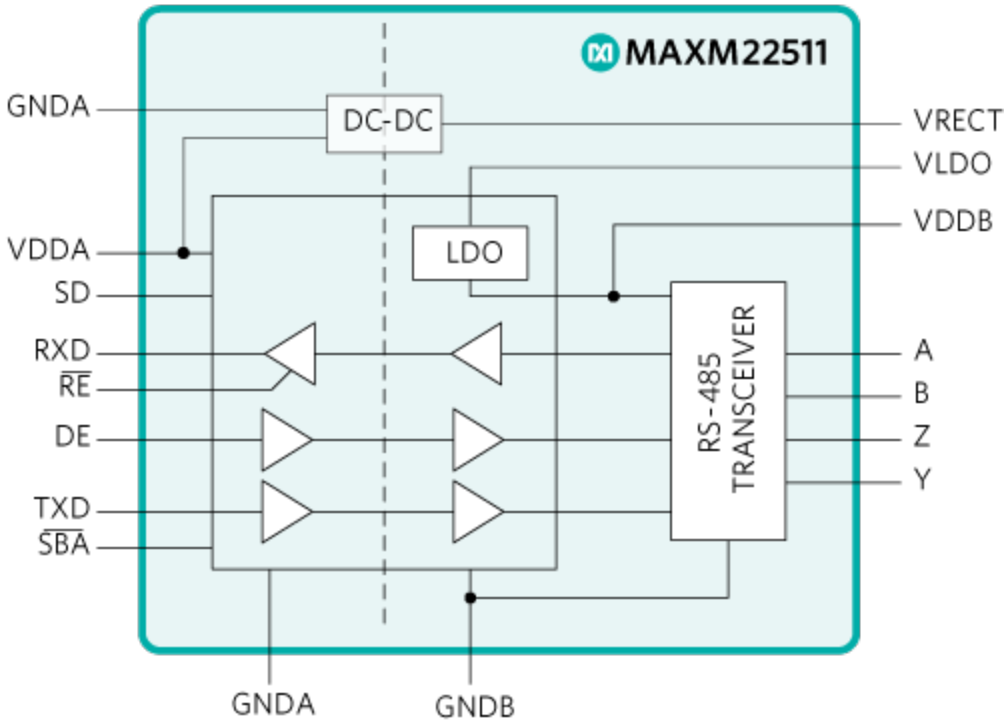


Figure 4. MAXM22511 functional diagram.

Table 1 includes a brief summary of the evolution of Maxim's isolated RS-485 communication solutions.

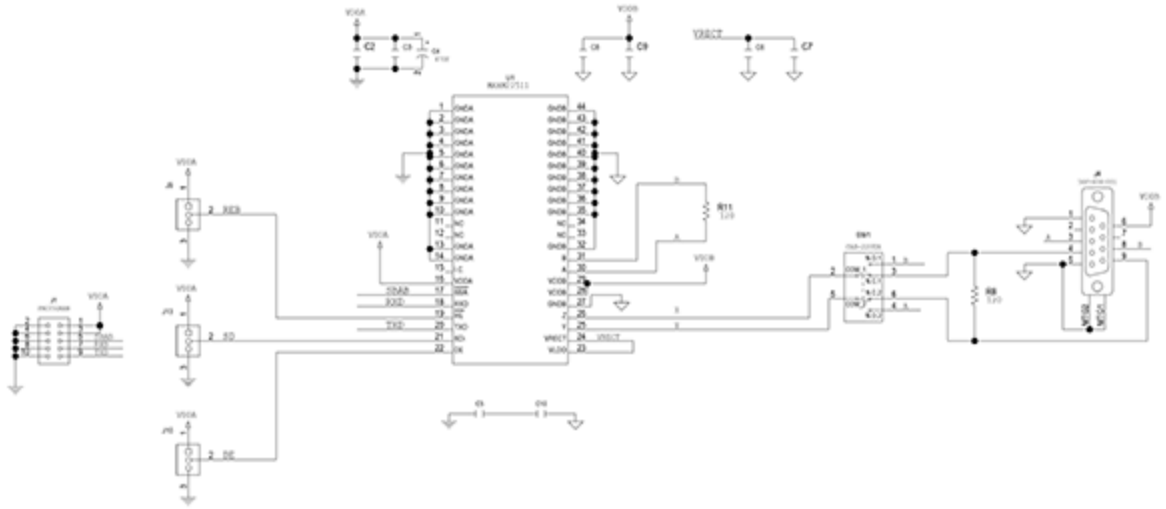
Table 1. Evolution of the Maxim Isolated RS-485 Solutions

	DISCRETE SOLUTION	FIRST GENERATION INTEGRATED SOLUTION	FULLY INTEGRATED SOLUTION
Description and Key ICs:	1. MAX13487E RS-485 transceiver 2. MAX256 transformer driver 3. LDO MAX1659 4. Transformer 5. Two Optocouplers PS9151-A	1. MAX14949 isolated RS-485, with integrated transformer driver 2. Transformer	1. MAXM22511 RS-485 with isolated data and power

No. of ICs/components	6	2	1
Representative EV Kit	MAX13487EEVKIT	MAX149X2EVKIT	MAXM22511EVKIT
Total PCB area	2500mm^2	1000mm^2	100mm^2

MAXM22511 Optimized Design and Layout

The MAXM22511 evaluation kit is designed for flexibility to support testing and prototyping circuits to verify the functionality of the MAXM22511 and is not optimized for the lowest EMI performance. Because PCB layout and component selection are of paramount importance when designing a circuit or product for optimum EMC/EMI performance, Maxim also designed two EMC/EMI optimized boards (MAXM22511 STITCH and MAXM22511 NO_STITCH EVAL boards) for an in-house evaluation of radiated noise (**Figure 5**). Contact Maxim to request the availability of these boards. The MAXM22511 EMI Gerber file is available to download.



More detailed image

Figure 5. MAXM22511 EMI test board schematic.

Maxim's EMC/EMI optimized boards incorporate three design techniques for improving EMC/EMI performance:

- Integrated floating stitching capacitance (STITCH board only)
- Edge guarding/via guard ring

- EMI-optimized component selection

Of the two boards, only the STITCH board is designed with an integrated floating stitching capacitor on the inner layers. Both boards include safety Y-capacitors across the isolation barrier.

Floating Stitch Capacitance
Poor EMI performance is often found in boards with isolation barriers. Image charges are formed on the ground layer beneath a signal layer when a signal runs through traces on a PCB. When the charge image is forced to stop, for example, at an isolation barrier, differential currents and voltages are created in the PCB and generate EMI.

A capacitor is formed when two layers in a PCB overlap. PCB layers can be specially placed and sized to create something called a stitching capacitance (**Figure 6**). Stitching capacitors in the PCB allow image charges following the current path of signals to remain steady, reducing high-switching signals without adding additional cost to the PCB. The inductance between the two parallel plates of this type of capacitor is very low and the capacitance is distributed over a large area.

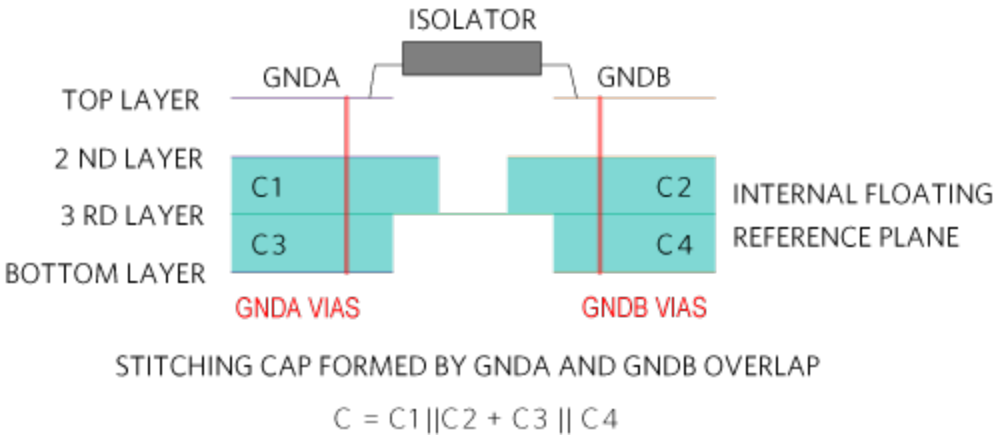


Figure 6. Sample stitching capacitor layout.

The stitch capacitance of the board is calculated as $C_{STITCH} = C_1 \parallel C_2 + C_3 \parallel C_4$.
Each capacitance between the layers is calculated as $C = (l \times w \times \varepsilon_0 \times \varepsilon_r)/d$
where ε_0 is a constant (8.854×10^{-12} F/m) and ε_r is determined by the PCB material. For FR4, $\varepsilon_r = 4.5$ (typ).

The floating stitching capacitance on the MAXM225511 STITCH evaluation board consists of an isolated copper island on an internal layer that overlaps the ground planes on both the cable-side and the UART-side of the transceiver module. Using the equations above, the stitching capacitance for the MAXM22511 STITCH evaluation board is approximately 49pF.

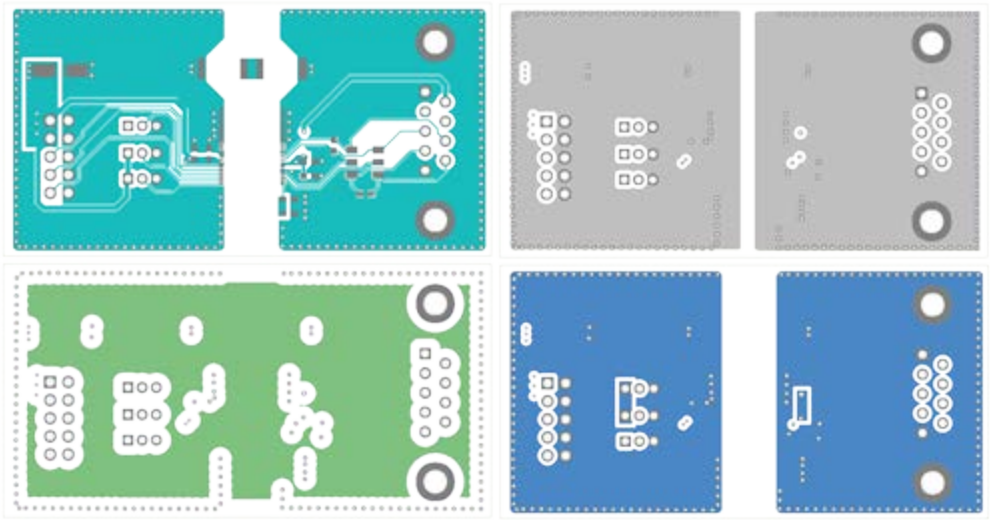


Figure 7. MAXM22511 EMC/EMI optimized board layout. Top (top left), layer 1 (top right), layer 2 for the stitching capacitor (bottom left), and bottom (bottom right).

Edge Guarding/Via Guard Ring

Noise on the ground and power layers in a PCB can radiate upon reaching the edge of the board. While helpful, the use of edge guarding, or a via guard ring around the ground layers, has a significant tradeoff because edge guarding reduces the area on the stitching capacitor layer. In some cases, the board size might need to be slightly increased to obtain the optimum stitching capacitance.

Maxim uses a via guard ring around the edges of the GNDA and GNDB layers of the EMC/EMI optimized boards.

EMI-Optimized Component Selection

To optimize a PCB board for EMC/EMI testing, pay careful attention to the component selection for the circuit. The MAXM22511 does not require any additional external components for operation, but the EMC/EMI optimized boards do include some jumpers and headers to access digital signals and a DB9 connector for the RS-485/RS-422 bus connection. The headers used are compact, and the placement and layout are tightly controlled to avoid compromising the EMC/EMI capabilities of the PCB. The DB9 connector includes an internal ferrite filter to help quell board switching noise.

High dv/dt switching between isolated barriers can cause currents to flow in parasitic capacitances. If these unintended paths have a large loop area, currents flowing through the loop can radiate, causing electromagnetic interference (EMI). Safety rated (5kV PEAK) Y2 capacitors are placed between GNDA and GNDB to help reduce this noise. These capacitors create a short path with a small loop area for parasitic currents to flow, reducing the EMI generated on the board.

MAXM22511 EMC/EMI Performance

Maxim's STITCH vs NO_STITCH

Maxim's in-house EMC/EMI evaluations on the MAXM22511 STITCH evaluation board and the MAXM22511 NO_STITCH evaluation boards are shown in **Figure 8a** and **Figure 8b**. Although all measurements pass the CISPR 11 requirements, any high frequency noise is eliminated with the use of the stitching capacitance.

Note that tests were done with 1MHz switching signals applied to TXD (DE = V_{DDA}, RE = GNDA, 60½ load between Y and Z, and loopback configuration).

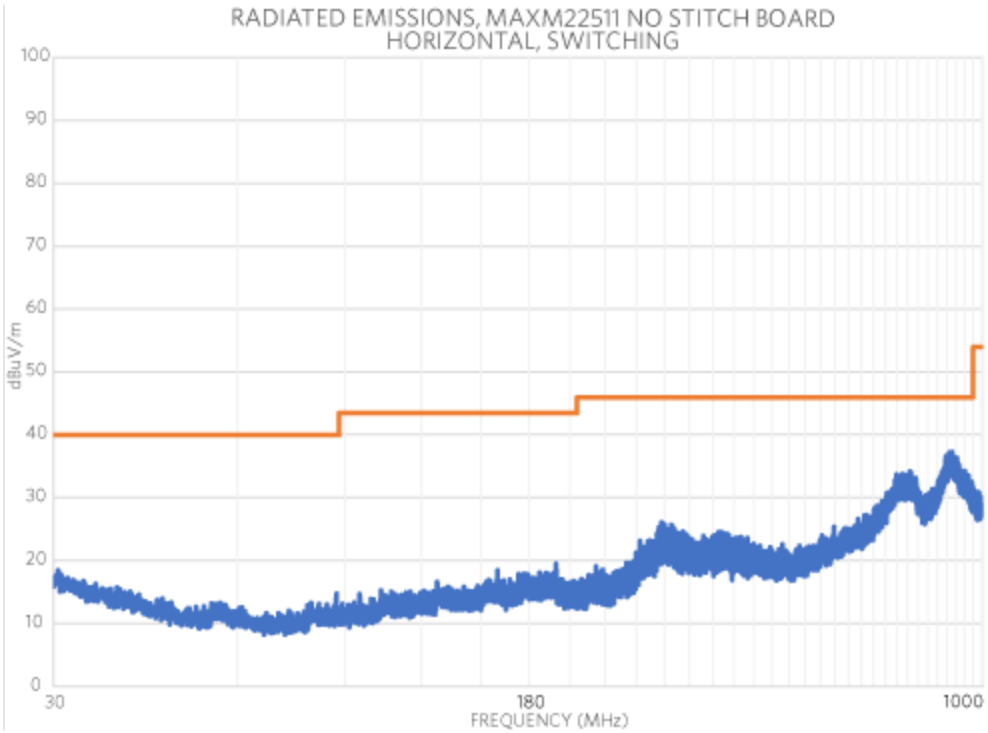


Figure 8a. MAXM22511 EMI optimized NO_STITCH evaluation board measurements.

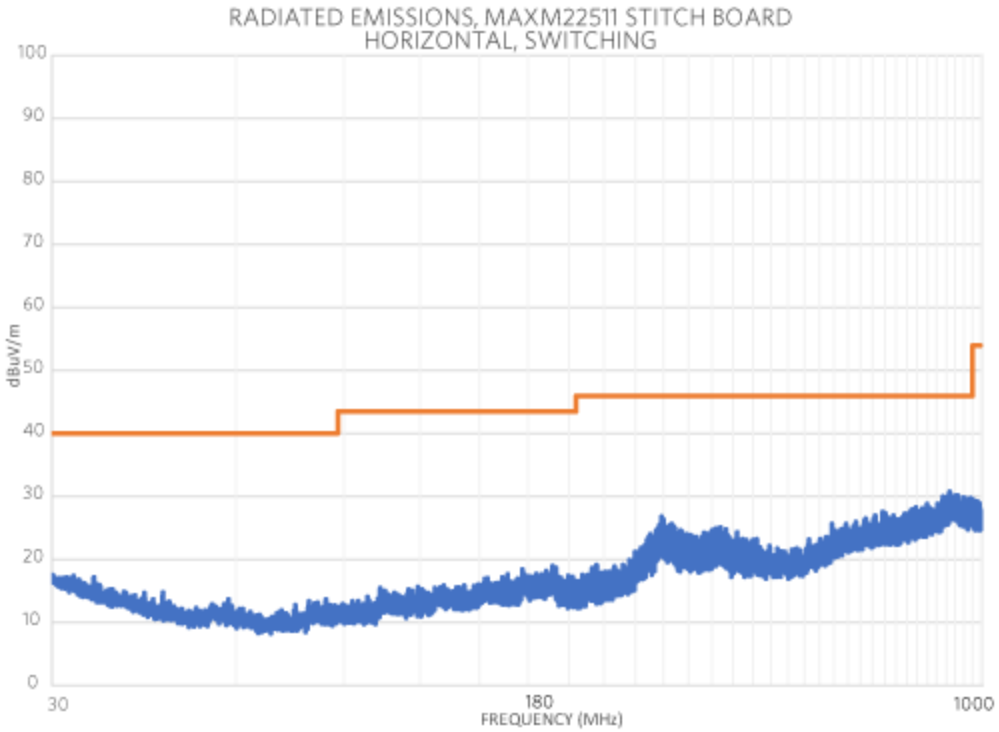


Figure 8b. MAXM22511 EMI optimized STITCH evaluation board measurements.

Comparative Analysis

Using Maxim's in-house lab, we also tested and compared the MAXM22511 (with the MAXM22511 STITCH evaluation board) to two competitors: Competitor A and Competitor B. Both competitor parts were tested on EMI-optimized evaluation boards designed and assembled by their respective manufacturers. Results are shown in **Figure 9**, **Figure 10**, and **Figure 11**. Note that tests were done with 1MHz switching signals applied to TXD (DE = V_{DDA}, RE = GNDA, 60½ load between Y and Z, and loopback configuration).

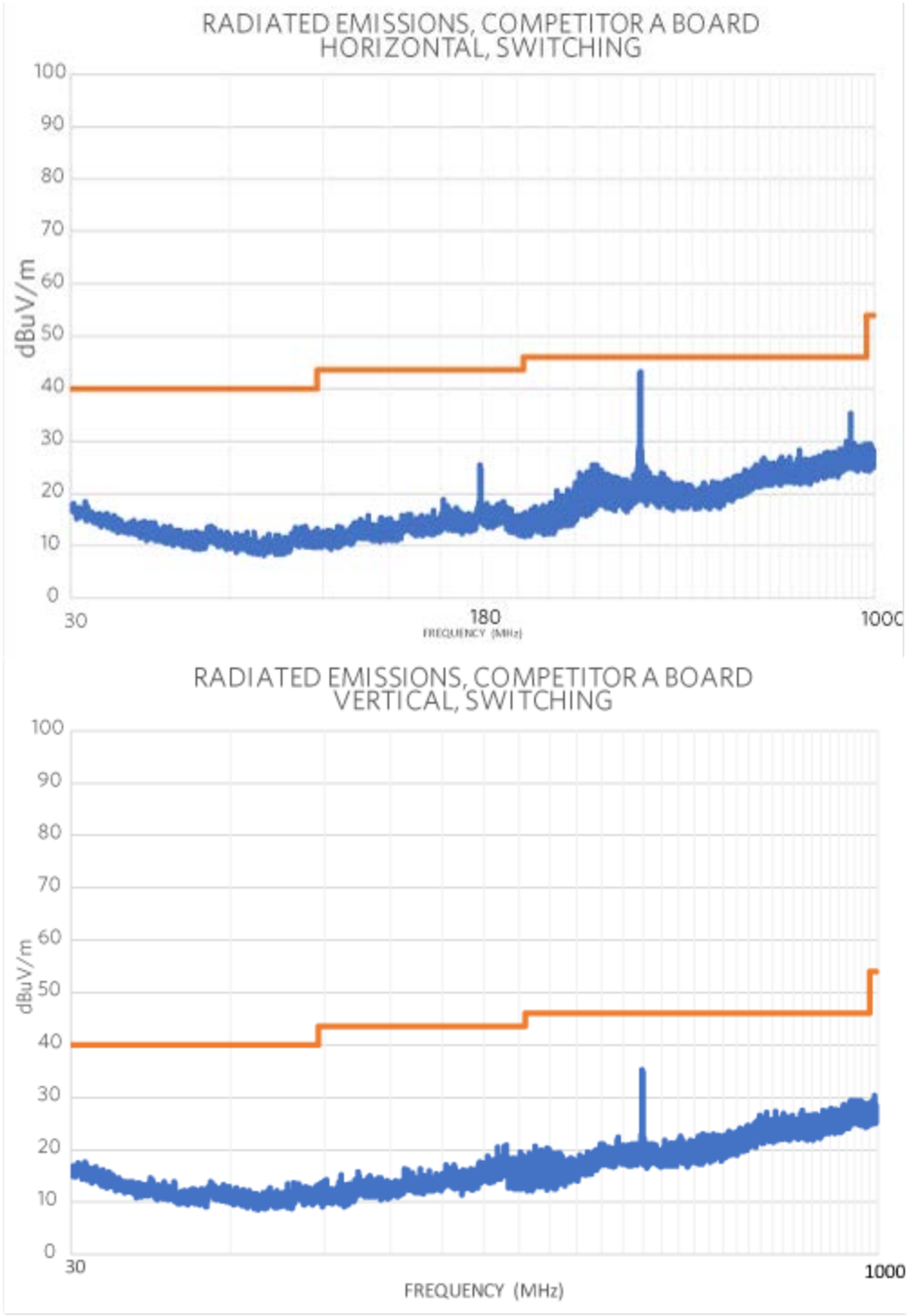


Figure 9. Maxim's in-house radiated emissions test result using competitor A.

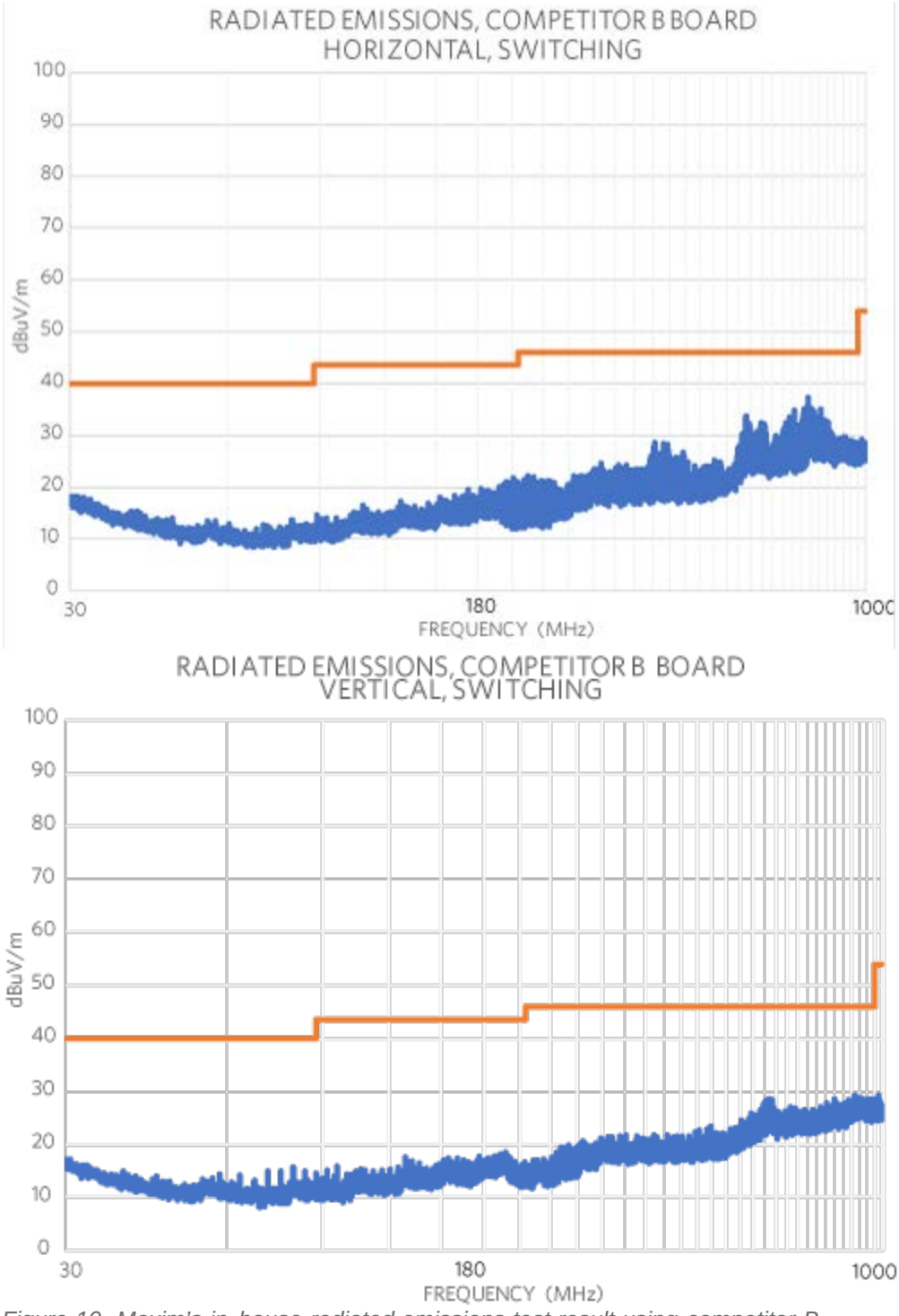


Figure 10. Maxim's in-house radiated emissions test result using competitor B.

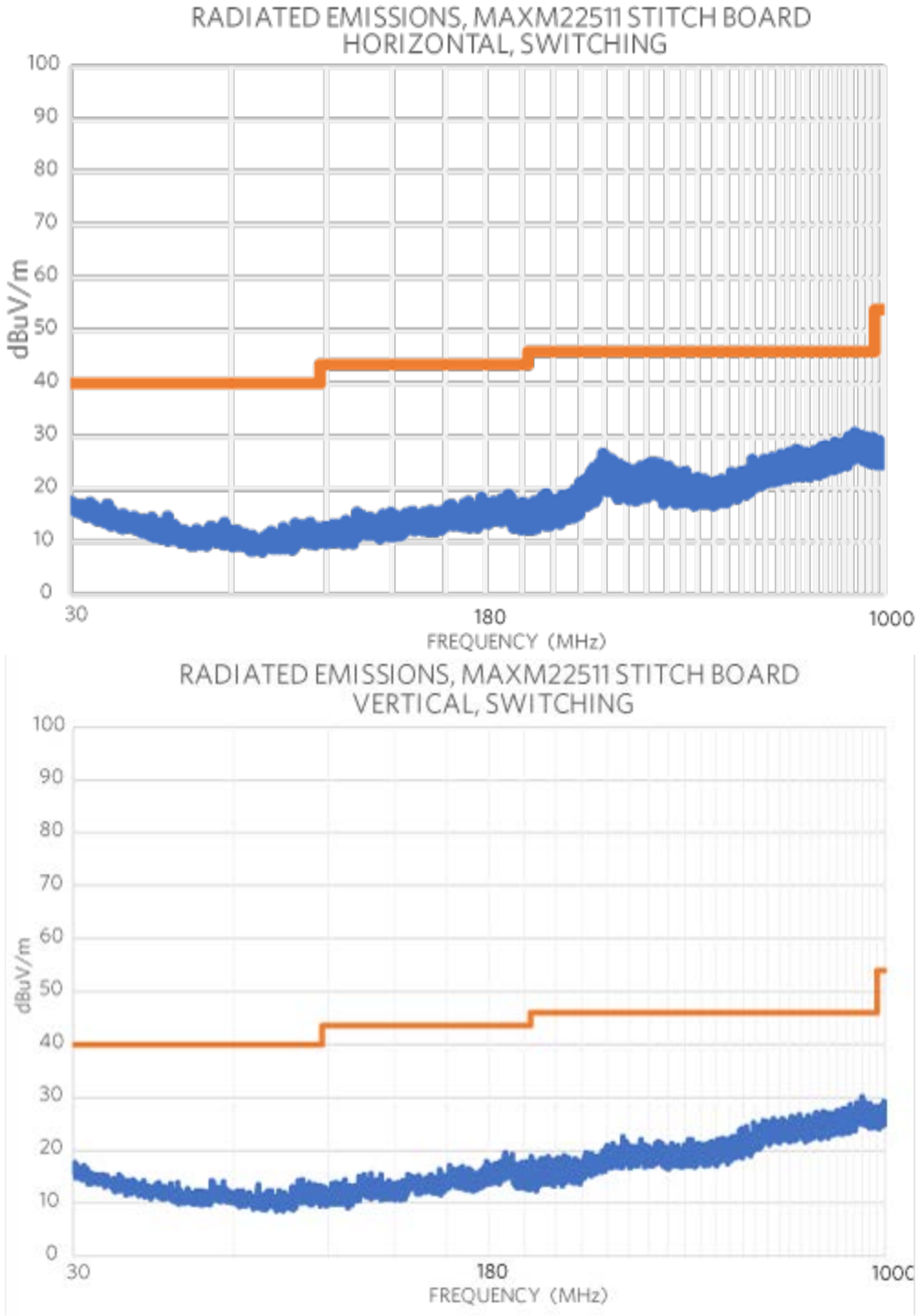


Figure 11. Maxim's in-house radiated emissions test result using the MAXM22511.

Summary

The MAXM22511 module provides RS-485 communication and an integrated DC/DC power supply for robust communication in harsh industrial environments. The combination of Maxim's proprietary technology and an EMI-optimized PCB layout ensures that this transceiver module has the best EMI performance for noise sensitive applications even without the use of stitch-capacitor PCBs.

Related Parts		
MAXM22510	2.5kV$_{RMS}$ Complete Isolated RS-485/RS-422 Module Transceiver + Power	Samples
MAXM22511	2.5kV$_{RMS}$ Complete Isolated RS-485/RS-422 Module Transceiver + Power	Samples

More Information
For Technical Support: https://www.maximintegrated.com/en/support
For Samples: https://www.maximintegrated.com/en/samples
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