USER GUIDE

UG470: Si88xxx Low EMC EVB

Description

This document describes the operation of the Si88xxx Low EMC EVB.

The Si88241 is a digital isolator with an integrated dc-to-dc converter. As with all dc-to-dc converters, conducted and radiated emissions must be carefully studied and controlled.

“AN1131: Design Guide for Reducing Radiated and Conducted Emissions in Isolated Systems Using Skyworks’ Isolators” describes useful EMI suppression techniques in isolated systems using Skyworks’ isolators. The Si88xxx Low EMC EVB reference design using Si88241 describes best practices (described in AN1131) for mitigating emissions and presents test results against the very stringent requirements of the CISPR 25 standard. Customers are encouraged to read AN1131 to understand this EVB implementation.

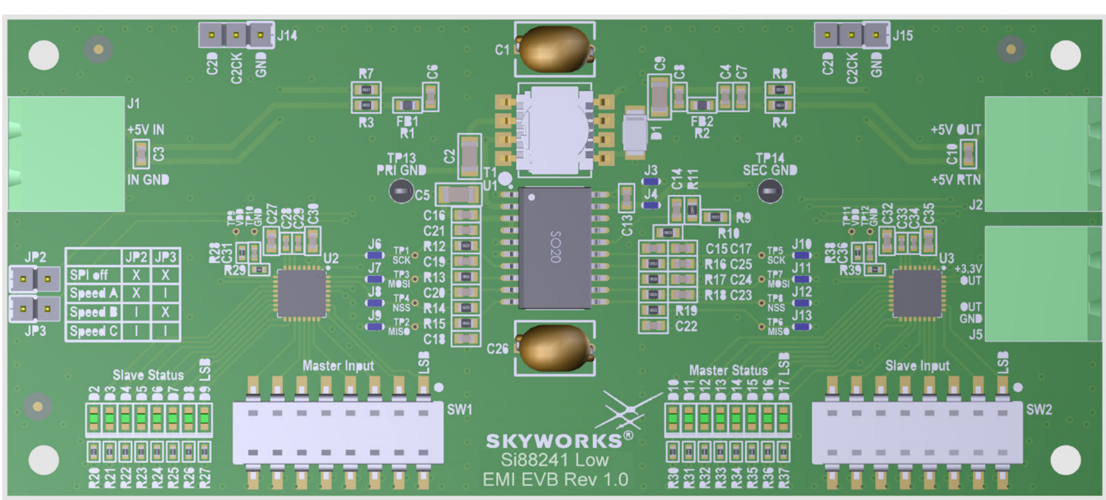
Two MCUs on the primary and secondary sides continuously send SPI data across the isolators. Four channels of bidirectional isolated data transfer with jumper-selectable SPI data rates allow the testing of emissions with actual data traffic. See Figure 1 on page 2.

Key Points

- Operation of the Si88xxx Low EMC EVB
- Schematics and layout
- Bill of materials
- EMC mitigation techniques
- CISPR-25 conducted and radiated emission test results

Kit Contents

- Si88xxx Low EMC EVB



1. Example SPI Waveforms

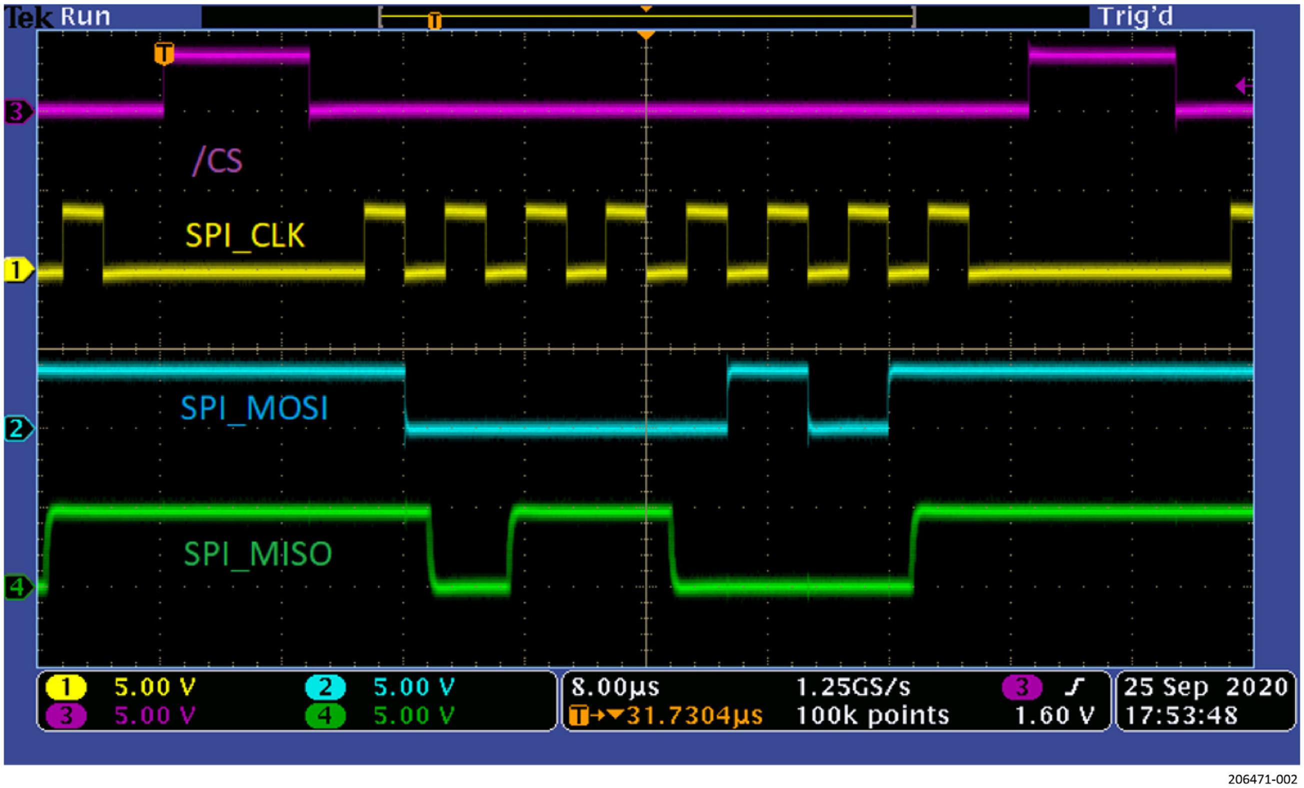


Figure 1. Example SPI Waveforms

2. Hardware Overview and Setup

The Si88xxx Low EMC EVB is a self-contained kit without the need of software control. Its operation is very simple. Power input ranging from 3.3 V to 5 V is applied to J1. The current draw is ~40 – 55 mA after startup, but a power supply or batteries capable of supplying at least 100 mA is recommended to avoid any startup issues. 5 V output power up to 100 mA is available at J2. Regulated 3.3 V output power is available at J5.

The preprogrammed EFM8UB "Universal Bee" MCUs are used for the SPI data demonstration. The main side MCU is U2, and the secondary side MCU is U3. The main MCU continuously reads the switch positions of the 8 SW1 DIP switches and the data are displayed on the LEDs D10–D17 on the secondary side. The secondary side MCU reads the switch positions of the 8 SW2 DIP switches and this data is displayed by LEDs D2 – D9 on the main side. SPI bus communication is used between U2 and U3 MCUs. The SPI data rate is selectable by JP2 and JP3 as shown in the table below.

By default, the Si88241 secondary side is powered from the regulated 3.3 V, but this can be changed to 5 V with solder jumpers J3 and J4.

Table 1. Jumper Position to Select MCU SPI Bus Speed

JP2	JP3	SPI Data Rate
Not populated	Not populated	SPI off
Not populated	Populated	50 KHz
Populated	Not populated	100 KHz
Populated	Populated	187 KHz

3. Si88xxx Low EMC EVB Schematics

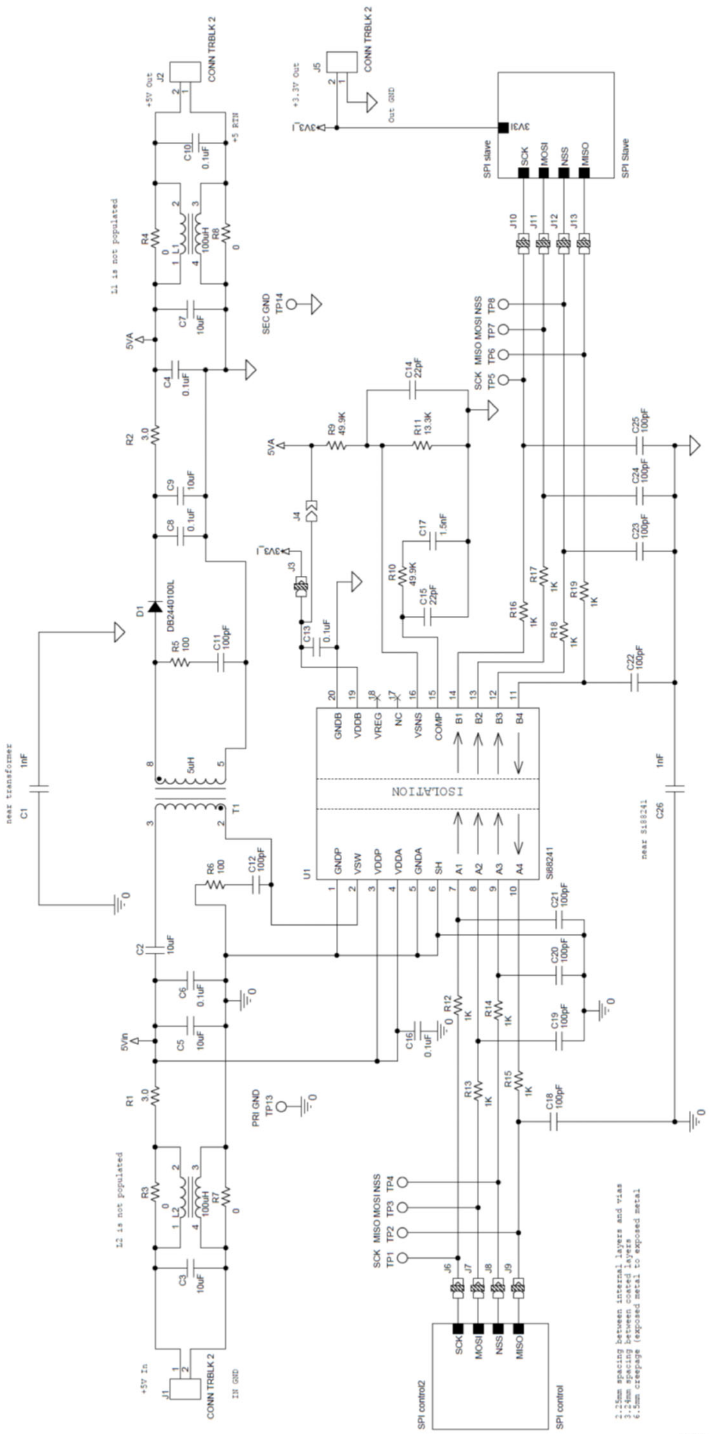


Figure 2. Top Level Schematic Showing Si88241 Connections

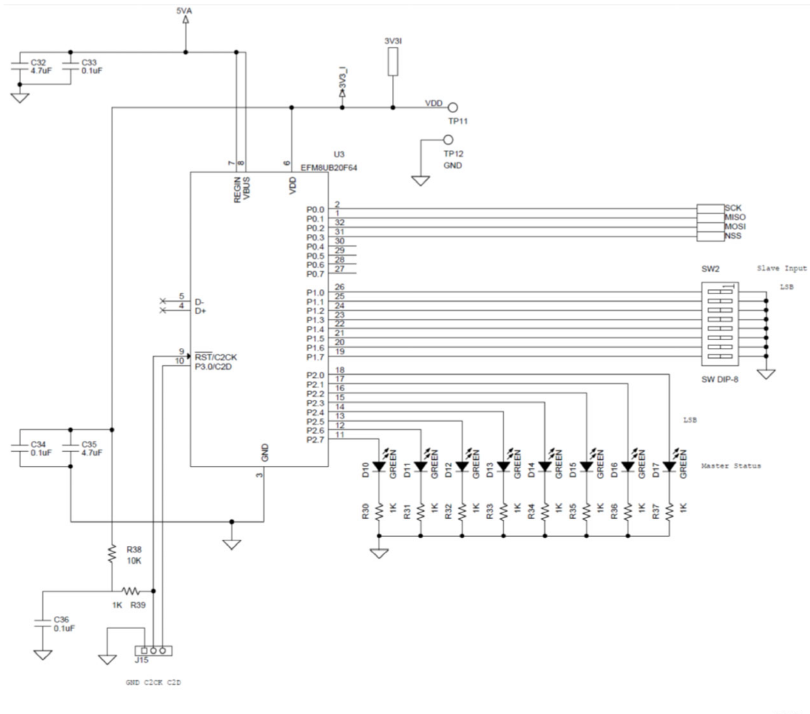


Figure 3. Secondary Side MCU

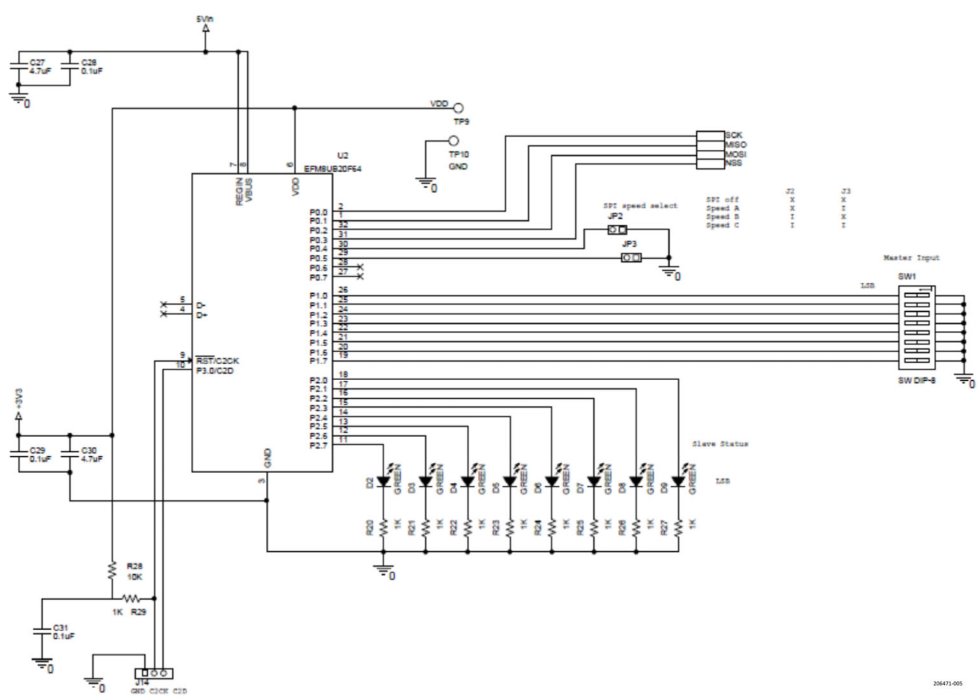


Figure 4. Main Side MCU

4. Bill of Materials

Table 2. Si88xxx Low EMC EVB Bill of Materials

Item	NI	Qty	Ref	Value	Mfr Part Number	Mfr
1		2	C1, C26	1 nF	VY2102M29Y5US6TV7	Vishaly
2		3	C2, C5, C9	10 µF	C1206X7R100-106K	Venkel
3		2	C3, C7	10 µF	C0603X5R100-106K	Venkel
4		6	C4, C6, C8, C10,C13, C16	0.1 µF	C0603X7R100-104K	Venkel
5		2	C11, C12	100 pF	C0603X7R500-101K	Venkel
6		2	C14, C15	22 pF	C0603C0G500-22K	Venkel
7		1	C17	1.5 nF	C0603X7R160-152K	Venkel
8		8	C18, C19, C20,C21, C22, C23, C24,C25	100 pF	C0603C0G500-101M	Venkel
9		4	C27, C30, C32,C35	4.7 µF	C0603X5R6R3-475K	Venkel
10		6	C28, C29, C31,C33, C34, C36	0.1 µF	C0402X7R160-104M	Venkel
11		1	D1	DB24401 00L	DB2440100L	Panasonic
12		16	D2, D3, D4, D5, D6, D7, D8, D9, D10, D11, D12, D13, D14, D15, D16, D17	Green	598-8081-107F	Dialight
13		2	JP2, JP3	Header 1x2	TSW-102-07-T-S	Samtec
14		3	J1, J2, J5	CONN TRBLK 2	1757242	Phoenix Contact
15		9	J3, J6, J7, J8, J9, J10, J11, J12, J13	NC	SB0603-NC	N/A
16		1	J4	NO	SB0603-NO	N/A
17		2	J14, J15	Header 1x3	TSW-103-07-T-S	Samtec
18	X	2	L1, L2	100 µH	DLW43SH101XK2L	Murata
19		2	R1, R2	3 Ω	CR0603-10W-3R00F	Venkel
20		4	R3, R4, R7, R8	0 Ω	ERJ-3GEY0R00V	Panasonic
21		2	R5, R6	100 Ω	CR0603-16W-1000F	Venkel
22		2	R9, R10	49.9 k Ω	CR0603-10W-4992F	Venkel
23		1	R11	13.3 k Ω	CR0603-16W-1332F	Venkel
24		8	R12, R13, R14, R15, R16, R17, R18, R19	1 k Ω	CR0603-16W-1001F	Venkel

Table 2. Si88xxx Low EMC EVB Bill of Materials

Item	NI	Qty	Ref	Value	Mfr Part Number	Mfr
25		16	R20, R21, R22, R23, R24, R25, R26, R27, R30, R31, R32, R33, R34, R35, R36, R37	1 k Ω	CR0402-16W-102J	Venkel
26		2	R28, R38	10 k Ω	CR0402-16W-1002F	Venkel
27		2	R29, R39	1 k Ω	CR0402-16W-1001F	Venkel
28		2	SW1, SW2	SW DIP-8	219-8MST	CTS
29		12	TP1, TP2, TP3, TP4, TP5, TP6, TP7, TP8, TP9, TP10, TP11, TP12	TPV	N/A	N/A
30		2	TP13, TP14	Black	151-203-RC	Kobiconn
31		1	TP1	5 µH	TTER09-1149SG	Mentech
32		1	U1	Si88241	Si88241EC-IS	Skyworks
33		2	U2, U3	EFM8UB 20F64		

5. Si88xxx Low EMC EVB Layout

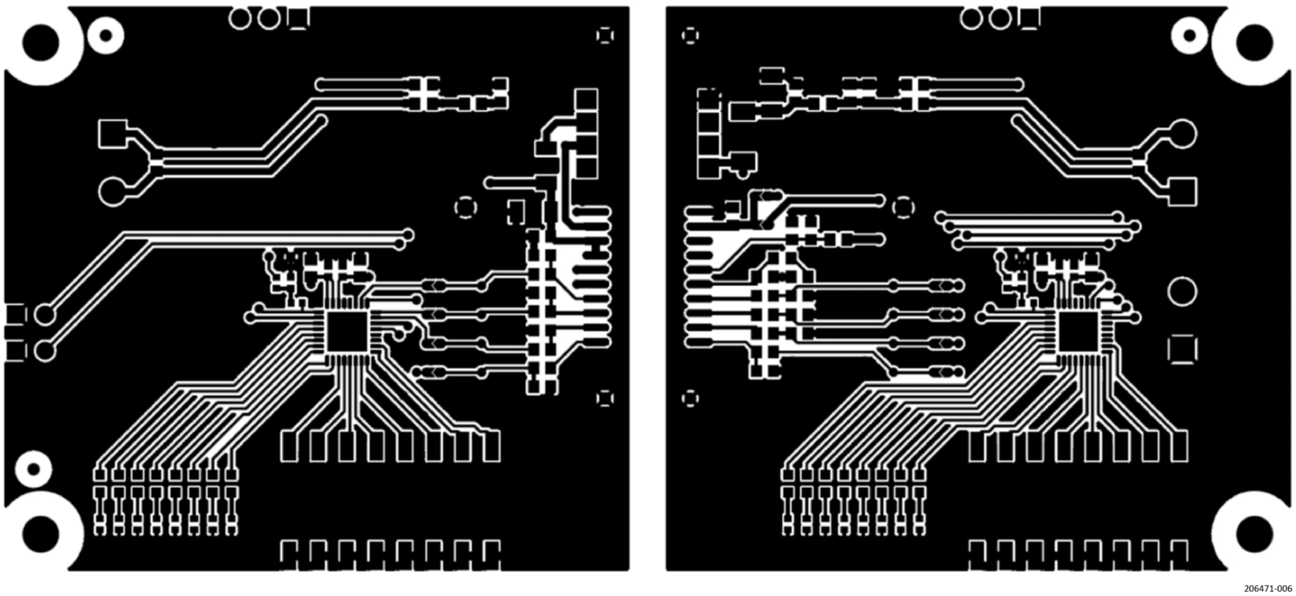


Figure 5. Top Side Layout

The top layer has the input and output ground planes filling in the areas where there is not routing. Stitching vias connect to other ground planes throughout.

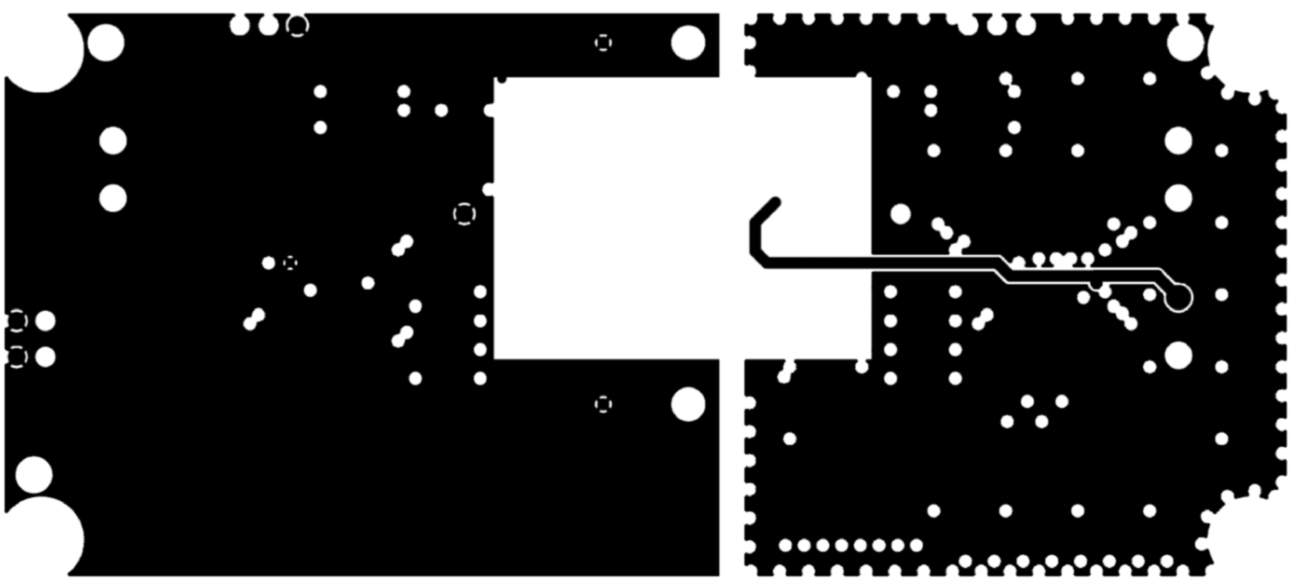


Figure 6. Layer 2 Layout

Layer 2 has a ground plane on the left side that extends under the top side Layer 1 ground plane. There is no fill in the transformer area so that switching nodes on one side do not couple noise to the ground planes on the other side.

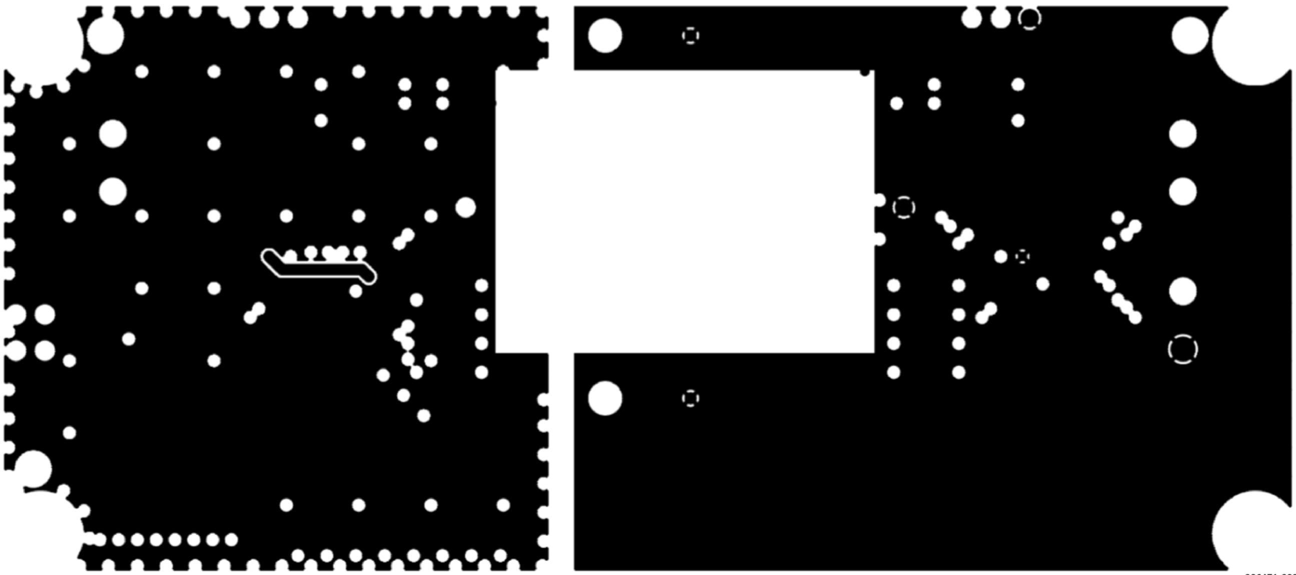


Figure 7. Layer 3 Layout

Layer 3 has a ground plane on the right side that extends under the top side Layer 1 ground plane. There is no fill in the transformer area so that switching nodes on one side do not couple noise to the ground planes on the other side.

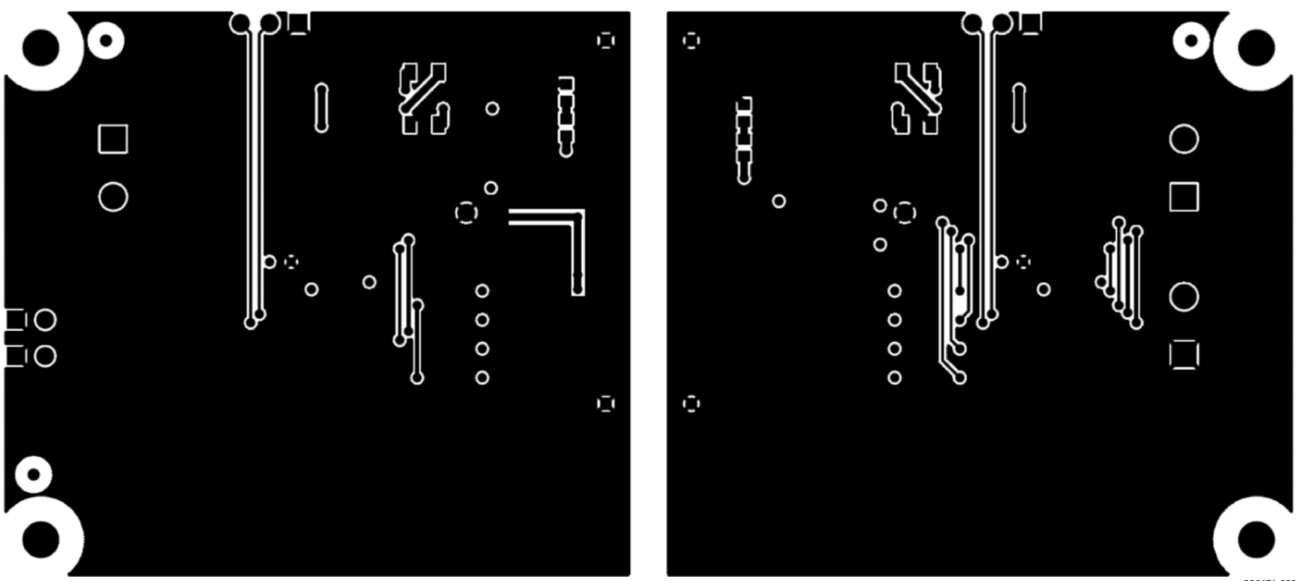


Figure 8. Bottom Side Layout

The bottom layer has the input and output ground planes filling in the areas where there is not routing. Stitching vias connect to other ground planes throughout.

6. EMC Mitigation Techniques and Results

The Si88241 digital isolator with integrated dc-dc controller can produce emissions from a variety of sources. More detail about the emission source and mitigation skills can be found in "AN1131: Design Guide for Reducing Radiated and Conducted Emissions in Isolated Systems Using Skyworks' Isolators." These sources include:

- Input or output ripple associated with the dc-to-dc converter can cause conducted emissions.
- Interwinding capacitance of the dc-to-dc converter transformer can result in conducted emissions.
- Current loops associated with the dc-to-dc converter operation can cause radiated emissions.
- The RF energy associated with transmitting digital 1s and 0s across the isolation barrier can result in either conducted or radiated emissions.
- Variable current consumption of the RF transmitter can modulate the power supply voltage resulting in conducted emissions.

6.1. EMC Mitigation Techniques Described in AN1131

To mitigate the EMC issues, the following techniques were used:

- An RC filter of 3 Ω plus 10 µF was used for the input and output ports to filter power supply ripple. This limits the available power level from the dc-to-dc converter. For higher power applications, an inductor could be used.
- The flyback transformer is a special design with 8-10 layers of tape between the primary and secondary side winding to reduce interwinding capacitance.
- The inner ground planes overlap external ground planes to give a very high quality capacitor shorting conducted emissions.
- Additional "Y" capacitors were added between the planes to improve the shorting at lower frequencies. Through hole capacitors were used for up to 2500 Vrms isolation.
- The ground planes are all stitched together with a large number of vias.
- The layout of the primary and secondary wiring in the area between the IC controller and the flyback transformer was optimized for short lead length and the smallest possible current loops.
- Power supply decoupling capacitors are placed as close to IC power leads as possible.
- Small capacitors C18-C25 are used in the SPI signal path so that data transitions do not produce sharp edges. While not strictly required for emissions.
- A small capacitor, C14, is used in the dc-to-dc controller feedback path to reduce susceptibility to radiated emissions.
- An option for common-mode chokes on the input and output power leads was added-these chokes are not generally required, and the test results are without chokes.

6.2. EMC Requirements

The following are some representative specifications.

CISPR 16—Specification for radio disturbance and immunity measuring apparatus and methods - Part 1: Radio disturbance and immunity measuring apparatus:

This specification refers to measurement techniques for conducted and radiated emissions but generally does not give specific requirements. The results section of this note covers conducted emissions measured at the input and output power ports. Conducted emissions requirements refer to power and signal lines that can be routed over relatively long distances - this is not generally the case for the SPI data lines on the evaluation board, so these lines are not measured. That said, SPI traffic can contribute to conducted emissions measured at the power ports. Conducted and radiated emissions are for the complete demo board with SPI traffic at the maximum speed of 187.25 kHz.

CISPR 22(EN55022)—Information Technology Equipment - Radio Disturbance characteristics - limits and methods of measurement:

This specification gives limits for radiated and conducted emissions from telecommunications equipment. This specification is generally for complete systems and does not have requirements to the component level. These system level requirements would probably not apply for conducted emissions for a component like the Si88241, but radiated emissions from the Si88241 and associated circuitry would likely add to radiated emissions from other components so the radiated emissions from the Si88241 should be well below the system requirement, for example, 30 – 230 MHz, 30 dBµV/m quasi-peak, and 230 –1000 MHz, 37 dBµV/m quasi-peak.

CISPR 25—Vehicles, boats and internal combustion engines - Radio disturbance characteristics - Limits and methods of measurement for the protection of onboard receivers:

This specification applies to complete vehicles, such as automobiles, but also gives limits for components within the vehicle. For example, if the Si88241 were part of a module within a car that is power by the car battery and thus could have long power leads, the module would be considered a "component" and the component level conducted emissions requirements would apply. While the Si88241 is generally powered by a lower voltage such as 5 V, the conducted emissions requirements of CISPR 25 could apply directly if the 5 V power source was routed by long leads or to the extent that conducted emissions produced by the Si88241 would also appear at the battery connection leads. As these specifications apply to the component level. they are more restrictive than for a complete system. For example, in the FM band, the requirements are 18 dBµV average for conducted emissions and 18 dBµV/m average for radiated emissions.

In addition to international standards, system manufacturers may have their own requirements and these requirements are generally more restrictive than international standards. For example, VW TL81000 has a component level requirement that is similar to CISPR 25 but with limits as low as 12 dBµV average for conducted emissions in the FM band.

6.3. Test CISPR-25 Test Result

6.3.1. Test Setup

The figure below shows the EMI test setup connection based on CISPR-25 standard Annex I clause. The Si88xxx Low EMC EVB is designed to interface with LV (low voltage) and HV (high voltage, typically >60 V) power domains in the electrical/hybrid vehicle application. Please note that J2 and J5 provide the isolated power output which has the different isolated ground reference than the J1 input power rail. In this test setup, two bench power supplies are used to produce +5 V (LV) and +91 V (HV) floating voltage sources. The ultimate voltage reference point is the ground reference plane in the EMI test lab. All J1, J2, J5, LV power supply, and HV power supply are not grounded. The artificial network (AN) is used to interface the EVB power connectors (J1, J2, and J5) and external LV/HV bench power supplies. An AN blocks the noise from the power supply and also provides the 50 Ω termination resistor.

A 100 Ω resistor is connected at 5 V power output (J2) to simulate the power load. In the EV/HEV battery management application, MCU on the secondary side often needs to monitor the HV battery voltage level. The high impedance 10 M Ω sense resistor is used between MCU 3.3 V voltage rail and HV power source in the test setup to mimic this A-D convert behavior.

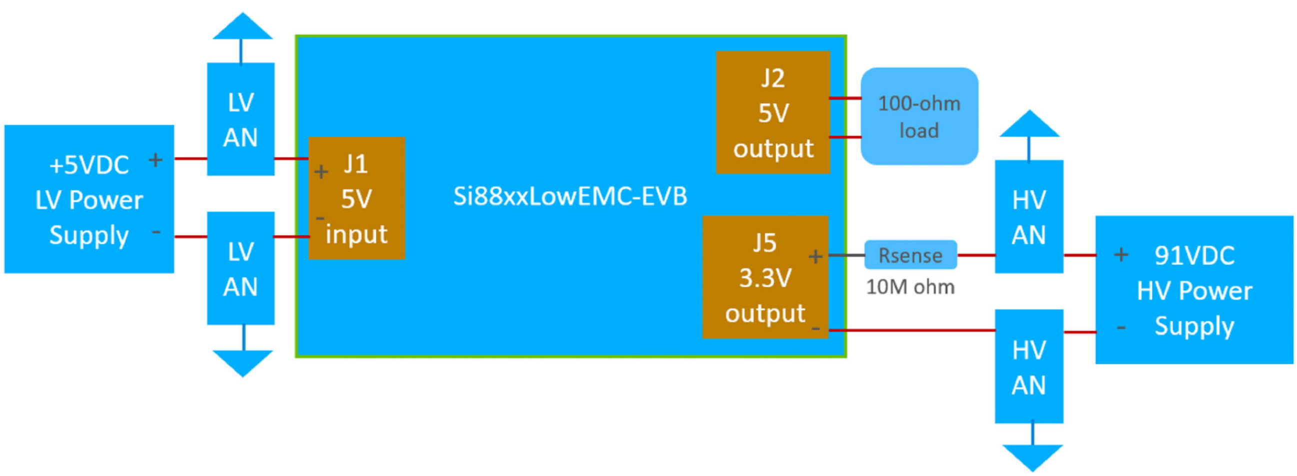


Figure 9. CISPR-25 EMI Test Setup Connection

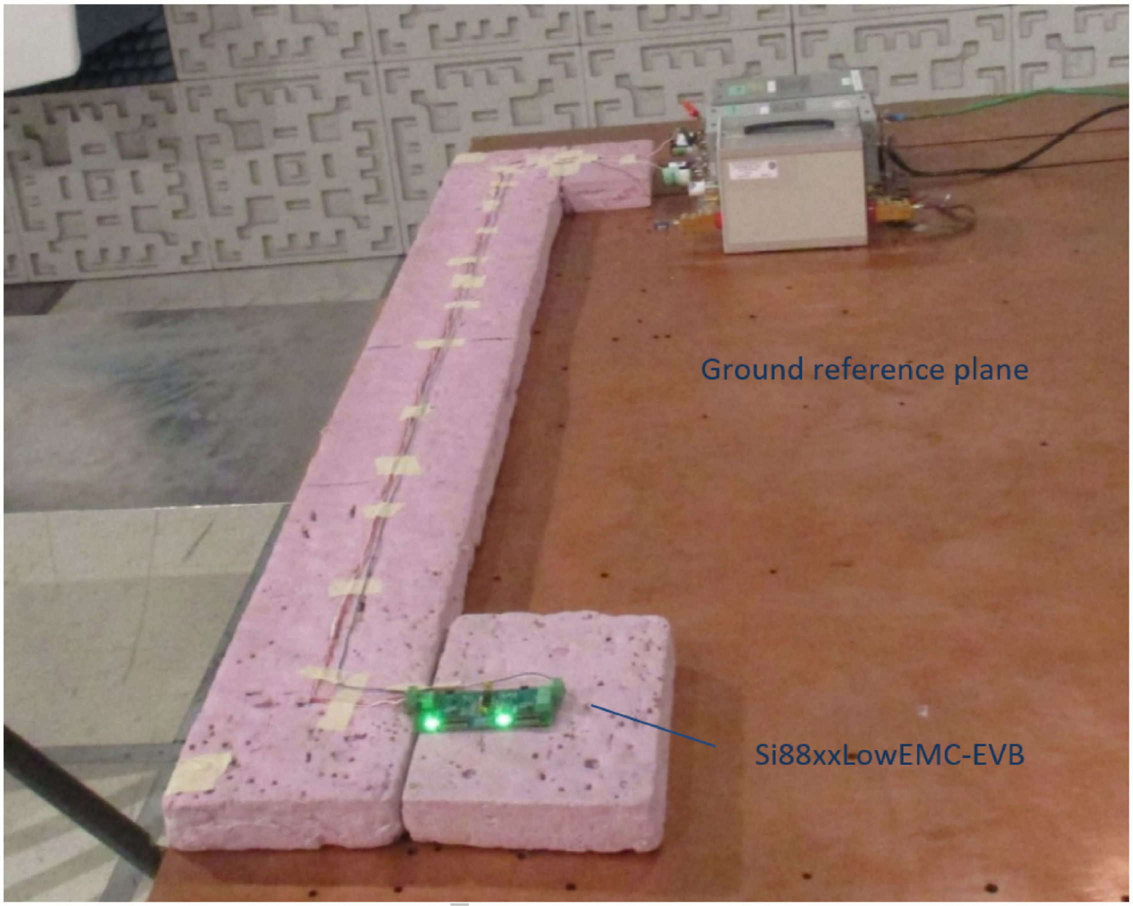


Figure 10. CISPR-25 EMI Lab Test Setup

6.3.2. CISPR-25 Conducted and Radiated Test Results

The Si88xxx Low EMC EVB passed the CISPR-25 conducted and radiated EMI tests with Class 5 limits. The only exception was 250KHz frequency point in the radiated emission test slightly exceeded Class 5 limit but still complied with Class 4 limit. This frequency point belongs to the LW (long wave) AM radio frequency band and is not commonly used in the vehicles.

There are two types of conducted emission measurements: voltage method and current method. For voltage method, the conduced emission was measured on artificial networks of both positive and negative LV power supply lines. For the current method, the current probe was clamped on all power supply lines. The radiated emission results included vertical and horizontal antenna polarities.

Class 5 limits and the measured results are represented in the following figures.

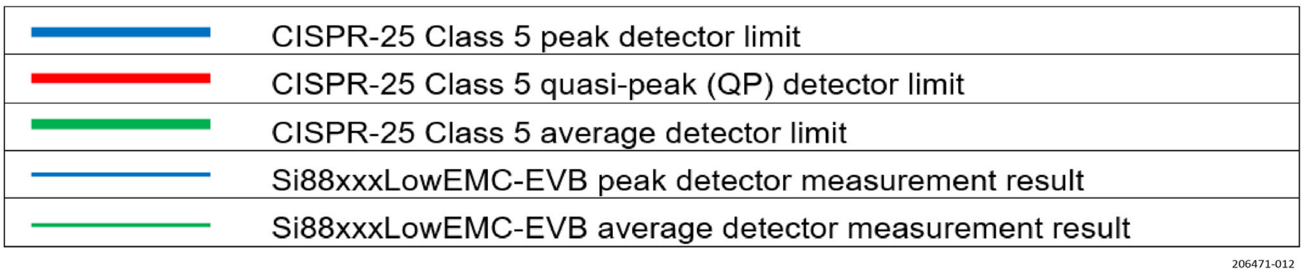


Figure 11. Test Results Legend

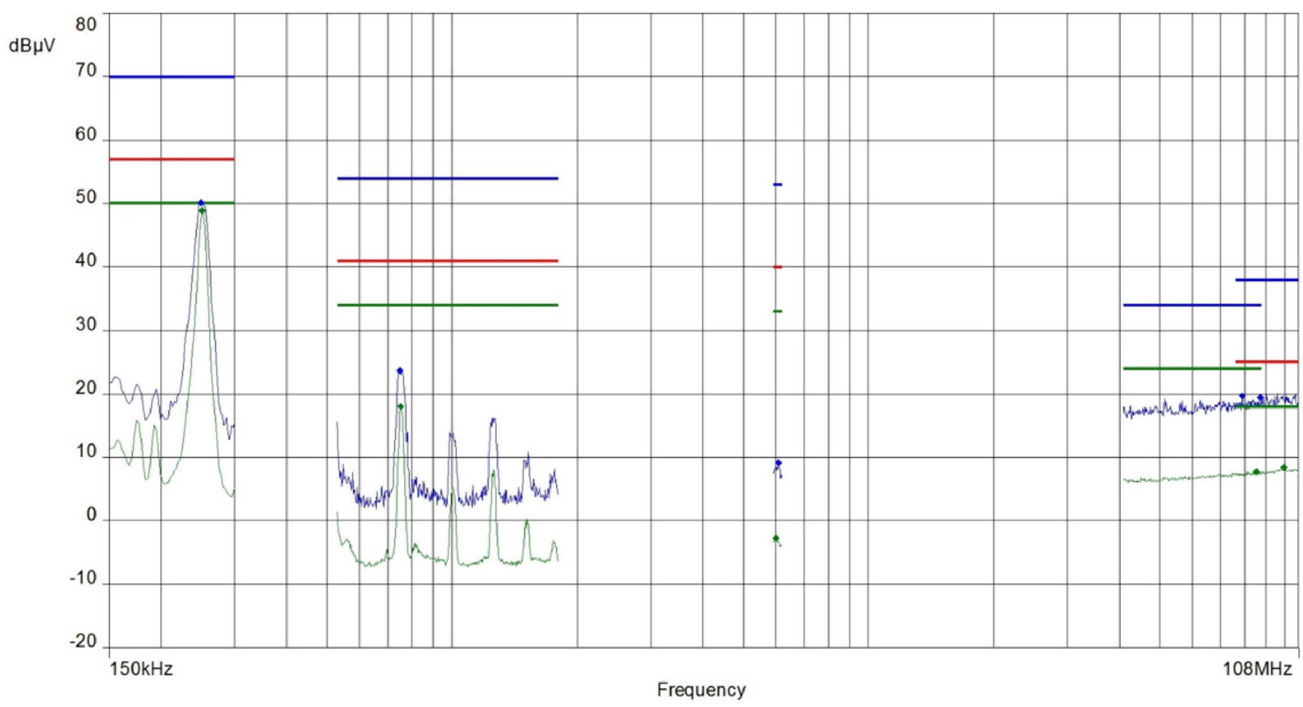


Figure 12. Conducted Noise-LV Power Positive Line Voltage 150 kHz ~ 108 MHz

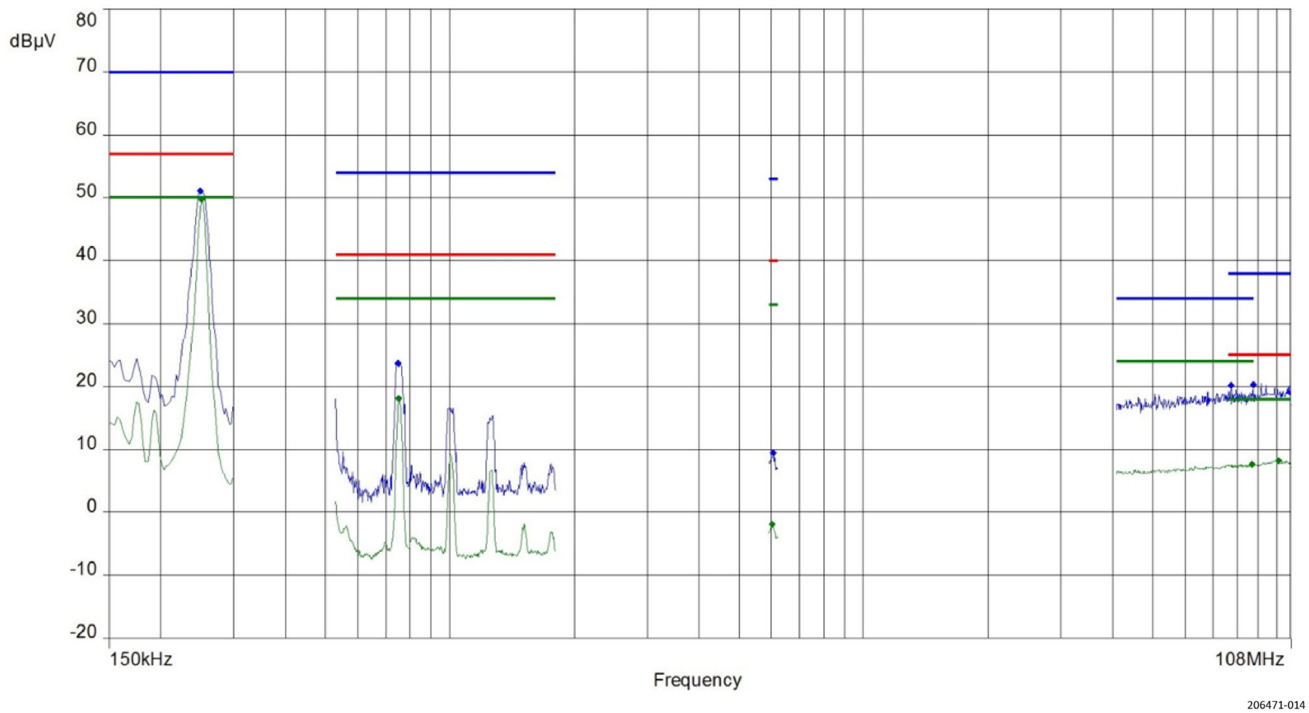


Figure 13. Conducted Noise-LV Power Negative Line Voltage 150 kHz ~ 108 MHz

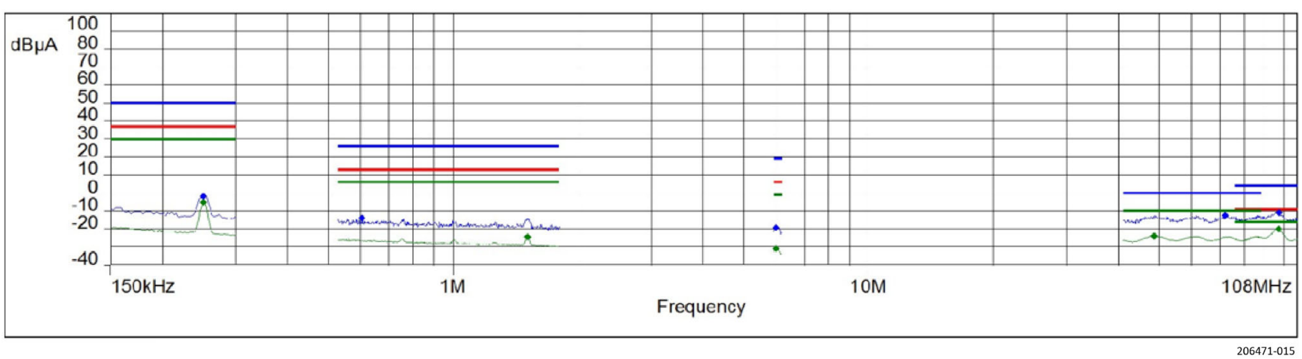


Figure 14. Conducted Noise-Power Line Current 150 kHz ~ 108 MHz

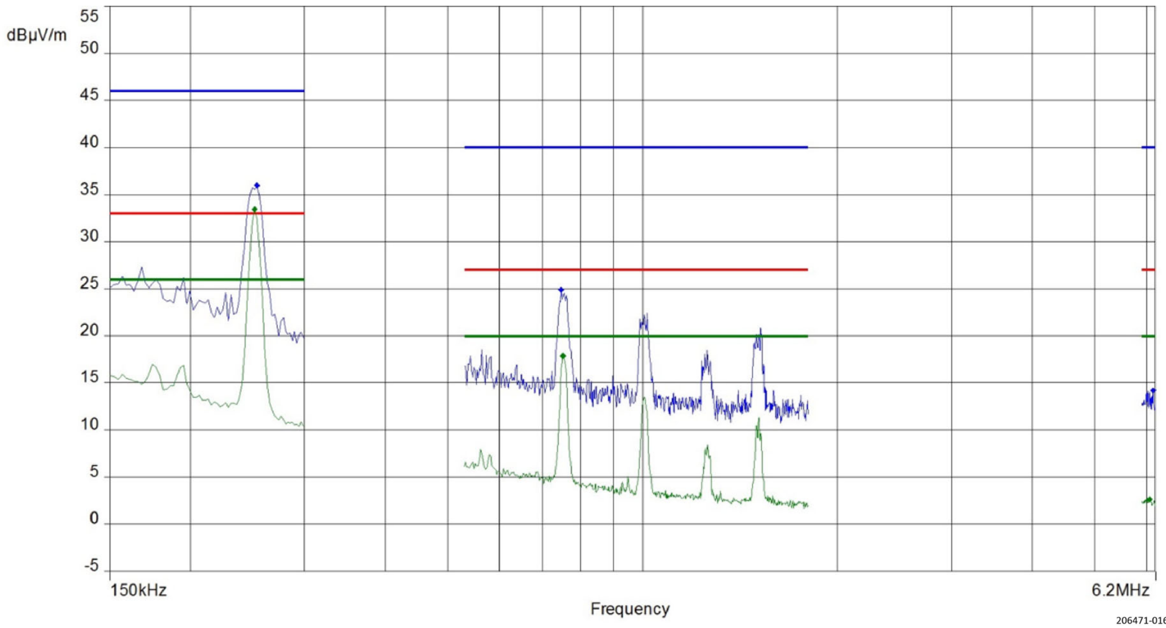


Figure 15. Radiated Emission-150 kHz ~ 6.2 MHz

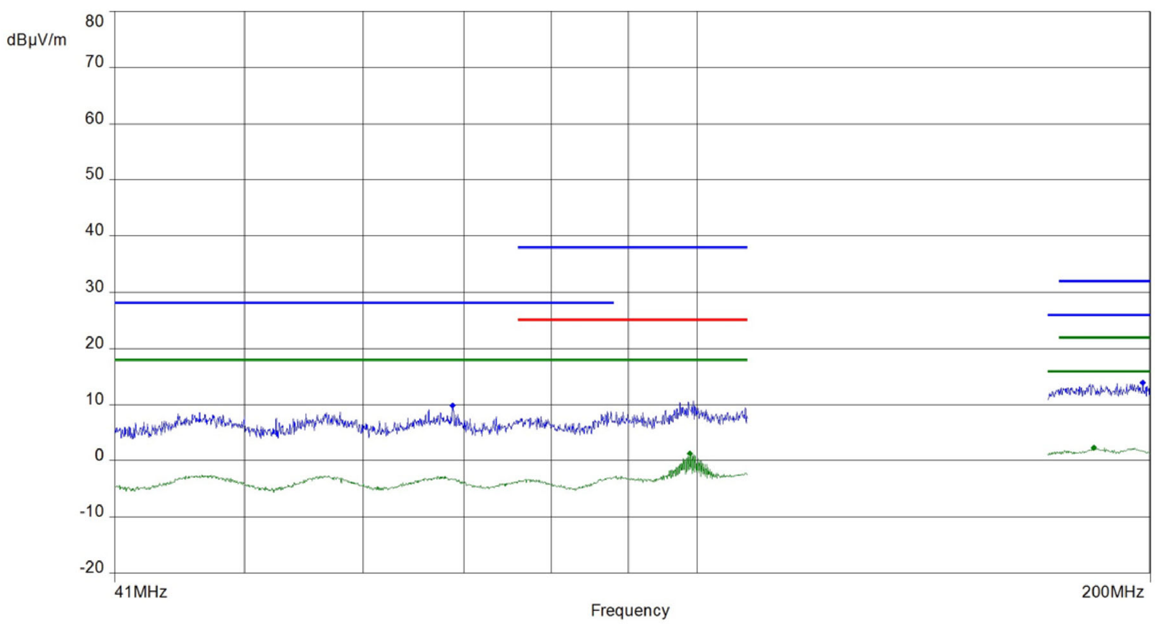


Figure 16. Radiated Emission-41 MHz ~ 200 MHz Vertical Mode

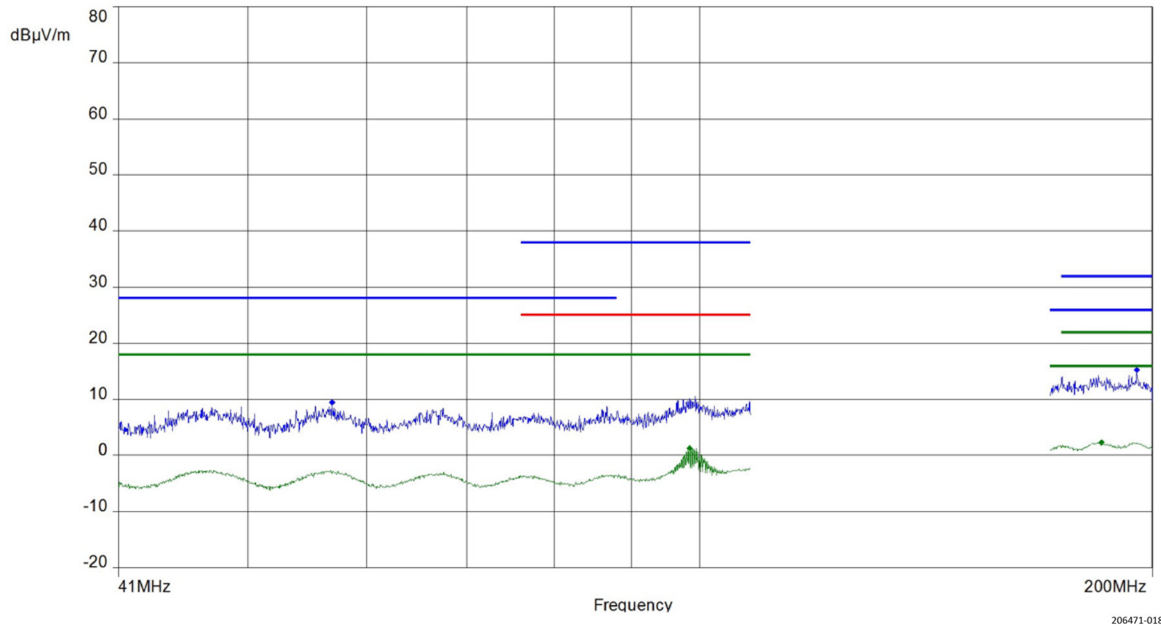


Figure 17. Radiated Emission-41 MHz ~ 200 MHz Horizontal Mode

7. Ordering Information

Full schematic, BOM, and layout files are available for download.

Ordering Part Number	Description
Si88XXXLOWEMC-KIT	Si88xxx EVB optimized for low EMC

8. Revision History

Revision	Date	Description
B	July, 2023	Added new section for ordering information
A	January, 2023	Initial release