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AN-1398 APPLICATION NOTE

System Level EMC Solution for Isolated RS-485 Communication Interfaces in Harsh Industrial Environments Using the ADM2795E

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INTRODUCTION

The ADM2795E is a 5 kV rms signal isolated RS-485 transceiver, integrating Analog Devices, Inc., *i*Coupler® technology with an RS-485 transceiver, and international electrotechnical commission (IEC) electromagnetic compatibility (EMC) protection in a single package. The ADM2795E is designed for RS-485 communication interfaces in harsh industrial environments that face a number of threats, which can disrupt communication or result in permanent damage. Industrial automation programmable logic controller (PLC) communication ports, which commonly use RS-485 interfaces, can be subjected to large common-mode noise, ground potential differences, miswiring faults, and high voltage transients such as electrostatic discharge (ESD), electrical fast transients (EFT), and lightning surges. System level IEC standards, such as IEC 61131-2 for industrial automation, specify varying levels of protection against IEC ESD, EFT, and surge, as well as immunity to radiated, conducted, and magnetic disturbances.

SUMMARY OF CERTIFIED IEC EMC PERFORMANCE

The ADM2795E provides a complete system level solution, with compliance to IEC 61000 surge, EFT, and ESD standards as well as immunity to conducted, radiated, and magnetic disturbances, common in industrial environments. Integration of isolation robustness and EMC protection saves significant printed circuit board (PCB) board space for the communication port interface. The ADM2795E also integrates a comprehensive ±42 V high voltage fault protection.

This application note provides reference evaluation board and sample test setups, which demonstrate the certified IEC EMC performance of the ADM2795E:

- Certified Level 4 EMC protection on RS-485 A and B bus pins
    - IEC 61000-4-5 surge protection (±4 kV)
    - IEC 61000-4-4 EFT protection (±2 kV)
    - IEC 61000-4-2 ESD protection
        - ±8 kV contact discharge
        - ±15 kV air discharge
    - IEC 61000-4-6 conducted RF immunity (10 V/m rms)
- Certified IEC 61000 immunity across the isolation barrier
    - IEC 61000-4-2 ESD, IEC 61000-4-4 EFT, IEC 61000-4-5 surge, IEC 61000-4-6 conducted RF immunity, IEC 61000-4-3 radiated immunity, and IEC 61000-4-8 magnetic immunity

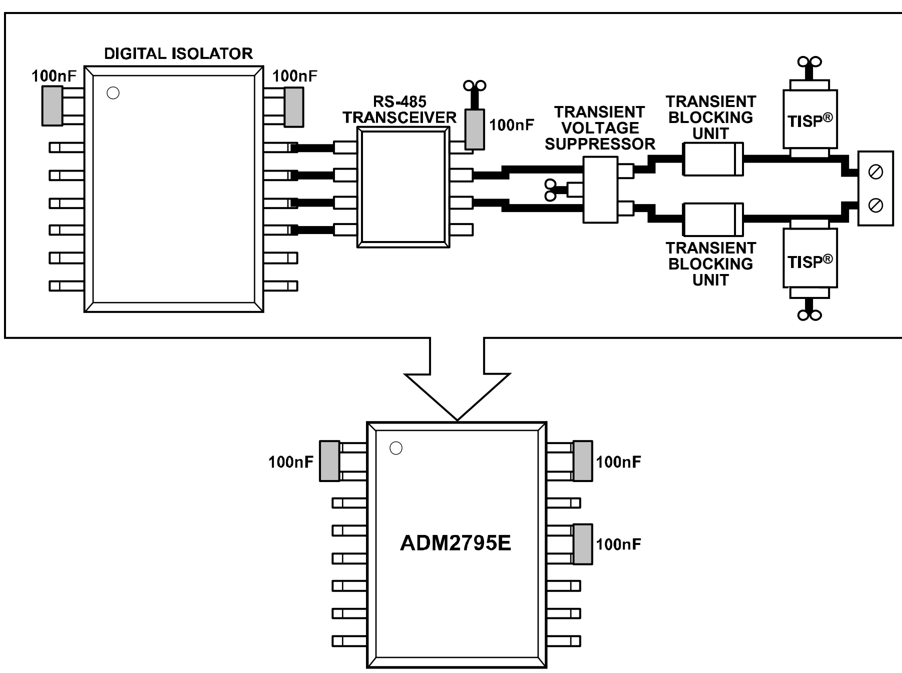

Figure 1. ADM2795E Certified Integrated IEC 61000-4-5 Surge Solution, Saving the Designer Significant PCB Area

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REVISION HISTORY

12/2016—Revision 0: Initial Version

IEC ESD, EFT, AND SURGE PROTECTION

Electrical and electronic equipment must be designed to meet system level IEC standards. The following are examples of system level IEC standards:

- Process control and automation: IEC 61131-2
- Motor control: IEC 61800-3
- Building automation: IEC 60730-1

For data communication lines, these system level standards specify varying levels of protection against the following three types of high voltage transients:

- IEC 61000-4-2 ESD
- IEC 61000-4-4 EFT
- IEC 61000-4-5 surge

Each of these specifications defines a test method to assess the immunity of electronic and electrical equipment against the defined phenomenon. The following sections summarize each of these tests. The ADM2795E has been fully tested in accordance with these IEC EMC specifications, and has been certified IEC EMC compliant.

ELECTROSTATIC DISCHARGE

ESD is the sudden transfer of electrostatic charge between bodies at different potentials caused by near contact or induced by an electric field. It has the characteristics of high current in a short time period. The primary purpose of the IEC 61000-4-2 test is to determine the immunity of systems to external ESD events outside the system during operation. IEC 61000-4-2 describes testing using two coupling methods: contact discharge and air gap discharge. Contact discharge implies a direct contact between the discharge gun and the unit under test. During air discharge testing, the charged electrode of the discharge gun is moved toward the unit under test until a discharge occurs as an arc across the air gap. The discharge gun does not make direct contact with the unit under test. A number of factors affect the results and repeatability of the air discharge test, including humidity, temperature, barometric pressure, distance, and rate of approach to the unit under test. The air gap discharge test method is a better representation of an actual ESD event but is not as repeatable as contact discharge testing; therefore, contact discharge is the preferred test method.

During testing, the data port is subjected to at least 10 positive and 10 negative single discharges with a minimum of a 1 sec interval between each pulse. Selection of the test voltage is dependent on the system end environment.

Figure 2 shows the 8 kV contact discharge current waveform as described in the IEC 61000-4-2 specification. Some of the key waveform parameters are rise times of less than 1 ns and pulse widths of approximately 60 ns.

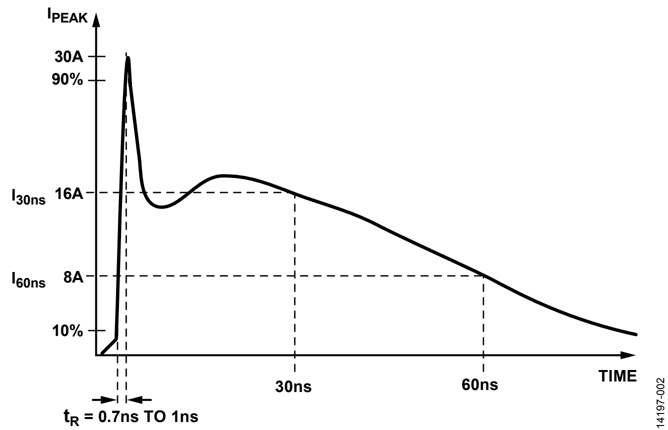

Figure 2. IEC61000-4-2 ESD Waveform (8 kV)

Figure 3 shows an example test setup where the ADM2795E evaluation board was tested to both contact discharge and air discharge for the IEC 61000-4-2 ESD standard.

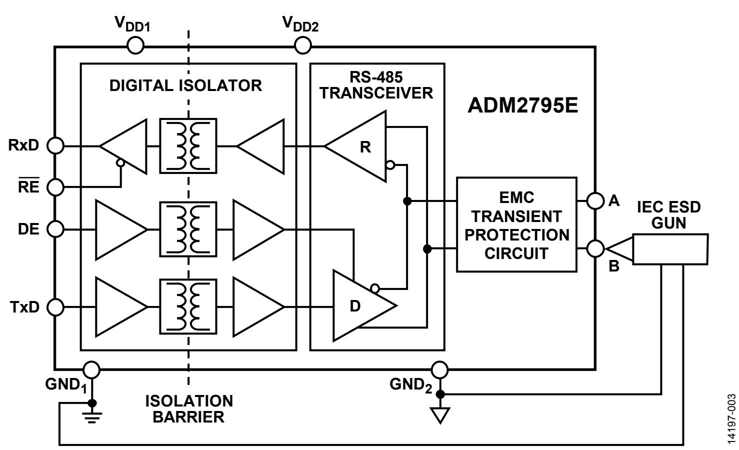

Figure 3. IEC 61000-4-2 ESD Testing to GND_1 or GND_2

Testing was performed with the IEC ESD gun connected to the local bus, GND_2. In testing to GND_2, the ADM2795E is robust to IEC 61000-4-2 events and passes the highest level recognized in the standard, Level 4, which defines a contact discharge voltage of ±8 kV and an air discharge voltage of ±15 kV.

Testing was also performed with the IEC ESD gun connected to the logic side, GND_1. Testing to GND_1 demonstrates the robustness of the ADM2795E isolation barrier. The isolation barrier is capable of withstanding IEC 61000-4-2 ESD to ±9 kV contact and to ±8 kV air. Testing was performed in normal transceiver operation with the ADM2795E clocking data at 2.5 Mbps. Table 1 and Table 4 summarize the certified test results.

Table 1. IEC 61000-4-2 Certified Test Results

ESD Gun Connection	IEC 61000-4-2 Test Result	Certified Result
GND_2	±15 kV (air), ±8 kV (contact), Level 4 protection	Yes
GND_1	Withstands ±8 kV (air), ±9 kV (contact)	Yes

Figure 4 shows the 8 kV contact discharge current waveform from the IEC 61000-4-2 standard compared to the human body model (HBM) ESD 8 kV waveform. Figure 4 shows that the two standards specify a very different waveform shape and peak current. The peak current associated with an IEC 61000-4-2 8 kV pulse is 30 A, and the corresponding peak current for HBM ESD is more than 5× less, at 5.33 A. The other difference is the rise time of the initial voltage spike, with the IEC 61000-4-2 ESD having a much faster rise time of 1 ns, compared to the 10 ns associated with the HBM ESD waveform. The amount of power associated with an IEC ESD waveform is much greater than that of a HBM ESD waveform. The ADM2795E with IEC 61000-4-2 ESD ratings is better suited for operation in harsh environments compared to other RS-485 transceivers that state varying levels of HBM ESD protection.

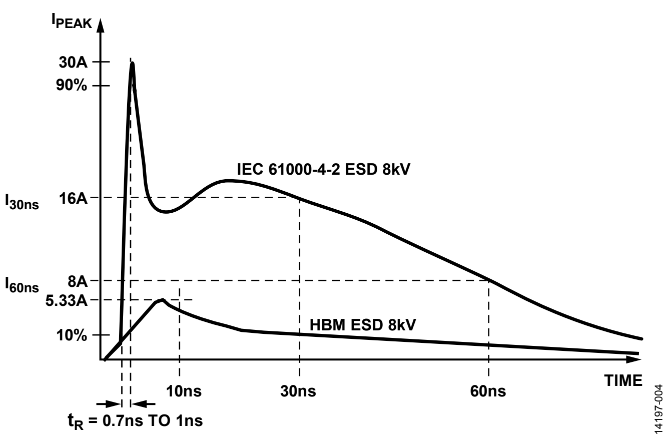

Figure 4. IEC 61000-4-2 ESD Waveform (8 kV) Compared to HBM ESD Waveform (8 kV)

ELECTRICAL FAST TRANSIENTS

EFT testing involves coupling a number of extremely fast transient impulses onto the signal lines to represent transient disturbances (associated with external switching circuits that are capacitively coupled onto the communication ports), which can include relay and switch contact bounce or transients originating from the switching of inductive or capacitive loads, all of which are very common in industrial environments. The EFT test defined in IEC 61000-4-4 attempts to simulate the interference resulting from these types of events.

Figure 5 shows the EFT 50 Ω load waveform. The EFT waveform is described in terms of a voltage across a 50 Ω impedance from a generator with a 50 Ω output impedance. The output waveform consists of a 15 ms burst of 5 kHz high voltage transients repeated at 300 ms intervals. The EFT test is also performed with a 750 µs burst at a higher 100 kHz frequency. Each individual pulse has a rise time of 5 ns and a pulse duration of 50 ns, measured between the 50% point on the rising and falling edges of the waveform. The total energy in a single EFT pulse is similar to that in an ESD pulse.

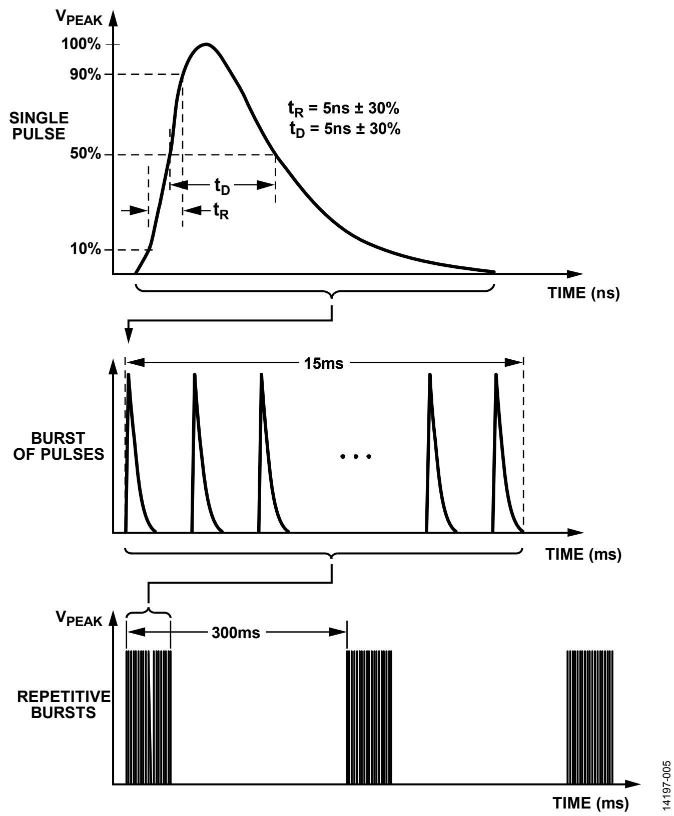

Figure 5. IEC 61000-4-4 EFT 50 Ω Load Waveforms

During testing, these EFT fast burst transients are coupled onto the communication lines using a capacitive clamp, as shown in Figure 6. The EFT is capacitively coupled onto the communication lines by the clamp rather than by direct contact. This clamp also reduces the loading caused by the low output impedance of the EFT generator. The coupling capacitance between the clamp and the cable depends on cable diameter, shielding, and insulation on the cable. The EFT clamp edge is placed 50 cm from the equipment under test (EUT), the EVAL-ADM2795EEBZ evaluation board. The EFT generator is set up for either 5 kHz or 100 kHz repetitive EFT bursts. The EVAL-ADM2795EEBZ was tested in both 5 kHz and 100 kHz test setups.

With the EFT clamp connected to GND_2, the EVAL-ADM2795EEBZ is robust to IEC 61000-4-4 EFT transients and protects against the highest level recognized in the standard, Level 4, which defines a voltage level of ±2 kV. With the IEC 61000-4-4 EFT clamp connected to GND_1, the EVAL-ADM2795EEBZ is robust to IEC 61000-4-4 EFT transients and withstands up to ±2 kV. Testing was performed in normal transceiver operation, with the EVAL-ADM2795EEBZ clocking data at 2.5 Mbps. The results shown in Table 2 are valid for a setup with or without an RS-485 cable shield connection to GND_2. The EVAL-ADM2795EEBZ withstands up to ±2 kV IEC 61000-4-4 EFT without damage. Table 2 and Table 4 summarize the certified test results.

Table 2. IEC 61000-4-4 Certified Test Results

EFT Clamp Connection	IEC 61000-4-4 Test Result	Certified Result
GND_2	±2 kV Level 4 protection	Yes
GND_1	Withstands ±2 kV	Yes

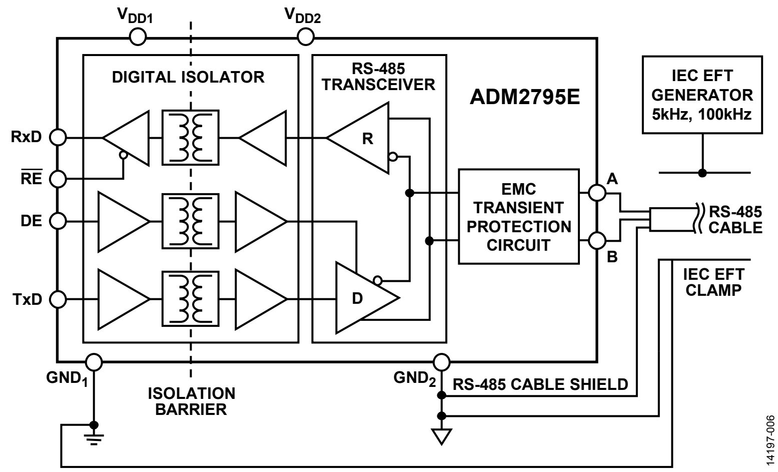

Figure 6. IEC 61000-4-4 EFT Testing to GND_1 or GND_2

SURGE

Surge transients are caused by overvoltage from switching or lightning transients. Switching transients can result from power system switching, load changes in power distribution systems, or various system faults such as short circuits. Lightning transients can be a result of high currents and voltages injected into the circuit from nearby lightning strikes. IEC 61000-4-5 defines waveforms, test methods, and test levels for evaluating immunity against these destructive surges.

The waveforms are specified as the outputs of a waveform generator in terms of open-circuit voltage and short-circuit current. For RS-485 ports, the 1.2 µs/50 µs waveform is predominantly used and is described in this section. The waveform generator has an effective output impedance of 2 Ω; therefore, the surge transient has high currents associated with it.

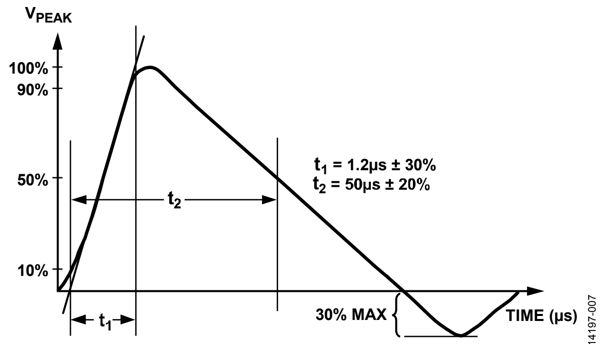

Figure 7. IEC 61000-4-5 Surge 1.2 µs/50 µs Waveform

Figure 7 shows the 1.2 µs and 50 µs surge transient waveform. ESD and EFT have similar rise times, pulse widths, and energy levels; however, the surge pulse has a rise time of 1.25 µs and the pulse width is 50 µs.

Additionally, the surge pulse energy is three to four orders of magnitude larger than the energy in an ESD or EFT pulse. Therefore, the surge transient is considered the most severe of the EMC transients.

IEC 61000-4-5 surge testing involves using a coupling/decoupling network (CDN) to couple the surge transient into the RS-485 A and B bus pins. The coupling network for a half-duplex RS-485 device consists of an 80 Ω resistor on both the A and B lines and a coupling device. The total parallel sum of the resistance is 40 Ω. The coupling device can be capacitors, gas arrestors, clamping devices, or any method that allows the EUT to function correctly during the applied test. During the surge test, five positive and five negative pulses are applied to the data ports with a maximum time interval of one minute between each pulse. The standard states that the device must be set up in normal operating conditions for the duration of the test. Figure 8 shows the test setup for surge testing. Testing was performed in normal transceiver operation, with the ADM2795E clocking data at 2.5 Mbps.

With the IEC surge generator connected to GND_2, the ADM2795E is robust to IEC 61000-4-5 events and protects against the highest level recognized in the standard, Level 4, which defines a peak voltage of ±4 kV.

With the IEC surge generator connected to GND_1, the ADM2795E is robust to IEC 61000-4-5 events and withstands up to 4.0 kV of surge. The ADM2795E withstands up to 4.0 kV IEC 61000-4-5 surge without damage and with no bit errors in data communications. Testing to GND_1 demonstrates the robustness of the ADM2795E isolation barrier. Table 3 and Table 4 summarize the certified test results.

Table 3. IEC 61000-4-5 Certified Test Results

Surge Generator Connection	IEC 61000-4-5 Test Result	Certified Result
GND_2	±4 kV Level 4 protection	Yes
GND_1	Withstands ±4 kV	Yes

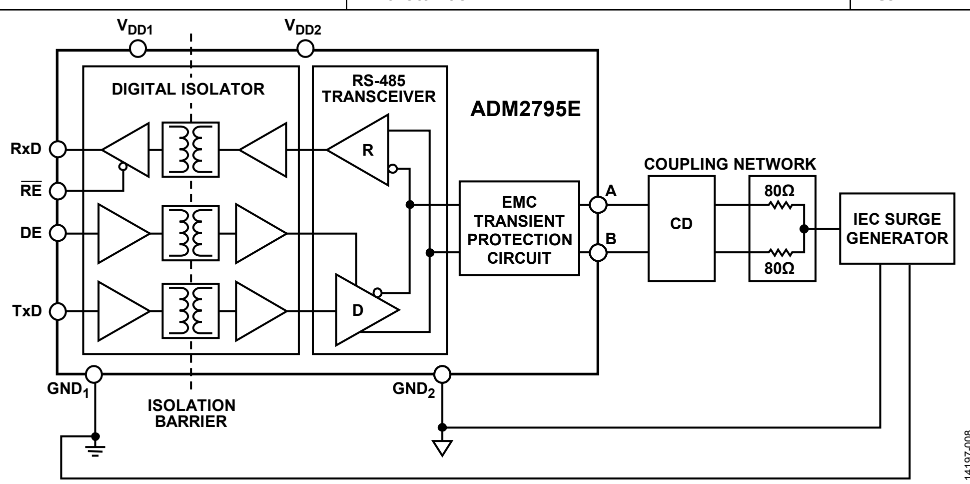

Figure 8. IEC 61000-4-5 Surge Testing to GND_1 or GND_2

Table 4 shows the ADM2795E performance and classification achieved for the noted IEC system level EMC standards.

The performance corresponds to each classification as follows:

- Class A: normal operation
- Class B: temporary loss of performance (bit errors)
- Class C: system needs reset
- Class D: permanent loss of function

Table 4. Summary of Certified EMC System Level Classifications for the ADM2795E

Test	Ground Connection	Classification	Highest Pass Level
IEC 61000-4-5 Surge	GND_1	Class A	±4 kV
	GND_2	Class B	±4 kV
IEC 61000-4-4 Electrical Fast Transient	GND_1	Class B	±2 kV
	GND_2	Class B	±2 kV
IEC 61000-4-2 Electrostatic Discharge	GND_1	Class B	±8 kV (air), ±9 kV (contact)
	GND_2	Class B	±15 kV (air), ±8 kV (contact)
IEC 61000-4-6 Conducted RF Immunity	GND_1	Class A	10 V/m rms
	GND_2	Class A	10 V/m rms
IEC 61000-4-3 Radiated RF Immunity	GND_2	Class A	30 V/m
IEC 61000-4-8 Magnetic Immunity	GND_2	Class A	100 A/m

IEC CONDUCTED, RADIATED, AND MAGNETIC IMMUNITY

IEC 61000-4-6 CONDUCTED RF IMMUNITY

The IEC 61000-4-6 conducted immunity test is applicable to products that operate in environments where radio frequency fields are present and that are connected to main supplies or other networks (signal or control lines). The source of conducted disturbances are electromagnetic fields, emanating from RF transmitters that can act on the whole length of cables connected to the installed equipment.

In the IEC 61000-4-6 test, an RF voltage is stepped from 150 kHz to 80 MHz or 100 MHz. The RF voltage is 80% amplitude modulated (AM) by a 1 kHz sinusoidal wave. One EVAL-ADM2795EEBZ evaluation board was tested to Level 3, which is the highest test level of 10 V. For IEC 61000-4-6 testing, the stress signal is applied by using the clamp detailed in Table 5. The clamp is placed on the communications cable between two ADM2795E transceivers. For all testing, the equipment and EUT setup are as described in Table 5 and Figure 9.

Table 6 shows the test results where the EUT passed IEC 61000-4-6 to Level 3. For all of the tests, the IEC 61000-4-6 clamp was placed at the EUT (EVAL-ADM2795EEBZ), and the cable shield was either floating or earth grounded. The second EVAL-ADM2795EEBZ (auxiliary equipment) was placed on the network to terminate the communications bus. The IEC 61000-4-6 generator clamp was connected to either GND_1 or GND_2 of the EVAL-ADM2795EEBZ EUT to provide a return current path for the IEC 61000-4-6 transient current.

The ADM2795E evaluation board has been tested and certified to pass IEC 61000-4-6 conducted RF immunity testing to Level 3 at 10 V/m rms, in a variety of configurations as described in Table 6.

Table 5. IEC 61000-4-6 EUT and Equipment

Parameter	Details
IEC 61000-4-6 Clamp	Schaffner KEMZ 801, placed at 30 cm from the EUT
IEC 61000-4-6 Test Level	Level 3, 0.15 MHz to 80 MHz, 10 V/m rms, 80% AM by a 1 kHz sinusoidal wave
EUT	EVAL-ADM2795EEBZ
EUT Data Rate	2.5 Mbps
EUT Power	9 V battery at V_{DD1} and V_{DD2}, regulated on EUT to 5 V
Cable Between EUT	5 m, Unitronic Profibus, 22 American wire gauge (AWG)
Cable Termination	120 Ω resistor at both cable ends
Pass/Fail Criteria	Pass: data at receiver with a pulse width distortion within 10% of mean

Table 6. IEC 61000-4-6 Certified Test Results

Clamp Location from EUT (cm)	Cable Shield	Current Return Path	IEC 61000-4-6 Test Frequency (MHz)	Certified Result
30	Floating	GND_1	0.15 to 80	Pass
30	Earthed	GND_1	0.15 to 80	Pass
30	Floating	GND_2	0.15 to 80	Pass
30	Earthed	GND_2	0.15 to 80	Pass

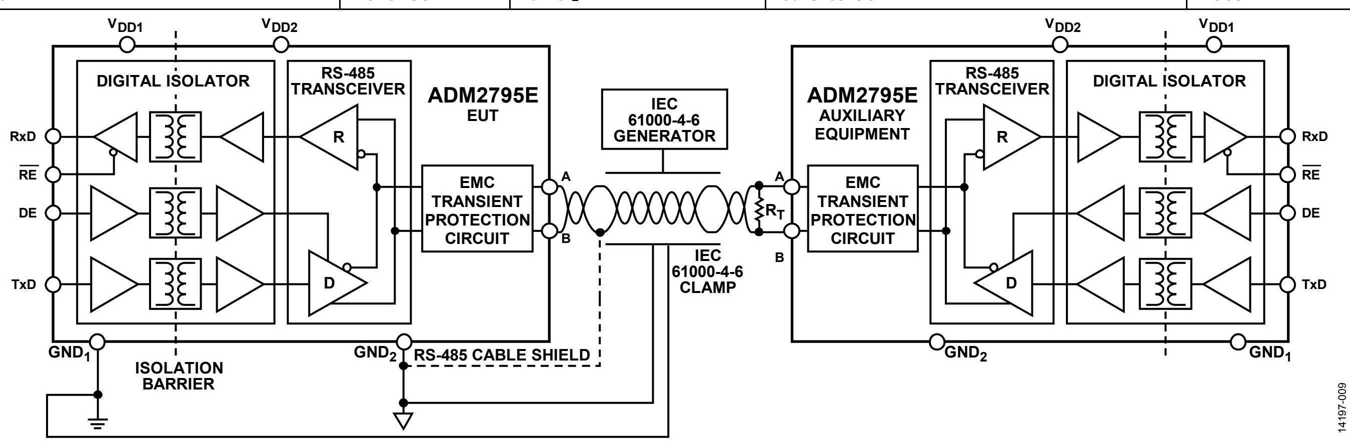

Figure 9. IEC 61000-4-6 Conducted RF Immunity Example Test Setup Testing to GND_1 or GND_2

IEC 61000-4-3 RADIATED RF IMMUNITY

Testing to IEC 61000-4-3 ensures that electronic equipment is immune to commonly occurring radiated RF fields. Some commonly occurring unintentional RF emitting devices in an industrial application are electric motors and welders.

In the IEC 61000-4-3 test, a radiated RF field is generated by an antenna in a shielded anechoic chamber using a precalibrated field, swept from 80 MHz to 2.7 GHz. The RF voltage is amplitude modulated 80% at 1 kHz. Each face of the EUT is subjected to vertical and horizontal polarizations.

Figure 10 shows the test setup with the EVAL-ADM2795EEBZ, the EUT, placed in an anechoic chamber, powered with two 9 V batteries. The EVAL-ADM2795EEBZ on-board regulators are used to power V_{DD1} at 5.0 V and V_{DD2} at 5.0 V. The EVAL-ADM2795EEBZ is loaded with a 120 Ω termination resistor for the duration of the test. A pattern generator provides a 2.5 Mbps data input to the ADM2795E TxD pin. The ADM2795E receiver output (RxD) is monitored with an oscilloscope.

The pass criteria chosen is less than a 10% change in the bit width of the RxD signal in the presence of the IEC 61000-4-3 radiated RF field.

The EVAL-ADM2795EEBZ evaluation board has been tested and certified to pass IEC 61000-4-3 radiated RF immunity testing to Level 4 (30 V/m). Level 4 is the highest level in the IEC 61000-4-3 standard.

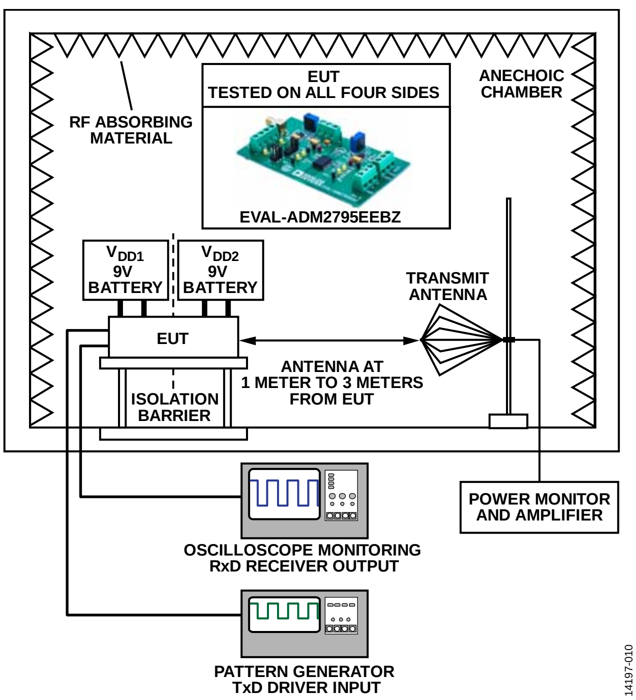

Figure 10. Testing for IEC 61000-4-3 Radiated Immunity

IEC 61000-4-8 MAGNETIC IMMUNITY

Testing to IEC 61000-4-8 ensures that electronic equipment is immune to commonly occurring magnetic fields. The source of magnetic fields in typical industrial communication applications is power line current or 50 Hz or 60 Hz transformers in close proximity to the equipment.

In the IEC 61000-4-8 test, a controlled magnetic field of defined field strength is produced by driving a large coil (induction coil) with a test current generator. The EUT is placed at the center of the induction coil, subjecting the EUT to a magnetic field.

Figure 11 shows the test setup with the EVAL-ADM2795EEBZ, the EUT, placed in an anechoic chamber, powered with two 9 V batteries. The EVAL-ADM2795EEBZ on-board regulators are used to power V_{DD1} at 5.0 V and V_{DD2} at 5.0 V. The EVAL-ADM2795EEBZ is loaded with a 120 Ω termination resistor for the duration of the test. A pattern generator provides a 2.5 Mbps data input to the ADM2795E TxD pin. The ADM2795E receiver output (RxD) is monitored with an oscilloscope. The pass criteria chosen is less than a 10% change in the bit width of the RxD signal in the presence of the IEC 61000-4-8 magnetic field.

The EVAL-ADM2795EEBZ evaluation board has been tested and certified to pass IEC 61000-4-8 magnetic immunity testing to Level 5 (100 A/m). Level 5 is the highest level specified in the IEC 61000-4-8 standard.

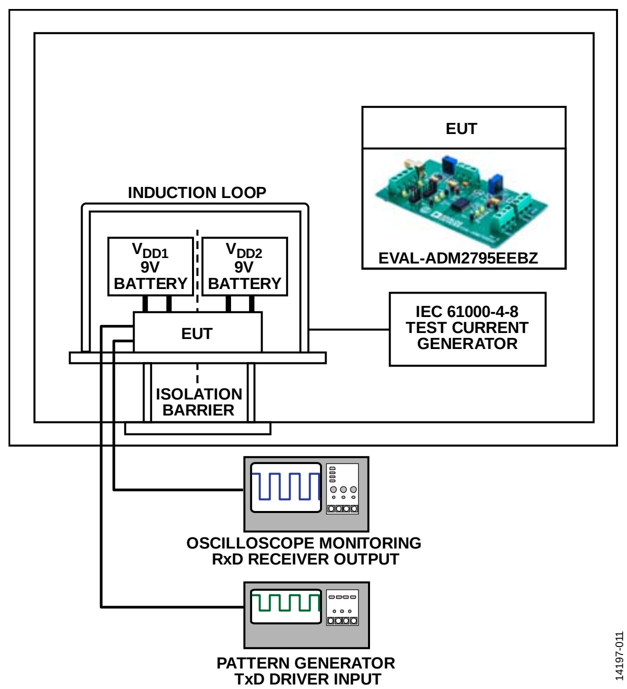

Figure 11. Testing for IEC 61000-4-8 Magnetic Immunity

OVERVOLTAGE FAULT PROTECTION

The ADM2795E is the first RS-485 transceiver to offer fault protection over a 3 V to 5.5 V V_{CC} operating range without the need for close examination of the logic pin state (TxD input, DE, and $\overline{RE}$) of the RS-485 transceiver. The transceiver is also fault protected over the entire extended common-mode operating range of ±25 V.

The ADM2795E RS-485 driver outputs and receiver inputs are protected from short circuits to any voltage within the range of −42 V to +42 V ac/dc peak. The maximum current in a fault condition is ±250 mA. The RS-485 driver includes a foldback current limiting circuit that reduces the driver current at voltages exceeding the ±25 V common-mode range limit of the transceiver. This current reduction due to the foldback feature allows better management of power dissipation and heating effects.

±42 V MISWIRE PROTECTION

The ADM2795E is protected against high voltage miswire events when it operates on a bus that does not have RS-485 termination or bus biasing resistors installed. A typical miswire event is where a high voltage 24 V ac/dc power supply is connected directly to RS-485 bus pin connectors. The ADM2795E can withstand miswiring faults of up to ±42 V peak on RS-485 bus pins with respect to GND_2 without damage. Miswiring protection is guaranteed on the ADM2795E RS-485 A and B bus pins, and is guaranteed in the case of a hot swap of connectors to the bus pins. Table 7 and Table 8 provide a summary of the high voltage miswire protection offered by the ADM2795E. The ADM2795E is tested with ±42 V dc and with ±24 V ± 20% rms, 50 Hz or 60 Hz, with both a hot plug and dc ramp test waveforms. The test is performed in both powered and unpowered power supply cases, and at a range of different states for the RS-485 TxD input, DE, and $\overline{RE}$ enable pins. The RS-485 bus pins survive a high voltage miswire from Pin A to ground, from Pin B to ground, and between Pin A and Pin B.

Table 7. Miswire Protection Table Abbreviations

Letter	Description
H	High level for logic pin
L	Low level for logic pin
X	On or off power supply state

Table 8. High Voltage Miswire Protection

Supply		Inputs			Miswire Protection at RS-485 Outputs Pins[1,2]
V_{DD1}	V_{DD2}	DE	$\overline{RE}$	TxD	
X	X	H/L	H/L	H/L	-42 V dc ≤ V_A ≤ +42 V dc
X	X	H/L	H/L	H/L	-42 V dc ≤ V_B ≤ +42 V dc
X	X	H/L	H/L	H/L	-42 V ac ≤ V_A ≤ +42 V ac
X	X	H/L	H/L	H/L	-42 V ac ≤ V_B ≤ +42 V ac

[1] This is the ac/dc peak miswire voltage between Pin A and GND_2, or Pin B and GND_2, or between Pin A and Pin B.
[2] V_A refers to the voltage on Pin A, and V_B refers to the voltage on Pin B.

RS-485 NETWORK BIASING AND TERMINATION

For a high voltage miswire on the RS-485 A and B bus pins with biasing and termination resistors installed, there is a current path through the biasing network to the ADM2795E power supply V_{DD2} pin. To protect the ADM2795E in this scenario, the device has an integrated V_{DD2} protection circuit.

The ADM2795E is a fault protected RS-485 device that also features protection for its power supply pin. This fault protection means that the current path through the R1 pull-up resistor does not cause damage to the V_{DD2} pin, although the pull-up resistor itself can be damaged if not appropriately power rated (see Figure 12). The R1 pull-up resistor power rating depends on the miswire voltage and the resistance value.

If there is a miswire between the A and B pins in the Figure 12 bus setup, the ADM2795E is protected, but the R_T bus termination resistor can be damaged if not appropriately power rated. The R_T termination resistor power rating depends on the miswire voltage and the resistance value.

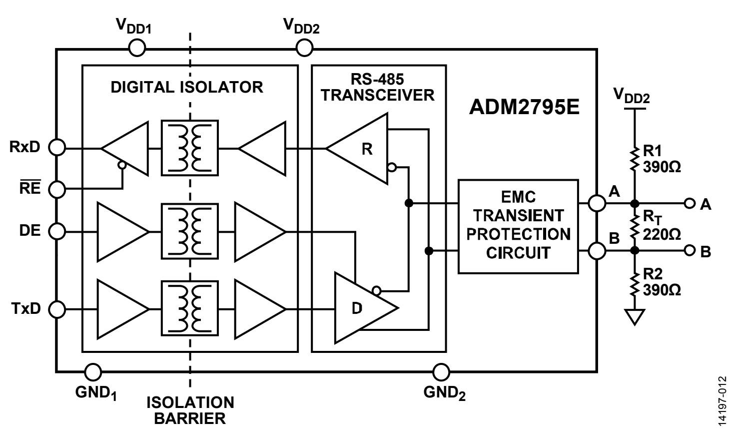

Figure 12. High Voltage Miswiring Protection for the ADM2795E with Bus Termination and Biasing Resistor

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