How to reduce radiated emissions of digital isolators for systems with RF modules

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Introduction

A typical industrial system has a dedicated subsystem to enable communication with other systems known as a communication module. Communication modules interact with other systems either through wired media or wirelessly. Applications using wireless communication include human machine interfaces (HMIs) (Wi-Fi®/*Bluetooth*®), energy meters (Global System for Mobile Communication [GSM]/ Long-Term Evolution [LTE]) and patient monitoring (Wi-Fi/*Bluetooth*). These applications often use a digital isolator for ground-loop isolation in wired communications, or for human/component safety isolation.

Digital isolators employ proprietary modulation techniques to transmit data across an isolation barrier over a carrier signal. The chosen carrier frequency is typically a few hundred megahertz to support high data rates. When used in the vicinity of wireless radio-frequency (RF) modules, the digital isolator's carrier and its harmonics may interfere with radio signals from the communication modules. This could lead to lower RF-module sensitivity, thereby reducing the error-free communication range that the modules can support. This article describes methods to minimize the impact of digital isolators on the sensitivity of RF modules so that they can support the expected error-free communication range.

Operation of a digital isolator

On-off keying (OOK) is a common circuit architecture implemented in high-performance digital isolators to establish data communication over an isolation barrier. For example, TI's ISO7741 high-speed, robust-EMC, reinforced digital isolator employs an OOK modulation scheme to transmit digital data across a silicon dioxide-based isolation barrier.

Figure 1 is a conceptual block diagram of an OOK-based digital isolator, ISO7741. Figure 2 shows the corresponding modulation scheme.

Figure 1. ISO7741 conceptual block diagram

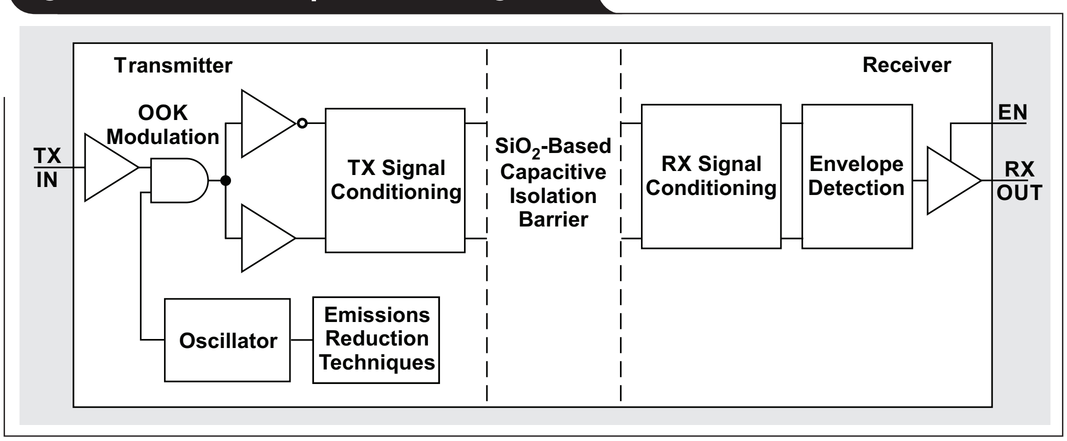
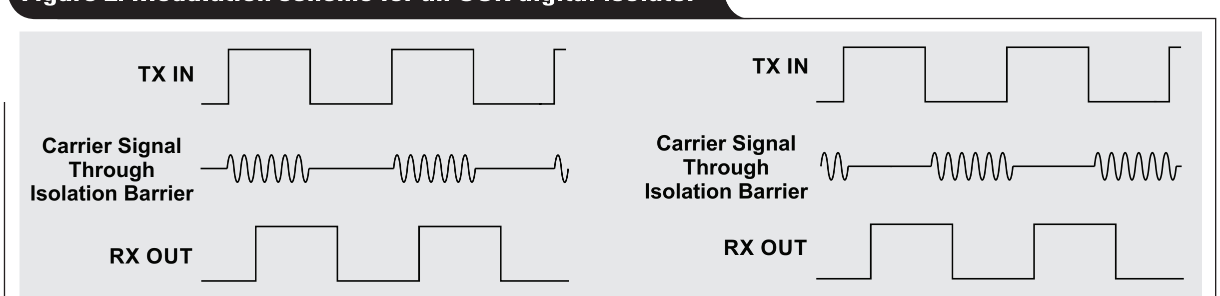


Figure 2. Modulation scheme for an OOK digital isolator



(a) Default low-state digital isolator, ISO7741F

(b) Default high-state digital isolator, ISO7741

In the OOK-based architecture, an internal clock modulates the incoming digital bit-stream to generate OOK signaling. One of the input states is represented by the transmission of a carrier signal, and the other state is represented by no transmission. This modulated signal couples through the isolation barrier and appears in an attenuated form on the receive side. The receive path consists of a preamplifier to gain up the incoming signal, followed by an envelope detector that serves as a demodulator to regenerate the original digital pattern. The ISO7741 also incorporates spread-spectrum modulation techniques to minimize radiated emissions from the high-frequency carrier.

RF modules

An RF module is usually a small electronic device used to transmit and/or receive radio signals between two devices. There are various types of RF modules; some can transmit up to a few tens of feet and others can transmit as far as a few kilometers. Good electronic radio design is notoriously complex, and radio circuits are usually subject to limits on radiated emissions. Radio circuits also require conformance testing and certification by standards bodies such as the Federal Communications Commission (FCC). For these reasons, design engineers will often drop a readily available radio module into their board rather than attempt a discrete design, which saves development time and money.

Commercially available RF modules use several carrier frequencies that include the industrial, scientific and medical (ISM) radio bands such as 433.92 MHz, 915 MHz and 2,400 MHz. The GSM open and digital cellular technology operates in the 850-MHz, 900-MHz, 1,800-MHz and 1,900-MHz frequency bands.

RF modules may comply with a defined protocol for RF communications such as Zigbee®, *Bluetooth* low energy or Wi-Fi, or may implement a proprietary protocol.

Performance impact on sensitivity of RF module

RF sensitivity is one of the key specifications of any radio receiver, whether it is used for Wi-Fi, cellular telecommunication broadcasts, or any other form of wireless communication. A radio receiver's ability to pick up the required level of radio signals enables it to operate more effectively within its application.

One of the parameters used to represent the receiver sensitivity of an RF module is the minimum detectable or discernible signal (MDS), which is the smallest signal level that a radio receiver can detect. In other words, an MDS signal level is the smallest signal that can be processed through the analog and digital signal chain and demodulated by the receiver to provide usable information at the output.

In digital isolators, data transmits through a carrier signal across an isolation barrier. Since this is only a signal transmission and not a power transmission, the power levels of the carrier signal being transmitted will be very low. Therefore, most digital isolators that transmit only data do not pose any challenges in meeting standard emissions requirements for most industrial (like Comité International Spécial des Perturbations Radioélectriques [CISPR] 22) and automotive (like CISPR 25) applications.

RF-module sensitivity is typically very high; its MDS is usually expressed in decibel-milliwatts (0 dBm = 1 mW). When a digital isolator and an RF module are used on a same printed circuit board (PCB) side by side, it is possible for the isolator's carrier signal to affect RF module sensitivity, thereby degrading its MDS to some extent. A degraded RF-module MDS may result in a lower range than what it can originally support. If the supported range is lower than the acceptable range, then the impact of the isolator on module sensitivity must be minimized.

Improving RF-module sensitivity

There are many ways to minimize the impact of a digital isolator on RF-module sensitivity. A few of the most effective solutions to improve RF-module sensitivity so that it can support its original communication range include:

- **Implementing an interlayer PCB stitching capacitor.** In the TI application report identified by Reference 1, Section No. 1 describes how a carrier signal transmitted across an isolation barrier could create common-mode currents, resulting in radiated emissions. To address potential interference with any RF modules in the vicinity, a capacitor can be used across the isolation barrier to shorten the common-mode current loop.

  Section No. 4 of the same application report (Reference 1) describes how a high-voltage Y2 capacitor can reduce digital-isolator emissions. It also covers the capacitor's limitations because of its lead inductances and how an interlayer PCB stitching capacitor overcomes such limitations by having zero lead inductance.

The report also explains in detail the design and implementation of an interlayer PCB stitching capacitor on a multilayer PCB. Figure 3 shows a cross-section of an interlayer PCB stitching capacitor.

- **Data modulation.** As previously described, one of the input states of a digital isolator is represented by the transmission of a carrier signal, while the other input state is represented by no transmission. In Figure 2a for the ISO7741F, a logic 1 input transmits a carrier signal across the isolation barrier, while a logic 0 (zero) input doesn't transmit any carrier signal. For a fixed data-rate application, if the input logic 1 data bit can be represented by a pattern that has a 10% high state followed by a 90% low state constituting one data bit, the amount of time a carrier signal transmits across the barrier will be significantly reduced, as shown in Figure 4a. Once it passes through the barrier, such a data pattern is easily recoverable to get back the original data bit. This approach reduces radiated emissions tenfold and proportionally improves RF-module sensitivity. It's even possible to reduce emission further by reducing the high-state duration to values lower than 10%.

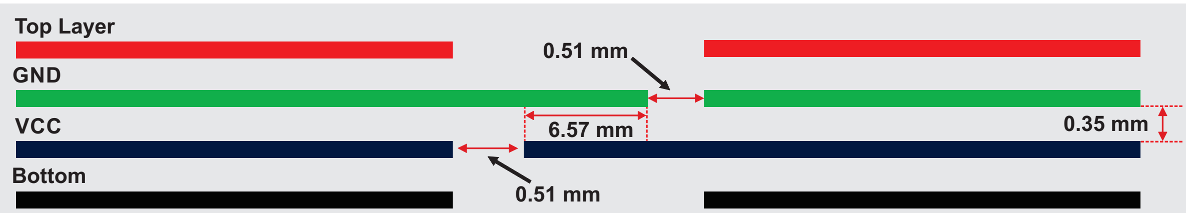
  In the ISO7741, a logic 0 input transmits a carrier signal across the isolation barrier and a logic 1 input doesn't transmit any carrier signal, as shown in Figure 2b. Emissions can be reduced by following the approach shown in Figure 4b.

  The data modulation technique can be implemented in software if the communication across the isolation barrier is happening between two microcontrollers (MCUs) or programmable devices. This approach doesn't use any external components to reduce radiated emissions by tenfold or more. Thus, it is one of easiest and most efficient approaches to reduce emissions and improve sensitivity.

  Alternatively, data modulation can be implemented in hardware by using external components without affecting the system software. The key components required for implementing data modulation are an oscillator with an adjustable duty cycle to generate a modulated data pattern and an envelope detector to recover the original data stream. This approach is useful for applications where the software is large and sophisticated and involves critical system interrupts with the highest execution priority.

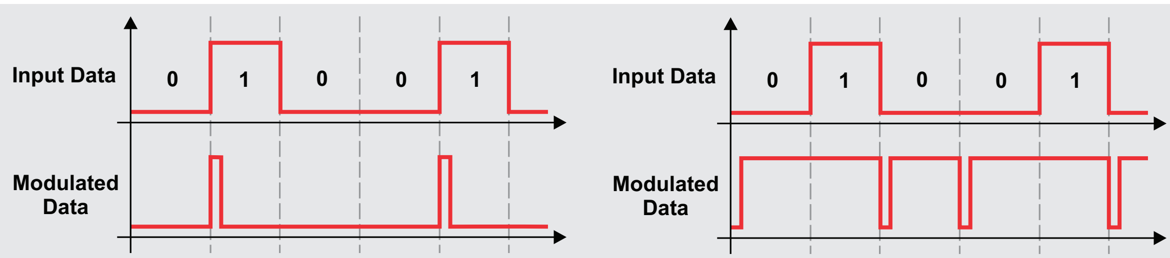
- **Choosing an isolator with the right default state.** Many applications use isolators on various communication interfaces/protocols, including Serial Peripheral Interface (SPI), Inter-Integrated Circuit (I^2C), RS-485 and Controller Area Network (CAN). Many of these applications require intermittent data transmission in the form of packets. There are long periods of time between data-packet transmissions when the communication bus is idle. The communication interface may

Figure 3. Cross-sectional view of an interlayer PCB stitching capacitor



K	E_O	D	L	W	C (pF)
4.2	8.85×10^{-12}	0.35	77.3	6.5	53.38

Figure 4. Data modulation approach to reduce radiated emissions



(a) Default low-state digital isolator, ISO7741F

(b) Default high-state digital isolator, ISO7741

require the bus to be in a particular state (either high, low or custom) during this idle state.

Choosing an isolator whose default state matches the communication bus idle state will prevent the isolator from contributing any radiated emissions or disturbances. The correct choice will leave the sensitivity of RF modules unaffected, especially during communication bus idle time. Along with data-packet transmission, careful isolator selection may be sufficient to meet the required RF module sensitivity for an application.

Test results

Various methods discussed here were tested with the ISO7741EVM digital-isolator evaluation module that was placed close to a high-sensitivity RF receiver. Table 1 lists the results of these various emission-reduction techniques, which show that it is possible to completely recover any degradation of the receiver's RF sensitivity that was caused by a digital isolator.

Table 1. Summary of RF-module sensitivity tests with various improvement techniques

Test Condition	MDS (dBm)	Degradation (dB)
Without isolator	–124	0
Isolator with low inputs	–110	14
Isolator with high inputs	–124	0
With stitching capacitor, 50 pF	–124	0
With 10% duty cycle	–124	0

Conclusion

Various applications for industrial, automotive and personal electronics use digital isolators for ground-loop isolation, safety isolation or high-side driving. Many applications also include an RF module for wirelessly communicating with other systems. RF modules, being very sensitive to high-frequency radiations, are prone to disturbance by the very-low radiated emissions of a carrier signal in digital isolators, thus affecting their sensitivity and supported range.

The various approaches described in this article can minimize the impact of a carrier signal in digital isolators on RF-module sensitivity and restore the supported range.

References

1. Anand Reghunathan, Koteshwar Rao, Anant Kamath, "Low Emissions Designs With ISOW7841 Integrated Signal and Power Isolator," Texas Instruments Application Report (SLLA368A), August 2017.
2. "Digital Isolator Design Guide," Texas Instruments Developer's Guide (SLLA284A), November 2014.

Related Web sites

Product tool:
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