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Isolator Architecture for Electrical Isolators

Abstract

In one embodiment, an electrical isolator includes a first electrical component and a second electrical component configured to wirelessly communicate electrical signals with each other. The electrical isolator includes an isolation barrier that has one or more dielectric layers that electrically isolate the first electrical component from the second electrical component. The electrical isolator further includes one or more dielectric layers between a substrate on which the isolator is mounted and the isolation barrier, where the one or more dielectric layers between the substrate and the isolation barrier include (1) one or more thin dielectric layers; and (2) one or more thick dielectric layers that reduce a parasitic electrical coupling between the substrate and at least one of the first electrical component and the second electrical component.

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Background/Summary

PRIORITY CLAIM [0001] This application claims the benefit under 35 U.S.C. § 119 of (1) U.S. Provisional Patent Application No. 63/555,118 filed Feb. 19, 2024 and (2) U.S. Provisional Patent Application No. 63/555,124 filed Feb. 19, 2024, which are incorporated by reference herein.

TECHNICAL FIELD

[0002] This application generally relates to electrical isolators.

BACKGROUND

[0003] Electrical isolators create electrical separation between two or more components of an electrical system. However, electrical isolators can pass signals or power through the isolated components, for example by using capacitive or inductive methods. For instance, electrical isolators may be used to safely transmit data between electrical components that operate at different voltage domains.

[0004] Inductive isolators use a changing magnetic field between two coils to transmit signals across an isolation barrier. Inductive isolators can use transformers to vary the magnetic field, where the strength of the magnetic field depends on the coil structure of the primary and secondary windings, the permittivity of the magnetic core, and the current magnitude.

[0005] Capacitive isolators use a changing electric field to transmit signals across an isolation barrier. A capacitive isolator is typically formed by using two capacitor plates with a dielectric material between the plates. The isolation barrier rating is determined by the capacitor plate size, distance between the plates, and the dielectric material. Capacitive isolators may have a higher efficiency, in both size and energy transfer, compared to inductive isolators. Capacitive isolators also have higher immunity to magnetic fields, thereby providing superior performance in the presence of external magnetic fields.

Description

BRIEF DESCRIPTION OF THE DRAWINGS

[0006] FIG. 1 illustrates an example isolator structure.

[0007] FIG. 2 illustrates an example in which an isolator is used to isolate a modulator from a demodulator.

DESCRIPTION OF EXAMPLE EMBODIMENTS

[0008] FIG. 1 illustrates an example isolator structure of embodiments described herein. Isolator **100** is mounted on a substrate **102**, i.e., substrate **102** provides mechanical support for the isolator.

[0009] Isolator **100** includes components **120** and **122** for wirelessly transmitting signals between those components, i.e., without current directly flowing between components **120** and **122**. In particular embodiments, components **120** and **122** may form a capacitive structure, for example where component **120** and component **122** are each metal plates. In particular embodiments, components **120** and **122** may form an inductive structure, for example where components **120** and **122** are each inductive coils.

[0010] Components **120** and **122** are separated by an isolation barrier **118**. Isolation barrier **118** is typically a dielectric material, such as SiO₂. In the example of FIG. 1, isolation barrier **118** is composed of two distinct dielectric layers—layer **114** and layer **116**—although an isolation barrier may also be composed of a single dielectric layer or more than 2 dielectric layers. Each dielectric layer **114** and **116** is relatively thick, and the physical thickness of isolation barrier **118** results in

the electrical isolation of components **120** and **122** from each other. In capacitive embodiments, the isolation-barrier rating of isolation barrier **118** is determined by the plate size of components **120** and **122**, the distance between the those components, and the dielectric material used in dielectric layer **114** and dielectric layer **116**. In particular embodiments, dielectric layers **114** and **116** may be the same dielectric material or may be made of different dielectric materials.

[0011] Isolator **100** is mounted on a substrate **102**, for example which provides the mechanical support for, and electrical connections to, isolator **100**. In the example of FIG. **1**, thin dielectric layer **106** creates a dielectric-substrate boundary **104** between substrate **102** and the components of isolator **100**. The example of FIG. **1** also includes a second thin dielectric layer **108**. Each thin dielectric layer **106** and **108** may, for example, be made of SiO₂, although other dielectric materials may be used, and layers **106** and **108** may be made of different dielectric materials. While the example of FIG. **1** illustrates components **120** and **122** as being vertically oriented relative to substrate **102**, such that component **122** is further from the substrate than is component **120**, this disclosure contemplates that other orientations of components **120** and **122** (and of isolation barrier **118** between them) may be used, such as a “horizontal” configuration in which components **120** and **122** are equidistant from the substrate.

[0012] In particular embodiments, thin layers **106** and **108** and **110** may be 0.1 to 0.5 μm thick, while thick dielectric layers **114** and **116** may be 5-10 μm thick. While other embodiments may use other thicknesses, thick dielectric layers are typically around 10-100 times (or more) thicker than thin dielectric layers in an isolator.

[0013] While substrate **102** is not a conductive material, substrate **102** nevertheless can electrically interact with either or both of electrical components **120** and **122**. For example, the electrical coupling between substrate **102** and component **120** may be modeled as a parasitic capacitive coupling **124**, and this coupling can introduce noise in isolator **100** and degrade the signal to be transmitted over isolation barrier **118**. Parasitic coupling from substrate **102** may occur with either or both of components **120** and **122**.

[0014] A relatively higher parasitic coupling results in relatively worse signal transfer performance over an isolation barrier and relatively higher noise characteristics in the transferred signal. This signal degradation can have a significant impact on the operation of isolator **100**. For instance, if isolator **100** is integrated into a modulator/demodulator circuit, the parasitic coupling to the substrate can reduce the performance of the transmitted signal, and even degrade the signal to the point that the demodulator is unable to detect the information in the modulated signal.

[0015] The example isolator structure **100** of FIG. **1** introduces a thick dielectric layer **112** between thin dielectric layer **110** (i.e., the thin dielectric layer nearest isolation barrier **118**) and isolation barrier **118**. Thick dielectric layer **112** effectively increases the distance between substrate **102** and components **120** and **122**, thereby decreasing the parasitic coupling between the substrate and those components, therefore improving signal quality and common mode transient immunity. For instance, as parasitic capacitance is inversely proportional to distance from the substrate, thick dielectric layer **112** greatly decreases the parasitic capacitance coupling between substrate **102** and components **120** and **122**—for example, a reduction by 75%-90% or more. Thick dielectric layer **112** may have a thickness similar to, or the same as, a thick layer in the isolation barrier (e.g., layers **114** and **116** in the example isolator of FIG. **1**); or may have a different thickness than such layers (e.g., may be thicker or may be somewhat thinner).

[0016] While the example of FIG. **1** illustrates a single thick dielectric layer in between substrate **102** and isolation barrier **118**, this disclosure contemplates that additional thick dielectric layers and/or multiple thin dielectric layers may be used to increase the distance between substrate **102** and isolation barrier **118**.

[0017] By reducing parasitic capacitive coupling, isolator **100** improves signal quality between components **120** and **122**. As a result, isolator **100** provides better performance than a conventional isolator for a given purpose, and isolator **100** enables the transfer of signals in low-level or noisy

conditions that conventional isolators cannot successfully operate in. For example, FIG. 2 illustrates an example in which isolator **200** is used to isolate a modulator **205** from a demodulator **210**. By incorporating the structure described herein (e.g., the structure of isolator **100** of FIG. 1), isolator **200** improves the fidelity of the signal communicated between modulator **205** and demodulator **210** across isolation barrier **200**.

[0018] This disclosure contemplates that particular embodiments may place one or more thick dielectric layers **112** between any of what in FIG. 1 is shown as three thin dielectric layers **106**, **108**, and **110**. In other words, one or more thick dielectric layers may be placed between thin layers **108** and **110** or between thin layers **106** and **108**, etc. However, in practice, foundry limitations may effectively require thin dielectric layers to be deposited on top of each other, so that the introduction of thick dielectric layer **112** is mostly feasible after those layers have been deposited. Other foundry limitations include the thickness of various layers, particularly of thin layers **106**, **108** and **110**. The thickness of these thin layers are typically set by the foundry's process and are essentially fixed, and are not feasible to change during the manufacturing process; however, if such changes are feasible, then effectively introducing thick dielectric layer **112** to one or more of the thin dielectric layers (e.g., increasing the thickness of thin dielectric layer **110**) would also be an example embodiment of this disclosure.

[0019] In the example of FIG. 1, thick dielectric layers and thin dielectric layers already exist in the manufacturing process for an isolator, and therefore thick dielectric layer **112** can be introduced between substrate **102** and isolation barrier **118** without requiring the creation of custom or non-standard layer thickness to the existing manufacturing process; rather, a new layer with an existing thickness specification is added to the isolator. For instance, thick dielectric layer **112** may be identical to thick dielectric layers **114** and **116** in terms of its manufacturing specifications (e.g., its thickness and dielectric material).

[0020] Herein, “or” is inclusive and not exclusive, unless expressly indicated otherwise or indicated otherwise by context. Therefore, herein, “A or B” means “A, B, or both,” unless expressly indicated otherwise or indicated otherwise by context. Moreover, “and” is both joint and several, unless expressly indicated otherwise or indicated otherwise by context. Therefore, herein, “A and B” means “A and B, jointly or severally,” unless expressly indicated otherwise or indicated otherwise by context.

[0021] The scope of this disclosure encompasses all changes, substitutions, variations, alterations, and modifications to the example embodiments described or illustrated herein that a person having ordinary skill in the art would comprehend. The scope of this disclosure is not limited to the example embodiments described or illustrated herein. Moreover, although this disclosure describes and illustrates respective embodiments herein as including particular components, elements, feature, functions, operations, or steps, any of these embodiments may include any combination or permutation of any of the components, elements, features, functions, operations, or steps described or illustrated anywhere herein that a person having ordinary skill in the art would comprehend.

Claims

1. An electrical isolator comprising: a first electrical component and a second electrical component configured to wirelessly communicate electrical signals with each other; an isolation barrier comprising one or more dielectric layers that electrically isolate the first electrical component from the second electrical component; and one or more dielectric layers between a substrate on which the isolator is mounted and the isolation barrier, comprising: one or more thin dielectric layers; and one or more thick dielectric layers that reduce a parasitic electrical coupling between the substrate and at least one of the first electrical component and the second electrical component.
2. The electrical isolator of claim 1, wherein the first electrical component comprises a first capacitor plate and the second electrical component comprises a second capacitor plate.

- 3.** The electrical isolator of claim 1, wherein the first electrical component comprises a first inductive coil and the second electrical component comprises a second inductive coil.
 - 4.** The electrical isolator of claim 1, wherein each of the one or more thick dielectric layers are at least 10 times as thick as each of the one or more thin dielectric layers.
 - 5.** The electrical isolator of claim 1, wherein each thin dielectric layer has a thickness of about 0.1 to 0.5 micrometers.
 - 6.** The electrical isolator of claim 1, wherein each thick dielectric layer has a thickness of about 5 to 10 micrometers.
 - 7.** The electrical isolator of claim 1, wherein the one or more thick dielectric layers that reduce the parasitic electrical coupling separate the one or more thin dielectric layers from the isolation barrier.
 - 8.** The electrical isolator of claim 1, wherein each of the one or more thick dielectric layers between the substrate and the isolation barrier have substantially the same thickness as each of the one or more dielectric layers in the isolation barrier.
 - 9.** The electrical isolator of claim 1, wherein at least one first thick dielectric layer between the substrate and the isolation barrier has a thickness that is different than a thickness of at least one second thick dielectric layer in the isolation barrier.
 - 10.** The electrical isolator of claim 9, wherein the at least one first thick dielectric layer is thicker than the at least one second thick dielectric layer.
 - 11.** The electrical isolator of claim 9, wherein the at least one first thick dielectric layer is thinner than the at least one second thick dielectric layer.
 - 12.** The electrical isolator of claim 1, wherein: the first electrical component is electrically coupled to an output of a modulator; and the second electrical component is electrically coupled to the input of a demodulator.
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