

Anatomy of a Digital Isolator

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For years, designers of industrial, medical and other isolated systems had limited options when implementing safety isolation: the only reasonable choice was the optocoupler. Today, digital isolators offer advantages in performance, size, cost, power efficiency and integration. Understanding the nature and interdependence of three key elements of a digital isolator is important in choosing the right digital isolator. These elements are insulation material, their structure and data transfer method.

Designers incorporate isolation because of safety regulations, or to reduce noise from ground loops, etc. Galvanic isolation ensures data transfer without an electrical connection or leakage path that might create a safety hazard. Yet, isolation imposes constraints such as delays, power consumption, cost and size. A digital isolator's goal is to meet safety requirements while minimizing incurred penalties.

Optocouplers, a traditional isolator, incur the greatest penalties, consuming high levels of power and limiting data rates to below 1 Mbps. More power efficient and higher speed optocouplers are available, but they impose a higher cost penalty.

Digital isolators were introduced over 10 years ago to reduce penalties associated with optocouplers. They use CMOS-based circuitry and offer significant cost and power savings while significantly improving data rates. They are defined by the elements noted earlier. Insulating material determines inherent isolation capability and is selected to ensure compliance to safety standards. Structure and data transfer method are chosen to overcome the cited penalties. All three elements must work together to balance design targets, but the one target that cannot be compromised and "balanced" is the ability to meet safety regulations.

Insulation Material

Digital isolators use foundry CMOS processes and are limited to materials commonly used in foundries. Non-standard materials complicate production, resulting in poor manufacturability and higher costs. Common insulating materials include polymers

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such as polyimide (PI), which can be spun on as a thin film, and silicon dioxide (SiO₂). Both have well known insulating properties and have been used in standard semiconductor processing for years. Polymers have been the basis for many optocouplers, giving them an established history as a high-voltage insulator.

Safety standards typically specify a one minute voltage withstand rating (typically 2.5 kV rms to 5 kV rms) and working voltage (typically 125 V rms to 400 V rms). Some standards also specify shorter duration, higher voltage (e.g., 10 kV peak for 50 μs) as part of certification for reinforced insulation. Polymer/polyimide-based isolators yield the best isolation properties:

	Polymer-based Optocoupler	Polyimide-based Digital Isolator	SiO ₂ -based Digital Isolator
Withstand Voltage (1 minute)	7.5 kV rms	5 kV rms	5 kV rms
Lifetime at 400 V rms Working Voltage	25 years	50 years	25 years
Surge Level for Reinforced Insulation	20 kV	12 kV	7 kV
Distance Through the Insulation (Insulation Thickness)	400 μm	14-26 μm	7-15 μm

Polyimide-based digital isolators are similar to optocouplers and exceed lifetime at typical working voltages. SiO₂-based isolators provide weaker protection against surges, preventing use in medical and other applications.

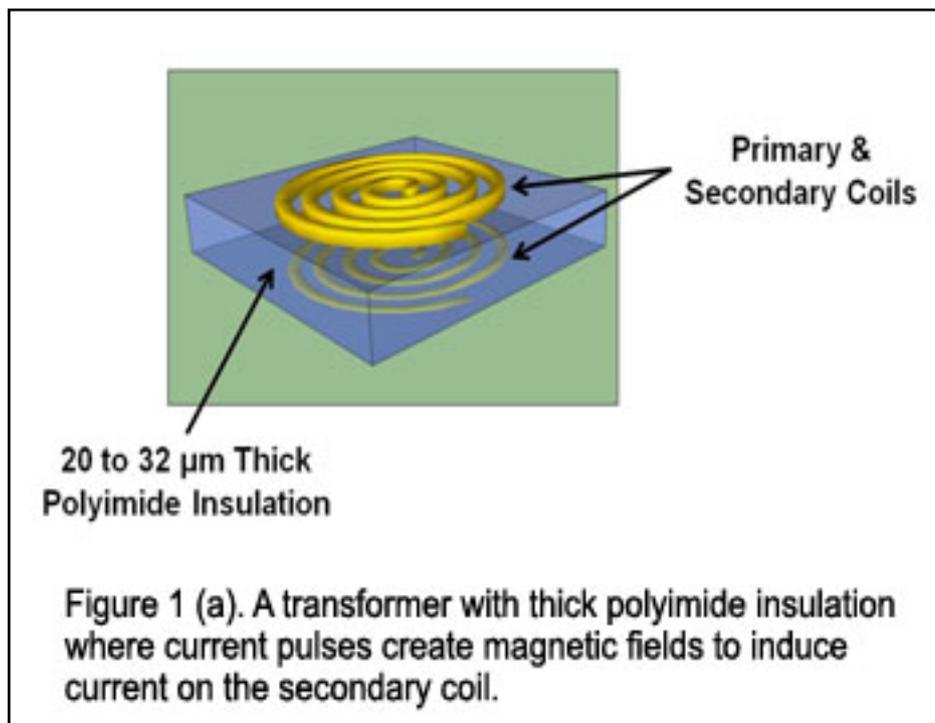
The inherent stress of each film is also different. Polyimide has lower stress than SiO₂ and can increase in thickness as needed. SiO₂ thickness, and therefore isolation capability, is limited; stress beyond 15 μm may result in cracked wafers during processing or delamination over the life of the isolator. Polyimide-based digital isolators use isolation layers as thick as 26 μm.

Isolator Structure

Digital isolators use transformers or capacitors to magnetically or capacitively couple data across an isolation barrier, compared to optocouplers that use light from LEDs.

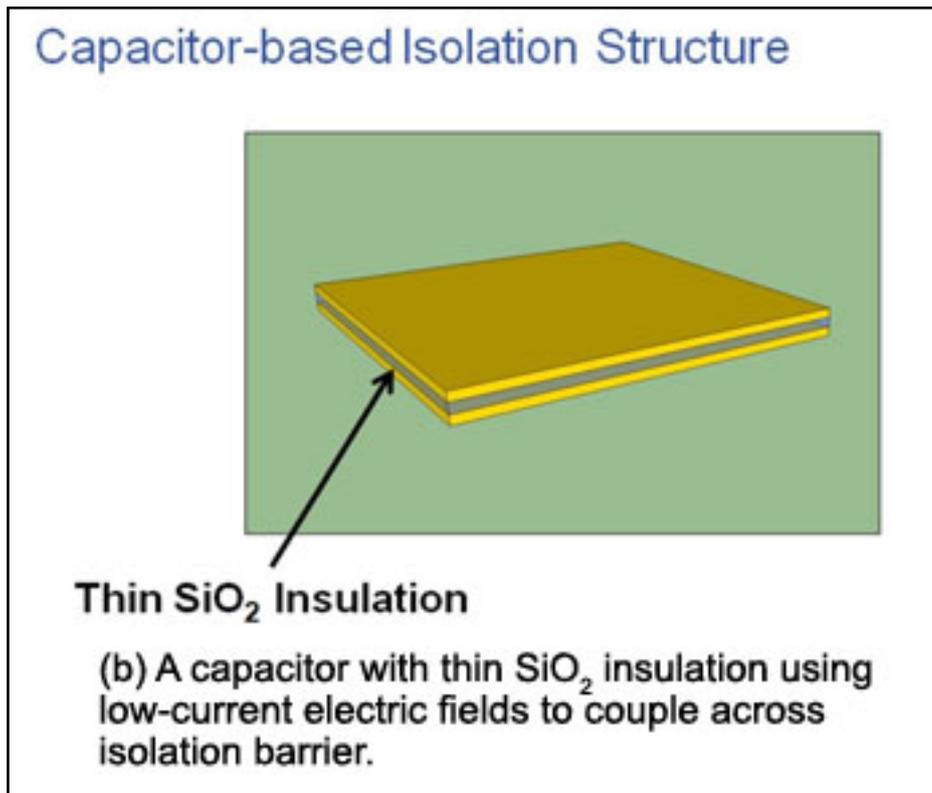
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Transformers pulse current through a coil, as shown in Figure 1, to create a small, localized magnetic field that induces current in another coil. The current pulses are short, 1 ns, so the average current is low. Transformers are also differential and provide excellent common mode transient immunity, as high as 100 kV/ μs (optocouplers are typically about 15 kV μs). Magnetic coupling also has a weaker dependence on the distance between the transformer coils compared with the dependence for capacitive coupling on the distance between plates. This allows for thicker insulation between transformer coils resulting in higher isolation capability. Combined with low-stress polyimide films, high levels of isolation may be achieved for transformers using polyimide versus capacitors using SiO₂.

Capacitors are also single-ended and have higher susceptibility to common mode transients. Differential pairs of capacitors can compensate, but this increases size and cost.



One benefit of capacitors

is that they use low currents to create the coupling electric field. This becomes noticeable at high data rates, above 25 Mbps.

Data Transmission Methods

Optocouplers use light from LEDs to transmit data across an isolation barrier: the LED turns on for logic HIGH and off for logic LOW. While the LED is on, the optocoupler burns power -- making optocouplers a poor choice wherever power consumption is a concern. Most optocouplers leave the signal conditioning at the input and/or output to the designer, which is not always the easiest to implement.

Digital isolators use more advanced circuitry to encode and decode data allowing for more rapid data transmission and the ability to handle complex, bi-directional interfaces such as USB and I2C. One method encodes rising and falling edges as double or single pulses that drive a transformer (Figure 2). These pulses are decoded back into rising/falling edges on the secondary side. This reduces power consumption by 10x to 100x compared to optocouplers because power is not continuously applied as with optocouplers. Refresh circuits can be included to regularly update the DC level.

Another method uses RF modulated signals in much the same way that optocouplers use light; logic HIGH signal results in continuous RF transmission. This consumes more power than the pulsed method because logic HIGH signals continuously burn power. Differential techniques may also be employed for common mode rejection; however, these are best used with differential elements such as transformers.

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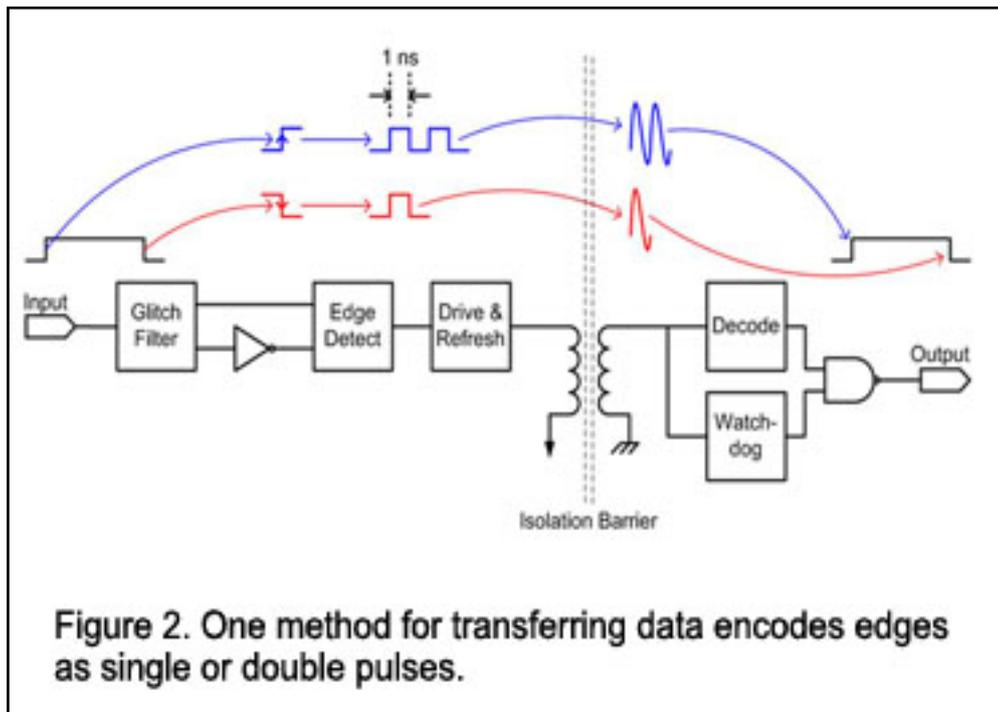


Figure 2. One method for transferring data encodes edges as single or double pulses.

Choosing the Right

Combination

Digital isolators offer significant, compelling advantages over optocouplers in terms of size, speed, power consumption, ease-of-use and reliability. Within the class of digital isolators, different combinations of insulating material, structure and data transfer method distinguish different products, thereby making some more or less suitable to particular applications. As noted earlier, polymer-based materials offer the most robust isolation capability; this material can be used in almost all applications; but the most stringent, such as healthcare and heavy industrial equipment, will gain the most advantage. To achieve the most robust isolation, polyimide thickness may be increased beyond what is reasonable for capacitors; therefore, capacitor-based isolation may be best suited for functional isolation where safety isolation is not required. In those cases, transformer-based isolation may make the most sense, especially when combined with a differential data transfer method that takes full advantage of the differential nature of transformers.

About the author:

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