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Digital Isolator Evolution Drives Optocoupler Replacement

Introduction

Optocouplers have existed in various forms since the late 1960s and find use in many different applications. Because optocouplers suffer from a myriad of technical issues, the user community has been forced to remedy optocoupler quirks by adding external components. Without a superior solution to immediately address the isolation function, optocouplers have been regarded by the design community as “good enough.”

But, times are changing. Many end applications demand performance and reliability beyond an optocoupler’s capability. For example, wear-out and aging effects in light emitting diode (LED) based optocouplers often limit device lifetimes to about 10 years, creating a problem for industrial system designers who want to develop products with 20+ year warranties. Industrial applications, such as solar power inverters, switched mode power supplies (SMPS), industrial drives, programmable logic controllers (PLCs) and high-voltage medical equipment, now require more robust isolation devices with significantly higher performance, reliability and integration, none of which can be provided by the venerable optocoupler. While advanced CMOS isolation devices have been on the market for more than 10 years, their package and pin-out configurations often require significant changes to the designer’s printed circuit board (PCB) layout, increasing design risk and system cost.

21st Century Alternatives to Optocouplers

Developers have long recognized that optocouplers are based on outdated technology, and only recently have cost-effective and easy-to-use alternatives become available. These advanced package-and pin-compatible drop-in optocoupler replacements provide substantially higher performance and reliability with none of the technical liabilities of optocouplers.

For example, the Si87xx digital isolators from Skyworks directly replace 6- and 8-pin optocouplers and are suitable for both optocoupler retrofit and new system designs. They directly connect to existing external optocoupler input circuits, including those that reverse-bias the optocoupler input LED. These devices use a CMOS-based isolation architecture that is ten times more reliable than optocouplers, enabling manufacturers to support longer end-product warranties and reduce costs associated with repairs or replacement. In addition, device operating parameters vary only slightly across voltage and temperature, simplifying system designs since engineers no longer need to account for optocoupler aging effects.

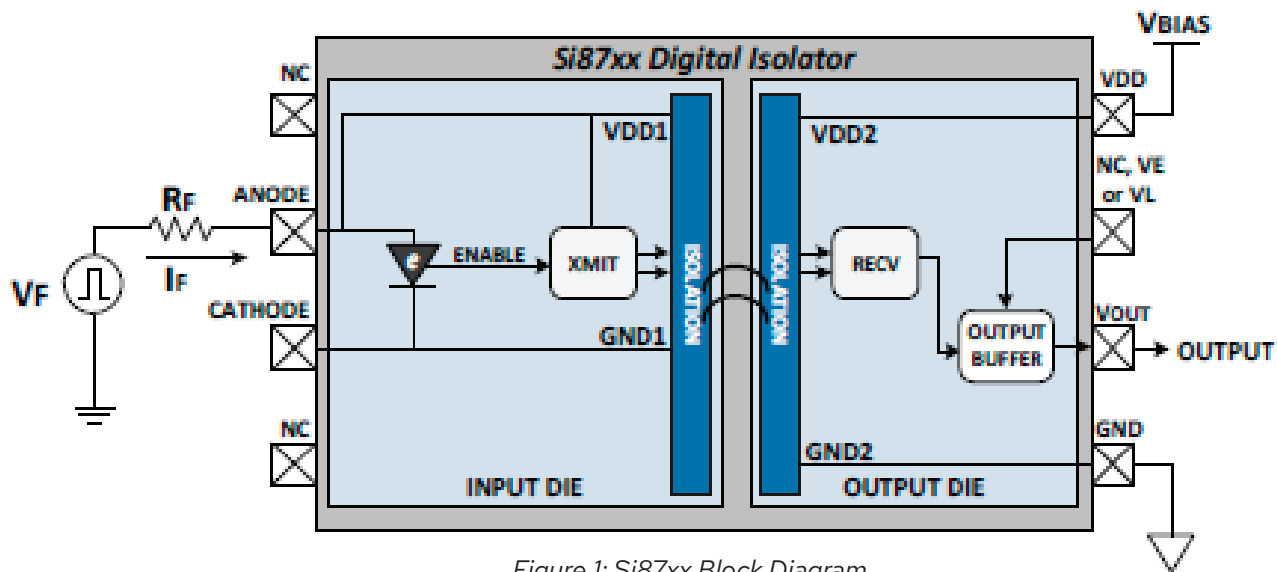


Figure 1: Si87xx Block Diagram

Figure 1 shows the Si87xx device's two-die architecture in which the diode emulator, high-frequency transmitter and galvanic isolator are on the input-side die, and the galvanic isolator, receiver and output switch are on the output-side die. The device operating principal is straightforward: the diode emulator mimics the behavior of an optocoupler LED to enable retrofit with existing external optocoupler input-side circuits. The diode emulator activates the transmitter when anode current is at or above its logic high threshold value, causing the transmitter to propagate a high-frequency carrier to the output-side receiver. When sufficient in-band energy is detected, the receiver drives the output pin low. Conversely, anode current below its logic high threshold value disables the transmitter, causing the receiver to disable the output driver to be pulled high by the pull-up resistor.

Grail Isolation

The latest generation of CMOS isolators supports isolation ratings as high as 5 kV with compliance to IEC 60747-5-2 including 10 kV surge protection per IEC 60065. These next-generation isolators also meet the requirements of IEC 60950-1, 61010-1, 60601-1 (reinforced insulation) with working voltages up to 1200 V. The strength and reliability of digital isolators like the Si87xx family enable them to be used in a wide range of end applications while withstanding the harshest electrical environments over a continuous period of 60+ years and a $-40\text{ }^{\circ}\text{C}$ to $+125\text{ }^{\circ}\text{C}$ temperature range.

Isolator input current thresholds determine the amount of input current required to turn the isolator on or off (Figure 2). The accuracy and stability of these thresholds are important, yet digital optocouplers have ambiguous or temperature-dependent thresholds that create logic errors, forcing designers to increase timing margins, which reduces system throughput. Input threshold requirements also vary with the end application. For example, low-power applications require a lower input current threshold than applications in noisy environments, which require high common-mode transient immunity (CMTI).

The Si87xx isolators offer different input current threshold options: A-grade devices have a guaranteed turn-on threshold of 1.2 mA, and B-grade devices have a guaranteed turn-on threshold of 2.3 mA. These input current thresholds remain stable from unit to unit and over voltage, current and temperature. The precise current thresholds guarantee that these isolators will be either on or off, eliminating the need to specify a current transfer ratio (CTR) and its associated temperature dependency.

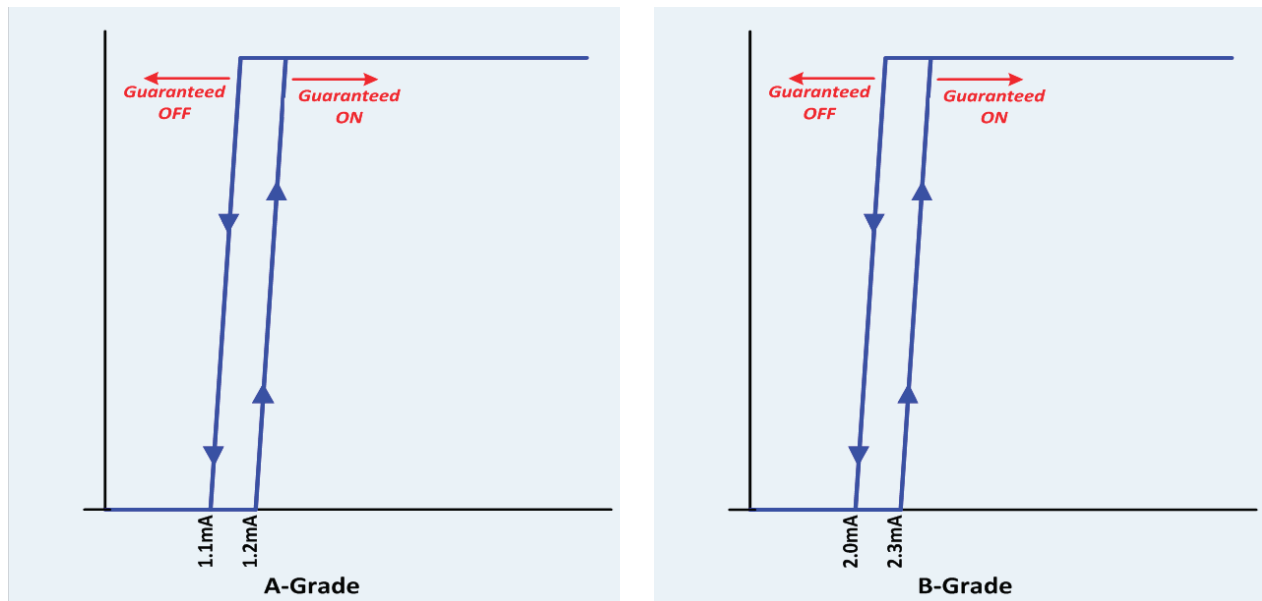


Figure 2. Digital Isolator Input Threshold Behavior

The inherent parasitic couplings within optocouplers often cause data errors during common-mode transient (CMT) events. Until recently, designers were forced to either add external components, such as shunting switches, to keep the LED in its proper state during the transient or dramatically increase input current at the expense of lower efficiency. While the Si87xx isolators also have internal parasitic couplings, their magnitude is 2x to 3x lower compared to the best optocouplers available. This reduced internal parasitic coupling results in higher CMTI, which means that a much higher and faster CMT event would be required to perturb Si87xx devices and cause data errors.

Figure 3 shows common-mode voltage (VCM) perturbing both the anode and cathode inputs. In this example, a positive-going CMT event momentarily drives the cathode high, turning-off the input diode and allowing the pull-up resistor to pull the output pin high. Note that the Si87xx device output rises to 500 mV for about 90 ns and then returns to ground level, all the while with no logic state change. In comparison, HCPL-4506 output momentarily goes high to 2.75 V for a duration of approximately 400 ns.

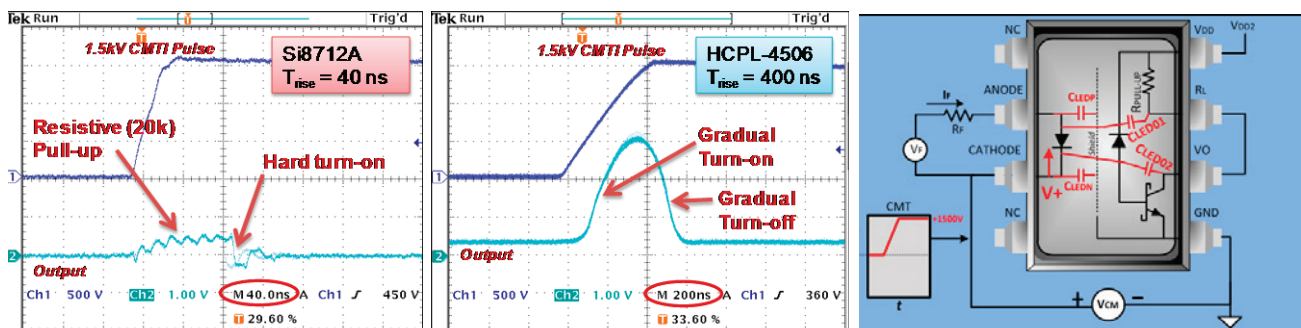


Figure 3. Positive-Going CMTI Event Comparison

Many designers add a load capacitor on the output side from the Vo pin to ground to eliminate output glitches. While this technique has been demonstrated to work, it has the unwanted side effect of increasing propagation time, lowering the isolator's output dv/dt and creating an interdependency between the values of R_L and C_L . Modern CMOS digital isolators are either on or off and therefore do not require the output filter and its associated downside effect on timing.

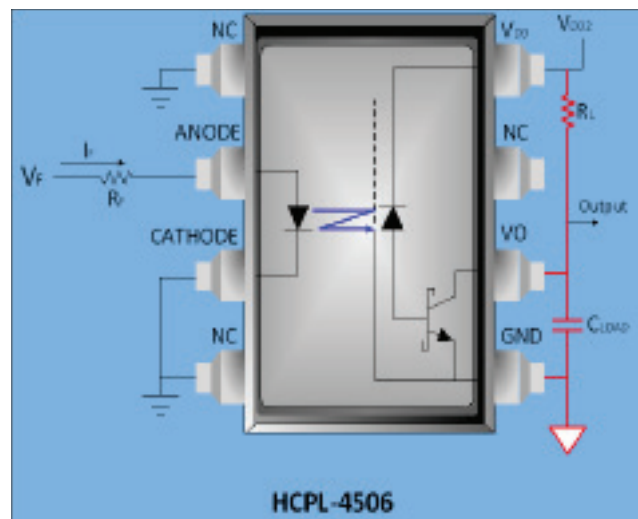


Figure 4. Optocoupler Output Filter

Over the years, designers have discovered the inadequacies of optocouplers and have generated various external component fixes. Optocoupler manufacturers have also become more aware of the customer's needs and have published numerous remedies to compensate for the optocoupler's shortcomings. In contrast, next-generation digital isolators designed to replace optocouplers are more intuitive and easier to use and typically do not need external component fixes associated with optocoupler-based designs.

Table 1 shows a set of solutions for improving the CMTI and propagation time of optocouplers and the Si87xx CMOS digital isolator. Note that the Si87xx device is immune to several optocoupler issues and relies almost exclusively on adjustment of the values of R_F and/or R_L or use of the B-grade (higher threshold) device.

The optocoupler solutions include additional external transistors, diodes or peaking capacitors and adjustment of R_F and/or R_L and C_{Load} . Table 2 summarizes the high-level differences between optocouplers and the Si87xx digital isolators.

Issue	Optocoupler Solutions	Si87xx Solutions
Improve CMTI: Spurious Turn-on	Use higher threshold device Use clamping diode or switch Decrease value of R_F (more current) Increase value of C_L (more current) Decrease value of R_L (more current)	Use higher threshold device Decrease value of R_F (more current) (Note 1) Remove C_L
Improve CMTI: Spurious Turn-off	Decrease value of R_F (more current) Decrease value of R_F (more current) Increase value of R_L	Use higher threshold device Decrease value of R_F (more current) (Note 1) Increase value of R_L
Decrease t_{PHL}	Decrease R_F value (more current) Increase R_L value Decrease C_L value Add peaking cap across R_F	Non-issue Non-issue Non-issue Non-issue
Decrease t_{PLH}	Decrease value of R_L (more current) Decrease value of C_L Add peaking cap across R_F	Decrease value of R_L (more current) Remove C_L Non-issue
Address CTR Variation	Use worst case # (more current)	Non-issue
Address LED Aging	Decrease R_F (more current)	Non-issue

Table 1. Optocoupler vs. Digital Isolation Solution

Item	Si87xx/826x	Optocoupler
Parasitics	Less than half the parasitic coupling of optocouplers; most parameters independent from each other	High parasitic coupling with interdependent parameters
Reliability	No wear out mechanisms, 60+ year operating lifetime at 125 °C at maximum V_{DD}	Intrinsic wear-out mechanisms; 10x lower lifetime
Input Current	Low parasitic coupling requires less current	Requires higher input current to be competitive
Ease-of-Use	Fewer second order effects, tight unit-to-unit matching, no CTR	Significant first and second order effects, temperature dependencies, imprecise current thresholds, CTR
Opto Retrofit	Simple: Use Si87xx/826x B-grade (high threshold device) with $I_F = 6$ mA	Make design trade-offs for optimum input current, CMTI performance, operating temperature and operating lifetime
Input Interface	Precise thresholds, multiple threshold versions	Ambiguous threshold often positioned below specifications
Performance	Fast prop time, better CMTI, stable over temperature and voltage, -40 °C to +125 °C operating range	Slow prop time, narrow temperature range, parametric change with temperature, input current and device age

Table 2. Digital Isolator Advantages over Optocouplers

Summary

Pin-compatible digital isolators provide an ideal upgrade solution to replace outdated optocouplers. Advanced optocoupler replacements, such as the Si87xx digital isolators, are now available to replace 6- and 8-pin optocouplers, connecting directly to existing external optocoupler input circuits, including designs that reverse-bias the anode input. These optocoupler replacements are useful in both new and retrofit applications, offer more than 10x higher reliability than optocouplers, use less power, and provide faster and more uniform timing performance. Put simply, modern optocouplers cannot match the performance and reliability of the latest generation of CMOS isolators.



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