Application Note

Using TI Opto-Emulator to Achieve High Speed and High Reliability Digital Output Applications

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ABSTRACT

Digital output modules are widely used in industrial automation applications for PLC, motor drives, robotics and machine automation. At first glance, the digital output module is a simple device which translates a logic-level signal into a load or a specific sensor communication protocol. On closer inspection, the modern systems raise higher requirements on DO module to enable flexibility, scalability, low-power consumption, simplicity and smaller size, while needing reliability and robustness to give longevity to automation systems. TI's opto-emulator ISOM86x0 features a robust isolation technology with symmetrical 80V output switch that is a drop-in replacement and pin-to-pin upgrade to industry-standard photo relays. The ISOM86x0 family adds performance with an ultra-low off-state leakage and input trigger current, a fast response time, and wider temperature range (-55°C to +125°C). They also add EMC robustness to withstand up to 70V output blocking voltage and immunity up to 10kV surge pulses, and 7kV ESD impact. This application note discusses how to effectively use different features of ISOM8600 and ISOM8610 to maximize system benefits.

Table of Contents

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1 Digital Output in PLC/DCS, Motor Drives and Robotics

1.1 Sink and Source Outputs: Supports Bidirectional Operation

In traditional PLC and motor drive applications, the digital output module typically supports both sinking and sourcing mode. The digital output stages are implemented by using discrete elements such as opto-transistors for isolation, discrete transistors for increasing output source and sink current, or a bridge rectifier stage to enable source and sink capable outputs. The entire design is bulky and often requires additional power to compensate for lifetime operation.

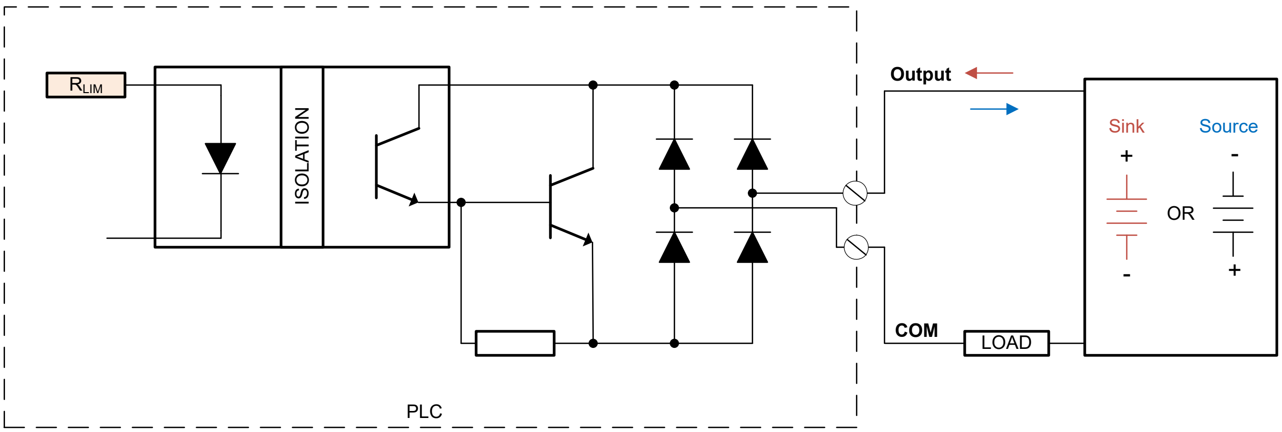

Figure 1-1. Typical Digital Output Stage with Discrete Implementation

However, ISOM8600 is a smaller and simpler alternative to the discrete implementation with the device allowing up to 150mA of bidirectional source and sink capable output in the ON state with up to 80V blocking voltage in the OFF state. The ISOM8600 can be simply used as an 80V isolated switch when used within the recommended operating conditions.

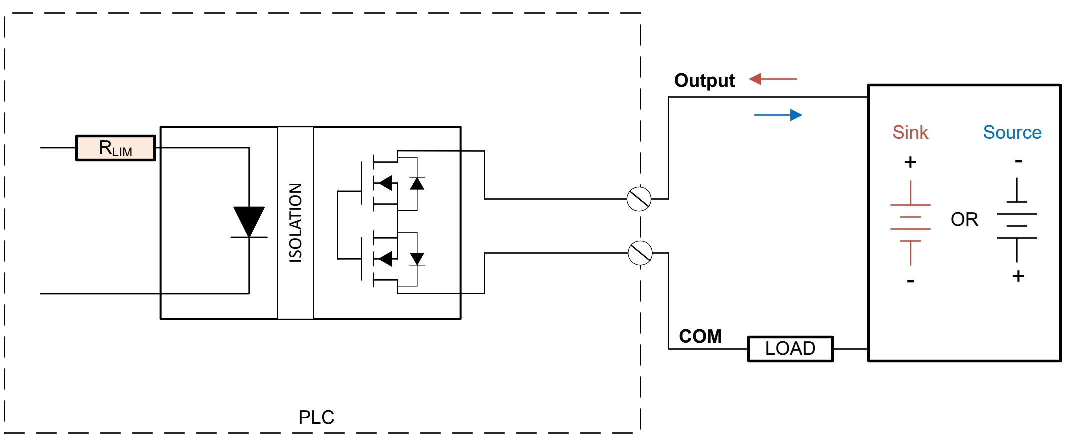

Figure 1-2. Recommended Digital Output Stage Implementation with ISOM8600

1.2 PLC/DCS

ISOM86x0 can be used in PLC/DCS for modules including typical digital output, safety I/O, position interface (generate a pulse output) to the sensors, motor drives, and so on. The ISOM86x0 is a good option for the above applications when typical output current is less than 150mA and 24V output voltages (Digital Output Module Application Information).

1.3 Motor Drives

In motor drives applications, digital outputs are typically used in the following functions:

1. Isolated output connecting to a PLC, to indicate fault, motion or other signals.
2. Driving external relays, actuators or indicators.
3. Other signal outputs such as line drivers and open collector outputs to encoders.

ISOM86x0 series is a good fit for the first two functions, while the last function typically can be supported by an isolated RS-485 transceiver or RS-485 transceivers with a digital isolator or high-speed opto-emulator (Servo and Stepper Drive Application Information).

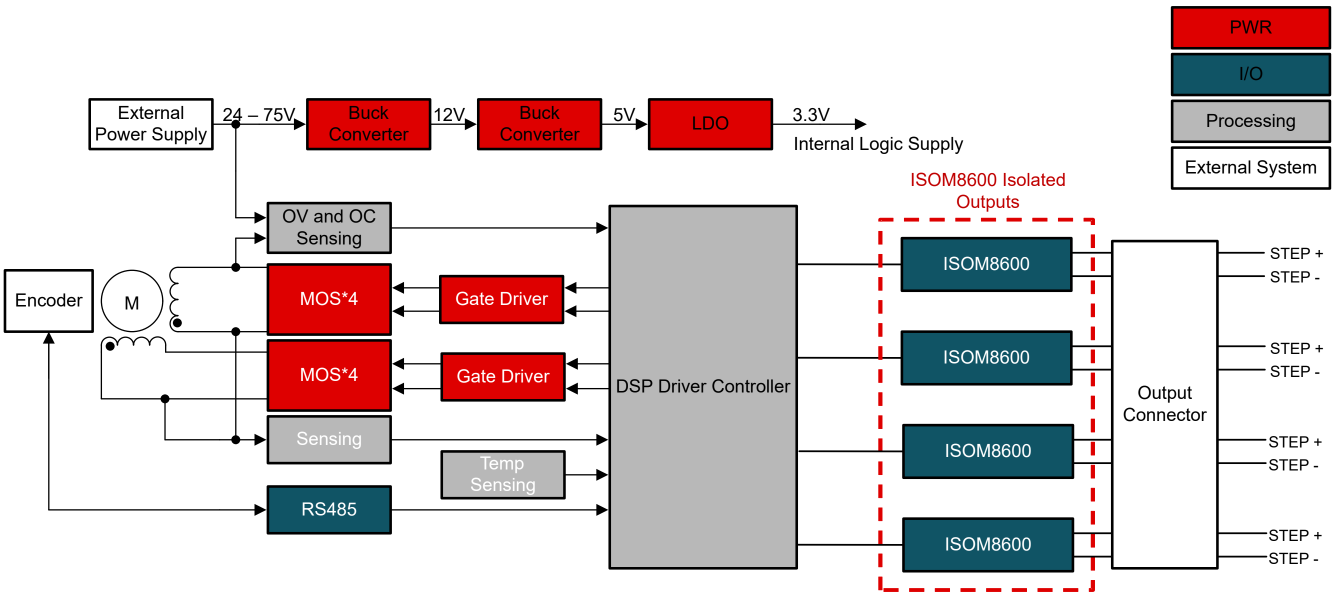

Figure 1-3. Typical Stepper Motor Driver Block Diagram

1.4 Robotics

Similar to PLCs and motor drives, Robotics designs also use digital I/O module for the following functions:

1. Transfer signals related to functional safety standards such as safety torque off (STO), backup error, speed limit, and so on.
2. Driving external relays.
3. Driving LEDs and other standard I/O signals.

Robotics applications share a lot of common use cases with motor drives. Specifically, opto-emulators are good devices for STO robotics applications due to the current type input. This allows for the safety circuits remain active without a local power supply and maintain a high lifetime and fast response to the input signal (Robotics Safety Module Application Information).

2 Design Procedures for Driving a Relay (Inductive Load)

2.1 Introduction to a Mechanical Relay

Mechanical relays are electromechanical devices that use an inductive coil to move mechanical contact. The relay is commonly used in power stages to connect or disconnect power stages and voltage rails. Solid state relays, such as ISOM8600, are used as an intermediate driver for the inductive coil which cannot be driven by a low current MCU GPIO.

2.2 ISOM8600 Design Example

The input side of the ISOM86x0 is current-driven. As shown in Figure 1-2, a user can place R_{LIM} in series with the input to limit the current flowing into AN pin. R_{LIM} is selected to set the input current ON threshold according to the Recommended Operating Conditions (0.8mA to 20mA) for the ISOM8600.

The equation to calculate RIN for a given input voltage (VIN) and desired input forward current (IF) is shown in Equation 1 where VF is the maximum specification for the ISOM8610 input forward voltage:

$$R_{LIM} = V_{IN} - V_F / I_{F\_MAX} \tag{1}$$

For example, with a 24V input and 2mA desired I_F, R_{LIM} can be calculated as:

$$R_{LIM} = 24V - 1.5V / 2mA = 11.25k\Omega \tag{2}$$

2.3 Test Results based on ISOM8600 and relay

One important consideration for design is the V_{OFF} of the output when driving a relay or an inductive load. The ISOM8600 supports up to VOFF = $80V_{DC}$, however, the free-wheeling voltage (or back EMF) when the ISOM8600 output stops driving the relay coil can cause a transient up to $150V_{PK}$. Therefore, additional protection is needed to resolve this challenge.

The energy from the 24V supply is stored in the mechanical relay coil while the output (P1 and P2) is ON. The back EMF is the released coil energy that appears at pin 4 when the output (P1 and P2) switches OFF.

Two common mechanical relays were selected to test the circuit in Figure 2-1 to demonstrate this challenge. The first test shows the free-wheeling voltage generated from the mechanical relay.

2.3.1 Test 1: No Protection

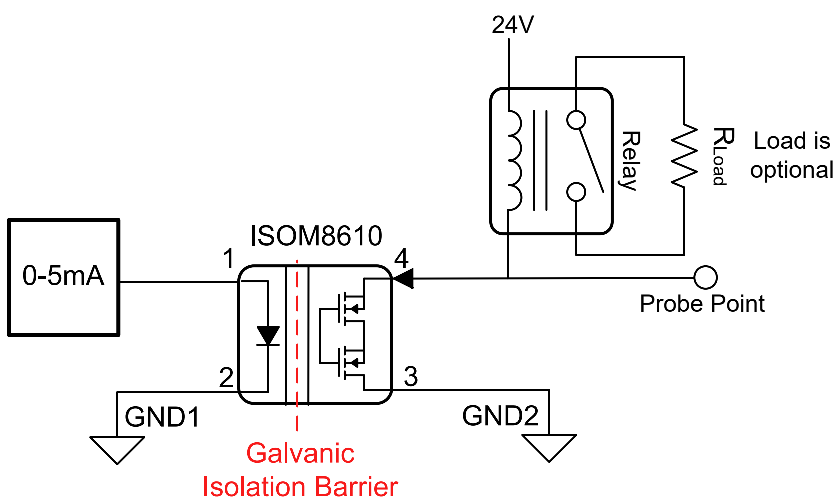

Figure 2-1. Test Circuit 1 – No Protection

Figure 2-1 was constructed, and the scope was set trigger on the first falling edge. The input of ISOM8600 is driven using a 5mA supply current. When the input is switched off the transient was captured.

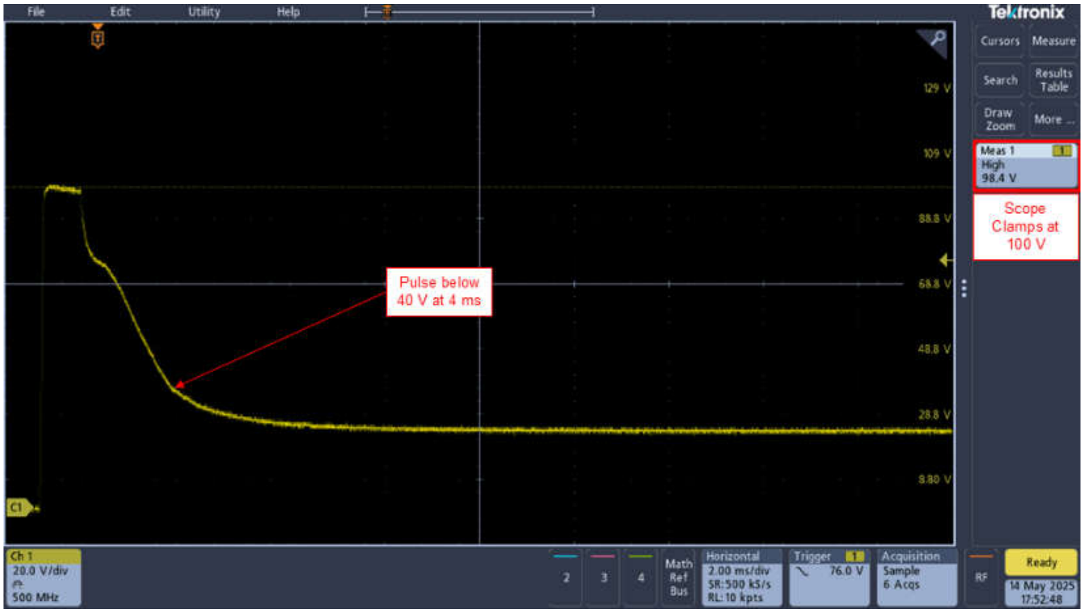

Figure 2-2. Back EMF for Circuit 1

The scope probe protections circuits cause clamping at 100V however the transient exceeds the recommended V_{OFF} of the ISOM8600 above 40V. To maintain the lifetime reliability of the ISOM8600 we need consider a protection circuit to limit the back EMF.

2.3.2 Test 2: Capacitive Filter

The second test utilizes a 1µF capacitor to filter out the transient. The capacitive filter (Figure 2-3) succeeds in lowering the high level of the transient, however, the time that the transient is above 40V extended from 4ms to 10ms. The capacitive filter increases the duration of the transient and does not actively clamp the pulse. This may not be possible for certain applications.

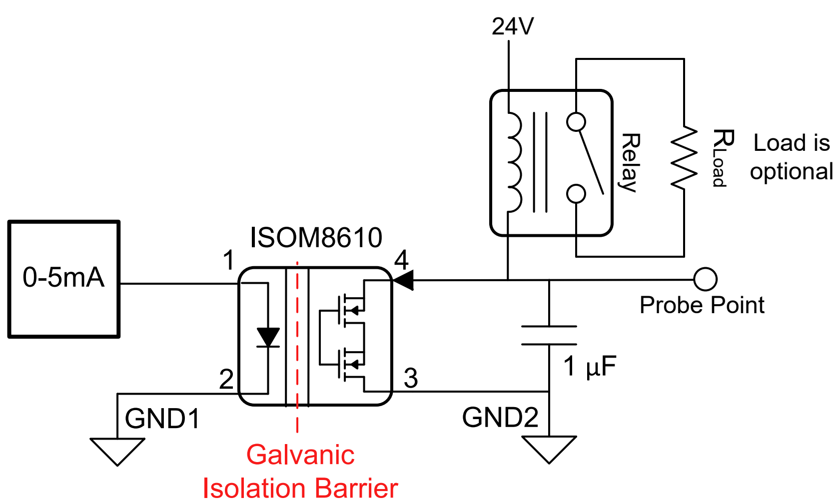

Figure 2-3. Test Circuit 2 – Capacitive Filter

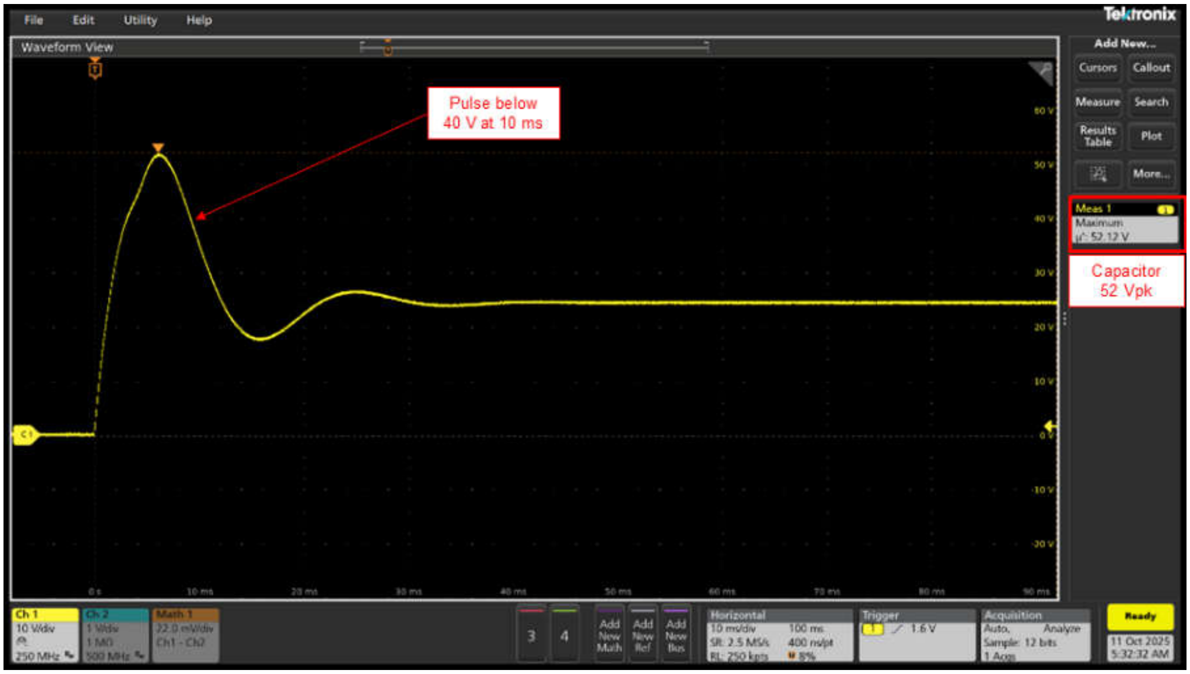

Figure 2-4. Back EMF for Circuit 2

2.3.3 Test 3: Zener Active Clamping Diode

The third test uses a Zener to clamp the transient below 40V. BZX84C39VDBZR was selected at a clamping voltage (V_Z) = 39V) lower than the V_{OFF} (40V) of the ISOM8600. A Zener diode was selected over a TVS due to the transients high energy and duration.

The Zener was soldered to ISOM8600 pins 4 and 3 and the test was repeated. As shown in Figure 2-5 , the Zener clamps to 40V for the duration of the transient and does not extend the time constant.

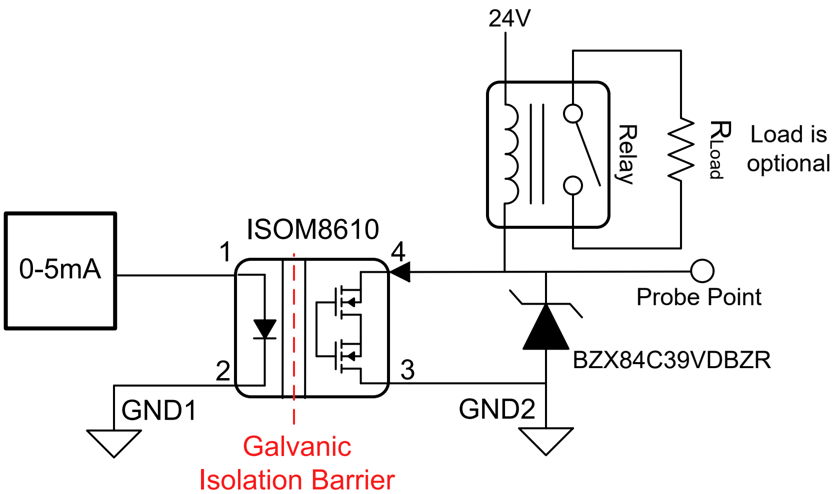

Figure 2-5. Test Circuit 3 – Zener Protection Diode

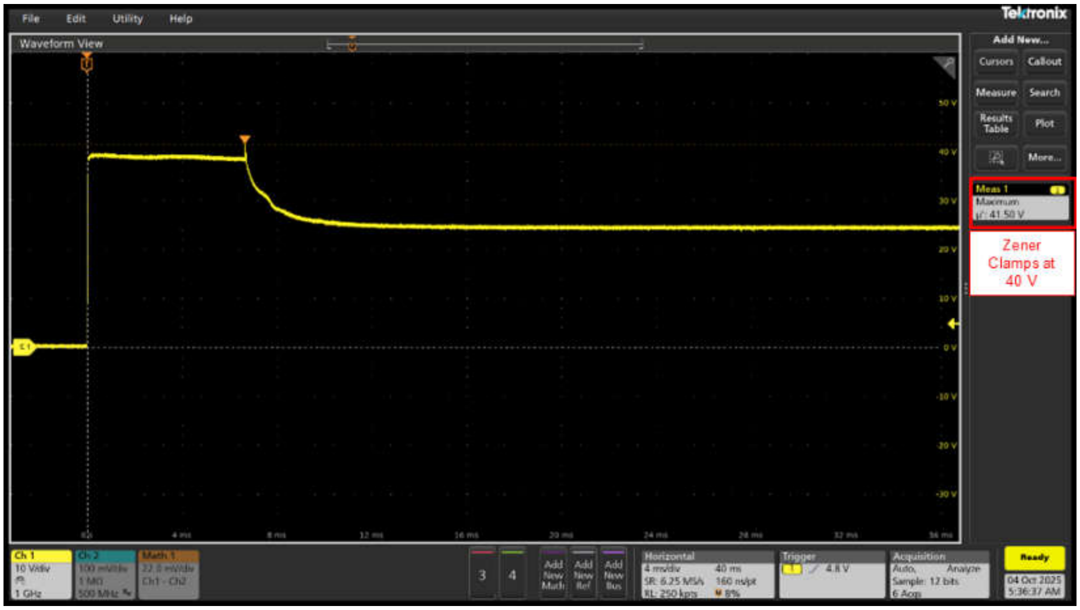

Figure 2-6. Back EMF for Circuit 3

3 ISOM86x0 Advantages

3.1 Isolation Technology

ISOM86x0 implements TI's latest opto-emulator technology which uses TI's patented SiO2 insolation material as a dielectric. SiO2 offers the highest dielectric strength in industry unlike airgap or epoxy based isolation utilized in opto-couplers.

Table 3-1. Dielectric Strength of Various Insulating Materials

Insulator Materials	Technology	Dielectric Strength
Air	Optocouplers	approximately $1V_{RMS}$/μm
Epoxies	Optocouplers	approximately $20V_{RMS}$/μm
Silica Filled Mold Compounds	Optocouplers	approximately $100V_{RMS}$/μm
SiO_2	Opto-emulators and Digital Isolators	approximately $500V_{RMS}$/μm

LED signal transmissions in opto-couplers are affected by aging, therefore upgrading to the ISOM8610 also offers another benefit. TI's optocoupler does not use and LED. Instead, the diode characteristics are emulated. This means that the opto-emulators can certify according to the more stringent standard IEC 60747-17 with lifetime isolation testing. The standard for traditional optocouplers - IEC 60747-5-5 - does not require lifetime testing of the isolation barrier. Therefore, opto-emulators can provide better device performance and capability over lifetime (Demystifying Isolation Certification Standards: Optocouplers vs Opto-emulators).

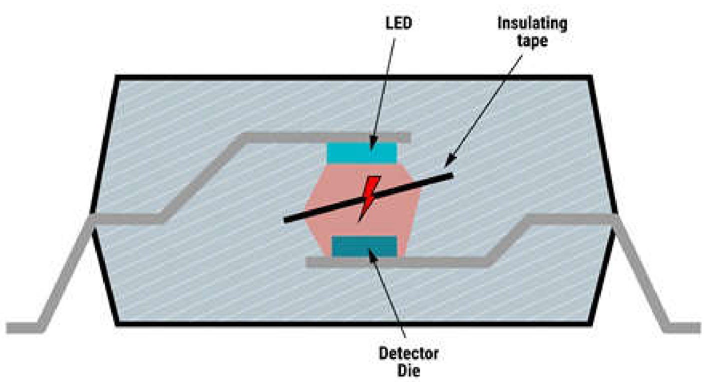

Figure 3-1. Optocoupler Cross-Section

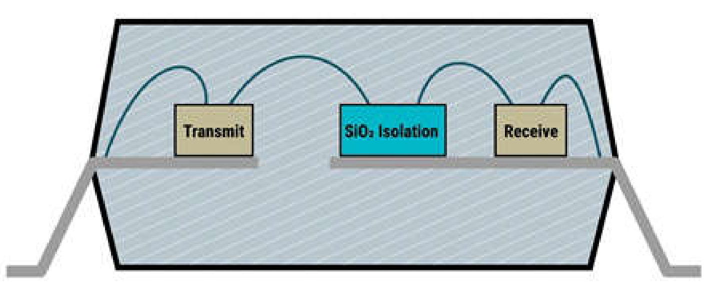

Figure 3-2. Opto-Emulator Cross-Section

Additionally, the ISOM86x0 opto-emulator switch offers advantages like wider temperature ranges and tight process controls resulting in small part-to-part variations. Since there is no aging effect to compensate for, the emulated diode-input stage consumes less power and enables system power saving than optocouplers that have LED aging and require higher bias currents over the device lifetime.

3.2 Opto-Emulator Signal Chain

In opto-emulators, the input signal is transmitted across the isolation barrier using an on-off keying (OOK) modulation scheme. OOK can provide higher CMTI and reliable noise immunity for the application. The isolation topology also allows for fast TON and TOFF times which can help to enable higher throughput and can be used higher-speed applications.

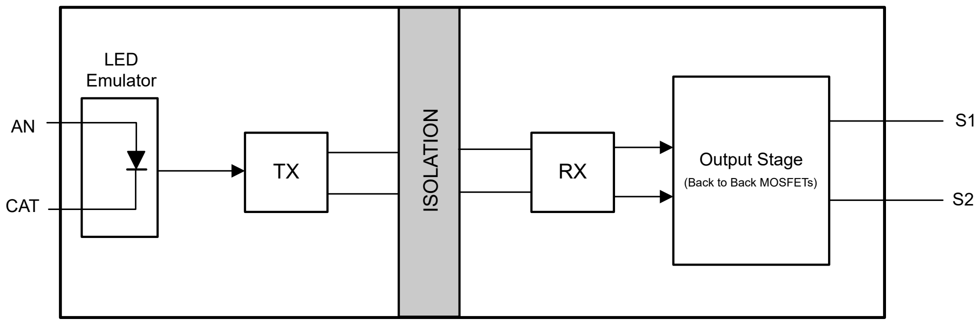

Figure 3-3. Opto-Emulator Functional Block Diagram

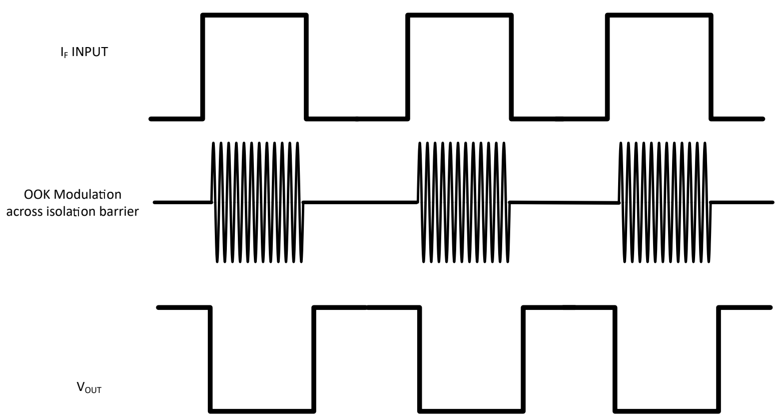

Figure 3-4. Opto-Emulator On-Off Keying (OOK) Based Modulation Scheme

4 Summary

The ISOM8600 and ISOM8610 opto-emulators from Texas Instruments are a high-performance designs for digital output applications, offering robust isolation technology and a range of benefits. These include ultra-low off-state leakage, fast response time, and a wider temperature range, making this preferred for use in PLC/DCS, motor drives, and robotics. The device also supports bi-directional operation and is designed to be a compact and efficient replacement for traditional discrete implementations. We also discussed procedures for driving a relay and protecting against transients. By utilizing the ISOM86x0, designers can create more reliable and efficient digital output systems. The devices' advanced features and capabilities make it an attractive option for a wide range of applications.

5 References

1. Texas Instruments, *ISOM8600 80V, 150mA Functionally Isolated Normally Open Opto-emulator Switch With Integrated FETs*, data sheet.
2. Texas Instruments, *ISOM8610 80V, 150mA Normally Open Opto-emulator Switch With Integrated FETs*, data sheet.
3. Texas Instruments, *Digital Output Module Application Information*, product page.
4. Texas Instruments, *Servo and Stepper Drive Application Information*, product page.
5. Texas Instruments, *Robotics Safety Module Application Information*, product page.
6. Texas Instruments, *Demystifying Isolation Certification Standards: Optocouplers vs Opto-emulators*, application brief.
7. Texas Instruments, *Upgrade photoMOS, SSR and Push-Pull, Totem-Pole, or Transistor Output Optocouplers With Opto-emulators*, product overview.
8. Texas Instruments, *Upgrading Relays with Opto-Emulator Switch* , product overview.

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