

Overvoltage-Tolerant Digital Isolators Enable Simplified and Robust System Designs



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Abstract

Overvoltage tolerant inputs are digital isolator input pins that can safely accept logic signals at voltages higher than the isolator's input-side supply. Digital isolators with overvoltage tolerant inputs, such as ISO6441 and ISO6041, provide several system-level benefits, including safe operation with higher-than-supply logic levels, simplified interfacing between devices with different supply voltages or power sequences, and improved robustness during brown-out conditions. They can also withstand signal overshoots caused by parasitics, maintain signal integrity during EMC transients without requiring additional filtering networks, and enable the isolator to be powered down during portions of normal system operation to reduce power consumption. By reducing the need for external protection and filtering components, overvoltage tolerant inputs can also help minimize board area. This application note reviews these benefits and discusses implementation considerations for digital isolators with overvoltage tolerant inputs.

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1 Introduction

Overvoltage tolerant inputs in digital isolators can safely accept logic signals at voltages higher than the isolator's own input-side supply without latching up or back-feeding into the isolator's supply. This capability is typically achieved through internal protection structures, such as reverse-direction diodes and clamp circuitry, that prevent excessive current from flowing into the device's supply rail when the input is driven above VCC. As a result, overvoltage tolerant inputs allow digital isolators to interface directly with higher-voltage logic signals and tolerate certain transient conditions without requiring additional level-shifting or protection circuitry.

For example, an overvoltage tolerant digital isolator such as the ISO6441 can allow a low-voltage isolated domain, such as 2.5V, to receive signals from a higher-voltage domain, such as 5V (Figure 1-1). This simplifies interfacing between devices with different supply voltages or power sequences, reduces component count and board area, and can improve system robustness during brown-out conditions. The inputs can also tolerate signal overshoots caused by parasitic effects, while helping preserve signal integrity during EMC transients by reducing the need for additional filtering networks. In some applications, the overvoltage tolerant input capability can also allow the isolator to be powered down during portions of normal system operation while signals remain present, helping reduce system power consumption and simplify power sequencing.

Overvoltage tolerant inputs are particularly useful in applications such as:

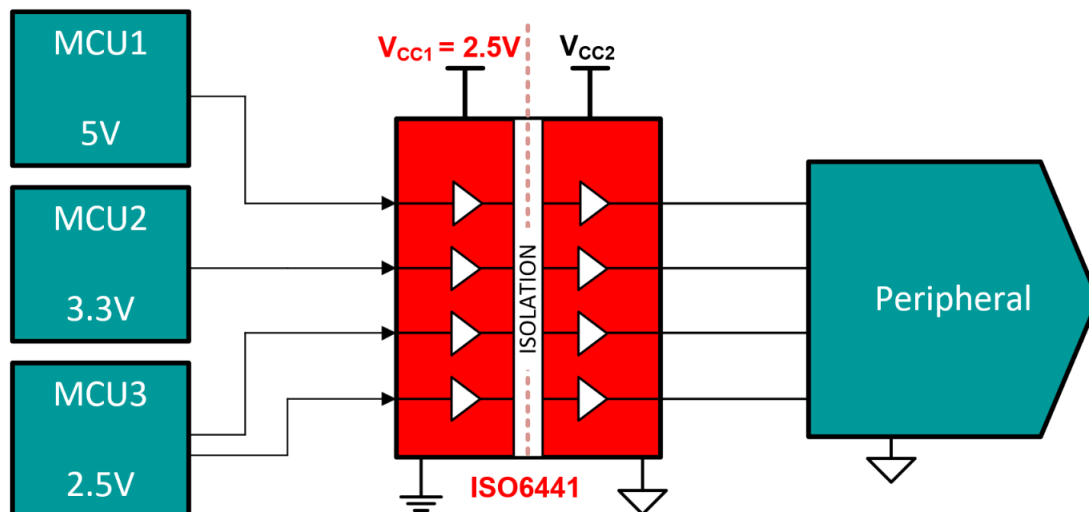


Figure 1-1. Block Diagram of Mixed-Voltage Domain using Digital Isolator With Overvoltage Tolerant Inputs

Overvoltage tolerant inputs are particularly useful in applications such as:

- Industrial I/O
- PLC modules
- Motor drives
- Power electronics gate driver interfaces

In these applications, field-side logic signals, power-sequencing conditions, parasitic-induced overshoots, or transient events can result in input voltages that temporarily exceed the supply voltage of the isolator. Overvoltage tolerant inputs provide a way to accommodate these conditions within the device's specified operating limits, while maintaining the benefits of digital isolation, noise immunity, and safety compliance. By reducing the need for external level shifters, protection components, and filtering networks, overvoltage tolerant inputs can optimize overall design and improve system-level robustness.

2 How to Determine if a Digital Isolator Has Overvoltage-Tolerant Inputs?

Digital isolators that feature overvoltage-tolerant inputs can accommodate voltages exceeding the device's supply voltage. Verify this capability by checking the datasheet's absolute maximum ratings section where the input voltage specification indicates if the inputs are overvoltage tolerant.

In the datasheets of digital isolators, such as the ISO6741, find the input voltage rating specified as $V_{CC} + 0.5V$ (Figure 2-1). This indicates that the permissible input voltage is tied directly to the VCC supply voltage. Exceeding this limit violates the absolute maximum ratings specification and can damage the device, therefore, these devices do not support overvoltage tolerant inputs.

7.1 Absolute Maximum Ratings

See⁽¹⁾

		MIN	MAX	UNIT
Supply voltage ⁽²⁾	V_{CC1} to GND1	-0.5	6	V
	V_{CC2} to GND2	-0.5	6	
Input/Output Voltage	INx to GNDx	-0.5	$V_{CCX} + 0.5$ ⁽³⁾	V
	OUTx to GNDx	-0.5	$V_{CCX} + 0.5$ ⁽³⁾	
Output current	I_O	-15	15	mA
Temperature	Operating junction temperature, T_J		150	°C
	Storage temperature, T_{stg}	-65	150	°C

Figure 2-1. Absolute Maximum Ratings of a Digital Isolator Without Overvoltage-Tolerant Inputs

In the datasheets of digital isolators that feature overvoltage-tolerant inputs, the allowable input voltage is often specified as a fixed range — for example, $-0.5V$ to $6V$ (Figure 2-2). Unlike the ISO6741, where the input limit is expressed relative to VCC, this voltage range is independent of the supply voltage. Therefore, the signal can be applied to the input even when the supply is powered down, provided it remains within the absolute maximum ratings limits.

6.1 Absolute Maximum Ratings

See⁽¹⁾

		MIN	MAX	UNIT
Supply voltage ⁽²⁾	V_{CC1} to GND1	-0.5	6	V
	V_{CC2} to GND2	-0.5	6	
Digital Input Voltage	INx to GNDx	-0.5	6	V
Digital Input Voltage	ENx to GNDx	-0.5	6	V
Digital Output Voltage	OUTx to GNDx	-0.5	$V_{CCX} + 0.5$ ⁽³⁾	V
Digital Output current	I_O	-15	15	mA
Temperature	Operating junction temperature, T_J		150	°C
	Storage temperature, T_{stg}	-65	150	°C

Figure 2-2. Absolute Maximum Ratings of a Digital Isolator with Overvoltage-Tolerant Inputs

3 The Benefits of Digital Isolators with Overvoltage-Tolerant Inputs

Using digital isolators with overvoltage-tolerant inputs can have many benefits that help simplify designs while potentially allowing for more flexible operation of the system. The following sections list the various benefits and implementations of using digital isolators with overvoltage-tolerant inputs in the system.

3.1 Accept Higher-Than-Supply Input Levels Safely

Overvoltage-tolerant inputs let a TI digital isolator accept input signals that rise above its local supply voltage without being damaged. This is especially useful when a digital logic signal comes from a device powered at a different voltage or when the input side is not yet fully powered. In practice, it makes mixed-voltage and power-sequencing situations much easier to handle.

For example, if an MCU (or any upstream driver) can provide a 5V signal to the input pin of the digital isolator while the supply voltage is at a lower voltage level, such as 2.5V or 3.3V:

1. In this configuration, a digital isolator without overvoltage-tolerant inputs can have unexpected behavior or can experience damage due to the violation of the absolute maximum ratings ([Figure 1-1](#))
2. In a digital isolator with overvoltage-tolerant inputs, it can support this mixed-voltage application without causing negative impacts to application functionality ([Figure 2-1](#))

[Figure 3-1](#) illustrates this behavior for an ISO6441 digital isolator. The waveforms show three simultaneous signals ([Table 3-1](#)):

Table 3-1. Waveform Legend

Color	Waveform Signals	Description
Red	Supply voltage (V_{CC1}/V_{CC2})	2.5V DC voltage supply
Yellow	Input pin (INx)	5V input signal
Blue	Output pin (OUTx)	The output follows the input signal. Since $V_{CC2}=2.5V$, the output signal uses the same voltage levels to reproduce a 2.5V signal with the same frequency

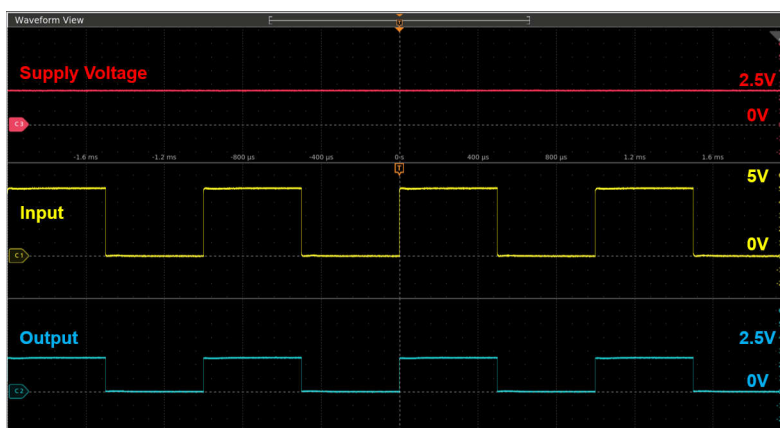


Figure 3-1. Waveform Showing Input Voltage Greater Than Supply Voltage

3.2 Simplify Interfacing Between Devices with Different Supplies or Power Sequences

Digital isolators with overvoltage-tolerant inputs allow designers to simplify power-sequencing in their applications. The isolation channel can be powered up or down independently of the surrounding logic, while the data bus remains correctly defined. This reduces the need for complex sequencing logic and enhances overall system robustness, especially in applications where the MCU must remain active while other devices are still initializing.

On a digital isolator without overvoltage-tolerant inputs, applying an input signal when the isolator is powered down can cause the current to back feed into the internal diode structures through the primary side and can cause damage to the isolator. Due to this, designers often need to be more attentive to when components power up in relation to the isolator power up time, often requiring added components for added protection to avoid stressing the isolator.

On a digital isolator with overvoltage-tolerant inputs, the isolator is designed to be less sensitive to power-up and power-down transients. Because the input pins can withstand voltages higher than the isolator's own supply, a logic-level signal may be driven onto the input even when the supply of the isolator is still powered down.

This allows for the timing of the data path to be independent from the power-sequencing of the isolation channel, allowing the MCU (or any upstream driver) to remain active throughout system start-up and shutdown without risking latch-up or damage to the isolator.

Figure 3-2 illustrates this behavior for an ISO6441 digital isolator. The waveforms show three simultaneous signals (Table 3-2):

Table 3-2. Waveform Legend

Color	Waveform Signals	Description
Red	Input-side supply voltage (VCC1)	Initially 0V (isolator un-powered)
Yellow	Input pin (INx)	A valid logic-level waveform is applied continuously, irrespective of supply voltage
Blue	Output pin (OUTx)	When VCC1 = 0V, the output defaults to the ISO6441's internal pull-up state (logic HIGH). When VCC1 crosses its power-on threshold, the output instantly follows the input, reproducing the logic signal present on the input pin

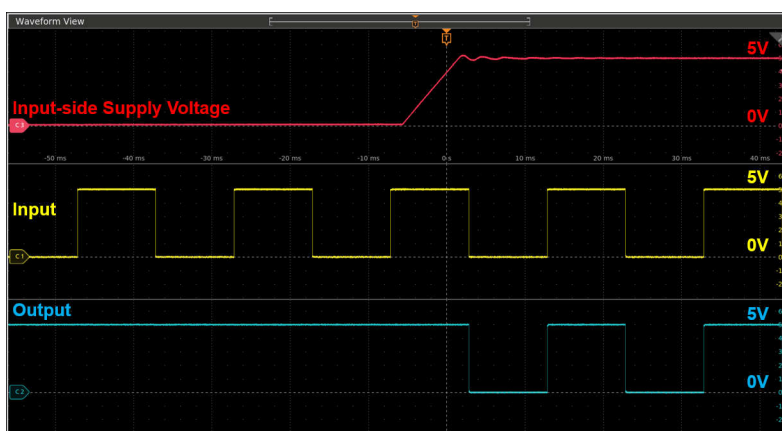


Figure 3-2. MCU is Powered on and Signal is Applied before the Digital Isolator is Powered On

3.3 Improve Robustness During Brown-Out Conditions

A digital isolator with overvoltage-tolerant inputs can improve system robustness during brownout conditions by allowing the input pins to safely tolerate signal voltages even when the isolator's local supply voltage is reduced or momentarily unavailable due to system-level EMC events.

On a digital isolator without overvoltage-tolerant inputs, this can result in excessive current through the input protection structures, potentially causing unintended current injection, abnormal device behavior, or possible damage to the isolator.

On a digital isolator with overvoltage-tolerant inputs, the isolator is designed to tolerate input voltages above its supply voltage over the specified recommended operating conditions, reducing the risk of these issues during supply transients and brownout events. This provides greater flexibility in power sequencing and helps prevent the input signal from becoming a source of stress when the isolator supply is unstable.

During a brownout event, the upstream device may remain active and continue driving signals while the isolator's supply voltage is disturbed or momentarily drops. When the isolator's supply voltage is restored, normal signal transmission resumes in the system.

Figure 3-3 illustrates this behavior for an ISO6441 digital isolator. The waveforms show three simultaneous signals (Table 3-3):

Table 3-3. Waveform Legend

Color	Waveform Signals	Description
Red	Input-side supply voltage (VCC1)	VCC1 is Initially 5V, has a short brownout event in which VCC drops to 0V for 20-30ms before recovering back to 5V
Yellow	Input pin (INx)	A valid logic-level waveform is applied continuously, irrespective of supply voltage
Blue	Output pin (OUTx)	The output follows the input signal initially. During the brownout event, the output goes into default HIGH state until VCC1 recovers

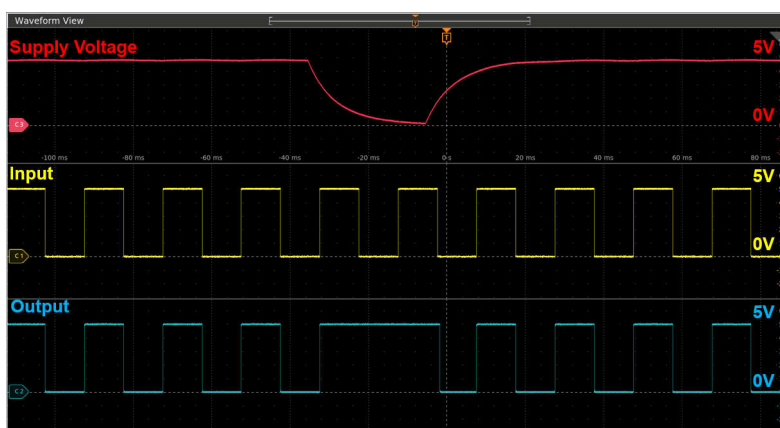


Figure 3-3. Supply Voltage Experiences Momentary Brownout Event

3.4 Reduce Power Consumption by Powering Down During Normal System Operation

A practical benefit of digital isolators is the ability to momentarily remove power from the device when signal transmission is not required. When the isolator is powered down, it stops driving the output side, eliminating unnecessary switching activity and reducing the power consumed by the isolator.

On a digital isolator without overvoltage-tolerant inputs, the signal transmission along with the isolator itself would need to be powered off or keep everything on, causing the designer to have to solve power sequencing for the peripheral devices and the isolator.

On a digital isolator with overvoltage-tolerant inputs, the isolator can provide additional flexibility by allowing the supply to be powered off while the MCU is still applying an input signal. When the signal is not actually required for the system.

This approach is particularly useful in systems that spend extended periods in a steady state or inactive communication mode. By disabling the isolator during these periods and re-enabling the isolator when signal transmission is needed, system designers can reduce overall energy consumption without requiring changes to the rest of the system.

To demonstrate this power-saving benefit, ICC can be measured under two conditions on a digital isolator with overvoltage tolerant inputs:

1. Digital isolator powered on and an input signal applied
2. Digital isolator powered down while the same input signal remains present.

Comparing the two measurements helps quantify the current that can be eliminated by temporarily disabling the isolator when signal transmission is not required ([Table 3-4](#)).

Table 3-4. Digital Isolator I_{CCx} Comparison

Test Conditions	ICC1	ICC2
ISO6441 VCC1 = VCC2 = 5V Input signal = 5V, 100kHz	4.2mA	2.2mA
ISO6441 VCC1 = VCC2 = 0V Input signal = 5V, 100kHz	-0.0078mA	0mA

3.5 Withstands Signal Overshoots Due to Parasitics

Digital isolators with overvoltage tolerant inputs improve robustness against signal overshoot caused by parasitic elements in the system. PCB trace inductance, package parasitics, connector capacitance, and other related effects can produce transient voltage spikes that exceed the supply voltage.

On a digital isolator without overvoltage-tolerant inputs, the input structure operates within a specified input-voltage range relative to its supply (Figure 1-1). During fast signal transitions, parasitic inductance and capacitance can cause the input voltage to temporarily exceed the supply rail. These transient overvoltage conditions can stress the input circuitry, particularly when the overshoot occurs repeatedly at high switching frequencies.

On a digital isolator with overvoltage-tolerant inputs, the input voltage is completely independent from the supply voltage (Figure 2-1) and allows the isolator to tolerate input voltages above their supply voltage within a specified range. This provides additional design margin against PCB and system-level parasitics and can improve robustness in applications with fast switching signals, long traces, connectors, etc. that may generate signal overshoots.

Figure 3-4 illustrates this behavior for an ISO6441 digital isolator. The waveforms show three simultaneous signals (Table 3-5):

Table 3-5. Waveform Legend

Color	Waveform Signals	Description
Red	Input-side supply voltage (VCC1)	VCC1 is Initially 5V, has a short brownout event in which VCC drops to 0V for 20-30ms before recovering back to 5V
Yellow	Input pin (INx)	A valid logic-level waveform is applied continuously, irrespective of supply voltage
Blue	Output pin (OUTx)	The output follows the input signal initially. During the brownout event, the output goes into default HIGH state until VCC1 recovers

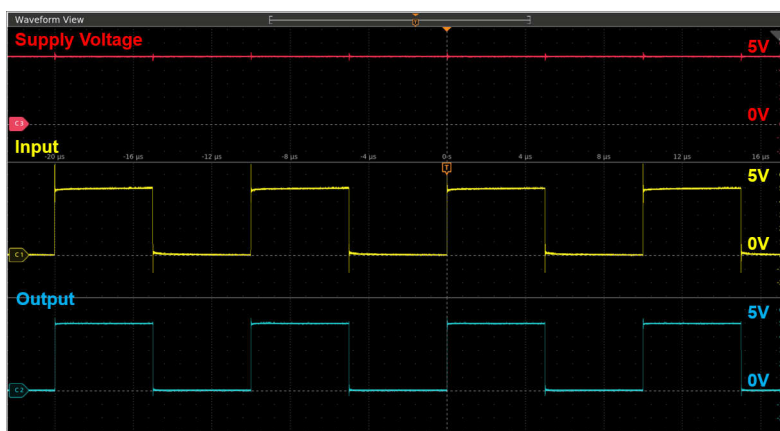


Figure 3-4. Input Voltage Overshoots Due to Transient

3.6 Preserve Signal Integrity by Avoiding Extra Filtering Networks During EMC Transients

Overvoltage-tolerant inputs can help preserve signal integrity by reducing the need for external protection and filtering components on the signal path.

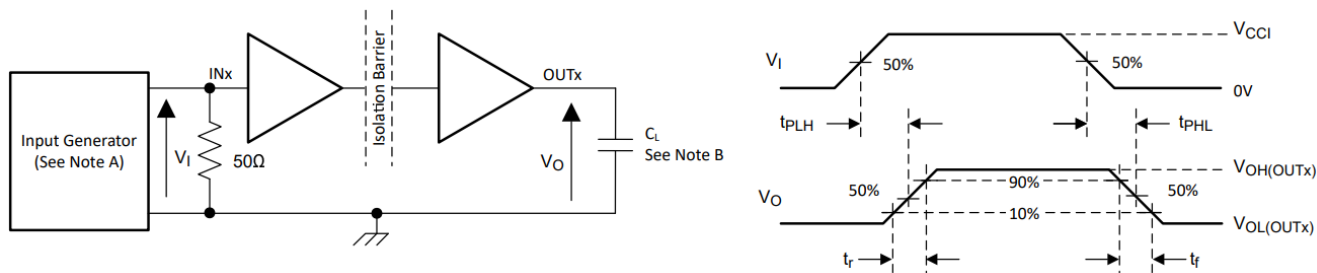
On a digital isolator without overvoltage-tolerant inputs, additional circuitry such as clamps, diodes, RC filters, or other filtering networks may be utilized to protect the input from transient voltages. These components add impedance and parasitic effects to the signal path, which can introduce signal distortion, increase propagation delay, and reduce signal integrity, particularly during fast switching or EMC transients.

On a digital isolator with overvoltage-tolerant inputs, the isolator can tolerate higher input voltages directly within the absolute maximum ratings, reducing the need for additional components on the signal path. By simplifying the signal path and minimizing added impedance, signal timing can be preserved while also reducing board complexity and component count.

To demonstrate this benefit, an ISO6441 digital isolator with an RC network on the input pin (Figure 3-6) was compared against an ISO6441 without additional filtering on the signal path (Figure 3-7). A 50KHz input signal and a 50Ω termination were used for both configurations and the propagation delay was measured on an oscilloscope.

The rising edge of both input and output signals were captured and used to calculate the propagation delay. Under the parametric measurement information of the ISO6441 datasheet (Figure 3-5), the test setup, measurement calculations and descriptions are provided. By taking the time difference between the midpoints of the input rising edge and output rising edge, the propagation delay can be calculated.

7 Parameter Measurement Information



- The input pulse is supplied by a generator having the following characteristics: PRR $\leq$ 50kHz, 50% duty cycle, $t_r \leq 1$ ns, $t_f \leq 1$ ns, $Z_O = 50\Omega$. At the input, 50Ω resistor is required to terminate INx (input) generator signal. The 50Ω resistor is not needed in the actual application.
- $C_L = 15$ pF and includes instrumentation and fixture capacitance within $\pm 20\%$.

Figure 7-1. Switching Characteristics Test Circuit and Voltage Waveforms

Figure 3-5. Section 7 of ISO6441 Datasheet – Switching Characteristics Test Circuit and Voltage

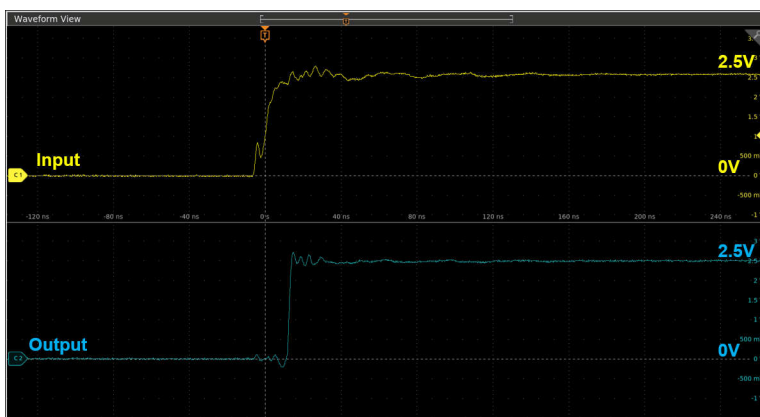


Figure 3-6. ISO6441 With RC on Input Pin; Input = 50kHz, R = 1kΩ, C=100pF, 50Ω Termination

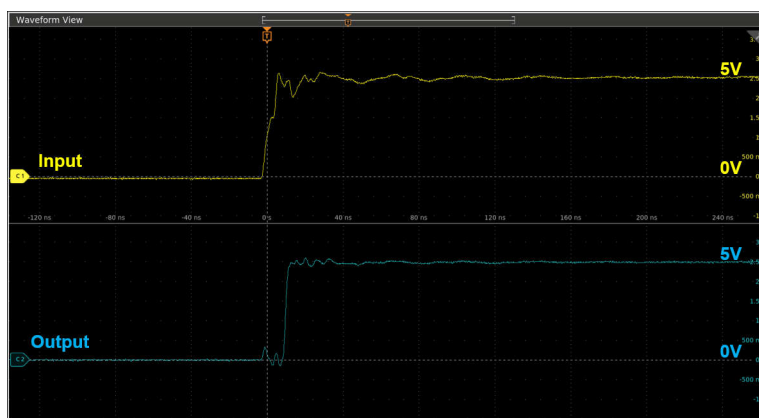


Figure 3-7. Only ISO6441; Input = 50kHz, 50Ω Termination

The configuration without the RC network exhibited a faster propagation delay and a sharper output square wave, demonstrating how eliminating additional impedance and filtering components can help maintain signal integrity and improve signal performance.

Table 3-6. Propagation Delay Measurements

	Only ISO6441	ISO6441 with RC on input side (R= Ω , C=100pF)
Measured Propagation Delay (ns)	8.85ns	12.03ns

3.7 Reduce Board Area Utilization

Digital isolators with overvoltage tolerant inputs can allow the designer to reduce usage of board area and component count. In applications where signal overshoot or transient voltages are a concern, traditional digital isolators may require additional filtering or protection components, such as resistors, capacitors, or other components. Digital isolators with overvoltage tolerant inputs can reduce or eliminate the need for some of these components, simplifying the overall design.

Reducing the number of external components can also help lower BOM cost and simplify PCB layout. Fewer components around the isolation interface can provide additional board space for other circuitry while reducing assembly requirements and potential points of failure.

Digital isolators with overvoltage tolerant inputs are also available in smaller, PCB-optimized package options, such as the DFP and DFB packages. This allows designers to take advantage of the overvoltage tolerant inputs capability while selecting a package that allows for a refined, area-optimized design.

Figure 3-8 illustrates the package comparison between some of the popular package options, such as 16DW, 8D, to the new package options for digital isolators with overvoltage tolerant inputs, such as 16DFP, 16DFB and 10DFB. More information regarding package options and digital isolator selection can be found on the [Digital Isolator Selection Guide](#).

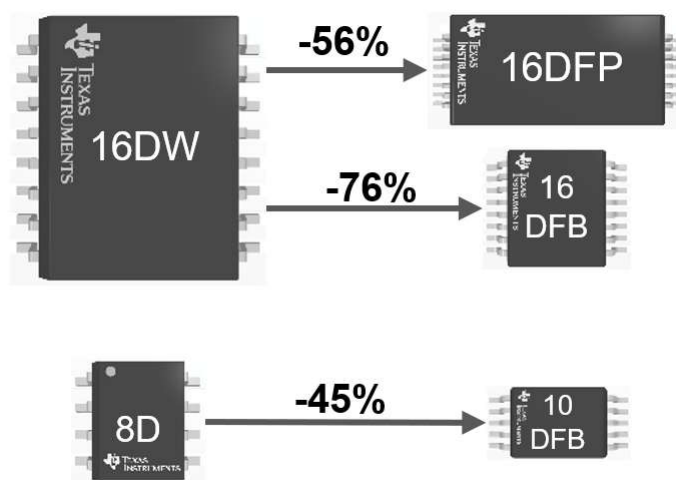


Figure 3-8. Package Comparison Between 16DW, 8D, 16DFP, 16DFB, and 10DFB; Showing Percent Difference in Package Area

4 Digital Isolators with Overvoltage Tolerant Inputs

Commercial Devices	Automotive Devices	Supply Voltage (VCC) Range	Integrated DC/DC	Features
ISO60xx		1.71 to 5.5V	-	Highest bandwidth: 200Mbps, 1.2ns (max.), PWD and channel to channel skew, Low power (ICC) per Mbps (635µA/ch max.at 1Mbps), Reinforced isolation, Small footprint package options
ISO64xx	ISO64xx-Q1	2.25 to 5.5V	-	200kV/µs (min.) CMTI, 150Mbps Data rate, Reinforced and basic isolation, Small footprint package options
ISOW64xx	ISOW64xx-Q1	2.25 to 5.5V	Yes	Reinforced digital isolator with integrated DC/DC, Low emissions, High efficiency output power 42.5%
ISOW308x		2.25 to 5.5V	Yes	Full duplex isolated RS485 with integrated DC/DC, Low emissions, High efficiency output power 41.5%
ISOW1050		2.25 to 5.5V	Yes	Reinforced digital isolator with integrated DC/DC, Low emissions, High efficiency output power 41%

5 Summary

Overall, overvoltage tolerant inputs on digital isolators provide several system-level design benefits by allowing inputs to safely accept signals that exceed the device supply voltage within specified limits. This capability simplifies interfacing between devices with different supply voltages or power sequences and can improve robustness during brown-out conditions and signal overshoots caused by parasitics. By reducing the need for external level-shifting, protection, and filtering networks, overvoltage tolerant inputs can preserve signal integrity during EMC transients, reduce component count and board area, and simplify the overall design. In addition, the ability to maintain valid input operation when the isolator supply is removed or powered down can enable power-saving strategies during normal system operation.

These benefits make overvoltage tolerant digital isolators particularly useful in industrial automation, PLCs, motor drives, and power-electronics applications, where multiple voltage domains, power-sequencing conditions, and transient events are common. By combining voltage-domain compatibility with robust isolation and protection, overvoltage tolerant inputs can help designers develop simpler, more compact, lower-power, and more robust systems while maintaining compliance with applicable safety and reliability requirements.

6 References

- Texas Instruments, [Protecting Your Digital Isolator Using Overvoltage Tolerant Inputs](#), product overview.
- Texas Instruments, [\[FAQ\] What are overvoltage tolerant inputs of digital isolators? - TI E2E support forums](#), webpage.
- Texas Instruments, [\[FAQ\] Can a digital isolator signal voltage be different from its power supply voltage? - TI E2E support forums](#), webpage.
- Texas Instruments, [Digital Isolator Design Guide](#), application note.
- Texas Instruments, [Digital Isolator Selection Guide](#), application note.
- Texas Instruments, [Top design questions about digital isolators](#), technical article.

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