Welcome!
Texas Instruments New Product Update

- This webinar will be recorded and available at www.ti.com/npu
- Phone lines will be muted
- Please post questions in the chat or contact your sales person or field applications engineer

New Product Update:
Understanding high-voltage isolated I2C and hot-swap performance

Neel Seshan

May 20, 2021

Texas Instruments

Agenda

- Introduction to isolated I2C
- Implementations of isolated I2C
- TI's SiO_2 capacitive isolation technology
- Product highlight: ISO164x
- Hot-swap
  - Benefits of hot-swap
  - Performance comparison of regular and hot-swappable isolated I2C
- Isolating power for isolated I2C
- Digital isolators update
- TI.com resources

Isolation portfolio

Digital isolators

Products

- Low-cost digital isolators
- Reinforced isolators
- Basic isolators
- Ultra-low power isolators

Applications

- Factory automation
- Motor control and grid infrastructure
- Power delivery
- Automotive – HEV/EV

Isolated interfaces

Products

- ISO RS-485
- ISO CAN
- ISO I2C
- ISO IO
- ISO LVDS

Applications

- Factory automation
- Motor drives and grid infrastructure
- Servers/Enterprise
- Automotive – HEV/EV

Isolated data + DC/DC

Products

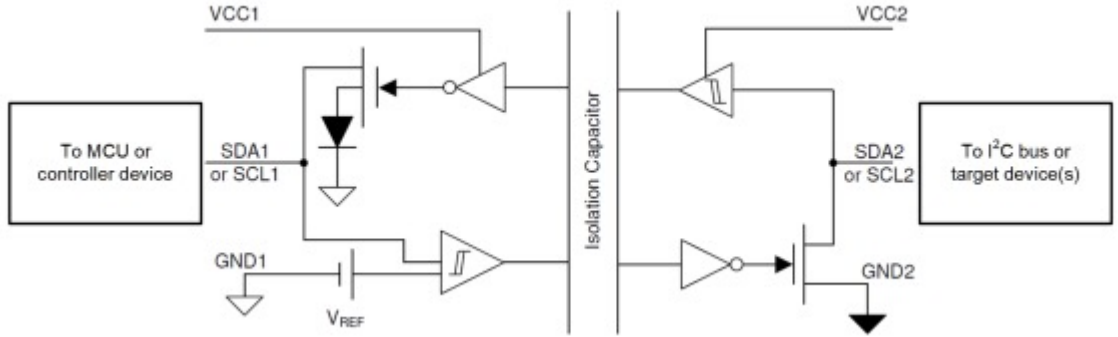
- ISOW – Channel ISO
- ISOW – RS-485
- ISOW – CAN
- Transformer drivers

Applications

- Industrial networks
- Grid infrastructure
- Industrial transport
- Automotive – HEV/EV

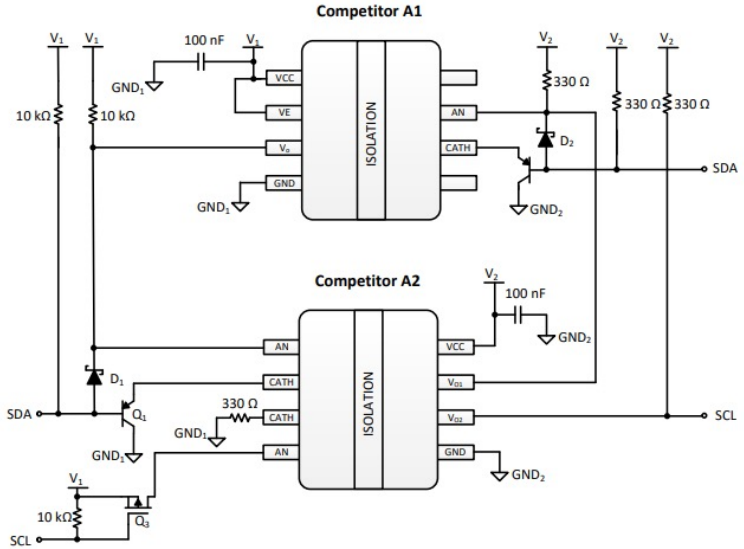
Introduction to isolated I2C

- Inter-Integrated Circuit (I2C or I²C) communication standard
  - Inter-chip communication
  - Open-drain, open-collector communication standard
  - Aerospace, automotive, personal electronics, and industrial applications
- Isolated I2C
  - Used in systems that are physically distant, operating at different local voltage potentials and require isolation protection for operation or safety



Discrete implementation of isolated I2C

- Isolating I2C with optocouplers and discrete logic to control the data direction on the lines
- The discrete components are required to avoid bus glitches and any latch up conditions on the bidirectional lines.



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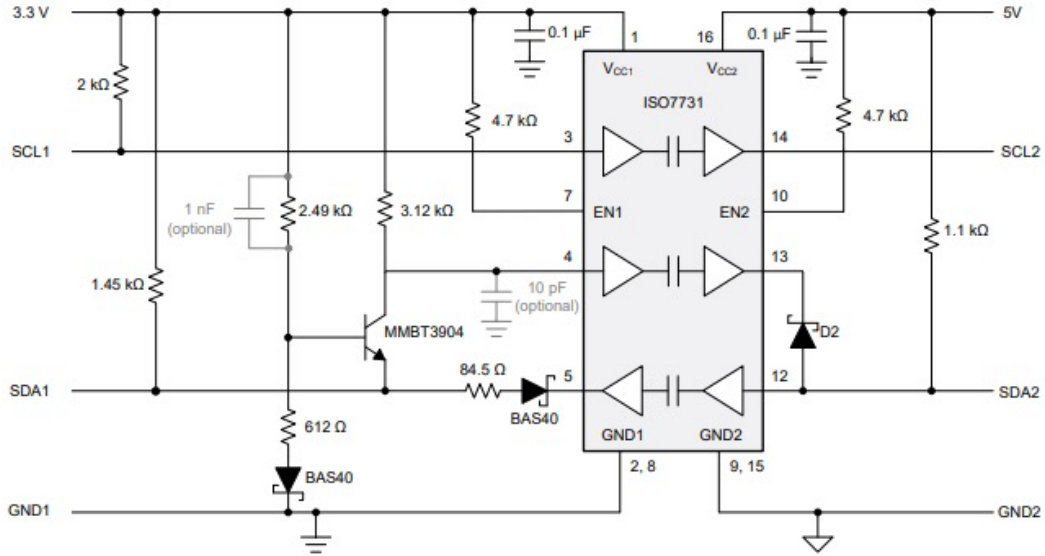
Discrete implementation of isolated I2C

Digital isolator with external circuitry to separate the bidirectional data path into two unidirectional channels



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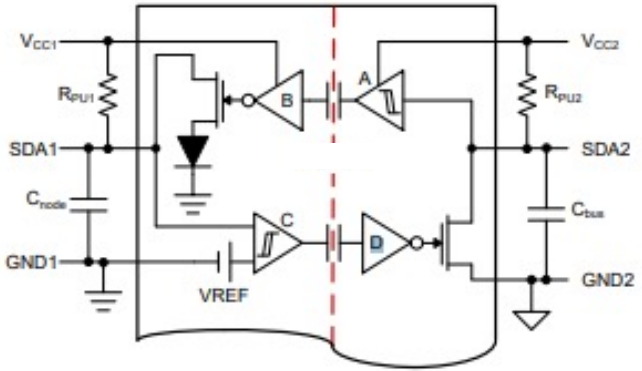
Integrated implementation of isolated I2C

Integrated solutions use internal circuitry combined with the digital isolator to achieve the same isolated I2C buffer functionality.



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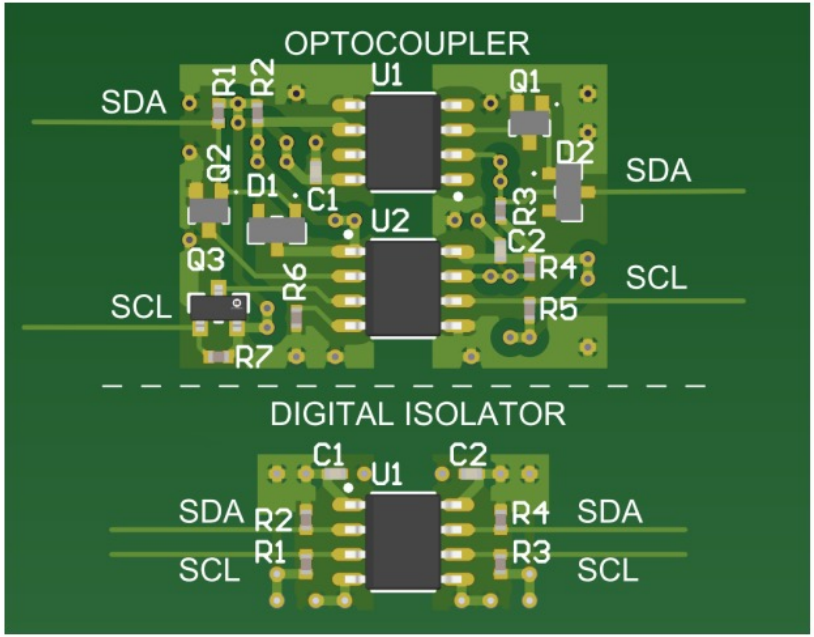
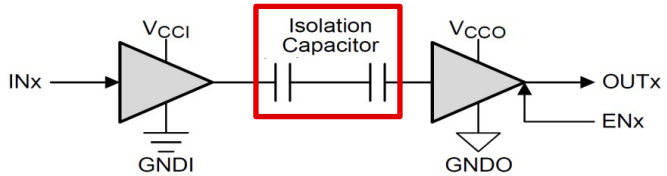
Space savings with integrated implementation



I2C footprint of optocoupler circuit versus ISO1641 isolator circuit

TI's capacitive isolation technology

TI's reinforced isolators use a logic input and output buffer separated by a **double capacitive SiO_2 insulation barrier**



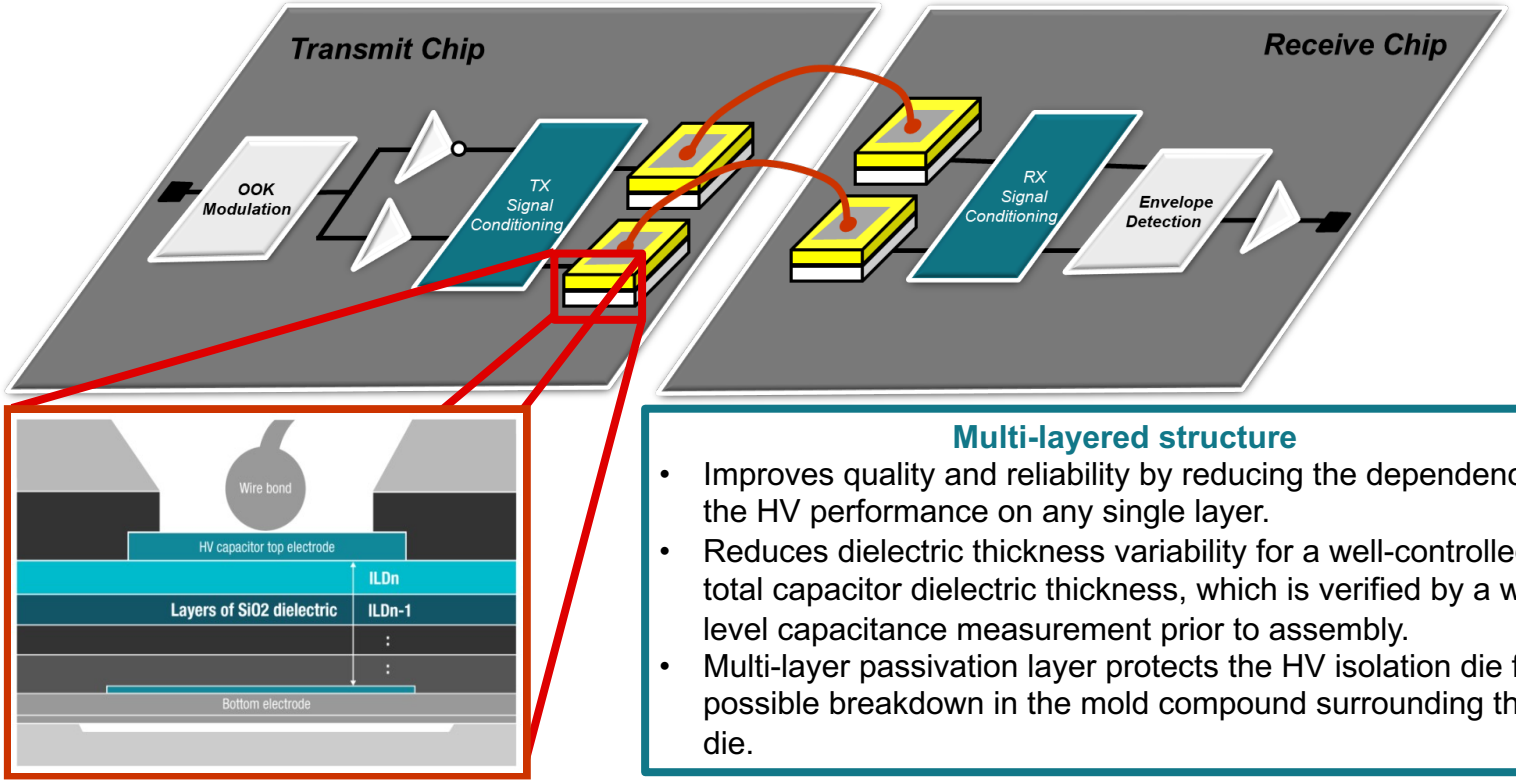
Manufactured and thoroughly tested in a controlled environment to ensure highest quality of isolation products

Silicon dioxide (SiO_2) offers the **highest** dielectric strength in the industry

Insulator Materials	Dielectric Strength
Air	~1 Vrms/µm
Epoxies	~20 Vrms/µm
Silica filled Mold Compounds	~100 Vrms/µm
Polyimide	~300 Vrms/µm
SiO_2	~500 Vrms/µm

Unlike polyimide and other polymer based insulators, the reliability of an SiO_2-insulated capacitor does not degrade with exposure to ambient moisture.

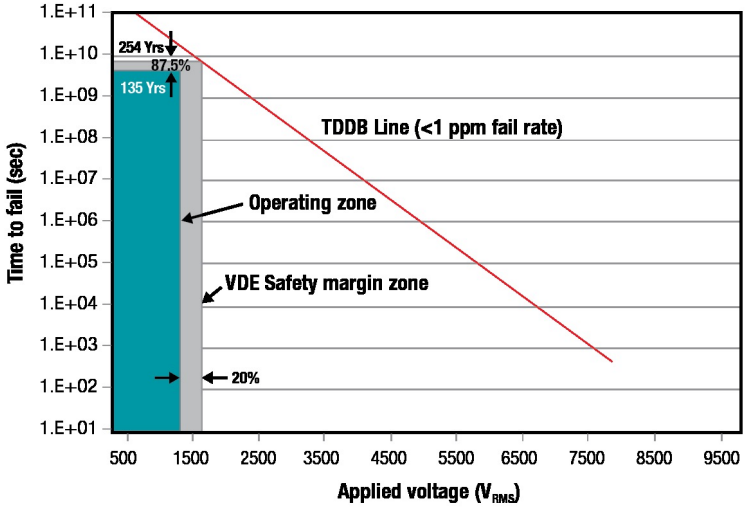
TI's capacitive isolation technology



Multi-layered structure

- Improves quality and reliability by reducing the dependence of the HV performance on any single layer.
- Reduces dielectric thickness variability for a well-controlled total capacitor dielectric thickness, which is verified by a wafer-level capacitance measurement prior to assembly.
- Multi-layer passivation layer protects the HV isolation die from possible breakdown in the mold compound surrounding the die.

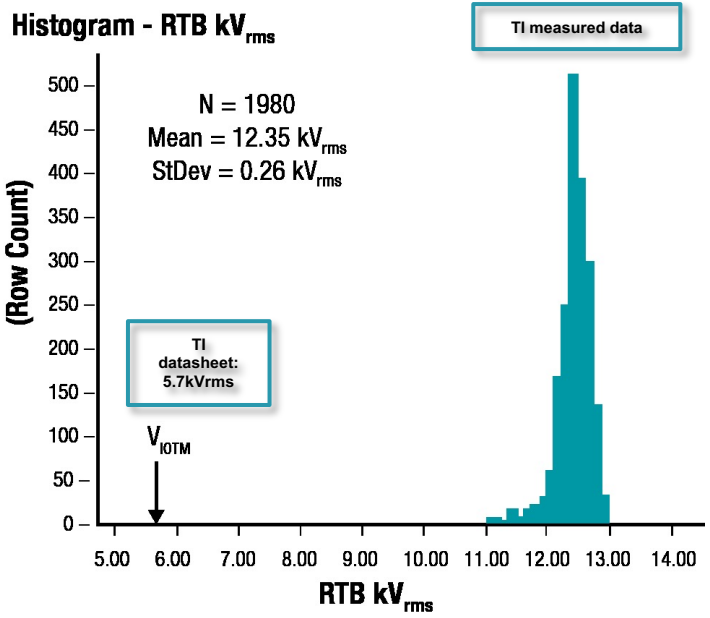
TI's capacitive isolation technology



T_A upto 150°C
Modeled insulation life time = 135 years

Stress voltage frequency = 60 Hz
Working isolation voltage = 1500 V_{RMS}

Insulation lifetime projection



Ramp to breakdown qualification test

TI's capacitive isolation portfolio combines **highest working voltage** and **highest reliability** to enable extended system lifetime and protection.

ISO1640/1:

Robust bidirectional functional, 3-kVrms and 5-kVrms I2C digital isolators

Features

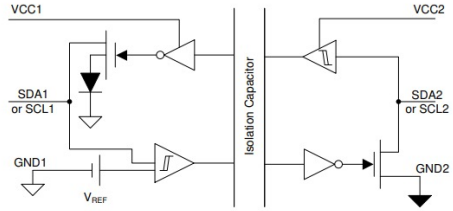
- **Isolation, immunity and certifications**
  - Integrated SiO2 dielectric capacitors
  - Basic and reinforced isolation (DIN V VDE V 0884-11)
  - IEC-ESD: >8 kV unpowered same side, >8 kV across the barrier
  - V_{ISO} rating: 3,000 V_{RMS}, and 5,000 V_{RMS} options
  - V_{IOSM} surge: up to 10 kV_{PK} (DW package)
  - V_{IOWM} working voltage: up to 1,500 V_{RMS} (DW package)
  - CMTI: 100 kV/µs (typ)
- **Electrical characteristics**
  - I2C isolators supporting hot-swap
  - Unidirectional (ISO1641) & bidirectional (ISO1640) clock options
  - Data rate: Up to 1.7 MHz operation
  - Wide supply range: 2.25 V to 5.5 V on side 2
  - Low power: 2.4 mA / channel (typ) when channels high
  - Operating temperature range: -40˚C to 125˚C
- **Package**
  - SOIC-16: 8 mm creepage / clearance (5,000 V_{RMS})
  - Small SOIC-8: 4 mm creepage / clearance (3,000 V_{RMS})

Applications

- Isolated I2C, SMBus, PMBus interfaces
- Open-drain network interfaces
- Power over Ethernet
- Power supplies
- Battery management
- Motor control systems
- Level shifting

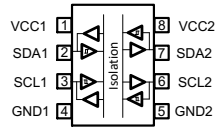
Benefits

- Plug or unplug the device into a system without disruption on the I2C bus.
- Reduces cost and board space by not requiring external logic devices to support bidirectional I2C support
- Single & multi-master applications enabling clock stretching
- Allows use with 2.5-V, 3.3-V and 5.0-V FPGAs and MCUs
- Industry standard footprint: Pin-to-pin with previous generation ISO154x family and competitive solutions in the market
- Internal thermal shutdown feature to protect system when improper connections are present.

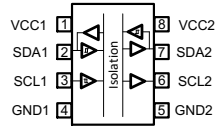


Simplified Isolated Bidirectional Data Channel Schematic

ISO1640BD



ISO1641BD



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What is hot-swap?

- Replacement or addition of components to a powered system without pausing, powering down, or restarting the system and maintaining normal operation.
  - Preserving normal operation of an I2C bus includes not affecting communication by loading the bus or corrupting an ongoing bitstream.
- When an I2C node or device is first connected to a system, there is no power supply holding the gates of the internal I2C output FETs to ground, and if the power-up transient on the drain of these pins is fast enough, it may couple to the gate of these output FETs, lifting the gate voltage enough to turn the switch ON momentarily.
  - This could reduce bus voltage levels enough to cross the HIGH/LOW thresholds of different devices, resulting in communication errors or data corruption across the bus.

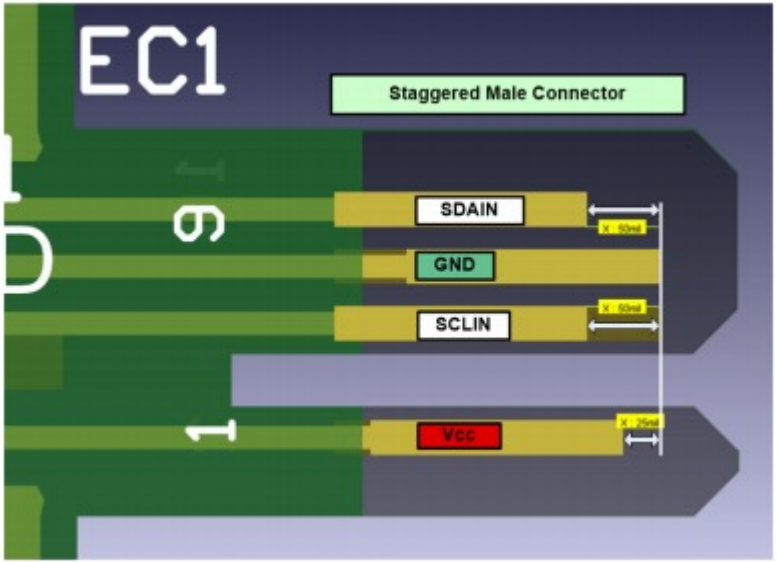
Benefits of hot-swappable isolated I2C

- Isolated I2C devices with full “hot-swap” compliance can help prevent:
  - Data corruption due to transients while plugging in the part.
  - Loading the bus at every low to high bus transition if the supply is not present, as partially hot-swappable devices can.
  - Excessive voltages on the I2C bus appearing on the local supply rail due to parasitic leakage paths if the part has non-failsafe ESD.

- Hot-swapping capabilities allow zero down-time

How hot-swap capability is achieved today

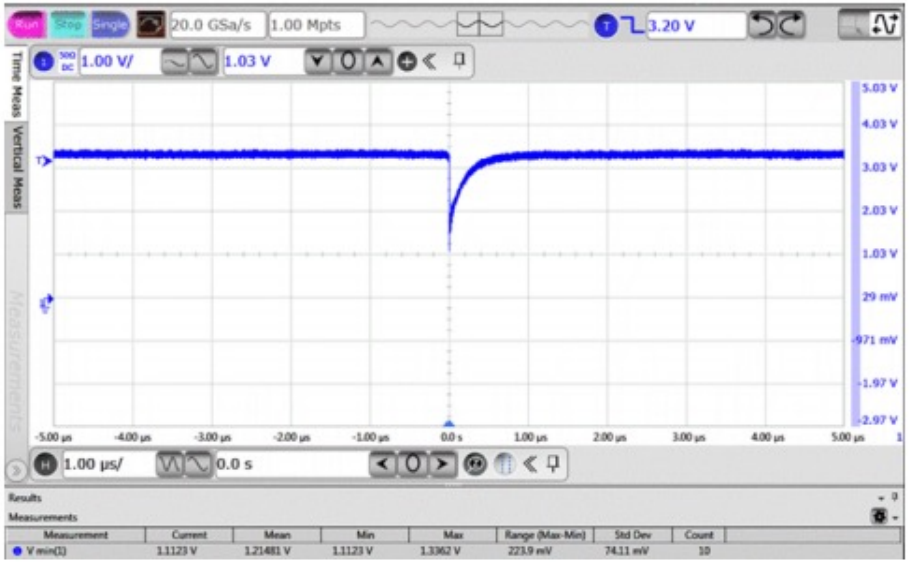
- Staggered-pin design at the point of connection
  - Ensures grounds and local power supplies are reliably connected before other connections are made
  - Adds to PCB design and additional cost



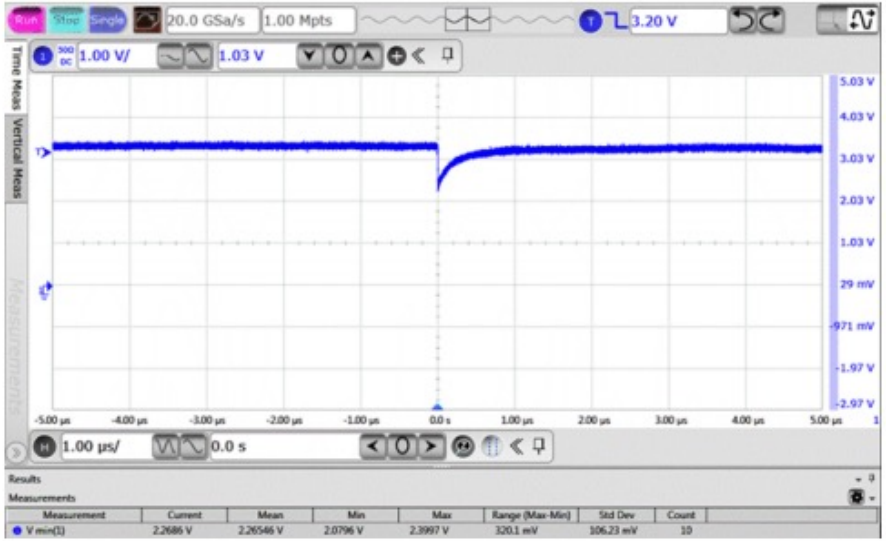
Pre-charging

- “Power-on hot-swap” using staggered connectors or hot-swap controllers
  - Preserve communication if the bus-side power supply (VCC) level of the device is always above or equal to the bus voltage levels during connection
  - ISO164x has pre-charge to minimize the loading on the bus when connected

Effect of pre-charging on hot-swap

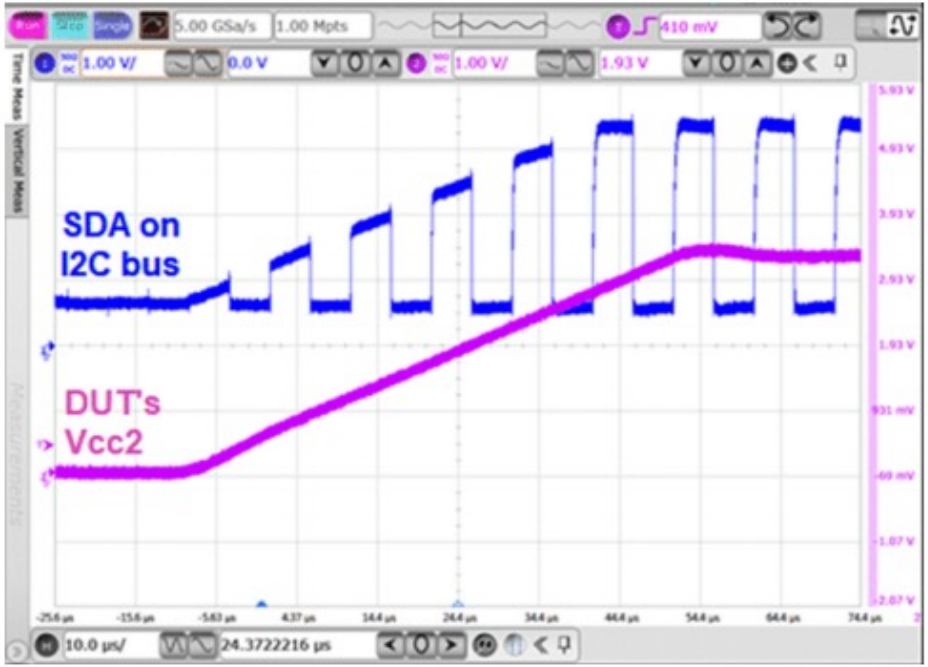


Regular I2C device without pin pre-charge loading the 3.3-V bus down to 1.2 V during plug-in

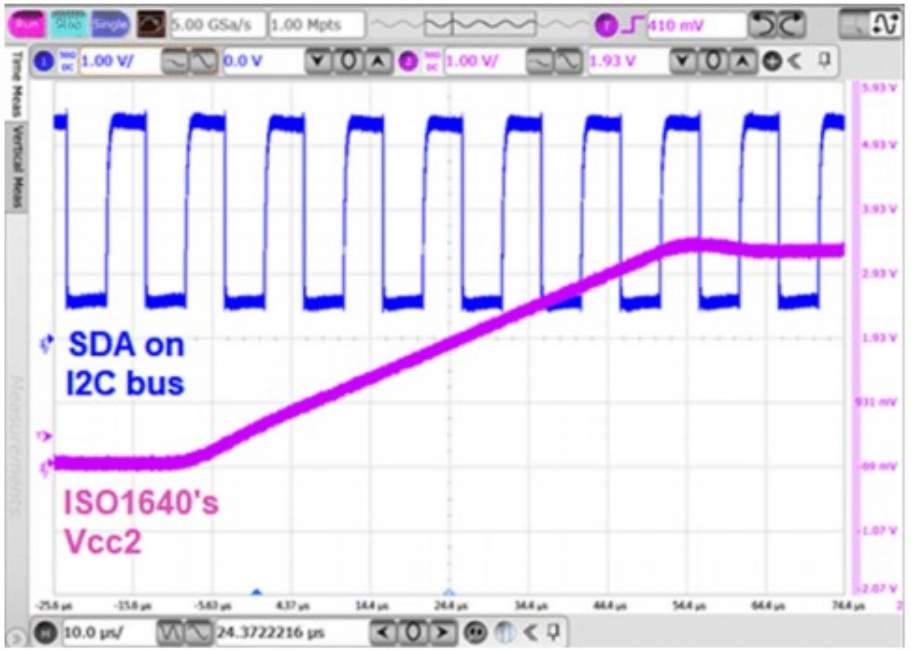


Pin pre-charge in ISO1640 reduces bus loading to 2.3 V during a hot-swap plug-in

Communication with Vcc2 ramping

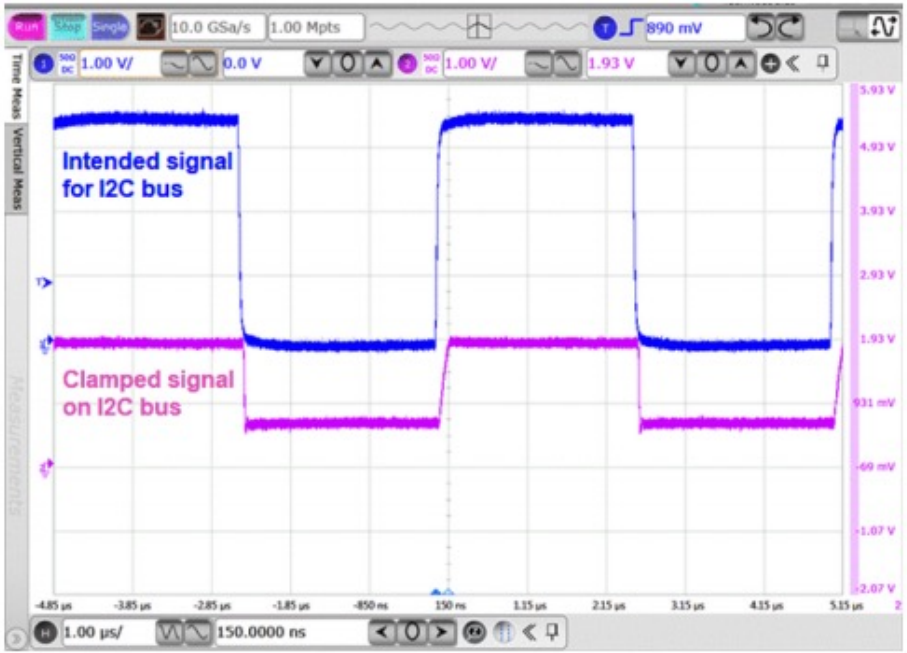


Regular I2C device corrupting bus communication during plug-in

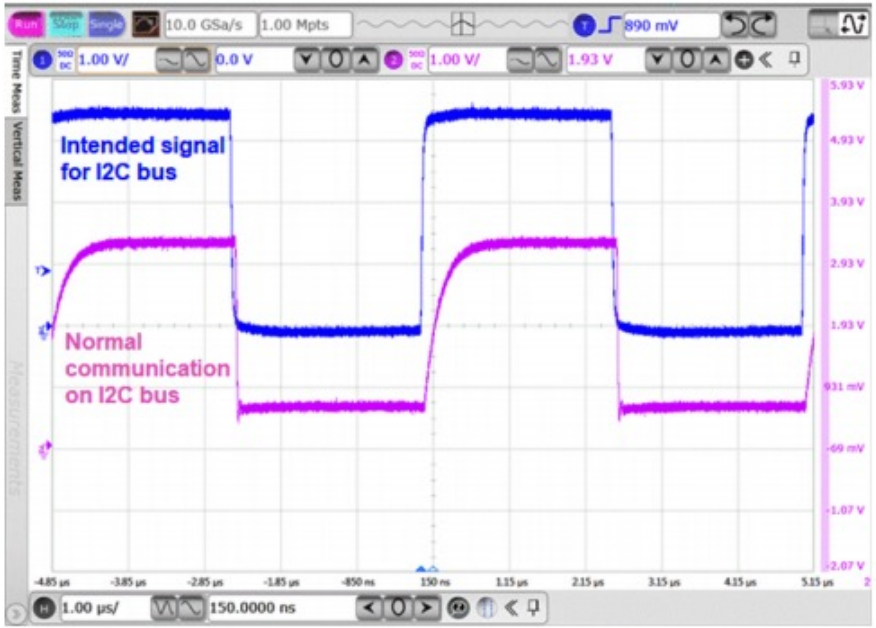


Hot-swap circuitry in ISO1640 maintains data integrity of the bus during plug-in

Communication with Vcc2 floating



I2C bus clamped to approximately 2 V from 3.3 V by a regular I2C device

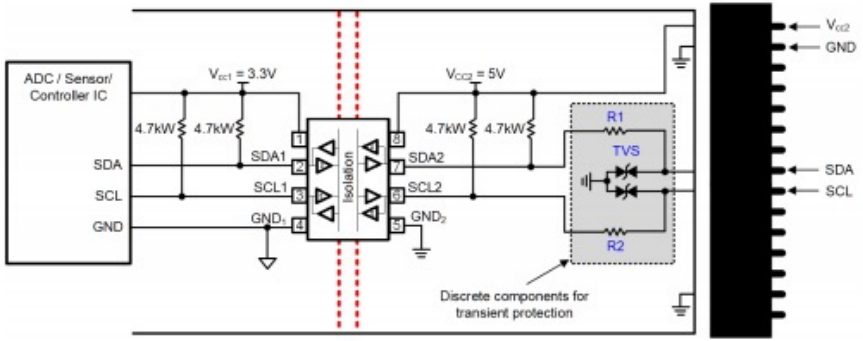


I2C bus is unaffected if the Vcc2 supply of the ISO1640 is floating

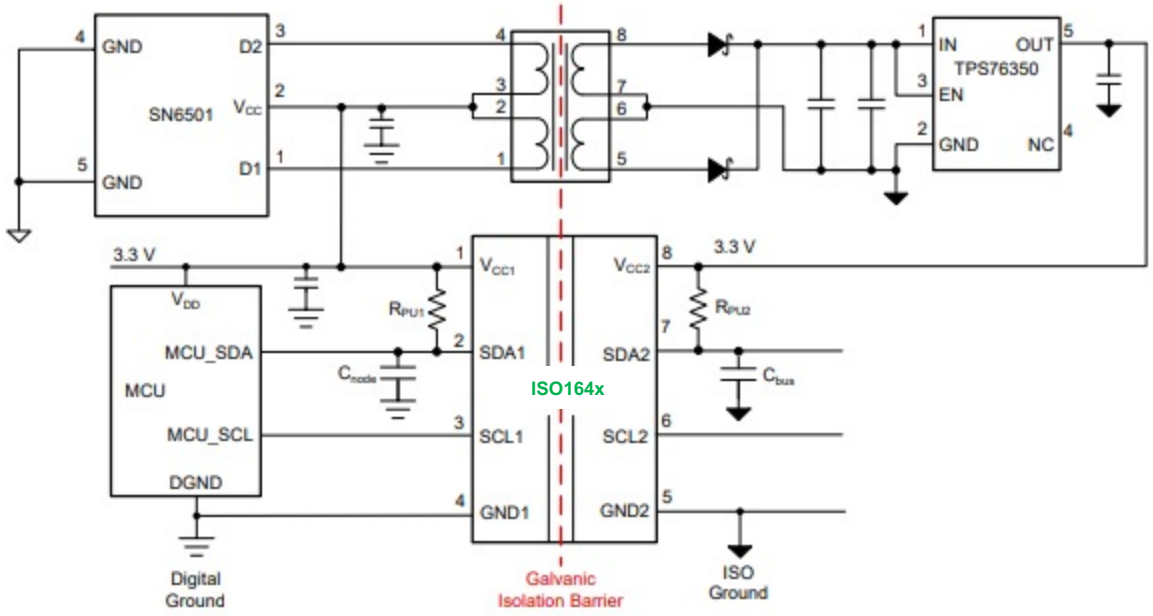
Same-side IEC ESD

- ISO164x offers significantly improved IEC-ESD performance.

	ISO154x	ISO164x
SIDE1 - HBM	8 kV	10 kV
SIDE2 - HBM	8 kV	14 kV
SIDE1 – IEC (pass)	3 kV	8 kV
SIDE2 – IEC (pass)	3 kV	8 kV



Isolating power for ISO-I2C (discrete solution)



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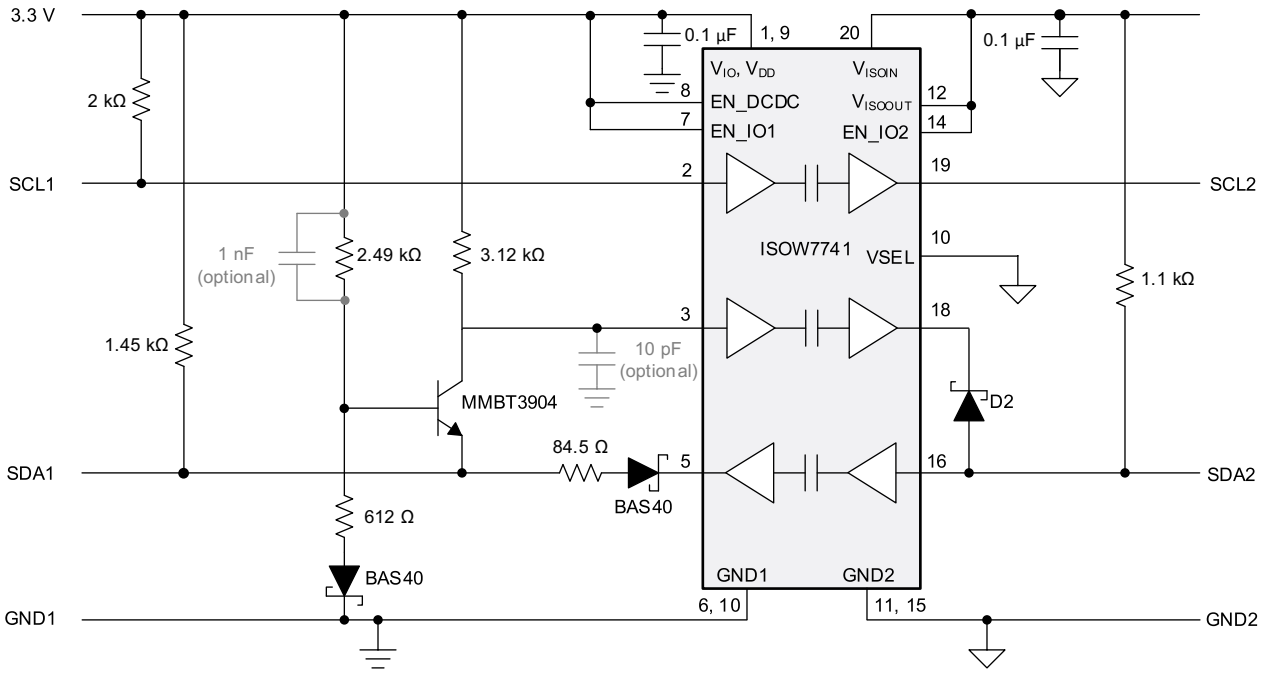
Isolating power for ISO-I2C (integrated solution)



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Isolated data solutions

ISO67xx

Isolation for cost-sensitive designs

- 50 Mbps
- 3.0 up to 5 kVrms
- 1.8 V – 5 V supply
- 2, 3, 4 and 6 channels
- Narrow and wide body packages

ISO77xx

High-speed, robust isolation for basic and reinforced applications

- 100 Mbps
- 3.0 up to 5 kVrms
- Up to 6 channels
- High CMTI
- Narrow and wide body packages
- -55˚C to 150˚C

ISO78xx

Industry's highest reliability reinforced isolation barrier

- 100 Mbps
- 5.7 kVrms
- 1 to 4 channels
- High CMTI
- Wide and Extra-Wide packages
- -55˚C to 125˚C

ISO70xx

Ultra-low-power isolation

- 4 Mbps
- 0.13 mA/ch @ 1 Mbps
- 3.0 kVrms
- 1.8 V – 5 V supply
- 1, 2 and 4 channels
- Narrow body packages

Series Capacitor Isolation Technology

ISO67xx

Cost-optimized 5-kVrms and 3-kVrms digital isolators

Features

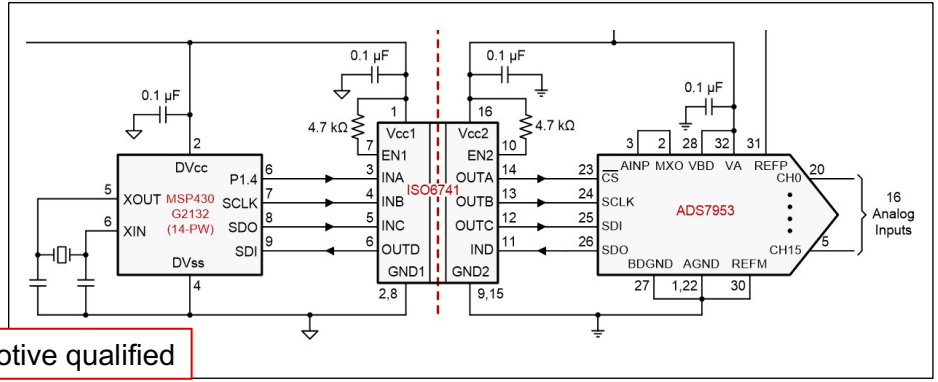
- **Isolation, immunity and certifications**
  - Integrated SiO_2 dielectric capacitors
  - Reinforced and basic isolation (DIN V VDE V 0884-11)
  - V_{ISO} rating: up to 5,000 V_{RMS}
  - V_{IOSM} surge: up to 10,000 V_{PK}
  - V_{IOWM} working voltage: up to 1,000 V_{RMS}
  - CMTI: 75 kV/µs (typ) 50 kV/µs (min)
- **Electrical characteristics**
  - Data rate: 50 Mbps (max)
  - Propagation delay: 11 ns (typ)
  - Wide supply range: 1.71 V to 5.5 V
  - Low power: 1.9 mA / channel (typ) at 1 Mbps
  - High and low default states available
  - Operating temperature range: -40˚C to 125˚C
- **Package**
  - SOIC-16: 8 mm creepage / clearance (6, 4 and 3 channels)
  - SOIC-8 DWV: 8 mm creepage / clearance (2 channels)
  - Small SOIC-8: 4 mm creepage / clearance (2 channels)

Applications

- HEV/EV
- Power delivery
- Grid infrastructure
- Factory automation
- Building automation
- Appliances

Benefits

- Robust SiO_2 dielectric does not degrade with moisture or temperature, providing industry's longest isolation barrier lifetime
- Component level certifications → simplified system level certification
- High CMTI provides low-voltage-side protection from high switching transients in harsh environments
- Low propagation delay and tight skew improves data transfer efficiency
- Allows use with 1.8-V, 2.5-V, 3.3-V and 5.0-V FPGAs and MCUs
- Thoroughly tested in a controlled environment to ensure high quality
- Pin-to-pin compatible with TI and competitor parts for ease of upgrade



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TI.com resources

- Technical documents:
  - How do isolated I2C buffers with hot-swap capability and IEC ESD improve isolated I2C?
  - How to replace optocouplers with digital isolators in standard interface circuts
  - Improve your system performance by replacing optocouplers with digital isolators
  - Top 6 design questions about I2C isolators
  - Designing an isolated I2C bus interface by using digital isolators
  - Simplify current and voltage monitoring with isolated SPI and I2C in your BMS
- Evaluation modules:
  - ISO1640 and ISO1641 robust-EMC bidirectional I2C digital isolator evaluation module
  - ISO1640 IBIS model

www.ti.com/isolation

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