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Galvanic Isolation Strengthens I²C Communications

Optocouplers hold the key to minimizing ground loops and noise in this popular interface.

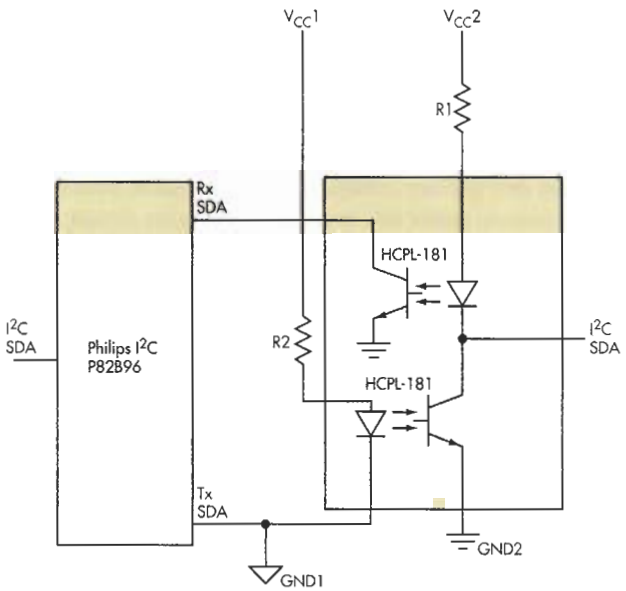
When considering short-distance communication protocols for industrial, consumer, medical, and telecom systems, engineers often turn to the Inter-Integrated Circuit (I^2C) bus standard developed by Philips.

Like Motorola's Serial Peripheral Interface (SPI) and National Semiconductor's Microwire, these common synchronous data-communication interfaces connect peripheral integrated chips on the same printed-circuit board (PCB).

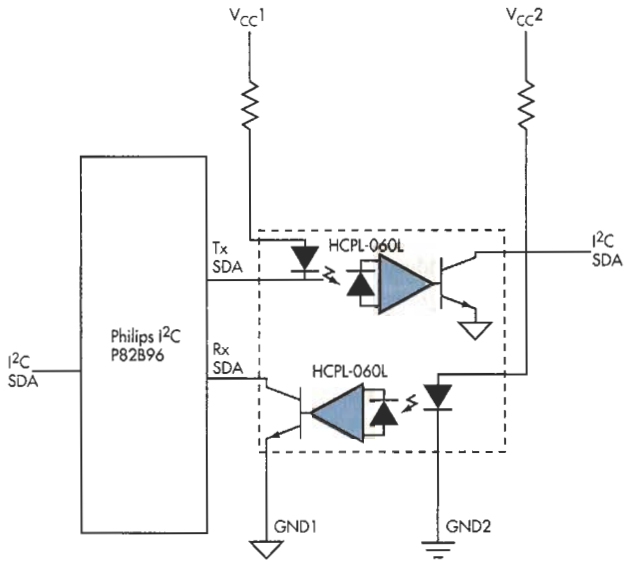
The application may include a microcontroller sending handshaking data signals to its peripheral devices, such as I/O ports, LCD drivers, data converters, and memory ICs (EEPROMs). Of course, connecting more peripheral devices to the common bus creates greater complexity within these protocols.

I²C OVERVIEW

The I^2C standard data bus protocol can address up to 128 devices on the bus without a chip select (CS) signal. (SPI and Microwire both require a CS address line.) Efficiently designed equipment can particularly take advantage of I^2C's scalable architecture. The I^2C control bus, which uses a bidirectional two-wire serial data (SDA) and serial clock (SCL) bus, is implementable in many IC fabrication processes, such as bipolar and CMOS technologies.



1. Single-channel, general-purpose optocouplers deliver galvanic isolation at a data rate up to 50 kbits/s.



2. Galvanic isolation at data rates up to 3.5 Mbits/s is possible when implementing single-channel, high-speed, 10-MBd optocouplers.

The protocol defines three main different operating frequencies: 100 kHz (standard speed), 400 kHz (fast speed), and 3.5 MHz (high speed). Digital data transmission is carried from masters (transmit) to slaves (receive) or vice versa through the SDA and SCL address line.

For example, a microcontroller (master) generates a clock signal and initiates a data transmission. An LCD driver (slave) addressed by the microcontroller will receive the data information. Because many masters and slaves may be connected to the I^2C control bus, the possibility arises that masters initiate data transfer and slaves receive data information at the same time.

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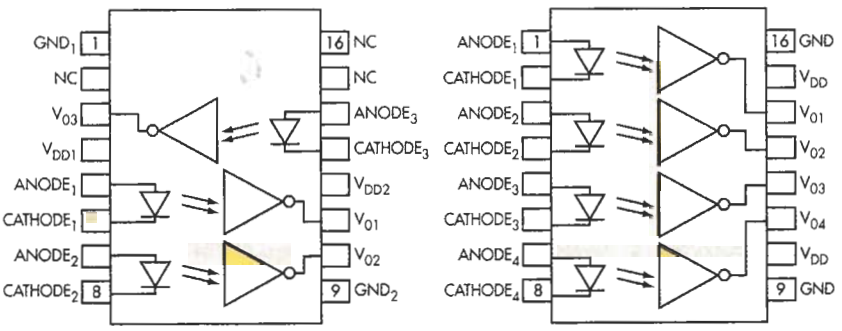
When two masters send data simultaneously, the first to produce a "1" when the other produces a "0" will lose the arbitration. In other words, priority is given to the microcontroller that first sends a "0."[1] As for the slaves, each is assigned with a unique address.

Unlike I^2C, the SPI or Microwire interface requires an additional chip select pin to connect to a peripheral device. The I^2C uses a 7-bit address through SDA and SCL to initiate the device selection.[1]

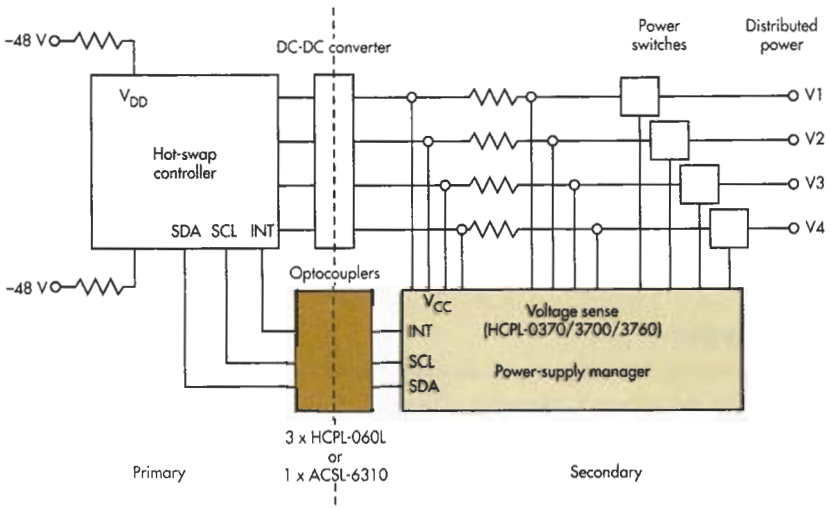


3. Advances in smaller component packaging allow for multichannel optocouplers, such as the ACSL-6310 and the ACSL-6400.

WHY GALVANIC ISOLATION?

Differences in ground potentials cause transient signal noise, which leads to data integrity issues. In addition, safety issues arise from common ground loop current, resulting in a short circuit or potential electrocution of the user. Optocouplers address this problem by providing galvanic isolation between the master (transmit) and slave (receive).

For instance, implementing two single-channel, general-purpose optocouplers such as the HCPL-181 or 4N35 will deliver galvanic isolation from 5 to 50 kHz *(Fig. 1)*. One channel is used for transmit, the other for receive. Low-speed applications include remote control of appliances or lighting, driving of remote displays, access control systems, security systems, and data logging.



4. In SMBus applications, optocouplers are used for power and control in telecommunication and Ethernet infrastructures. In a typical SMBus power and control module, a designer can employ three HCPL-06L optocouplers or a single ACSL-6310 optocoupler to isolate transient signal noise from the hot-swap controller and the power-supply manager.

On the other hand, when operating at full 100-kHz to 3.5-MHz clock speed, many reference designs recommend higher-speed optocouplers for galvanic isolation. For example, take Avago's HCPL-060L, which is a 10-MBd (megabaud) single-channel optocoupler.[2]

This open-collector-output optocoupler provides common-mode rejection (CMR) of up to 15 kV/μs at a common-mode voltage (V_{CM}) of 1 kV. It operates at 2.7 to 3.6 V and comes with a dual-channel version integrated in one SO-8 package.

Figure 2 shows two single-channel HCPL-060Ls—one used to transmit, and the other in the receiver channel. The optocoupler has expanded to a smaller low-voltage small-outline five-pin (SO-5) package.

A newer version called the ACPL-M60L is designed to accommodate high-speed applications such as Power over Ethernet (PoE), power-control modules found in telecommunication base-stations, and data-acquisition applications used in temperature controllers, pressure controllers, and weighing machines.

ADVANTAGES OF OPTOCOUPLERS

Beyond their primary advantage of signal isolation from noisy environments to ensure data integrity, optocouplers provide safety insulation from high voltages. This helps protect against high-voltage electrocution, such as in sensitive equipment like patient-monitoring instruments.

Galvanic isolation, with the use of optocouplers, offers both basic and reinforced insulation (a greater level of protection against hazardous live voltage). The other major advantage to optocouplers is their immunity to electromagnetic interference (EMI). EMI results from radiated copper traces found in printed-circuit boards.

The most common component acceptance safety standards are International Electrotechnical Commission 60747-5-2 (IEC/EN/DIN EN 60747-5-2), Underwriters Laboratories 1577 (UL 1577), and Canadian Standards Association (CSA) standards.

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OPTOCOUPLER REVOLUTION

Optical isolation technology continues to play a more prominent role in the marketplace thanks to myriad advances over the last 20-plus years. Many processes have been developed to integrate the light-emitting diode (LED) and the photodetector into a single package.

For example, the 300-mil and 400-mil dual-in-line (DIP) package and the 5-, 8-, and 16-pin small-outline (SO) surface-mount package have become the most commonly used packages for the optocoupler industry. These optocouplers undergo common processes that include double-mould, dielectric, and planar processes. Such processes ensure both quality and reliability when transferring an optical light signal to the detector IC.

Optocoupler technology is also moving toward smaller component packages to save space and simplify design. Thanks to some newly patented manufacturing processes, stacking LED die onto silicon substrates enables higher integration in monolithic IC packages.[3] This new process can integrate up to four channels with bidirectional configurations into a single SO-8 and SO-16 thin outline package *(Fig. 3)*.

Another growing trend involves packages designed to meet a clearance and creepage (C/C) of 8 mm for reinforced or safe insulation purposes,[4] with an operating voltage of up to 250 V_{RMS}. Equipment standards governed by the IEC, such as IEC60950 (for office machines and data processing) and IEC60204 (for industrial controls), require optocouplers to meet C/C of 8 mm before they can be used in equipment designs. Medical standards, such as IEC60601-1 revision 3, have been redrafted to include the distance through insulation (DTI), which mandates an increase of 0.08 mm to 0.4 mm to enhance the reinforced insulation.

Much like the continual evolution in optocoupler packaging, the overall market is morphing as well. The trends include 10-MBd or higher speeds; lower operating voltages at 3.3 V for power-sensitive devices; wide operating temperatures (–40°C to 100°C or higher) to ensure optocoupler functionality and performance while operating under extreme temperatures; and high CMR ratings (15 kV/μs at V_{CM} = 1 kV) to maintain data integrity even in noisy environments.

I^2C FAST SPEED APPLICATIONS

Figure 4 shows how the optocouplers are used for isolation in a power supply using the system management bus. A standard

defined by Intel in 1995, the SMBus is a variation of the I^2C bus found in telecommunication and Ethernet infrastructures such as power and control module applications. In a typical SMBus power and control module, a designer can employ three HCPL-060L (SDA, SCL, and INT) optocouplers or a single 15-MBd, multichannel, ACSL-6310 optocoupler to isolate transient signal noise from the hot-swap controller and the power-supply manager.

Optocouplers can also be used for isolation in a PoE application. The PoE standard, which is also known as IEEE 802.3af, specifies transference of data and power (13 W, 48 V) over CAT5 copper wire. The power source equipment (PSE) from the PoE application uses a single multichannel optocoupler, ACSL-6420 (two forward and reverse channels), to provide galvanic isolation between the I^2C address bus and the 48-V power-supply lines.[5]

Optocouplers can be used for isolation in a data-acquisition system. A single chip, the ACSL-6410, can be used to isolate between the analog-to-digital converter (ADC) IC and microcontroller, providing often needed galvanic isolation.

Among the synchronous interfaces in the marketplace, the I^2C bus brings an added edge over the other protocols. I^2C is ideal for connecting many peripheral devices onto a single bus line via its simple two-wire address line protocol.

Due to the bus' increased usage, many I^2C applications require galvanic isolation. High-quality and reliable optocouplers provide the required galvanic isolation, preventing ground loop noise that distorts data integrity, and delivering the safety insulation from high voltages. Because of their critical role, it is essential for optocouplers to be certified for reinforced insulation assurance. ed

REFERENCES

1. Philips I^2C bus specification version 2.1, January 2000, section 8
2. HCPL-060L/HCPL-063L datasheet Pub: AV01-0581EN, May 22, 2007; ACPL-M60L datasheet Pub: AV01-0273EN June 17, 2007; *www.avagotech.com/optocoupler*
3. Stacked LED Technology Enables Highly Integrated Optocouplers, Avago Technologies white paper (5989-1473EN, May 3, 2006)
4. Avago Optoisolator Safety Standards and Regulatory Environment; Publication # 5968-5626E (5/99), page 16 ; *www.avagotech.com/optocoupler*
5. ACSL-6xxx datasheet; Publication # AV02-0235EN, June 1, 2007