Ensure Interference-free data communication

Galvanic isolation of circuit components is required in many cases, especially in industrial environments. Capacitive digital isolators can be used to safely and reliably transmit user signals across an isolation barrier. The following circuit example shows how capacitive digital isolators can be used to galvanically isolate remote industrial equipment.

For electronics in typical industrial environments interference-free data communication and personal safety are the two major challenges. Strong electromagnetic fields, overvoltages, transient voltages and high EMC interference are the order of the day. If, for example, the communication cable is laid unfavorably close to a control cable of a frequency inverter, the pulses are capacitively coupled in and the signals in the communication cable oscillate with the pulse pattern of the frequency inverter. This interference can quickly reach a level where significant malfunctions can occur and even endanger the safety of people.

For example, when a thermocouple is used to measure the temperature of a motor, voltages in the millivolt range are generated. If these voltages are transmitted over a cable length of several meters to a central control unit that is referenced to a different ground potential, the measurement signal will be distorted by the potential differences.

Summarizing the phenomena described, the following four challenges arise

- Interference free data transmission
- Separation of ground loops between spatial circuits
- Minimize common-mode interference
- A safety barrier between hazardous voltages and a user

Figure 1 shows the situation of the data transmission system. In order to meet the requirements of shielding dangerous voltages from the user and still guarantee interference-free data transmission, galvanic isolation must be implemented to separate the zones electrically, i.e. in terms of potential, so that they can work separately and thus without interference. The data flow passes through the isolator. However, interference and potential equalization currents are prevented by the galvanic isolation.

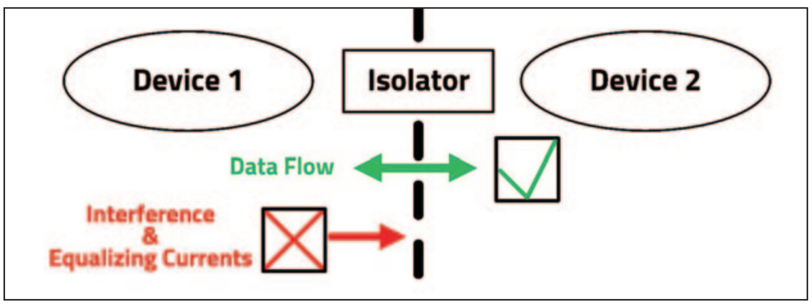

Figure 1: Basic concept of an isolated system for separating different potentials.

Isolated battery voltage measurement

Distributed sensing of physical parameters is the state of the art, and powerful microcontrollers facilitate data processing. However, recording the data on the object is often a challenge, and wireless transmission of the data is often not possible. The data must be recorded on the object in such a way that the probe does not influence the variable to be measured, otherwise measurement errors will occur. This requires electrical decoupling, which must be implemented in the circuitry. Furthermore, the wired transmission of the data must be potential-free and symmetrical so that the transmission is not disturbed by electromagnetic coupling and ground loops. In this application, the use of microcontrollers was deliberately avoided in order to demonstrate that a powerful, interference-free design can be implemented with little effort using analog circuit technology. The design is divided into two circuits, a transmitter and a receiver. The transducer can record a DC

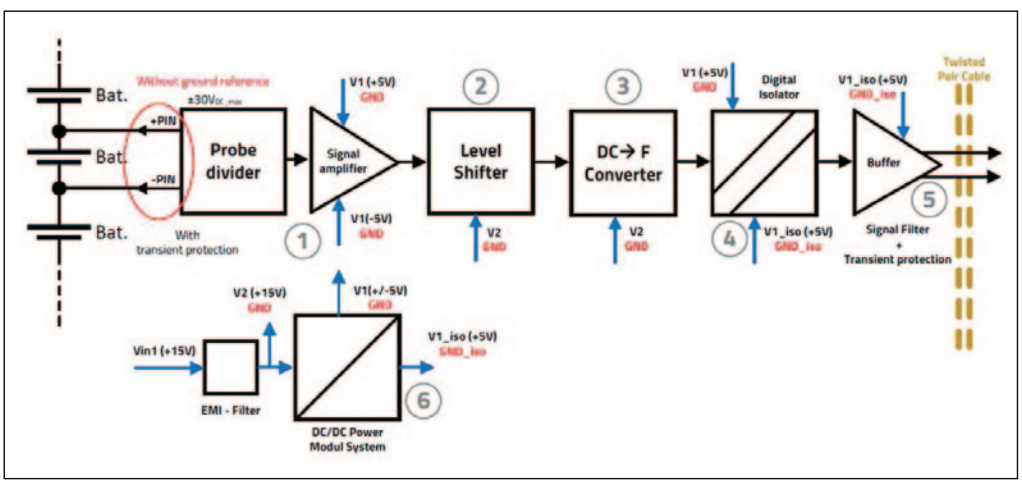

Figure 2: Block diagram of the transmitter for potential-free voltage measurement.

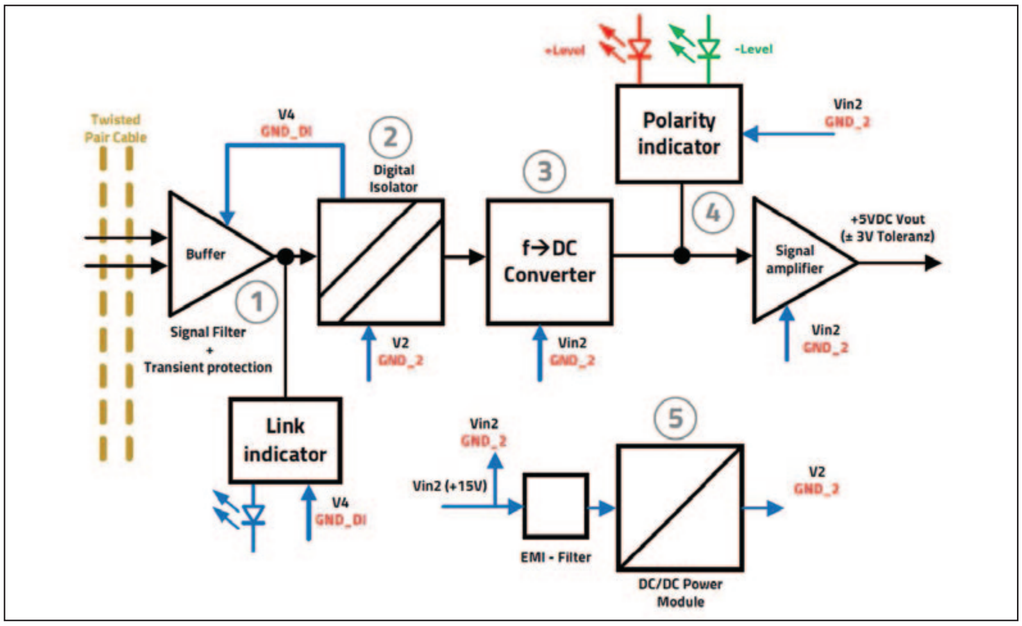

Figure 3: Block diagram of the receiver for potential-free voltage measurement.

voltage of ±30 V max. with a variation period of one second. The current consumption has been minimized to < 85 mA for the transmitter and < 25 mA for the receiver with a voltage supply of 15 V. Both the transmitter and the receiver are electrically isolated, the transmitter between the measurement data acquisition and the signal transmission path and the receiver between the signal transmission path and the data output. Special DC/DC power modules and digital isolators with galvanic isolation and particularly low parasitic coupling capacitance were used to achieve this isolation in the circuitry. The signal is transmitted between the transmitter and receiver via a two-wire cable. Depending on the electromagnetic environmental influences, the distance can be several hundred meters.

Transmit circuit

Figure 2 shows the block diagram of the transmitter. The circuit is divided into six blocks:

1. probe: transducer with voltage divider and amplifier for measuring positive and negative polarity.

2. level shifter: level shifter for the voltage-frequency converter.

3. voltage-frequency converter: digital output signal, frequency dependent on the input voltage.

4. digital isolator: galvanic isolation between measuring potential and interface.

5. interface buffer: Low-impedance line driver with balanced output.

6. power supply: DC/DC converter, galvanically isolated converters for the probe head section.

To ensure functional reliability, measures for transient protection and filters are provided both on the probe side and at the driver output; low-pass filters are also provided before and after the DC/DC power modules to effectively attenuate RF coupling.

Receiver circuit

Figure 3 shows the block circuit of the receiver. The circuit is divided into five blocks:

1. input buffer: signal pick-up, signal conditioning with balanced input. The link indicator shows whether there is a detectable connection to the transmitter.

2. digital isolator: galvanic isolation between input signal and secondary signal processing / output interface. Additional galvanically isolated voltage for the input-side buffer.

3. frequency-to-voltage converter: Generates an output voltage from a digital signal. The voltage level depends on the frequency of the input signal.

4. interface buffer with polarity indicator: Level converter for the output signal. The output signal has a positive polarity, the polarity indicator shows the polarity of the input signal.

5. power supply: DC/DC converter for the secondary-side supply.

Numerous EMC measures are also provided in the receiver section. The signal input from the twisted pair cable is equipped with transient protection and a common mode filter to effectively attenuate interference from the cable. The power supplies around the DC/DC converters are equipped with low-pass filters on both the input and output sides to significantly reduce electromagnetic interference from outside and inside the circuit caused by the switching operations of the DC/DC converters. This ensures a high signal-to-noise ratio and high reliability.

Capacitive digital isolators

The digital isolator from Würth Elektronik [1,2] consists of an oscillator and a modulator on the primary side. A demodulator and a signal buffer are located on the seco ndary side. The components on the primary side are electrically isolated from the components on the secondary side by a capacitive structure with an isolation barrier made of

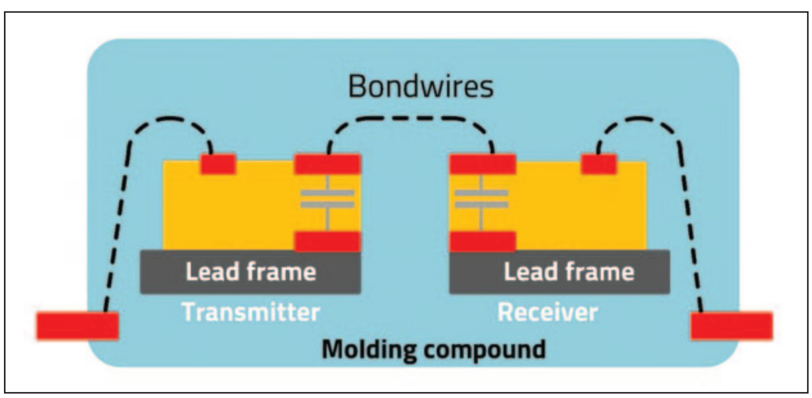

Figure 4: Basic structure of a digital isolator from Würth Elektronik.

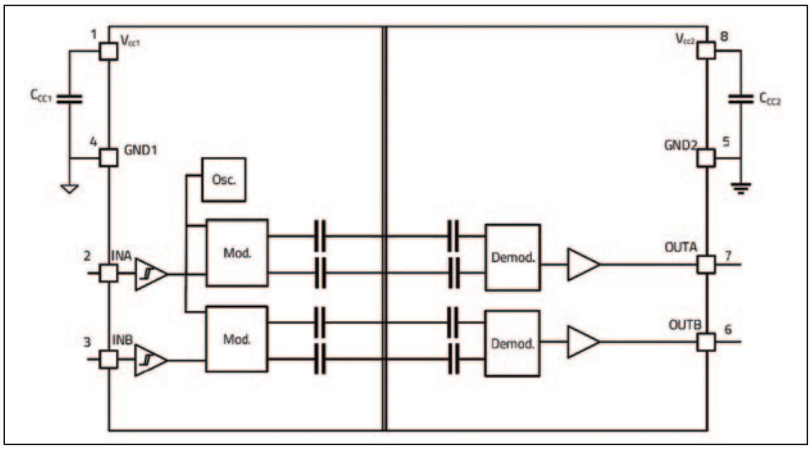

Figure 5: Block diagram of the digital isolator

SiO_2.

The signal is transmitted across the isolation barrier using a modulation process known as on/off keying. The on-chip oscillator is used to modulate the input signal, which is driven by a Schmitt trigger. The modulator generates a differential signal that is transmitted across the capacitive isolation lines.

Figure 4 shows the basic structure of a capacitive digital isolator. The demodulator, on the secondary side of the isolator, performs the functions of amplification, filtering and reconstruction of the input signal. The signal delay and signal distortion are minimal. Finally, a buffer routes the signal from the demodulator output to the overall output, whereby the buffer amplifies the signal to the required level. Figure 5 illustrates the internal structure.

Digital isolators are manufactured using standard CMOS technology, which means they use familiar and proven materials and processes. The transmitter and receiver capacitors are mounted on a lead frame. The capacitors themselves, shown in gray in Figure 4, are located between the two horizontal contacts shown in red. The dielectric material between the electrodes or capacitor plates serves as a galvanic isolation barrier.

The isolation thickness achieved by the process is in the range of a few tens of micrometers. In digital isolators, SiO_2 is used as the isolating material in the capacitor because its much higher dielectric strength of 500 V/µm means that it requires considerably less space for the isolating gap. Other common insulation materials, such as polyimide, have a dielectric strength of only 300 V/µm. The two capacitors are electrically connected with a bonding wire so that two capacitors are connected in series, as shown in the block circuit in Figure 4. To protect the entire structure, the die and leadframe are molded using a standard IC assembly process.

Reliability and safety

Digital isolators are designed to protect people from dangerous voltages. They must therefore meet the highest safety and durability requirements. The digital isolators of the CDIP and CDIS series from Würth Elektronik have been certified by the VDE in Germany according to the latest and most demanding standard DIN EN IEC 60747-17 (VDE 0884-17):2021-10 “Magnetic and capacitive couplers for basic insulation and reinforced insulation”.

But what do the terms “basic” and “reinforced” actually mean for the safety of a person? The standard itself only gives a rather abstract definition here, see IEC 60747-17:202X:

	Basic Isolation	Reinforced Isolation
Package	SOIC-8NB	SOIC-16WB
VIOSM - max. Surge Isolation voltage	5000 Vpk	7070 Vpk
Test	VTEST = 1.3 x VIOSM VTEST = 6.5kV	VTEST = 1.6 x VIOSM VTEST = 11.3kV
Error rate over the lifetime	≤ 1000 ppm	≤ 1 ppm

So, when do you use basic or reinforced isolation? Simply put, it comes down to “single fault condition” and “normal operating conditions”. Reinforced insulation provides protection against electric shock even under single-fault conditions in normal operation. Basic insulation is only effective in normal operation, i.e. without considering a single fault.

Literature:

[1] Uludag, T.: Reliable Galvanic Isolation, Simplified. Power Electronics News, December 2023, S. 6ff.

[2] Digital Isolators WPME-CDIS from Würth Elektronik: **https://www.we-online.com/en/components/products/DIGITAL-ISOLATORS-WPME-CDIS**

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Timur Uludag graduated with a degree in mechatronics engineering from Regensburg University of Applied Sciences. He then worked for several years as a hardware engineer in the fields of switching power supplies and analog circuit design. Since 2015, Uludag has been working as Senior Technical Marketing Manager at Würth Elektronik eiSos in the MagI?C Power Modules business unit. There he specializes in the roadmap planning and market launch of new power modules.

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