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**Self-Powered Isolated RS-232 to UART Interface**

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TI Designs provide the foundation that you need including methodology, testing and design files to quickly evaluate and customize the system. TI Designs help you accelerate your time to market.

**Design Resources**

- TIDA-00163
- ISO7421
- TRS3232
- TPS7633
- EVM430-F6779

- Tool Folder Containing Design Files
- Product Folder

**Design Features**

- High Voltage RS-232 Isolation
- Bit Rates Up to 1 Mbps
- 2-kV Operating Isolation Boundary
- Integrated Power Harvesting for Isolation and RS-232 Transceiver
- Operates with 5-V to 12-V RS-232 drivers

**Featured Applications**

- Energy Meters
- Non-Isolated HV Sensing

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1 System Description

Many sensing applications are designed around low power microcontroller units (MCUs), which do not require isolated power supply designs. In order to save costs, many systems use capacitive-drop power supplies as opposed to transformer-based designs. Using capacitive-drop power designs puts a sensing solution at a very high voltage in relation to a potentially connected host computer. The high voltage creates the need for an isolation boundary.

The RS-232 interface from a host computer is still very popular in the industrial space due to the robust nature of the interface and low cost. However, to facilitate proper RS-232 translation to an embedded system requires an intermediate-level shifting stage. The CMOS TTL voltages are typically in the 3.3-V to 5-V range, while the RS-232 can be near 12 V. Powering the translation on the RS-232 side of the isolation boundary typically requires addition of an isolation power supply to RS-232 interface. The added power supply means unwanted cost to the system. By harvesting power from the RS-232 protocol itself, a fully-isolated, self-powered converter can be implemented.

The TI portfolio offers devices in a broad range of products. Most notably for this industrial design, TI offers products in isolation, interface charge pumps, and power management. By choosing the correct combination of products, a system can be designed to meet the requirements of these isolated industrial interfaces.

2 Design Features

2.1 Power Harvesting

In order to power the data terminal equipment (DTE) side of the isolation boundary and the RS-232 charge pump, there are two choices. The interface can either implement an isolated power supply or harvest power from the RS-232 line. Integrating a power supply adds cost and complexity to the system, which is difficult to justify in low-cost sensing applications.

To implement the second option of harvesting power from the RS-232 port itself, this design utilizes the flow control lines that are ignored in most embedded applications. The RS-232 specification (when properly implemented on a host computer or adapter cable) keeps the RTS and DTR lines high when the port is active. As long as the host has the COM port open, these two lines will have voltage on them. This voltage can vary from 5 V to 12 V, depending on the driver implementation. 5 V to 12 V is sufficient for the usage needed in this design.

The voltage is put through a diode arrangement to block signals from entering back into the pins. The voltage goes through a capacitor to store energy. Then the capacitor releases this energy when the barrier and charge pump pull more current than is instantaneously allowed. A simple low dropout (LDO) is sufficient to bring the line voltage down to a working voltage of 3.3 V for the charge pump and isolation device.

The downside of this design is that the total current available to the devices on the RS-232 side of the boundary are limited to only a few mA (~5), largely depending on what type of driver is available on the DTE side of the RS-232 connection. The following segments will discuss designing the remainder of the system to account for the driver type.
2.2 Isolation Boundary

This design uses capacitive galvanic isolation, which has an inherent life span advantage over an opto-isolator. Industrial devices are typically pressed into service for much longer periods of time than consumer electronics. Therefore, maintenance of effective isolation over a period of 15+ years is important.

The TI ISO7421 device is a simple dual channel isolator which only draws ~4 mA. The TI ISO7421 device is capable of operating at 3.3 V or 5 V, enabling a wide range of devices to be connected to the DCE side of the interface. The ISO7421 device can simply be inserted into a UART signal path, with the appropriate power supplies on each side to enable operation. The ISO7421 device also maintains 2.5 kV of isolation and 4-kV peak in order to meet UL certification levels.

It is important to remember during layout that the traces with high voltage differentials should be kept as far away from each other as possible. Therefore, no signals or ground pours should be placed under the device. All traces should come directly into the device pads. Please see the reference design layout in Section 7.

2.3 RS-232 Charge Pump

To properly interface with the RS-232 standard, a voltage translation system is required to go from the 3.3-V domain on the isolated side of the interface and from the 12 V on the port itself. To facilitate the translation, the design uses a TPS3232 device. The TPS3232 device is capable of driving the higher voltage signals on the RS-232 port from only 3.3-V \( V_{CC} \) via a charge pump system.

3 Block Diagram

![System Block Diagram](image-url)
4 Test Setup and Results

4.1 Power Supply Test

To verify the power harvesting design, the board was connected to several off-the-shelf USB to RS-232 converters. Each of these converters can have a different driver device to generate the RS-232 compliant signals, which results in various TTL voltage levels. In testing, each converter had its TTL level measured. This design uses a 5-V and a 12-V model.

Once connected to the DUT and the USB port of a computer, the COM port must be opened in software in order to enable the RTS and DTR lines of the RS-232 port. This design uses Putty, a popular terminal emulation application. At this point, Putty is only used to open the port, not communicate any data. For each of the converters used, the GND and V_{CC} pins on the board were measured with a multimeter, reading the expected 3.3 V each time.

4.2 Hardware Loopback Test

To determine functional operation, a jumper was placed between the RXD and TXD pins on the isolated input headers. Using the jumper results in any character being transmitted to immediately echo back. To power this side of the isolator, a second EVM is used that is capable of producing both 3.3 V and 5 V, in order to evaluate usage for diverse host processors. The connection setup is shown in Figure 2.

Figure 2. Hardware Loopback
The port was reopened in Putty using the standard port settings (9600 baud, 8 data bits, 1 stop bit, no parity, and no flow control) that interacts with embedded system UART protocols well. Via the now open terminal session, a test string was repeatedly sent. On a correct echo, the terminal would read exactly what was sent out on the line. To help observe for errors, the window was sized to easily show a continuous stream of repeated text. The test results are shown in Figure 3.

This test was also repeated with a data rate of 1 Mbaud, and with a 5-V supply on the input connection with no issues. The tests show that from the isolation boundaries' standpoint, the communication remains robust across different host designs.

4.3 Software Connection

To evaluate integration into a full system, the reference design was connected to a TI EVM430-F6779 e-metering EVM. The EVM is powered by a nonisolated capacitive-drop power supply. The EVM has headers for UART communication and power. The EVM comes with software that enables the EVM to communicate with a PC via a serial port. The EVM430-F6779's communication and power features make the EVM a perfect test bed for this isolated reference design.

The EVM was connected as shown in Figure 4. The EVM disconnects the onboard isolated UART and replaces the UART with the daughter board. Once connected, the EVM was able to be used as described in Implementation of a Three-Phase Electronic Watt-Hour Meter Using the MSP430F677x, literature number SLAA577.
To download the Schematics, see the design files at [TIDA-00163](https://www.ti.com).
6 Bill of Materials

To download the bill of materials (BOM), see the design files at www.ti.com/tool/TIDA-00163. Table 1 shows the BOM for this design.

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Layer Plots

To download the layer plots, see the design files at www.ti.com/tool/TIDA-00163. Figure 6 shows the layer plot for this design.

Figure 6. Layer Plot
8 Altium Project
To download the Altium files, see the design files at www.ti.com/tool/TIDA-00163.

9 Gerber Files
To download the Gerber files, see the design files at www.ti.com/tool/TIDA-00163.

10 Software Files
To download the software files, see the design files at www.ti.com/tool/TIDA-00163.

11 About the Author
BART BASILE is a systems and applications engineer in the Texas Instruments Smart Grid Solutions Team, focusing on the e-metering and grid infrastructure industries. Bart works across multiple product families and technologies to leverage the best solutions possible for system level application design. Bart received his Bachelors of Science in Electronic Engineering from Texas A&M University.
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