参考資料

# TI Designs: TIDM-1005
# M-BusおよびRS-485プロトコル変換機能付きデータ・コレクタの リファレンス・デザイン

## 概要

TIDM-1005では、Meter Bus (M-Bus)とRS-485ネットワークとのプロトコル変換機能付きのスマート・メータ・データ・コレクタを実装します。M-BusとRS-485ネットワークは一部のネットワーク・ドメインで混在でき、この場合にシステムを完全に統合するにはブリッジ機能が必要になります。このTI Designは中間ノードとなり、個別の流量メータからM-Busのデータ・パケットを収集してフォーマットし、より大きなRS-485ネットワークを通して、主要なデータ・コンセントレータへ送信します。

## リソース

| | |
|---|---|
| TIDM-1005 | デザイン・フォルダ |
| MSP432P401R | プロダクト・フォルダ |
| THVD1500 | プロダクト・フォルダ |
| ISOW7841 | プロダクト・フォルダ |
| UCC28711 | プロダクト・フォルダ |
| TPS62177 | プロダクト・フォルダ |
| TPS62175 | プロダクト・フォルダ |
| SN74LV1T34 | プロダクト・フォルダ |
| TPS3808 | プロダクト・フォルダ |
| TMP102 | プロダクト・フォルダ |

TI E2E™ Community

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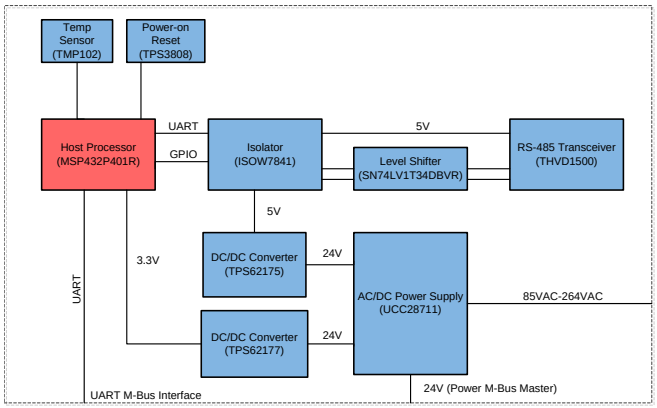
## 特長

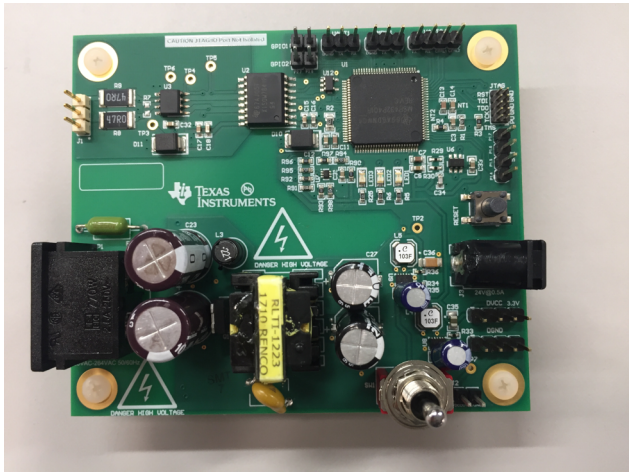
- コストが制約されたアプリケーション向けの、M-BusとRS-485のトランシーバ間のプロトコル変換機能を持つ、単純なデータ・コレクタ
- 24Vの絶縁電源出力で、M-Busのマスタ・モジュールが100個のM-Busスレーブをサポートするために十分な電力、MSP432™を駆動するための3.3V、RS-485信号チェーンを駆動するための5Vを供給
- ±2KV IEC61000-4-4 EFT、±8KV IEC61000-4-2 ESD、およびCISPR22 Class-Bの伝導放射がテスト済み
- TI Design EVMには追加ピン配列(SPI、UART、GPIO用)およびソフトウェア・サンプルが付属し、他のワイヤレスや有線の通信プロトコルを簡単に評価可能

## アプリケーション

- データ・コレクタ
- データ・コンセントレータ
- 電気メータ





# 1 System Description

The TIDM-1005 provides a cost-constrained and low-power data collector with protocol conversion between M-Bus and RS-485 transceiver. The design's primary goal is to provide seamless connection among devices with mixed connectivity of M-Bus or RS-485 transceiver. 図 1 shows the TIDM-1005 system overview. The design runs as M-Bus master to manage the smart meters having M-Bus slave communication and to collect meter reading information from those meters. On the other side to the RS-485 lines, this design runs as a RS-485 slave node to the data concentrator having the RS-485 communication.

This design can also be a reference design for the electrical meter with RS-485 communication because the design is built with the complete RS-485 signal chains [protection, isolation, RS-485 transceiver, and microcontroller (MCU)]. For this purpose, this design provides the software examples for RS-485 standalone operation as well as RS-485 and M-Bus protocol converter.

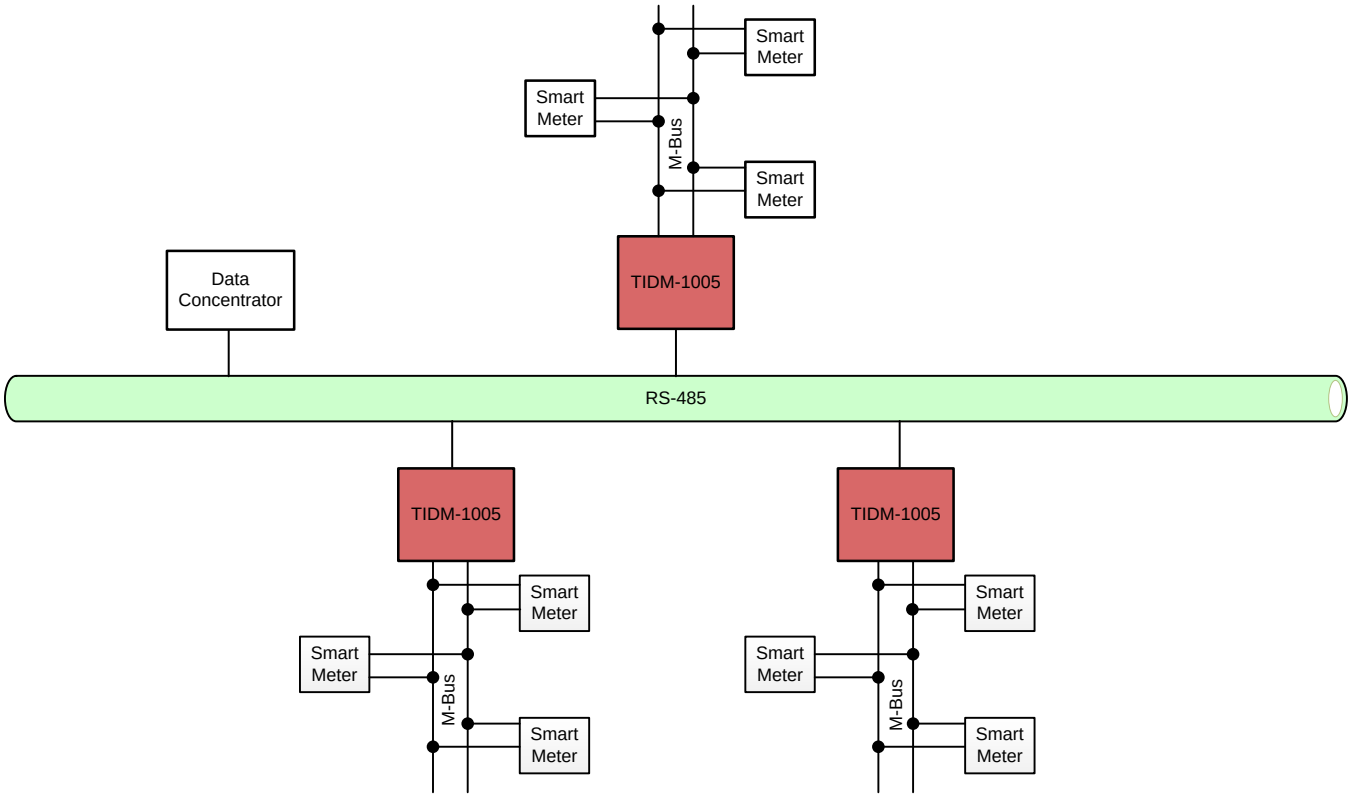
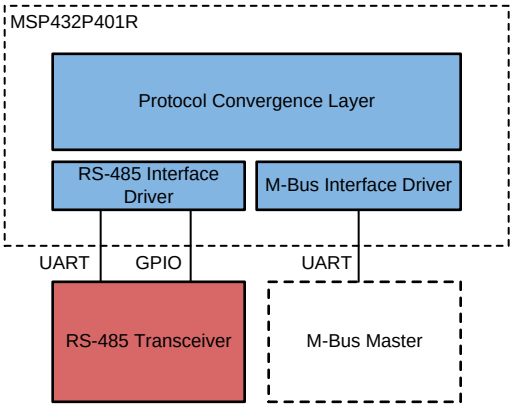



**図 1. TIDM-1005 System Overview**

図 2 shows the software architecture. The MSP432™ runs the protocol convergence protocol implemented in software interfacing to RS-485 transceiver from UART and GPIO and to M-Bus from UART. The UARTs for the RS-485 and the M-Bus are used for data TX and RX, and the GPIO for the RS-485 is to enable the RS-485 TX or RX. The protocol convergence layer includes M-Bus data link framing and parsing per EN 13757-2 standard in addition to passing the received data from one to the other interface.






The M-Bus master module is not included as part of the TIDM-1005. The details for testing with the external M-Bus master module can be found in 3.2.1.

**図 2. TIDM-1005 Software Architecture**

## 1.1 Key System Specifications

**表 1. Key System Specifications**

| PARAMETER | SPECIFICATIONS | DETAILS |
|---|---|---|
| Input power source | Option one: internal AC-DC power supply (input of 85 VAC to 264 VAC, 50 or 60 Hz, and output of 0.42 A at 24 V)<br>Option two: external AC-DC power adaptor (output ≥ 0.42 A at 24 V) | 3.1.1 |
| RS-485 transceiver | 200-kbps, half-duplex, 5-V supply power | 2.3.2 |
| Host processor | ARM® 32-bit Cortex®-M4F CPU, 48 MHz, 256KB Flash, 64-kB RAM | 2.3.1 |
| DC-DC converter | Input: 0.42 A at 24 V<br>Output: 3.3 V and 5 V | 2.3.5 |
| Digital isolator | Integrated DC-DC converter with on-chip transformer, 3-V to 5.5-V wide input supply range, forward/reverse channels: 3/1 | 2.3.3 |
| IEC61000-4-2 electro static discharge (ESD) protection | ±8 KV, contact discharge | 3.2.4 |
| IEC61000-4-4 electrical fast transient (EFT) protection | ±2 KV, BER <$10^{-7}$ | 3.2.5 |
| Conducted emission | CISPR22 Class-B | 3.2.3 |

# 2 System Overview

## 2.1 Block Diagram

図 3 shows the system block diagram. The MSP432P401R is the host processor that runs protocol convergence protocol in software and that interfaces to RS-485 and M-Bus transceiver from UART. The temperature sensor (TMP102) and power-on reset (TPS3808) are built in the design as optional features to supervise reset line and temperature.

The ISOW7841 isolates the RS-485 signal chain from the MCU (MSP432P401R) to reduce noise currents on a data bus and to protect damaging sensitive circuitry. The ISOW7841 is integrated with reinforced power converter to supply 5-V power to the RS-485 transceiver. The level shifter (SN74LV1T34DBVR) installed between the ISOW7841 and MSP432P401R adjusts the voltage level in the control (GPIO) and data (UART) paths between the MSP432 and THVD1500 to deliver the proper logical value to each device.

The THVD1500 is a cost-optimized, half-duplex RS-485 transceiver (up to 300 kbps). The THVD1500 operate from a single 5-V supply, which is provided by the ISOW7841.

The AC-DC power supply supports a wide range of AC voltage input from 85 VAC to 264 VAC and output 0.42 mA at 24 V to power an external M-Bus master and to input to the DC-DC converter. The DC-DC converter steps the input voltage down to 3.3 V and 5 V to power the host processor and the RS-485 transceiver, respectively.

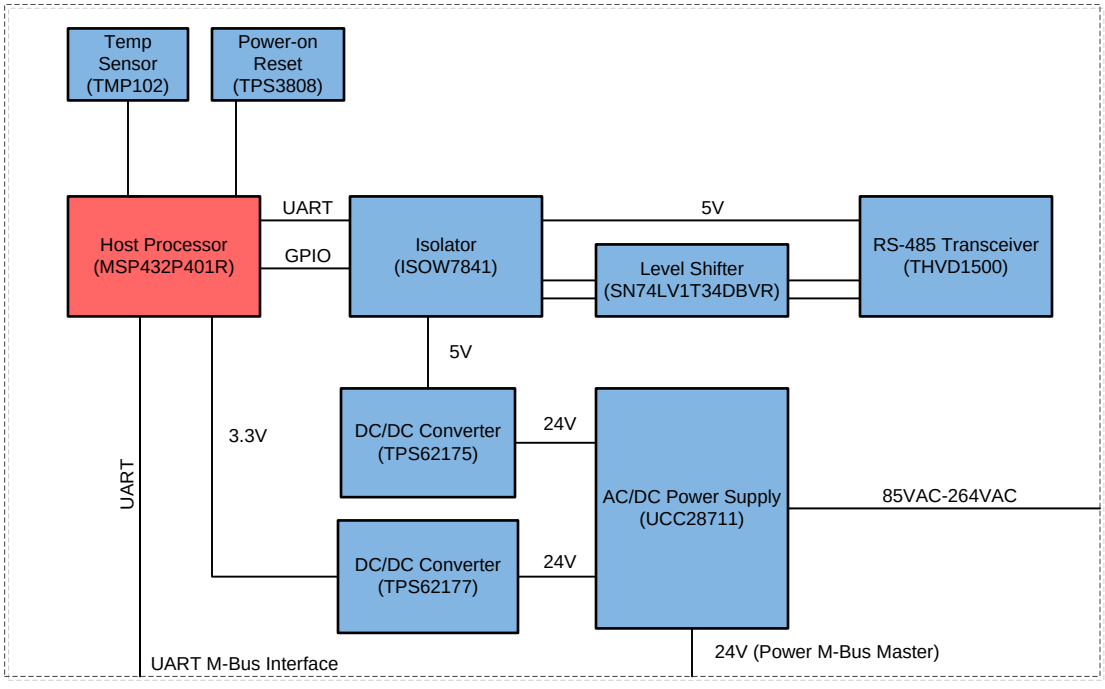





**図 3. TIDM-1005 System Block Diagram**

## 2.2 Design Considerations

For this design, these devices were chosen due to:

- The MSP432P401R is a cost-constrained and ultra-low-power 32-bit, ARM Cortex-M4F processor that

supports necessary peripherals and speed for M-Bus and RS-485 transceiver.

- The THVD1500 is a robust half-duplex RS-485 transceiver with external protection circuitry to satisfy ±8-KV IEC61000-4-2 contact discharge and ±2-KV IEC61000-4-4 fast transient burst.
- The ISOW7841 is a high-performance, digital isolator with on-chip transformer and an integrated reinforced power converter with up to 650 mW of isolated power.
- The UCC28711 is a flyback power supply controller that provides isolated-output constant-voltage (CV) and constant-current (CC) output regulation.
- The TPS62177 or TPS62175 is a high-efficiency, synchronous, step-down, DC-DC converter with a wide operating input voltage range of 4.75 V to 28 V, which provides up to 500-mA output current.

## 2.3 Highlighted Products

### 2.3.1 MSP432P401R

The MSP432P401x MCU family is TI's latest addition to its portfolio of efficient ultra-low-power mixed-signal MCUs. The MSP432P401x MCUs feature the ARM Cortex-M4 processor in a wide configuration of device options, which include a rich set of analog, timing, and communication peripherals, thereby catering to a large number of application scenarios where both efficient data processing and enhanced low-power operation are paramount.

Overall, the MSP432P401x is an ideal combination of the TI MSP430™ low-power DNA, advance mixed-signal features, and the processing capabilities of the ARM 32-bit Cortex-M4 RISC engine. The devices ship with bundled peripheral driver libraries and are compatible with standard components of the ARM ecosystem.

図 4 shows the MSP432 functional block diagram.

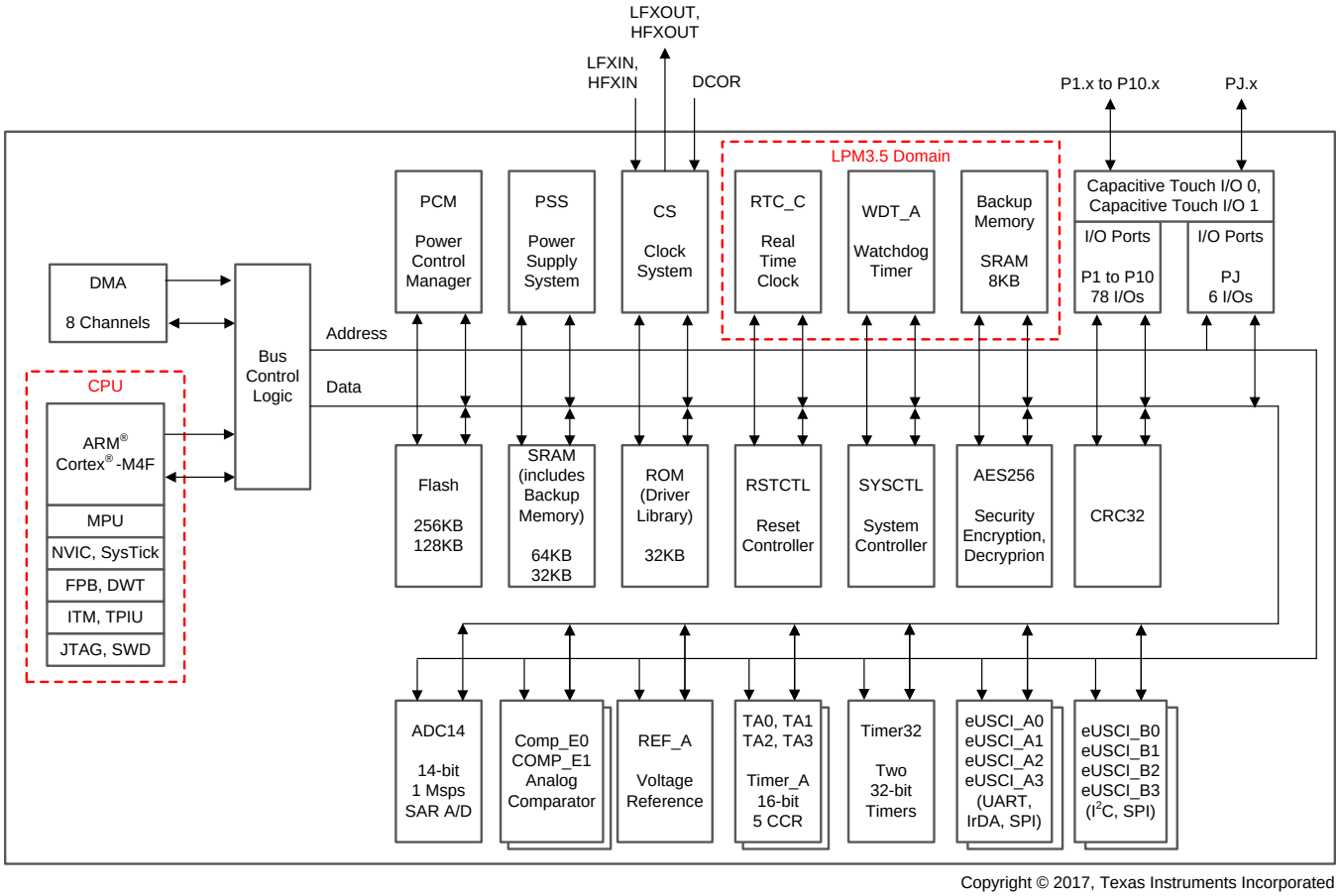





**図 4. MSP432™ Functional Block Diagram**

### 2.3.2 THVD1500

THVD1500 is a robust half-duplex RS-485 transceiver for industrial applications. The bus pins are immune to high levels of IEC Contact Discharge ESD events eliminating need of additional system level protection components. The device operates from a singl 5-V supply. The wide common-mode voltage range and low input leakage on bus pins make THVD1500 suitable for multi-point applications over long cable runs. THVD1500 is available in industry standard 8-pin SOIC package for drop-in compatibility. The device is characterized from -40°C to 125°C.

図 5 shows the THVD1500 functional block diagram.

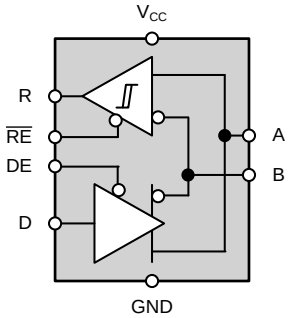



**図 5. Functional Block Diagram**

### 2.3.3 ISOW7841

The ISOW784x family of devices comprises a high-efficiency, low-emissions isolated DC-DC converter and four high-speed isolated data channels. 図 6 shows the functional block diagram of the ISOW784x family of devices.

The integrated DC-DC converter uses switched mode operation and proprietary circuit techniques to reduce power losses and boost efficiency. Specialized control mechanisms, clocking schemes, and the use of a high-Q, on-chip transformer provide high efficiency and low radiated emissions. The integrated transformer uses thin film polymer as the insulation barrier.

The $V_{CC}$ supply is provided to the primary power controller that switches the power stage connected to the integrated transformer. Power is transferred to the secondary side, rectified, and regulated to either 3.3 V or 5 V depending on the SEL pin. The output voltage, $V_{ISO}$, is monitored, and feedback information is conveyed to the primary side through a dedicated isolation channel. The duty cycle of the primary switching stage is adjusted accordingly. The fast feedback control loop of the power converter ensures low overshoots and undershoots during load transients. Undervoltage lockout (UVLO) with hysteresis is integrated on the $V_{CC}$ and $V_{ISO}$ supplies, which ensures robust system performance under noisy conditions. An integrated soft-start mechanism ensures controlled inrush current and avoids any overshoot on the output during power up.

The integrated signal-isolation channels employ an ON-OFF keying (OOK) modulation scheme to transmit the digital data across a silicon-dioxide based isolation barrier. The transmitter sends a high-frequency carrier across the barrier to represent one state and sends no signal to represent the other state. The receiver demodulates the signal after signal conditioning and produces the output through a buffer stage. The signal-isolation channels incorporate advanced circuit techniques to maximize the CMTI performance and minimize the radiated emissions from the high frequency carrier and IO buffer switching. 図 7 shows a functional block diagram of a typical signal isolation channel.

The ISOW784x family of devices is suitable for applications that have limited board space and require more integration. These devices are also suitable for very-high voltage applications where power transformers meeting the required isolation specifications are bulky and expensive.

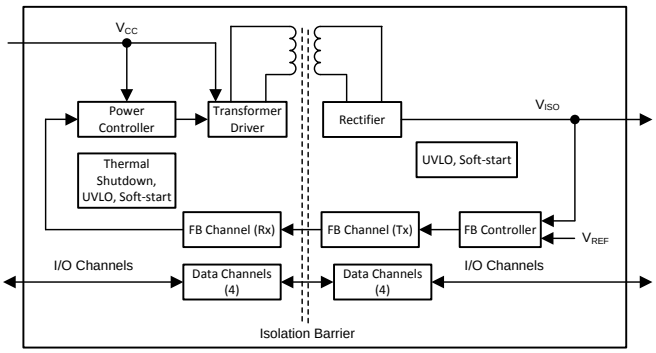



図 6. Functional Block Diagram

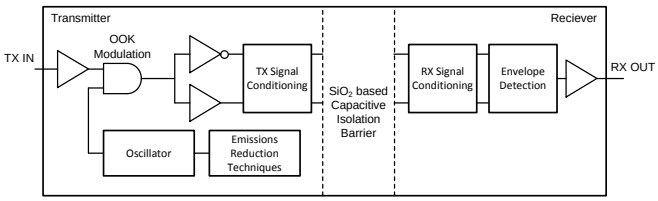



図 7. Conceptual Block Diagram of a Capacitive Data Channel

### 2.3.4 UCC28711

The UCC2871x family of flyback power supply controllers provides isolated-output CV and CC output regulation without the use of an optical coupler. The devices process information from the primary power switch and an auxiliary flyback winding for precise control of output voltage and current.

An internal, 700-V start-up switch, dynamically-controlled operating states, and a tailored modulation profile support ultra-low standby power without sacrificing start-up time or output transient response.

Control algorithms in the UCC28710 family allow operating efficiencies to meet or exceed applicable standards. The output drive interfaces to a MOSFET power switch. Discontinuous conduction mode (DCM) with valley switching reduces switching losses. Modulation of switching frequency and primary current peak amplitude (FM and AM) keeps the conversion efficiency high across the entire load and line ranges.

The controllers have a maximum switching frequency of 100 kHz and always maintain control of the peak-primary current in the transformer. Protection features help keep primary and secondary component stresses in check. The UCC28710, UCC28714, and UCC28715 allow the cable compensation to be programmed. The UCC28711, UCC28712, and UCC28713 devices allow remote temperature sensing using a negative temperature coefficient (NTC) resistor while providing fixed cable-compensation levels.

図 8 shows the functional block diagram.

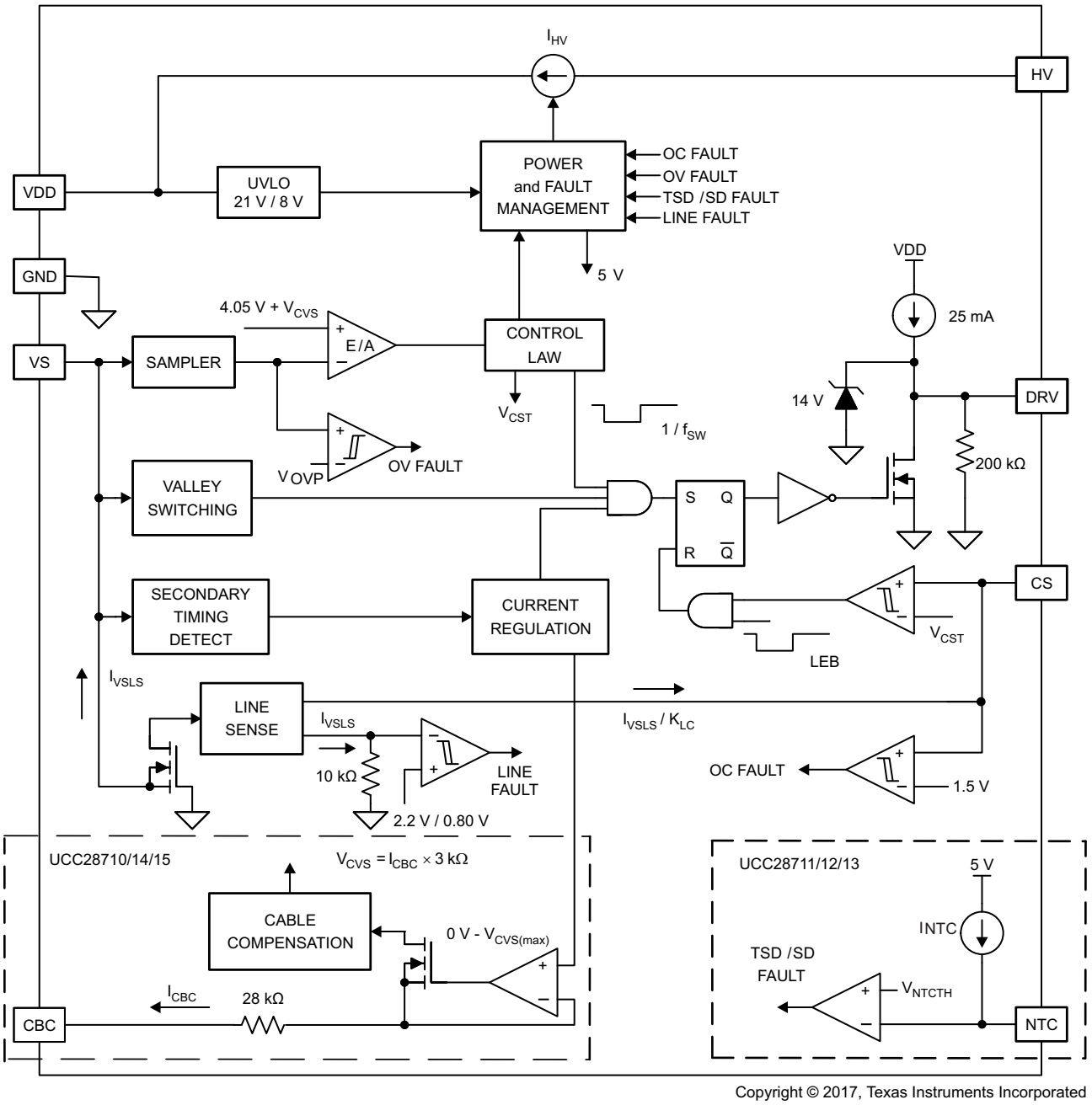





**図 8. Functional Block Diagram**

### 2.3.5 TPS62175 and TPS62177

The TPS6217x synchronous switch mode power converters are based on DCS-Control™ (direct control with seamless transition into power save mode), which is an advanced regulation topology that combines the advantages of hysteretic, voltage mode, and current mode control that includes an AC loop directly associated to the output voltage. This control loop takes information about output voltage changes and feeds the information directly to a fast comparator stage. The control loop sets the switching frequency, which is constant for steady state operating conditions, and provides immediate response to dynamic load changes. To get accurate DC load regulation, a voltage feedback loop is used. The internally compensated regulation network achieves fast and stable operation with small external components and low-ESR capacitors. The DCS-Control topology supports pulse width modulation (PWM) mode for medium and heavy load conditions and a power save mode at light loads. During PWM, the DCS-Control topology operates at its nominal switching frequency in continuous conduction mode. This frequency is typically about 1 MHz with a controlled frequency variation depending on the input voltage. If the load current decreases, the converter enters power save mode to sustain high efficiency down to very light loads. In power save mode the switching frequency decreases linearly with the load current. Because DCS-Control supports both operation modes within one single building block, the transition from PWM to power save mode is seamless without effects on the output voltage. Fixed output voltage versions provide smallest solution size and lowest current consumption requiring only three external components. An internal current limit supports nominal output currents of up to 500 mA.

The TPS6217x offer both excellent DC voltage and superior load transient regulation, combined with very low output voltage ripple, which minimizes interference with RF circuits [6].

図 9 and 図 10 show the functional block diagram of TPS62175 and TPS62177, respectively.

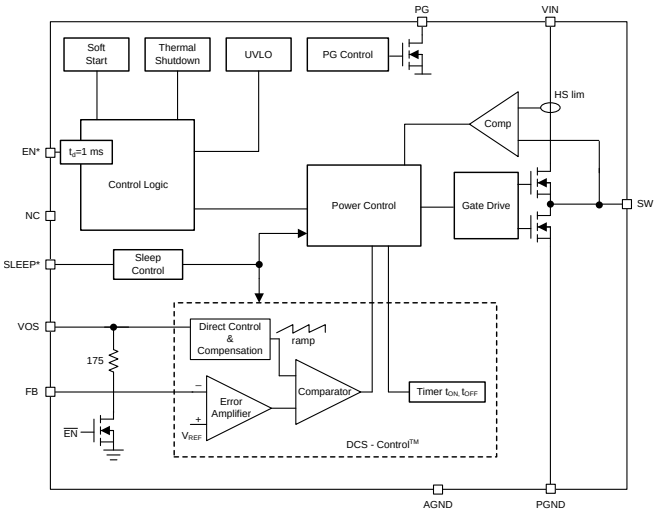



**図 9. Functional Block Diagram: TPS62175-Adjustable Output Voltage**

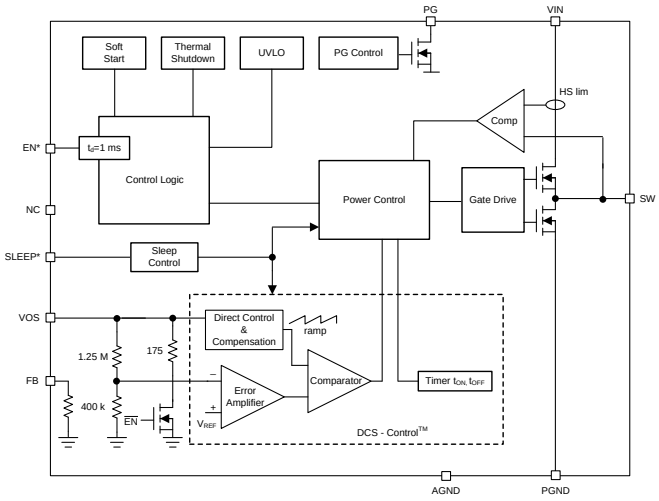



**図 10. Functional Block Diagram: TPS62177-Fixed Output Voltage**

# 3 Hardware, Software, Testing Requirements, and Test Results

## 3.1 Required Hardware and Software

### 3.1.1 Hardware

図 11 shows the TIDM-1005 hardware architecture. The TIDM-1005 design includes four sub-blocks: isolated RS-485 signal chain, MSP432P401R host processor interfaced to TMP102 and TPS3808, AC-DC power supply (UCC28711), and DC-DC power supply to step down the input voltage to 3.3 V and 5 V.

The M-Bus module (master or slave) is not included as part of the TIDM-1005 design. Instead, the TIDM-1005 design experiments the M-Bus communication by connecting external M-Bus modules (master or slave) with powering the M-Bus master through 24-V output pin and M-Bus transmission or reception through a dedicated M-Bus pin (UART). The details of the external M-Bus module used for testing will be discussed in 3.2.1.

**CAUTION**

HIGH VOLTAGE! Use caution when connecting to the power grid. Do not leave EVM powered when unattended when the internal AC-DC power supply is used.

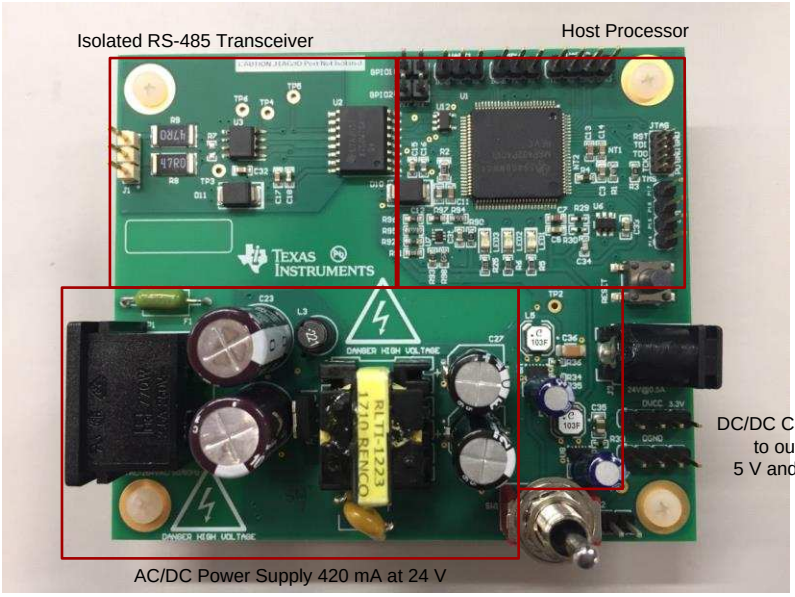





**図 11. TIDM-1005 Hardware Architecture**

### 3.1.1.1 MSP432™ Host Processor

The host processor block includes the MSP432P401R, which includes 32-bit ARM Cortex-M4F core that runs the protocol converter software example. As optional features, the host processor block includes the supervisionary IC of TPS3808 to monitor the reset line to the MCU and TMP102 to sense temperature. The host process block includes pin-out for multiple peripherals for extensive usage of the board on the end-product development: three UARTs (one for M-Bus signal chain, the others for RS-232, host connection, and so on), one SPI, and two GPIOs. In addition, this block includes three LEDs that indicate software status, TRX status, and so on. The 10-pin JTAG connector is used to program firmware to the MSP432 and to debug the developing software.

### 3.1.1.2 Isolated RS-485 Transceiver

The isolated RS-485 signal chain consists of a protection circuit against 1-kV surge (IEC 61000-4-5) transients, THVD1500, RS-485 transceiver, and ISOW7841 to isolate the RS-485 signal domain from the MCU domain as well as to power 5 V to the RS-485 transceiver. The two-pin jumper of *RS485_GND* can be connected to the earth ground when performing the ESD testing. 図 12 shows the schematic of the isolated RS-485 signal chain.

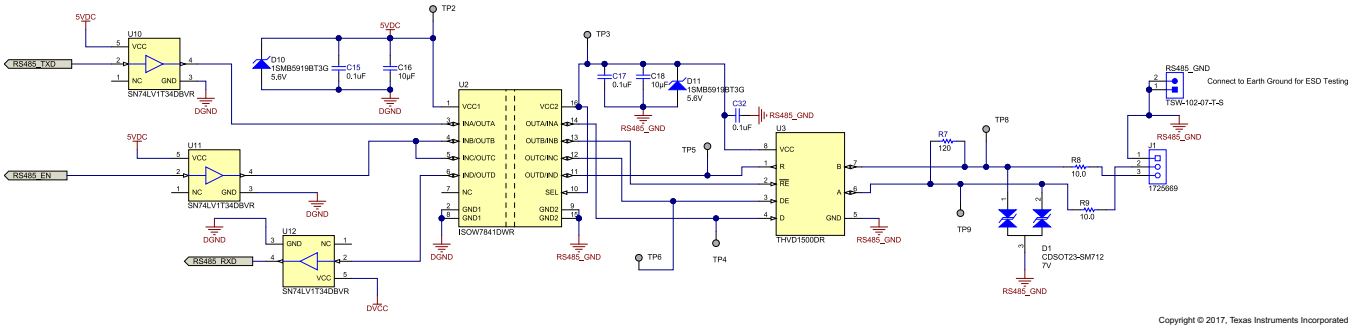



**図 12. Schematic: Isolated RS-485 Signal Chain**

### 3.1.1.3 AC-DC Power Supply

The AC-DC power supply block includes UCC28711, a flyback power supply controller. The AC-DC power supply inputs a wide range of voltages from 85 VAC to 264 VAC and outputs at 420 mA at 24 V. The 24-V voltage output is used to power M-Bus master module as well as to input voltages to the DC-DC converter block. 図 13 shows the schematic of the AC-DC power supply.

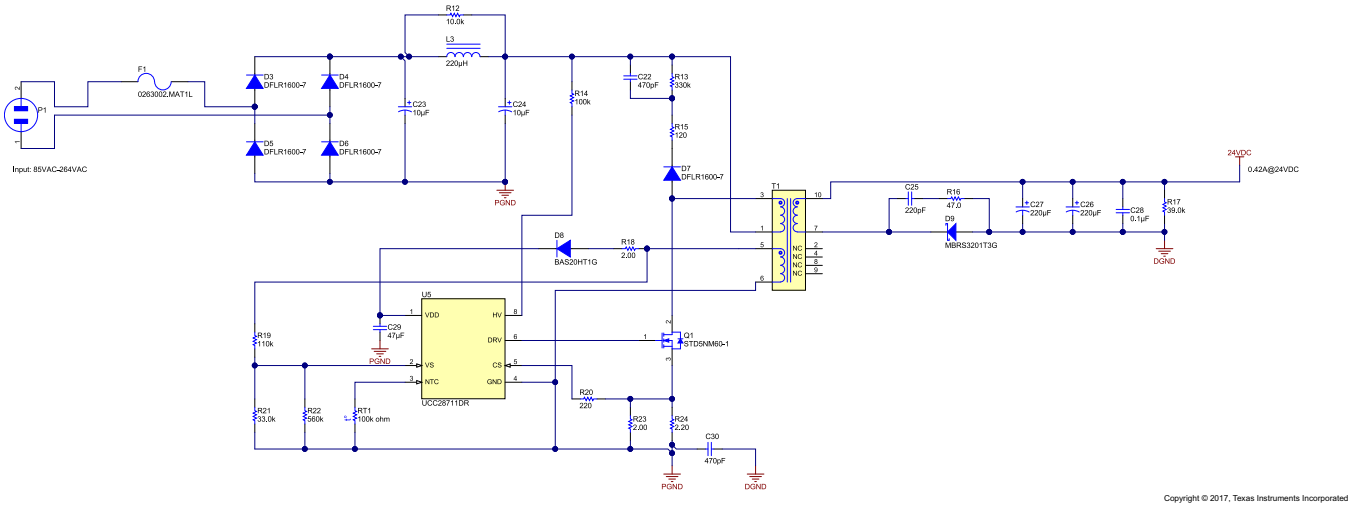



**図 13. Schematic: AC-DC Power Supply**

### 3.1.1.4 DC-DC Converter

The DC-DC converter block includes two buck converters of TPS62175 and TPS62177. The TPS62175 converts the input voltage of 24 V to 5 V to power the RS-485 signal chain block. The TPS62177 steps down the input voltage of 24 V to 3.3 V to power the host processor block. 図 14 shows the schematic of the DC-DC converter. C39 and C40 protect the TPS62177 and TPS62175 to be damaged from the transient voltage.

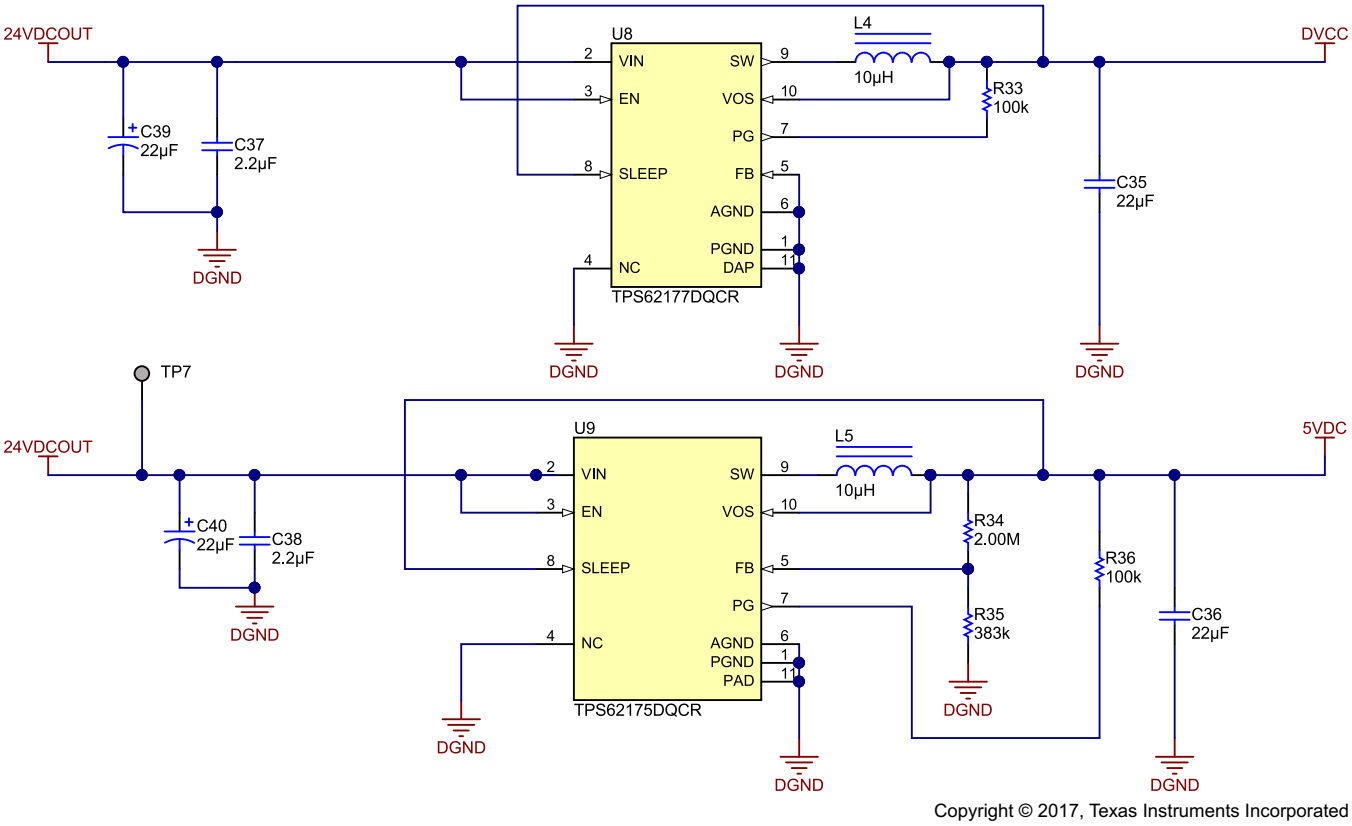



**図 14. Schematic: DC-DC Converter**

### 3.1.1.5 Power Options

The TIDM-1005 has two power options: one is powering from the internal AC-DC power supply and another option is to input 24-V DC power from the AC-DC wall power adaptor (0.5 A at 24 V). This can be selected by SW1. 図 15 shows the schematic of the power switch block.

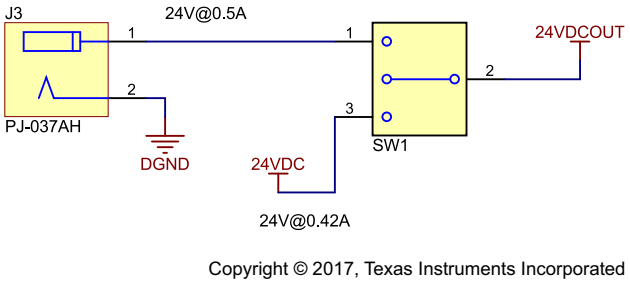



**図 15. Schematic: Power Switch (SW1)**

### 3.1.2 Software

The TIDM-1005 provides a Code Composer Studio™ (CCS) software example (RS485_MBus_Protocol_Converter_Example) including protocol convergence protocol, M-Bus framing and parsing, RS-485 framing and parsing, RS-485 UART driver, and M-Bus UART driver. This section covers details of the example software architecture and is followed by instructions to build and flash the binaries with the CCS.

The prerequisite to build the software example is to install CCS v7.1 (or above) with the software update (select *Help* → *Check for Updates* in the CCS top menu) and the MSP43x TI-RTOS version of v2.20.0.06. The TI-RTOS version can be checked in the RTSC menu (right-click on the example CCS project and then property → *General*) as shown in 図 16.

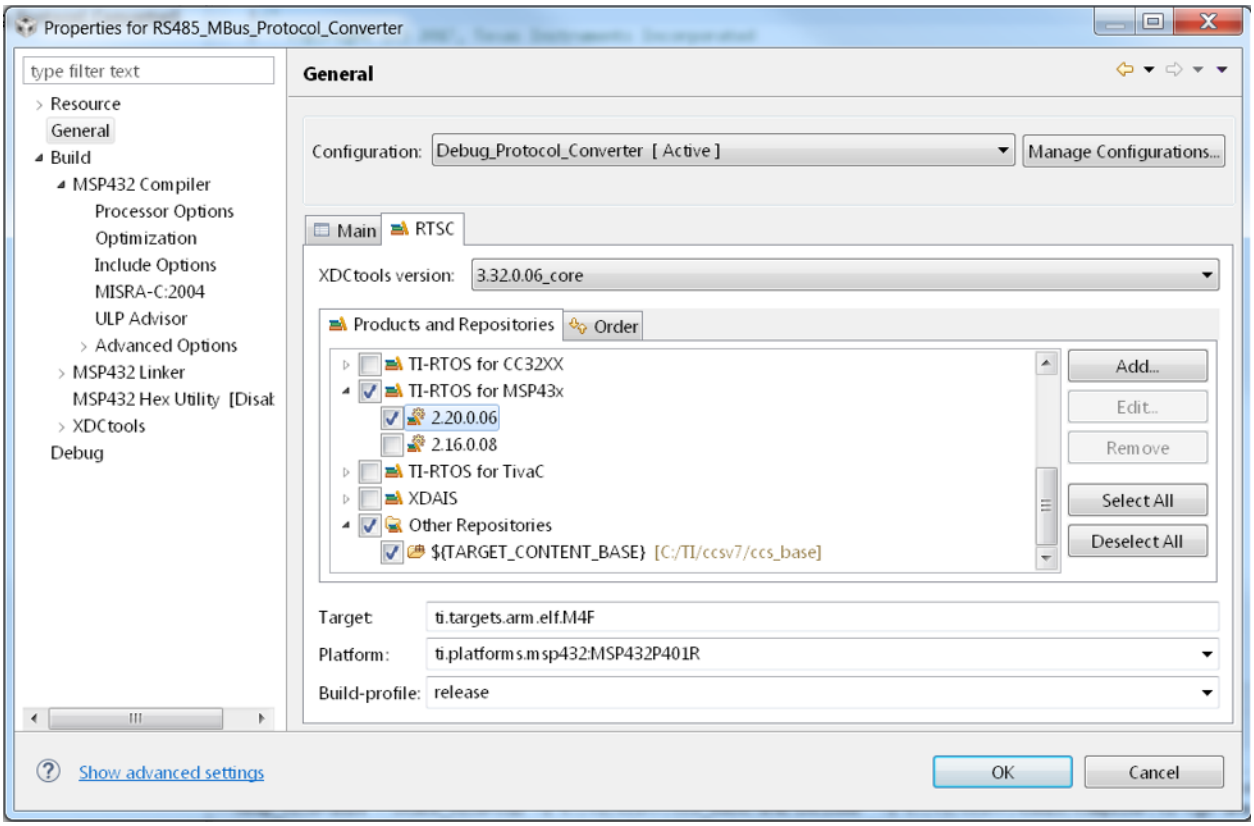



**図 16. CCS TI-RTOS Version**

The RS485_MBus_Protocol_Converter project consists of three build configurations for demonstration purposes: Debug_Protocol_Converter, Debug_RS485_Data_Collector, and Debug_MBus_Slave. 図 17 shows the available build configurations for the example project. The Debug_Protocol_Converter is the target example that includes protocol convergence layer for RS-485 and M-Bus, which will be discussed in this section. The Debug_RS485_Data_Collector build configuration is to emulate the data collector having RS-485 only, and the Debug_MBus_Slave build configuration is to emulate the slave meter having M-Bus slave module only. These two binaries can be used for 3-node demonstration that will be discussed in 図 23.

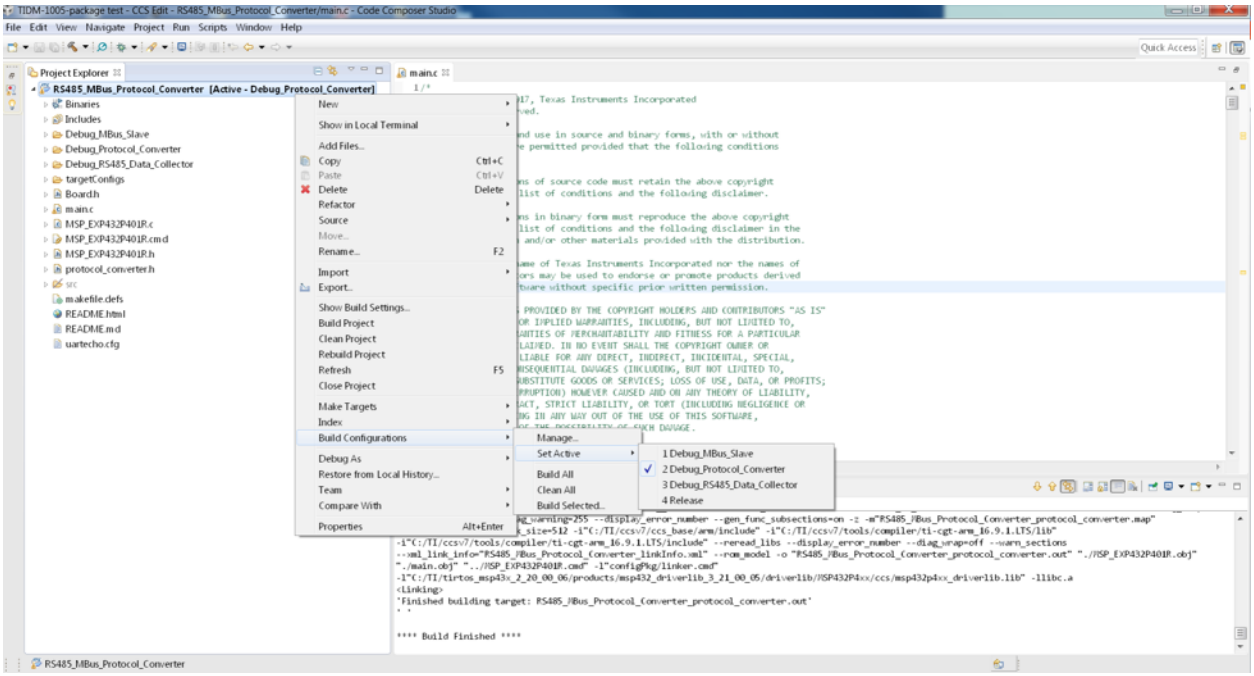



**図 17. CCS Build Configuration**

### 3.1.2.1 RS485_MBus_Protocol_Converter Example

The RS485_MBus_Protocol_Converter example runs TI-RTOS on ARM Cortex-M4 core in the MSP432. The software example includes three tasks: ProtocolConverterTask, uartRS485RxTask, and uartMbusRxTask.

図 18 shows the interaction among the tasks. The uartRS485RxTask and uartMbusRxTask signals to ProtocolConverterTask through mailbox messages when RX events from RS-485 or M-Bus happen.

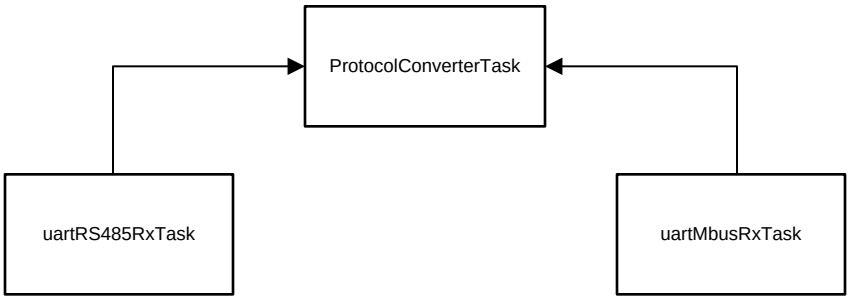



**図 18. Task Interaction in RS485_MBus_Protocol_Converter Example**

**注:** The example software is provided as a working example but does not consider optimizing software in terms of performance, code size, and memory usage.

#### 3.1.2.1.1 uartRS485RxTask

The task initially configures the UART with baud rate of 115200 bps and waits to receive data from the UART. The task first extracts the 2-byte header, which includes payload length, and then the task extracts the payload by reading the UART buffer based on the given payload length. For the RS-485 communication, a simple frame format is used in this example: 2-byte length header followed by payload as shown in 図 19.

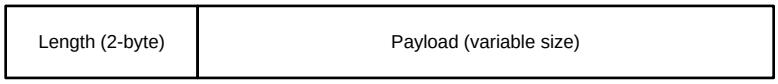



**図 19. RS-485 Frame Format in Example Project**

Once the received data is verified, the message with the ID of TX_MBUS is posted in the mailbox to deliver to the ProtocolConverterTask. In this example, the task fills the TX buffer with REQ_UD2 message (SHORT frame based on EN 13757-2) with the TX_MBUS ID. This example assumes that the received RS-485 message from the primary data collector triggers the protocol converter with a meter reading request to the M_Bus slave meter. The details will be discussed in 3.2.1.

#### 3.1.2.1.2 uartMbusRxTask

The task initially configures the UART with baud rate of 9600bps and then 1-byte M-Bus address. Because the RS485_MBus_Protocol_Converter acts as M-Bus master node, this example sets the M-Bus master address to 0x00.

This example implements the M-Bus link-layer frame format per EN 13757-2. The task waits for 1-byte START from the UART, which indicates whether the received frame is SHORT frame or not. If the received byte is 0x10, this is the fixed-size short frame (5-byte in total), and thus the task extracts the remaining 4-byte payload. If the received byte is 0x68, the received frame can be CONTROL or LONG frame. To figure out the message type, the task reads 2-byte L-field. If each byte of the L-field is equal to 0x03, this is the fixed-size CONTROL frame and the task extracts the remaining 6-byte payload. If each byte of the L-field is not equal to 0x03, the received frame is variable-sized LONG frame. The task then reads the payload size, indicated by the L-field, plus 3-byte since the 3B control fields (1B START, 1B Checksum, and 1B STOP fields) are not counted as payload length in the L-field.

Once receiving the frame, the next step is to parse the frame (parseMBusRxData function in the example). The parsing routine includes validating the received frame in terms of size, checksum, destination address, and subfield values. Once the verification passes, the task posts the message with the ID of TX_RS485 to the ProtocolConverterTask. This post is because the message received from M-Bus slave will be forwarded to the data collector through RS-485.

#### 3.1.2.1.3 ProtocolConverterTask

The ProtocolConverterTask waits for mailbox messages. Once receiving the mailbox messages, the task sends data from either M-Bus or RS-485 depending on the message ID.

#### 3.1.2.1.4 LED Configuration

This example configures LED1 (red) for RS-485 TX and RX events, LED2 (yellow) for M-Bus TX and RX events, and LED3 (blue) for invalid RX events.

### 3.1.2.2 Building the Software Example With CCS

The example project is built with CCS IDE v7.1 (or above). The CCS project can be opened by importing the CCS project files in the installation directory (by default C:\TI\RS485_MBus_Protocol_Converter_Example_V1.0.0.0). Then choose one of three build configurations in the project. 図 20 shows a screen capture. The final step is to build the project. Note to clean the project before rebuilding the project. Once built successfully, the binary file can be found under the Debug_ directory.

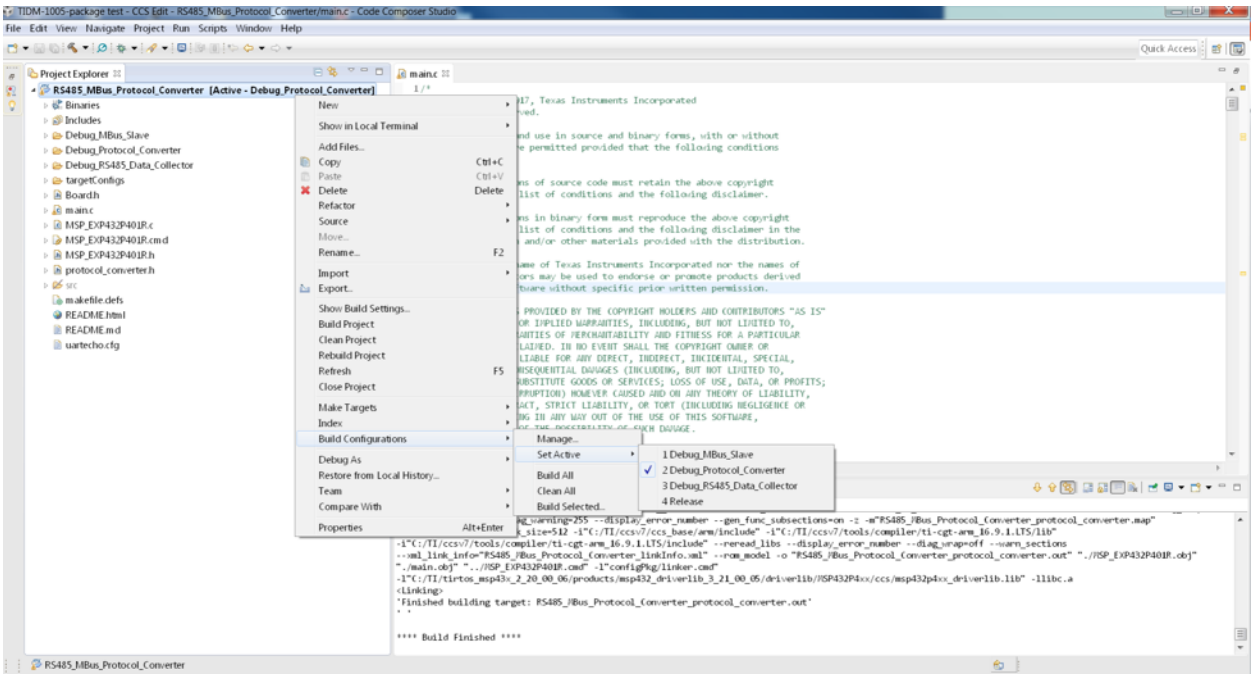


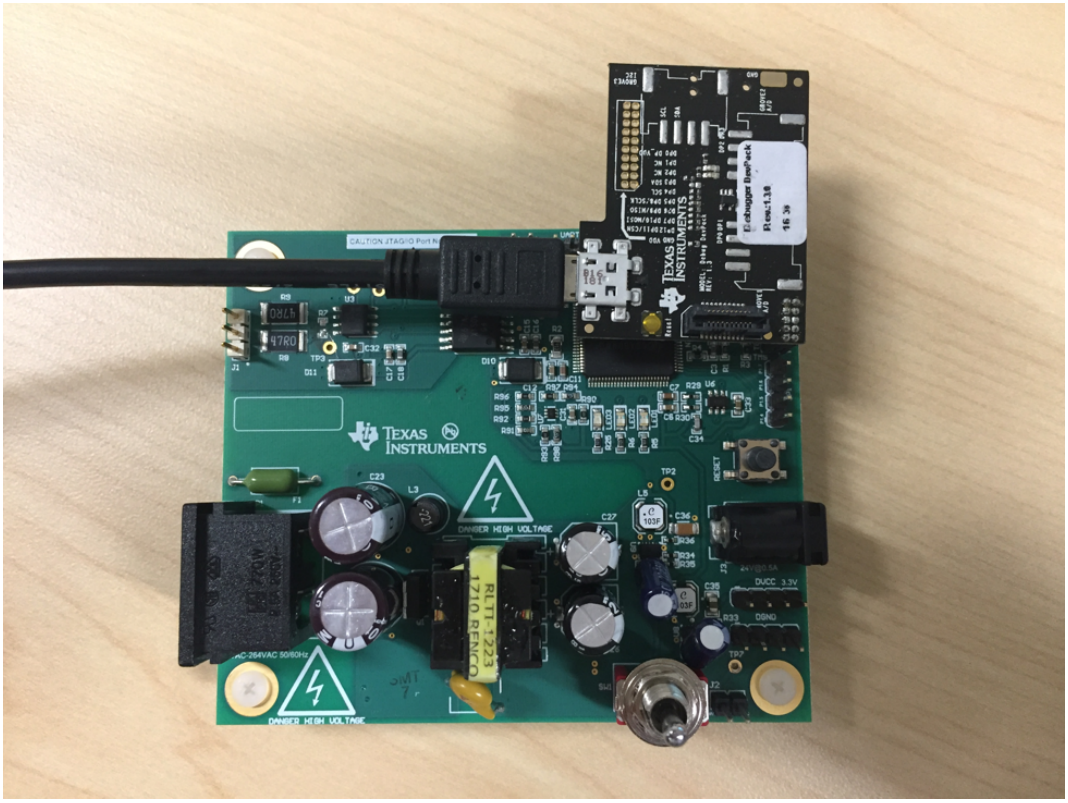

**図 20. Build Configuration of RS485_MBus_Protocol_Converter Example**

The software example package provides three prebuilt binaries that can be used for 3-node demonstration described in 3.2.1:

- RS485_MBus_Protocol_Converter_protocol_converter.out
- RS485_MBus_Protocol_Converter_rs485_data_collector.out
- RS485_MBus_Protocol_Converter_mbus_slave.out

### 3.1.2.3 Flashing the Software Example With CCS

The first step to flash the example binary on the MSP432 is to connect the 10-pin JTAG debugger (SimpleLink SensorTage Debugger DevPack) on the JTAG pin-out on the board. 図 21 shows the connection between the JTAG debugger and the TIDM-1005 EVM.



Need additional header on the 10-pin JTAG connector to connect properly on the TIDM-1005 EVM.

**図 21. 10-pin JTAG Debugger Connection**

Once properly connected to the JTAG pin, the next step is to launch the target configuration and to flash the binary in the CCS. The example project includes the target configuration file (MSP432P401R.ccxml) under targetConfigs as shown in 図 22.

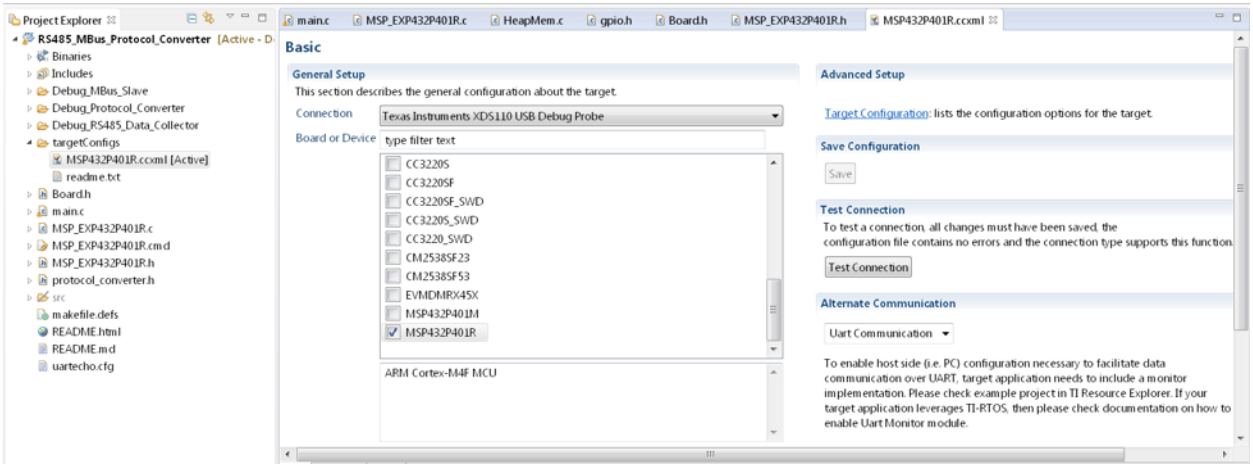



**図 22. CCS Target Configuration**

## 3.2 Testing and Results

### 3.2.1 Test Setup and 3-Node Demonstration

図 23 shows the 3-node setup for testing and demonstration. The setup consists of RS-485 data collector, TIDM-1005 protocol converter connected with external M-Bus master module, and M-Bus slave with external M-Bus slave modem. In the setup the RS-485 data collector installs RS-485 communication only. The TIDM-1005 protocol converter acts as a mini data collector to interconnect between the RS-485 data collector and M-Bus slave node by using RS-485 (for the RS-485 data collector) and M-Bus (for M-Bus slave).

The demonstration with the prebuilt binaries runs in the following sequences:

1. The RS-485 data collector triggers 10B meter reading request message to the TIDM-1005 protocol converter from RS-485. In this example, the data collector trigger the 10B message every 5 seconds.
2. The TIDM-1005 protocol converter processes the request message and sends out REQ_UD2 frame (request for Class 2 Data) to M-Bus slave from M-Bus.
3. The M-Bus slave responds back to the TIDM-1005 protocol converter with RSP_UD message from M-Bus. The RSP_UD payload size varies. In this example for every transmission, the payload size increases by 1 B, starting from 1B (minimum) to 255B (maximum).
4. The TIDM-1005 protocol converter processes the RSP_UD message, converts payload into the RS-485 format, and delivers to RS-485 data collector through RS-485.

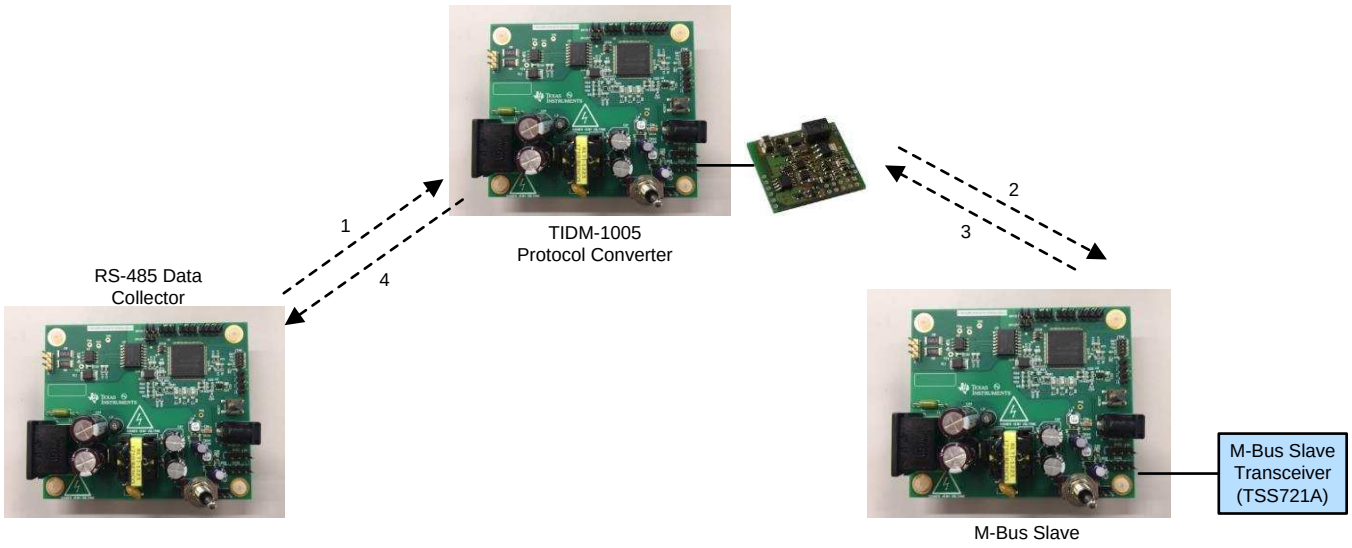





**図 23. 3-Node Test Setup**

表 2 summarizes the binary to be flashed on each of board for the demonstration setup.

**表 2. Demonstration Software Setup**

| BOARD | BINARY TO BE FLASHED |
|---|---|
| RS-485 data collector | RS485_MBus_Protocol_Converter_rs485_data_collector.out |
| TIDM-1005 protocol converter | RS485_MBus_Protocol_Converter_protocol_converter.out |
| M-Bus slave | RS485_MBus_Protocol_Converter_mbus_slave.out |

Because the RS-485 data collector only uses RS-485 and the TIDM-1005 EVM includes the complete path for RS-485, no external module is necessary to set up the RS-485 data collector.

The protocol converter acts as a M-Bus master and thus requires an external M-Bus master module as shown in 図 24. For the 3-node setup, Solvimus M-Bus Master module was used for the external M-Bus master module. The power supply module in the TIDM-1005 EVM is designed to provide sufficient power for the external M-Bus master to support more than 100 M-Bus slave nodes. In addition, the software example is not limited to support the maximum number of M-Bus slave nodes. Depending on the external M-Bus master module specification, further limitation can be applied on the number of M-Bus slave nodes to be supported.

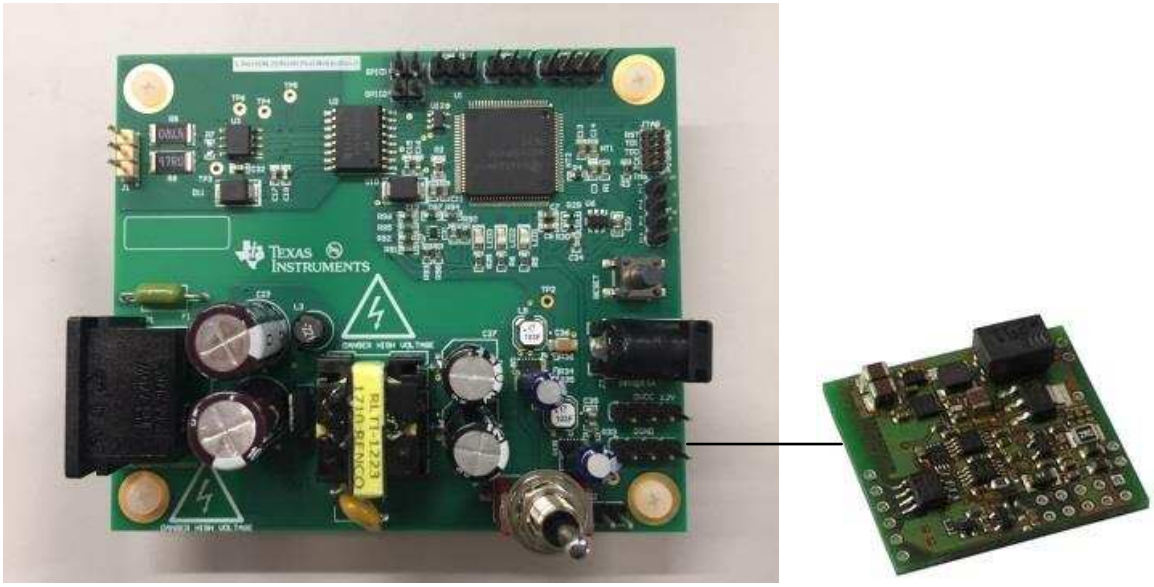




**図 24. TIDM-1005 Protocol Converter With External M-Bus Master Module (Protocol Converter)**

図 25 shows the details on pin connections between TIDM-1005 and the external M-Bus master module.

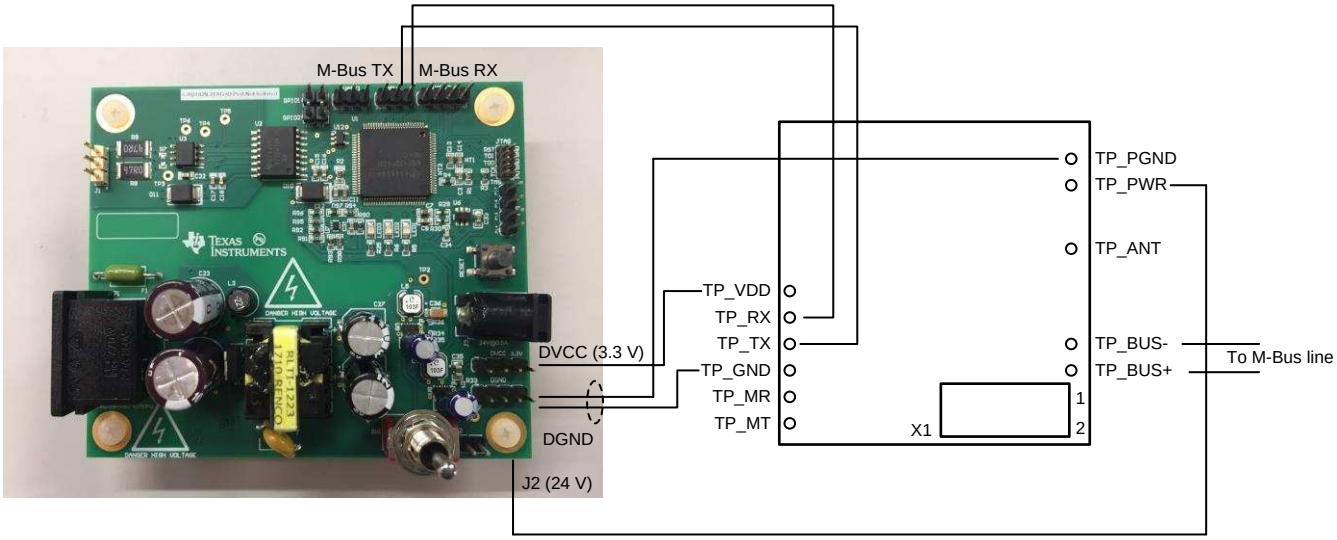



**図 25. Pin Connection Between TIDM-1005 and M-Bus Master Module**

The M-Bus slave node is built with TIDM-1005 board and M-Bus slave module.

図 26 shows the detailed pin connection between the TIDM-1005 and M-Bus slave module. 図 27 and 表 3 show the schematic and BOM for the M-Bus slave module.

**注:** The BOM and schematic for the M-Bus slave module are provided as a working example for the 3-node setup. For general setup for the M-Bus slave, refer to the *METER-BUS TRANSCEIVER* [7].

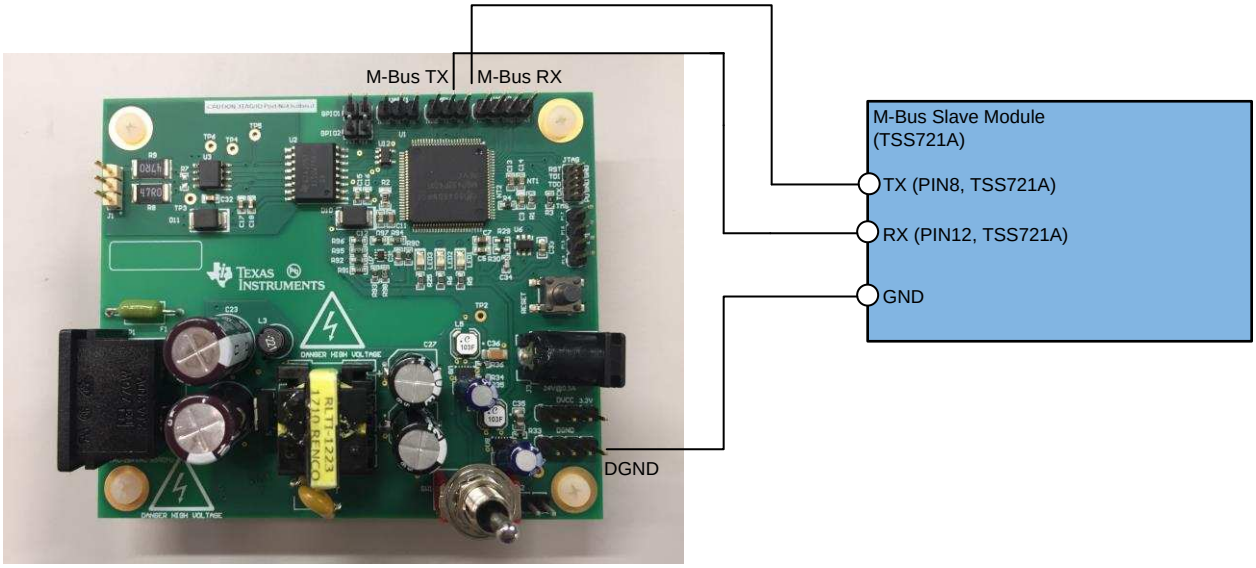





**図 26. Pin Connection Between TIDM-1005 and M-Bus Slave Module**

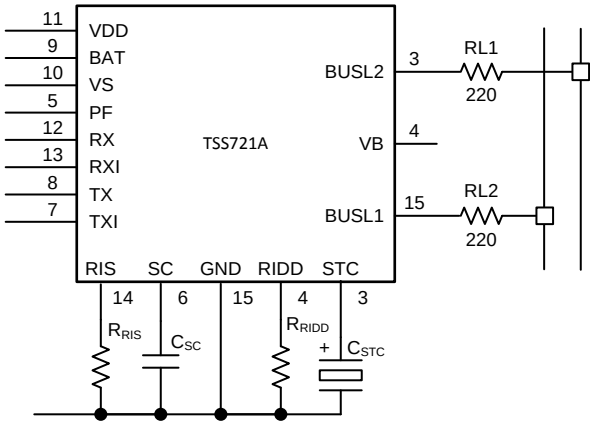





**図 27. M-Bus Slave Module with TSS721A**

**表 3. BOM of the M-Bus Slave Module**

| PART | VALUE | DIGIKEY PART NUMBER | QUANTITY |
|---|---|---|---|
| $C_{STC}$ | 47 uF | P10321-ND | 1 |
| $R_{RIS}$ | 100 | CF18JT100RCT-ND | 1 |
| $C_{SC}$ | 220 nF | 493-10257-1-ND | 1 |
| $R_{RIDD}$ | 30 K | CF14JT30K0CT-ND | 1 |

表 3. BOM of the M-Bus Slave Module (continued)

| PART | VALUE | DIGIKEY PART NUMBER | QUANTITY |
|---|---|---|---|
| RL1 | 220 | CF14JT220RCT-ND | 1 |
| RL2 | 220 | CF14JT220RCT-ND | 1 |

### 3.2.2 Software Functionality Testing

The delivery ratio is measured in the 3-node setup by counting the number of TX and RX measured at the RS-485 data collector. The TX is initiated by the data collector at the step one in 3.2.1. The RX is initiated by the M-Bus slave node at the step four in 3.2.1. To ensure the protocol converter to handle all the data sizes properly, the testing runs 4-cycle of a complete set of data size (1B to 255B). 表 4 summarizes the delivery ratio result.

表 4. Delivery Ratio Performance

| DELIVERY RATIO | NUMBER OF TX | NUMBER OF RX |
|---|---|---|
| 100% | 1065 | 1065 |

### 3.2.3 CISPR22 Class-B Conducted Emission

図 28 and 図 29 shows CISPR22 Class-B conducted emission test results. For the measurement, the TIDM-1005 EVM is powered by the internal AC-DC power supply to measure the impact of the AC-DC power supply on the conducted emission. The quasi-peak voltages on line and neutral were measured at 120 VAC and 60 Hz and 230 VAC and 50 Hz over the frequency range from 150 kHz to 30 MHz . The test results show that the TIDM-1005 passes the CISPR22 Class-B conducted emission.

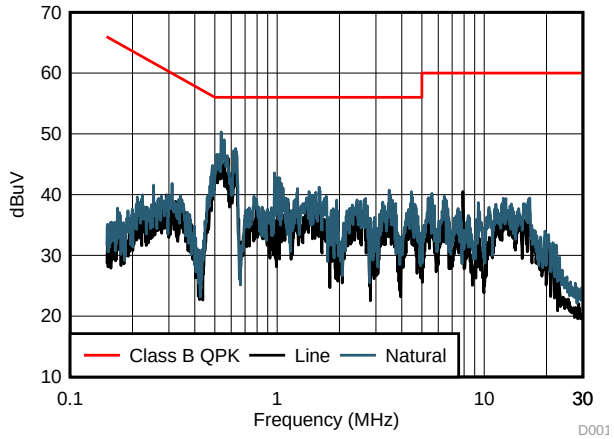



図 28. Quasi-peak Measurement With 120-V and 60-Hz Input

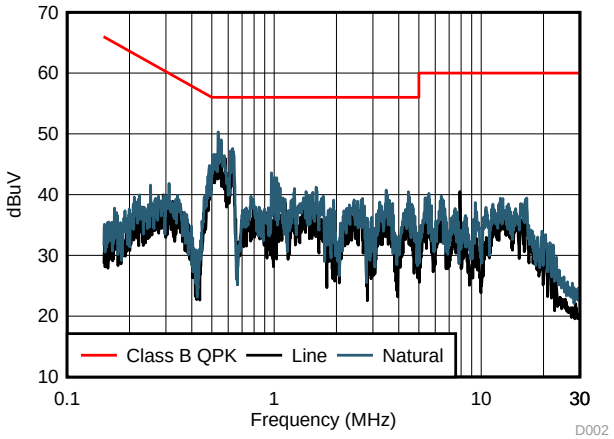



図 29. Quasi-peak Measurement With 230-VAC and 50-Hz Input

### 3.2.4 IEC61000-4-2 ESD Testing

図 30 and 図 31 shows the IEC61000-4-2 ESD testing setup. The IEC61000-4-2 ESD testing was performed in contact discharge from ±8 KV to ±12 KV while the TIDM-1005 EVM turns on. For the testing setup, the RS485_GND is connected to earth ground. The testing passes if the TIDM-1005 EVM is in operating condition after a series of voltage spikes. 表 5 summarizes the IEC61000-4-2 ESD test results.

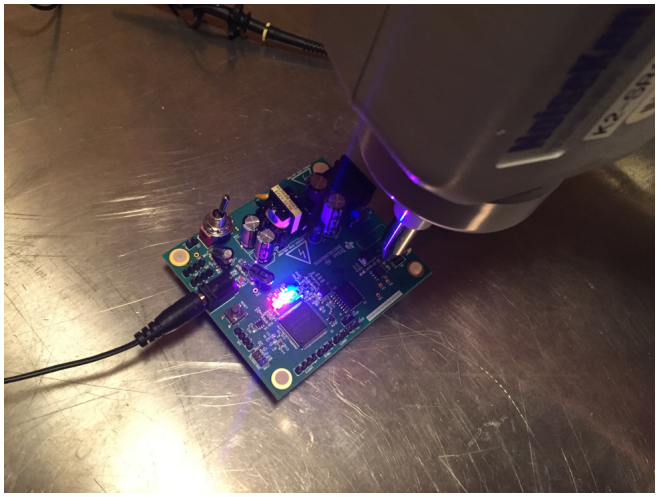


図 30. IEC61000-4-2 ESD Testing (Contact Discharge When TIDM-1005 Turns on)


図 31. IEC61000-4-2 ESD Testing Configuration (12 KV With Interval of 1-s Voltage Spike Over 10-s Period)

表 5. IEC61000-4-2 ESD Test Results

| TEST VOLTAGE IN KV | TEST RESULT |
|---|---|
| ±8 | Pass |
| ±10 | Pass |
| ±12 | Pass |

### 3.2.5 IEC61000-4-4 EFT Testing

図 32 shows IEC61000-4-4 EFT test setup. For the testing, two TIDM-1005 EVMs are connected at each end, and the burst voltage pulses are injected on the RS-485 line. Per IEC61000-4-4 EFT specification, three voltage repetition rates of 100 KHz (0.75-ms burst period), 20 KHz (3.75-ms burst period), and 5 KHz (15-ms burst period) are used. 表 6 summarizes the test results. Each set of testing runs 120 seconds to ensure sufficient number of TXs to measure the bit error rate (BER) performance. Each test passes if the BER performance is less than $10^{-7}$ . The TX generated continuous byte stream with a known pattern. The RX measured the total bytes of RX and the number of incorrect bytes to calculate the BER. 表 6 summarizes the test results.

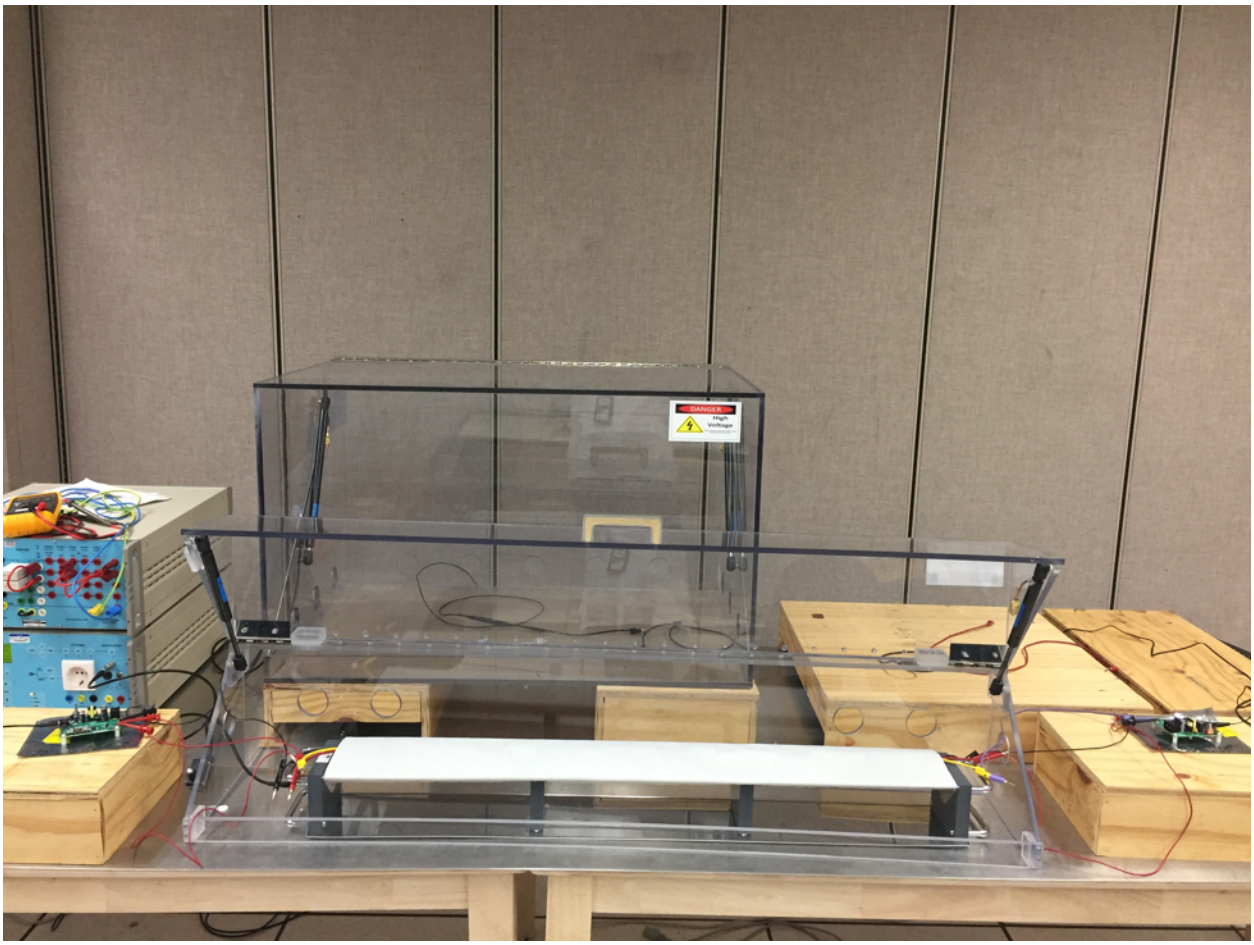



**図 32. IEC61000-4-4 EFT Testing Setup**

**表 6. IEC61000-4-4 EFT Test Results**

| VOLTAGE PEAK IN KV | REPETITION RATE IN KHz | BER PERFORMANCE (<$10^{-7}$ ) |
|---|---|---|
| ±2 | 100 | Pass |
| ±2 | 20 | Pass |
| ±2 | 5 | Pass |

# 4 Design Files

## 4.1 Schematics

To download the schematics, see the design files at TIDM-1005.

## 4.2 Bill of Materials

To download the bill of materials (BOM), see the design files at TIDM-1005.

## 4.3 PCB Layout Recommendations

### 4.3.1 Layout Prints

To download the layer plots, see the design files at TIDM-1005.

## 4.4 Altium Project

To download the Altium project files, see the design files at TIDM-1005.

## 4.5 Gerber Files

To download the Gerber files, see the design files at TIDM-1005.

## 4.6 Assembly Drawings

To download the assembly drawings, see the design files at TIDM-1005.

# 5 Software Files

To download the software files, see the design files at TIDM-1005.

# 6 Related Documentation


1. Texas Instruments, *MSP432P401R, MSP432P401M SimpleLink™ Mixed-Signal Microcontrollers* , Datasheet (SLAS826)
2. Texas Instruments, *THVD1500 300 kbps RS-485 Transceivers With 8-kV IEC ESD Protection* , Datasheet (SLLSEY4)
3. Texas Instruments, *ISOW784x High-Performance, 5000-VRMS Reinforced Quad-Channel Digital Isolators With Integrated High-Efficiency, Low-Emissions DC-DC Converter* , Datasheet (SLLSEY2)
4. Texas Instruments, *UCC2871x Constant-Voltage, Constant-Current Controller With Primary-Side Regulation* , Datasheet (SLUSB86)
5. Texas Instruments, *ISOW784x High-Performance, 5000-VRMS Reinforced Quad-Channel Digital Isolators With Integrated High-Efficiency, Low-Emissions DC-DC Converter* , Datasheet (SLLSEY2)
6. Texas Instruments, *TPS6217x 28-V, 0.5-A Step-Down Converter With Sleep Mode* , Datasheet (SLVSB35)
7. Texas Instruments, *METER-BUS TRANSCEIVER* , Datasheet (SLAS222)


## 6.1 商標

## 7 About the Author

**WONSOO KIM** is a system engineer at Texas Instruments, where he is responsible for driving Grid communication system solutions, defining future requirements in TI product roadmap, and providing system-level support and training focusing on communication systems for Smart Grid customers. He received the Ph.D. degree in Electrical and Computer Engineering from the University of Texas at Austin, Austin, Texas.

# リビジョンAの改訂履歴

資料番号末尾の英字は改訂を表しています。その改訂履歴は英語版に準じています。

**2017年6月発行のものから更新** **Page**

- タイトルを、「低コスト・アプリケーション用のM-BusおよびRS-485プロトコル変換機能付きデータ・コレクタのリファレンス・デザイン」から「M-BusおよびRS-485プロトコル変換機能付きデータ・コレクタのリファレンス・デザイン」に 変更 ..... 1
- 「リソース」でSN65HVD3082Eへのリンクを THVD1500へのリンクに 変更 ..... 1
- 「特長」で「*±2KV IEC61000-4-4 EFT*、*±12KV IEC61000-4-2 ESD*、および*CISPR22 Class-Bの伝導放射がテスト済み*」を「*±2KV IEC61000-4-4 EFT*、*±8KV IEC61000-4-2 ESD*、および*CISPR22 Class-Bの伝導放射がテスト済み*」に 変更 ..... 1
- 表紙のブロック図を 変更 ..... 1
- *±12 KV, contact discharge* to *±8 KV, contact discharge* in 表 1 変更 ..... 4
- instances of *SN65HVD3082E* to *THVD1500* 変更 ..... 4
- *(up to 200 kbps)* to *(up to 300 kbps)* 変更 ..... 4
- 図 3 変更 ..... 4
- *The SN65HVD3082E is a cost-optimized, half-duplex RS-485 transceiver with external protection circuitry to satisfy ±12-KV IEC61000-4-2 contact discharge and ±2-KV IEC61000-4-4 fast transient burst.* to *The THVD1500 is a robust half-duplex RS-485 transceiver with external protection circuitry to satisfy ±8-KV IEC61000-4-2 contact discharge and ±2-KV IEC61000-4-4 fast transient burst.* 変更 ..... 5
- title of 2.3.2 from *SN65HVD3082E* to *THVD1500* 変更 ..... 6
- *The SNx5HVD308xE devices are half-duplex transceivers designed for RS-485 data bus networks. Powered by a 5-V supply, the transceivers are fully compliant with TIA/EIA-485A standard. With controlled transition times, these devices are suitable for transmitting data over long twisted-pair cables. SN65HVD3082E and SN75HVD3082E devices are optimized for signaling rates up to 200 kbps. The SN65HVD3085E device is suitable for data transmission up to 1 Mbps, whereas the SN65HVD3088E device is suitable for applications that require signaling rates up to 20 Mbps.* 削除 ..... 6
- *The wide common-mode range and high ESD-protection levels of these devices makes them suitable for demanding applications, such as energy meter networks, electrical inverters, status and command signals across telecom racks, cabled chassis interconnects, and industrial automation networks where noise tolerance is essential. These devices match the industry-standard footprint of the SN75176 device. Power-on-reset circuits keep the outputs in a high-impedance state until the supply voltage has stabilized. A thermal-shutdown function protects the device from damage due to system fault conditions. The SN75HVD3082E is characterized for operation from 0°C to 70°C and SN65HVD308xE are characterized for operation from –40°C to 85°C air temperature. The D package version of the SN65HVD3082E has been characterized for operation from –40°C to 105°C.* 削除 ..... 6
- *THVD1500 is a robust half-duplex RS-485 transceiver for industrial applications. The bus pins are immune to high levels of IEC Contact Discharge ESD events eliminating need of additional system level protection components. The device operates from a singl 5-V supply. The wide common-mode voltage range and low input leakage on bus pins make THVD1500 suitable for multi-point applications over long cable runs. THVD1500 is available in industry standard 8-pin SOIC package for drop-in compatibility. The device is characterized from -40°C to 125°C.* 追加 ..... 6
- reference 2 from *SNx5HVD308xE Low-Power RS-485 Transceivers, Available in a Small MSOP-8 Package* (SLLS562) to *THVD1500 300 kbps RS-485 Transceivers With 8-kV IEC ESD Protection* (SLLSEY4) 変更 ..... 27

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お客様は、自らのアプリケーションの設計において、ご自身が独自に分析、評価、判断を行う責任がお客様にあり、お客様のアプリケーション(および、お客様のアプリケーションに使用されるすべてのTI製品)の安全性、および該当するすべての規制、法、その他適用される要件への遵守を保証するすべての責任をお客様のみが負うことを理解し、合意するものとします。お客様は、自身のアプリケーションに関して、(1) 故障による危険な結果を予測し、(2) 障害とその結果を監視し、および、(3) 損害を引き起こす障害の可能性を減らし、適切な対策を行う目的での、安全策を開発し実装するために必要な、すべての技術を保持していることを表明するものとします。お客様は、TI製品を含むアプリケーションを使用または配布する前に、それらのアプリケーション、およびアプリケーションに使用されているTI製品の機能性を完全にテストすることに合意するものとします。TIは、特定のTIリソース用に発行されたドキュメントで明示的に記載されているもの以外のテストを実行していません。

お客様は、個別のTIリソースにつき、当該TIリソースに記載されているTI製品を含むアプリケーションの開発に関連する目的でのみ、使用、コピー、変更することが許可されています。明示的または黙示的を問わず、禁反言の法理その他どのような理由でも、他のTIの知的所有権に対するその他のライセンスは付与されません。また、TIまたは他のいかなる第三者のテクノロジまたは知的所有権についても、いかなるライセンスも付与されるものではありません。付与されないものには、TI製品またはサービスが使用される組み合わせ、機械、プロセスに関連する特許権、著作権、回路配置利用権、その他の知的所有権が含まれますが、これらに限られません。第三者の製品やサービスに関する、またはそれらを参照する情報は、そのような製品またはサービスを利用するライセンスを構成するものではなく、それらに対する保証または推奨を意味するものでもありません。TIリソースを使用するため、第三者の特許または他の知的所有権に基づく第三者からのライセンス、あるいはTIの特許または他の知的所有権に基づくTIからのライセンスが必要な場合があります。

TIのリソースは、それに含まれるあらゆる欠陥も含めて、「現状のまま」提供されます。TIは、TIリソースまたはその仕様に関して、明示的か暗黙的かにかかわらず、他のいかなる保証または表明も行いません。これには、正確性または完全性、権原、続発性の障害に関する保証、および商品性、特定目的への適合性、第三者の知的所有権の非侵害に対する黙示の保証が含まれますが、これらに限られません。

TIは、いかなる苦情に対しても、お客様への弁護または補償を行う義務はなく、行わないものとします。これには、任意の製品の組み合わせに関連する、またはそれらに基づく侵害の請求も含まれますが、これらに限られず、またその事実についてTIリソースまたは他の場所に記載されているか否かを問わないものとします。いかなる場合も、TIリソースまたはその使用に関連して、またはそれらにより発生した、実際的、直接的、特別、付随的、間接的、懲罰的、偶発的、または、結果的な損害について、そのような損害の可能性についてTIが知らされていたかどうかにかかわらず、TIは責任を負わないものとします。

お客様は、この注意事項の条件および条項に従わなかったために発生した、いかなる損害、コスト、損失、責任からも、TIおよびその代表者を完全に免責するものとします。

この注意事項はTIリソースに適用されます。特定の種類の資料、TI製品、およびサービスの使用および購入については、追加条項が適用されます。これには、半導体製品(http://www.ti.com/sc/docs/stdterms.htm)、評価モジュール、およびサンプル(http://www.ti.com/sc/docs/sampterms.htm)についてのTIの標準条項が含まれますが、これらに限られません。