Design Guide: TIDA-010963

Digital Addressable Lighting Interface 103 Reference Design Based on MSPM0

Description

This reference design implements a Digital Addressable Lighting Interface (DALI) 103 utilizing the MSPM0 MCU, which meets compliant hardware and software requirements for IEC 62386-103. The design features a customizable DALI transceiver, power supply, isolation, and firmware that enables seamless communication for advanced lighting control.

Resources

TIDA-010963	Design Folder
MSPM0L1306	Product Folder
MSPM0G3507	Product Folder

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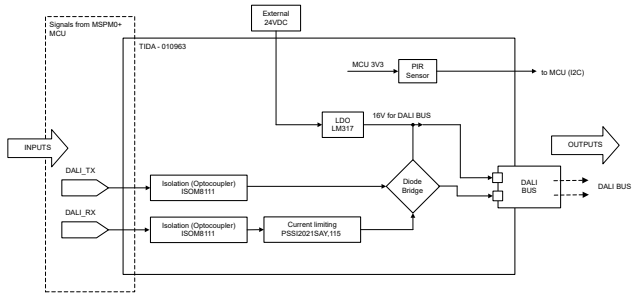
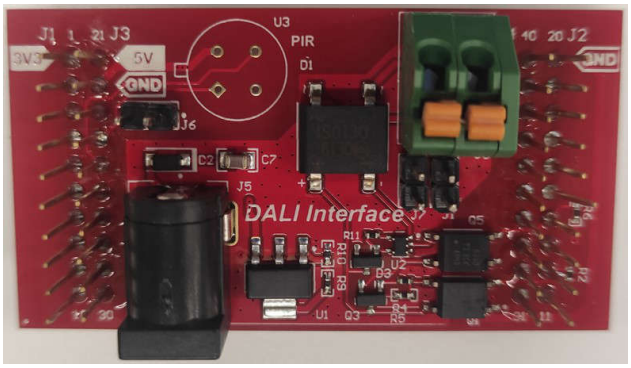
Features

- Full hardware interface implementation and onboard power supply to support 16V_{DC} on the DALI bus
- Functions to receive and transmit DALI commands and responses respectively:
  - Half-duplex digital communication using *Manchester Encoding*
  - Support for *DALI 103 commands*
- Support for multi-controller topology (collision detection, collision avoidance, and collision recovery)

Applications

- Daylight sensor
- Exit and emergency lighting
- Lighting sensor
- Wired control





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1 System Description

The DALI bus carries DALI power and data on the same pair of wires. Each DALI subnet can have 64 control gears and 64 control devices. Control gears provide power to LEDs and other light sources. Control devices include application controllers (which make decisions and send commands), and input devices such as sensors, switches, and push-button devices. A bus power supply is required, providing up to 250mA and typically 16V to the DALI bus. A gateway to an external network is often integrated into an application controller.

1.1 Input Devices (DALI 103)

Input devices are relatively simple components that provide user-derived and environmental information to the lighting control system. Input devices include sensors that provide data for automated control, and interfaces enabling users to make adjustments, such as dimming, color, and scene recall. Examples of input devices include push-buttons, sliders, occupancy sensors, and light sensors.

Input devices typically operate in a multi-controller mode. The devices can be polled, but are typically used in an event-driven mode. This system utilizes a Passive Infrared (PIR) sensor as one type of input device.

1.2 Control Gear (DALI 102)

Control gear, such as LED drivers, provide power to light sources and are normally directly connected to the lamp.

The DALI protocol supports various types of control gear, including ballasts for fluorescent lamps and control devices for self-contained emergency lighting.

In DALI-2, each DALI subnet is capable of supporting up to 64 control gears and 64 control devices.

1.3 Control Devices (Application Controllers)

Application controllers serve as the central logic unit of a DALI-2 system. The controllers utilize information, make decisions, and send commands to the control gear.

Application controllers can use information from any source, including:

- Control gear
- Input devices (for example, sensors or buttons)
- Other application controllers
- External devices, buses, and systems

This reference design uses the MSPM0 microcontroller unit (MCU) as the application MCU of the system.

1.4 Introduction

The DALI protocol is a half-duplex digital communication composed of forward and backward frames. Forward frames consist of one start bit, one address byte, one data byte, and two stop bits. The backward frame (the response after reception of a query or memory command in the forward frame) consists of one start bit, one data byte, and two stop bits. DALI uses Manchester encoding, and the voltage of the interface power supply can vary from 11.5V to 22.5V per the standard.

DALI enables the easy installation of robust, scalable, and flexible lighting networks. DALI originated to enable digital control, configuration, and querying of fluorescent ballasts, replacing the simple, one-way, broadcast-like operation of *0/1–10V* analog control.

With DALI, the broadcast option is also available; in addition, with simple configuration, each DALI device can be assigned a separate address, allowing *digital control of individual devices*.

Furthermore, the DALI devices can also be programmed to *operate in groups*. This provides excellent flexibility since the lighting systems can be *reconfigured* by software reprogramming, without the need to change the wiring. Different lighting functions and moods can be achieved in different rooms or areas of a building, and then *easily adjusted and optimized*.

Wiring is relatively simple; DALI power and data is carried by the same pair of wires, without the need for a separate bus cable. The polarity of the wires does not have to be observed, in contrast with *0/1–10V* systems where wiring errors are common.

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The system is comprised of Control Devices (application controller), Control Gears, and Input Devices:

- Device Control Instructions
- Device Configuration Instructions
- Device Queries
- Instance Control Instructions
- Special Commands

Table 1-1 shows details of single-controller or multi-controller variants.

Table 1-1. Single- and Multi-controllers

SINGLE-CONTROLLERS	MULTI-CONTROLLERS
Only one allowed on the DALI bus	More than one can be used on the same bus
Receiver is optional	Supports event-driven operation of input devices
Can allow polling of input devices, or checking status of control gear	Uses a short address

2 System Overview

2.1 Block Diagram

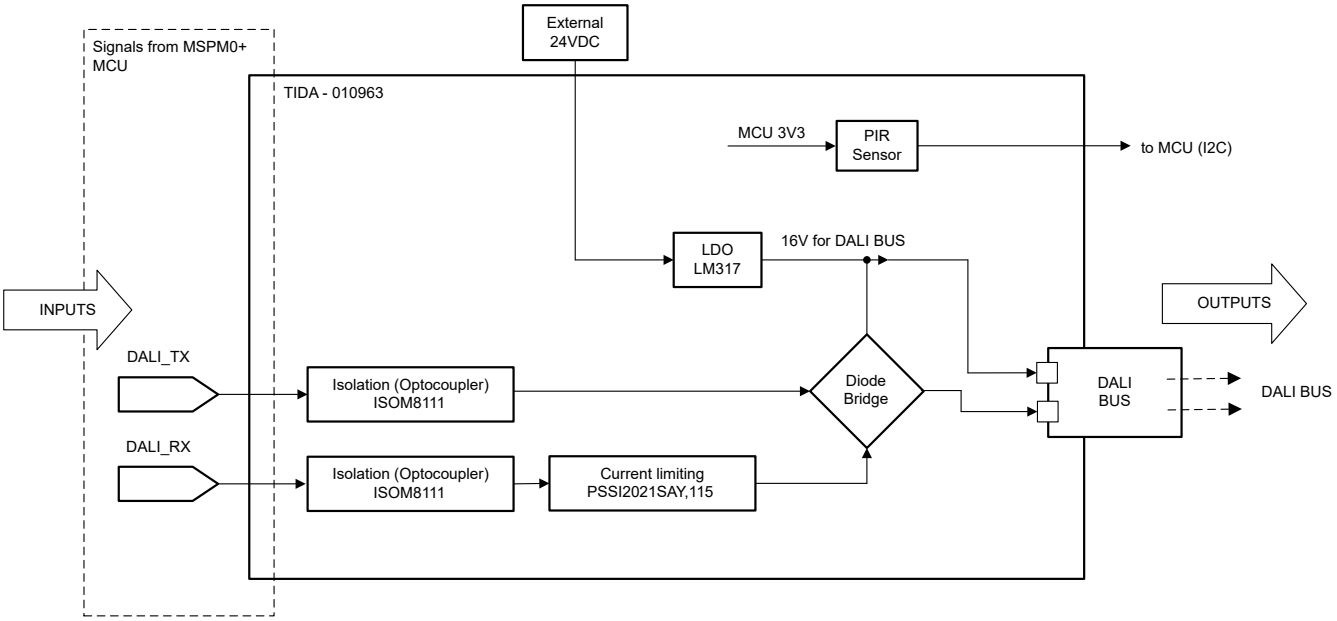

Figure 2-1. DALI Block Diagram

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2.2 Design Considerations

2.2.1 Manchester Encoding

Manchester encoding is a method of data transmission employed in computer networks and telecommunications. Data transmission is facilitated by combining clock and data signals into one stream, thereby simplifying synchronization of the data.

Each bit of data is represented by a transition - specifically, a change from high to low or low to high in the signal. Synchronization of the data is made possible through this precise representation. As a result, receiving devices can accurately interpret the transmitted data.

Widely used in Ethernet technology and other digital communication systems, Manchester encoding offers reliability and simplicity in data transmission.

Manchester encoding divides the duration of each bit into two distinct halves. In the first half, the voltage remains constant at one level, while in the second half, the voltage transitions to the other level.

This approach enables synchronization through a transition point midway through the bit. Differential Manchester is an adaptation that combines elements from Return-to-Zero (RZ) and Non-Return-to-Zero-Inverted (NRZ-I) encoding schemes.

A defining characteristic of Manchester encoding is that there is always a transition in the middle of each bit, resulting from this voltage change across two levels. The value of each bit is determined at the outset, with transitions occurring only for bits with values of zero. Conversely, bits with values of one exhibit no transition.

Note

Manchester Encoding facilitates robust signal synchronization, making the technology an attractive choice for data transmission applications.

2.2.2 Using Opto-Emulators Instead of Optocouplers

Using TI's SiO^2-based isolation technology empowers opto-emulators to break through the limitations of traditional optocouplers, delivering outstanding performance and reliability.

Opto-emulators provide several key benefits, including the following:

1. Lower power consumption
2. Fast data rates
3. Improved Common Mode Transient Immunity (CMTI)
4. Wide temperature range
5. Robust isolation
6. Stable and tight Current Transfer Ratio (CTR)
7. Bandwidth

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2.3 Highlighted Products

2.3.1 MSPM0G350x

MSPM0G350x microcontrollers (MCUs) are part of the MSP highly integrated, ultra-low-power, 32-bit MCU family based on the enhanced Arm® Cortex®-M0+ 32-bit core platform operating at up to 80MHz frequency. These cost-optimized MCUs offer high-performance analog peripheral integration, support extended temperature ranges from –40°C to 125°C, and operate with supply voltages ranging from 1.62V to 3.6V. The MSPM0G350x devices provide up to 128KB embedded flash program memory with built-in error correction code (ECC) and up to 32KB SRAM with hardware parity option. These MCUs also incorporate a memory protection unit, 7-channel DMA, math accelerator, and a variety of high-performance analog peripherals such as two 12-bit 4Msps ADCs, configurable internal shared voltage reference, one 12-bit 1Msps DAC, three high-speed comparators with built-in reference DACs, two zero-drift zero-crossover op amps with programmable gain, and one general-purpose amplifier. These devices also offer intelligent digital peripherals such as two 16-bit advanced control timers, five general-purpose timers (with one 16-bit general-purpose timer for Quadrature Encoder Interface (QEI), two 16-bit general-purpose timers for STANDBY mode, and one 32-bit general-purpose timer), two windowed-watchdog timers, and one RTC with alarm and calendar modes.

These devices provide data integrity and encryption peripherals (AES, CRC, TRNG) and enhanced communication interfaces (four UART, two I2C, two SPI, CAN 2.0/FD). The TI MSPM0 family of low-power MCUs consists of devices with varying degrees of analog and digital integration allowing customers to find the MCU that meets the needs of the project. The MSPM0 MCU platform combines the Arm Cortex-M0+ platform with a holistic ultra-low-power system architecture, allowing system designers to increase performance while reducing energy consumption. MSPM0G350x MCUs are supported by an extensive hardware and software ecosystem with reference designs and code examples to get the design started quickly.

Tools include a *LaunchPad™* development kit available for purchase. TI also provides a free MSP Software Development Kit (SDK), which is available as a component of *Code Composer Studio™ IDE* desktop and cloud version within the *TI Resource Explorer*. MSPM0 MCUs are also supported by extensive online collateral, training with *MSP Academy*, and online support through the *TI E2E™ design support forums*. For complete module descriptions, see the *MSPM0 G-Series 80MHz Microcontrollers* technical reference manual.

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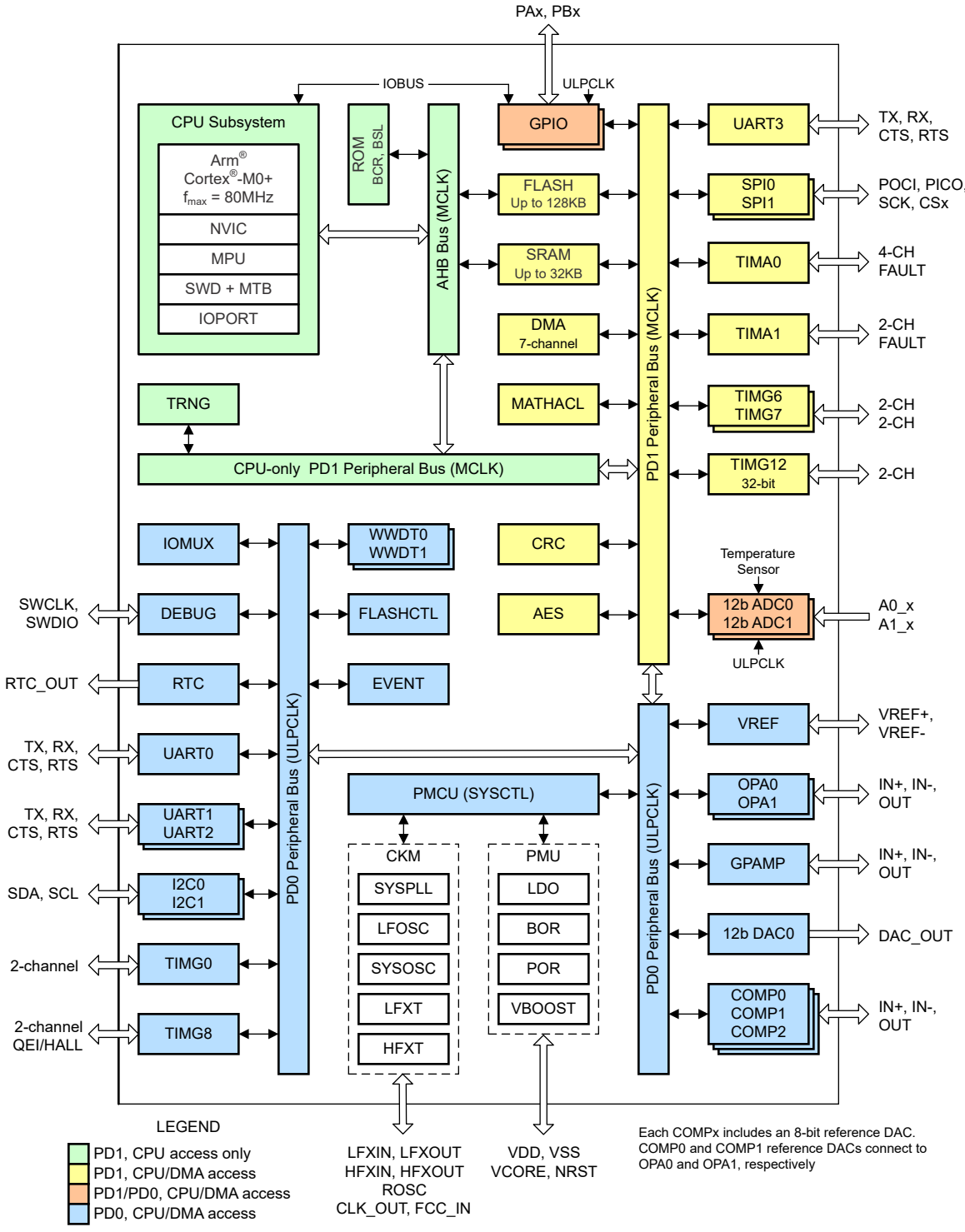

Figure 2-2. MSPM0G350x Functional Block Diagram

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2.3.2 ISOM8111

The ISOM811x devices are single-channel optocoupler-emulators with LED-emulator input and transistor output. The devices are footprint compatible and pin-to-pin upgrades for many traditional optocouplers, allowing enhancement to existing systems with no PCB redesign. ISOM811x opto-emulators offer significant reliability and performance advantages compared to optocouplers, including high bandwidth, low turn-off delay, low power consumption, wider temperature ranges, flat CTR, and tight process controls resulting in small part-to-part skew. Since there is no aging effect or temperature variation to compensate for, the emulated LED input stage consumes less power than optocouplers. ISOM811x devices are offered in small SOIC-4 packages with 2.54mm and 1.27mm pin pitches, supporting 3750V_{RMS} and 5000V_{RMS} isolation ratings with DC (ISOM811[0-3]) and bidirectional DC (ISOM811[5-8]) input options. The high performance and reliability of ISOM811x enables these devices to be used in power supply feedback design, motor drives, I/O modules in industrial controllers, factory automation applications, and more.

2.3.2.1 ISOM8111 Features

- Footprint compatible, pin-to-pin upgrade to industry-standard phototransistor optocouplers
- 1-channel LED-emulator input
- Current transfer ratio (CTR) at IF = 5mA, VCE = 5V:
  - ISOM8110, ISOM8115: 100% to 155%
  - ISOM8111, ISOM8116: 150% to 230%
  - ISOM8112, ISOM8117: 255% to 380%
  - ISOM8113, ISOM8118: 375% to 560%
- High collector-emitter voltage: VCE (maximum) = 80V
- Robust SiO2 isolation barrier – Isolation rating: Up to 5000V_{RMS}
  - Working voltage: Up to 750V_{RMS} , 1061V_{PK}
  - Surge capability: Up to 10kV_{PK}
- Temperature range: –55°C to 125°C
- Response time: 3µs (typical) at V_{CE} = 10V, IC = 2mA, RL = 100Ω

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3 Hardware, Software, Testing Requirements, and Test Results

3.1 Hardware Requirements

To evaluate DALI 103 (303) communication, the following hardware components are required:

1. 2 × LP-MSPM0G3507 evaluation boards
2. 2 × DALI HW interface (TIDA-010963)
3. 24V DC power supply with barrel jack connector

Figure 3-1 depicts a comprehensive system diagram, illustrating the connections between two LaunchPads. The LaunchPad on the left serves as the Device Under Test (DUT), featuring a PIR sensor and external 24VDC supply enabled using the J1, J6, and J7 jumpers. On the right side, a separate LaunchPad is employed to transmit commands to the DUT during run time, facilitating a precise testing procedure.

This setup is designed to validate that the DUT accurately receives and responds to commands from the DALI bus.

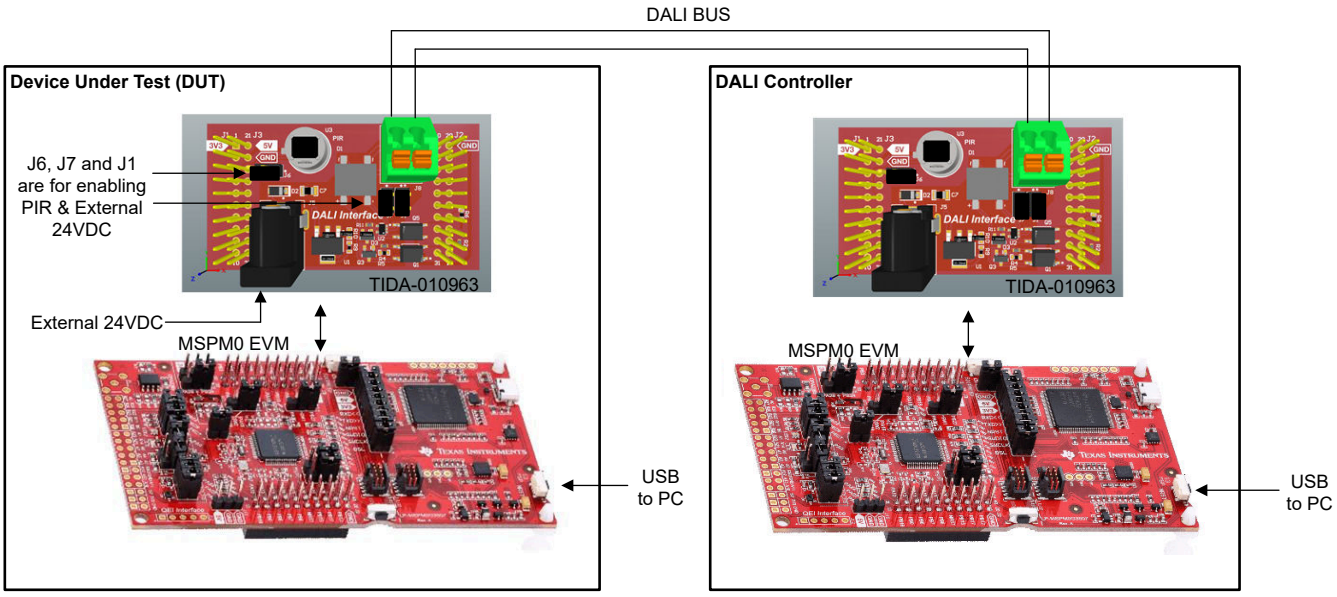

Figure 3-1. Connections Between Two LaunchPad™ Development Kits

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3.2 Software Requirements

3.2.1 DALI Stack Layer

This section includes the DALI stack software, Figure 3-2 shows the DALI stack layer.

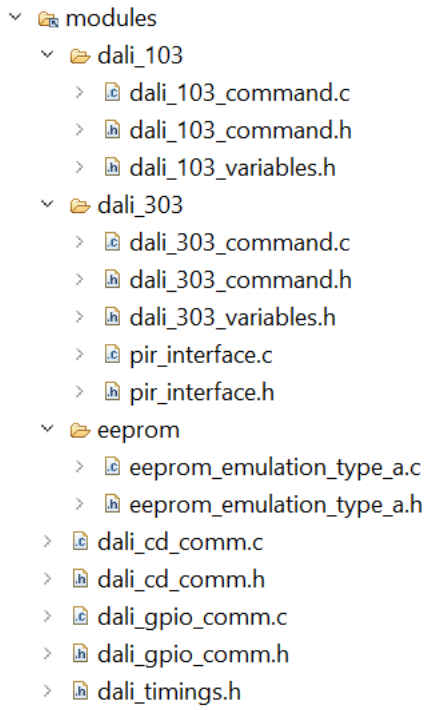

Figure 3-2. DALI Stack Layer

The following list provides a detailed explanation of the structure along with the functions implemented.

1. **dali_103**
   - dali_103_command (.h and .c files)
     - Contains the declarations and definitions for the DALI Commands specified in the standard IEC 62386-103: General Requirements for Control Device.
   - dali_103_variables.h
     - defines the structures, enumerations, and macros for control device variables as given in the DALI 103 spec.
2. **dali_303**
   - dali_303_command (.h and .c files)
     - Contains the declarations and definitions for DALI 303 Commands specified in the standard IEC 62386-303: Particular Requirements – Input Devices – Occupancy Sensor
   - dali_303_variables.h
     - defines the structures, enumerations, and macros for Part 303 input device variables as given in the DALI 303 spec.
   - pir_interface (.h and .c files)
     - Contains declarations and definitions for configuring the PIR sensor and interpreting the digital output.
3. **dali_cd_comm (.h and .c files)**
   - Contains the declarations and definitions for DALI Software module initialization and command handling.
4. **dali_gpio_comm (.h and .c files)**
   - Contains the declarations and definitions for configuring the Timer for receiving and transmitting Manchester encoded frame through DALI RX and TX respectively.

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5. **dali_main.c**
   - Contains the DALI Software stack main function loop.
6. **dali_timings.h**
   - defines macros for timing-related parameters as given in the spec.
7. **eeprom_emulation_type_a (.h and .c files)**
   - Existing design in MSPM0 SDK is integrated for storing certain DALI variables in flash.
   - Type B design can also be used if the user needs to store small variable data.
   - For additional information, see also the *EEPROM emulation Type A Design* application note.

3.3 Test Setup

The DALI BoosterPack™ Plug-in Module is tested by connecting two MSPM03507 LaunchPad development kits, each with a DALI BoosterPack, over a DALI bus.

One MSPM0G3507 is programmed with DALI 103 code and functions as a controller. MSPM0G3507 sends 24-bit DALI command frames manually during run time to simulate control operations. Another MSPM0G307 acts as the DUT and is programmed with DALI 103 with support for DALI 303 functionality. MSPM0G3507 receives and processes DALI commands, responds according to the DALI 103 protocol, and uses the PIR sensor on the BoosterPack to detect motion and send event messages, as specified in DALI 303.

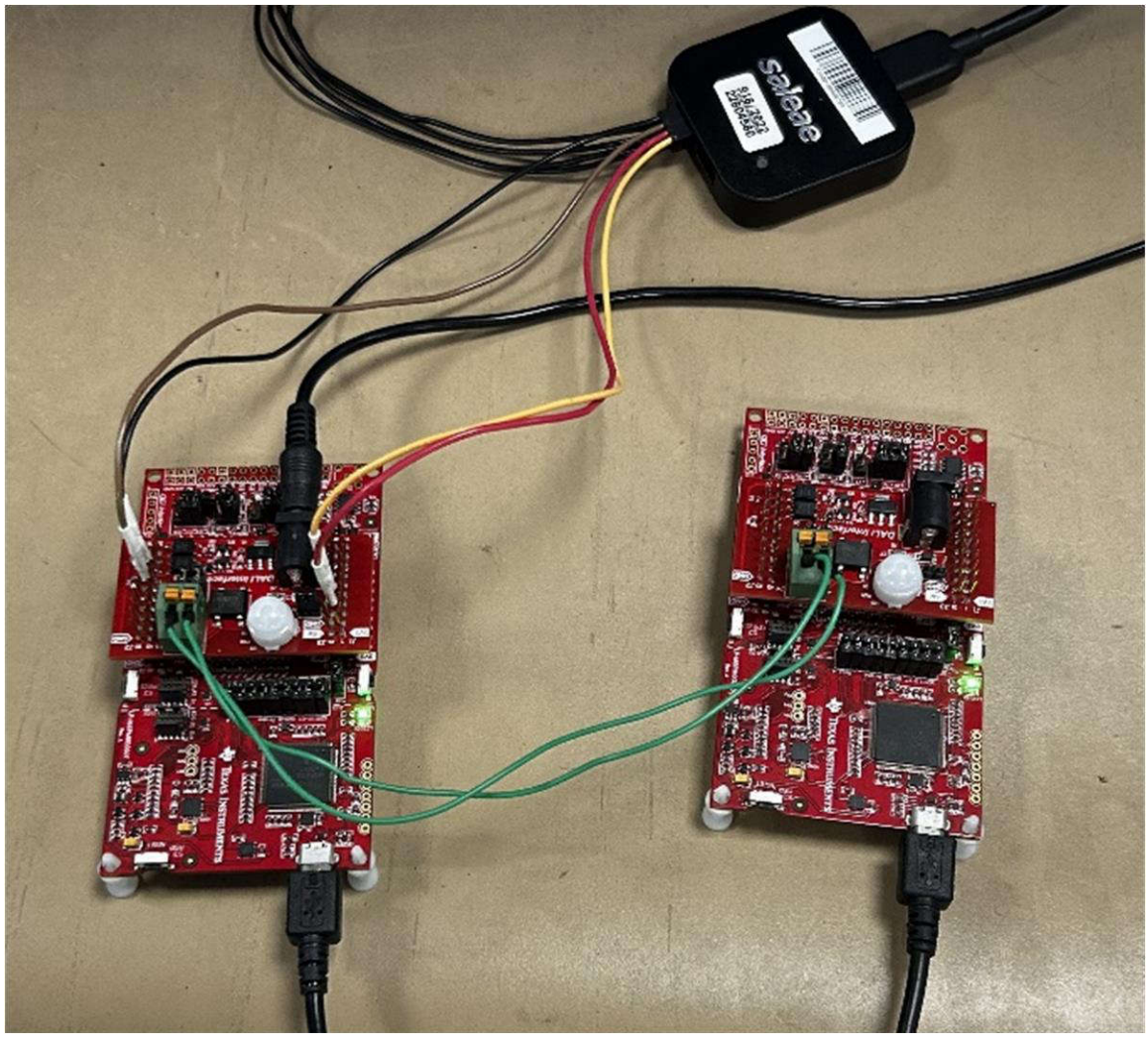

Figure 3-3. Hardware Setup

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3.3.1 Configuring the PIR

The PIR sensor is configured through the firmware by setting the configuration register.

Table 3-1. Configuration Register Settings

BIT NUMBER	DESCRIPTION	SIZE [BIT]	REMARKS
[24:17]	Threshold	8	Detection threshold on BPF value
[16:13]	Blind Time	4	= 0.5s + [Reg Val] × 0.5s
[12:11]	Pulse Counter	2	= 1 + [Reg Val]
[10:9]	Window Time	2	= 2s + [Reg Val] × 2s
[8:7]	Operation Modes	2	0: Forced Readout 1: Interrupt Readout 2: Wake Up 3: Reserved
[6:5]	Signal Source	2	0: PIR (BPF) 1: PIR (LPF) 2: Reserved 3: Temperature Sensor
[4:3]	Reserved	2	Reserved: Must be set to dec 2
[2]	HPF Cutoff	1	0: 0.4Hz 1: 0.2Hz
[1]	Reserved	1	Reserved: Must be set to dec 0
[0]	Count Mode	1	Count with (0) or without (1) BPF sign change

The waveform in Figure 3-4 shows the signal sent from MSPM0G3507 to the PIR sensor during the configuration phase.

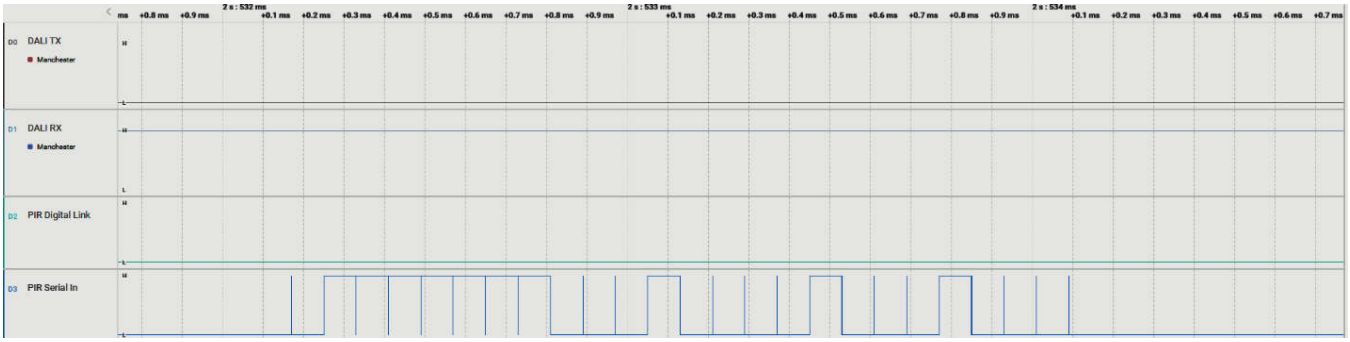

Figure 3-4. PIR Configuration Signal

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3.4 Test Results

3.4.1 Event Message When PIR Detects a Motion

Figure 3-5 shows how the DUT initiates an event message in response to motion detected by the PIR sensor. Upon detecting motion, the PIR Digital Link sends an immediate signal, and subsequently, the DUT transmits a DALI event message on the DALI TX line.

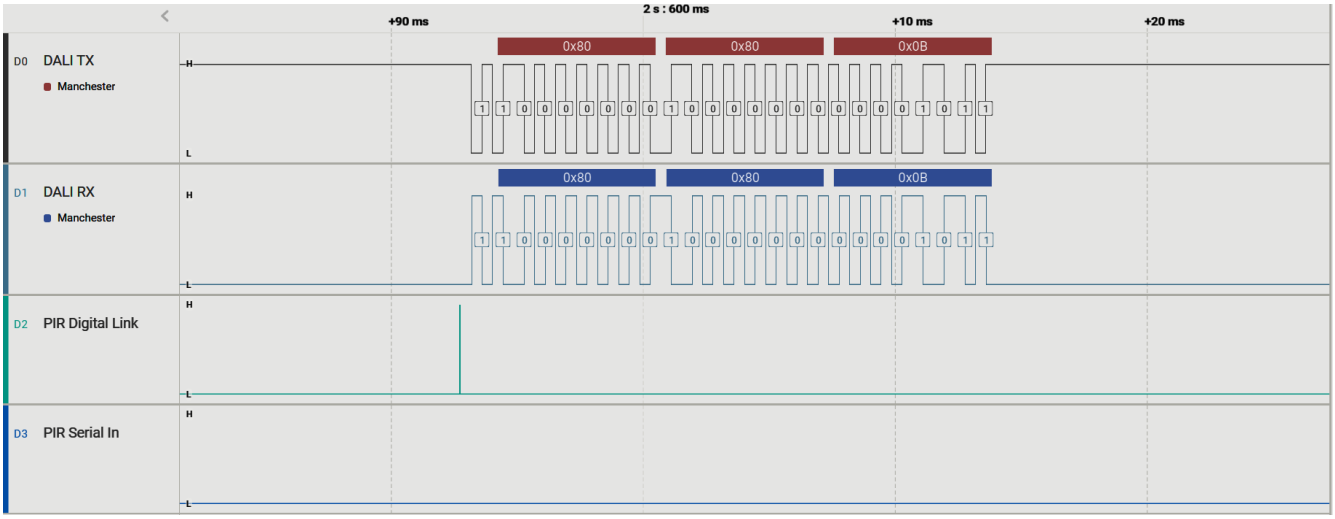

Figure 3-5. Event Message

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3.4.2 Event Message Generation Through Report Timer

The controller initiates the process of setting a report timer on the DUT by sending a DALI 303 command. First, the controller configures the DTR0 register with the desired period for the report timer. Next, the controller sends the enable report timer command to the DUT, using the value from DTR0 as the period. As a result, the DUT periodically sends event messages, independent of any motion detected by the PIR sensor.

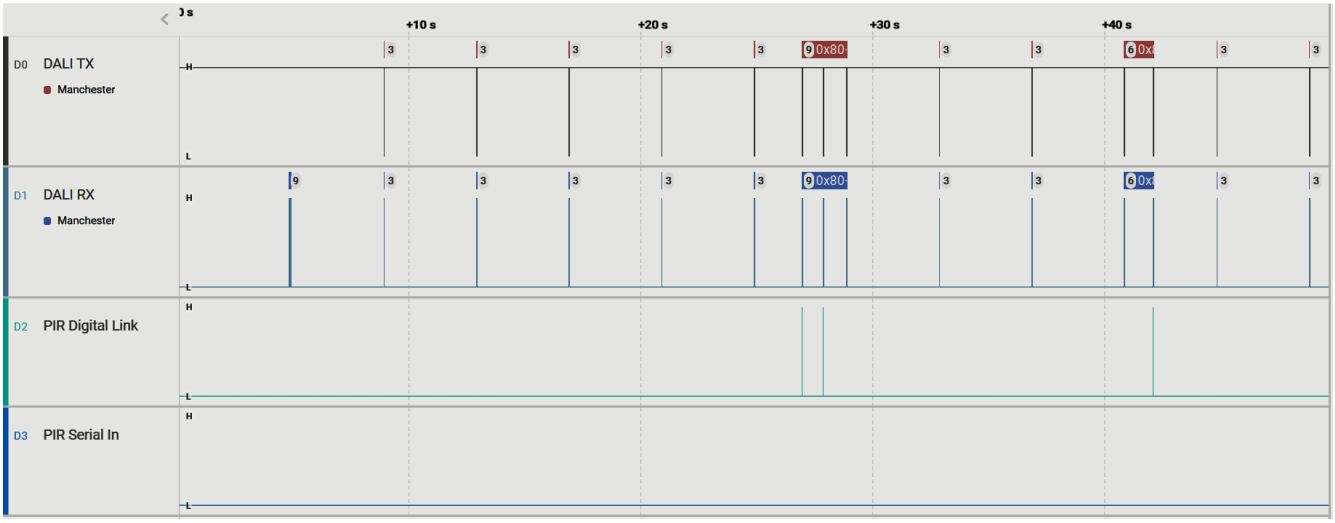

Figure 3-6. DALI 303 Command

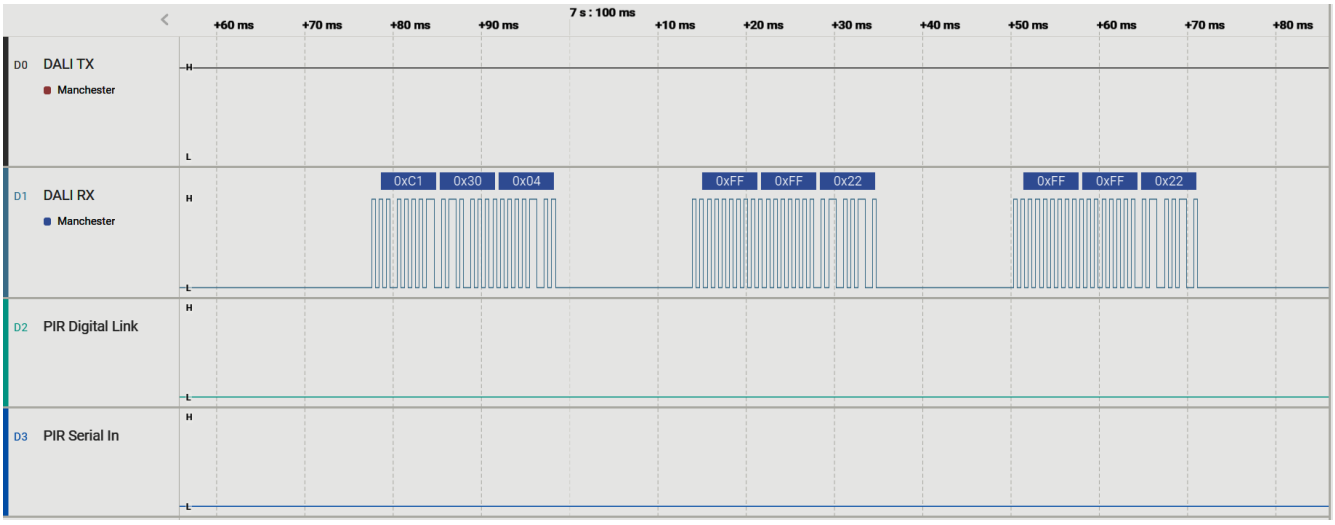

Figure 3-7. Commands From Controller

The controller sets the DTR0 register value to 4 by sending a specific command. Next, the controller transmits the Set Report Timer command ('Send-Twice' Command), which configures the Report Timer period using the DTR0 value and activates the report timer.

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4 Design and Documentation Support

4.1 Design Files

4.1.1 Schematics

To download the schematics, see the design files at TIDA-010963.

4.1.2 BOM

To download the bill of materials (BOM), see the design files at TIDA-010963.

4.1.3 PCB Layout Recommendations

4.1.3.1 Layout Prints

To download the layer plots, see the design files at TIDA-010963.

4.2 Tools and Software

Tools

MSPM0-SDK	The MSPM0 SDK provides the ultimate collection of software, tools and documentation to accelerate the development of applications for the MSPM0 MCU platform under a single software package.
SYSCONFIG	SysConfig is a configuration tool designed to simplify hardware and software configuration challenges to accelerate software development.
CCS-STUDIO	Code Composer Studio is an integrated development environment (IDE) for TI's microcontrollers and processors. Code Composer Studio comprises a suite of tools used to develop and debug embedded applications. Code Composer Studio is available for download across Windows®, Linux®, and macOS® desktops. Code Composer Studio can also be used in the cloud by visiting the TI Developer Zone.

4.3 Documentation Support

1. Texas Instruments, *LMR436x0-Q1, 36V, 1A / 2A, Automotive Buck Converter With < 2.5µA I_Q at 150°C T_{JMAX} in 4mm^2 HotRod™ QFN Data Sheet*
2. Texas Instruments, *TPS62850x-Q1 2.7V to 6V, 1A / 2A / 3A Automotive Step-Down Converter in SOT583 Package Data Sheet*
3. Texas Instruments, *TLIN1021A-Q1 Fault-Protected LIN Transceiver with Inhibit and Wake Data Sheet*
4. Texas Instruments, *AWRL1432 Single-Chip 76- to 81GHz Automotive Radar Sensor Data Sheet*
5. Texas Instruments, *E2E on Opto-Emulators*
6. GeeksforGeeks, *Manchester Encoding*

4.4 Support Resources

TI E2E™ support forums are an engineer's go-to source for fast, verified answers and design help — straight from the experts. Search existing answers or ask your own question to get the quick design help you need.

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