

# Subsystem Design

## CAN to I2C Bridge



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### Design Description

This subsystem demonstrates how to build a CAN-I2C bridge. CAN-I2C bridge allows a device to send/receive information on one interface and receive/send the information on the other interface [Download the code for this example](#). Two example codes are provided to support I2C to work in controller mode or target mode respectively.

Figure 1-1 shows a functional diagram of this subsystem. Please note that one line is added for IO interrupt to implement message transmission from I2C target to I2C controller.

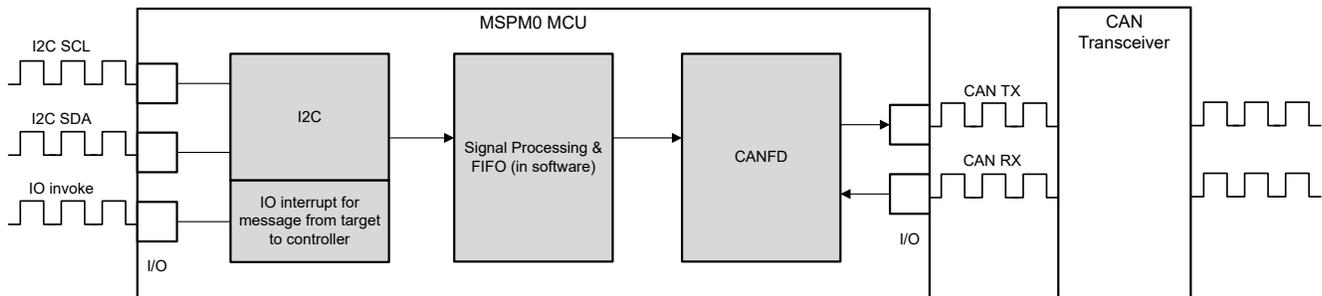


Figure 1-1. Subsystem Functional Block Diagram

### Required Peripherals

This application requires CANFD and I2C.

Table 1-1. Required Peripherals

Sub-block Functionality	Peripheral Use	Notes
CAN interface	(1x) CANFD	Called <i>MCAN0_INST</i> in code
I2C interface	(1x) I2C	Called <i>I2C_INST</i> in code

### Compatible Devices

Based on the requirements in Table 1-1, this example is compatible with the devices in Table 1-2. The corresponding EVM can be used for prototyping.

Table 1-2. Compatible Devices

Compatible Devices	EVM
MSPM0G35xx	LP-MSPM0G3507

### Design Steps

1. Determine the basic setting of CAN interface, including CAN mode, bit timing, message RAM configuration and so on. Consider which setting is fixed and which setting is changed in the application. In example code, CANFD is used with 250kbit/s arbitration rate and 2Mbit/s data rate.
  - a. Key features of the CAN-FD peripheral include:
    - i. Dedicated 1KB message SRAM with ECC

- ii. Configurable transmit FIFO, transmit queue and event FIFO (up to 32 elements)
  - iii. Up to 32 dedicated transmit buffers and 64 dedicated receive buffers. Two configurable receive FIFOs (up to 64 elements each)
  - iv. Up to 128 filter elements
  - b. If CANFD mode is enabled:
    - i. Full support for 64-byte CAN-FD frames
    - ii. Up to 8Mbit/s bit rate
  - c. If CANFD mode is disabled:
    - i. Full support for 8-byte classical CAN frames
    - ii. Up to 1Mbit/s bit rate
2. Determine the CAN frame, including data length, bit rate switching, identifier, data and so on. Consider which part is fixed and which part need to be changed in the application. In example code, identifier, data length and data can change in different frames, while others are fixed. Note that users need to modify the code if protocol communication is required.

```

/**
 * @brief Structure for MCAN Rx Buffer element.
 */
typedef struct {
    /*! Identifier */
    uint32_t id;
    /*! Remote Transmission Request
     * 0 = Received frame is a data frame
     * 1 = Received frame is a remote frame
     */
    uint32_t rtr;
    /*! Extended Identifier
     * 0 = 11-bit standard identifier
     * 1 = 29-bit extended identifier
     */
    uint32_t xtd;
    /*! Error State Indicator
     * 0 = Transmitting node is error active
     * 1 = Transmitting node is error passive
     */
    uint32_t esi;
    /*! Rx Timestamp */
    uint32_t rxts;
    /*! Data Length Code
     * 0-8 = CAN + CAN FD: received frame has 0-8 data bytes
     * 9-15 = CAN: received frame has 8 data bytes
     * 9-15 = CAN FD: received frame has 12/16/20/24/32/48/64 data bytes
     */
    uint32_t dlc;
    /*! Bit Rat Switching
     * 0 = Frame received without bit rate switching
     * 1 = Frame received with bit rate switching
     */
    uint32_t brs;
    /*! FD Format
     * 0 = Standard frame format
     * 1 = CAN FD frame format (new DLC-coding and CRC)
     */
    uint32_t fdf;
    /*! Filter Index */
    uint32_t fidx;
    /*! Accepted Non-matching Frame
     * 0 = Received frame matching filter index FIDX
     * 1 = Received frame did not match any Rx filter element
     */
    uint32_t anmf;
    /*! Data bytes.
     * Only first dlc number of bytes are valid.
     */
    uint16_t data[DL_MCAN_MAX_PAYLOAD_BYTES];
} DL_MCAN_RxBufElement;

```

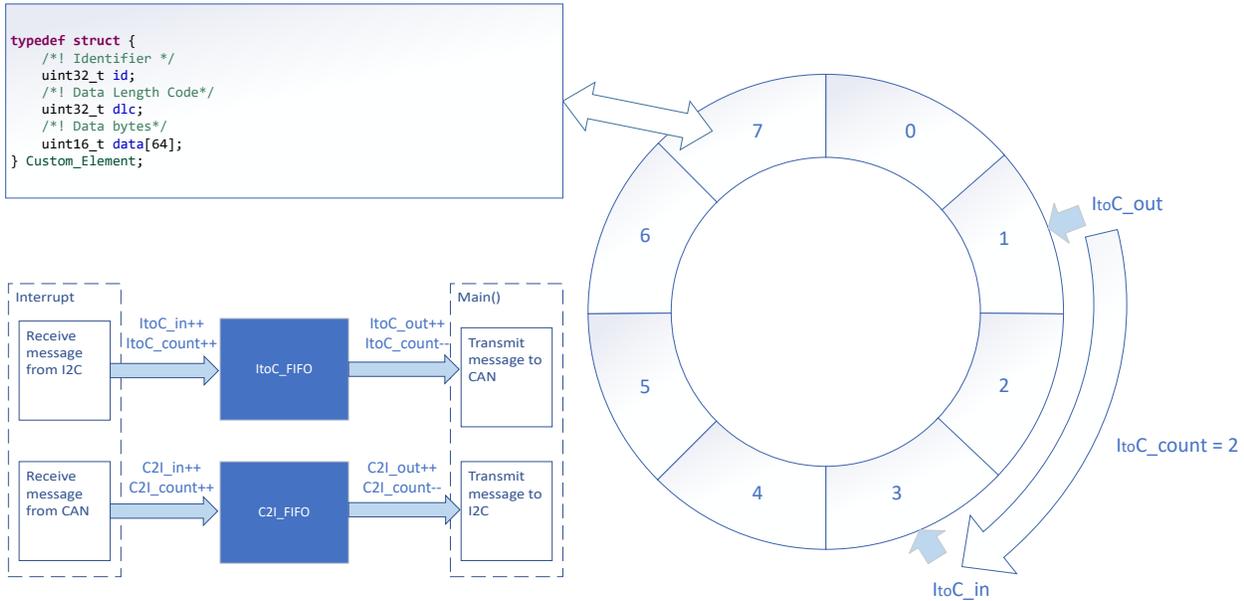
3. Determine the basic setting of I2C interface, including I2C mode, bus speed, target address, FIFO and so on. Consider which setting is fixed and which setting is changed in the application. One example code is used for I2C controller with 400kHz bus speed, the other one is used for I2C target with address 0x48.
- a. Key features of the I2C peripheral include:

- i. Configurable as a controller or a target with a bit rate up to 1Mbps
  - ii. Independent 8-byte FIFOs for reception and transmission
  - iii. Dual target address capability, glitch suppression
  - iv. Independent controller and target interrupt generation, and hardware support for DMA
  - v. Controller operation with arbitration, clock synchronization, multiple controller support
4. Determine the I2C message format. Typically I2C is transmitted in bytes. To achieve high-level communication, users can implement frame communication through software. If necessary, users can also introduce specific communication protocols. In example code, the message format is < 55 AA ID1 ID2 ID3 ID4 Length Data1 Data2 ...>. Users can send data through I2C as the same format. 55 AA is the header. ID area is 4 bytes. Length area is 1 byte, indicating the data length. Note that if users need to modify the I2C packet form, the code for frame acquisition and parsing also need to be modified.

**Table 1-3. I2C Packet Form**

Header	Address	Data Length	Data
0x55 0xAA	4 bytes	1 byte	(Data Length) bytes

5. Determine the bridge structure, including what messages need to be converted, how to convert messages and so on.
- a. Consider whether the bridge is one-way or two-way. Typically each interface has two functions: receiving and sending. Consider whether only some functions need to be included (such as I2C reception and CAN transmission). In example code, CAN-I2C bridge is a two-way structure. Since the receiving and transmitting of the I2C target are controlled by the I2C controller, the I2C target cannot initiate transmission to the I2C controller. To achieve communication from the target to the controller, a line is added to this design. The target's IO pull-down notifies the controller that there is information to be sent.
  - b. Consider what information to convert and the corresponding carrier(variable, FIFO). In example code, identifier, data and data length are convert from one interface to the other interface. There are two FIFOs defined in code as shown in [Figure 1-2](#).



**Figure 1-2. Bridge Structure**

6. (Optionally) Consider priority design, congestion situation, error handling, and so on.

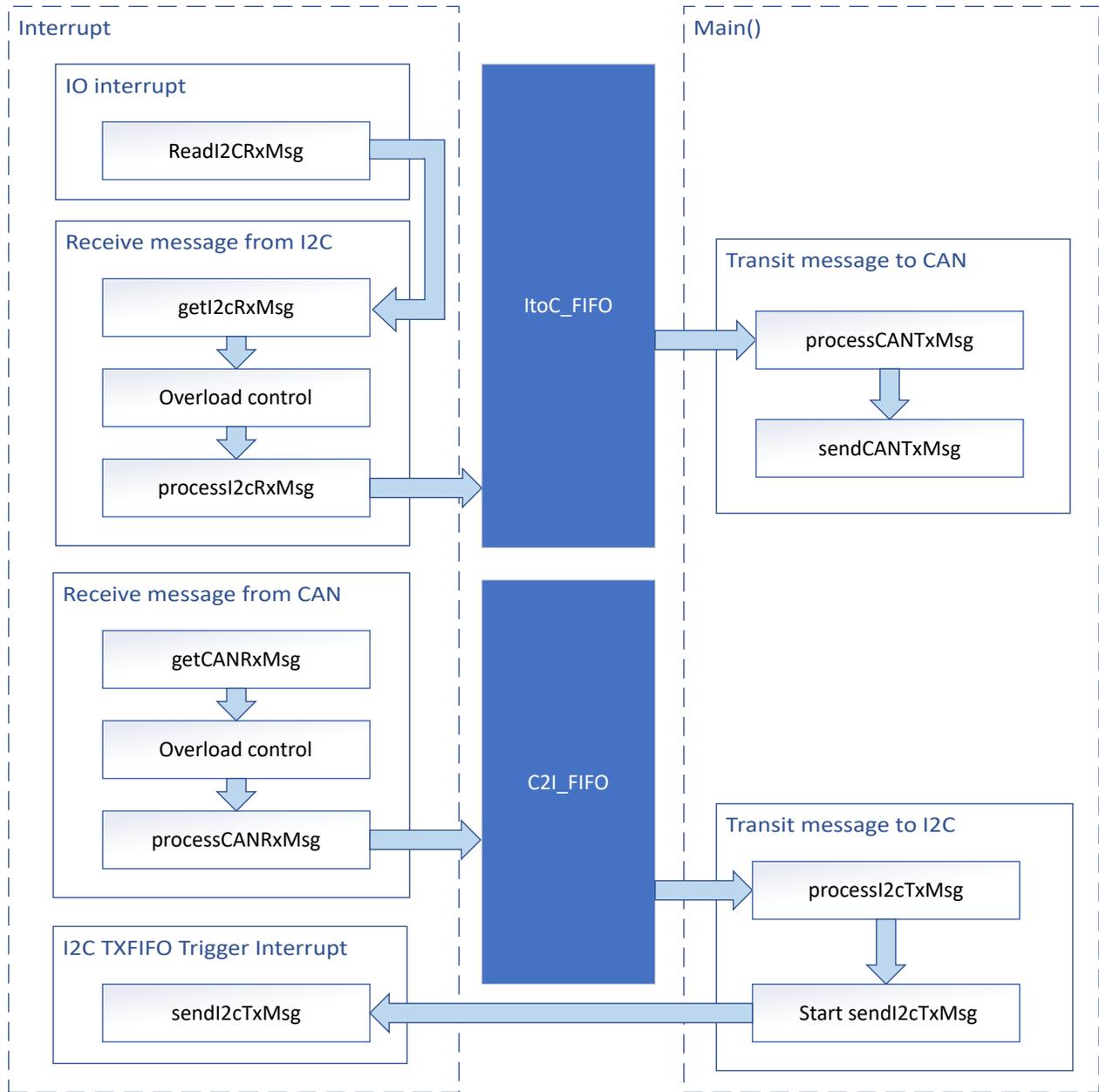
## Design Considerations

1. Consider the information flow in the application to determine the information to be received or sent by each interface, the protocols to be followed, and design appropriate information transfer carriers to connect different interfaces.
2. The recommendation is to test the interface separately first, and then implement the overall bridge function. In addition, consider the handling of abnormal situations, such as communication failure, overload, frame format error, and so on.
3. The recommendation is to implement interface functions through interrupts to make sure of timely communication. In example code, interface functions are usually implemented in the interrupt, and the transfer of information is completed in the main() function.

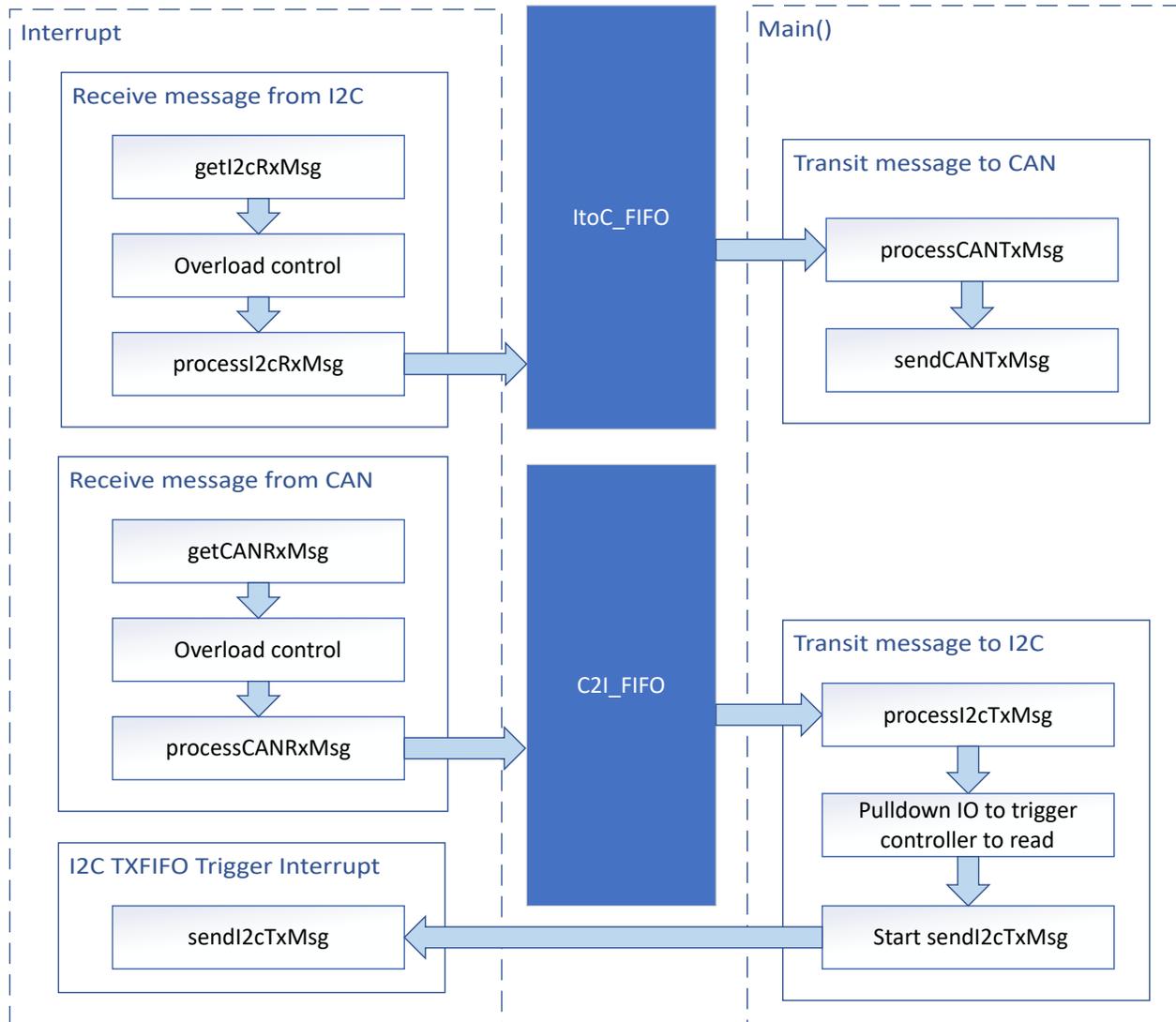
## Software Flowchart

[Figure 1-3](#) shows the code flow diagram for *CAN-I2C bridge* which explains how the messages received in one interface and sent in the other interface. The *CAN-I2C bridge* can be divided into four independent tasks: receive from I2C, receive from CAN, transmit through CAN, transmit through I2C. Two FIFOs implement bidirectional message transfer and message caching.

Note that I2C is a communication method that I2C controller control the transmit and receive. In general, I2C target cannot initiate communication. For I2C target-to-controller communication, I2C target can pull down the IO when messages needed to be sent, as shown in [Figure 1-3](#). I2C controller can initiate I2C read command in IO interrupt when IO is detected low, as shown in [Figure 1-4](#). In this demo, I2C can be configured as I2C target or controller.



**Figure 1-3. Application Software Flowchart of CAN-I2C (I2C Controller) Bridge**

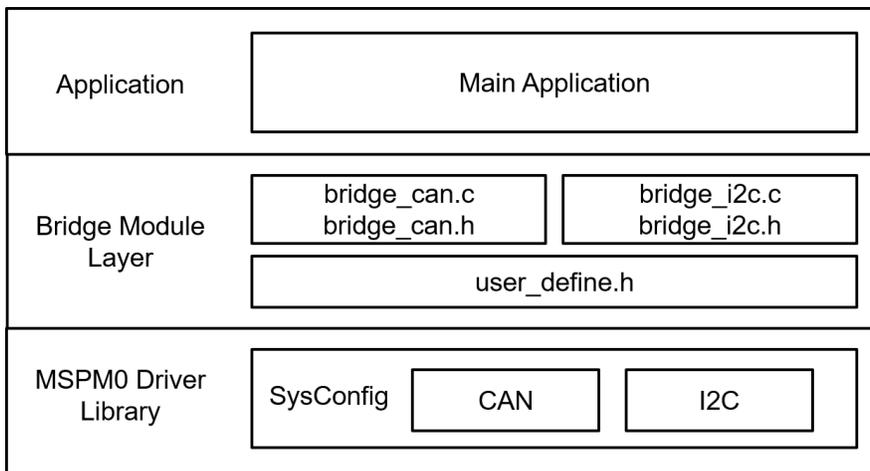


**Figure 1-4. Application Software Flowchart of CAN-I2C (I2C Target) Bridge**

## Device Configuration

This application makes use of TI System Configuration Tool (SysConfig) graphical interface to generate the configuration code for the CAN and I2C. Using a graphical interface to configure the device peripherals streamlines the application prototyping process.

The code for what is described in [Figure 1-3](#) can be found in the files from example code as shown in [Figure 1-5](#).



**Figure 1-5. File Structure**

## Application Code

The following code snippet shows where to modify the interface function. Functions in table are categorized into different files. Functions for I2C receive and transmit are included in `bridge_i2c.c` and `bridge_i2c.h`. Functions for CAN receive and transmit are included in `bridge_can.c` and `bridge_can.h`. Structure of FIFO element is defined in `user_define.h`.

Users can easily separate functions by file. For example, if only I2C functions are needed, users can reserve `bridge_i2c.c` and `bridge_i2c.h` to call the functions.

See the MSPM0 SDK and DriverLib documentation for the basic configuration of peripherals.

**Table 1-4. Functions and Descriptions**

Tasks	Functions	Description	Location
I2C receive	<code>readI2CRxMsg_controller()</code>	Send a read request to slave (I2C master only)	<code>bridge_i2c.c</code> <code>bridge_i2c.h</code>
	<code>getI2CRxMsg_controller()</code>	Get the received I2C message (I2C master only)	
	<code>getI2CRxMsg_target()</code>	Get the received I2C message (I2C slave only)	
	<code>processI2cRxMsg()</code>	Convert the received I2C message format and store it into <code>gI2C_RX_Element</code>	
I2C transmit	<code>processI2cTxMsg()</code>	Convert the <code>gI2C_TX_Element</code> format to be sent through I2C	
	<code>sendI2CTxMsg_controller()</code>	Send message through I2C (I2C master only)	
	<code>sendI2CTxMsg_target()</code>	Send message through I2C (I2C slave only)	
CAN receive	<code>getCANRxMsg()</code>	Get the received CAN message	<code>bridge_can.c</code> <code>bridge_can.h</code>
	<code>processCANRxMsg()</code>	Convert the received CAN message format and store the message into <code>gCAN_RX_Element</code>	
CAN transmit	<code>processCANTxMsg()</code>	Convert the <code>gCAN_TX_Element</code> format to be sent through CAN	
	<code>sendCANTxMsg()</code>	Send message through CAN	

Custom\_Element is the structure defined in user\_define.h. Custom\_Element is used as the structure of FIFO element, output element of I2C/CAN transmit and input element of I2C/CAN receive. Users can modify the structure according to the need.

```
typedef struct {
    /*! Identifier */
    uint32_t id;
    /*! Data Length Code*/
    uint32_t dlc;
    /*! Data bytes*/
    uint16_t data[64];
} Custom_Element;
```

For FIFO, there are 2 global variables used as FIFO. 6 global variables are used to trace the FIFO.

```
Custom_Element ItoC_FIFO[ItoC_FIFO_SIZE];
Custom_Element C2I_FIFO[C2I_FIFO_SIZE];
uint16_t ItoC_in = 0;
uint16_t ItoC_out = 0;
uint16_t ItoC_count = 0;
uint16_t C2I_in = 0;
uint16_t C2I_out = 0;
uint16_t C2I_count = 0;
```

## Results

By using CAN analyzer, users can send and receive messages on the CAN side. As a demonstration, two launchpads can be used as two CAN-I2C bridges (one I2C master and one I2C slave) to form a loop. When the CAN analyzer sends CAN messages through master launchpad, the analyzer can receive CAN messages from the slave launchpad.

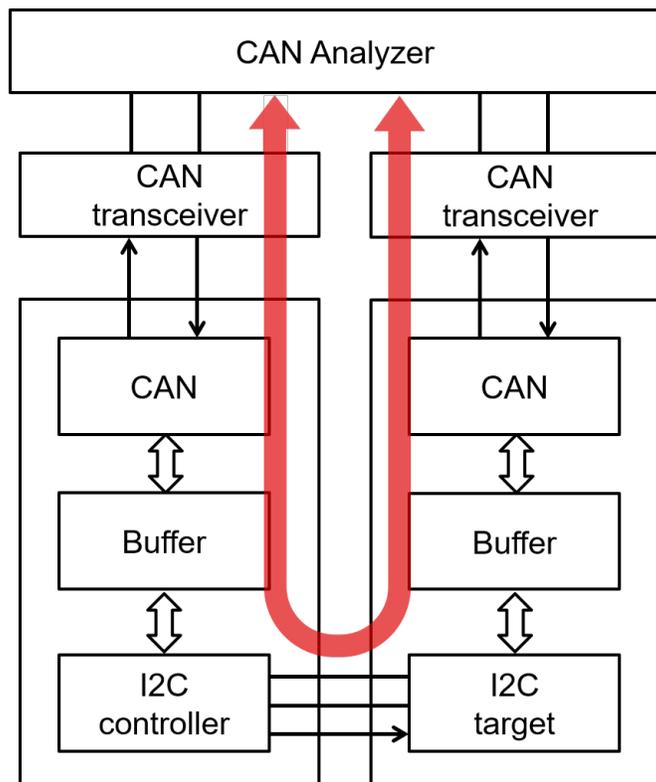
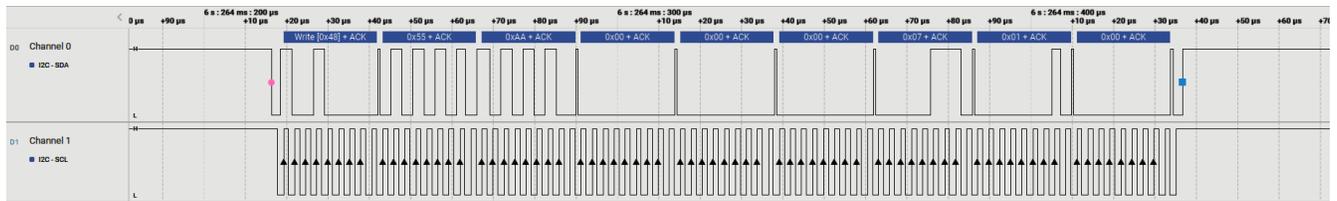


Figure 1-6. Demonstration

Index	Time	Device	Channel	Frame ID	Type	CANType	RT	Len	Data
					ALL	ALL	ALL		
0	0.000000	Device0	0	0x1	StandardFrame	CANFD Accelerate	Tx	16	00 11 22 33 44 53 66 77 88 99 AA BB CC DD EE FF
1	0.000900	Device0	1	0x1	StandardFrame	CANFD Accelerate	Rx	16	00 11 22 33 44 53 66 77 88 99 AA BB CC DD EE FF
2	75.392500	Device0	1	0x2	StandardFrame	CANFD Accelerate	Tx	16	00 11 22 33 44 53 66 77 88 99 AA BB CC DD EE FF
3	75.393400	Device0	0	0x2	StandardFrame	CANFD Accelerate	Rx	16	00 11 22 33 44 53 66 77 88 99 AA BB CC DD EE FF
4	96.807600	Device0	1	0x3	StandardFrame	CANFD Accelerate	Tx	12	00 11 22 33 44 53 66 77 88 99 AA BB
5	96.808400	Device0	0	0x3	StandardFrame	CANFD Accelerate	Rx	12	00 11 22 33 44 53 66 77 88 99 AA BB
6	111.433500	Device0	0	0x4	StandardFrame	CANFD Accelerate	Tx	8	00 11 22 33 44 53 66 77
7	111.434100	Device0	1	0x4	StandardFrame	CANFD Accelerate	Rx	8	00 11 22 33 44 53 66 77
8	127.068700	Device0	1	0x5	StandardFrame	CANFD Accelerate	Tx	4	00 11 22 33
9	127.069200	Device0	0	0x5	StandardFrame	CANFD Accelerate	Rx	4	00 11 22 33
10	137.580700	Device0	0	0x6	StandardFrame	CANFD Accelerate	Tx	4	00 11 22 33
11	137.581200	Device0	1	0x6	StandardFrame	CANFD Accelerate	Rx	4	00 11 22 33
12	160.259200	Device0	0	0x7	StandardFrame	CANFD Accelerate	Tx	1	00
13	160.259700	Device0	1	0x7	StandardFrame	CANFD Accelerate	Rx	1	00

**Figure 1-7. Messages Sent and Received by CAN Analyzer for the Demo**



**Figure 1-8. PC Terminal Program of Logic Analyzer**

**Additional Resources**

- Texas Instruments, [Download the MSPM0 SDK](#)
- Texas Instruments, [Learn more about SysConfig](#)
- Texas Instruments, [MSPM0 G-Series 80-MHz Microcontrollers](#), technical reference manual
- Texas Instruments, [MSPM0G LaunchPad development kit](#)
- Texas Instruments, [MSPM0 CAN academy](#)
- Texas Instruments, [MSPM0 I2C academy](#)

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