High Brightness LED Driver
Using the MM908E625 with:
   MC13192 RF Interface and SMAC 4.1, and
   DMX2SMAC for DMX512 to SMAC 4.1 Bridge

Designer Reference Manual
High Brightness LED Driver
Designer Reference Manual

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Revision History

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<thead>
<tr>
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Preface

This reference manual provides all the design guidelines and considerations when designing a High Brightness LED Driver using the MM908E625 Integrated Quad Half H-Bridge with Power Supply, Embedded MCU, and LIN Serial Communication. This manual also includes the installation and setup instructions for the HBLED RD Graphical User Interface that controls the HBLED RD Driver using RF communication and Freescale's IEEE® 13192 Evaluation Board.

Audience

This document is intended for application developers who are setting up Freescale's HBLED Reference Design.

Suggested Reading

Additional documentation, include that listed here, may be found at www.freescale.com

1. 13193 Evaluation Board Development Kit (13193EVB) User's Guide, document number 13193EVBUG.
2. MC13192/MC13193 2.4 GHz Low Power Transceiver for the IEEE® 802.15.4 Standard, document number: MC13192
4. Data Sheet of the MM908E625, H-Bridge Power Supply with Embedded MCU and LIN
5. USITT DMX512 Digital Data Transmission Standard for Dimmers and Controllers at www.usitt.org

Conventions

This document uses the following conventions:

<table>
<thead>
<tr>
<th>Term or Value</th>
<th>Definition</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Terminal names</td>
<td>Terminal names are the physical connections and are shown in text as all upper case.</td>
<td>... the external supply voltage VSUP1.</td>
</tr>
<tr>
<td>Terminal values</td>
<td>Terminal values are the currents to/from a terminal and are shown as upper and subscripted text.</td>
<td>In Stop Mode the voltage regulator still supplies the MCU with VDD</td>
</tr>
<tr>
<td>Decimal values</td>
<td>No special symbol attached to the number</td>
<td>1.0&lt;br&gt;34</td>
</tr>
<tr>
<td>Numbers</td>
<td>Considered positive unless specifically noted as a negative value</td>
<td>5.0&lt;br&gt;–10</td>
</tr>
<tr>
<td>Blue text</td>
<td>Linkable on-line</td>
<td>... refer to Table 2-1. Default Jumper Configuration</td>
</tr>
</tbody>
</table>
Chapter 1
Introduction and Setup

1.1 Introduction

The high brightness LED driver (HB LED) is a development platform for the MM908E625 integrated quad half H-bridge with:

- Power supply
- LIN serial communication
- Embedded low-cost 8-bit microcontroller

The integrated quad half H-bridge on the MM908E625 is used to drive four high brightness LEDs from suppliers like Lumileds and OSRAM. Also, it handles an MC13192 RF interface daughter board to communicate to a ZigBee/IEEE 805.11 MC13192 evaluation board, which is attached to a PC running a graphical user interface to demonstrate some control capabilities. For example, dimming the LEDs and establishing Flash sequences.

The second phase of the project demonstrates how to control the high brightness LEDs on the HBLED using the DMX2SMAC board with a standard DMX512 console.

- The development platform demonstrates the cost effectiveness of using the one MM908E625 to control four high brightness LEDs
- Also, it demonstrates the RF capabilities of the IEEE 802.15.4, MC13192 RF transceivers
- An MC13192 RF interface daughter board is connected directly to the HB LED board with SPI emulation used for communication between the two boards
- The LED boards are pluggable to the HB LED board, and are interchangeable between the Lumileds and the OSRAM high brightness LEDs
- The HB LED platform works with an external +12 V power supply
- The graphical user interface program enables the PC to control the brightness of the four high brightness LEDs, and gives the user the ability to program a sequence for turning ON, OFF, Dim, or Flash the four LEDs at a programmable rate
- The graphical user interface communicates with the MC13192 evaluation board through an RS232 serial port fixed at 38.4 Kbaud
- Freescale's SMAC 4.1 protocol is used for the communication between the IEEE 802.15.4 MC13192 evaluation board and the HBLED RD board.

*Figure 1-1* shows the HBLED RD board PCB1 and PCB 2 along with the MC13192 RF daughter card connected to it.
1.2 HBLED RD PCB 1 (Key Features)

The HBLED RD board number 1 is composed of the MM908E625 low-cost microcontroller, one female header to connect to the MC13192 RF daughter card, and four female headers to connect to the HBLED RD board number 2 (PCB 2).

Features of this board are listed here and illustrated in Figure 1-2:
- MM908E625 integrated quad half H-bridge with power supply, embedded MCU, and LIN serial communication
- Jack and terminal block for +12-V external power supply
- SPST ON/OFF switch
- Internal 5-V voltage regulator
- External 3.3-V voltage regulator.
- MON08 multilink connector interface
- MC13192 RF daughter card connector interface
- On-board status LEDs for 3.3 V, 5 V, MON08 communication, and MCU running
- Pin headers with access to MCU I/Os
- Headers and terminal blocks for connecting to HBLED RD PCB 2 (high brightness LEDs)
- 3.3 V–5 V interface logic drivers to communicate to MC13192 RF daughter card
- Reset pushbutton
- Optional 8-MHz external crystal resonator

Figure 1-2. HBLED RD PCB 1 Features
1.3 HBLED RD PCB 2 (Key Features)

The HBLED RD board number 2 is composed of the four high brightness LEDs as well as the headers and terminal blocks to connect to the HBLED RD board number 1 (PCB 1).

Features of this board are listed here and illustrated in Figure 1-3:
- Headers and terminal blocks to connect to the HBLED RD PCB 1
- Different pads to place either the Lumileds or OSRAM high brightness LEDs
Figure 1-4 shows the DMX2SMAC board used to provide an interface between a DMX512 console and the HBLED RD boards using the SMAC.

1.4 DMX2SMAC (Key Features)

The DMX2SMAC board is composed of the MC9S08GT60 low-cost microcontroller, the MC13192 2.4-GHz low-power transceiver for the IEEE® 802.15.4 Standard, and the proper drivers and connectors to interface to a DMX512 console.

Features of this board are listed here and illustrated in Figure 1-5:
- MC9S08GT60 microcontroller
- MC13192 2.4-GHz low-power transceiver for the IEEE® 802.15.4 Standard
- PCB copper traced F antenna
- Jack and terminal block for +12-V external power supply
- SPST ON/OFF switch
- External 3.0-V voltage regulator
- On-board status LEDs for 3 V background debug activity and MCU running
Introduction and Setup

- Background debug interface pin header for programming/debugging MC9S08GT60
- Pin headers with access to MCU I/Os
- Reset pushbutton
- RS485 driver for receiving DMX512 protocol communication
- DB9 male connector and terminal block for connecting DMX512 communication

Figure 1-5. DMX2SMAC Board Features
Chapter 2
System Description

2.1 Introduction

The HBLED RD project is divided into two sections.

1. To demonstrate the use of the HBLED RD PCB 1 and PCB 2 along with the MC13192 RF daughter card connected to it. And, the use of the MC13192 evaluation board attached to a PC, through an RS232 interface, running a graphical user interface to send control messages to the HBLED RD for remote brightness and sequence control of the high brightness LEDs.

2. To implement a bridge between a DMX512 console and the HBLED RD board using a DMX2SMAC board

2.2 Controlling the HBLED RD Using a PC

Connecting the MC13192 RF daughter card to the HBLED RD board offers the ability to control it through the use of the IEEE® 802.15.4 Standard. Connecting an MC13192 evaluation board to a PC through a serial port opens the possibility of sending command messages to the HBLED RD board using Freescale's SMAC 4.1 protocol. In this way, you will have the ability to control the brightness of the LEDs attached to the HBLED RD board. For this purpose, a graphical user interface was developed.

Refer to Figure 2-1.

2.3 Controlling the HBLED RD Using a DMX512 Console

The design of the DMX2SMAC gives the ability to control the HBLED RD board when connecting the MC13192 RF daughter card to it, through the use of the IEEE® 802.15.4 Standard.

The DMX2SMAC has an RS485 serial communication driver that allows it to monitor the DMX512 protocol sent by a DMX512 console, and to serve as a bridge between the DMX512 protocol and the HBLED RD board.

Refer to Figure 2-2.
System Description

Figure 2-1. Controlling the HBLED RD by Using a Graphical User Interface
Controlling the HBLED RD Using a DMX512 Console

Figure 2-2. Controlling the HBLED RD Board by Using a DMX512 Console
2.4 Setup Instructions and User Guide for Controlling the HBLED RD Using a PC

The required elements for testing the first section of the project, which is to control the HBLED RD along with the MC13192 RF daughter card using a graphical user interface loaded into a PC are:

- HBLED RD PCB 1 and 2
- MC13192 RF daughter card
- +12 Vdc external power supply for HBLED RD
- MC13192 evaluation board
- +9 V battery or external power supply for the MC13192 evaluation board
- Straight RS232 cable
- Graphical user interface, HBLedsRD.exe, running on a PC

2.4.1 Configuration Jumpers

Configuration jumpers on the HBLED RD PCB1 are JP4, JP6, and E1.

- JP4 selects the IRQ_A output from the analog part to be connected to the MCU's IRQ input on the MM908E625.
- JP6 selects the IRQ output from the MC13192 RF daughter card to be connected to the MM908E625's IRQ input.
- E1 selects either:
  - The reset signal going into the MC13192 RF daughter card which is coming from the general reset signal of the HBLED RD PCB 1, or
  - A dedicated I/O from the MM908E625

The default jumper configuration is shown in Table 2-1 and Figure 2-3.

<table>
<thead>
<tr>
<th>Jumper</th>
<th>Configuration</th>
</tr>
</thead>
<tbody>
<tr>
<td>JP4</td>
<td>Open</td>
</tr>
<tr>
<td>JP6</td>
<td>Closed</td>
</tr>
<tr>
<td>E1</td>
<td>Position 2–3 Closed</td>
</tr>
</tbody>
</table>
On-Board Test Points

The HBLED RD PCB 1 includes test points of the main signals. The purpose of these test points is both for testing the electrical performance of the board and to easily access the main signals involved in the application.

Table 2-2 shows a description of the signals that can be observed at the test points.

<table>
<thead>
<tr>
<th>Test Point Number</th>
<th>Signal Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>TP1</td>
<td>FGEN</td>
<td>Generated by the MCU going to analog part of the MM908E625, for switching low-side drivers</td>
</tr>
<tr>
<td>TP2</td>
<td>BEMF</td>
<td>Output from MM908E625's analog part that gives user information about back electromagnetic force</td>
</tr>
<tr>
<td>TP3</td>
<td>SPARE</td>
<td>Not used</td>
</tr>
<tr>
<td>TP4</td>
<td>GND</td>
<td>System ground, electrical reference test point</td>
</tr>
<tr>
<td>TP5</td>
<td>+5V</td>
<td>5-V power supply output coming from MM908E625</td>
</tr>
<tr>
<td>TP6</td>
<td>+3.3V</td>
<td>3.3-V power supply output coming from voltage regulator U7</td>
</tr>
</tbody>
</table>
2.4.3 Starting Up HBLED RD

The following sequence of steps gets the HBLED RD board up and running and gets the graphical user interface ready to control it.

1. Set up the MC13192 evaluation board by connecting it to a PC through the use of a straight RS232 cable into one of the PC’s COM ports.

2. Power the MC13192 evaluation board with a 9 V battery or an external power supply through connector jack J105 and turn switch S106 to the ON position. LED D105 should turn ON.

3. Set the configuration jumpers to their default position on the HBLED RD PCB 1.


5. Insert the MC13192 RF daughter card into female header J6 on HBLED RD PCB1. The three boards should look like the picture shown on Figure 2-1.

6. Connect an external +12 V power supply to HBLED RD PCB 1 using either terminal block TB5 or connector jack J9.

7. Turn switch SW1 to the ON position.

8. Check that LED1 and LED3 are ON to test for system voltages, +3.3 V and +5 V.

   **NOTE**

   LED 2 only flashes when using the MON08 interface for programing or debugging the MM908E625.

9. At startup, LED4 will flash and then it will turn OFF, turning ON again when acknowledging RF messages coming through the MC13192 RF daughter card.

10. It is now time to run the graphical user interface program, HBLedsRD.exe, on the PC. At startup, the interface should look like Figure 2-4.

---

**Figure 2-4. Graphical User Interface Startup Window**
11. The COM port and the baud rate used to connect to the MC13192 evaluation board, is indicated at the upper right level. Change the COM if necessary, selecting it from the drop down list. The baud rate should be at 38.4 Kbaud. It may be necessary to change it in the case another one is selected. See Figure 2-5.

![Figure 2-5. COM Port Selection](image)

12. After proper COM and baud rate selection, we can now start controlling the high brightness LEDs on the HBLED RD boards by moving the sliders shown in the graphical user interface. Moving one slider to the highest position turns the corresponding LED to 100%, at the lowest position the LED is turned OFF. When moving any of the sliders, make sure the LED located on the upper right corner of the window is turned green, indicating that the RF messages sent to the HBLED RD board are acknowledged.

NOTE
If the LED located on the upper right corner is turned RED while moving any of the sliders, either the communication with the MC13192 evaluation board is lost or that the HBLED RD board is not acknowledging any message.
Please make sure that the HBLED RD boards and the MC13192 evaluation board are properly powered and turned ON.
Figure 2-6. Controlling High Brightness LEDs on the HBLED RD PCB 2
2.4.4 Using the Graphical User Interface Sequencer

Another functional part of the HBLeadsRD.exe graphical user interface program gives the ability to create small sequences to turn ON and OFF the LEDs for a certain amount of time, or run it in a continuous loop. Also, gives the option to store and load different sequences. To go to the sequencer, CLICK on the Configure Demo button located in the bottom left part of the window. If no previous sequence was stored, the window should look like Figure 2-7.

![Sequencer Window on the Graphical User Interface](image)

Figure 2-7. Sequencer Window on the Graphical User Interface
2.4.5 Sequencer Description

The sequencer is a practical tool that allows us to control the LEDs on the HBLED RD board over their full scale (0% to 100%) in a certain amount of time that we call it “total cycle time.” During this time, we can program the LEDs to go ON, OFF, or to a certain light level for a fraction of the “total cycle time” or even for the whole cycle. Figure 2-8 shows the main parts of the sequencer window which are described in more detailed following the figure.

**Figure 2-8. Sequencer Window Main Parts**

**Total Cycle Time Box**
This box is used to input the time duration, in seconds, for the actual sequence to take place. Practical values for the total cycle time could be between 0.5 to 60 seconds, but longer cycle times are accepted.

**Exit Sequencer Button**
This button is used to close the sequencer part of the window and only show the LED sliders part of it.

**Run Sequence Button**
When a sequence is ready, pressing this button will initiate sending the proper messages to the HBLED RD board to turn ON, OFF, or Dim at a certain level the high brightness LEDs.

**Continuous Sequence Check Box**
If this box is checked and a sequence is initiated, it will cycle until it is stopped by pressing the “Run/Stop Button”. If it is not checked, the sequence will go through only one time.

**Save Sequence Button**
Press this button to name and save the actual sequence into a folder of your selection. The file extension used for the sequence is *.dat.

**Load Sequencer Button**
Press this button to load a previously saved sequence.
Clear Sequence Map
Pressing this button clears any sequence defined in the sequence map.

Select Time Position Box
This box is used to move between the total cycle time and to select a specific fraction of time where we want to turn ON, OFF, or Dim one or all of the LEDs.

Time Position Slider
This slider is also used to move between the total cycle time and to select a specific fraction of time where we want to turn ON, OFF, or Dim one or all of the LEDs.

LED's Light Level Adjust Box
This box is used to set the brightness level of the LEDs.

LED's Light Level Adjust Slider
This slider is also used to set the brightness level of the LEDs.

Sequence Map
This is a graphical representation of the sequence defined in the total cycle time. In this map we can easily view which LED is ON, OFF, or Dim and how much time it stays in this state during the entire sequence.

2.5 Setup Instructions and User Guide for Controlling the HBLED RD Using a DMX512 Console

The required elements for testing the second section of the project which is to control the HBLED RD along with the MC13192 RF Daughter Card, using a DMX512 Console, are the following:
- HBLED RD PCB 1 and 2
- MC13192 RF daughter card
- DMX2SMAC board
- DMX512 console
- +12 Vdc external power supply for HBLED RD
- +12 Vdc external power supply for DMX2SMAC board
- Custom made cable for connecting the DMX2SMAC to a DMX512 console

2.5.1 Configuration Jumpers

Configuration jumpers on the DMX2SMAC Board are JP7 and JP9.
- JP7 is used to enable reset pushbutton, PB1
  - In normal operation should be closed
  - When programming/debugging should be opened
- JP9 is used to enable/disable the termination resistor for the RS485 serial communication.

The default jumper configuration is shown in Table 2-3 and Figure 2-9.

### Table 2-3. Default Jumper Configuration

<table>
<thead>
<tr>
<th>Jumper</th>
<th>Configuration</th>
</tr>
</thead>
<tbody>
<tr>
<td>JP7</td>
<td>Closed</td>
</tr>
<tr>
<td>JP9</td>
<td>Open</td>
</tr>
</tbody>
</table>
2.5.2 On-Board Test Points

The DMX2SMAC board includes test points of the main signals. The purpose of these test points is both testing the electrical performance of the board and to easily access the main signals involved in the application.

Table 2-4 shows a description of the signals that can be observed in the test points.

Table 2-4. Test Point Signal Descriptions

<table>
<thead>
<tr>
<th>Test Point Number</th>
<th>Signal Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>TP1</td>
<td>ZCLK0</td>
<td>External Oscillator Input to the MC9S08GT60, coming from MC13192.</td>
</tr>
<tr>
<td>TP2</td>
<td>+3V</td>
<td>3V power supply output, coming from Voltage Regulator U5.</td>
</tr>
</tbody>
</table>
2.5.3 DMX2SMAC DB9 Connector and Terminal Blocks

The DMX512 protocol specifies the use of three main signals for serial data communication that relies on the RS485 Standard. The DMX512 specifies the use of XLR type connectors for the connection of the DMX512 devices. The signals involved in these connectors are:

1. Ground / 0 V
2. Data –
3. Data +
4. Spare Data –
5. Spare Data +

On the DMX2SMAC, these signals are present in the DB9 male connector (P1) and on terminal blocks TB2 and TB3. Table 2-5 and Table 2-6 show the DMX512 signals on the DMX2SMAC board.

Table 2-5. DMX512 Signals on the DB9 Male Connector

<table>
<thead>
<tr>
<th>P1–DB9 Male Connector Positions</th>
<th>Signal Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Not connected</td>
</tr>
<tr>
<td>2</td>
<td>Data +</td>
</tr>
<tr>
<td>3</td>
<td>Data –</td>
</tr>
<tr>
<td>4</td>
<td>Not connected</td>
</tr>
<tr>
<td>5</td>
<td>Ground / 0 V</td>
</tr>
<tr>
<td>6</td>
<td>Not connected</td>
</tr>
<tr>
<td>7</td>
<td>Not connected</td>
</tr>
<tr>
<td>8</td>
<td>Not connected</td>
</tr>
<tr>
<td>9</td>
<td>Not connected</td>
</tr>
</tbody>
</table>

Table 2-6. DMX512 Signals on Terminal Blocks TB2 and TB3

<table>
<thead>
<tr>
<th>TB2 and TB3 Positions</th>
<th>Signal Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>TB2.1</td>
<td>Data –</td>
</tr>
<tr>
<td>TB2.2</td>
<td>Ground / 0 V</td>
</tr>
<tr>
<td>TB3.1</td>
<td>Ground / 0 V</td>
</tr>
<tr>
<td>TB3.2</td>
<td>Data +</td>
</tr>
</tbody>
</table>

2.5.4 Starting Up DMX2SMAC Board

The following step sequence gets the HBLED RD and the DMX2SMAC boards up and running and gets a DMX512 console ready to control the high brightness LEDs.

1. Set up the HBLED RD PCB 1 and 2 and get it ready for the test, following steps 3 to 9 from 2.4.3 Starting Up HBLED RD.
2. Connect the DMX512 console to the DMX2SMAC board through the use of a custom cable from the console’s XLR connector to either the DB9 male connector or to terminal blocks TB2 and TB3 using the information found in Table 2-5 and Table 2-6.
3. Power on the DMX512 console.
4. Set the configuration jumpers to their default on the DMX2SMAC board.
5. Connect an external +12-V power supply to the DMX2SMAC board using either terminal block TB1 or connector jack J5.
6. Turn switch SW1 to the ON position on the DMX2SMAC board.
7. Check that LED1 is ON, to test for +3-V system voltage.

**NOTE**

LED 2 only flashes when using the BDM interface for programming or debugging the MC9S08GT60.

8. When the DMX512 console is turned ON, then LED3 on the DMX2SMAC board will start to flash as an indication that it is receiving DMX512 protocol information through the serial communication channel.
9. Start controlling the high brightness LEDs on the HBLED RD boards by changing channels 1 to 4 on the DMX512 console.
Chapter 3  
Software Design Considerations

3.1 Introduction

The software implementation for the HBLED RD has two important parts.

1. The first one is in charge of the communication with the MC13192 RF daughter card.
2. The second part is in charge of the dimming of the four high brightness LEDs.

3.2 Communication with the MC13192 RF Daughter Card

Communication with the MC13192 RF daughter card is done through the SPI. But, since the SPI on the MM908E625 is only used for communication with the analog part of the die, an SPI emulation had to be developed using available I/Os on the MM908E625. For handling the MC13192 reception and transmission of information, Freescale’s SMAC 4.1 protocol was used.

The IRQ input on the MM908E625 is connected to the active low interrupt request output on the MC13192. All of the interrupt service routines are handled by the SMAC 4.1 protocol implementation on the MM908E625.

3.3 Dimming the Four High Brightness LEDs

A PWM mechanism was chosen for dimming of the four LEDs. Having set the maximum current through the LEDs by switching ON and OFF the low-side MOSFETs using the FGEN signal and taking advantage of the current limit feature on the MM908E625. Note that:

- If a brightness of 100% is required, it is only necessary to turn ON the low-side MOSFETs and have the automatic feature to take place.
- If a percentage different than full brightness is required, it is necessary to switch ON and OFF the driving of the LEDs. This needs to be done at a relatively low frequency with a certain duty cycle to generate a dimming sensation to the human eye, reducing the amount of current flowing through the LED over time.

A recommended refreshing frequency for this PWM, can be from 75 Hz to 100 Hz to avoid any flickering sensation to the human eye. Also, it was decided to have a 20-step resolution for the duty cycle to keep the whole implementation as simple as possible.

Figure 3-1 shows a graphical representation of the PWM implementation used to dim the high brightness LEDs.

The two timer interface B (TIMB) module channels available on the MM908E625 where used for controlling the duty cycle, one channel for every two LEDs. This approach takes a lot of processing out from the “main” loop.
3.4 Software Design Considerations for the DMX2SMAC

The software implementation for the DMX2SMAC can also be divided into two important parts:

1. The first one in charge of the communication with the MC13192
2. The second is the one in charge of receiving and handling of the DMX512 protocol

3.4.1 Communication with the MC13192

The software implementation on the DMX2SMAC board is based on the MC13192 Evaluation Board guidelines. Communication with the MC13192 is done through the MC9S08GT60’s SPI module. Freescale’s SMAC 4.1 protocol is used for handling the MC13192 reception and transmission of information.

3.4.2 DMX512 Protocol Handling

The DMX2SMAC board handles the DMX512 protocol in such a way that the board serves as a bridge between this protocol and the SMAC 4.1. This is used to send and receive messages to the HBLED RD board for controlling the high brightness LEDs.

For the software development of the DMX2SMAC board, two restrictions were taken into account:

1. The bridge between the DMX512 protocol and the SMAC 4.1 is not done in real time.
2. Only the first four channels on the DMX512 protocol where scanned to match the four channels available on the HBLED RD board.

Using one of the MC9S08GT60’s two independent SCI modules, the DMX512 serial communication protocol is read through the use of an RS485 serial driver. The use of the automatic error detection feature for parity, framing, and noise in the SCI receiver allows for the detection of the start of a DMX512 packet.
Following the start of a DMX512 packet, is the start code (SC) byte of information which always has a value of 0. After the SC byte, the SCI detects the following bytes of information that correspond to the 512 channels that the protocol handles. Only the first four bytes after the SC are stored and processed for updating the four high brightness LEDs on the HBLED RD board.

Refer to Figure 3-2.

![DMX512 Protocol Packet](image)

**Figure 3-2. DMX512 Protocol Packet**

The light level information used by the DMX512 protocol goes from 0 to indicate the lowest level (channel OFF) to a value of 255 to indicate the maximum light level (full ON).

Before sending the corresponding information to the HBLED RD board, the first four DMX512 channel's light level is converted to match with the 20-steps of light level that the HBLED RD board can handle for dimming the high brightness LEDs.

### 3.5 Flow Diagrams

Refer to Figure 3-3 and Figure 3-4 for the HBLED RD and DMX2SMAC software main flow diagrams.
Figure 3-3. HBLED RD Software Main Flow Diagram
Figure 3-4. DMX2SMAC Software Main Flow Diagram
Chapter 4
Hardware Design Considerations

4.1 Advantages Using the MM908E625 to Drive High Brightness LEDs

There are some advantages over other solutions to drive today’s high brightness LEDs using the MM908E625. These are:

- Low-cost solution to drive four high brightness LEDs with only one chip
- Simple software and hardware design to control LED brightness
- Independent control over the four high brightness LEDs
- High efficiency output control implementing a step-down buck switching regulator
- On-chip low-side MOSFET current limit feature used to control the amount of current flowing through the high brightness LEDs
- Low heat generation due to the use of the MM908E625 internal power MOSFETs with low $R_{\text{DS(ON)}}$
- RF communication can be established interfacing to a MC13192 RF daughter card by emulating SPI communication using MCU I/Os

4.2 MM908E625 Driving High Brightness LEDs Basics

The following is a brief introduction to the basic circuit design used to drive the high brightness LEDs using the MM908E625 integrated quad half H-bridge with power supply, embedded MCU, and LIN serial communication.

The main idea behind the circuit design to control the amount of current flowing through the high brightness LEDs is to implement a type of step-down buck regulator controlling the current instead of the voltage output. Taking advantage of the low-side MOSFET current limit feature of the MM908E625 simplifies the overall design.

The circuit configuration shown in Figure 4-1 illustrates the basic operation of our current regulator.

When switching ON the low-side MOSFET (Figure 4-2) current flows through the high brightness LED and inductor (L), when it reaches the current limit previously defined inside the MM908E625, the MOSFET is turned OFF automatically. At this point, the energy stored in the inductor (L) will continue to flow through the LED thanks to the Schottky diode (D). The idea is to maintain a constant flow of current through the high brightness LED and before the current drops to zero, the low-side MOSFET is turned ON again to start a new current cycle.

The switching frequency of our regulator was set up at 25 kHz. It is internally generated by the MM908E625 using the timer interface A (TIMA) module in a PWM configuration, feeding this signal into the FGEN input.

Each low-side MOSFET switches OFF if a current above the selected current limit is detected. The MM908E625 offers five different current limits, the 370 mA was selected to comply with the LED’s specification. The low-side MOSFET switches ON again if a rising edge on the FGEN input is detected.
Figure 4-1. Basic Circuit Used to Drive the High Brightness LEDs

Figure 4-2. Low-side MOSFET Switching on the MM908E625 to Drive the High Brightness LEDs
4.3 Selection of Inductor L for Driving the High Brightness LEDs

In order to determine the value for the inductor L used for driving the high brightness LEDs, a list of factors were considered:

- The maximum switching frequency for the low-side MOSFETs on the MM908E625
- The system's main voltage input (V_{IN})
- The high brightness LED's forward voltage drop (V_{FD})
- The peak-to-peak AC component of the current flow through the inductor (I_{RPP})
- The commercially available Inductor values

On any switching regulator configuration, the inductance value is inversely proportional to the switching frequency. That is why, in order to keep the value and size of the inductor as small as possible, the maximum switching frequency specification for the low-side MOSFETs on the MM908E625 was chosen. Using TIM A's PWM feature on the MM908E625, a frequency of 25 kHz was supplied on the FGEN input.

- The specified voltage input for the HBLED RD is +12 V (V_{IN})
- Taken from the OSRAM data sheet, the high brightness LED has a typical V_{FD} = 3.8 V

Having the general formula to calculate the voltage on an inductor:

\[ V_L = L \frac{di}{dt} \]

We can determine that:

\[ V_L = L \frac{\Delta I_{PP}}{\Delta t} \]

Where:

- \( V_L \) is the voltage across the inductor L which is calculated as \( V_{IN} - V_{FD} \).
- \( \Delta I_{PP} \) is the peak-to-peak AC component. In order for the regulator to work in continuous mode, a 150 mA of ripple current was chosen considering an average current around the 300 mA.
- \( \Delta t \) is the charging time, the time the low-side MOSFET switches stay ON. Considering a switching frequency of 25 kHz with a duty cycle of 50%, the time the MOSFET switches are ON is 20 \( \mu \)s.

Clearing away the inductance, we now have the following formula:

\[ L = \frac{V_L \cdot \Delta t}{\Delta I_{PP}} \]

If we substitute the known values in the formula we get:

\[ L = \frac{(12 \text{ V} - 3.8 \text{ V}) \cdot 20 \text{ } \mu\text{s}}{0.150 \text{ Amp}} \]

\[ L = 1.093 \text{ mH} \]

From the given result, a commercially available option for the inductor was chosen, with a value of 1 mH.
4.4 Hardware Considerations for the DMX2SMAC Board

Much of the DMX2SMAC’s hardware is based on Freescale’s MC13192 Evaluation Board. This board uses the MC9S08GT60 MCU and the MC13192, IEEE 802.15.4, 2.4 GHz low-power transceiver.

The main features added are:
- RS485 driver, for receiving the DMX512 serial protocol
- Pin headers J2, J3, and J4 with access to most of the MCU I/Os
- System's LEDs to indicate +3 V, BKGD debug activity and communication status
- +3-V voltage regulator
- DB9 connector and terminal blocks to connect to DMX512 serial communication protocol

4.5 Printed Circuit Board Layouts

Detailed PCB layouts are provided here for:
- HBLED RD PCB 1 and HBLED RD PCB 2 — refer to Figure 4-3 and Figure 4-4
- DMX2SMAC PCB — refer to Figure 4-5 and Figure 4-6

For the bill of materials and schematics refer to Appendix A Bill of Materials and Schematics.
Figure 4-3. HBLED RD PC1 and PCB 2 Layout TOP Side
Figure 4-4. HBLED RD PC1 and PCB 2 Layout BOTTOM Side
Figure 4-5. DMX2SMAC PCB Layout TOP Side

Figure 4-6. DMX2SMAC PCB Layout BOTTOM Side.
Appendix A
Bill of Materials and Schematics

A.1 Bill of Materials

Bill of materials for the high brightness LED driver reference design are shown in Table A-1, Table A-2, and Table A-3.

<table>
<thead>
<tr>
<th>Reference</th>
<th>Description</th>
<th>Case</th>
<th>Manufacturer</th>
<th>Manufacturer Part Number</th>
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<td>KEMET</td>
<td>T491D476k020AS</td>
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<td>C2, C4, C8, C10, C11, C13, C16, C17, C20, C21, C24–27, C29–34</td>
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<td>PANASONIC</td>
<td>ECJ-2YB1H104K</td>
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<td>ECJ-2VC1H220J</td>
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<tr>
<td>C7</td>
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<td>B SIZE</td>
<td>PANASONIC</td>
<td>ECS-T1CX106R</td>
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<td>PANASONIC</td>
<td>ECS-T0JY106R</td>
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<td>D1–9</td>
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<td>SMD</td>
<td>TOSHIBA</td>
<td>CMS01(TE12L)</td>
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<tr>
<td>E1</td>
<td>3 PIN 0.100 HEADER</td>
<td>TH</td>
<td>MOLEX</td>
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<td>JP1–3, JP5, JP7–9</td>
<td>JUMPER 0 OHM</td>
<td>0805</td>
<td>PANASONIC</td>
<td>ERJ-6GEY0R00V</td>
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<tr>
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<td>TH</td>
<td>Sullins Electronics Corp.</td>
<td>PPTC042LJB DN</td>
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<tr>
<td>J5</td>
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<td>PTC36DAAN</td>
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<td>J6</td>
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<td>LED1</td>
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<td>SMD</td>
<td>Coiltronics</td>
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<td>PB1</td>
<td>SW PUSHBUTTON</td>
<td>TH</td>
<td>PANASONIC</td>
<td>EVQ-PAE07K</td>
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<td>PANASONIC</td>
<td>ERJ-6GEYJ105V</td>
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<td>Reference</td>
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<td>Manufacturer Part Number</td>
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<td>On Shore Technology</td>
<td>ED555/2DS</td>
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<td>TP1–6</td>
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<td>KEYSTONE</td>
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<td>U1</td>
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<td>SOIC54</td>
<td>Freescale Semiconductor</td>
<td>MM9908E625ACDWB</td>
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<td>Fairchild</td>
<td>NC7W207P6X</td>
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<td>U7</td>
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<td>ON Semiconductor</td>
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<td>X1</td>
<td>8MHz CRYSTAL</td>
<td>SMID</td>
<td>ECS</td>
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Table A-2. HBLED RD PCB 2 Bill of Materials

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<td>SMD</td>
<td>Osram Opto Semiconductors Inc.</td>
<td>LB W5SG-DY6Z-35</td>
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<td>SMD</td>
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<td>LV W5SG-GXHX-35</td>
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<td>SMD</td>
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<tr>
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### Table A-3. DMX2SMAC Bill of Materials

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<td>22-03-2021</td>
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<td>LED1</td>
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<td>LED2</td>
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<td>0805</td>
<td>Lite-On Trading USA Inc.</td>
<td>LTST-C171KYKT</td>
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<td>Murata Electronics</td>
<td>LQG18HN1NS00D</td>
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<td>B3F-1050</td>
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<td>DB9M</td>
<td>AMP/Tyco Electronics</td>
<td>747250-4</td>
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<td>TRANS ARRAY NPN/NPN WIRES</td>
<td>SOT23 (MINI SP)</td>
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<td>XN121200L</td>
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<td>IC RF TRANS NPN LOW NOISE</td>
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<td>MBC13900T1</td>
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<td>ON Semiconductor</td>
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<td>0805</td>
<td>PANASONIC</td>
<td>ERJ-6GEY4272V</td>
</tr>
<tr>
<td>R4</td>
<td>RESISTOR 120 OHM, 1/4W, 5%</td>
<td>1206</td>
<td>PANASONIC</td>
<td>ERJ-6GEY1J121V</td>
</tr>
</tbody>
</table>
A.2 Schematics

Schematics for the high brightness LED driver reference design are shown in Figure A-1, Figure A-2, and Figure A-3.
Figure A-1. HBLED RD PCB 1 Schematic
Figure A-2. HBLED RD PCB 2 Schematic
Figure A-3. DMX2SMAC Schematic
## Appendix B
### Glossary

<table>
<thead>
<tr>
<th>Term</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>COM</td>
<td>Serial communication channel on a PC, usually an RS232 port</td>
</tr>
<tr>
<td>DB9</td>
<td>9-pin D-shell connector</td>
</tr>
<tr>
<td>DMX512</td>
<td>Standard interface between dimmers and consoles developed by the USITT</td>
</tr>
<tr>
<td>HBLED RD</td>
<td>High brightness LED reference design</td>
</tr>
<tr>
<td>I/O</td>
<td>Microcontroller inputs and outputs</td>
</tr>
<tr>
<td>IEEE</td>
<td>Institute of Electrical and Electronics Engineers</td>
</tr>
<tr>
<td>LED</td>
<td>Light emitting diode</td>
</tr>
<tr>
<td>LIN</td>
<td>Local interconnect network</td>
</tr>
<tr>
<td>MCU</td>
<td>Microcontroller unit</td>
</tr>
<tr>
<td>MON08</td>
<td>The monitor read-only memory (ROM) or monitor mode — allows complete testing of Freescale's 08 MCU family, through a single-wire interface</td>
</tr>
<tr>
<td>MULTILINK</td>
<td>Tool available from P&amp;E Microcomputer Systems that uses the MON08</td>
</tr>
<tr>
<td>PC</td>
<td>Personal Computer</td>
</tr>
<tr>
<td>PCB</td>
<td>Printed Circuit Board</td>
</tr>
<tr>
<td>PWM</td>
<td>Pulse width modulator</td>
</tr>
<tr>
<td>RF</td>
<td>Radio Frequency</td>
</tr>
<tr>
<td>RS232</td>
<td>Standard for serial binary data interconnection between DTE (data terminal equipment) and DCE (data communication equipment)</td>
</tr>
<tr>
<td>RS485</td>
<td>Open systems interconnection physical layer electrical specification of a two-wire, half-duplex, multipoint serial connection</td>
</tr>
<tr>
<td>SPST</td>
<td>Single pole, single throw type of switch</td>
</tr>
<tr>
<td>SMAC</td>
<td>Freescale's small media acces control for the MC13192 transceiver</td>
</tr>
<tr>
<td>SPI</td>
<td>Serial peripheral interface</td>
</tr>
<tr>
<td>TIMA</td>
<td>Timer interface A module on the MM908E625</td>
</tr>
<tr>
<td>TIMB</td>
<td>Timer interface B module on the MM908E625</td>
</tr>
<tr>
<td>USITT</td>
<td>U.S. Institute of Theatre Technology</td>
</tr>
<tr>
<td>Glossary</td>
<td>Description</td>
</tr>
<tr>
<td>------------</td>
<td>---------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td><strong>XLR</strong></td>
<td>A rugged electrical connector design, used mostly in professional audio and video electronics cabling applications</td>
</tr>
<tr>
<td><strong>ZigBee</strong></td>
<td>Name of a specification for a suite of high-level communication protocols using small, low-power digital radios based on the IEEE 802.15.4 standard for wireless personal area networks (WPANs).</td>
</tr>
</tbody>
</table>
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