XC82x/XC83x

DMX512 Receiving Device with XC836

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26	Figure 26. R5 changed from 1k to 560R
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-	Updated all Figures with DALI-DMX512 Board version 1.5

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1 Introduction

DMX512 is a communication protocol commonly used in stage lighting applications. It describes the digital data transmission between the controller and the stage equipment, such as a washlight, moving head, or fog machine for example. The E1.11-2008 USITT DMX512-A protocol is maintained by ESTA (Entertainment Service and Technology Association).

This application note describes the implementation of a DMX512 software stack to act as a receiving device, using the XC836 microcontroller from Infineon. We start with an overview of the DMX512, where the system architecture and protocol structure are explained, then discuss the implementation using the XC836 microcontroller, and finally describe the integrated DALI-DMX512 board which can be used to control the on-board RGB LED via the DMX512 protocol.

2 Overview of DMX512

DMX512 is a packet-based, asynchronous, serial and unidirectional communication protocol. Because there is no error checking or correction mechanism specified in the standard, this makes it relatively simple, but also means that it is unsuitable for safety-critical applications.

DMX512 uses differential signals for communication specified by the RS-485 standard. Therefore, it has good immunity against noise and is able to communicate at relatively long distance (up to 1200 meters). However, it also inherits the limitation of RS-485 which allows only a maximum of 32 devices to be connected to the same communication line.

2.1 System Overview

A DMX512 system consists of one master device (transmitting device) connected to multiple slave devices (receiving devices) in 'daisy-chain' manner as illustrated in **Figure 1** below.

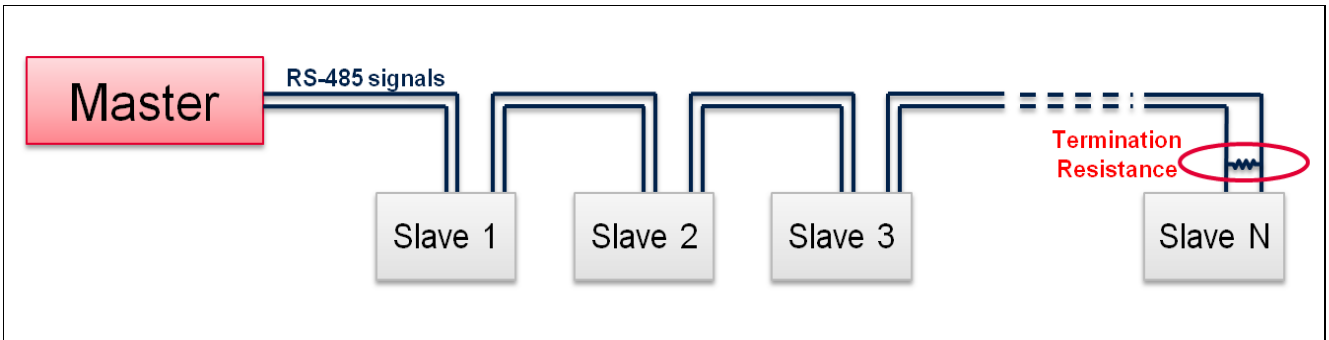


Figure 1 DMX512 System connected in Daisy Chain

A unique address must be assigned to each slave device by configuring the DIP switch embedded on each device. The address may range from 1 to 512, depending on how many devices are connected and how many DMX512 slots/channels are consumed by each device. For example, an RGB-LED wallwasher may consume one DMX512 slot for each color. If its address is set at 10, it will consume slot 10, 11 and 12. The address for the next device must be set to 13.

A termination resistance typically of 120Ω is connected at the furthest slave device to prevent signal reflection.

In the case where more than 32 devices are required in a system, an in-line device, such as optosplitter, can be used.

2.2 Physical Layer

The standard specifies the physical layer of DMX512 to consist of the connector configuration and the circuit topology. DMX512 system uses XLR-5 connectors, as shown in **Figure 2**. Transmitting device uses Ground Referenced Topology while receving device uses Isolated Topology. In this document, only the physical layer of the slave/receiving device is discussed.

2.2.1 XLR-5 Connector

Each receiving device has both a male and a female XLR-5 connector that is used for receiving and transmitting the DMX512 signal, respectively. This is to create the daisy-chain topology that ensures the continuity of communication from the transmitting device to the last receiving device.

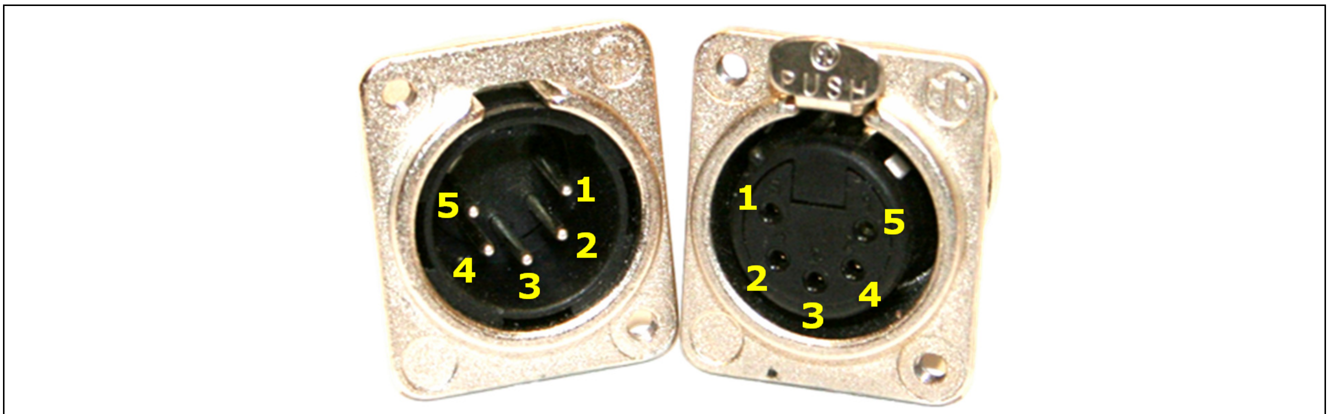


Figure 2 XLR-5 Connector Pinouts. Male-type is on the left and Female-type is on the right.

The following **Table 1** specifies the connections for the receiving device:

Table 1 DMX512 Pinout on XLR-5 Connector

Pin Number	Signal Name	Description
1	Common Reference	Data Link Common
2	Data 1+	Primary Data Link
3	Data 1-	
4	Data 2+	Secondary Data Link (Optional)
5	Data 2-	

In a typical DMX512 application, only Primary Data Link (DATA1+ and DATA1-) and Common Reference are used.

The Secondary Data Link is not used and is reserved for future use. It is therefore common to find some lighting fixtures that use XLR-3 connectors.

2.2.2 Isolated Topology

The standard specifies the use of isolated topology in the receiving device circuit, as illustrated in **Figure 3** below. This topology is not implemented in our solution, however users are encouraged to follow this topology strictly when implementing their own solution. Refer to **Figure 32** in the APPENDIX section for suggested circuit that fulfill isolated topology.

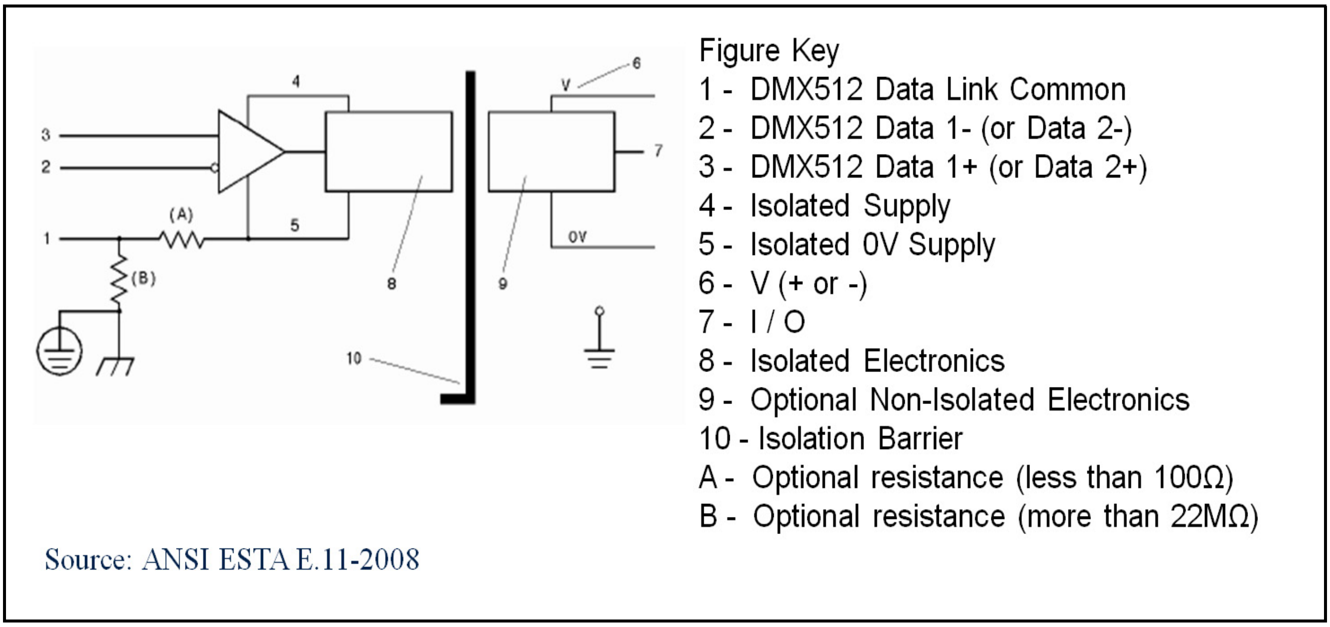


Figure 3 Isolated Topology as specified in the standard

2.3 DMX512 Protocol

As the name suggests, there are 512 "pieces of information" carried in a DMX512 packet. Each "piece of information" is also known as a slot or channel, which consists of 1 start bit, 8 data bits and 2 stop bits. A Reset Sequence consisting BREAK, MAB and NULL Start Code must be transmitted before the slots.

Figure 4 illustrates a DMX512 packet.

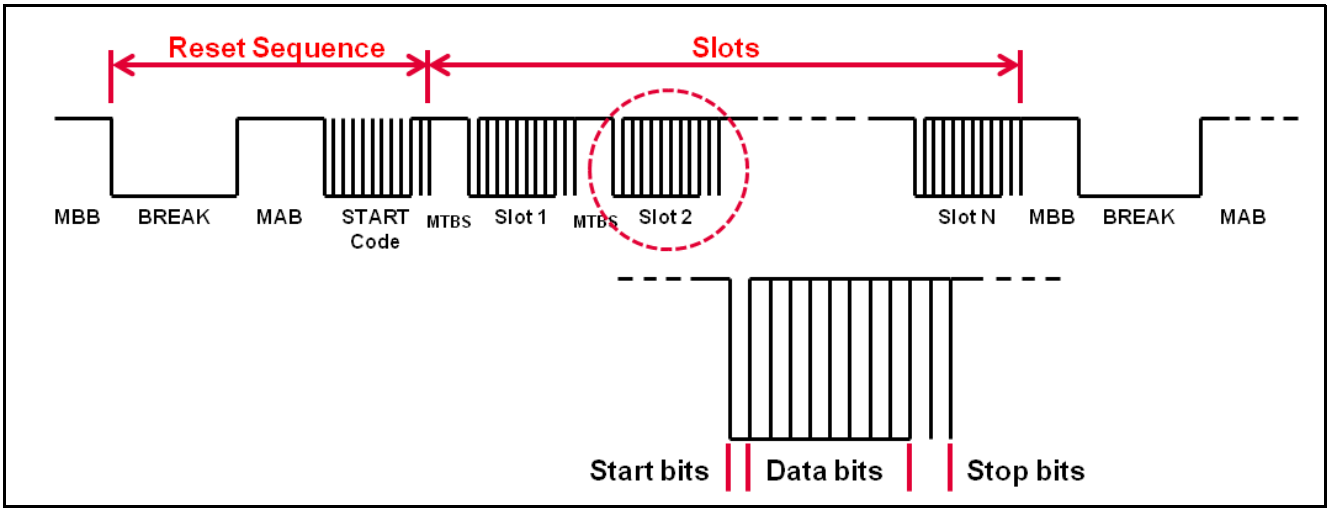


Figure 4 DMX512 Protocol

The timing requirements for the receiving device are shown in **Table 2**.

Table 2 Timing Requirements for Receiving Device

Signal	Min. Value	Typ. Value	Max. Value	Description
Bit Rate	245 kbps	250 kbps	255 kbps	Transmission rate for DMX512 protocol.
Bit Time	3.92 µs	4 µs	4.08 µs	
BREAK	88 µs	176 µs	-	A falling edge transition followed by a low of at least 88 µs followed by a rising edge.
MAB	8 µs	-	< 1 s	Mark After Break - The period of time measured from the rising edge at the end of BREAK to the falling edge of the start bit of the START Code.
MTBS	0	-	< 1 s	Mark Time Between Slot - The period measured from the end of the second stop bit (bit 9) of the previous slot to the falling edge of the start bit of the current slot.
MBB	0	-	< 1 s	Mark Before Break - The period measured from the end of the second stop-bit of the last slot to the falling edge of the next BREAK.
BREAK-TO-BREAK	1196 µs	-	1.25 s	The period between two BREAKs

3 DMX512 Implementation with XC836

Current solutions in the market use either a 16-bit or 32-bit microcontroller with a large memory size to implement DMX512. The microcontroller receives and stores all the slots before processing them. This method is inefficient as it requires 512 bytes of data memory while only a few are relevant to the receiving device. In addition, some implementations use two or more pins because each IO pin can only support one function.

The implemented software stack described in this Application Note will selectively receive and store relevant slots. This method reduces the required memory for the DMX512 software stack and gives more space for application-specific code. In addition, it will also be implemented on a single pin. This is possible because XC800 devices are able to map multiple functions into a single IO pin.

The software stack will be implemented using Timer 2, UART and Timer 0. It will occupy 1.2KB of Flash and a few bytes of RAM, depending on the number of required slots in the application.

Timer 2 and Timer 0 are 16-bit general purpose timers which are functionally compatible with the C501 product family. Timer 2 has Capture Mode for pulse width measurement, which is useful to measure the width of BREAK and MAB, while Timer 0 can be used to measure the BREAK-to-BREAK signal.

UART is an integrated communication peripheral that can be set as a 9-bit serial port to receive and validate the START Code and the following slots.

3.1 Hardware

Figure 5 shows the DMX512 solution from Infineon. Aside from DMX512, the DALI (Digitally Addressable Lighting Protocol) is also implemented on the board. This enables the evaluation of both lighting protocols on a single platform by simply downloading a different protocol stack via the programming connector. The previous protocol stack will be overwritten by the new one and the relevant circuitry will be activated after downloading.

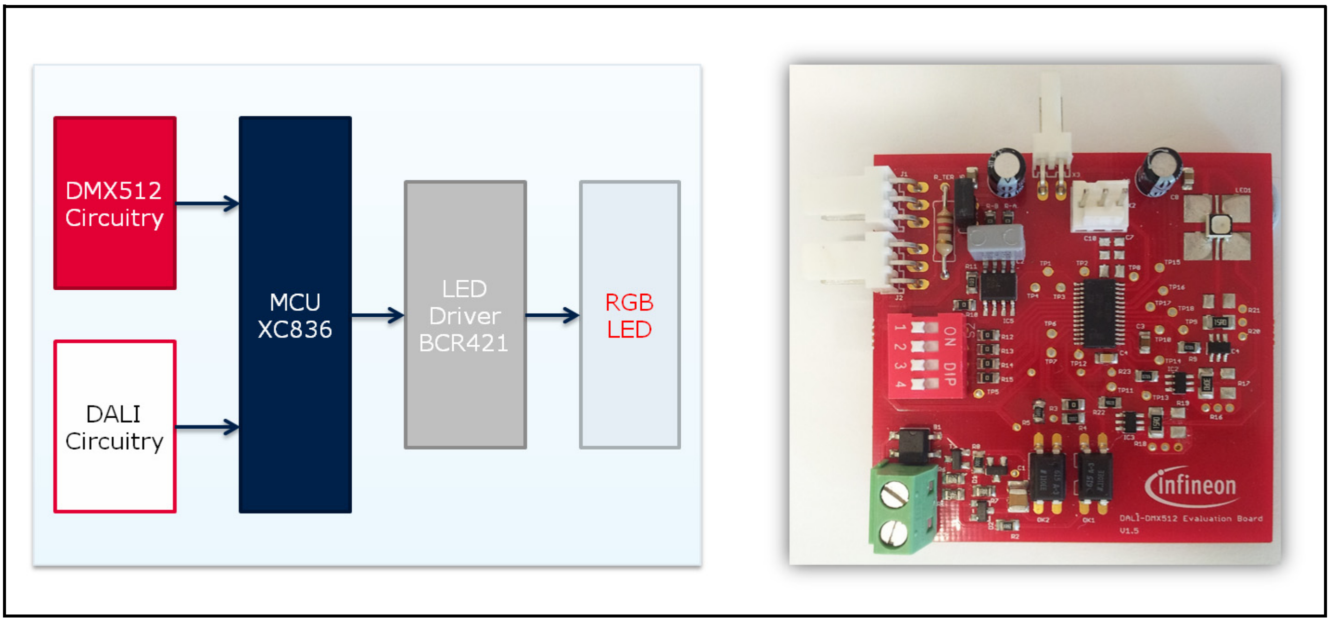


Figure 5 Block Diagram and Actual Board

The connectors found on the board are the DMX512, DIP switches, power supply connector and SPD (programming) connector.

3.1.1 DMX512 Connectors

The DMX512 connector is shown in **Figure 6** below. The differential DMX512 signal is received and converted to TTL level by RS485 transceiver, where its Receive Output (RO) pin and Receive Enable (RE) pin are connected to P2.7 and P0.6 of XC836, respectively.

In addition, there is a 120Ω termination resistance that must be enabled at the end of the daisy-chain connection to avoid signal reflection. Users can enable this termination resistance by shorting the on-board jumper.

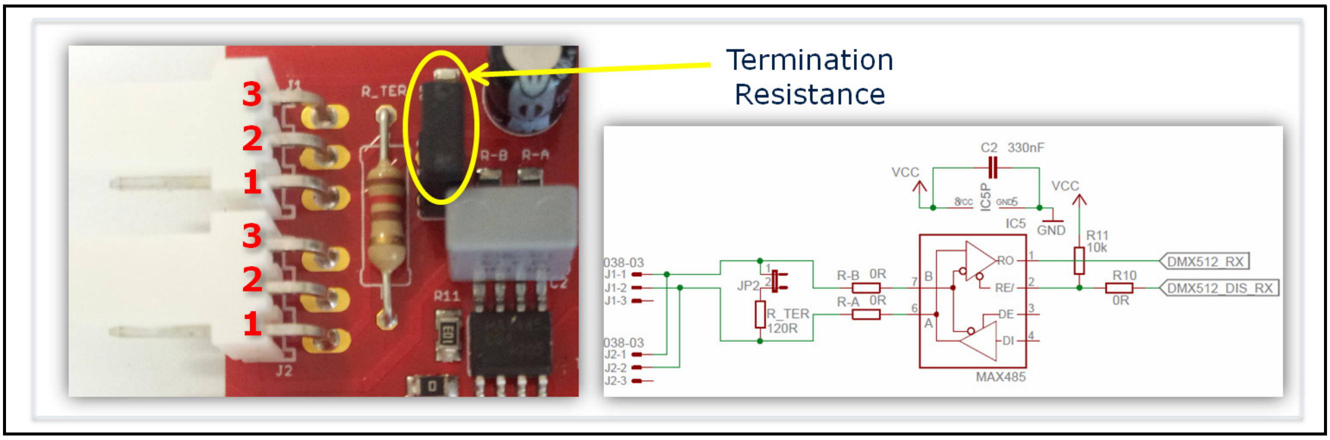


Figure 6 DMX512 Connector

3.1.2 DIP Switch

Each receiving device has embedded DIP switches to allow the user to assign a DMX512 address. In a typical DMX512 application, 9-bit DIP switches are used. This allows an address range from 1 to 512. The user can set the DIP switches to assign DMX Address 1 to 511, while address 512 is assigned by setting the DIP switches to zero.

As a demonstration only board, our solution only uses a 4-bit DIP switch, where the supported address will range from 1 to 16. Address 1 to 15 is achieved by setting the DIP switch and Address 16 is achieved by setting the DIP switch to zero.

When an address higher than 16 is required, the user is able to set it by software, which will be explained in **Chapter 4.3**.

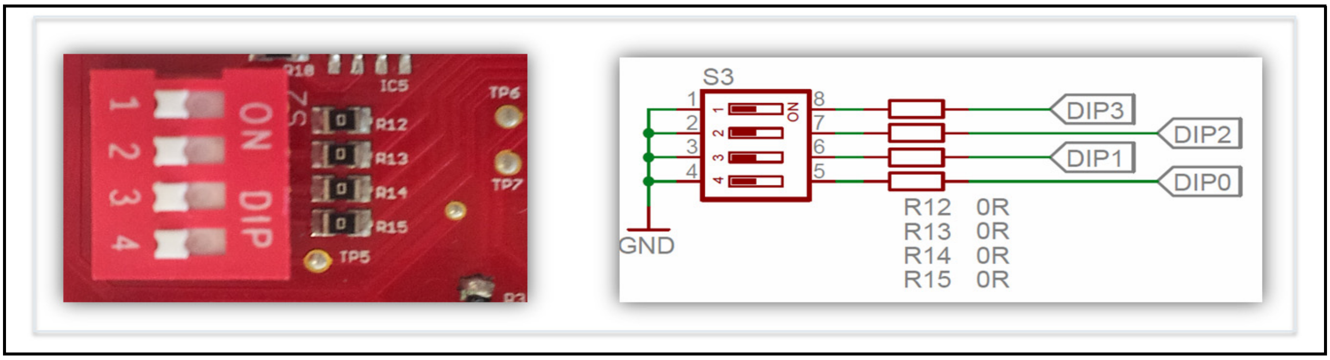


Figure 7 4-bit on-board DIP switch

3.1.3 Power Supply Connector and SPD Connector

5V DC is required at the power supply connector to power up the board. The programming connector (SPD) allows the user to download the application code and the software stack using miniWiggler.

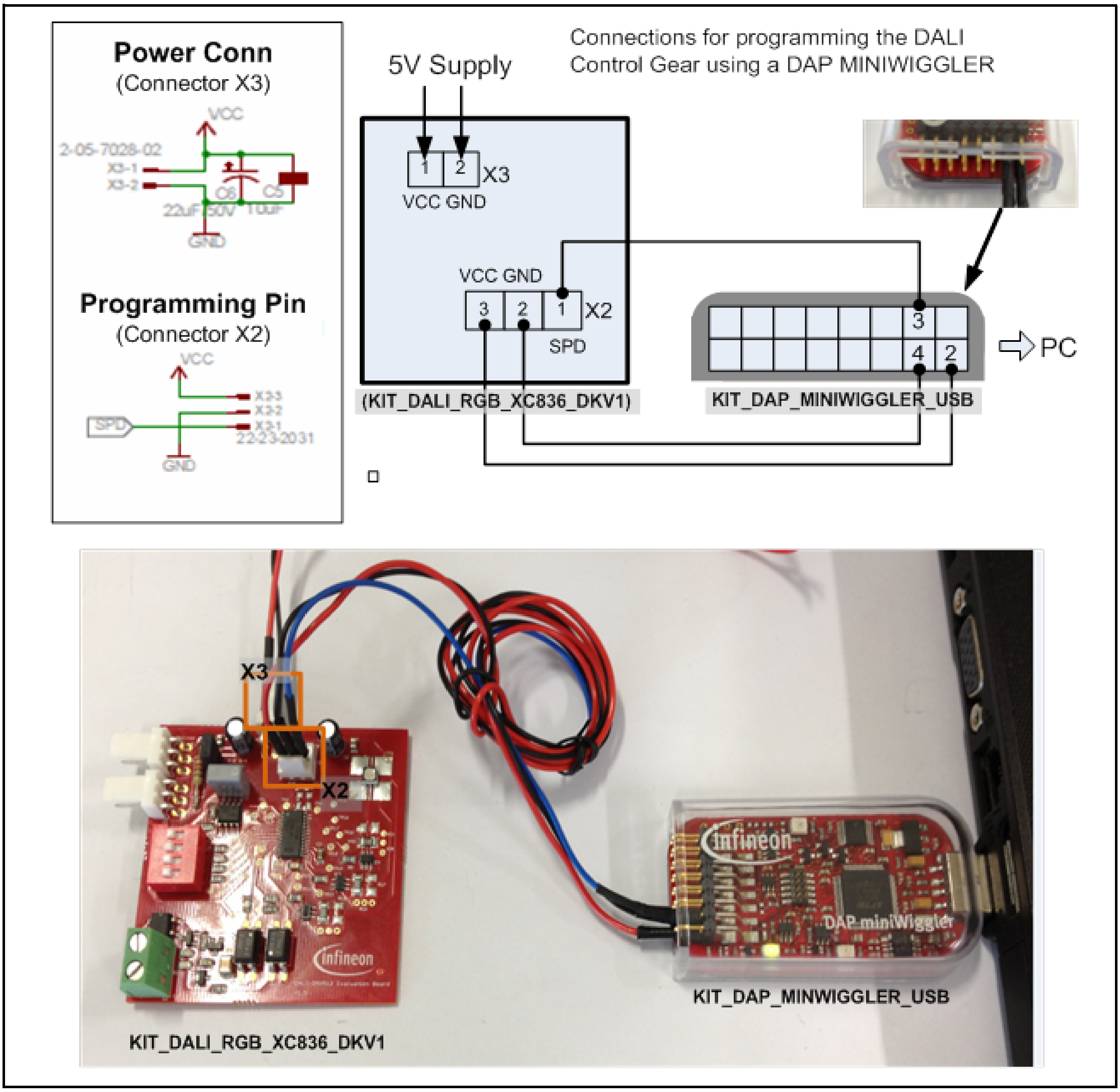


Figure 8 Power Supply Connector

3.2 Software

The protocol stack utilizes three peripherals from XC836, namely Timer 2, UART and Timer 0 to receive and process the DMX512 signal. It will validate and pass only the relevant slots to the application code.

This implementation demonstrates an RGB LED color control application where the protocol stack processes and passes three slots of information to the application code. Another peripheral called CCU6 (Capture/Compare Unit 6), a PWM generator module, is also used to control the intensity of each LED color channel.

3.2.1 Software Abstraction Layers

Figure 9 shows the software abstraction layers which illustrate the processing of the DMX512 signal.

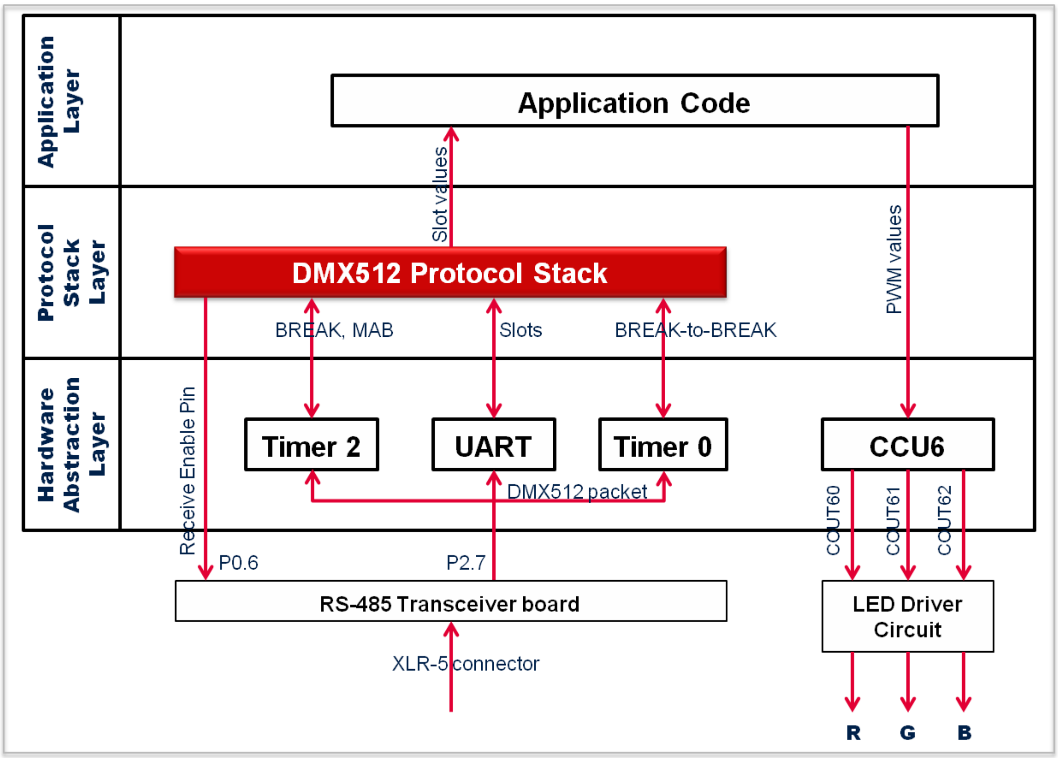


Figure 9 Software Abstraction Layer

When the DMX512 signal is received, its BREAK and MAB will be detected and verified by Timer 2. If the BREAK and MAB fulfills the timing requirements, UART will then be activated to receive the START code and the slots. The slots with an index number that matches the assigned DMX512 address will be stored temporarily.

BREAK-to-BREAK time is measured and validated using Timer 0. The temporary slot values are passed on to the application code only if the packet's BREAK-to-BREAK time fulfills the required timing.

3.2.2 Interrupt Timing Diagram

This process is summarized in **Figure 10**, the interrupt timing diagram.

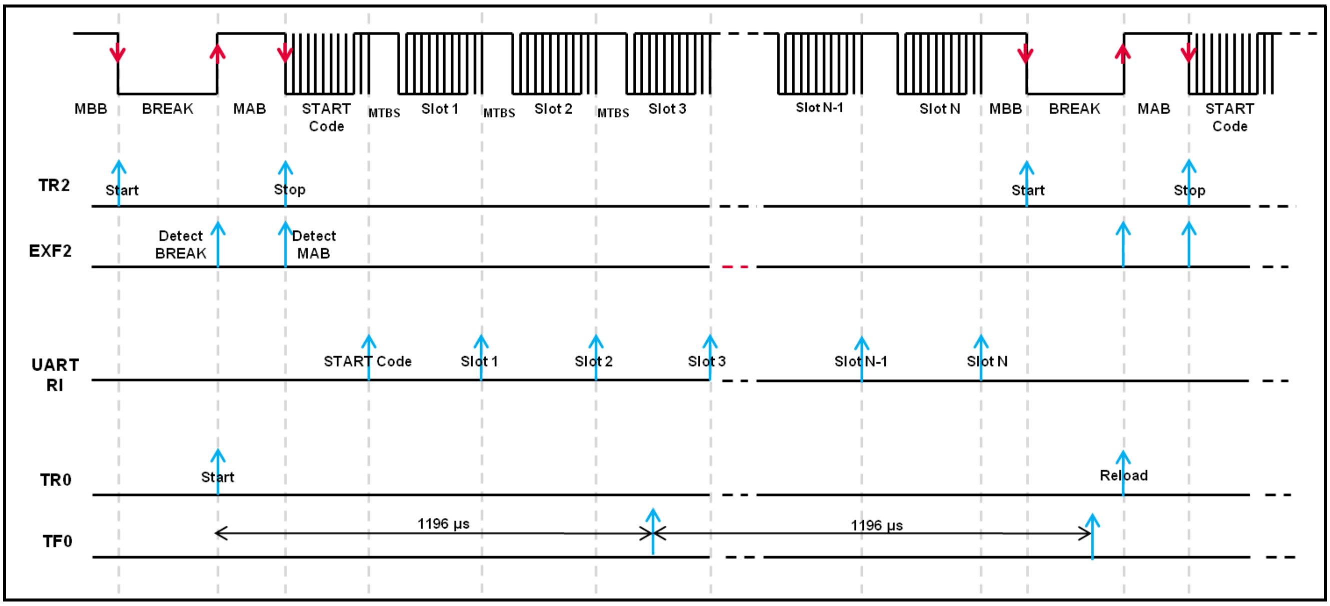


Figure 10 Interrupt Timing Diagram

The verified slots will be passed on to the application code, which updates the CCU6 duty cycle registers with the verified slots at a regular interval.

3.2.3 List of Source Code Files

The source code files used in the software stack are summarized in the following **Table 3**.

Table 3 List of Source Code Files for DMX512 Software Stack

Code Name	Description
DMX512_CONFIG.H	Contains Software Stack Defines and Configuration, e.g. DMX512 pin, RS485 Receive Enable pin, number of required slots, etc.
MAIN.C	Contains hardware peripherals initialization, Valid Addres Check code and sample of application code.
T2.C	Timer 2 initialization and Timer 2 External Interrupt subroutine (EXF2 flag) to detect BREAK and MAB.
UART.C	UART Initialization, the interrupt subroutine (RI flag) to detect START code and slots, reset sequence and Packet Length Check code.
T01.C	Timer 0 initialization and ISR to check for valid BREAK to BREAK time and Packet Loss Handling code.
IO.C	GPIO initialization for the software stack. It follows the assigned DMX512 pin in the DMX512_CONFIG.H
CC6.C	CCU6 peripheral initialization.

3.2.4 Recommended DMX512 Signal Characteristics

The following **Table 4** describes the recommended signal characteristics of the incoming DMX512 packet for the implemented software stack.

Table 4 Recommended DMX512 Signal Characteristics

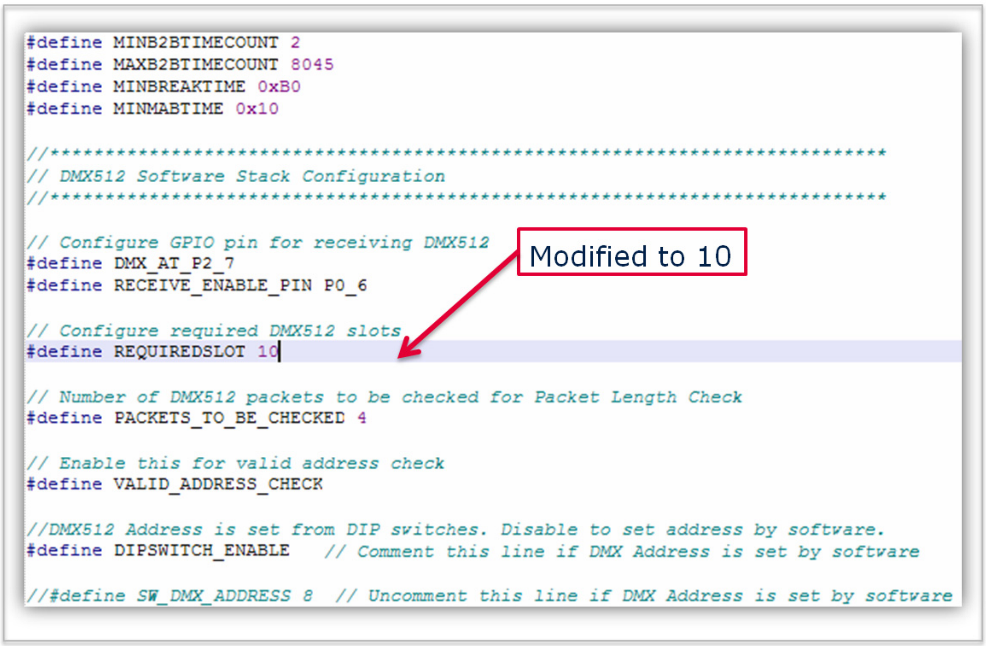
Signal	Recommended Value
Bit Rate	250 kbps
Bit Time	4 µs
BREAK	> 92 µs
MAB	> 12 µs
MTBS	> 8 µs
MBB	> 13 µs
BREAK-to-BREAK	> 1204 µs

4 DMX512 Software Stack Configuration

This chapter describes the configuration of the implemented software stack. All the settings can be found in DMX512_Config.h

4.1 Configuring the Required DMX512 Slots

For an RGB color control application, there are at least three required DMX512 slots. Some other applications may require a different number of slots. When this software stack is used for such applications, it can be configured to receive a different number of slots, as shown in **Figure 11** below.



```
#define MINB2BTIMECOUNT 2
#define MAXB2BTIMECOUNT 8045
#define MINBREAKTIME 0xB0
#define MINMABTIME 0x10

//**************************************************************************
// DMX512 Software Stack Configuration
//**************************************************************************

// Configure GPIO pin for receiving DMX512
#define DMX_AT_P2_7
#define RECEIVE_ENABLE_PIN P0_6

// Configure required DMX512 slots
#define REQUIREDSLOT 10

// Number of DMX512 packets to be checked for Packet Length Check
#define PACKETS_TO_BE_CHECKED 4

// Enable this for valid address check
#define VALID_ADDRESS_CHECK

//DMX512 Address is set from DIP switches. Disable to set address by software.
#define DIPSWITCH_ENABLE   // Comment this line if DMX Address is set by software

//#define SW_DMX_ADDRESS 8  // Uncomment this line if DMX Address is set by software
```


Figure 11 Configuring Required DMX512 Slots

4.2 Alternative Pinouts

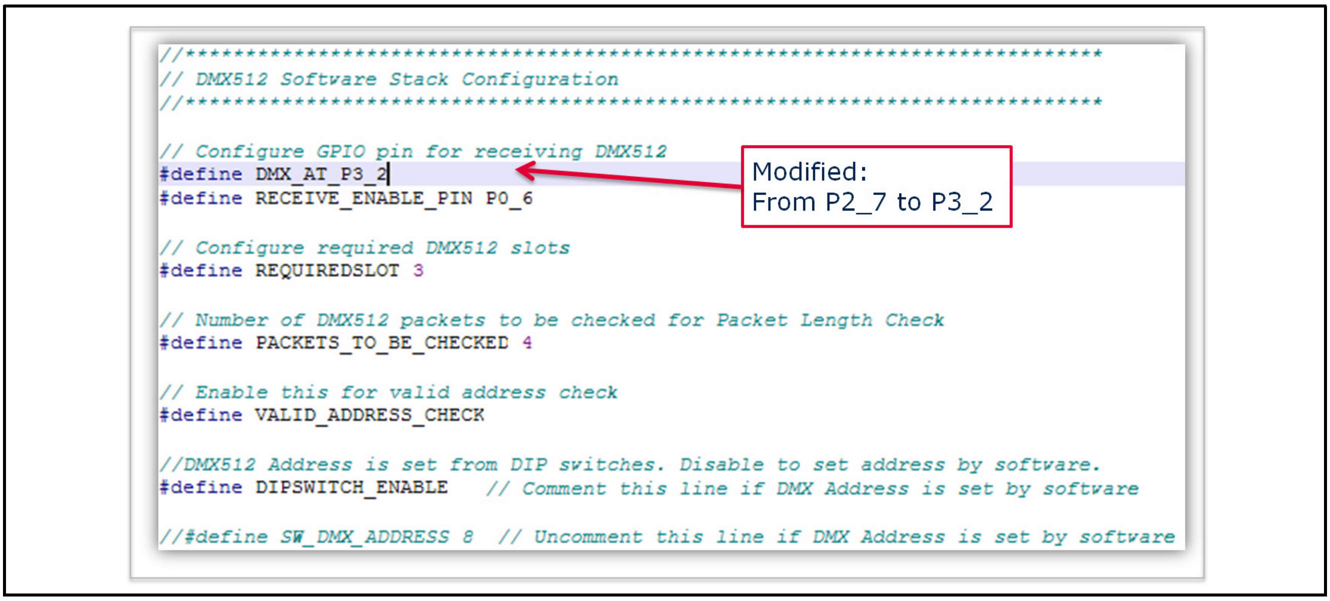
The implemented DMX512 software stack is designed to be portable across the XC800 microcontroller family and offers alternative pinouts, as shown in **Table 5** below.

Table 5 Alternative Pinouts for Various XC800 Devices

Device	Pin #
XC82x	P1.0
XC835	P1.0, P3.2
XC836	P1.0, P3.2, P2.7

The DMX512 pinout can be changed in DMX512_Config.h by typing the desired pinout after #define DMX_AT_P2_7 to another pinout.

The following **Figure 12** shows an example where the user changes the DMX512 pin to P3.2.



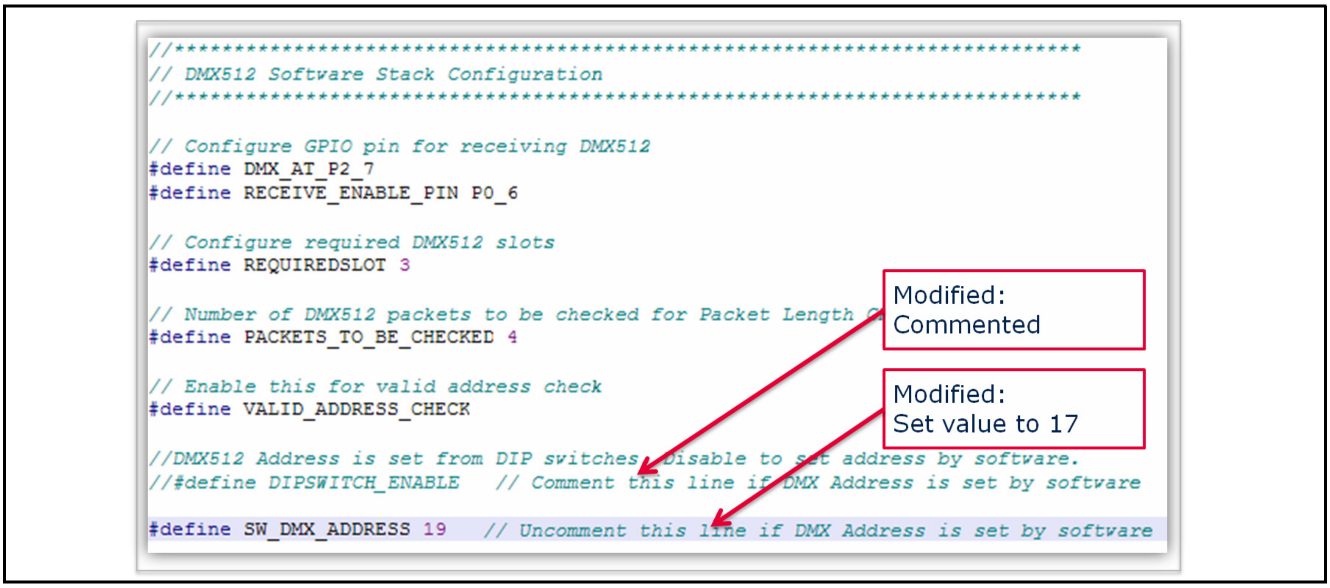
```
//****************************************************************************
// DMX512 Software Stack Configuration
//****************************************************************************

// Configure GPIO pin for receiving DMX512
#define DMX_AT_P3_2
#define RECEIVE_ENABLE_PIN P0_6

// Configure required DMX512 slots
#define REQUIREDSLOT 3

// Number of DMX512 packets to be checked for Packet Length Check
#define PACKETS_TO_BE_CHECKED 4

// Enable this for valid address check
#define VALID_ADDRESS_CHECK

//DMX512 Address is set from DIP switches. Disable to set address by software.
#define DIPSWITCH_ENABLE   // Comment this line if DMX Address is set by software

//#define SW_DMX_ADDRESS 8  // Uncomment this line if DMX Address is set by software
```


Figure 12 DMX512 Software Stack Configuration in DMX512_Config.h

When using P3.2 as the DMX512 pin, the SPD pin must be assigned to another pin. Refer to AP08108 for programming the BMI value in the XC82x and XC83x devices.

4.3 DMX512 Address Setting by Software

The implemented DALI-DMX512 board supports an address range from 1 to 16. The address of the receiving device can be set by software, by commenting the #define DIPSWITCH_ENABLE in DMX512_Config.h, then uncommenting the #define SW_DMX_ADDRESS and adding the desired address, as shown in the **Figure 13**:



```
//****************************************************************************
// DMX512 Software Stack Configuration
//****************************************************************************

// Configure GPIO pin for receiving DMX512
#define DMX_AT_P2_7
#define RECEIVE_ENABLE_PIN P0_6

// Configure required DMX512 slots
#define REQUIREDSLOT 3

// Number of DMX512 packets to be checked for Packet Length C
#define PACKETS_TO_BE_CHECKED 4

// Enable this for valid address check
#define VALID_ADDRESS_CHECK

//DMX512 Address is set from DIP switches. Disable to set address by software.
//#define DIPSWITCH_ENABLE   // Comment this line if DMX Address is set by software

#define SW_DMX_ADDRESS 19   // Uncomment this line if DMX Address is set by software
```


Figure 13 DMX512 Address Setting by Software

5 Evaluating DALI - DMX512 Board for LED Color Control Application

The DALI-DMX512 Board from Infineon is a receiving or slave device that contains the two common lighting protocols, DALI and DMX512. The board is designed to demonstrate an LED Color Control application on both protocols. This chapter is intended as a step-by-step guide for users to evaluate this board.

5.1 Connecting the Boards in a Daisy-Chain

A simple twisted pair of shielded wires can be used to connect the boards. The diagram inserted in the top-left of the following **Figure 14** shows the wiring connection.

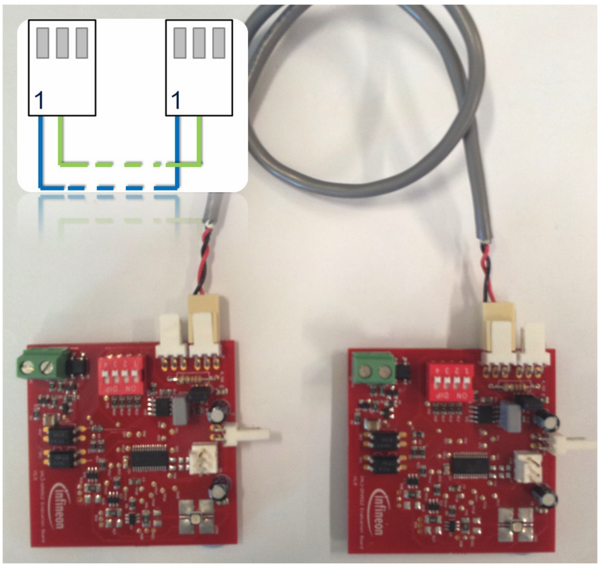


Figure 14 Two Boards connected in Daisy Chain

5.2 Setting the DMX512 Address with DIP switches

In a typical DMX512 device, the user can set the DMX512 address using DIP switch, where DIP switch #4 refers to the Least Significant Bit (LSB) of the address. The following **Figure 15** shows an example where the board is set to Address 11.

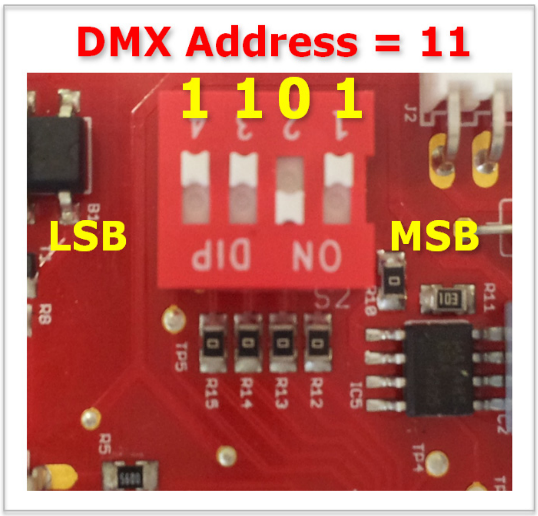


Figure 15 Setting DMX512 Address to 4

5.3 Connecting the Transmitting Device to the Daisy Chain

Once the address of each board is set, the transmitting device can be connected as shown in **Figure 16**.

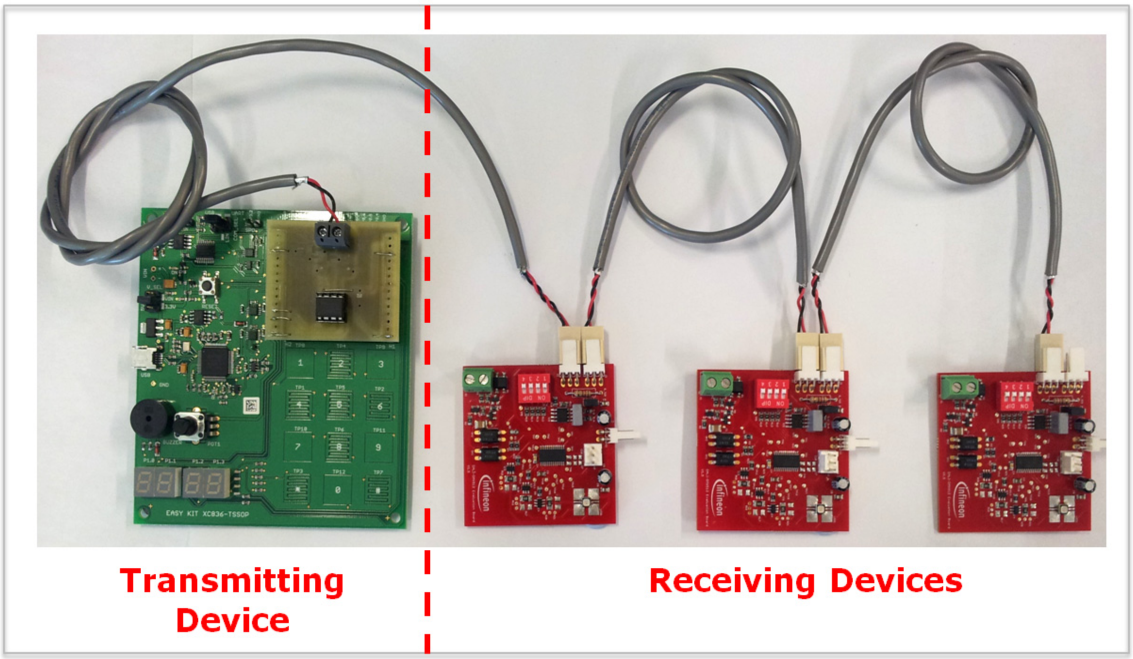


Figure 16 Connecting Transmitting Device with Receiving Devices

5.4 Powering Up the Receiving Devices

Figure 17 shows the receiving devices being powered up from 5V power supply with on-board LED turned on.

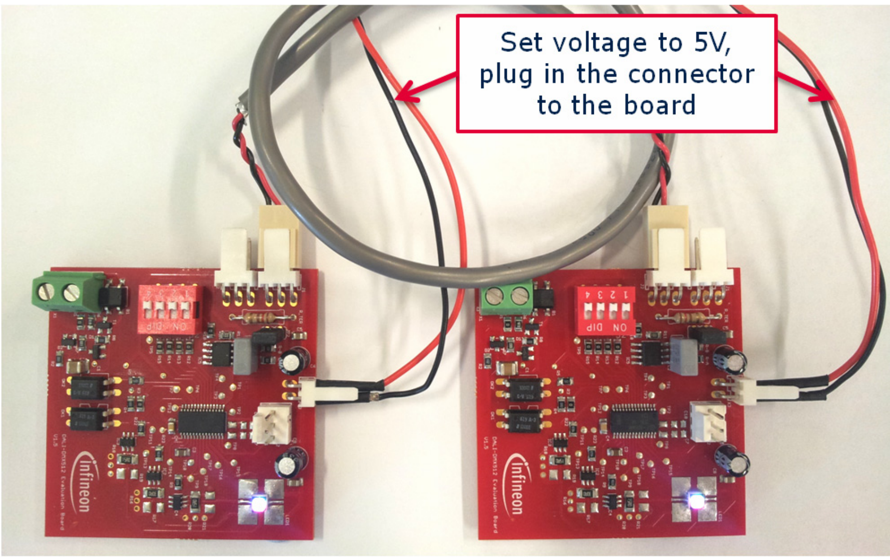


Figure 17 Powering the Receiving Devices

5.5 Powering Up the Transmitting Device from USB

The transmitting device requires 5V DC and is powered from USB, as shown in **Figure 18**.

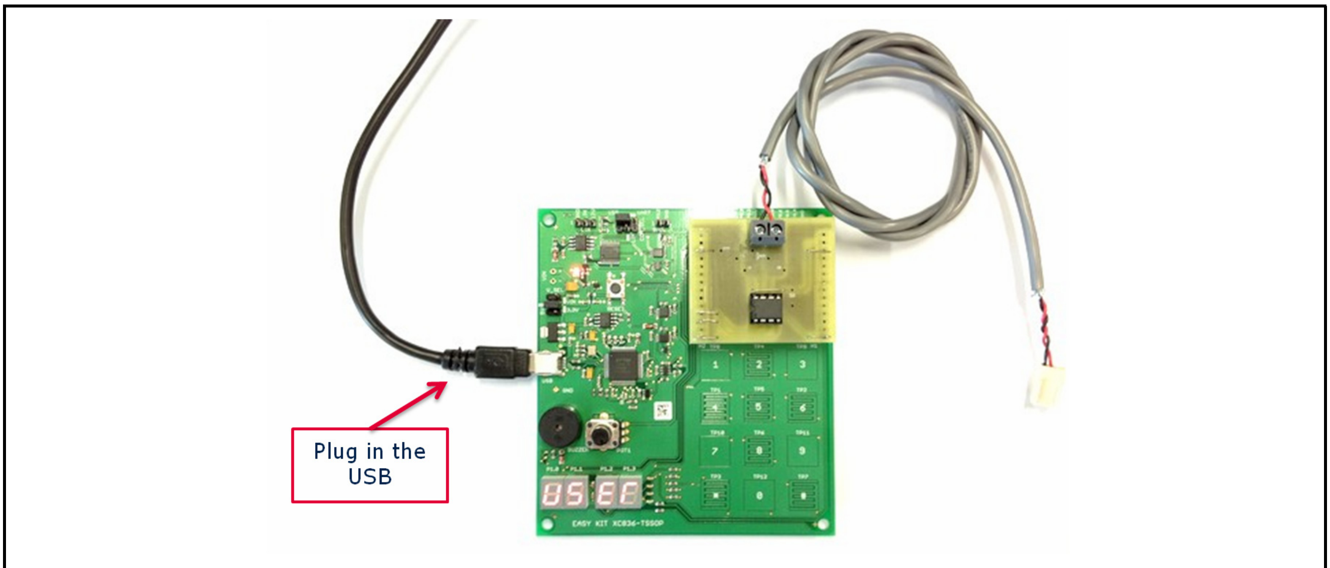


Figure 18 Powering the Transmitting Device via USB

5.6 Controlling LED Color with the Transmitting Device

Figure 19 and **Figure 20** show the touch pads and the 7-segment LED display functions on the transmitting device.

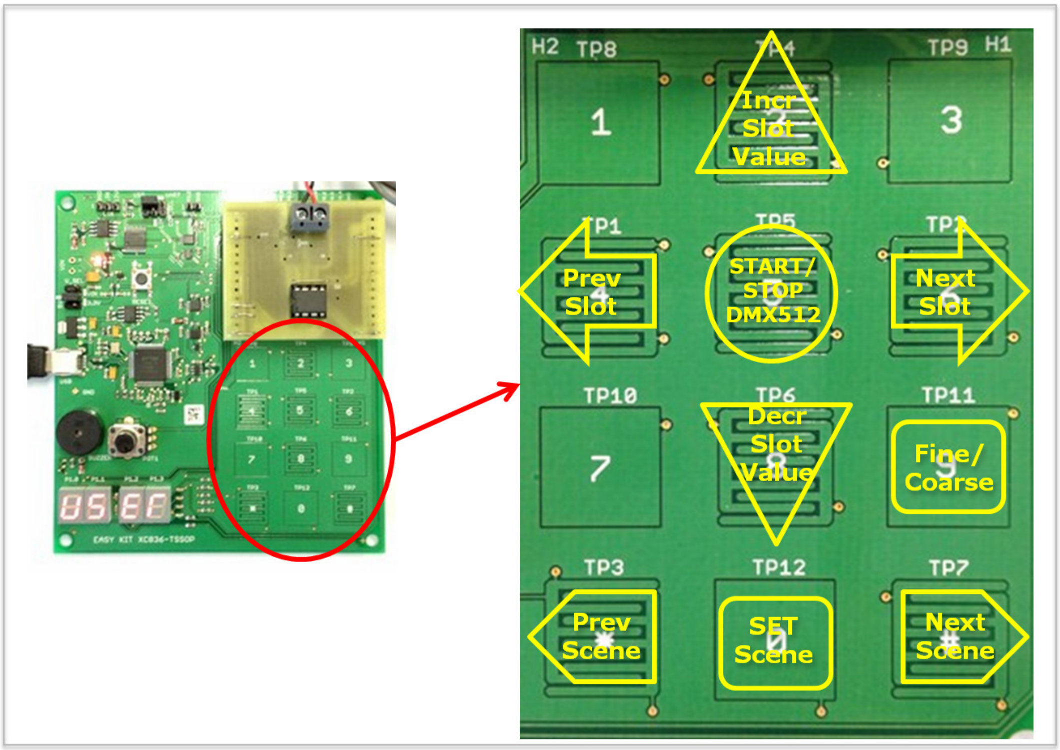


Figure 19 XC836 Easy Kit Touch Pads

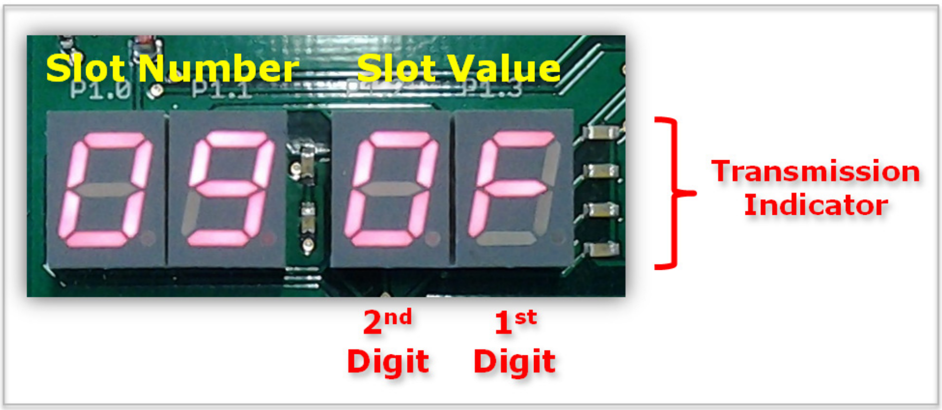


Figure 20 7-Segment LED display functions

The LED to indicate transmission will only light up when there is a DMX512 signal transmission.

The following **Table 6** describes the functionality of each touch pad.

Table 6 Touchpad Descriptions

Touchpad Name	Value Range	Description
Next Address	0 - 24[DEC]	Go to next/previous slot address. For demonstration purposes, only 24 slots are supported by the transmitting device.
Prev Address		
Incr Slot Value	0 - FF [HEX]	Increase/Decrease current slot values. The value is represented as hexadecimal.
Decr Slot Value		
Fine/Coarse	-	Adjust the resolution of Incr/Decr Slot Value. Selecting Coarse Mode will modify the 2nd digit of Slot Value while Fine Mode will modify the 1st digit of the Slot Value. Default mode is Coarse Mode.
START/STOP DMX512	-	Start/Stop DMX512 Transmission
Next Scene	0 - 99 [DEC]	Go to the next/previous predefined scene.
Prev Scene		
Set Scene	-	Set the selected scene to the receiving devices. Pressing this button will automatically enable the DMX512 transmission.

The following **Figure 21** shows the complete setup of DMX512 system for RGB-LED color control application.

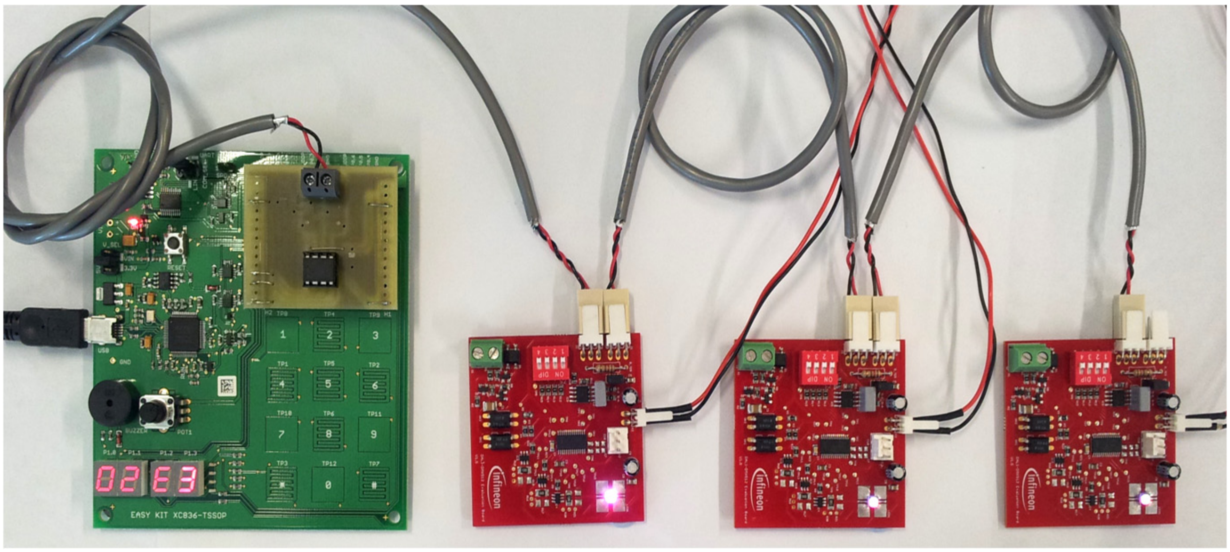


Figure 21 Complete Setup of DMX512 System

The user can now control the LED color on each board from the transmitting device. For example, when the slot value of address 04 is increased, the second board will display brighter red, while increasing the slot value of address 08 will make the third board display brighter green. For more information on the transmitting device, please refer to Application Note AP08132.

6 Enhancement Features

The following features are implemented to enhance the reliability of the software stack while still complying with the DMX512 standard.

6.1 Packet Length Check

The standard never specifies the minimum number of slots that must be transmitted, therefore it is common to find some devices transmitting less than 512 slots. An error may be introduced to the receiving devices when the sum of its assigned address and the number of required slots exceed the packet length. For example, a receiving device with the address of 29 which requires 3 slots may have an error if the packet sent by the transmitting device has only 30 slots. The receiving device will not be able to obtain the data for its third slot (slot 31).

This feature is implemented to make the software stack able to recognize the packet length of incoming DMX512 and adjust itself accordingly. Users do not have to worry about the packet length sent by the transmitting device. Using the example above, the receiving device will turn itself off when it is unable to receive slot 31.

This feature works by sampling the packet length of the first few incoming packets. It will assign the maximum value from the samples as the new packet length. By default, only the first four packets will be sampled by the software stack. During this check, no data will be passed on to the application code. The subsequent packets having a shorter or longer length will be considered as an error and will be discarded.

User can increase the number of packets to be checked by changing the PACKET_TO_BE_CHECKED in DMX512_Config.h to more than four. Setting the value to 0 will make the software stack take the length of the first received packet as the default packet length.

When this feature is disabled, the default packet length will be assumed as 513, i.e. START Code + 512 Slots. Users, however, can define their own packet length by changing uwPacketLength value in MAIN.C, as shown in **Figure 23**.

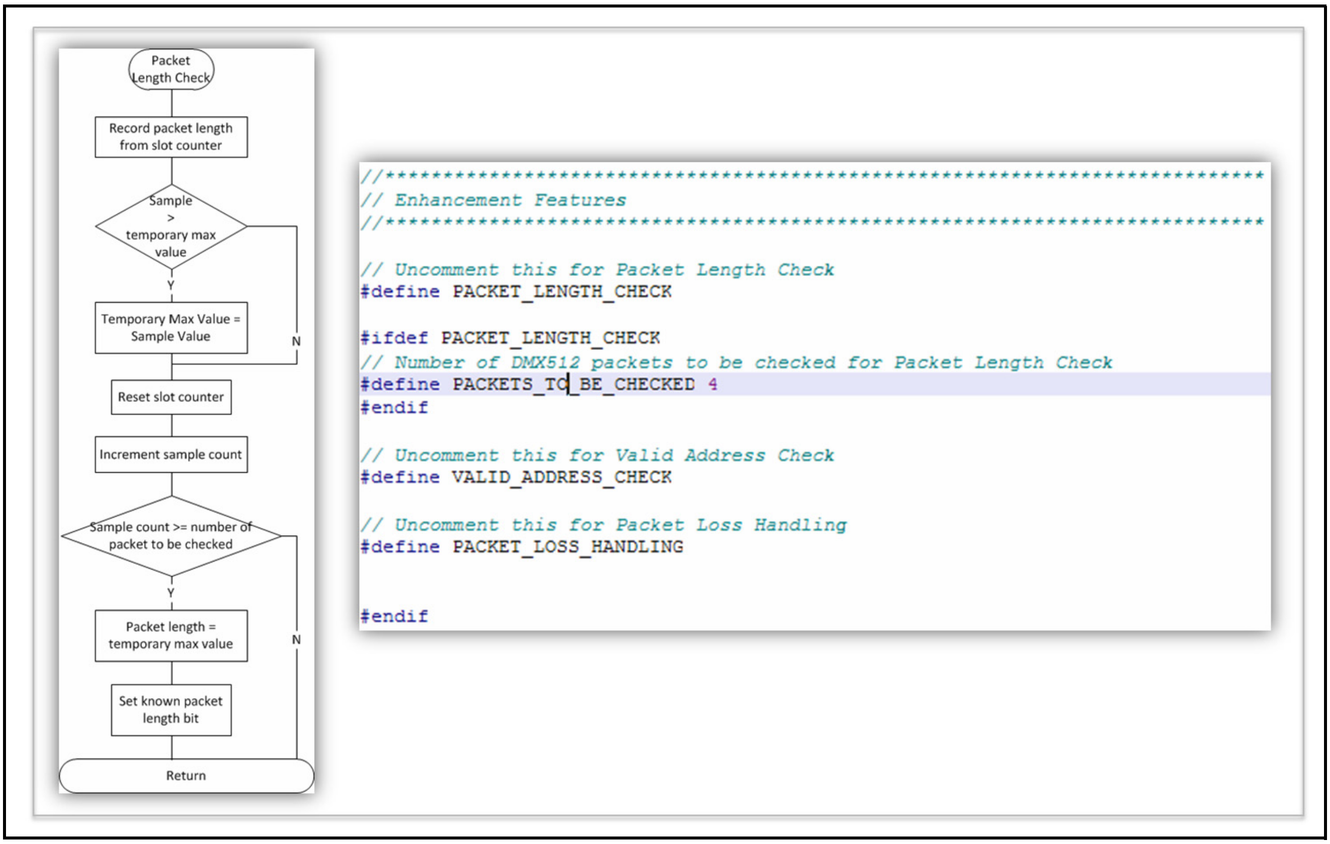


Figure 22 Packet Length Check Flowchart and its Code Snippet

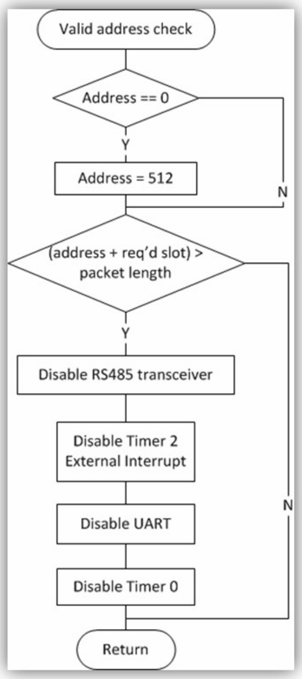
```c
#ifdef PACKET_LENGTH_CHECK
// Set default packet length as 514 (1 START Code + 512 Slots + 1 Offset for Packet Length Check)
uwPacketLength = 514;
#else
// User set their packet length here. Default = 513 (1 START Code + 512 Slots)
uwPacketLength = 513;

bKnownPacketLength = 1;
#endif
```

Figure 23 User-Defined Packet Length in MAIN.C

6.2 Valid Address Check

This feature is implemented to complement the Packet Length Check. After the packet length is known, it will check whether the sum of DMX512 address and the required slots exceed the packet length. For example, when a receiving device address is set to 30 while the received packet length is only 24, this will be recognized as an error, and all hardware peripherals (Timer 2, UART and Timer 0) and the RS485 transceiver will be switched off.

In addition, when using 9-bit DIP switches as the mean for DMX addressing, the maximum achievable address is only 511. On the other hand, when the DIP switches are not set, the receiving address will automatically be assigned to zero, the NULL START Code, which has no practical value for the receiving device. This feature will automatically set the address to 512 when the DIP switches are not set.




```c
//***************************************************************************
// Enhancement Features
//***************************************************************************

// Uncomment this for Packet Length Check
#define PACKET_LENGTH_CHECK

#ifdef PACKET_LENGTH_CHECK
// Number of DMX512 packets to be checked for Packet Length Check
#define PACKETS_TO_BE_CHECKED 4
#endif

// Uncomment this for Valid Address Check
#define VALID_ADDRESS_CHECK

// Uncomment this for Packet Loss Handling
#define PACKET_LOSS_HANDLING

#endif
```

Figure 24 Valid Address Check Flowchart and its Code Snippet

6.3 Packet Loss Handling

Packet loss may occur for several reasons, such as power failure at the transmitting device or because of a disconnected communication cable. When there is no DMX512 signal received after 9.6 secs, the DMX512 software stack is reset and waits for the incoming DMX512 signal while still retaining the data before the packet loss occured. The Packet Length Check feature will also reset to relearn the packet length.

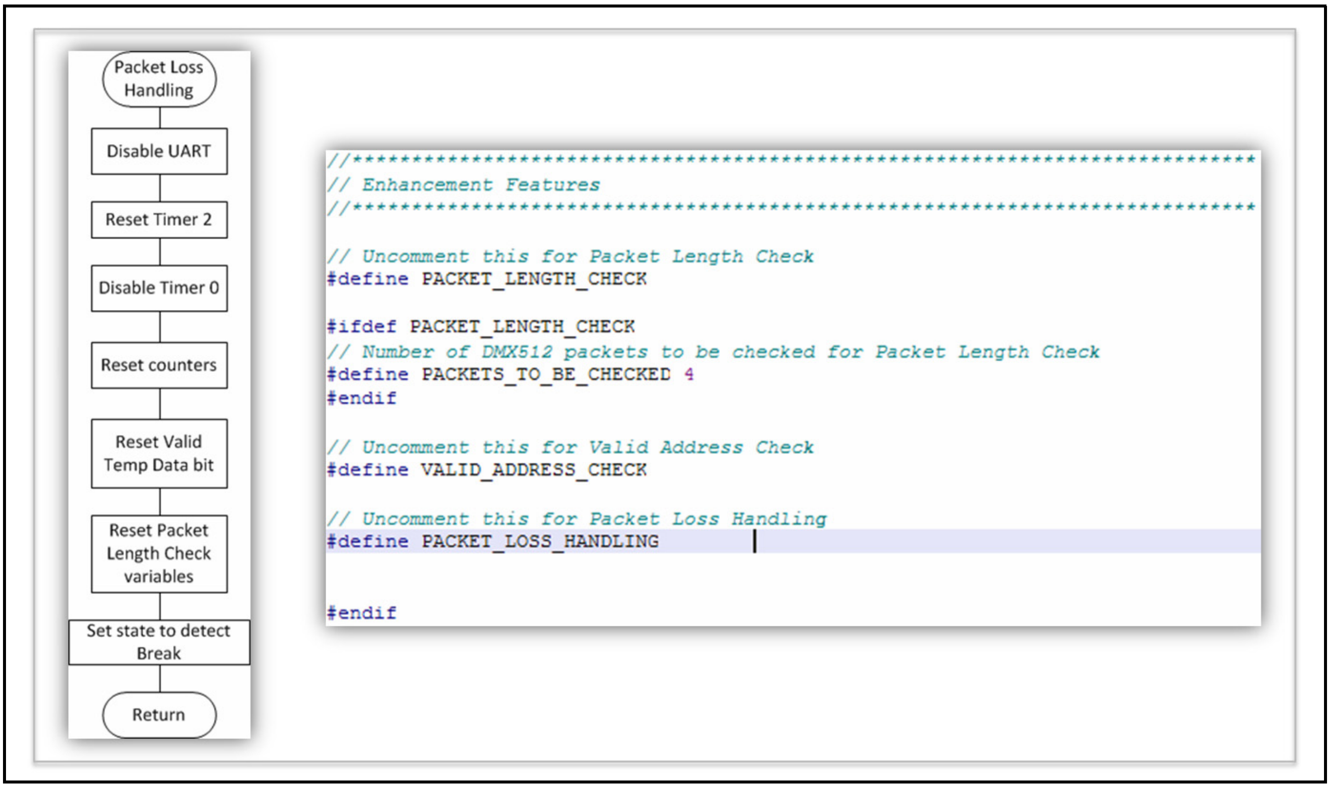


Figure 25 Packet Loss Handling Flowchart and its Code Snippet

7 Summary

This application note has described the DMX512 solution from Infineon implemented on the XC836, an 8051-based microcontroller. The DMX512 software stack is evaluated on an integrated DALI-DMX512 board, to also allow evaluation of the DALI protocol.

Unlike other implementations in the market, the software stack selectively receives and stores only relevant slots. This reduces the required memory size thus allowing for more complex application code. In addition, it is also implemented on a single pin which will reduce the pinout requirements. The software stack is portable to other XC800 devices and it also offers alternative pinouts.

Lastly, some additional features such as valid address check and packet length check are also implemented to increase the reliability of the software stack while maintaining compliance with the standard.

8 References

[1] ANSI ESTA E1.11 - 2008 “Asynchronous Serial Digital Data Transmission Standard for Controlling Lighting Equipment and Accessories”

[2] XC82x User Manual version 1.2

[3] XC83x User Manual version 1.1

[4] AP08108 “Programming the BMI Value in the XC82x and XC83x Products”

[5] AP08132 “DMX512 Transmitting Device using XC836”

[6] AP08102 “DALI Control Gear Software Stack”

[7] AP08114 “DALI Control Device using XC836”

[8] AP08104 “Guide to using the DALI LightNet Tool”

[9] AP08105 “DALI Demo using Touch Sense Control”

Appendix - DALI-DMX512 Board Schematic

Figure 26 and **Figure 27** show the schematic of DALI-DMX512 Board.

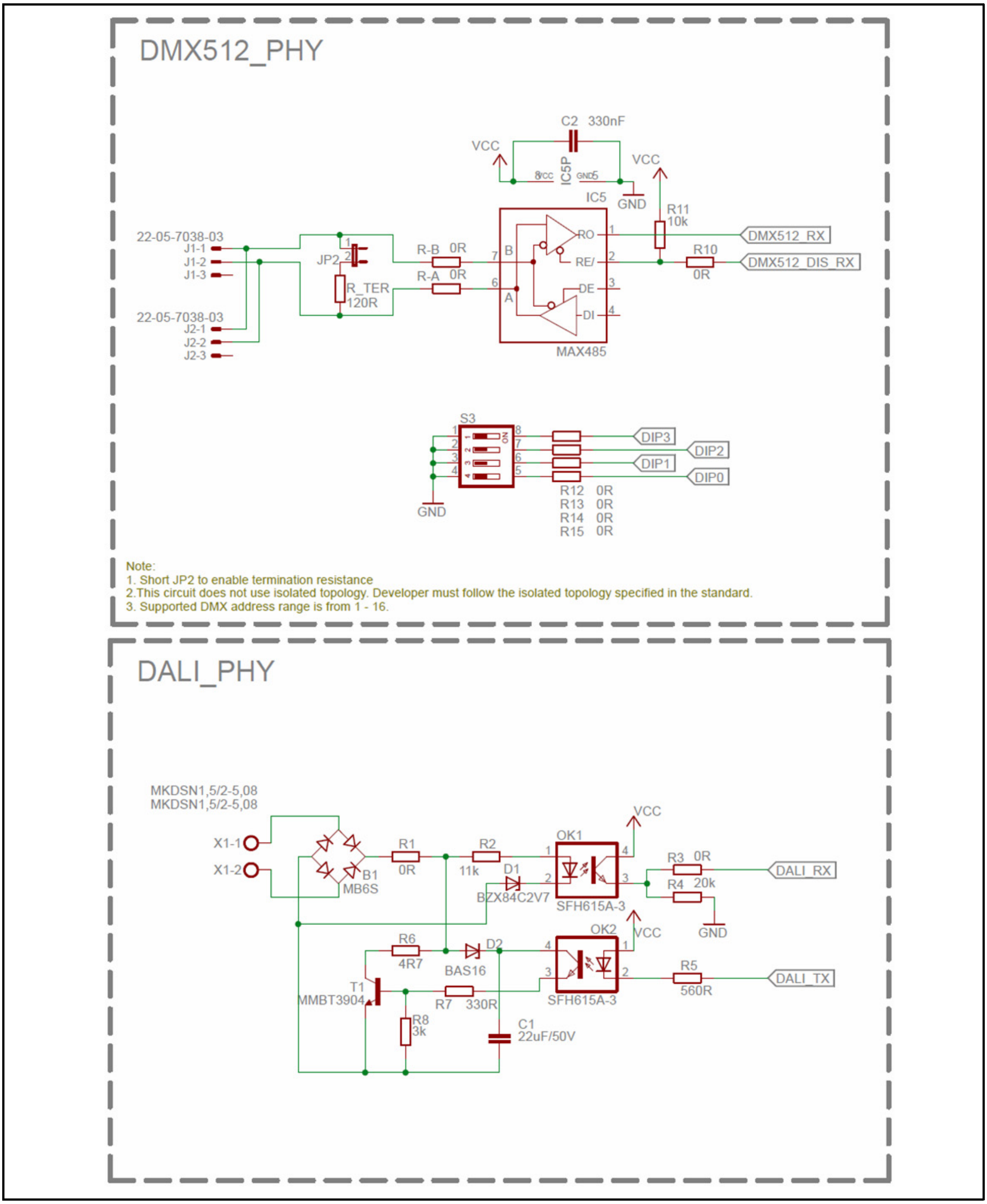


Figure 26 DALI-DMX512 Board Schematic - DALI/DMX512 PHY

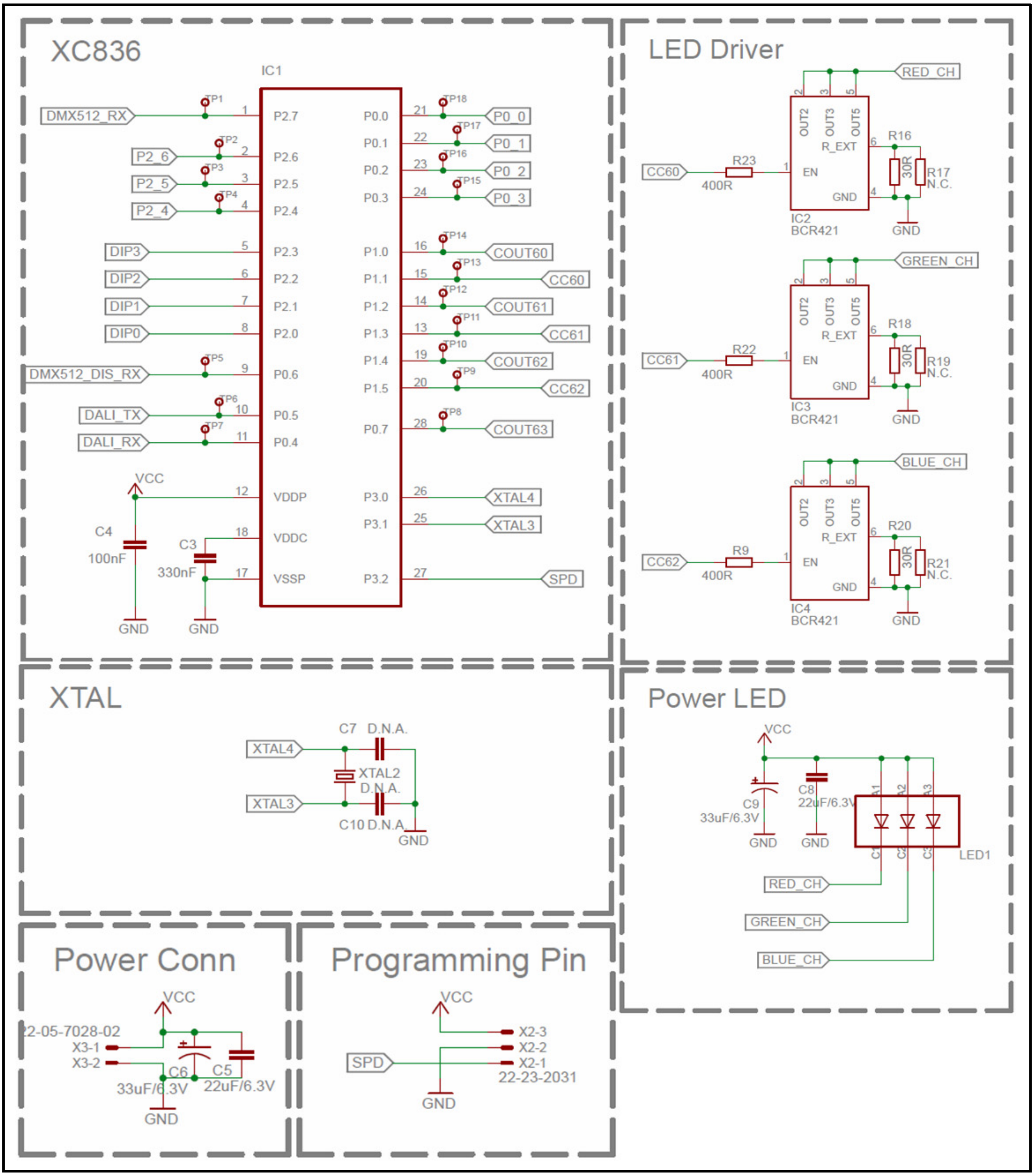


Figure 27 DALI-DMX512 Board Schematic - XC836 and RGB LED

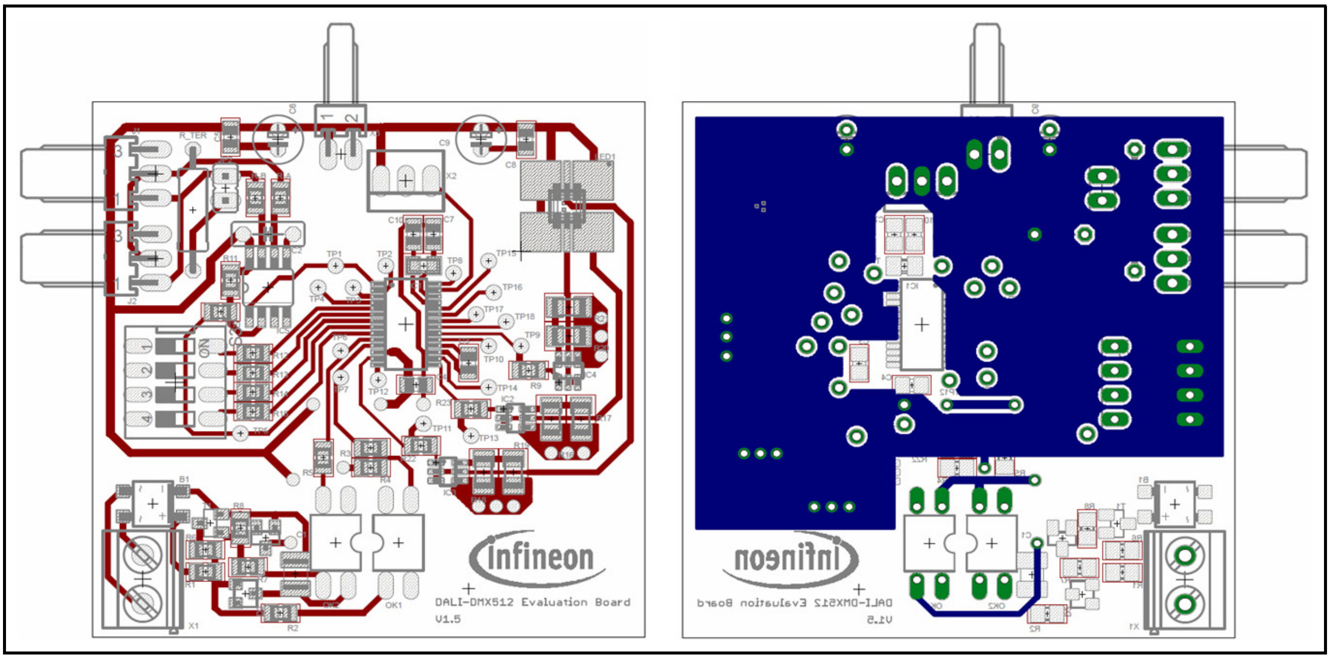


Figure 28 DALI-DMX512 Board Layout

Appendix - DMX512 Software Stack Flowchart

The following Figure 29, Figure 30 and Figure 31 shows the flowchart from each peripheral that is used to create the DMX512 software stack.

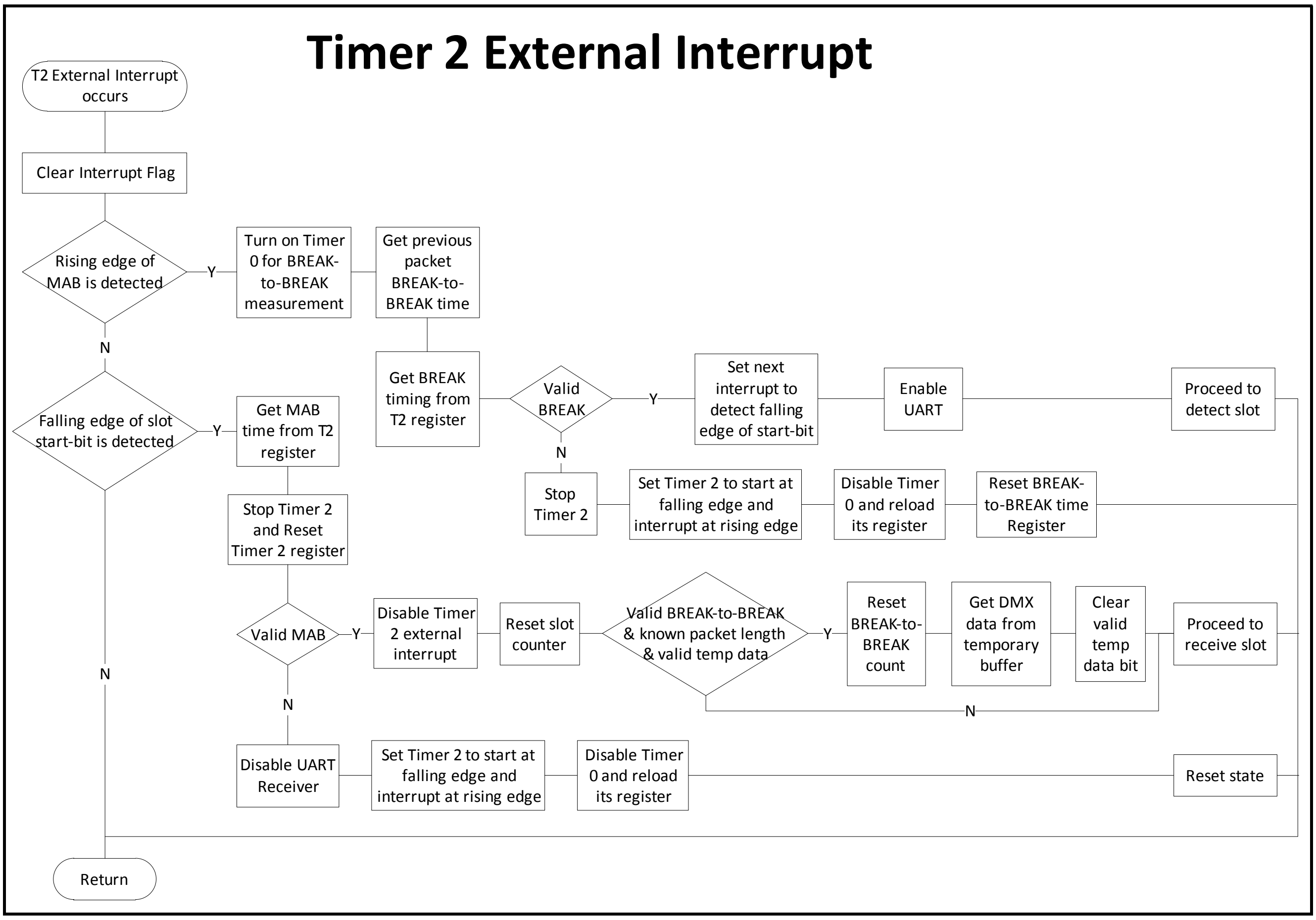


Figure 29 Timer 2 Flowchart

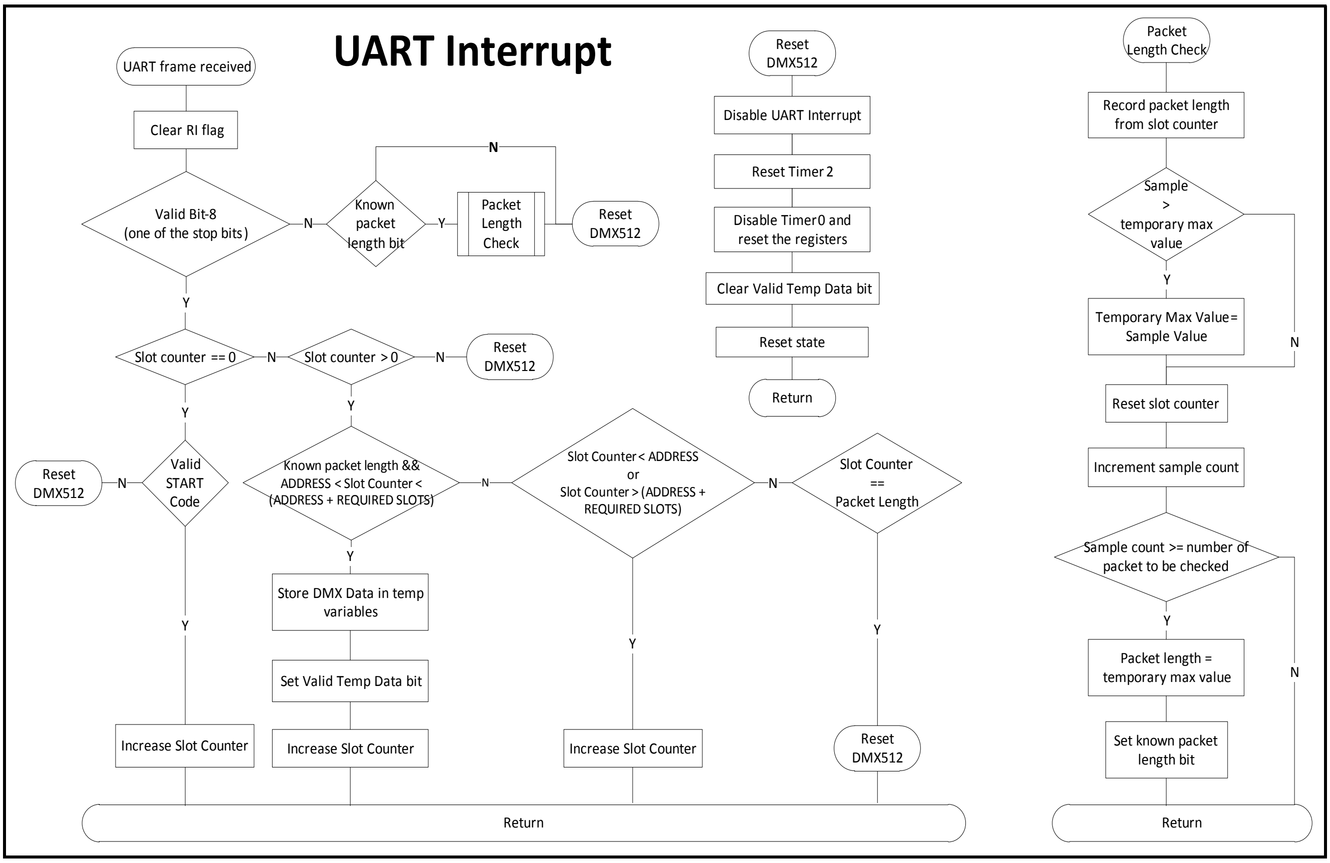


Figure 30 UART Flowchart

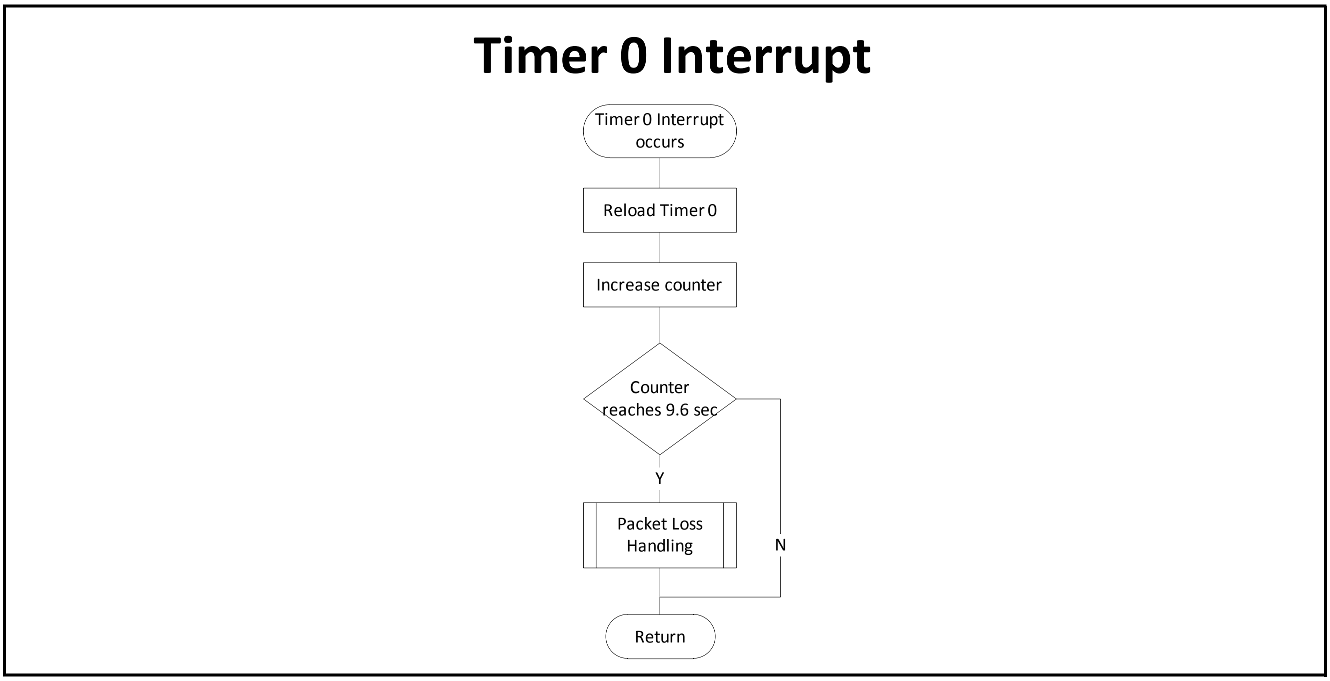


Figure 31 Timer 0 Flowchart

Appendix - Suggested Circuit to Fulfill Isolated Topology Requirement

As mentioned in **Section 2.2.2**, the standard requires all receiving devices to be implemented using isolated topology. The following **Figure 32** shows a suggested circuit using isolated topology for DMX512 Receiving Device.

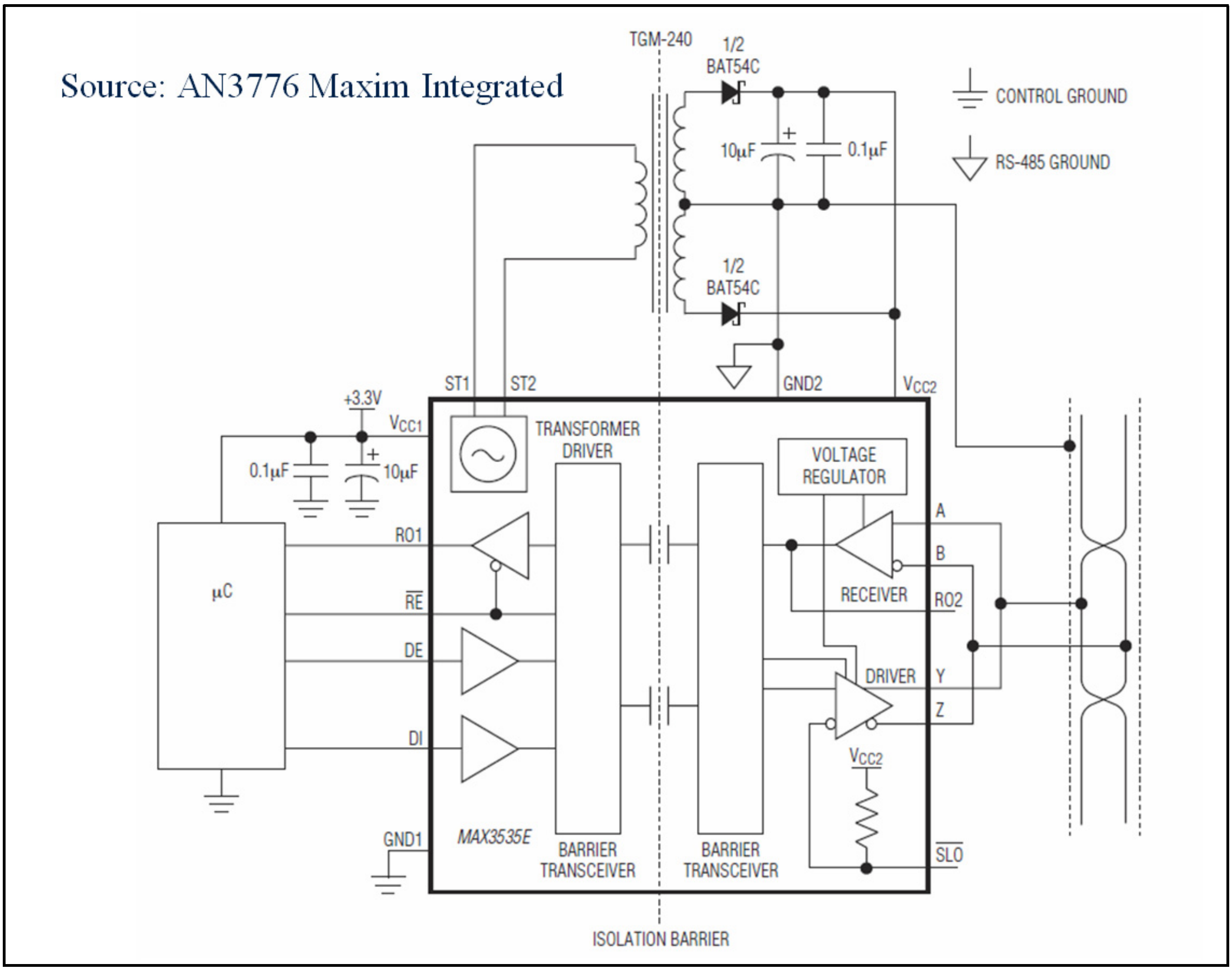


Figure 32 Suggested Isolated Circuit for DMX512 Receiving Device

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