Introduction

This document describes how to use the demonstration firmware for the DMX512 communication protocol for transmitter, receiver, and standalone mode. The USART (universal synchronous asynchronous receiver transmitter) module of the STM32F103C6 (ARM 32-bit Cortex™-M3) microcontroller is used to transmit/receive data via an RS-485 transceiver. This transmitter sends a DMX512 packet with “Null” start code, according to DMX512 2008 standard. The board contains the following:

- Microcontroller STM32F103C6
- USB protection device ESDAULC6-3BP6
- Voltage regulator LDS3985XX33
- RS485 communication IC, ST485AB
- Voltage protection device STBP120
- LED driver STCS1A

Figure 1. DMX based LED lighting solution
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1 Features

The DMX512 communication protocol has the following features:

- Option of configuring the board in transmitter, receiver, or standalone mode by just changing the jumpers J1, J2, J3, and J6
- STCS1A device for dimming control of the onboard LEDs
- Voltage protection device STBP120 for protecting the board from over- or undervoltage
- Advanced USB protection device ESDAULC6-3BP6
- Option of providing external power supply for Power LEDs or using 5 V power supply from the output of STBP120
- Potentiometer at the transmitter end provides the dimming data to be sent to onboard LEDs (standalone mode) or LEDs at the receiver end (in RS485 communication mode)
- Board running on internal clock source as a clock source (without using crystal)
- Mini-B USB connector can be used in transmitter, standalone, or receiver mode if power for LEDs is supplied separately from an external source. If USB is also used as a power source, then only a single LED can be driven for receiver and standalone mode.

This document includes the following:

- Block diagram overview of the complete solution
- STM32 demonstration firmware flow
- Schematics and layouts
2 Getting started

2.1 Package

The STEVAL-ILL030V1 demonstration board package includes the following items:

- Hardware content:
  - Demonstration board STEVAL-ILL030V1

- Documentation:
  - User manual (this document)
  - Schematics, Gerber files, BOM list

2.2 Setting up the board

- Settings for transmitter:
  - Place the jumper between 2 and 3 of J3 (mode select jumper)
  - Place the jumper between 1 and 2 of J1 (driver enable jumper)
  - Place the jumper between 1 and 2 of J2 (receiver enable jumper)
  - Leave the rest of the jumpers in open state

- Settings for receiver:
  - Place the jumper between 2 and 3 of J3 (mode select jumper)
  - Place the jumper between 2 and 3 of J1 (driver enable jumper)
  - Place the jumper between 2 and 3 of J2 (receiver enable jumper)
  - Place the jumper between 1 and 2 of J6 only at the receiver at the farthest end, otherwise place between 2 and 3
  - Leave the rest of the jumpers in open state

- Settings for standalone mode:
  - Place the jumper between 1 and 2 of J3 (mode select jumper)
  - Leave the rest of the jumpers in open state

- Settings for shutdown mode:
  - Place the jumper between 2 and 3 of J1 (driver enable jumper)
  - Place the jumper between 1 and 2 of J2 (receiver enable jumper).

If the board is in running condition and the user wants to change the communication mode, then change the jumper position in the order as specified above. There is no need to reset the board. In shutdown mode, ST485AB enters shutdown mode and stops consuming power.
2.3 Hardware layout

Figure 2. Top layer layout
3 DMX512 communication protocol

3.1 DMX512 packet format

DMX512 slots are transmitted sequentially in asynchronous serial format, beginning with slot 0 and ending with the last implemented slot, up to slot 512 (a maximum of 513 slots). Prior to the first data slot being transmitted, a reset sequence is transmitted - a break, followed by a mark after break, and a start code. Valid DMX512 data slot values under a null start code are from 0 to 255 decimal.

Figure 3. Timing diagram for DMX512 packet

Each listed point describes the numbers shown in Figure 3:
1. Space for break
2. Mark after break
3. Slot time
4. Start time
5. Least significant data bit
6. Most significant data bit
7. Stop bit
8. Stop bit
9. Mark time between slots
10. Mark before break
11. Break to break time
12. Reset sequence
13. DMX512 packet
14. Start code (slot 0, data)
15. Slot 1, data
16. Slot n, data (max 512)
3.2 DMX512 transmitter timing values

The transmitter follows the timing values as given in Table 1.

Table 1. Timing values of DMX512 packet transmitted

<table>
<thead>
<tr>
<th>Description</th>
<th>Min</th>
<th>Typical</th>
<th>Max</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bit rate</td>
<td>245</td>
<td>250</td>
<td>255</td>
<td>kbps</td>
</tr>
<tr>
<td>Bit time</td>
<td>3.92</td>
<td>4</td>
<td>4.08</td>
<td>µs</td>
</tr>
<tr>
<td>Minimum update time for 513 slots</td>
<td>-</td>
<td>22.7</td>
<td>-</td>
<td>ms</td>
</tr>
<tr>
<td>Maximum refresh rate for 513 slots</td>
<td>-</td>
<td>44</td>
<td>-</td>
<td>µs</td>
</tr>
<tr>
<td>“Space” for break</td>
<td>92</td>
<td>176</td>
<td>-</td>
<td>µs</td>
</tr>
<tr>
<td>“Mark” after break (MAB)</td>
<td>12</td>
<td>-</td>
<td>&lt;1.00</td>
<td>µs/s</td>
</tr>
<tr>
<td>“Mark” time between slots</td>
<td>0</td>
<td>-</td>
<td>&lt;1.00</td>
<td>s</td>
</tr>
<tr>
<td>“Mark” before break (MBB)</td>
<td>0</td>
<td>-</td>
<td>&lt;1.00</td>
<td>s</td>
</tr>
<tr>
<td>Break to break time</td>
<td>1204</td>
<td>-</td>
<td>1.00</td>
<td>µs</td>
</tr>
<tr>
<td>DMX512 packet</td>
<td>1204</td>
<td>-</td>
<td>1.00</td>
<td>µs</td>
</tr>
</tbody>
</table>

3.3 DMX512-A receiver timing values

The receiver accepts the data only if all the timing values given in Table 2 are followed.

Table 2. Timing values of DMX512 packet received

<table>
<thead>
<tr>
<th>Description</th>
<th>Min</th>
<th>Typical</th>
<th>Max</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bit rate</td>
<td>245</td>
<td>250</td>
<td>255</td>
<td>Kbps</td>
</tr>
<tr>
<td>Bit time</td>
<td>3.92</td>
<td>4</td>
<td>4.08</td>
<td>µs</td>
</tr>
<tr>
<td>Minimum update time for 513 slots</td>
<td>-</td>
<td>22.7</td>
<td>-</td>
<td>ms</td>
</tr>
<tr>
<td>Maximum refresh rate for 513 slots</td>
<td>-</td>
<td>44</td>
<td>-</td>
<td>µs</td>
</tr>
<tr>
<td>“Space” for break</td>
<td>88</td>
<td>176</td>
<td>-</td>
<td>µs</td>
</tr>
<tr>
<td>“Mark” after break (MAB)</td>
<td>8</td>
<td>-</td>
<td>&lt;1.00</td>
<td>µs/s</td>
</tr>
<tr>
<td>“Mark” time between slots</td>
<td>0</td>
<td>-</td>
<td>&lt;1.00</td>
<td>s</td>
</tr>
<tr>
<td>“Mark” before break (MBB)</td>
<td>0</td>
<td>-</td>
<td>&lt;1.00</td>
<td>s</td>
</tr>
<tr>
<td>Break to break time</td>
<td>1196</td>
<td>-</td>
<td>1.25</td>
<td>µs</td>
</tr>
<tr>
<td>DMX512 packet</td>
<td>1196</td>
<td>-</td>
<td>1.25</td>
<td>µs</td>
</tr>
</tbody>
</table>
4 DMX512 transmitter

4.1 DMX512 transmitter system

Figure 4 represents a typical DMX512 system.

- The multiple receivers are connected to the DMX host in a daisy-chain manner and every packet goes through every receiver in its entirety.
- The controller sends the packet to the RS485 transceiver, which transmits the corresponding differential signal to the DMX512 receiver.
- The transmitter sends the dimming potentiometer's data in the slot number as specified by the DIP switch of the transmitter.
- Each receiver checks its own address using the DIP switch mounted on it and processes data present in that particular slot number only.
- The transmitter is programmed with the number of bytes to be transmitted in each packet.

Figure 4. Typical DMX512 transmitter system

![Diagram of DMX512 transmitter system]

Figure 5. Typical DMX512 transmitter circuit

![Diagram of DMX512 transmitter circuit]
4.2 DMX512 transmitter block diagram

The block diagram of the DMX512 controller transmitter is shown in Figure 6. The signals are transmitted with the use of USART_Tx and an I/O pin. It is necessary to send a break signal at the beginning of each new packet of data. The break signal allows receivers to synchronize with the DMX transmitter. The USART module available on STM32 microcontrollers has the ability to automatically generate a 12-bit long break signal, corresponding to 48 µsec at 250 k baud. Unfortunately, this is too short for use in a DMX512 application as the protocol requires a minimum length of 92 µsec.

Figure 6 shows the alternative hardware method chosen to generate the longer break signal. A 100 Ω resistor is connected in series with the microcontroller’s USART transmit pin and the other end of the resistor to an I/O pin. With this solution, the break time can be varied, from 92 µsec to 176 µsec to meet the DMX protocol break time specification, when sending a break signal, the I/O pin is driven low. Later, the I/O pin is tri-stated to allow transmission from the USART to resume.

The dimming data is 8-bits wide, where '0' represents a light off and '255' represent full intensity. To generate the two stop bits required by the DMX512 protocol, the STM32 USART is configured for 8-bit mode.

The dimming data is stored in a 512-byte buffer (TX buffer), allocated to the RAM memory. The data is written to or read from the buffer using the indirect addressing registers available on the microcontroller architecture for linear memory access.

A counter keeps track of the number of bytes transmitted from the buffer. There are 512 data slots (max possible) in this case. The potentiometer is connected to channel_5 of ADC1. As ADC is 12-bit ADC, the data read from the potentiometer is 12-bit data, so for converting into 8-bit data, the data is shifted 4 bits to the right.

Figure 6. Block diagram of single DMX512 receiver

![Block diagram of single DMX512 receiver](image)
4.3 MCU block diagram

A connection to the STM32F10E-EVAL board is shown in Figure 7:

Figure 7. MCU block diagram

USART_Tx pin (PA9) is connected to PA4 through 100 Ω resistance. PA4 is connected to RS485_Tx of the RS485 transceiver board:

- PA4 is configured as push-pull low for sending a break signal with a specified duration and is then configured in tri-stated mode
- The break signal time is defined by TIM2
- The USART_Tx pin (PA9) is used for sending start code and data
- Mark time between slots is defined by TIM3
- PA5 is configured as analog input and ADC1 is configured as scan with continuous conversion mode. DMA is used for getting the analog converted data directly into the internal RAM.
4.4 Flowchart of firmware

4.4.1 Main routine

Figure 8. Main routine flow chart

START

Configure the Microcontroller

Configure the USART at baud rate of 250kbps

Configure the Timer2 for generating reset sequence and enable interrupt for CC1 and update event. Timer3 in the OC mode for generating mark time between slots and enable update interrupt

Configure the ADC1 with DMA for reading potentiometer value to control the dimming values to be sent

Send reset sequence (Configure PA4 push-pull IO low and enable TIM2)

Delay added to get the required Break to Break time

Send reset sequence and update dimming data from potentiometers in the array location as specified by DIP Switch
4.4.2 Timer2 interrupt routine

Figure 9. Timer2 interrupt flow chart

1. Clear update and CC1 interrupt
2. Is TIM2 update interrupt?
   - No
   - Yes
3. Disable TIM2 and reset counter
4. Configure PA4 in floating mode
5. Send null start code
6. Enable TIM3
7. End
4.4.3 Timer3 interrupt routine

Figure 10. Timer3 interrupt routine

- Clear update interrupt
- Is no. of bytes sent $\leq 512$?
  - Yes: Send data
  - No: Disable TIM3
- Increment byte counter
- End
5 DMX512 receiver

5.1 DMX512 receiver system

*Figure 11* represents a typical DMX512 system.

- The multiple receivers are connected to the DMX host in a daisy-chain manner and every packet goes through every receiver in its entirety.
- At each receiver, the differential signal is received by an RS485 transceiver and given to the receive side controller.
- Each receiver is programmed with a specific slot address so it knows which slot it has to extract from each packet.

*Figure 11. Typical DMX512 receiver system*

- There should be only one terminating resistance with a set of receivers and that terminating resistance should be connected with the farthest receiver from the transmitter/controller.

*Figure 12. Typical DMX512 receiver circuit*
5.2 **DMX512 receiver block diagram**

A block diagram of the single DMX512 receiver is shown in *Figure 13*. The signals are first received by the RS485 transceiver. The STM32 microcontroller receives the packet through the USART_RX pin according to the address programmed.

The receiver then extracts a particular slot from the packet and modifies the duty cycle of the PWM output as per the data received.

**Figure 13. Block diagram of single DMX512 receiver**

5.3 **MCU block diagram**

A connection to the STM32F10E-EVAL board is shown in *Figure 14*:

**Figure 14. MCU block diagram**
The RS485_RX signal is given to three GPIO pins, PA0, PA1, and PA10. PWM output is generated on pin PA6.

- PA0 is the configured channel1 of timer2. Falling edge input-capture is configured on this channel
- PA1 is the configured channel2 of timer2. Rising edge input-capture is configured on this channel
- PA10 is the configured Rx pin of USART1
- PWM of 120 Hz is produced on channel1 of timer3. The duty cycle of PWM is varied according to the data received.

5.4 Calculating the current through LEDs

The current is set with an external sensing resistor connected to the FB pin. The feedback voltage is 100 mV, a low resistor value can be chosen for reducing power dissipation. A 0.5A current is needed so R12 should be selected according to the following equation:

Equation 1

\[
R_{12} = \frac{V_{FB}}{I_{LEDs}} = \frac{100 \text{ mA}}{0.5 \text{ A}} = 200 \text{ m}\Omega
\]
5.5 Flowchart of firmware

5.5.1 Main routine

Figure 15. Main routine flow chart

START

Configure the MCU

Configure the channel 1 & channel 2 of Timer2 in input capture mode with opposite capture polarity and Timer3 in PWM1 mode to generate PWM of 120 Hz.

Enable the Receive interrupt of USART1 and overflow counter interrupt if timer2

Is packet flag set?

No

Yes

Change the Duty-Cycle of PWM from data slot as specified by the receivers address
5.5.2 Timer2 interrupt routine

Figure 16. Timer2 rising edge interrupt flow chart

Channel 2 Rising Edge Interrupt Routine

1. Disable the Channel 2 Rising Edge Interrupt
2. Is InitBreakFlagRx Set?
   - Yes: Store the value of timer counter in MARisingCounterRx. Subtract the BreakFallingCounterRx from MABRisingCounterRx and store the result in TimingCounterRx
   - No: Update the value of TimingCounterRx on the basis of GlobalOverflowCount
3. Is TimingCounterRx > Break time?
   - No: GlobalOverflowCount = 0
   - Yes: 1) Set the Break Flag, InitBreakFlag and Enable Channel 1 Falling Edge Interrupt
          2) Set MABOverflowCount equal to GlobalOverflowCount
Figure 17. Timer2 rising edge interrupt flow chart

- Subtract NextBreakFallingCounterRx from MABRisingCounterRx and store the result in TimingCounterRx. Update the value of TimingCounterRx on the basis of BreakOverflowCount and GlobalOverflowCount.

- Is TimingCounterRx > Break time?
  - Yes: Enable Channel 1 Falling Edge Interrupt and Reset the MAB Flag.
  - No: Subtract Break Falling Counter Rx from NextBreak Falling Counter Rx and store the result in TimingCounterRx. Update the value of TimingCounterRx on the basis of BreakOverflowCount.

1) Set Break flag and InitBreak Flag
2) BreakFallingCounterRx = NextBreakFallingCounterRx

- Is TimingCounterRx > DMX packet time?
  - Yes: Set Packet Flag
  - No: Reset Packet Flag
Channel 1 Falling Edge Interrupt Routine

1. Store the value of timer counter in MABFallingCounterRx.
   Subtract the MABRisingCounterRx from MABFallingCounterRx and store the result in TimingCounterRx

2. Update the value of TimingCounterRx on the basis of MABOverflowCount and GlobalOverflowCount

3. Is Break Flag Set?
   - Yes
   - No
     - Is NetCounter > MAB time?
       - Yes
         - Set the MAB Flag and Reset the Break Flag
       - No
         - GlobalOverflowCount = 0
         - Reset Break Flag and InitBreak Flag
5.5.3 USART1 interrupt routine

Figure 19. USART1 interrupt flow chart (part 1)

- Store value of Status Flag of USART1 in StatusRead flag
- Are StatusRead flag and Framing error Flag both Set?
  - Yes: Store the value of timer counter in BreakFallingCounterRx and Enable Channel2 Rising Edge Interrupt
  - No: Is MAB Flag Set?
    - Yes: Store the value of timer counter in NextBreakFallingCounterRx and Set BreakOverflowCount equals GlobalOverflowCount
    - No: Are Break flag and MAB Flag both Reset?
      - Yes: Store the value of timer counter in BreakFallingCounterRx
      - No:

Figure 20. USART1 interrupt flow chart (part 2)

- B
  - Are StatusRead flag and RXNE Flag both Set?
    - AND
  - Is MAB flag Set and DataCorrupt flag Reset?
  - Is DMXChannel Count Zero?
    - No
      - Is DMXChannel Count < 512?
        - Yes
          - Store received data in buffer and then increment DMXChannel Count by 1
        - MAB Flag Reset
          - InitBreak Flag Reset
          - GlobalOverflowCount = 0
  - Yes
    - Make DMXChannel Count zero and then store received data in buffer
    - Z
  - Z
Comment: we will use internal RC Clock for board
Figure 22. ST485AB section

Figure 23. DIP switch section
Figure 24. 3.3 V output

![3.3 V output schematic](image1)

Figure 25. JTAG connector section

![JTAG connector section schematic](image2)
Figure 26. USB section

Figure 27. STCS1A: LED driver
Figure 28. STBP120 section

Figure 29. Jumpers section
Figure 30. Dimming input POT

![Schematic Diagram]

- POT1 10K
- POT_SUPPLY_CONTROL_PA3
- DIMMING I/P_PA5
- SET = 0.5
- C19 100nF
- TP5 TEST POINT
- GND WITH STAR CONNECTION
<table>
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<tr>
<th>Category</th>
<th>Reference designator</th>
<th>Component description</th>
<th>Package</th>
<th>Manufacturer</th>
<th>Manufacturer's ordering code / orderable part number or equivalent</th>
<th>Supplier</th>
<th>Supplier ordering code</th>
</tr>
</thead>
<tbody>
<tr>
<td>Devices</td>
<td>U1</td>
<td>Low-density performance line, ARM-based 32-bit MCU with 16 or 32 KB Flash, USB, CAN, 6 timers, 2 ADCs, 6 communication interfaces</td>
<td>LQFP48</td>
<td>STMicroelectronics</td>
<td>STM32F103C6T6A</td>
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<tr>
<td></td>
<td>U2</td>
<td>Very high speed low power RS-485/RS-422 transceiver</td>
<td>SO-8</td>
<td>STMicroelectronics</td>
<td>ST485ABDR</td>
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<td></td>
<td>U3</td>
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<td>DFN8(3mmx3mm)</td>
<td>STMicroelectronics</td>
<td>STCS1APUR</td>
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<td>U4</td>
<td>Ultra low drop-low noise BiCMOS 300 mA voltage regulator for use with very low ESR output capacitor</td>
<td>SOT23-5L</td>
<td>STMicroelectronics</td>
<td>LDS3985M33R</td>
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<td></td>
<td>U5</td>
<td>ESD protection for high speed interface</td>
<td>SOT-666</td>
<td>STMicroelectronics</td>
<td>ESDAULC6-3BP6</td>
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<td></td>
<td>U6</td>
<td>Protection device (CutOff voltage 5.375 volts)</td>
<td>TDFN – 10-lead (2.5 x 2 mm)</td>
<td>STMicroelectronics</td>
<td>STBP120AVDK6F</td>
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<td>D8</td>
<td>Power Schottky rectifier</td>
<td>STPS340U_SMB</td>
<td>STMicroelectronics</td>
<td>STPS340U</td>
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<td>Crystal and Oscillator</td>
<td>Y1</td>
<td>Quartz crystal 8 MHz</td>
<td>11.35 mm x 4.35 mm, SS4</td>
<td>ECS Inc</td>
<td>ECS-80-S-5PX-TR</td>
<td>Digi-Key</td>
<td>XC1243CT-ND</td>
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<td>Reference designator</td>
<td>Component description</td>
<td>Package</td>
<td>Manufacturer</td>
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<td>Supplier</td>
<td>Supplier ordering code</td>
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</tr>
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<td>Connectors and jumpers</td>
<td>CN1</td>
<td>Socket, DC power jack, 2.0 MM, right angle, locking type</td>
<td>Through hole</td>
<td>Protectron</td>
<td>PDCJ01-08</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>CN2</td>
<td>JTAG connector</td>
<td>Box header, straight 20-way, 2x10 pin, 2.54 mm x 2.54 mm pitch, through hole</td>
<td>Protectron</td>
<td>P9603-20-15-1</td>
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<td>CN3</td>
<td>USB MINI-B connector</td>
<td>SMD</td>
<td>Samtec</td>
<td>MUSB-05-S-B-SM-A</td>
<td>Digi-Key</td>
<td>H2959CT-ND</td>
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7 Reference

1. STM32F103x4, STM32F103x6; Low-density performance line, ARM-based 32-bit MCU with 16 or 32 KB Flash, USB, CAN, 6 timers, 2 ADCs, 6 communication interfaces, datasheet
8 Revision history

Table 4. Document revision history

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