UM1004
User manual

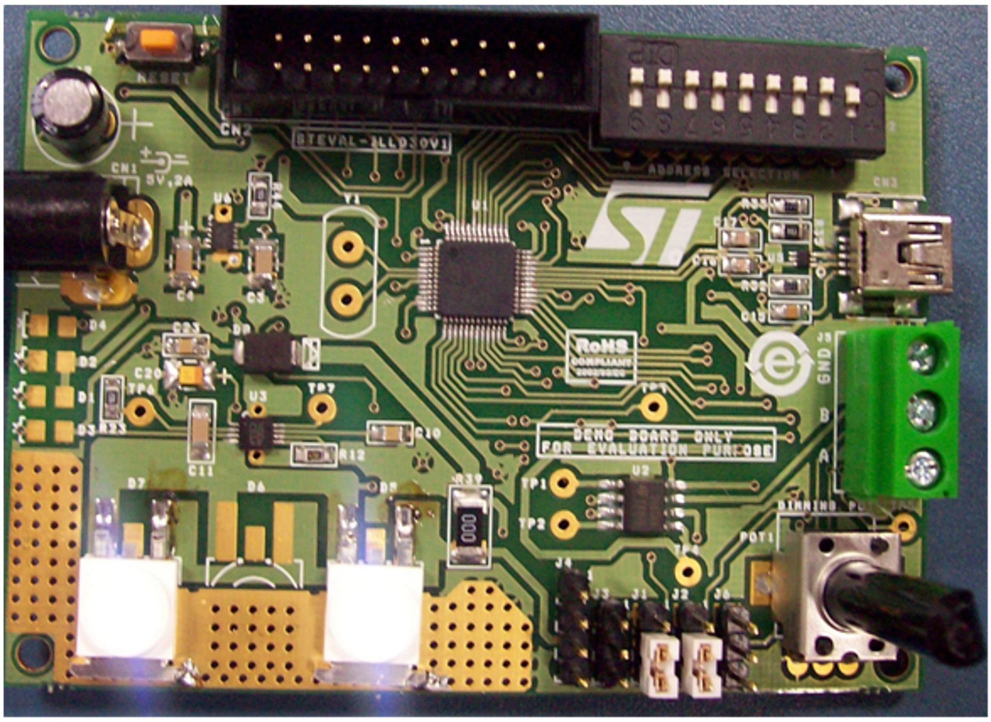
DMX 512 based LED lighting solution

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



Contents

List of figures

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

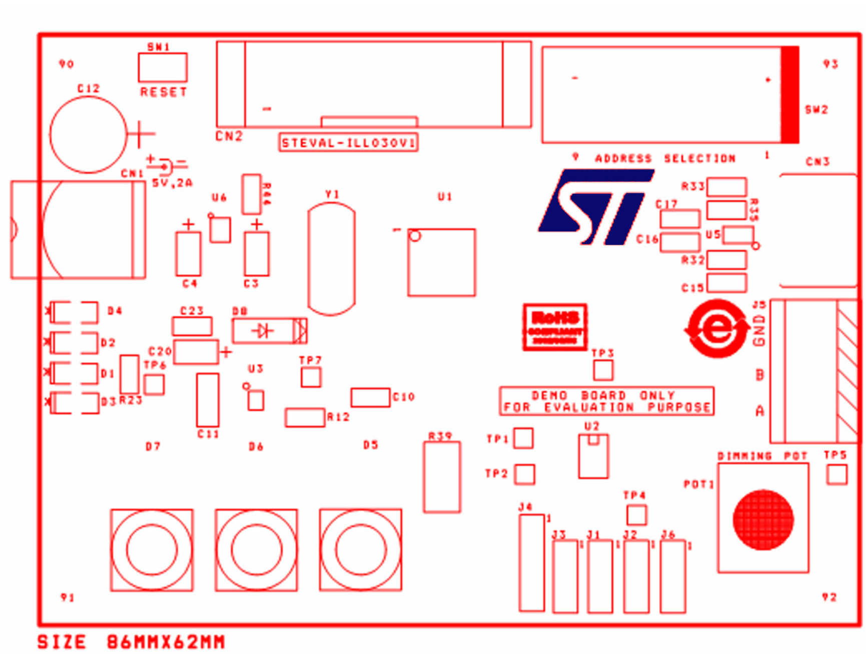
2.2 Setting up the board

- 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



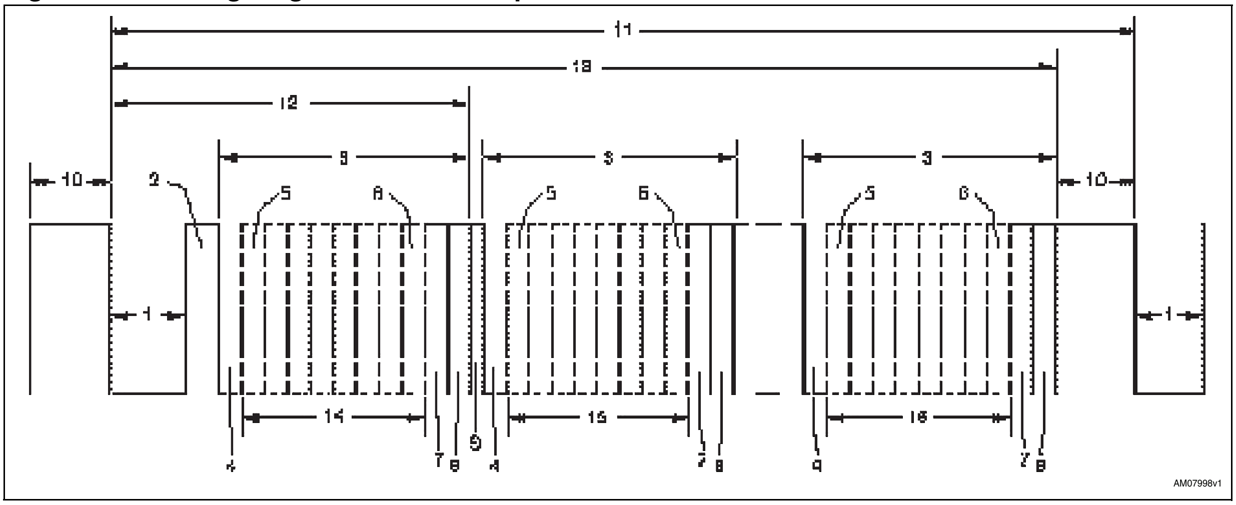
AM07997v1

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

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

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

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

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

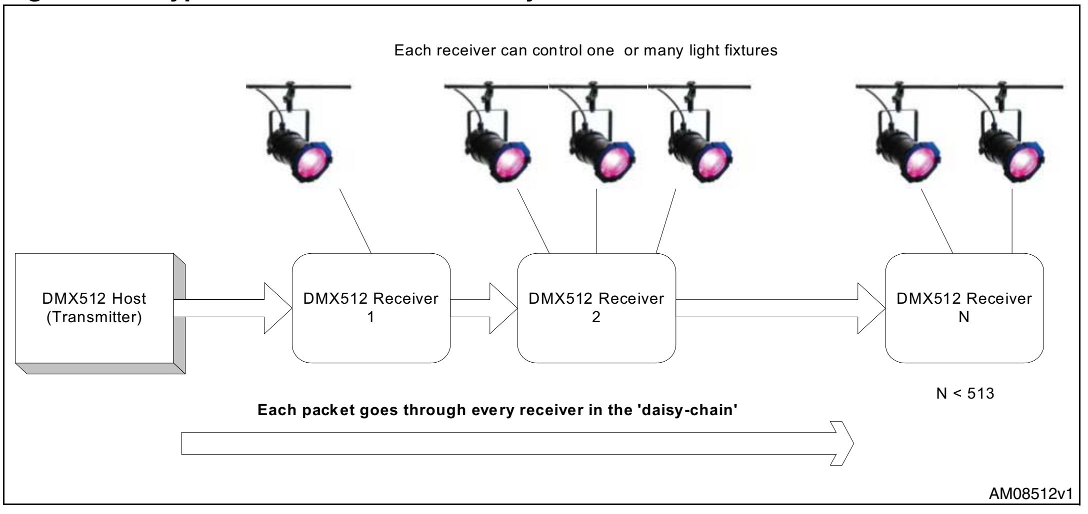
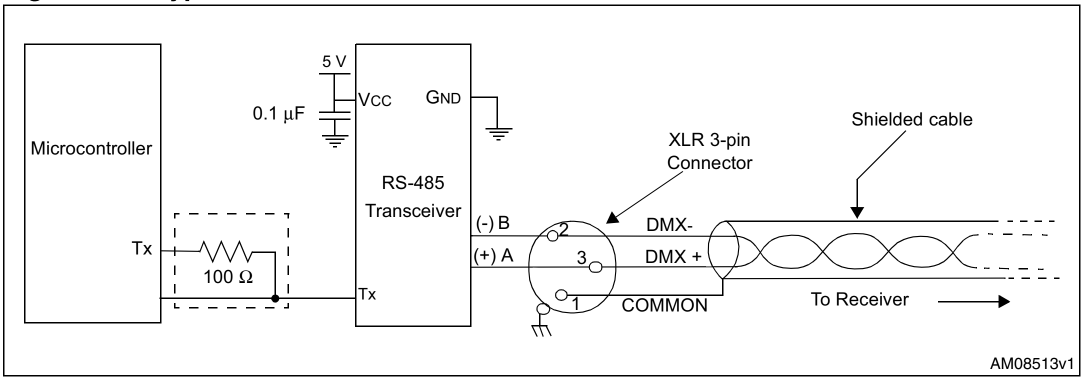


Figure 5. Typical DMX512 transmitter circuit



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.

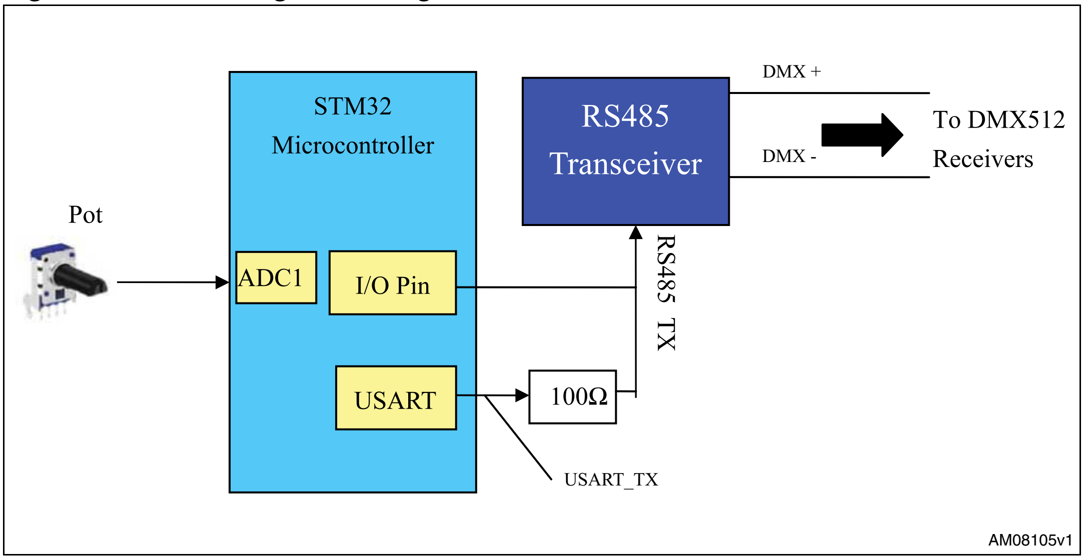
Figure 6 shows the alternative hardware method chosen to generate the longer break signal. A 100 Ω resistor is connected in series with the microcontroller's USART transmit pin and the other end of the resistor to an I/O pin. With this solution, the break time can be varied, from 92 µsec to 176 µsec 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.

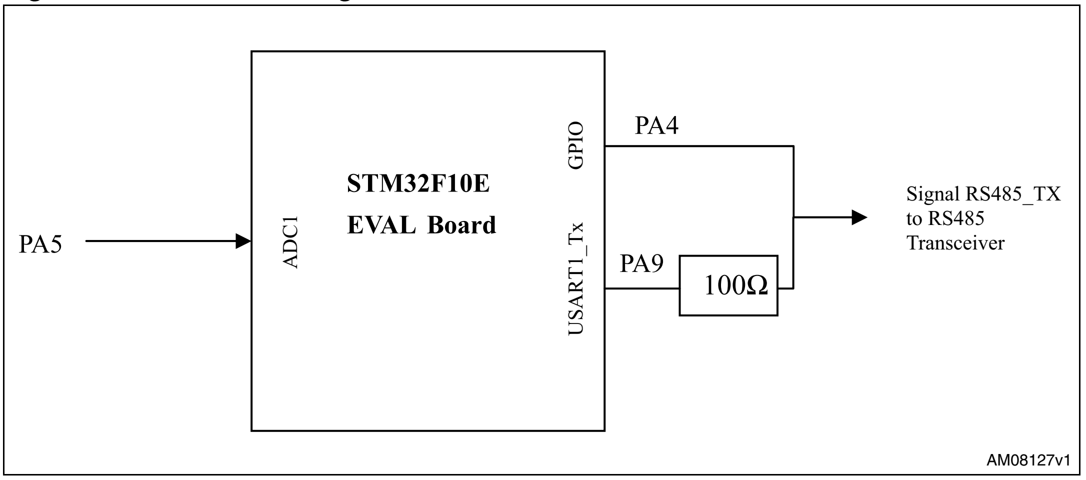
Figure 6. Block diagram of single DMX512 receiver



4.3 MCU block diagram

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

Figure 7. MCU block diagram



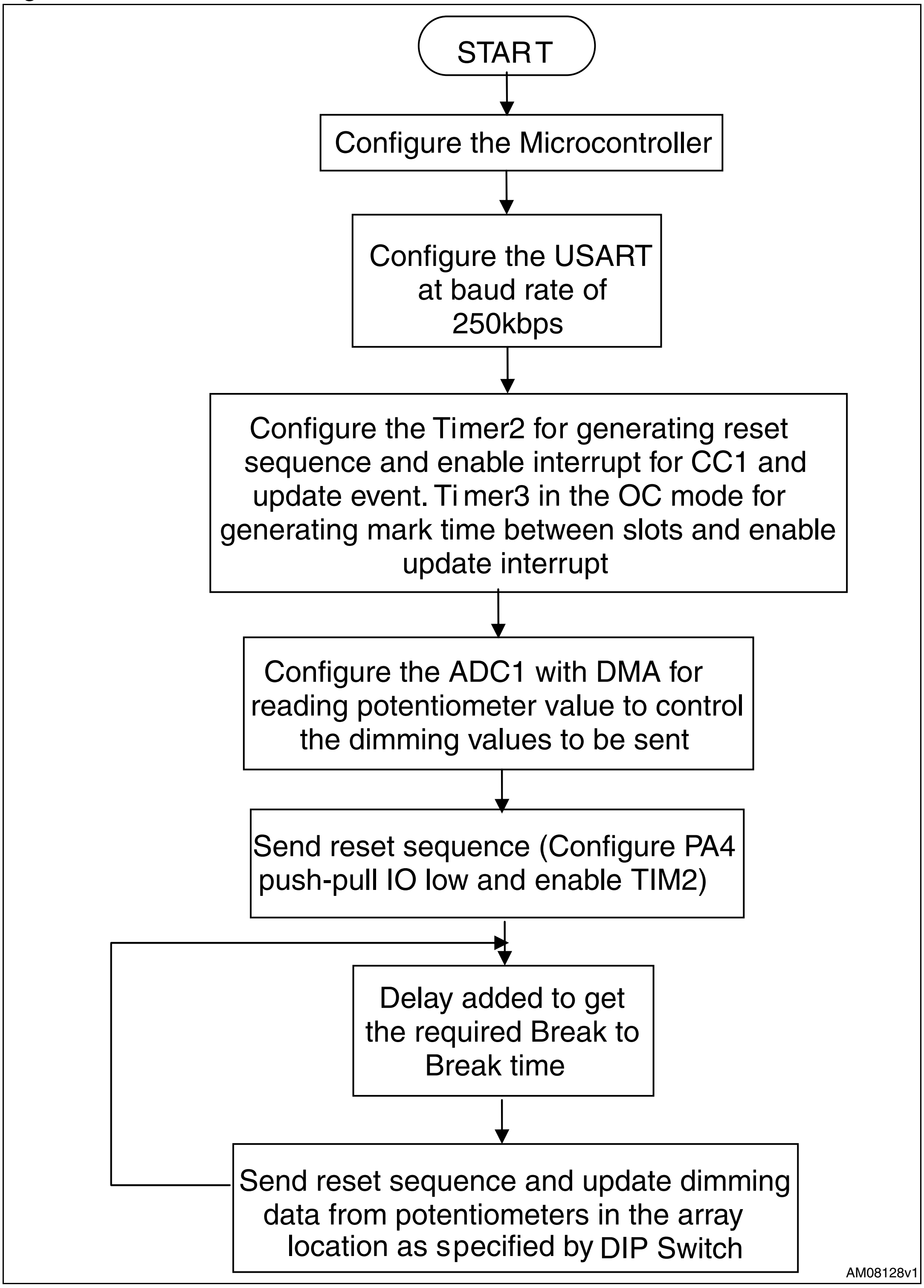
USART_Tx pin (PA9) is connected to PA4 through 100 Ω resistance. PA4 is connected to RS485_Tx of the RS485 transceiver board:

- 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

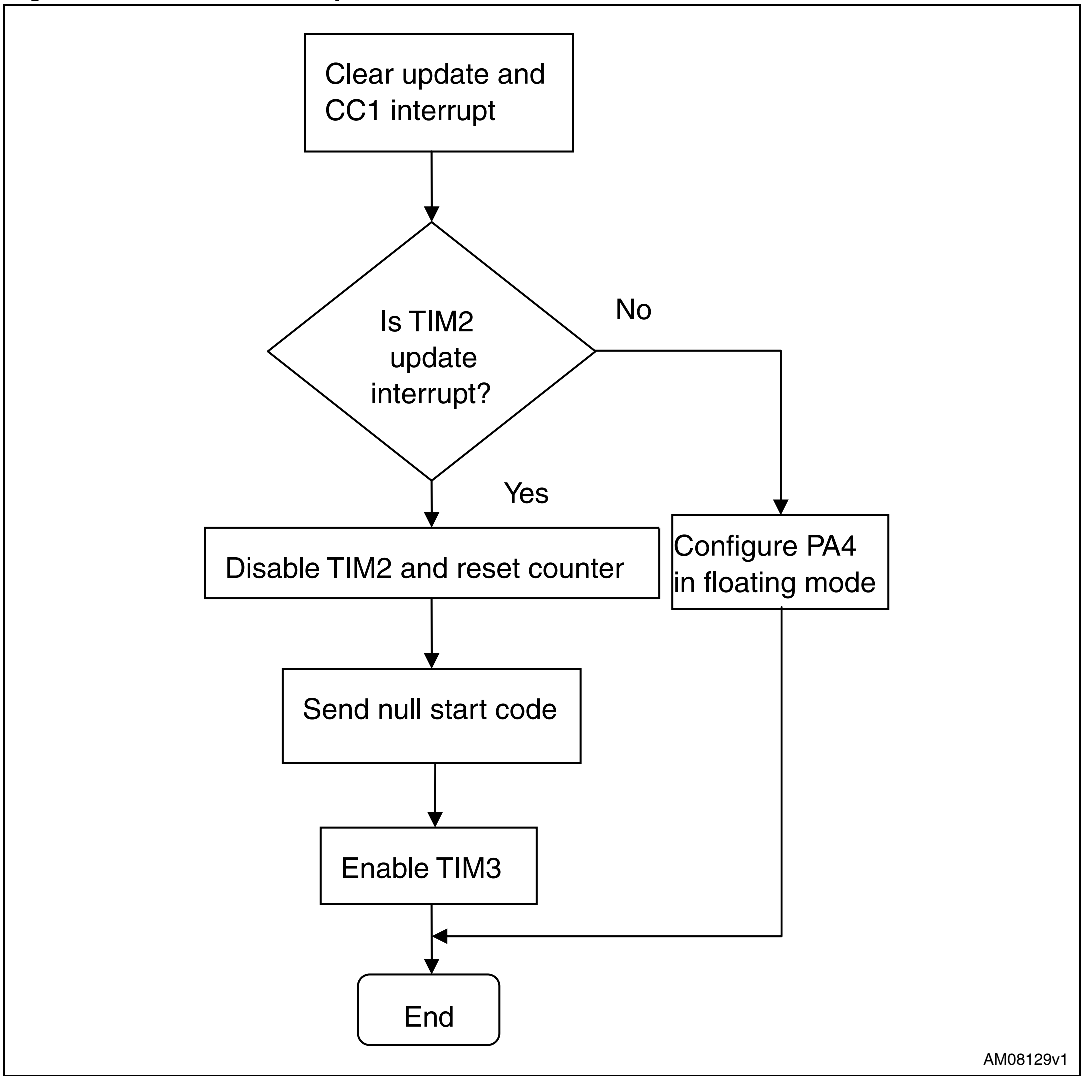
4.4.1 Main routine

Figure 8. Main routine flow chart



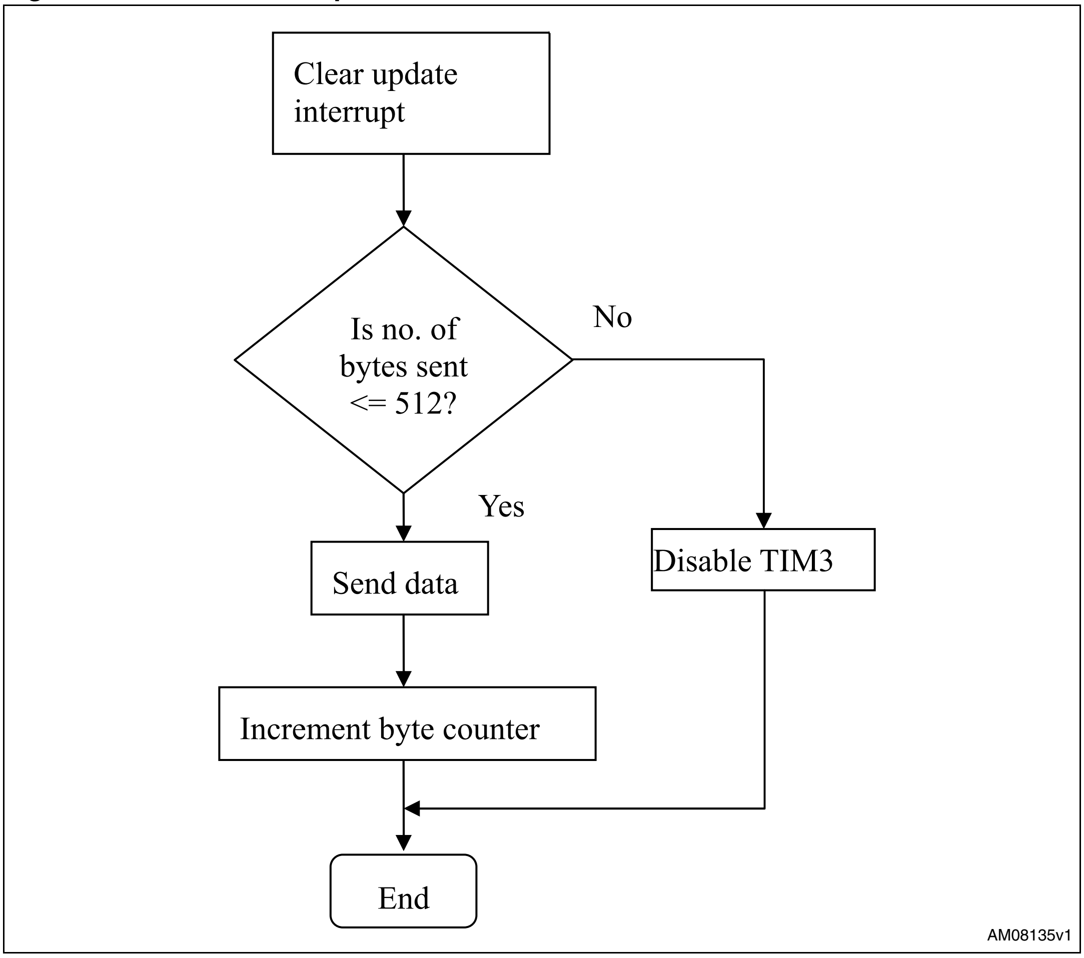
4.4.2 Timer2 interrupt routine

Figure 9. Timer2 interrupt flow chart



4.4.3 Timer3 interrupt routine

Figure 10. Timer3 interrupt routine



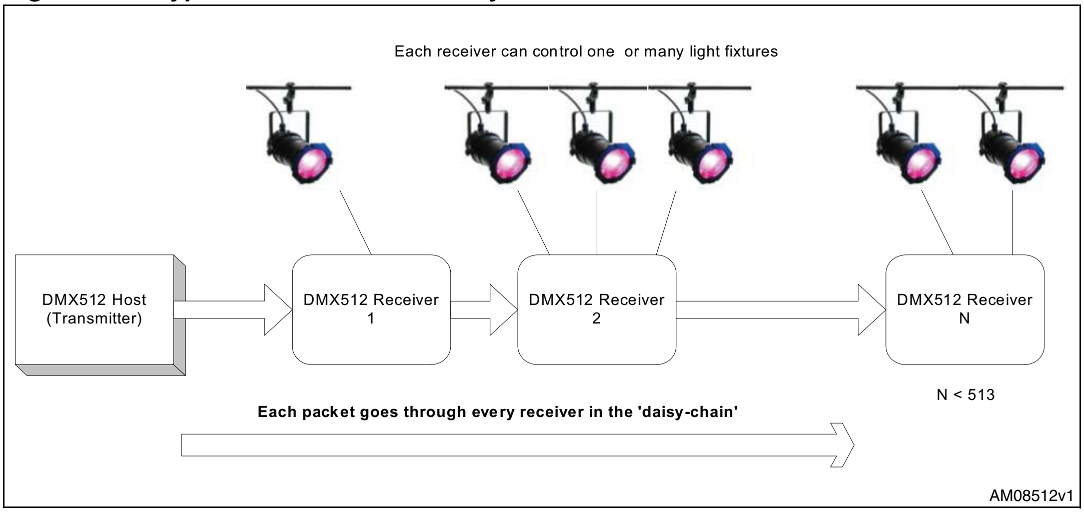
5 DMX512 receiver

5.1 DMX512 receiver system

Figure 11 represents a typical DMX512 system.

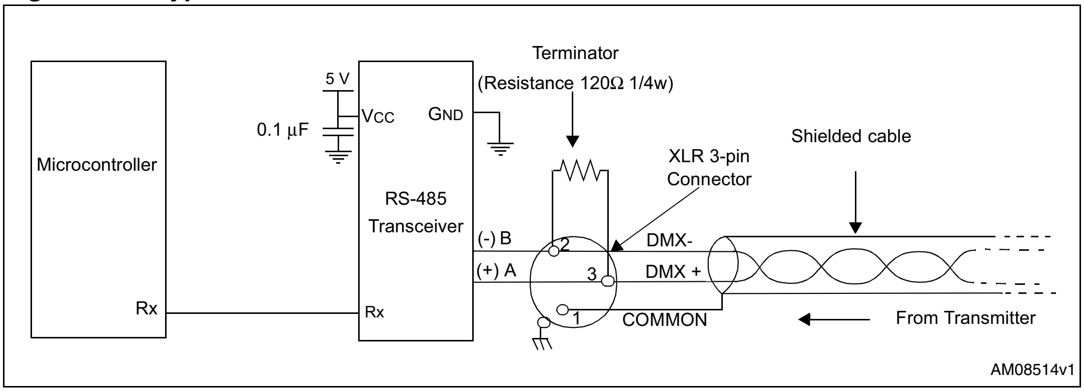
- The multiple receivers are connected to the DMX host in a daisy-chain manner and every packet goes through every receiver in its entirety
- At each receiver, the differential signal is received by an RS485 transceiver and given to the receive side controller
- Each receiver is programmed with a specific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

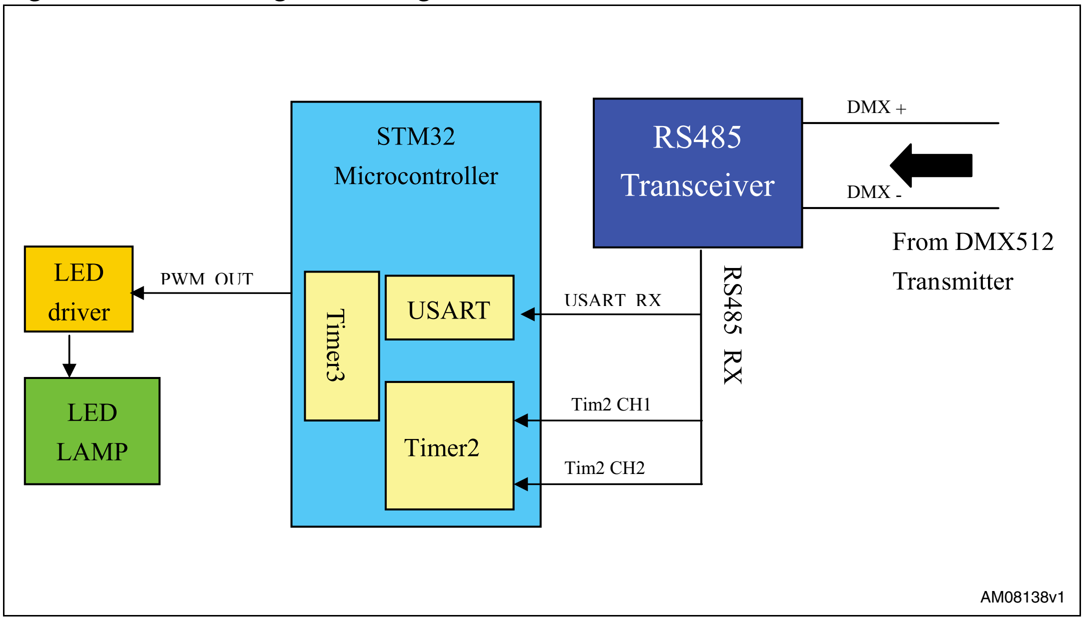


5.2 DMX512 receiver block diagram

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.

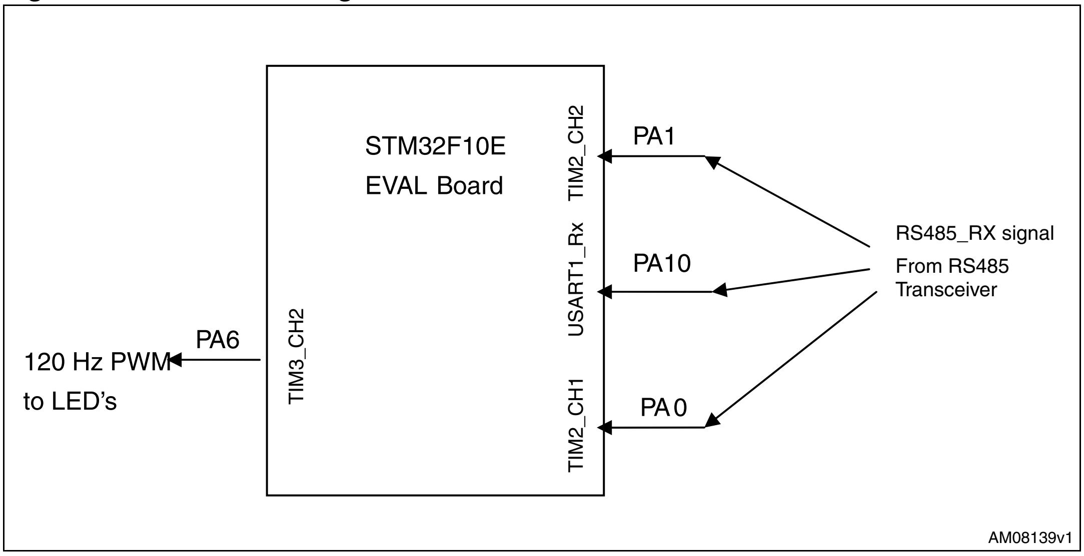
Figure 13. Block diagram of single DMX512 receiver



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:

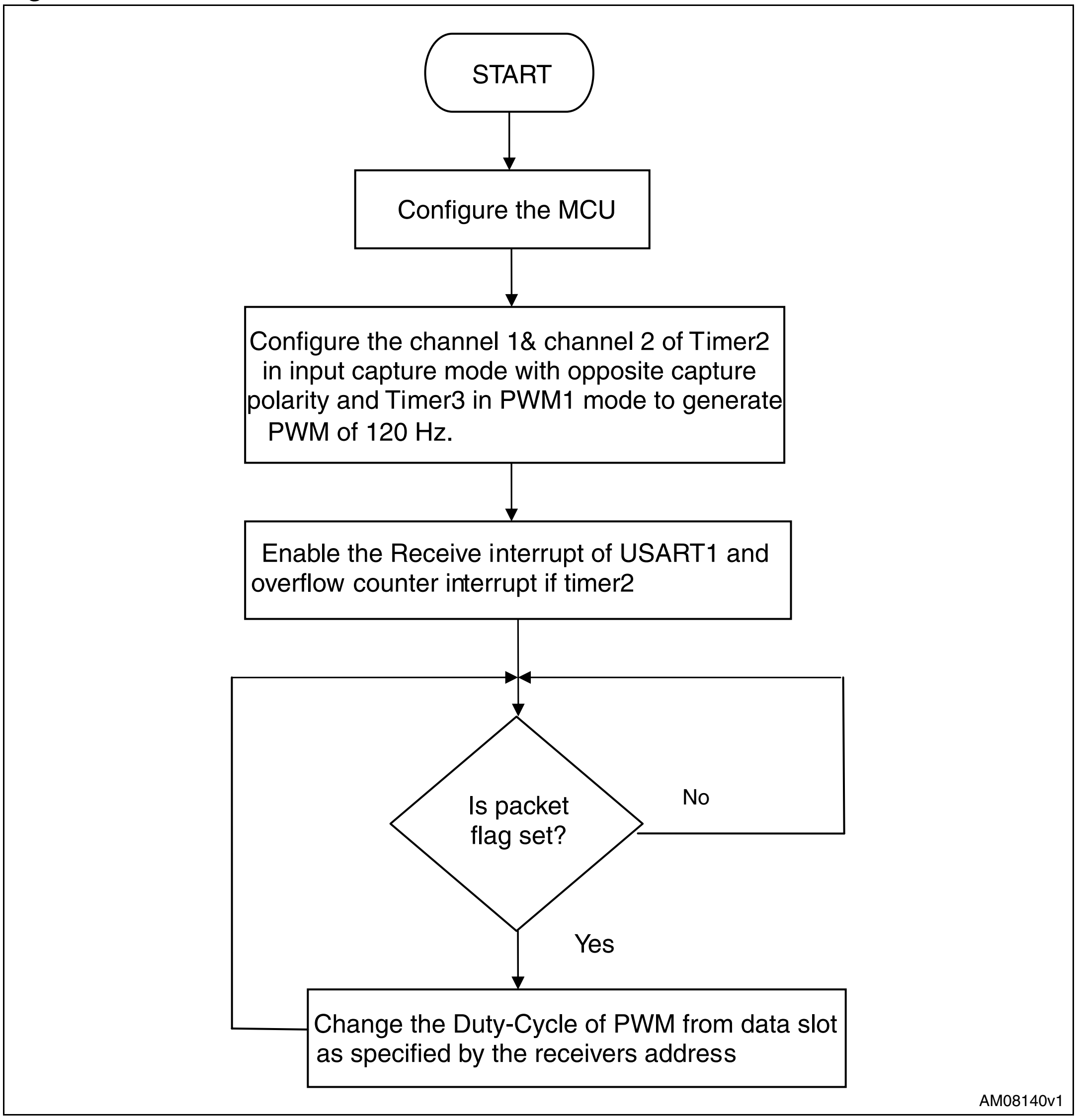
Equation 1

$$R12 = \frac{VFB}{ILEDs} = \frac{100\ mA}{0.5\ A} = 200\ m\Omega$$

5.5 Flowchart of firmware

5.5.1 Main routine

Figure 15. Main routine flow chart



5.5.2 Timer2 interrupt routine

Figure 16. Timer2 rising edge interrupt flow chart

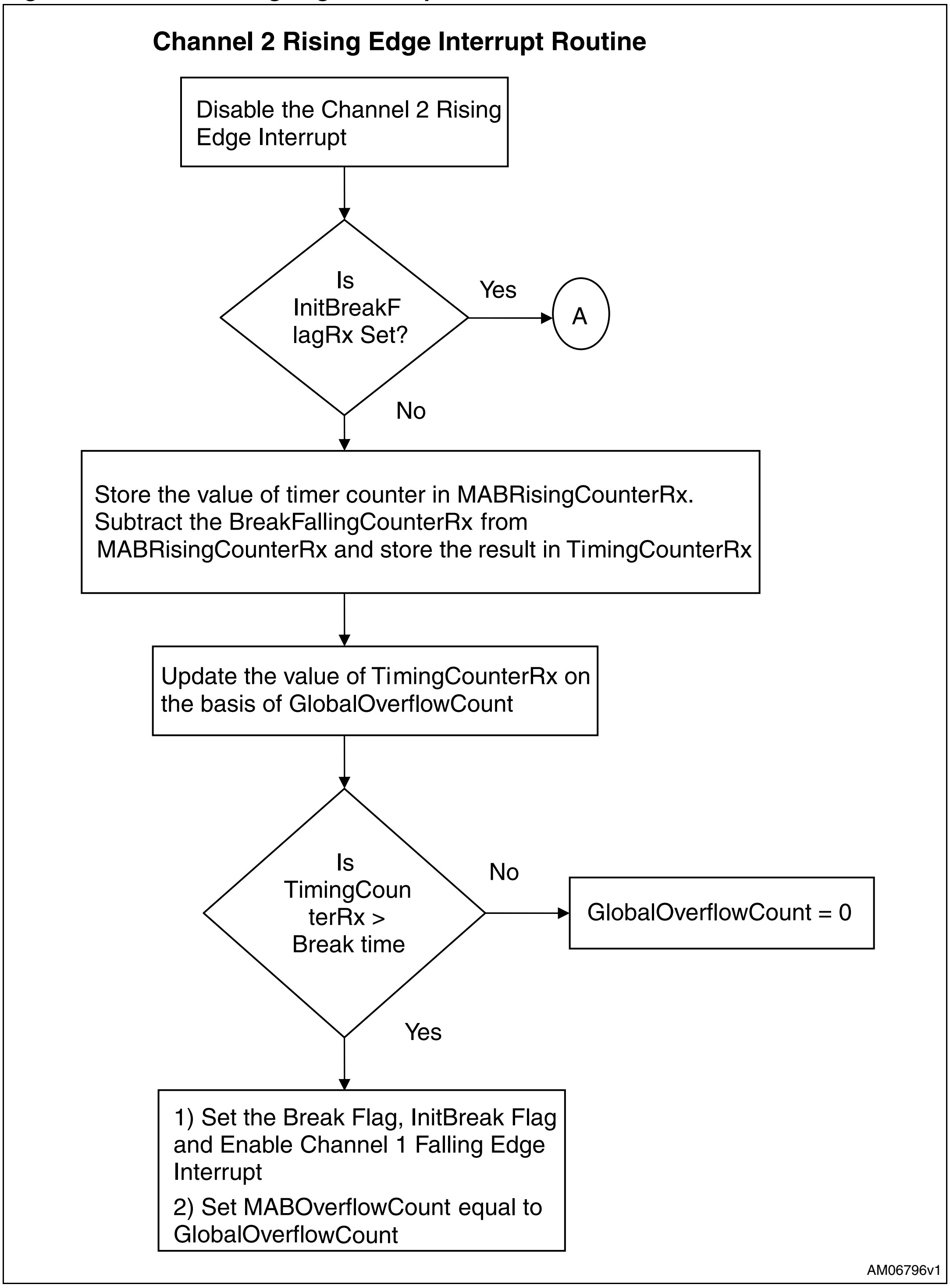


Figure 17. Timer2 rising edge interrupt flow chart

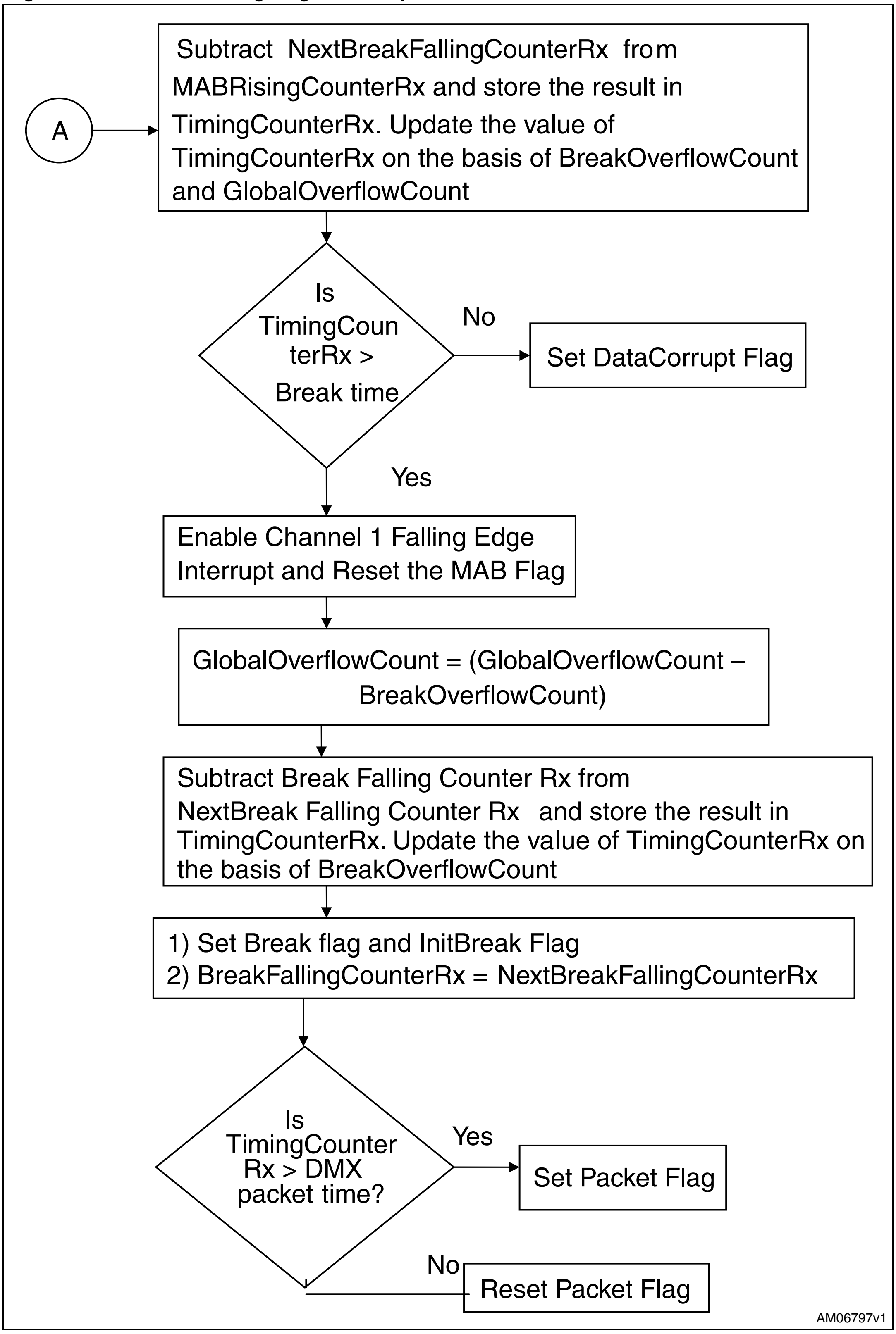
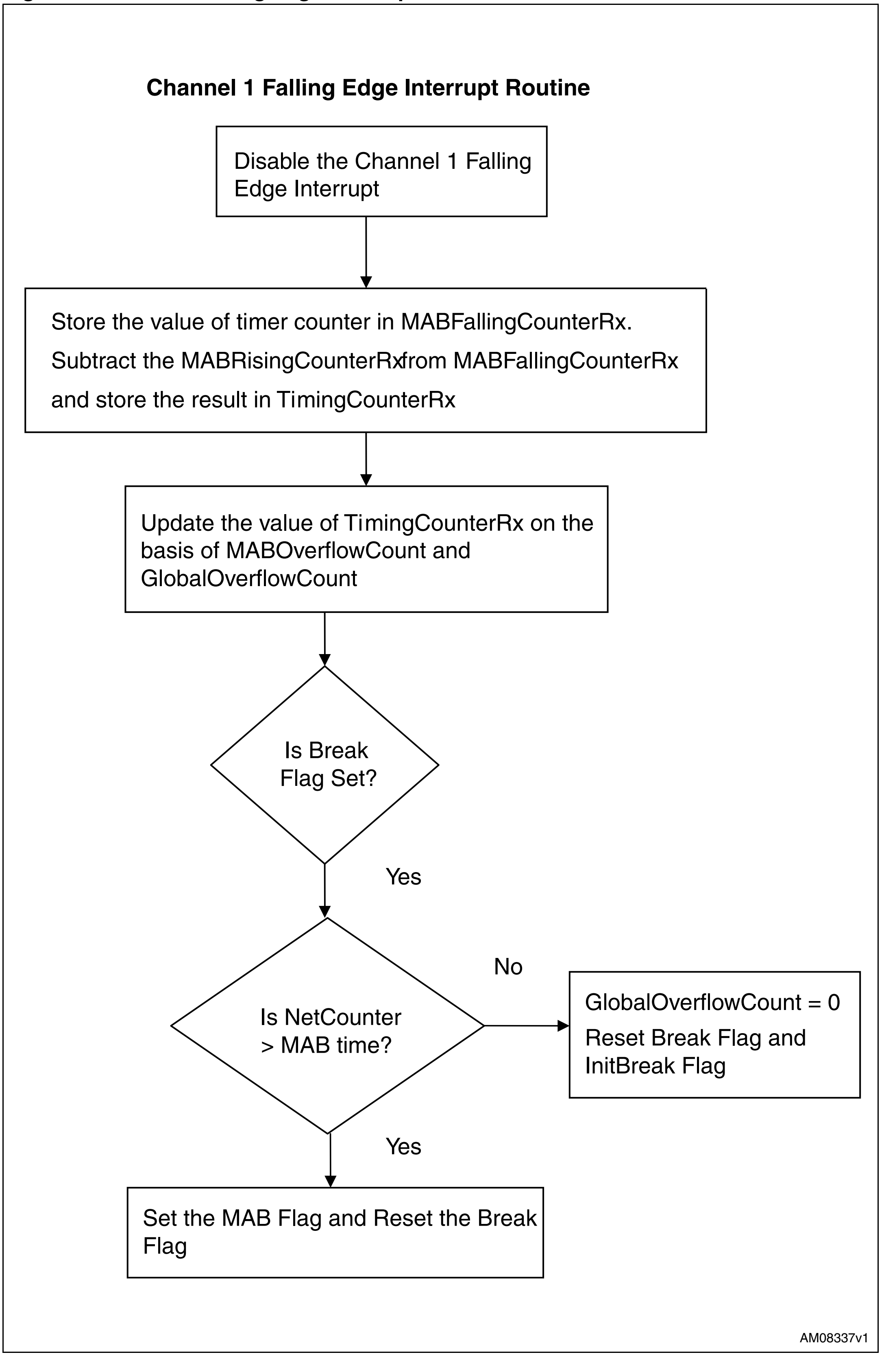


Figure 18. Timer2 falling edge interrupt flow chart



5.5.3 USART1 interrupt routine

Figure 19. USART1 interrupt flow chart (part 1)

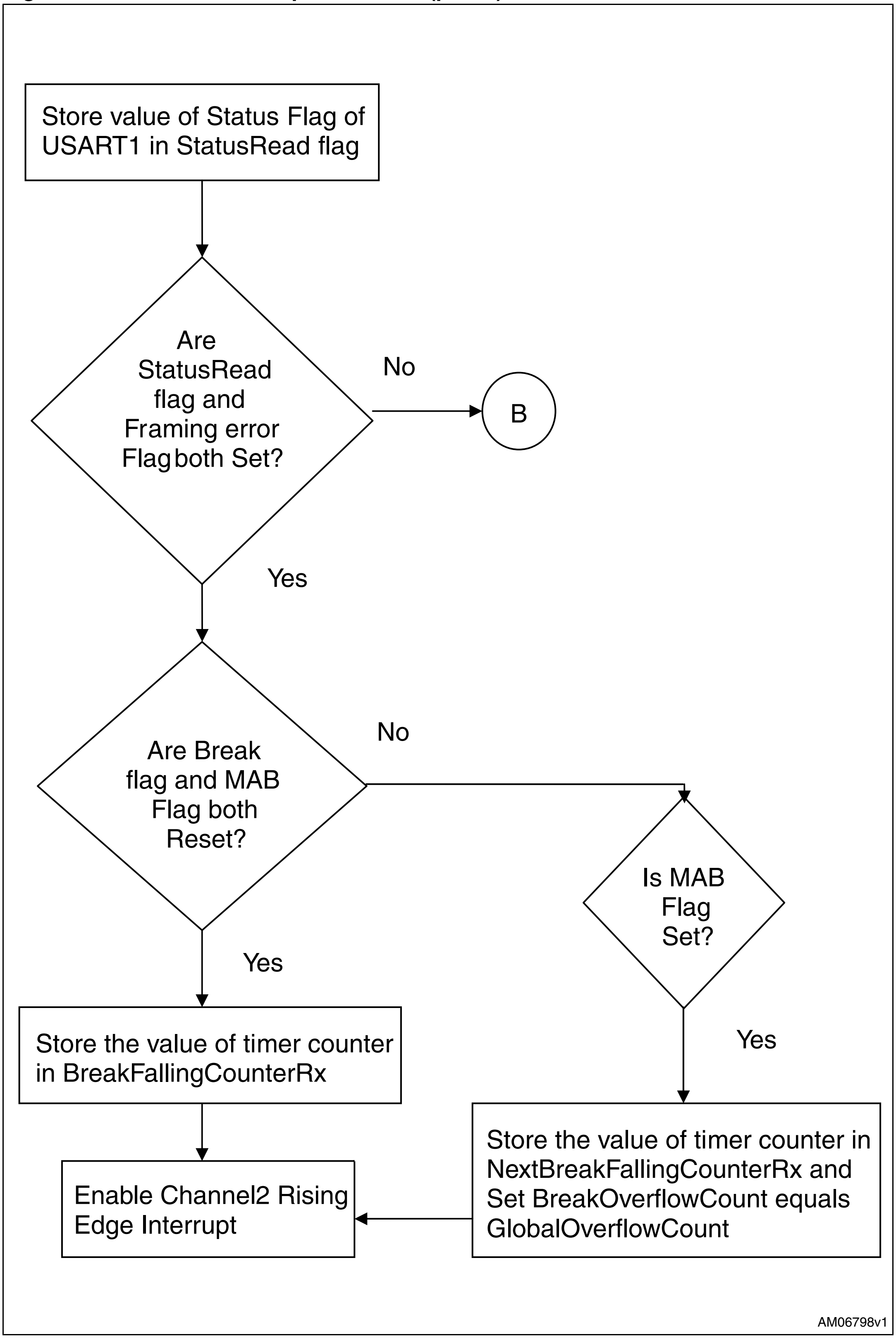
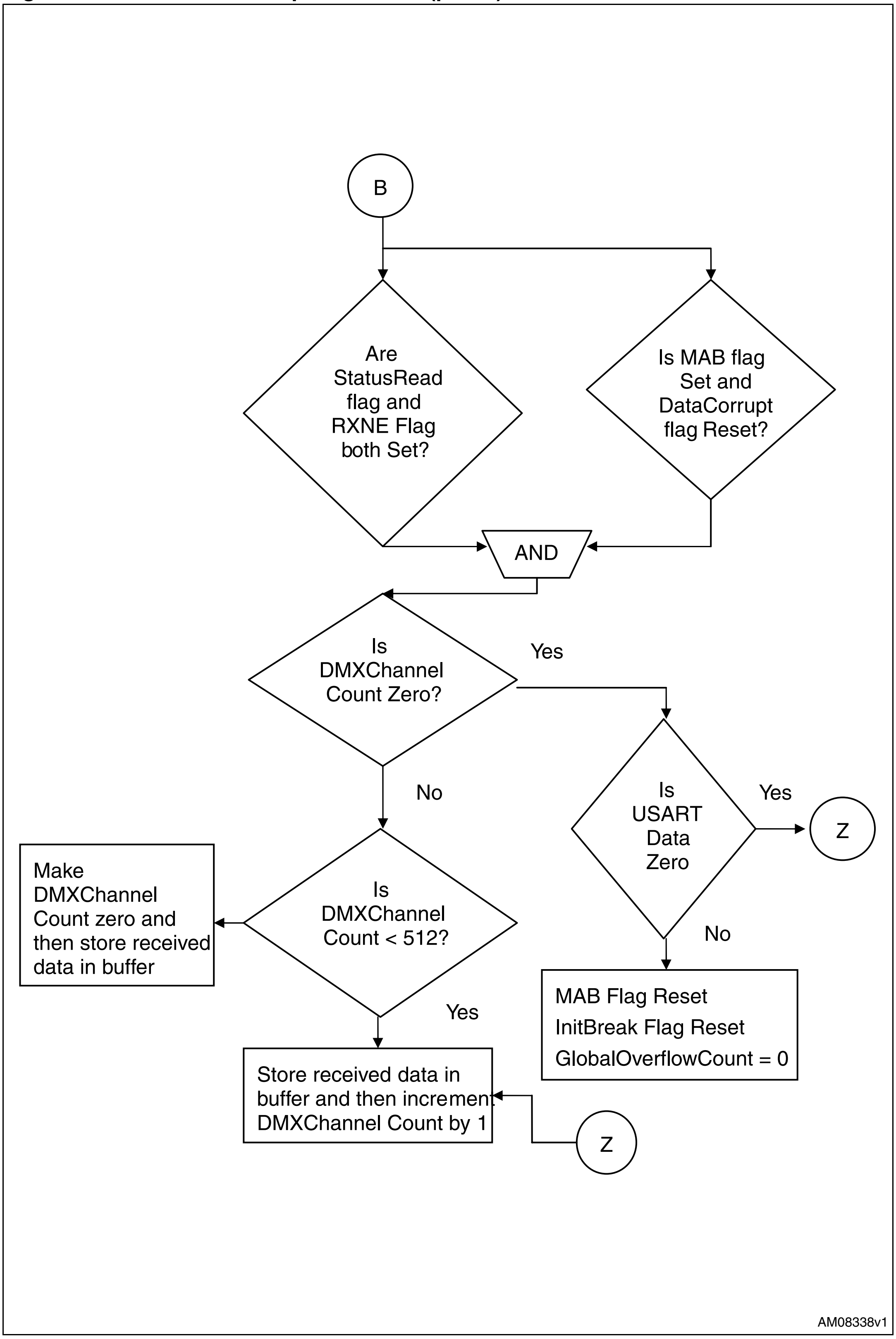


Figure 20. USART1 interrupt flow chart (part 2)



6 Schematics and bill of material

Figure 21. Microcontroller section

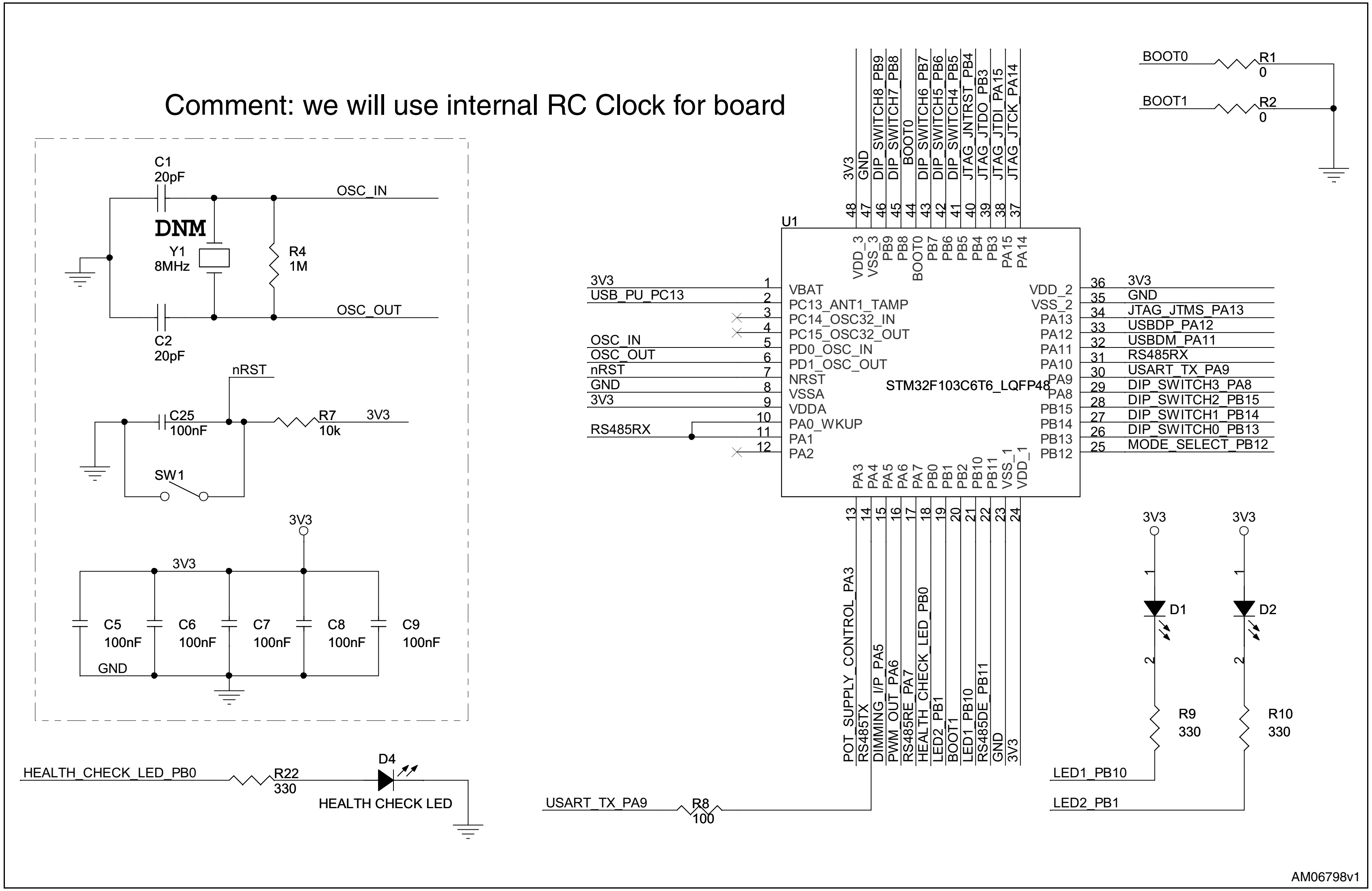


Figure 22. ST485AB section

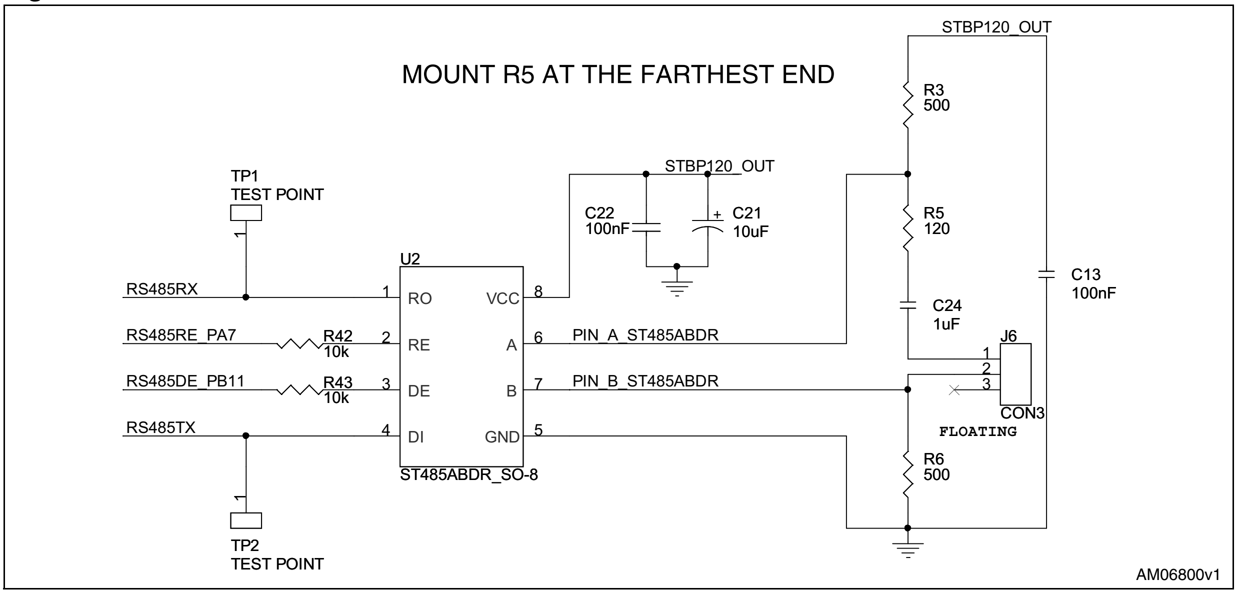


Figure 23. DIP switch section

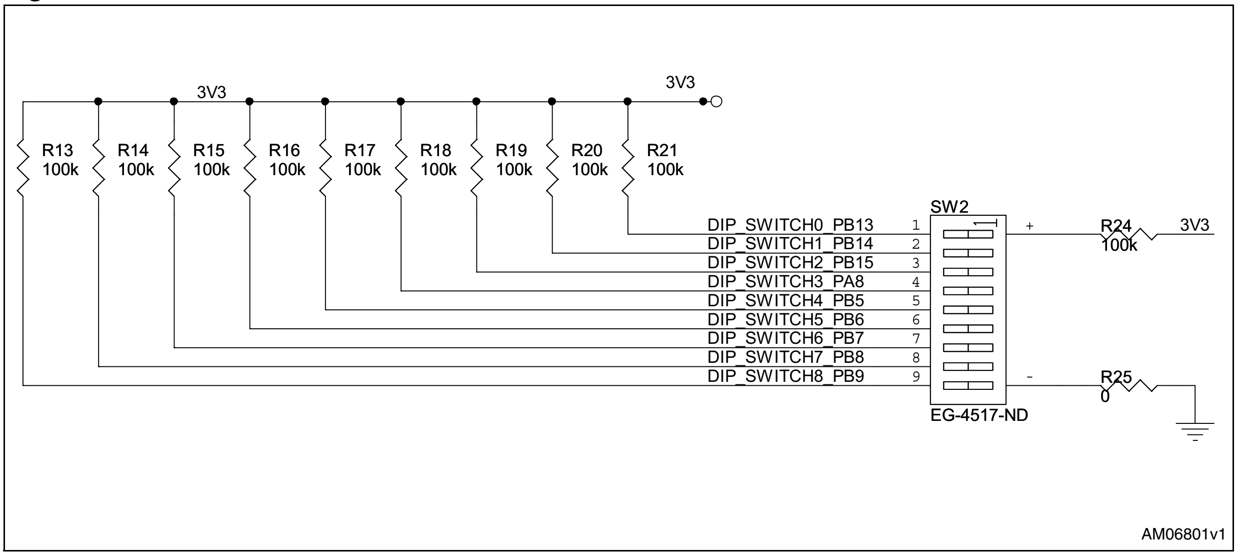


Figure 24. 3.3 V output

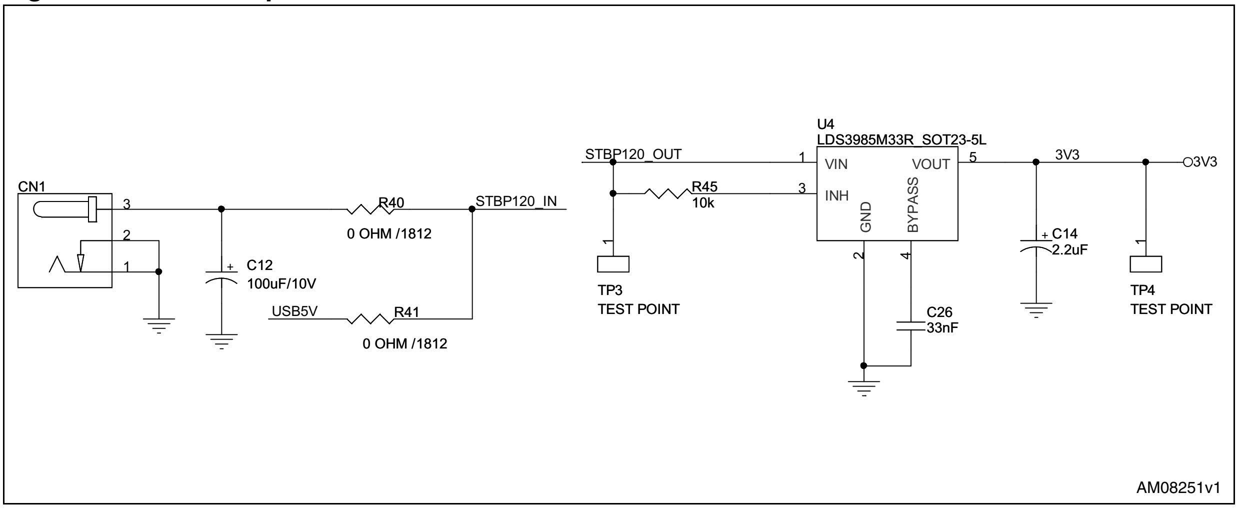


Figure 25. JTAG connector section

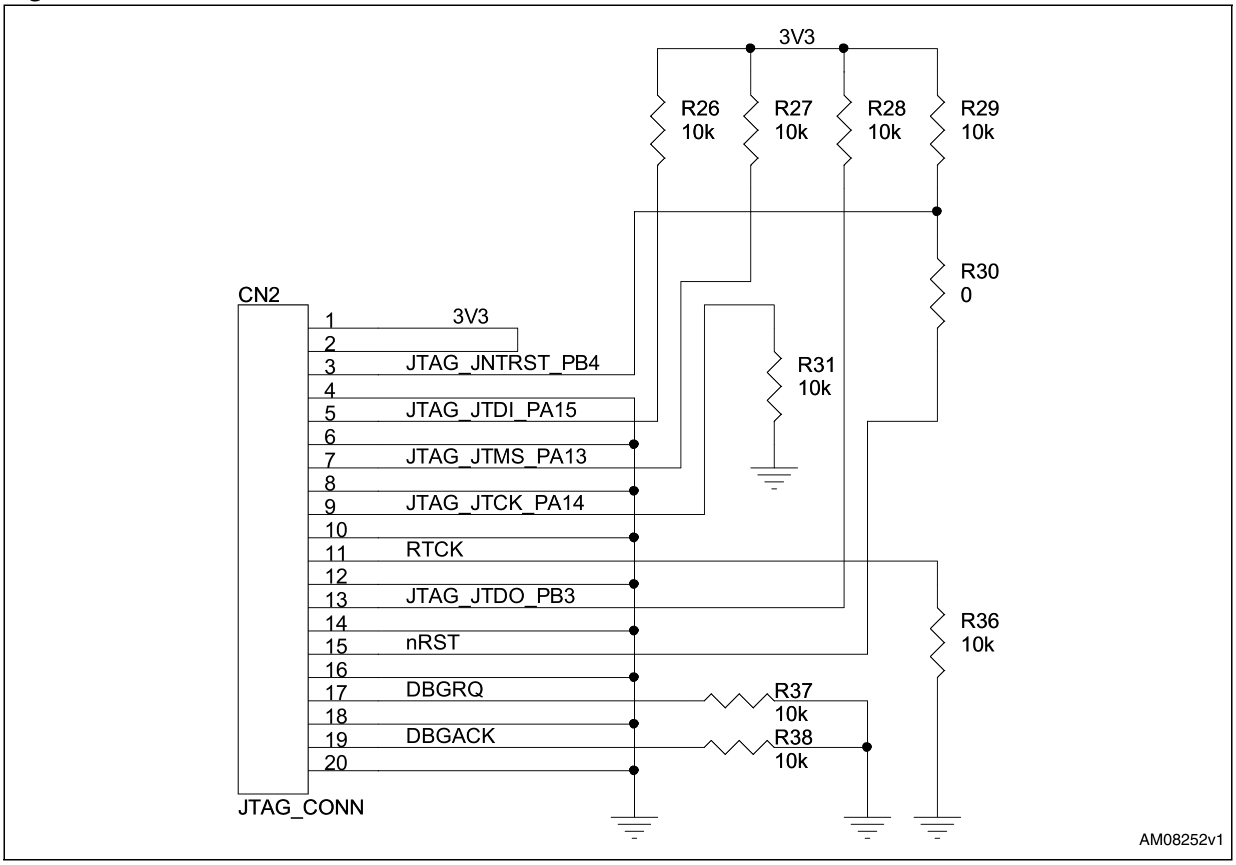


Figure 26. USB section

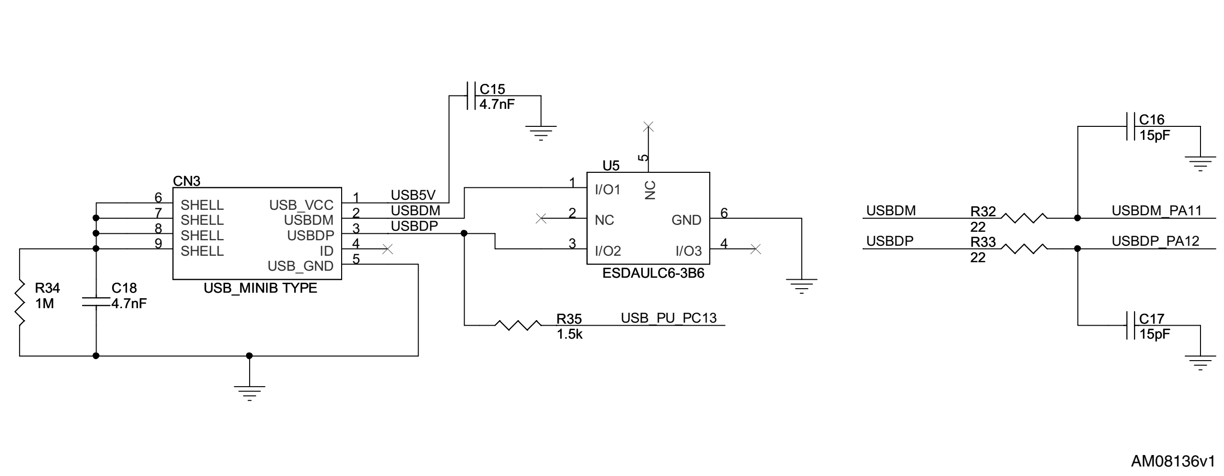


Figure 27. STCS1A: LED driver

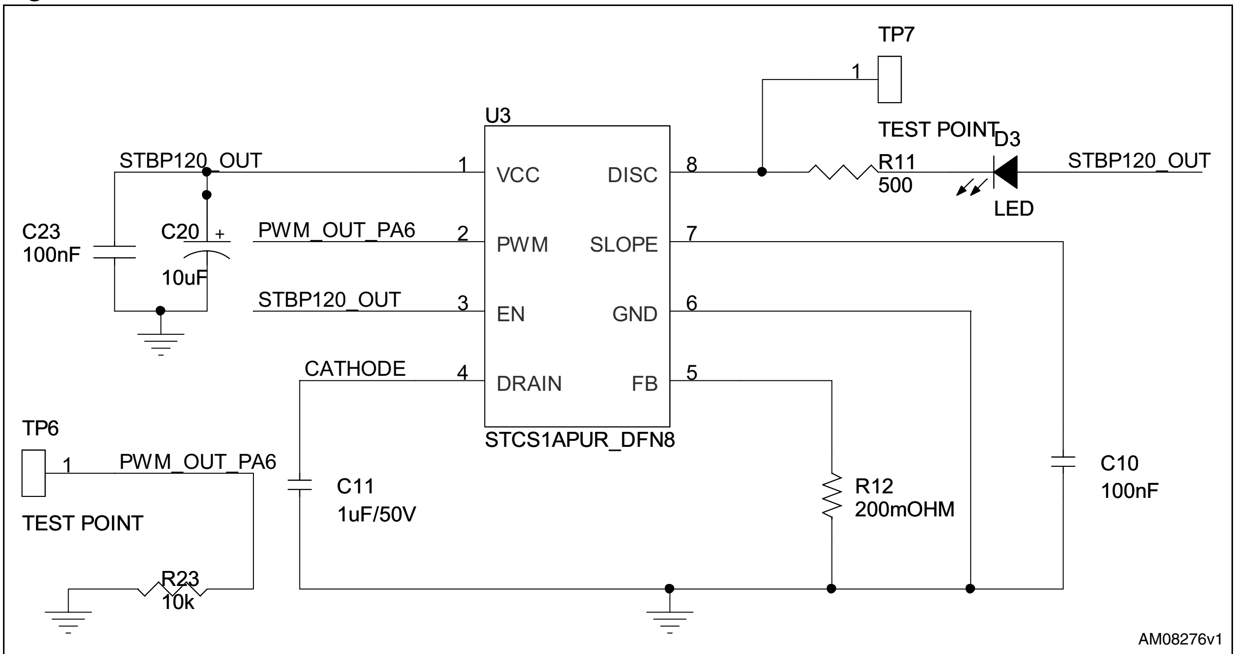


Figure 28. STBP120 section

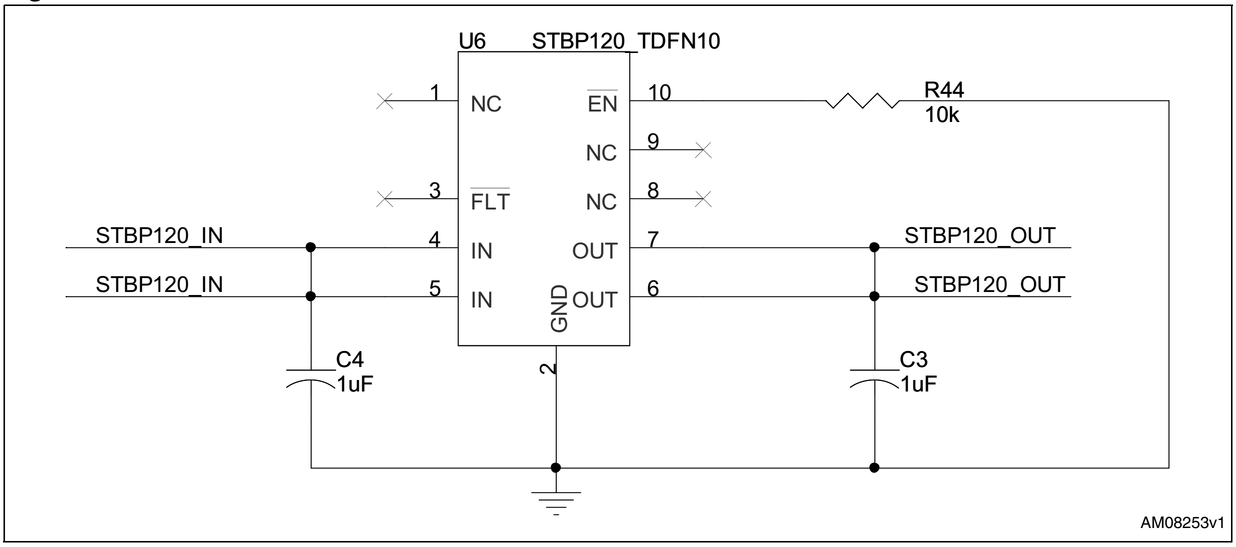


Figure 29. Jumpers section

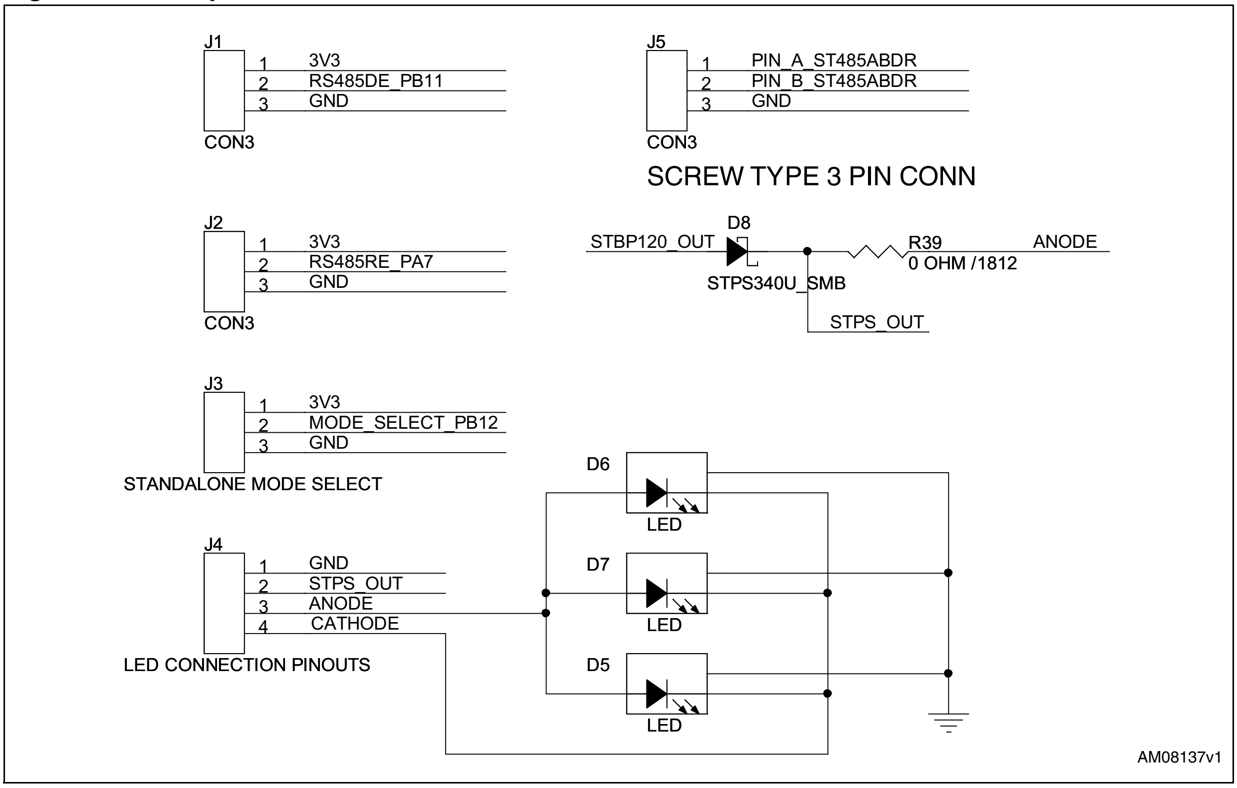


Figure 30. Dimming input POT

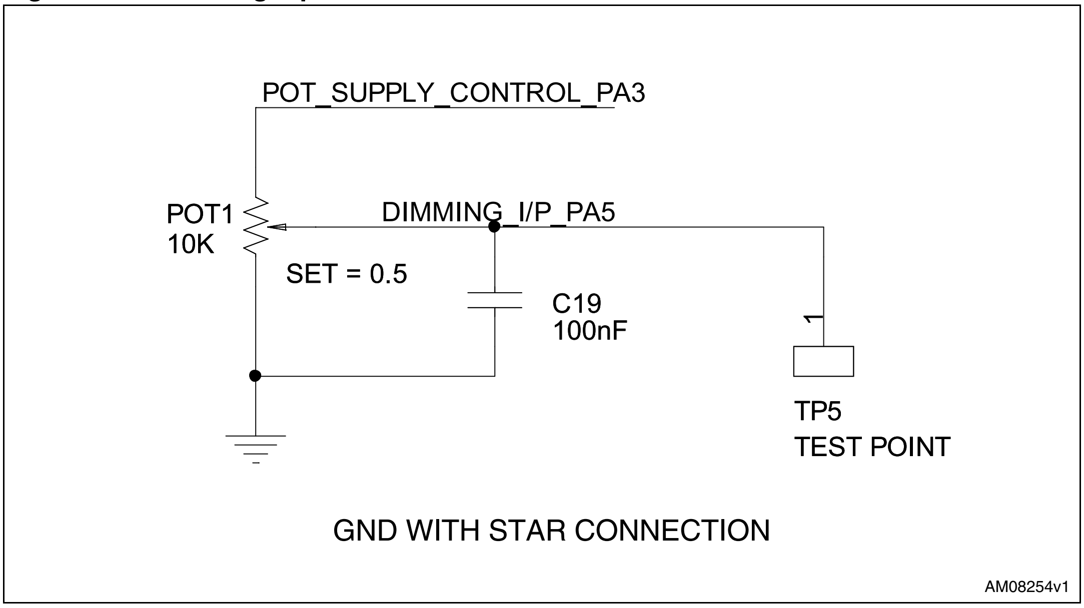


Table 3. BOM

Category	Reference designator	Component description	Package	Manufacturer	Manufacturer's ordering code / orderable part number or equivalent	Supplier	Supplier ordering code
Devices	U1	Low-density performance line, ARM-based 32-bit MCU with 16 or 32 KB Flash, USB, CAN, 6 timers, 2 ADCs, 6 communication interfaces	LQFP48	STMicroelectronics	STM32F103C6T6A		
	U2	Very high speed low power RS-485/RS-422 transceiver	SO-8	STMicroelectronics	ST485ABDR		
	U3	1.5 A max constant current LED driver	DFN8(3mmx3mm)	STMicroelectronics	STCS1APUR		
	U4	Ultra low drop-low noise BiCMOS 300 mA voltage regulator for use with very low ESR output capacitor	SOT23-5L	STMicroelectronics	LDS3985M33R		
	U5	ESD protection for high speed interface	SOT-666	STMicroelectronics	ESDAULC6-3BP6		
	U6	Protection device (CutOff voltage 5.375 volts)	TDFN – 10-lead (2.5 x 2 mm)	STMicroelectronics	STBP120AVDK6F		
	D8	Power Schottky rectifier	STPS340U_SMB	STMicroelectronics	STPS340U		
Crystal and Oscillator	Y1	Quartz crystal 8 MHz	11.35 mm x 4.35 mm, SS4	ECS Inc	ECS-80-S-5PX-TR	Digi-Key	XC1243CT-ND

Table 3. BOM (continued)

Category	Reference designator	Component description	Package	Manufacturer	Manufacturer's ordering code / orderable part number or equivalent	Supplier	Supplier ordering code
Connectors and jumpers	CN1	Socket, DC power jack, 2.0 MM, right angle, locking type	Through hole	Protectron	PDCJ01-08		
	CN2	JTAG connector	Box header, straight 20-way, 2x10 pin, 2.54 mm x 2.54 mm pitch, through hole	Protectron	P9603-20-15-1		
	CN3	USB MINI-B connector	SMD	Samtec	MUSB-05-S-B-SM-A	Digi-Key	H2959CT-ND
	J1,J2,J3,J6	PinOuts 1x3	Header 2.54 mm x 2.54 mm pitch	Any			
	J5	Terminal block	3-way vertical (through hole, pitch 5 mm)	MULTICOMP	PA001-3	Farnell	1357319
	J4	PinOuts 1x4	Header 2.54 mm x 2.54 mm pitch	Any			

Table 3. BOM (continued)

Category	Reference designator	Component description	Package	Manufacturer	Manufacturer's ordering code / orderable part number or equivalent	Supplier	Supplier ordering code
Capacitors	C1,C2	20 pF	SMD0805	Any			
	C3,C4,C11,C24	1 µF/16 V	SMD1206	Any			
	C5,C6,C7,C8, C9,C10,C13, C19,C22,C23, C25	100 nF	SMD0805	Any			
	C12	100 µF/10 V mini alum elect	Leaded	Panasonic-ECG	ECE-A1AKA101	Digikey	P831-ND
	C14	2.2 µF	Tantalum SMD EIA 3216-18/Size A	Any			
	C15,C18	4.7 nF	SMD0805	Any			
	C16,C17	15 pF	SMD0805	Any			
	C20,C21	10 µF	SMD0805	Any			
	C26	33 nF	SMD0805	Any			
Diodes							
	D1,D2,D3	LED					
Diodes	D4	Health check LED					
	D5,D6,D7	LED cool white		Avago technologies	ASMT-MW22-NNN00	Digi-Key	516-1973-5-ND
	D8		STPS340U_SMB				

Table 3. BOM (continued)

Category	Reference designator	Component description	Package	Manufacturer	Manufacturer's ordering code / orderable part number or equivalent	Supplier	Supplier ordering code
Resistors	POT1	10 kΩ		Panasonic-ECG	P3C3103-ND	DIgi-Key	P3C3103-ND
	R7,R26,R27, R28,R29,R31, R36,R37,R38, R42,R43,R44, R45,R46	10 kΩ	SMD0805	Any			
	R1,R2,R25,R 30	0	SMD0805	Any			
	R3,R6,R11	500 Ω	SMD0805	Any			
	R4,R34	1 MΩ	SMD0805	Any			
	R5	120 Ω	SMD0805	Any			
	R8	100 Ω	SMD0805	Any			
	R9,R10,R22	330 Ω	SMD0805	Any			
	R12	RES .068 Ω 1/4 W 1 % 0805 SMD	SMD0805	Rohm Semiconductor	MCR10EZHFSR06 8	Digi-Key	RHM.068NCT-ND
	R13,R14,R15, R16,R17,R18, R19,R20,R21, R24	100 kΩ	SMD0805	Any			
	R32,R33	22 Ω	SMD0805	Any			
	R35	1.5 kΩ	SMD0805	Any			
	R39,R40,R41	0 /2010	SMD2010	VISHAY/dale	CRCW20100000Z0 EF	Digi-Key	541-0.0WCT-ND

Table 3. BOM (continued)

Category	Reference designator	Component description	Package	Manufacturer	Manufacturer's ordering code / orderable part number or equivalent	Supplier	Supplier ordering code
Switches	SW1	Push-button switch, SMD	Tactile switch, SPNO, SMD. 6 mm x 3.5 mm	MULTICOMP	DTSM-32S-B	Farnell	Part# 9471898
	SW2	SW DIP tri-state 9 Pos unsealed		E-Switch	KAT1109E	Digi-Key	EG4517-ND
Test point	TP1,TP2,TP3, TP4,TP5,TP6, TP7	Test points	Through hole	Protectron	P8042-C5-22		

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

Date	Revision	Changes
25-Nov-2010	1	Initial release.