

ACAN_ESP32 library for ESP32

Version 1.0.3

Pierre Molinaro

August 13, 2021

Contents

1	Versions	2
2	Features	3
3	ESP32 builtin CAN Controller	3
4	Data flow	3
5	A simple example: LoopBackDemo	5
6	The CANMessage class	8
7	Driver instance	8
8	Pin selection	8
9	Sending frames	9
9.1	Driver transmit buffer size	10
9.2	The driverTransmitBufferSize method	10
9.3	The driverTransmitBufferCount method	10
9.4	The driverTransmitBufferPeakCount method	10
10	Retrieving received messages using the receive method	10
10.1	Driver receive buffer size	11
10.2	The driverReceiveBufferSize method	12
10.3	The driverReceiveBufferCount method	12
10.4	The driverReceiveBufferPeakCount method	12
11	Filtering received messages	12
11.1	Accept only standard frames	13

11.2	Accept only extended frames	14
11.3	Standard frame single filter	14
11.3.1	Example 1	14
11.3.2	Example 2	15
11.4	Extended frame single filter	15
11.4.1	Example 1	15
11.4.2	Example 2	16
11.5	Standard frame dual filter	16
11.5.1	Example	17
11.6	Extended frame dual filter	17
11.6.1	Example	18
11.7	Defining your own filter	18
12	The ACAN_ESP32::begin method reference	19
12.1	The ACAN_ESP32::begin method prototype	19
12.2	The error code	20
12.2.1	CAN Bit setting too far from desired rate	20
12.2.2	CAN Bit inconsistent configuration error	21
13	ACAN_ESP32_Settings class reference	21
13.1	The ACAN_ESP32_Settings constructor: computation of the CAN bit settings	21
13.2	The CANBitSettingConsistency method	23
13.3	The actualBitRate method	24
13.4	The exactBitRate method	24
13.5	The ppmFromDesiredBitRate method	25
13.6	The samplePointFromBitStart method	25
13.7	Properties of the ACAN_ESP32_Settings class	25
13.7.1	The mRequestedCANMode property	26

1 Versions

Releases < 1.0.3 do not compile on ESP32 Arduino 2.x.x.

Version	Date	Comment
1.0.3	August 13, 2021	Updated for ESP32 Arduino 2.0.0-rc1.
1.0.2	June 26, 2021	Fixed tryToSend bug (thanks to DirkMeintjies).
1.0.1	April 26, 2021	Adding reception filters. For some bit rate settings, RJW value was invalid. Error codes have been changed (section 12.2 page 20).
1.0.0	April 18, 2021	Initial release.

2 Features

The ACAN_ESP32 library is a CAN ("Controller Area Network") driver for Teensy 3.1 / 3.2, 3.5, 3.6. It has been designed to make it easy to start and to be easily configurable:

- default configuration sends and receives any frame – no default filter to provide;
- efficient built-in CAN bit settings computation from user bit rate;
- user can fully define its own CAN bit setting values;
- reception filters are easily defined;
- driver transmit buffer size is customisable;
- driver receive buffer size is customisable;
- overflow of the driver receive buffer is detectable;
- *loop back, self reception, listing only* controller modes are selectable;
- Tx pin and Rx pins are selectable.

3 ESP32 builtin CAN Controller

ESP32 builtin CAN Controller is not official. In section 4.1.18 page 36 of the ESP32 datasheet¹, it is very shortly documented as a TWAI² controller. Actually, it is a CAN 2.0B controller. Specifically, this CAN module implements most of the functionality of an SJA1000³.

This library is based upon the Mohamed Irfanulla MOHAMED ABDULLA Master⁴. You can find a copy of this thesis in the extras directory. The corresponding code is on the <https://github.com/irfanafa/ESP32ACAN> repository.

4 Data flow

The figure 1 illustrates message flow for sending and receiving CAN messages.

Builtin CAN controller is hardware, a module of the ESP32 micro-controller. It is a CAN 2.0B controller, it implements most of the functionality of a SJA1000 controller :

- one transmit buffer;

¹Espressif Systems, *ESP32 Series Datasheet*, Version 3.6, 2021, https://www.espressif.com/sites/default/files/documentation/esp32_datasheet_en.pdf

²TWAI: *Two-Wire Automotive Interface*.

³Philips, *SJA1000 Stand-alone CAN controller data sheet*, 2000 January 4, <https://www.nxp.com/docs/en/data-sheet/SJA1000.pdf>

⁴Mohamed Irfanulla MOHAMED ABDULLA, *Development of ESP32 CAN Driver*, École Centrale de Nantes, France, 28 August 2019.

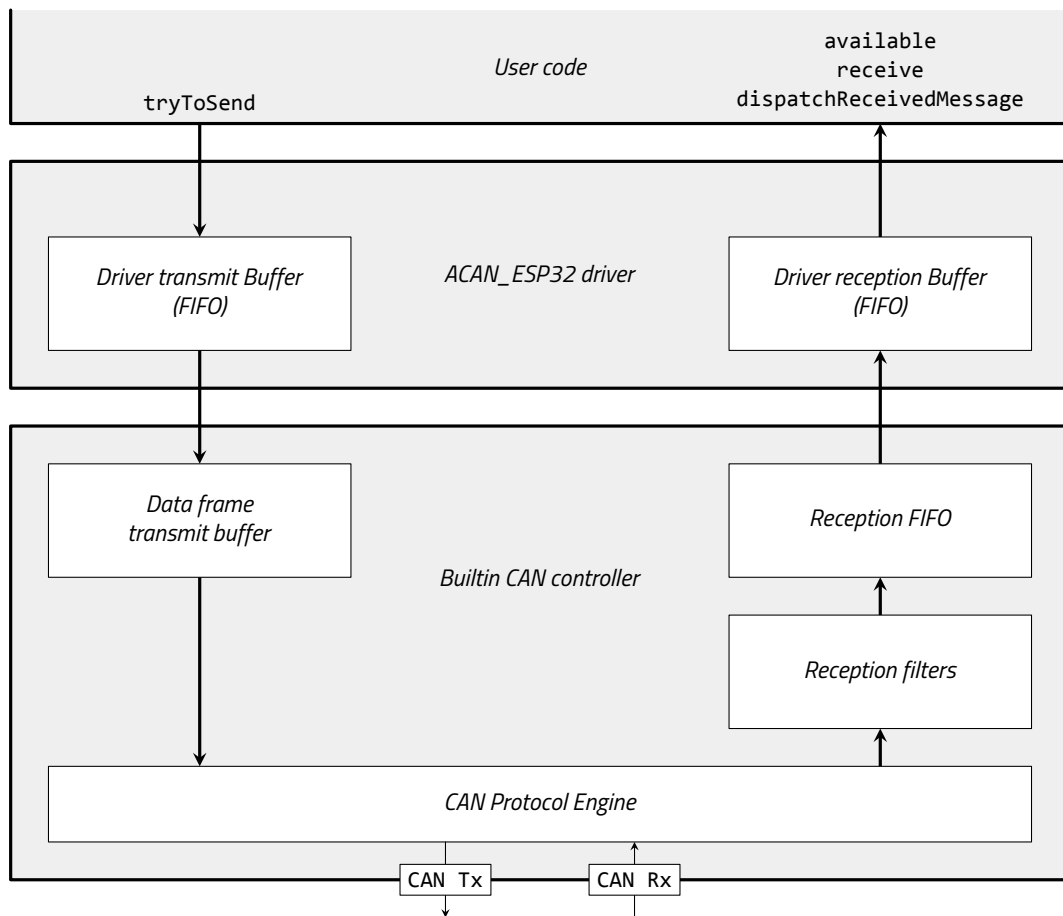


Figure 1 – Message flow in ACAN_ESP32 driver and Built-in CAN controller

- a 64-byte receive FIFO;
- 8 8-bits registers for handling receive filters.

Sending messages. The CAN hardware makes sending data frames different from sending remote frames. For both, user code calls the `tryToSend` method – see [section 9 page 9](#). The frames are stored in the *Driver Transmit Buffer*, before to be moved by the message interrupt service routine into the *data frame transmit buffer*. The size of the *Driver Transmit Buffer* is 16 by default – see [section 9.1 page 10](#) for changing the default value.

Receiving messages. The CAN *CAN Protocol Engine* transmits all correct frames to the *reception filters*. By default, they are configured as pass-all. Messages that pass the filters are stored in the 64-byte *Reception FIFO*. Its depth depends from the received message size: a standard frame with n data bytes occupies $n + 3$ bytes in the FIFO; an extended frame with n data bytes occupies $n + 5$ bytes in the FIFO. If, when receiving a frame that passes the filters, there is not enough room in the FIFO, the frame is lost. The message interrupt service routine transfers the messages from *Reception FIFO* to the *Driver Receive Buffer*. The size of the *Driver Receive Buffer* is 32 by default – see [section 10.1 page 11](#) for changing the default value. Two user methods are available:

- the `available` method returns `false` if the *Driver Receive Buffer* is empty, and `true` otherwise;

- the receive method retrieves messages from the *Driver Receive Buffer* – see [section 10 page 10](#);

Sequentiality. The ACAN_ESP32 driver and the configuration of the CAN controller ensures sequentiality of data messages. This means that if an user program calls `tryToSend` first for a message M_1 and then for a message M_2 , the message M_1 will be always retrieved by `receive` or `dispatchReceivedMessage` before the message M_2 .

5 A simple example: LoopBackDemo

The following code is a sample code for introducing the ACAN_ESP32 library. It demonstrates how to configure the driver, to send a CAN message, and to receive a CAN message.

Note that, unlike other microcontrollers, the loopback mode requires the connection with a transceiver. The [figure 2](#) shows a connection with a MCP2562 transceiver. The ACAN_ESP32 driver uses by default GPIO5 as CAN transmit signal, and GPIO4 as CAN receive signal. Other pins can be used, see [section 8 page 8](#).

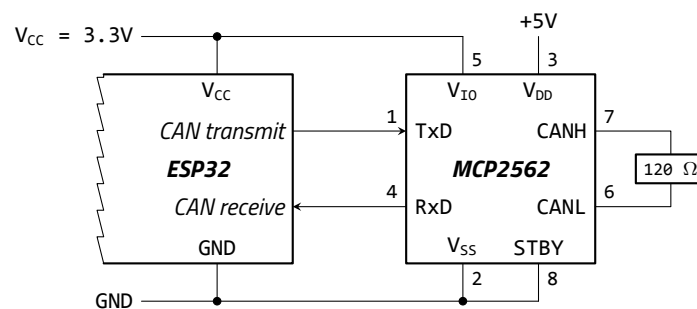


Figure 2 – Connecting an ESP32 to a MCP2562 CAN transceiver

The LoopBackDemo sketch is:

```

1  #include <ACAN_ESP32.h>
2
3  static const uint32_t DESIRED_BIT_RATE = 1000UL * 1000UL ; // 1 Mb/s
4
5  void setup() {
6  //--- Configure builtin led
7    pinMode (LED_BUILTIN, OUTPUT) ;
8    digitalWrite (LED_BUILTIN, HIGH) ;
9  //--- Start serial
10   Serial.begin (115200) ;
11  //--- Wait for serial (blink led at 10 Hz during waiting)
12   while (!Serial) {
13     delay (50) ;
14     digitalWrite (LED_BUILTIN, !digitalRead (LED_BUILTIN)) ;
15   }
16  //--- Configure ESP32 CAN
17   Serial.println ("Configure ESP32 CAN") ;
18   ACAN_ESP32_Settings settings (DESIRED_BIT_RATE) ; // CAN bit rate
19   settings.mRequestedCANMode = ACAN_ESP32_Settings::LoopBackMode; // Select loopback mode
20   // settings.mRxPin = GPIO_NUM_4 ; // Optional, default Tx pin is GPIO_NUM_4
21   // settings.mTxPin = GPIO_NUM_5 ; // Optional, default Rx pin is GPIO_NUM_5
22   const uint32_t errorCode = ACAN_ESP32::can.begin (settings) ;
23   if (errorCode == 0) {
24     Serial.print ("Bit Rate prescaler: ") ;

```

```

25     Serial.println (settings.mBitRatePrescaler) ;
26     Serial.print ("Time Segment 1:  ") ;
27     Serial.println (settings.mTimeSegment1) ;
28     Serial.print ("Time Segment 2:  ") ;
29     Serial.println (settings.mTimeSegment2) ;
30     Serial.print ("SJW:  ") ;
31     Serial.println (settings.mRJW) ;
32     Serial.print ("Triple Sampling:  ") ;
33     Serial.println (settings.mTripleSampling ? "yes" : "no") ;
34     Serial.print ("Actual bit rate:  ") ;
35     Serial.print (settings.actualBitRate ()) ;
36     Serial.println (" bit/s") ;
37     Serial.print ("Exact bit rate ?  ") ;
38     Serial.println (settings.exactBitRate () ? "yes" : "no") ;
39     Serial.print ("Sample point:  ") ;
40     Serial.print (settings.samplePointFromBitStart ()) ;
41     Serial.println ("%") ;
42     Serial.println ("Configuration OK!");
43 }else {
44     Serial.print ("Configuration error 0x") ;
45     Serial.println (errorCode, HEX) ;
46 }
47 }
48
49 static uint32_t gBlinkLedDate = 0;
50 static uint32_t gReceivedFrameCount = 0 ;
51 static uint32_t gSentFrameCount = 0 ;
52
53 void loop() {
54     CANMessage frame ;
55     if (gBlinkLedDate < millis ()) {
56         gBlinkLedDate += 500 ;
57         digitalWrite (LED_BUILTIN, !digitalRead (LED_BUILTIN)) ;
58         Serial.print ("Sent: ") ;
59         Serial.print (gSentFrameCount) ;
60         Serial.print ("\t") ;
61         Serial.print ("Receive: ") ;
62         Serial.print (gReceivedFrameCount) ;
63         Serial.print ("\t") ;
64         Serial.print (" STATUS 0x") ;
65         Serial.print (CAN_STATUS, HEX) ;
66         Serial.print (" RXERR ") ;
67         Serial.print (CAN_RX_ECR) ;
68         Serial.print (" TXERR ") ;
69         Serial.println (CAN_TX_ECR) ;
70         frame.len = 8 ;
71         const bool ok = ACAN_ESP32::can.tryToSend (frame) ;
72         if (ok) {
73             gSentFrameCount += 1 ;
74         }
75     }
76     while (ACAN_ESP32::can.receive (frame)) {
77         gReceivedFrameCount += 1 ;
78     }
79 }

```

Line 1. This line includes the ACAN_ESP32 library.

Line 3. Declaration of the baud rate, in bit/s.

Line 18. Configuration is a four-step operation. This line is the first step. It instanciates the `settings` object of the `ACAN_ESP32_Settings` class. The constructor has one parameter: the wished CAN bit rate. It returns a `settings` object fully initialized with CAN bit settings for the wished bit rate, and default values for other

configuration properties.

Line 19. This is the second step. You can override the values of the properties of `settings` object. Here, the `mRequestedCANMode` properties is set to `ACAN_ESP32_Settings::LoopBackMode` – it is `NormalMode` by default. If you want to change CAN transmit and receive pins, write here the new settings (see [section 8 page 8](#)). The [section 13.7 page 25](#) lists all properties you can override.

Line 20, 21. This is the third step, configuration of the `ACAN_ESP32::can` driver with `settings` values. Default CAN Tx pin is `GPIO_NUM_5`, default Rx pin is `GPIO_NUM_4`; here, you can choose your own pins (see [section 8 page 8](#)).

Line 22. This is the third step, configuration of the `ACAN_ESP32::can` driver with `settings` values. You cannot change the `ACAN_ESP32::can` name – see [section 7 page 8](#). The driver is configured for being able to send any (standard / extended, data / remote) frame, and to receive all (standard / extended, data / remote) frames. If you want to define reception filters, see [section 11 page 12](#).

Lines 23 to 46. Last step: the configuration of the `ACAN_ESP32::can` driver returns an error code, stored in the `errorCode` constant. It has the value 0 if all is ok – see [section 12.2 page 20](#).

Line 49. The `gBlinkLedDate` global variable is used for sending a CAN message every 0.5 s.

Line 50. The `gReceivedFrameCount` global variable counts the number of received messages.

Line 51. The `gSentFrameCount` global variable counts the number of sent messages.

Line 54. The message object is fully initialized by the default constructor, it represents a standard data frame, with an identifier equal to 0, and without any data – see [section 6 page 8](#).

Line 55. It tests if it is time to blink the led, print send and receive counters, and to send a message.

Line 70. Set the message length. In a real code, we set here message data, identifier, and for an extended frame the `ext` boolean property.

Line 71. We try to send the data message. Actually, we try to transfer it into the *Driver transmit buffer*. The transfer succeeds if the buffer is not full. The `tryToSend` method returns `false` if the buffer is full, and `true` otherwise. Note the returned value only tells if the transfer into the *Driver transmit buffer* is successful or not: we have no way to know if the frame is actually sent on the the CAN network.

Lines 72 to 74. We act the successfull transfer by setting `gSendDate` to the next send date and incrementing the `gSentCount` variable. Note if the transfer did fail, the send date is not changed, so the `tryToSend` method will be called on the execution of the `loop` function.

Line 76. As the CAN controller is configured in *loop back* mode (see lines 7 and 8), all sent messages are received. The receive method returns `false` if no message is available from the *driver reception buffer*. It returns `true` if a message has been successfully removed from the *driver reception buffer*. This message is assigned to the `message` object.

Line 77. If a message has been received, the `gReceivedFrameCount` is incremented and displayed.

6 The CANMessage class

Note. The CANMessage class is declared in the CANMessage.h header file. The class declaration is protected by an include guard that causes the macro GENERIC_CAN_MESSAGE_DEFINED to be defined. The ACAN2515 driver contains an identical CANMessage.h file header, enabling using both ACAN driver and ACAN2515 driver in a sketch.

A *CAN message* is an object that contains all CAN frame user informations. All properties are initialized by default, and represent a standard data frame, with an identifier equal to 0, and without any data.

```
class CANMessage {
public : uint32_t id = 0 ; // Frame identifier
public : bool ext = false ; // false -> standard frame, true -> extended frame
public : bool rtr = false ; // false -> data frame, true -> remote frame
public : uint8_t idx = 0 ; // Used by the ACAN driver
public : uint8_t len = 0 ; // Length of data (0 ... 8)
public : union {
    uint64_t data64 ; // Caution: subject to endianness
    uint32_t data32 [2] ; // Caution: subject to endianness
    uint16_t data16 [4] ; // Caution: subject to endianness
    float dataFloat [2] ; // Caution: subject to endianness
    uint8_t data [8] = {0, 0, 0, 0, 0, 0, 0, 0} ;
} ;
} ;
```

Note the message datas are defined by an **union**. So message datas can be seen as height bytes, four 16-bit unsigned integers, two 32-bit, one 64-bit or two 32-bit floats. Be aware that multi-byte integers and floats are subject to endianness (ESP32 processor is little-endian).

7 Driver instance

The driver instance name is ACAN_ESP32::can. You cannot choose its name, it is defined by the library.

Note. The driver variable is an ACAN_ESP32 class static property. This choice may seem strange. However, a common error is to declare its own driver variable:

```
ACAN_ESP32 myCAN ; // Don't do that, it is an error !!!
```

Declaring a driver variable as ACAN_ESP32 class static property⁵ enables the compiler to raise an error if you try to declare your own driver variable.

8 Pin selection

By default, CAN transmit pin is GPIO5, and CAN receive pin is GPIO4.

For using other pins, just set mTxPin and / or mRxPin properties of settings object. For example:

```
ACAN_ESP32_Settings settings (125 * 1000) ;
settings.mTxPin = GPIO_NUM_2 ;
settings.mRxPin = GPIO_NUM_13 ;
const uint32_t errorCode = ACAN_ESP32::can.begin (settings) ;
```

⁵The ACAN_ESP32 constructor is declared private.

The `mTxPin` and `mRxPin` properties type is `gpio_num_t`, so you should use the `GPIO_NUM_n` names.

Note. Particular care must be taken in the choice of pins. Indeed, some pins output a PWM at boot, others require a high or low level, ... The <https://randomnerdtutorials.com/esp32-pinout-reference-gpios/> shows what pins are best to use as inputs, outputs and which ones you need to be cautious.

For example, it is a bad choice to use `GPIO0` as CAN transmit pins: it outputs PWM signal at boot, disturbing the CAN bus. Using `GPIO12` as CAN receive pin provide a boot failure: if the CAN bus is recessive, the transceiver outputs a high level on its `RxD` pin, and boot fails if `GPIO12` is pulled high.

9 Sending frames

Call the method `tryToSend` for sending frames; it returns:

- `true` if the message has been successfully transmitted to driver transmit buffer; note that does not mean that the CAN frame has been actually sent;
- `false` if the message has not been successfully transmitted to driver transmit buffer, it was full.

So it is wise to systematically test the returned value. One way is to use a global variable to note if message has been successfully transmitted to driver transmit buffer. For example, for sending a message every 2 seconds:

```
static uint32_t gSendDate = 0 ;

void loop () {
    CANMessage message ;
    if (gSendDate < millis ()) {
        // Initialize message properties
        const bool ok = ACAN_ESP32::can.tryToSend (message) ;
        if (ok) {
            gSendDate += 2000 ;
        }
    }
}
```

An other hint to use a global boolean variable as a flag that remains true while the frame has not been sent.

```
static bool gSendMessage = false ;

void loop () {
    ...
    if (frame_should_be_sent) {
        gSendMessage = true ;
    }
    ...
    if (gSendMessage) {
        CANMessage message ;
        // Initialize message properties
        const bool ok = ACAN_ESP32::can.tryToSend (message) ;
        if (ok) {
            gSendMessage = false ;
        }
    }
    ...
}
```

9.1 Driver transmit buffer size

By default, driver transmit buffer size is 16. You can change this default value by setting the `mDriverTransmitBufferSize` property of `settings` variable:

```
ACAN_ESP32_Settings settings (125 * 1000) ;
settings.mDriverTransmitBufferSize = 30 ;
const uint32_t errorCode = ACAN_ESP32::can.begin (settings) ;
...
```

As the size of `CANMessage` class is 16 bytes, the actual size of the driver transmit buffer is the value of `settings.mDriverTransmitBufferSize * 16`.

9.2 The `driverTransmitBufferSize` method

It returns the size of the driver transmit buffer, that is the value of `settings.mDriverTransmitBufferSize`.

```
const uint32_t s = ACAN_ESP32::can.driverTransmitBufferSize () ;
```

9.3 The `driverTransmitBufferCount` method

The `transmitBufferCount` method returns the current number of messages in the transmit buffer.

```
const uint32_t n = ACAN_ESP32::can.driverTransmitBufferCount () ;
```

9.4 The `driverTransmitBufferPeakCount` method

The `transmitBufferPeakCount` method returns the peak value of message count in the transmit buffer.

```
const uint32_t max = ACAN_ESP32::can.driverTransmitBufferPeakCount () ;
```

If the transmit buffer is full when `tryToSend` is called, the return value is `false`. In such case, the following calls of `driverTransmitBufferPeakCount` will return `driverTransmitBufferSize ()+1`.

So, when `driverTransmitBufferPeakCount` returns a value lower or equal to `driverTransmitBufferSize ()`, it means that calls to `tryToSend` have always returned `true`.

10 Retrieving received messages using the receive method

This is a basic example:

```
void setup () {
    ACAN_ESP32_Settings settings (125 * 1000) ;
    ...
    const uint32_t errorCode = ACAN_ESP32::can.begin (settings) ; // No receive filter
    ...
}

void loop () {
    CANMessage message ;
```

```

if (ACAN_ESP32::can.receive (message)) {
    // Handle received message
}
}

```

The receive method:

- returns false if the driver receive buffer is empty, message argument is not modified;
- returns true if a message has been removed from the driver receive buffer, and the message argument is assigned.

You need to manually dispatch the received messages. If you did not provide any receive filter, you should check the rtr bit (remote or data frame?), the ext bit (standard or extended frame), and the id (identifier value). The following snippet dispatches three messages:

```

void setup () {
    ACAN_ESP32_Settings settings (125 * 1000) ;
    ...
    const uint32_t errorCode = ACAN_ESP32::can.begin (settings) ; // No receive filter
    ...
}

void loop () {
    CANMessage message ;
    if (ACAN_ESP32::can.receive (message)) {
        if (!message.rtr && message.ext && (message.id == 0x123456)) {
            handle_myMessage_0 (message) ; // Extended data frame, id is 0x123456
        } else if (!message.rtr && !message.ext && (message.id == 0x234)) {
            handle_myMessage_1 (message) ; // Standard data frame, id is 0x234
        } else if (message.rtr && !message.ext && (message.id == 0x542)) {
            handle_myMessage_2 (message) ; // Standard remote frame, id is 0x542
        }
    }
    ...
}

```

The handle_myMessage_0 function has the following header:

```

void handle_myMessage_0 (const CANMessage & inMessage) {
    ...
}

```

So are the header of the handle_myMessage_1 and the handle_myMessage_2 functions.

10.1 Driver receive buffer size

By default, the driver receive buffer size is 32.

You can change this default value by setting the mDriverReceiveBufferSize property of settings variable:

```

ACAN_ESP32_Settings settings (125 * 1000) ;
settings.mDriverReceiveBufferSize = 100 ;
const uint32_t errorCode = ACAN_ESP32::can.begin (settings) ;
...

```

The actual size of the driver receive buffer is the value of settings.mDriverReceiveBufferSize * 16 (the size of CANMessage class is 16 bytes).

10.2 The driverReceiveBufferSize method

The driverReceiveBufferSize method returns the size of the driver receive buffer, that is the value of settings.mDriverReceiveBufferSize.

```
const uint32_t s = ACAN_ESP32::can.receiveBufferSize ();
```

10.3 The driverReceiveBufferCount method

The driverReceiveBufferCount method returns the current number of messages in the driver receive buffer.

```
const uint32_t n = ACAN_ESP32::can.driverReceiveBufferCount ();
```

10.4 The driverReceiveBufferPeakCount method

The driverReceiveBufferPeakCount method returns the peak value of message count in the driver receive buffer.

```
const uint32_t max = ACAN_ESP32::can.driverReceiveBufferPeakCount ();
```

Note the driver receive buffer may overflow, if messages are not retrieved (by calls of the receive method or the dispatchReceivedMessage method). If an overflow occurs, further calls of the ACAN_ESP32::can.receiveBufferPeakCount () method return ACAN_ESP32::can.receiveBufferSize ()+1.

11 Filtering received messages

By default, no filtering of received message occurs, that is all network CAN frames are captured and transferred into the hardware CAN 64-byte RxFIFO, and then transferred into the driver receive buffer by the driver.

As SJA1000, ESP32 CAN module has 8 bytes dedicated to received message filtering. This is very little, so the filtering possibilities are very limited.

Six different filters are defined:

- accept only standard frames ([section 11.1 page 13](#), demo sketch: ESP32CANAcceptOnlyStandardFilterDemo);
- accept only extended frames ([section 11.2 page 14](#), demo sketch: ESP32CANAcceptOnlyExtendedFilterDemo);
- standard frame single filter ([section 11.3 page 14](#), demo sketch: ESP32CANSingleStandardFilterDemo);
- extended frame single filter ([section 11.4 page 15](#), demo sketch: ESP32CANSingleExtendedFilterDemo);
- standard frame dual filter ([section 11.5 page 16](#), demo sketch: ESP32CANDualStandardFilterDemo);
- extended frame dual filter ([section 11.6 page 17](#), demo sketch: ESP32CANDualExtendedFilterDemo).

If none of the above filters work for you, you can set your own ([section 11.7 page 18](#)).

A filter demo sketch iterates over:

- all standard data frames with no data (2^{11} frames);
- all standard remote frames (2^{11} frames);
- all extended data frames with no data (2^{29} frames);
- all extended remote frames (2^{29} frames).

The frames are transmitted in this order:

- standard data frame with identifier 0x000;
- standard remote frame with identifier 0x000;
- standard data frame with identifier 0x001;
- standard remote frame with identifier 0x001;
- ...
- standard data frame with identifier 0x7FF;
- standard remote frame with identifier 0x7FF;
- extended data frame with identifier 0x00000000;
- extended remote frame with identifier 0x00000000;
- extended data frame with identifier 0x00000001;
- extended remote frame with identifier 0x00000001;
- ...
- extended data frame with identifier 0x1FFFFFFF;
- extended remote frame with identifier 0x1FFFFFFF.

So it takes a while!

Every minute a progress message is printed.

Every accepted frame is printed. **So a huge number of lines can be printed!** For example, the ESP32CANAcceptOnlyExtendedFilterDemo sketch accepts all extended frames, so 2^{29} data frames and 2^{29} remote frames are received and printed.

11.1 Accept only standard frames

This filter accepts any (data and remote) standard frames, and rejects any extended frame.

Demo sketch: ESP32CANAcceptOnlyStandardFilterDemo.

```

void setup () {
  ...
  ACAN_ESP32_Settings settings (...);
  ...
  const ACAN_ESP32_Filter filter = ACAN_ESP32_Filter::acceptStandardFrames ();
  const uint32_t errorCode = ACAN_ESP32::can.begin (settings, filter);
  ...
}

```

11.2 Accept only extended frames

This filter accepts any (data and remote) extended frames, and rejects any standard frame.

Demo sketch: ESP32CANAcceptOnlyExtendedFilterDemo.

```

void setup () {
  ...
  ACAN_ESP32_Settings settings (...);
  ...
  const ACAN_ESP32_Filter filter = ACAN_ESP32_Filter::acceptExtendedFrames ();
  const uint32_t errorCode = ACAN_ESP32::can.begin (settings, filter);
  ...
}

```

11.3 Standard frame single filter

This filter accepts standard frames that pass filter, and rejects any extended frame.

Demo sketch: ESP32CANSingleStandardFilterDemo.

The `ACAN_ESP32_Filter::singleStandardFilter` static function prototype is:

```

ACAN_ESP32_Filter singleStandardFilter (const ACAN_ESP32_Filter::Type inType,
                                       const uint16_t inIdentifier,
                                       const uint16_t inDontCareMask);

```

The three parameters are:

1. `inType`: you can choose to receive only the data frames (`ACAN_ESP32_Filter::data`), to receive only the remote frames (`ACAN_ESP32_Filter::remote`), or both (`ACAN_ESP32_Filter::dataAndRemote`);
2. `inIdentifier`: the value of the identifier of the frames you want to receive; note: as a standard identifier consists of 11 bits, bits 11 to 15 of the supplied value are ignored;
3. `inDontCareMask`: here you specify the `inIdentifier` bits that are ignored for filtering (see examples below); a zero value means only frame with identifier equal to `inIdentifier` matches.

11.3.1 Example 1

I only want to receive standard data frames with an identifier of 0x123.

```

void setup () {
  ...

```

```

ACAN_ESP32_Settings settings (...);
...
const ACAN_ESP32_Filter filter = ACAN_ESP32_Filter::singleStandardFilter (
    ACAN_ESP32_Filter::data, 0x123, 0
);
const uint32_t errorCode = ACAN_ESP32::can.begin (settings, filter);
...
}

```

11.3.2 Example 2

From the previous example, the last parameter is changed to 0x404.

```

void setup () {
    ...
    ACAN_ESP32_Settings settings (...);
    ...
    const ACAN_ESP32_Filter filter = ACAN_ESP32_Filter::singleStandardFilter (
        ACAN_ESP32_Filter::data, 0x123, 0x404
    );
    const uint32_t errorCode = ACAN_ESP32::can.begin (settings, filter);
    ...
}

```

The 1-bits of 0x404 are the #2 and #10: 0x123 bits 2 and 10 are ignored for filtering. Therefore frames of identifier 0x123, 0x127, 0x523 and 0x527 are received.

11.4 Extended frame single filter

This filter accepts extended frames that pass filter, and rejects any standard frame.

Demo sketch: ESP32CANSingleExtendedFilterDemo.

The ACAN_ESP32_Filter::singleExtendedFilter static function prototype is:

```

ACAN_ESP32_Filter singleExtendedFilter (const ACAN_ESP32_Filter::Type inType,
                                        const uint32_t inIdentifier,
                                        const uint32_t inDontCareMask);

```

The three parameters are:

1. `inType`: you can choose to receive only the data frames (`ACAN_ESP32_Filter::data`), to receive only the remote frames (`ACAN_ESP32_Filter::remote`), or both (`ACAN_ESP32_Filter::dataAndRemote`);
2. `inIdentifier`: the value of the identifier of the frames you want to receive; note: as a extended identifier consists of 29 bits, bits 29 to 31 of the supplied value are ignored;
3. `inDontCareMask`: here you specify the `inIdentifier` bits that are ignored for filtering (see examples below); a zero value means only frame with identifier equal to `inIdentifier` matches.

11.4.1 Example 1

I only want to receive extended data frames with an identifier of 0x12345678.

```

void setup () {
    ...
    ACAN_ESP32_Settings settings (...);
    ...
    const ACAN_ESP32_Filter filter = ACAN_ESP32_Filter::singleExtendedFilter (
        ACAN_ESP32_Filter::data, 0x12345678, 0
    );
    const uint32_t errorCode = ACAN_ESP32::can.begin (settings, filter);
    ...
}

```

11.4.2 Example 2

From the previous example, the last parameter is changed to 0x20202.

```

void setup () {
    ...
    ACAN_ESP32_Settings settings (...);
    ...
    const ACAN_ESP32_Filter filter = ACAN_ESP32_Filter::singleExtendedFilter (
        ACAN_ESP32_Filter::data, 0x12345678, 0x20202
    );
    const uint32_t errorCode = ACAN_ESP32::can.begin (settings, filter);
    ...
}

```

The 1-bits of 0x20202 are the #1, #9 and #17: 0x12345678 bits 1, 9 and 17 are ignored for filtering. Therefore frames of identifier 0x12345478, 0x1234547A, 0x12345678, 0x1234567A, 0x12365478, 0x1236547A, 0x12365678 and 0x1236567A are received. The [table 1](#) shows how these identifier values can be found.

Parameter	Hex value	Binary value
inIdentifier	0x12345678	1 0010 0011 0100 0101 0110 0111 1000
inDontCareMask	0x00020202	0 0000 0000 0010 0000 0010 0000 0010
Accepted identifiers		1 0010 0011 01x0 0101 01x0 0111 10x0

Table 1 – ACAN_ESP32Filter::singleExtendedFilter filter example

11.5 Standard frame dual filter

This filter accepts standard frames that pass one of the filters, and rejects any extended frame.

The ACAN_ESP32_Filter::dualStandardFilter static function prototype is:

```

ACAN_ESP32_Filter dualStandardFilter (const ACAN_ESP32_Filter::Type inType0,
                                     const uint16_t inIdentifier0,
                                     const uint16_t inDontCareMask0,
                                     const ACAN_ESP32_Filter::Type inType1,
                                     const uint16_t inIdentifier1,
                                     const uint16_t inDontCareMask1);

```

The six parameters are:

1. inType0, inType1: you can choose to receive only the data frames (ACAN_ESP32_Filter::data), to receive only the remote frames (ACAN_ESP32_Filter::remote), or both (ACAN_ESP32_Filter::dataAndRemote);

2. `inIdentifier0`, `inIdentifier1`: the value of the identifier of the frames you want to receive; note: as a standard identifier consists of 11 bits, bits 11 to 15 of the supplied value are ignored;
3. `inDontCareMask0`, `inDontCareMask1`: here you specify the `inIdentifier` bits that are ignored for filtering (see examples below); a zero value means only frame with identifier equal to `inIdentifier` matches.

The first three parameters `inType0`, `inIdentifier0` and `inDontCareMask0` define the first filter. The last three parameters `inType1`, `inIdentifier1` and `inDontCareMask1` define the second one. The two filters are independant. A frame is received if it passes one filter (or both).

11.5.1 Example

Demo sketch: `ESP32CANDualStandardFilterDemo`.

```
void setup () {
  ...
  ACAN_ESP32_Settings settings (...);
  ...
  const ACAN_ESP32_Filter filter = ACAN_ESP32_Filter::dualStandardFilter (
    ACAN_ESP32_Filter::data, 0x123, 0x110,
    ACAN_ESP32_Filter::remote, 0x456, 0x022
  );
  const uint32_t errorCode = ACAN_ESP32::can.begin (settings, filter);
  ...
}
```

For the first filter, the 1-bits of `0x110` are the #4 and #8: `0x123` bits 4 and 8 are ignored for filtering. Therefore standard data frames of identifier `0x023`, `0x033`, `0x123` and `0x133` are received. For the second one, the 1-bits of `0x022` are the #1 and #5: `0x456` bits 1 and 5 are ignored for filtering. Therefore remote data frames of identifier `0x454`, `0x456`, `0x474` and `0x476` are also received.

11.6 Extended frame dual filter

This filter accepts extended frames that pass one of the filters, and rejects any standard frame.

The `ACAN_ESP32_Filter::dualExtendedFilter` static function prototype is:

```
ACAN_ESP32_Filter dualExtendedFilter (const uint32_t inIdentifier0,
                                     const uint32_t inDontCareMask0,
                                     const uint32_t inIdentifier1,
                                     const uint32_t inDontCareMask1 ;
```

The four parameters are:

1. `inIdentifier0`, `inIdentifier1`: the value of the identifier of the frames you want to receive; note: as a standard identifier consists of 29 bits, bits 29 to 31 of the supplied value are ignored; **special case for this filter, the 13 lower bits are also ignored**;
2. `inDontCareMask0`, `inDontCareMask1`: here you specify the `inIdentifier` bits that are ignored for filtering (see examples below); a zero value means only frame with identifier equal to `inIdentifier` matches; as for the previous parameter, bits 0 to 12 and bits 29 to 31 are ignored.

The first two parameters `inIdentifier0` and `inDontCareMask0` define the first filter. The last two parameters `inIdentifier1` and `inDontCareMask1` define the second one. The two filters are independant. A frame is received if it passes one filter (or both).

Unlike other filters, it is not possible to filter by the type (data, remote) of the received frame. Both data and remote extended frames with a given identifier are either accepted, either rejected.

11.6.1 Example

Demo sketch: `ESP32CANDualExtendedFilterDemo`.

```
void setup () {
  ...
  ACAN_ESP32_Settings settings (...);
  ...
  const ACAN_ESP32_Filter filter = ACAN_ESP32_Filter::dualExtendedFilter (
    0x12345678, 0x00060000, // First filter
    0x19876543, 0x0000A000 // Second filter
  );
  const uint32_t errorCode = ACAN_ESP32::can.begin (settings, filter);
  ...
}
```

The details of the filter operations are shown in [table 2](#). Note that parameter bits 0 to 12 are always ignored by this filter. For example, `inIdentifier0` can have any value between `0x12344000` and `0x12345FFF` without modifying filtering result. Note also that `inDontCareMask1` value is `0x00009000`, the two 1-bits are #12 and #15. The bit #12 is always ignored this filter, therefore `inDontCareMask1` can have any value between `0x00008000` and `0x00009FFF` without modifying filtering result. Finally, this filter accepts data and remote extended frames whose identifiers are of the form 1 0010 0011 0xx0 010x xxxx xxxx xxxx (2^{15} extended data frames, 2^{15} extended remote frames) or 1 1001 1000 0111 x00x xxxx xxxx xxxx (2^{14} extended data frames, 2^{14} extended remote frames).

Parameter	Hex value	Binary value
<code>inIdentifier0</code>	<code>0x12345678</code>	0001 0010 0011 0100 0101 0110 0111 1000
<code>inDontCareMask0</code>	<code>0x00060000</code>	0000 0000 0000 0110 0000 0000 0000 0000
Ignored bits		xxx x xxxx xxxx xxxx
Accepted identifiers		1 0010 0011 0xx0 010x xxxx xxxx xxxx
Parameter	Hex value	Binary value
<code>inIdentifier1</code>	<code>0x19876543</code>	0001 1001 1000 0111 0110 0101 0100 0011
<code>inDontCareMask1</code>	<code>0x00009000</code>	0000 0000 0000 0000 1001 0000 0000 0000
Ignored bits		xxx x xxxx xxxx xxxx
Accepted identifiers		1 1001 1000 0111 x00x xxxx xxxx xxxx

Table 2 – `ACAN_ESP32Filter::dualExtendedFilter` filter example

11.7 Defining your own filter

If none of the previous filters satisfy you, you can define your own filter. The properties of `ACAN_ESP32Filter` are public, so you can set them as you want:

```

void setup () {
    ...
    ACAN_ESP32_Settings settings (...);
    ...
    ACAN_ESP32_Filter filter = ACAN_ESP32_Filter::acceptAll (); // Providing a default value
    filter.mACR0 = ...;
    ...
    filter.mAMR3 = ...;
    filter.mAMFSingle = ...;
    filter.mFormat = ...;
    const uint32_t errorCode = ACAN_ESP32::can.begin (settings, filter);
    ...
}

```

Read the *SJA1000 Data sheet*⁶, section 6.4.15 from page 44. Section 6.3.9 from page 19 is irrelevant because it is for *basic* mode, but the driver sets the SJA1000 to *pelican* mode.

When the `ACAN_ESP32::begin` method is executed:

- the `mACR0` property of the `filter` parameter is set to the `ACR0` control register;
- ...
- the `mAMR3` property of the `filter` parameter is set to the `AMR3` control register;
- the `mAMFSingle` boolean property of the `filter` parameter is set to the `AFM` bit `MOD` control register.

The `mFormat` boolean property of the `filter` parameter is particular. It does not correspond to any control register, it is handled by the driver. The key point is that the SJA1000 filters are not designed to accept or reject a frame based on its standard or extended format. The contents of the `AMR0`, ..., `ACR3` registers are interpreted differently depending on whether the received frame is standard or extended. Thus, a filter setting always accepts, whatever the value of the `AMR0`, ..., `ACR3` registers, *some* standard frames and *some* extended frames.

When the `ACAN_ESP32::begin` method is executed, the `mFormat` boolean property of the `filter` parameter is set to the `mAcceptedFrameFormat` property of the `ACAN_ESP32` class. This property is only used in the `ACAN_ESP32::handleRXInterrupt` method for accepting or rejecting data or remote frames.

12 The ACAN_ESP32::begin method reference

12.1 The ACAN_ESP32::begin method prototype

The `begin` method prototype is:

```

uint32_t ACAN_ESP32::begin (const ACAN_ESP32_Settings & inSettings,
    const ACAN_ESP32_Filter & inFilter = ACAN_ESP32_Filter::acceptAll ());

```

The second parameter defines the receive filter and is optional; by default, the pass-all filter is provided.

⁶Philips, *SJA1000 Stand-alone CAN controller data sheet*, 2000 January 4, <https://www.nxp.com/docs/en/data-sheet/SJA1000.pdf>

12.2 The error code

The `begin` method returns an error code. The value `0` denotes no error. Otherwise, you consider every bit as an error flag. An error code could report several errors. Bits from 0 to 9 are actually defined by the `ACAN_ESP32_Settings` class and are also returned by the `CANBitSettingConsistency` method (see [section 13.2 page 23](#)). Bits from 16 are defined by the `ACAN_ESP32` class.

The `ACAN_ESP32_Settings` class defines static constant properties that can be used as mask error:

```
public: static const uint16_t kBitRatePrescalerIsZero           = 1 << 0 ;
public: static const uint16_t kBitRatePrescalerIsGreaterThan64 = 1 << 1 ;
public: static const uint16_t kTimeSegment1IsZero             = 1 << 2 ;
public: static const uint16_t kTimeSegment1IsGreaterThan16    = 1 << 3 ;
public: static const uint16_t kTimeSegment2IsLowerThan2       = 1 << 4 ;
public: static const uint16_t kTimeSegment2IsGreaterThan8     = 1 << 5 ;
public: static const uint16_t kTimeSegment2Is2AndTripleSampling = 1 << 6 ;
public: static const uint16_t kRJWTIsZero                     = 1 << 7 ;
public: static const uint16_t kRJWTIsGreaterThan4             = 1 << 8 ;
public: static const uint16_t kRJWTIsGreaterThanTimeSegment2 = 1 << 9 ;
```

The `ACAN_ESP32` class defines static constant properties that can be used as mask error:

```
public: static const uint32_t kNotInRestModeInConfiguration    = 1 << 16 ;
public: static const uint32_t kCANRegistersError              = 1 << 17 ;
public: static const uint32_t kTooFarFromDesiredBitRate        = 1 << 18 ;
public: static const uint32_t kInconsistentBitRateSettings     = 1 << 19 ;
public: static const uint32_t kCannotAllocateDriverReceiveBuffer = 1 << 20 ;
public: static const uint32_t kCannotAllocateDriverTransmitBuffer = 1 << 21 ;
```

For example, you can write:

```
const uint32_t errorCode = ACAN_ESP32::can.begin (settings) ;
if (errorCode != 0) {
    ...
    if ((errorCode & ACAN_ESP32::kTooFarFromDesiredBitRate) != 0) {
        // Error: too far from desired bit rate
    }
    ...
}
```

12.2.1 CAN Bit setting too far from desired rate

This error is raised when the `mBitRateClosedToDesiredRate` of the `settings` object is false. This means that the `ACAN_ESP32_Settings` constructor cannot compute a CAN bit configuration close enough to the wished bit rate. When the `begin` is called with `settings.mBitRateClosedToDesiredRate` false, this error is reported. For example:

```
void setup () {
    ACAN_ESP32_Settings settings (1) ; // 1 bit/s !!!
    // Here, settings.mBitRateClosedToDesiredRate is false
    const uint32_t errorCode = ACAN_ESP32::can.begin (settings) ;
    // Here, errorCode == ACAN_ESP32::kCANBitConfigurationTooFarFromWishedBitRateErrorMask
}
```

This error is a fatal error, the driver and the CAN module are not configured. See [section 13.1 page 21](#) for a discussion about CAN bit setting computation.

12.2.2 CAN Bit inconsistent configuration error

This error is raised when you have changed the CAN bit properties (mBitRatePrescaler, mTimeSegment1, mTimeSegment2, mRJW), and one or more resulting values are inconsistent. See [section 13.2 page 23](#).

13 ACAN_ESP32_Settings class reference

13.1 The ACAN_ESP32_Settings constructor: computation of the CAN bit settings

The constructor of the ACAN_ESP32_Settings has one mandatory argument: the wished bit rate. It tries to compute the CAN bit settings for this bit rate. If it succeeds, the constructed object has its mBitConfigurationClosedToWishedRate property set to true, otherwise it is set to false. For example:

```
void setup () {
  ACAN_ESP32_Settings settings (1 * 1000 * 1000) ; // 1 Mbit/s
  // Here, settings.mBitRateClosedToDesiredRate is true
  ...
}
```

Of course, CAN bit computation always succeeds for classical bit rates: 1 Mbit/s, 500 kbit/s, 250 kbit/s, 125 kbit/s. But CAN bit computation can also succeed for some unusual bit rates, as 842 kbit/s. You can check the result by computing actual bit rate, and the distance from the wished bit rate:

```
void setup () {
  Serial.begin (9600) ;
  ACAN_ESP32_Settings settings (842 * 1000) ; // 842 kbit/s
  Serial.print ("mBitRateClosedToDesiredRate: ") ;
  Serial.println (settings.mBitRateClosedToDesiredRate) ; // 1 (--> is true)
  Serial.print ("actual bit rate: ") ;
  Serial.println (settings.actualBitRate ()) ; // 842105 bit/s
  Serial.print ("distance: ") ;
  Serial.println (settings.ppmFromDesiredBitRate ()) ; // 125 ppm
  ...
}
```

The actual bit rate is 842,105 bit/s, and its distance from wished bit rate is 124 ppm. "ppm" stands for "part-per-million", and 1 ppm = 10^{-6} . In other words, 10,000 ppm = 1%.

By default, a wished bit rate is accepted if the distance from the computed actual bit rate is lower or equal to 1,000 ppm = 0.1 %. You can change this default value by adding your own value as second argument of ACAN_ESP32_Settings constructor:

```
void setup () {
  Serial.begin (9600) ;
  ACAN_ESP32_Settings settings (842 * 1000, 100) ; // 842 kbit/s, max distance is 100 ppm
  Serial.print ("mBitRateClosedToDesiredRate: ") ;
  Serial.println (settings.mBitRateClosedToDesiredRate) ; // 0 (--> is false)
  Serial.print ("actual bit rate: ") ;
  Serial.println (settings.actualBitRate ()) ; // 842105 bit/s
  Serial.print ("distance: ") ;
  Serial.println (settings.ppmFromDesiredBitRate ()) ; // 125 ppm
  ...
}
```

The second argument does not change the CAN bit computation, it only changes the acceptance test for setting the mBitRateClosedToDesiredRate property. For example, you can specify that you want the computed

13.1 The `ACAN_ESP32_Settings` constructor: computation of the CAN bit rate

actual bit to be exactly the wished bit rate:

```
void setup () {
  Serial.begin (9600) ;
  ACAN_ESP32_Settings settings (500 * 1000, 0) ; // 500 kbit/s, max distance is 0 ppm
  Serial.print ("mBitRateClosedToDesiredRate: ") ;
  Serial.println (settings.mBitRateClosedToDesiredRate) ; // 1 (--> is true)
  Serial.print ("actual bit rate: ") ;
  Serial.println (settings.actualBitRate ()) ; // 500,000 bit/s
  Serial.print ("distance: ") ;
  Serial.println (settings.ppmFromDesiredBitRate ()) ; // 0 ppm
  ...
}
```

The slowest exact bit rate is 25 kbit/s.

In any way, the bit rate computation always gives a consistent result, resulting an actual bit rate closest from the wished bit rate. For example:

```
void setup () {
  Serial.begin (9600) ;
  ACAN_ESP32_Settings settings (440 * 1000) ; // 440 kbit/s
  Serial.print ("mBitRateClosedToDesiredRate: ") ;
  Serial.println (settings.mBitRateClosedToDesiredRate) ; // 0 (--> is false)
  Serial.print ("actual bit rate: ") ;
  Serial.println (settings.actualBitRate ()) ; // 444,444 bit/s
  Serial.print ("distance: ") ;
  Serial.println (settings.ppmFromDesiredBitRate ()) ; // 1001 ppm
  ...
}
```

You can get the details of the CAN bit decomposition. For example:

```
void setup () {
  Serial.begin (9600) ;
  ACAN_ESP32_Settings settings (440 * 1000) ; // 440 kbit/s
  Serial.print ("mBitRateClosedToDesiredRate: ") ;
  Serial.println (settings.mBitRateClosedToDesiredRate) ; // 0 (--> is false)
  Serial.print ("actual bit rate: ") ;
  Serial.println (settings.actualBitRate ()) ; // 444,444 bit/s
  Serial.print ("distance: ") ;
  Serial.println (settings.ppmFromDesiredBitRate ()) ; // 1001 ppm
  Serial.print ("Bit rate prescaler: ") ;
  Serial.println (settings.mBitRatePrescaler) ; // BRP = 9
  Serial.print ("Time segment 1: ") ;
  Serial.println (settings.mTimeSegment1) ; // 15
  Serial.print ("Time segment 2: ") ;
  Serial.println (settings.mTimeSegment2) ; // 4
  Serial.print ("Resynchronization Jump Width: ") ;
  Serial.println (settings.mRJW) ; // SJW = 4
  Serial.print ("Triple Sampling: ") ;
  Serial.println (settings.mTripleSampling) ; // 0, meaning single sampling
  Serial.print ("Sample Point: ") ;
  Serial.println (settings.samplePointFromBitStart ()) ; // 80, meaning 80%
  Serial.print ("Consistency: ") ;
  Serial.println (settings.CANBitSettingConsistency ()) ; // 0, meaning Ok
  ...
}
```

The `samplePointFromBitStart` method returns sample point, expressed in per-cent of the bit duration from the beginning of the bit.

Note the computation may calculate a bit decomposition too far from the wished bit rate, but it is always consistent. You can check this by calling the `CANBitSettingConsistency` method.

You can change the property values for adapting to the particularities of your CAN network propagation time. By example, you can increment the `mTimeSegment1` value, and decrement the `mTimeSegment2` value in order to sample the CAN Rx pin later.

```
void setup () {
  Serial.begin (9600) ;
  ACAN_ESP32_Settings settings (500 * 1000) ; // 500 kbit/s
  Serial.print ("mBitRateClosedToDesiredRate: ") ;
  Serial.println (settings.mBitRateClosedToDesiredRate) ; // 1 (--> is true)
  settings.mTimeSegment1 -- ; // 15 -> 14: safe, 1 <= TS1 <= 16
  settings.mTimeSegment2 ++ ; // 4 -> 5: safe, 2 <= TS2 <= 8 and SJW <= PS2
  Serial.print ("Sample Point: ") ;
  Serial.println (settings.samplePointFromBitStart ()) ; // 75, meaning 75%
  Serial.print ("actual bit rate: ") ;
  Serial.println (settings.actualBitRate ()) ; // 500000: ok, bit rate did not change
  Serial.print ("Consistency: ") ;
  Serial.println (settings.CANBitSettingConsistency ()) ; // 0, meaning Ok
  ...
}
```

Be aware to always respect CAN bit timing consistency! The constraints are:

$$2 \leq \text{mBitRatePrescaler} \leq 128$$

$$\text{mBitRatePrescaler is even}$$

$$1 \leq \text{mTimeSegment1} \leq 16$$

$$\text{Single sampling: } 2 \leq \text{mTimeSegment2} \leq 8$$

$$\text{Triple sampling: } 3 \leq \text{mTimeSegment2} \leq 8$$

$$1 \leq \text{mRJW} \leq 4$$

$$\text{mRJW} \leq \text{mTimeSegment2}$$

Resulting actual bit rate is given by:

$$\text{Actual bit rate} = \frac{80 \text{ MHz}}{\text{mBitRatePrescaler} \cdot (1 + \text{mTimeSegment1} + \text{mTimeSegment2})}$$

And sampling points (in per-cent unit) are given by:

$$\text{Sampling point (single sampling)} = 100 \cdot \frac{1 + \text{mTimeSegment1}}{1 + \text{mTimeSegment1} + \text{mTimeSegment2}}$$

$$\text{Sampling first point (triple sampling)} = 100 \cdot \frac{\text{mTimeSegment1}}{1 + \text{mTimeSegment1} + \text{mTimeSegment2}}$$

13.2 The CANBitSettingConsistency method

This method checks the CAN bit decomposition (given by `mBitRatePrescaler`, `mTimeSegment1`, `mTimeSegment2`, `mRJW` property values) is consistent.

```
void setup () {
  Serial.begin (9600) ;
```

```

ACAN_ESP32_Settings settings (500 * 1000) ; // 500 kbit/s
Serial.print ("mBitRateClosedToDesiredRate: ") ;
Serial.println (settings.mBitRateClosedToDesiredRate) ; // 1 (--> is true)
settings.mTimeSegment1 = 0 ; // Error, mTimeSegment1 should be >= 1 (and <= 8)
Serial.print ("Consistency: 0x") ;
Serial.println (settings.CANBitSettingConsistency (), HEX) ; // 0x10, meaning error
...
}

```

The CANBitSettingConsistency method returns 0 if CAN bit decomposition is consistent. Otherwise, the returned value is a bit field that can report several errors.

The ACAN_ESP32_Settings class defines static constant properties that can be used as mask error:

```

public: static const uint16_t kBitRatePrescalerIsZero           = 1 << 0 ;
public: static const uint16_t kBitRatePrescalerIsGreaterThan64 = 1 << 1 ;
public: static const uint16_t kTimeSegment1IsZero              = 1 << 2 ;
public: static const uint16_t kTimeSegment1IsGreaterThan16     = 1 << 3 ;
public: static const uint16_t kTimeSegment2IsLowerThan2        = 1 << 4 ;
public: static const uint16_t kTimeSegment2IsGreaterThan8      = 1 << 5 ;
public: static const uint16_t kTimeSegment2Is2AndTripleSampling = 1 << 6 ;
public: static const uint16_t kRJWIsZero                        = 1 << 7 ;
public: static const uint16_t kRJWIsGreaterThan4               = 1 << 8 ;
public: static const uint16_t kRJWIsGreaterThanTimeSegment2    = 1 << 9 ;

```

13.3 The actualBitRate method

The actualBitRate method returns the actual bit computed from mBitRatePrescaler, mTimeSegment1, mTimeSegment2, mRJW property values.

```

void setup () {
  Serial.begin (9600) ;
  ACAN_ESP32_Settings settings (440 * 1000) ; // 440 kbit/s
  Serial.print ("mBitRateClosedToDesiredRate: ") ;
  Serial.println (settings.mBitRateClosedToDesiredRate) ; // 0 (--> is false)
  Serial.print ("actual bit rate: ") ;
  Serial.println (settings.actualBitRate ()) ; // 444,444 bit/s
  ...
}

```

Note. If CAN bit settings are not consistent (see [section 13.2 page 23](#)), the returned value is irrelevant.

13.4 The exactBitRate method

The exactBitRate method returns true if the actual bit rate is equal to the wished bit rate, and false otherwise.

```

void setup () {
  Serial.begin (9600) ;
  ACAN_ESP32_Settings settings (842 * 1000) ; // 842 kbit/s
  Serial.print ("mBitRateClosedToDesiredRate: ") ;
  Serial.println (settings.mBitRateClosedToDesiredRate) ; // 1 (--> is true)
  Serial.print ("actual bit rate: ") ;
  Serial.println (settings.actualBitRate ()) ; // 842105 bit/s
  Serial.print ("distance: ") ;
  Serial.println (settings.ppmFromDesiredBitRate ()) ; // 125 ppm
  Serial.print ("Exact: ") ;

```



```
Serial.println (settings.exactBitRate ()) ; // 0 (----> false)
...
}
```

Note. If CAN bit settings are not consistent (see [section 13.2 page 23](#)), the returned value is irrelevant.

There are 22 exact bit rates: 25 kbit/s, 31250 bit/s, 32 kbit/s, 40 kbit/s, 50 kbit/s, 62500 bit/s, 64 kbit/s, 78125 bit/s, 80 kbit/s, 100 kbit/s, 125 kbit/s, 156250 bit/s, 160 kbit/s, 200 kbit/s, 250 kbit/s, 312500 bit/s, 320 kbit/s, 400 kbit/s, 500 kbit/s, 625 kbit/s, 800 kbit/s, 1 Mbit/s.

13.5 The ppmFromDesiredBitRate method

The ppmFromDesiredBitRate method returns the distance from the actual bit rate to the wished bit rate, expressed in part-per-million (ppm): $1 \text{ ppm} = 10^{-6}$. In other words, 10,000 ppm = 1%.

```
void setup () {
  Serial.begin (9600) ;
  ACAN_ESP32_Settings settings (842 * 1000) ; // 842 kbit/s
  Serial.print ("mBitRateClosedToDesiredRate: ") ;
  Serial.println (settings.mBitRateClosedToDesiredRate) ; // 1 (--> is true)
  Serial.print ("actual bit rate: ") ;
  Serial.println (settings.actualBitRate ()) ; // 842105 bit/s
  Serial.print ("distance: ") ;
  Serial.println (settings.ppmFromDesiredBitRate ()) ; // 125 ppm
  ...
}
```

Note. If CAN bit settings are not consistent (see [section 13.2 page 23](#)), the returned value is irrelevant.

13.6 The samplePointFromBitStart method

The samplePointFromBitStart method returns the distance of sample point from the start of the CAN bit, expressed in part-per-cent (ppc): $1 \text{ ppc} = 1\% = 10^{-2}$. If triple sampling is selected, the returned value is the distance of the first sample point from the start of the CAN bit. It is a good practice to get sample point from 65% to 80%.

```
void setup () {
  Serial.begin (9600) ;
  ACAN_ESP32_Settings settings (500 * 1000) ; // 500 kbit/s
  Serial.print ("mBitRateClosedToDesiredRate: ") ;
  Serial.println (settings.mBitRateClosedToDesiredRate) ; // 1 (--> is true)
  Serial.print ("Sample point: ") ;
  Serial.println (settings.samplePointFromBitStart ()) ; // 80 --> 80%
  ...
}
```

Note. If CAN bit settings are not consistent (see [section 13.2 page 23](#)), the returned value is irrelevant.

13.7 Properties of the ACAN_ESP32_Settings class

All properties of the ACAN_ESP32_Settings class are declared public and are initialized ([table 3](#)).

Property	Type	Initial value	Comment
mTxPin	gpio_num_t	GPIO_NUM_5	See section 8 page 8
mRxPin	gpio_num_t	GPIO_NUM_4	See section 8 page 8
mDesiredBitRate	uint32_t	Initialized by constructor	See section 13.1 page 21
mBitRatePrescaler	uint8_t	Initialized by constructor	See section 13.1 page 21
mTimeSegment1	uint8_t	Initialized by constructor	See section 13.1 page 21
mTimeSegment2	uint8_t	Initialized by constructor	See section 13.1 page 21
mRJW	uint8_t	Initialized by constructor	See section 13.1 page 21
mTripleSampling	bool	Initialized by constructor	See section 13.1 page 21
mBitRateClosedToDesiredRate	bool	Initialized by constructor	See section 13.1 page 21
mRequestedCANMode	CANMode	NormalMode	See section 13.7.1 page 26
mDriverReceiveBufferSize	uint16_t	32	See section 10.1 page 11
mDriverTransmitBufferSize	uint16_t	16	See section 9.1 page 10

Table 3 – Properties of the ACAN_ESP32_Settings class

13.7.1 The mRequestedCANMode property

This property has three possible values, as described in the [table 4](#). It corresponds to the LOM and STM bits of the MODE control register. The default value is `ACAN_ESP32_Settings::NormalMode`.

Value	Comment, from SJA1000 datasheet
<code>ACAN_ESP32_Settings::NormalMode</code>	<i>An acknowledge is required for successful transmission.</i>
<code>ACAN_ESP32_Settings::ListenOnlyMode</code>	<i>In this mode the CAN controller would give no acknowledge to the CAN-bus, even if a message is received successfully; the error counters are stopped at the current value. This mode of operation forces the CAN controller to be error passive. Message transmission is not possible. The listen only mode can be used e.g. for software driven bit rate detection and 'hot plugging'. All other functions can be used like in normal mode.</i>
<code>ACAN_ESP32_Settings::LoopBackMode</code>	<i>In this mode a full node test is possible without any other active node on the bus using the self reception request command; the CAN controller will perform a successful transmission, even if there is no acknowledge received.</i>

Table 4 – Values of the mRequestedCANMode property of the ACAN_ESP32_Settings class