

ACAN2515Tiny library for Arduino

Version 1.0.4

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1 Versions

Version	Date	Comment
1.0.4	October 10, 2020	Fix interrupt disabling in <code>tryToSend</code> method (thanks to Fergus Duncan)
1.0.3	April 27, 2020	Added <code>dataFloat</code> to <code>CANMessage</code> (thanks to Koryphon) Added several forgotten <code>volatile</code>
1.0.2	June 7, 2019	Fixed incorrect <code>sjw</code> setting.
1.0.1	May 31, 2019	Use correct field separator in <code>keywords.txt</code> (thanks to <code>per1234</code>).
1.0.0	November 25, 2018	Initial release

2 Features

The `ACAN2515Tiny` library is a MCP2515 CAN ("Controller Area Network") Controller driver for any board running Arduino. It is an adaptation of `ACAN2515` library in order to reduce the memory footprint. This has been achieved by making the following restrictions:

- only `TXB0` buffer of MCP2515 CAN controller is used;
- driver transmit buffer and receiver transmit buffer accept a maximum size equal to 128;
- the driver does not handle the `CLKOUT/SOF` pin.

The [table 1](#) lists the program sizes of the `TinyLoopBackDemo` and `TinyLoopBackDemoBitRateSettings` sketches, for several platforms. The Teensy 3.5 settings are: USB Serial, 120 MHz, Smallest code with LTO.

Sketch Library	TinyLoopBackDemo		TinyLoopBackDemoBitRateSettings	
	ACAN2515	ACAN2515Tiny	ACAN2515	ACAN2515Tiny
Arduino Uno	7 600	7 162	6 410	5 986
Adafruit Feather M0	15 976	15 704	15 656	15 400
Teensy 3.5	14 004	13 996	13 524	13 516

Table 1 – Sketch program sizes (bytes)

As the `ACAN2515` library, 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;
- all reception filter registers are easily defined (2 mask registers, 6 acceptance registers);
- reception filters accept call back functions;
- driver transmit buffer sizes is customisable;
- driver receive buffer size is customisable;

- overflow of the driver receive buffer is detectable;
- *loop back, self reception, listing only* MCP2515 controller modes are selectable.

3 Data flow

The [figure 1](#) illustrates message flow for sending and receiving CAN messages.

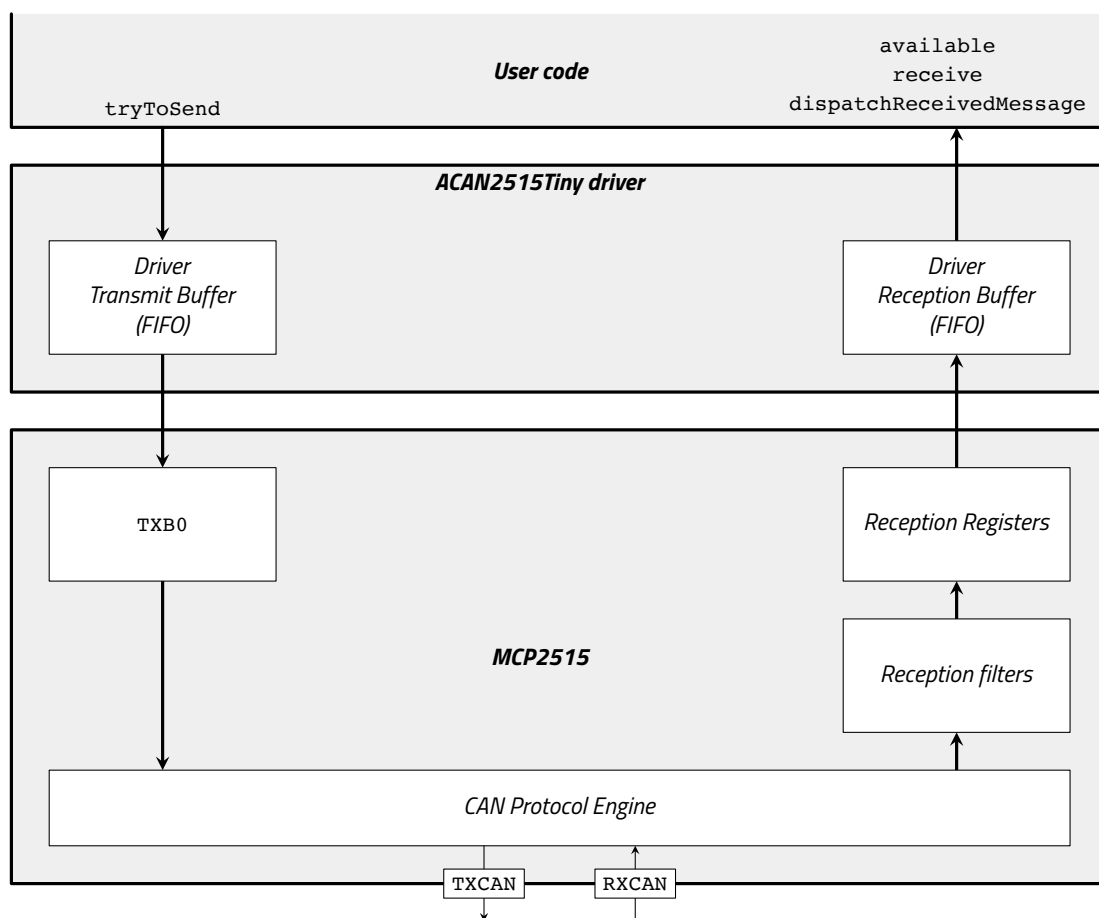


Figure 1 – Message flow in ACAN2515Tiny driver and MCP2515 CAN Controller

Sending messages. A message is defined by an instance of `CANMessage` class. For sending a message, user code calls the `tryToSend` method – see [section 7 page 12](#). The ACAN2515Tiny driver defines one transmit buffer, corresponding to the `TXB0` MCP2515 transmit buffer (`TXB1` and `TXB2` are not used by this driver). This buffer can contain at most one message. The message is transferred in the driver transmit buffer before to be moved by the interrupt service routine into the `TXB0` transmit buffer. The size of the *Driver Transmit Buffer* is 16 by default – see [section 7.2 page 13](#) for changing the default values.

Receiving messages. The MCP2515 *CAN Protocol Engine* transmits all correct frames to the *reception filters*. By default, they are configured as pass-all, see [section 9 page 16](#) for configuring them. Messages that pass the filters are stored in the *Reception Registers* (`RXB0` and `RXB1`). The interrupt service routine transfers the

messages from these registers to the *Driver Receive Buffer*. The size of the *Driver Receive Buffer* is 32 by default – see [section 8.1 page 15](#) for changing the default value. Three 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 8 page 14](#);
- the `dispatchReceivedMessage` method if you have defined the reception filters that name a call-back function – see [section 10 page 20](#).

Sequentiality. The `ACAN2515Tiny` driver and the configuration of the `MCP2515` controller can ensure sequentiality of data messages¹. The driver ensures the sequentiality of the emissions, provided that you use only one transmit buffer: if an user program calls `tryToSend` first for a message M_1 specifying the B_i buffer and then for a message M_2 specifying the same buffer, the driver ensures that M_1 will be sent on the CAN bus before M_2 . In reception, the driver ensures sequentiality based on the reception filters: if a received message M_1 passes a given filter, and then a received message M_2 passes the same filter, then the messages are retrieved in this order by the `receive` or the `dispatchReceivedMessage` methods.

4 A simple example: TinyLoopBackDemo

The following code is a sample code for introducing the `ACAN2515Tiny` library, extracted from the `TinyLoopBackDemo` sample code included in the library distribution. It runs natively on any Arduino compatible board, and is easily adaptable to any microcontroller supporting `SPI`. It demonstrates how to configure the driver, to send a CAN message, and to receive a CAN message.

Note: this code runs without any CAN transceiver (the `TXCAN` and `RXCAN` pins of the `MCP2515` are left open), the `MCP2515` is configured with the *loop back* setting on.

```
#include <ACAN2515Tiny.h>
```

This line includes the `ACAN2515Tiny` library.

```
static const byte MCP2515_SCK = 27 ; // SCK input of MCP2515
static const byte MCP2515_SI  = 28 ; // SI input of MCP2515
static const byte MCP2515_SO  = 39 ; // SO output of MCP2515
```

Define the `SPI` alternate pins. This is actually required if you uses `SPI` alternate pins.

```
static const byte MCP2515_CS  = 20 ; // CS input of MCP2515
static const byte MCP2515_INT = 37 ; // INT output of MCP2515
```

Define the pins connected to \overline{CS} and \overline{INT} pins.

```
ACAN2515Tiny can (MCP2515_CS, SPI, MCP2515_INT) ;
```

Instanciation of the `ACAN2515Tiny` library, declaration and initialization of the `can` object that implements the driver. The constructor names: the number of the pin connected to the \overline{CS} pin, the `SPI` object (you can use `SPI1`, `SPI2`, ...), the number of the pin connected to the \overline{INT} pin.

¹Sequentiality 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 .

```
static const uint32_t QUARTZ_FREQUENCY = 16 * 1000 * 1000 ; // 16 MHz
```

Specifies the frequency of the MCP2515 quartz.

```
void setup () {
  //--- Switch on builtin led
  pinMode (LED_BUILTIN, OUTPUT) ;
  digitalWrite (LED_BUILTIN, HIGH) ;
  //--- Start serial
  Serial.begin (38400) ;
  //--- Wait for serial (blink led at 10 Hz during waiting)
  while (!Serial) {
    delay (50) ;
    digitalWrite (LED_BUILTIN, !digitalRead (LED_BUILTIN)) ;
  }
}
```

Builtin led is used for signaling. It blinks led at 10 Hz during until serial monitor is ready.

```
SPI.begin () ;
```

You should call `SPI.begin`. Many platforms define alternate pins for SPI. On Teensy 3.x ([section 6.1 page 9](#)), selecting alternate pins should be done before calling `SPI.begin`, on Adafruit Feather M0 ([section 6.2 page 11](#)), this should be done after. Calling `SPI.begin` explicitly allows you to fully handle alternate pins.

```
ACAN2515TinySettings settings (QUARTZ_FREQUENCY, 125 * 1000) ;
```

Configuration is a four-step operation. This line is the first step. It instantiates the `settings` object of the `ACAN2515TinySettings` class. The constructor has two parameters: the MCP2515 quartz frequency, and the desired CAN bit rate (here, 125 kb/s). It returns a `settings` object fully initialized with CAN bit settings for the desired bit rate, and default values for other configuration properties.

```
settings.mRequestedMode = ACAN2515TinySettings::LoopBackMode ;
```

This is the second step. You can override the values of the properties of `settings` object. Here, the `mRequestedMode` property is set to `LoopBackMode` – its value is `NormalMode` by default. Setting this property enables *loop back*, that is you can run this demo sketch even if you have no connection to a physical CAN network. The [section 12.8 page 32](#) lists all properties you can override.

```
const uint16_t errorCode = can.begin (settings, [] { can.isr () ; }) ;
```

This is the third step, configuration of the CAN driver with `settings` values. 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 9 page 16](#). The second argument is the *interrupt service routine*, and is defined by a C++ lambda expression². See [section 11.2 page 22](#) for using a function instead.

```
if (errorCode != 0) {
  Serial.print ("Configuration error 0x") ;
  Serial.println (errorCode, HEX) ;
}
```

²<https://en.cppreference.com/w/cpp/language/lambda>

```

    }
}

```

Last step: the configuration of the can driver returns an error code, stored in the `errorCode` constant. It has the value 0 if all is ok – see [section 11.3 page 22](#).

```

static uint32_t gBlinkLedDate = 0 ;
static uint32_t gReceivedFrameCount = 0 ;
static uint32_t gSentFrameCount = 0 ;

```

The `gSendDate` global variable is used for sending a CAN message every 2 s. The `gSentCount` global variable counts the number of sent messages. The `gReceivedCount` global variable counts the number of received messages.

```

void loop() {
    CANMessage frame ;

```

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 5 page 8](#).

```

if (gBlinkLedDate < millis ()) {
    gBlinkLedDate += 2000 ;
    digitalWrite (LED_BUILTIN, !digitalRead (LED_BUILTIN)) ;
    const bool ok = can.tryToSend (frame) ;
    if (ok) {
        gSentFrameCount += 1 ;
        Serial.print ("Sent: ") ;
        Serial.println (gSentFrameCount) ;
    }else{
        Serial.println ("Send failure") ;
    }
}
}

```

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. Then, 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.

```

if (can.available ()) {
    can.receive (frame) ;
    gReceivedFrameCount ++ ;
    Serial.print ("Received: ") ;
    Serial.println (gReceivedFrameCount) ;
}
}

```

As the MCP2515 controller is configured in *loop back* mode, 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. If a message has been received, the `gReceivedCount` is incremented and displayed.

5 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 ACAN³ (version 1.0.3 and above) driver, the ACAN2517⁴ driver contain an identical `CANMessage.h` file header, enabling using ACAN driver, ACAN2515Tiny driver and ACAN2517 driver in a same 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 {
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 eight 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 (Cortex M7 processor of Teensy 4.x are little-endian).

The `idx` property is not used in CAN frames, but:

- for a received message, it contains the acceptance filter index (see [section 10 page 20](#));
- on sending messages, it is not used.

³The ACAN driver is a CAN driver for FlexCAN modules integrated in the Teensy 3.x microcontrollers, <https://github.com/pierremolinaro/acan>.

⁴The ACAN2517 driver is a CAN driver for the MCP2517 CAN controller, <https://github.com/pierremolinaro/acan2517>.

6 Connecting a MCP2515 to your microcontroller

Connecting a MCP2515 requires 5 pins (figure 2):

- hardware SPI requires you use dedicated pins of your microcontroller. You can use alternate pins (see below), and if your microcontroller supports several hardware SPIs, you can select any of them;
- connecting the $\overline{\text{CS}}$ signal requires one digital pin, that the driver configures as an OUTPUT ;
- connecting the $\overline{\text{INT}}$ signal requires one other digital pin, that the driver configures as an external interrupt input; so this pin should have interrupt capability (checked by the `begin` method of the driver object).

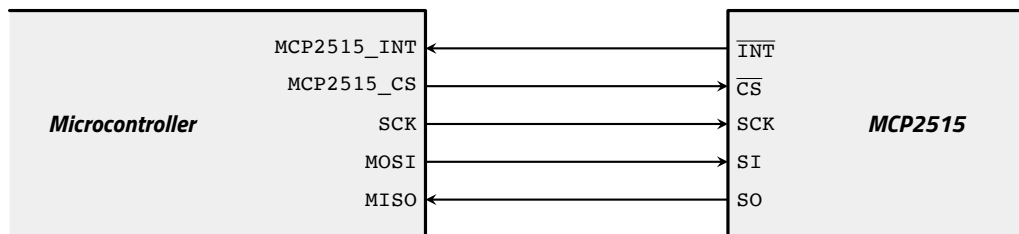


Figure 2 – MCP2515 connection to a microcontroller

The `begin` function of `ACAN2515Tiny` library configures the selected SPI with a frequency of 10 Mbit/s (the maximum frequency supported by the MCP2515). More precisely, the SPI library of your microcontroller may adopt a frequency lower than 10 Mbit/s; for example, the maximum frequency of the Arduino Uno SPI is 8 Mbit/s.

6.1 Using alternate pins on Teensy 3.x

Demo sketch: `TinyLoopBackDemoTeensy3x`.

On Teensy 3.x, "the main SPI pins are enabled by default. SPI pins can be moved to their alternate position with `SPI.setMOSI(pin)`, `SPI.setMISO(pin)`, and `SPI.setSCK(pin)`. You can move all of them, or just the ones that conflict, as you prefer."⁵

For example, the `TinyLoopBackDemoTeensy3x` sketch uses SPI0 on a Teensy 3.5 with these alternate pins⁶:

You call the `SPI.setMOSI`, `SPI.setMISO`, and `SPI.setSCK` functions **before** calling the `begin` function of your `ACAN2515Tiny` instance (generally done in the `setup` function):

```

ACAN2515Tiny can (MCP2515_CS, SPI, MCP2515_INT) ;
...
static const byte MCP2515_SCK = 27 ; // SCK input of MCP2515
static const byte MCP2515_SI  = 28 ; // SI input of MCP2515
static const byte MCP2515_SO  = 39 ; // SO output of MCP2515
  
```

⁵See https://www.pjrc.com/teensy/td_libs_SPI.html

⁶See <https://www.pjrc.com/teensy/pinout.html>

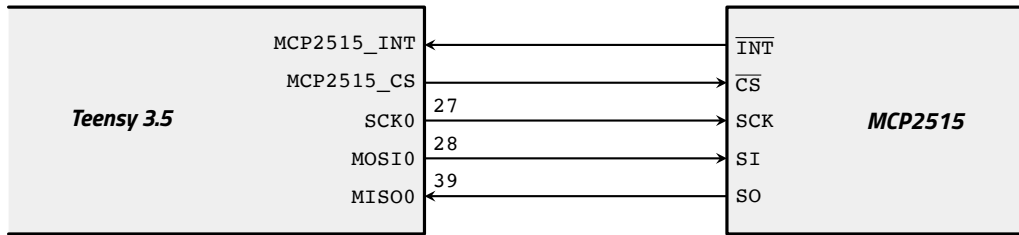


Figure 3 – Using SPI alternate pins on a Teensy 3.5

```

...
void setup () {
    ...
    SPI.setMOSI (MCP2515_SI) ;
    SPI.setMISO (MCP2515_SO) ;
    SPI.setSCK (MCP2515_SCK) ;
    SPI.begin () ;
    ...
    const uint16_t errorCode = can.begin (settings, [] { can.isr () ; }) ;
    ...
}
  
```

Note you can use the `SPI.pinIsMOSI`, `SPI.pinIsMISO`, and `SPI.pinIsSCK` functions to check if the alternate pins you select are valid:

```

void setup () {
    ...
    Serial.print ("Using pin #") ;
    Serial.print (MCP2515_SI) ;
    Serial.print (" for MOSI: ") ;
    Serial.println (SPI.pinIsMOSI (MCP2515_SI) ? "yes" : "NO!!!") ;
    Serial.print ("Using pin #") ;
    Serial.print (MCP2515_SO) ;
    Serial.print (" for MISO: ") ;
    Serial.println (SPI.pinIsMISO (MCP2515_SO) ? "yes" : "NO!!!") ;
    Serial.print ("Using pin #") ;
    Serial.print (MCP2515_SCK) ;
    Serial.print (" for SCK: ") ;
    Serial.println (SPI.pinIsSCK (MCP2515_SCK) ? "yes" : "NO!!!") ;
    SPI.setMOSI (MCP2515_SI) ;
    SPI.setMISO (MCP2515_SO) ;
    SPI.setSCK (MCP2515_SCK) ;
    SPI.begin () ;
    ...
    const uint16_t errorCode = can.begin (settings, [] { can.isr () ; }) ;
    ...
}
  
```

6.2 Using alternate pins on an Adafruit Feather M0

Demo sketch: TinyLoopBackDemoAdafruitFeatherM0.

See <https://learn.adafruit.com/using-atsamd21-sercom-to-add-more-spi-i2c-serial-ports/overview> document that explains in details how configure and set an alternate SPI on Adafruit Feather M0.

For example, the TinyLoopBackDemoAdafruitFeatherM0 sketch uses SERCOM1 on an Adafruit Feather M0 as illustrated in figure 4.

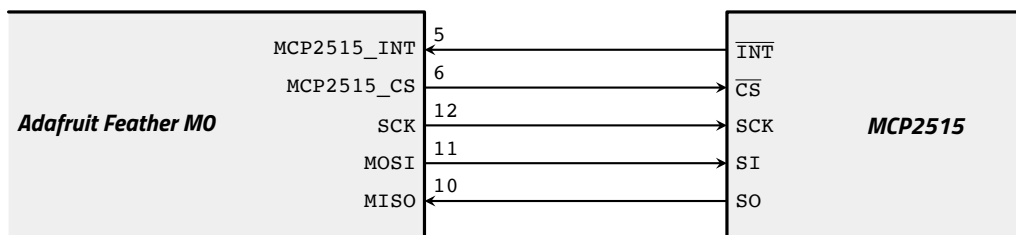


Figure 4 – Using SPI alternate pins on an Adafruit Feather M0

The configuration code is the following. Note you should call the `pinPeripheral` function **after** calling the `mySPI.begin` function.

```
#include <wiring_private.h>
...
static const byte MCP2515_SCK = 12 ; // SCK pin, SCK input of MCP2515
static const byte MCP2515_SI  = 11 ; // MOSI pin, SI input of MCP2515
static const byte MCP2515_SO  = 10 ; // MISO pin, SO output of MCP2515
...
SPIClass mySPI (&sercom1,
               MCP2515_SO, MCP2515_SI, MCP2515_SCK,
               SPI_PAD_0_SCK_3, SERCOM_RX_PAD_2);
...
static const byte MCP2515_CS  = 6 ; // CS input of MCP2515
static const byte MCP2515_INT = 5 ; // INT output of MCP2515
...
ACAN2515Tiny can (MCP2515_CS, mySPI, MCP2515_INT) ;
...
void setup () {
  ...
  mySPI.begin () ;
  pinPeripheral (MCP2515_SI, PIO_SERCOM);
  pinPeripheral (MCP2515_SCK, PIO_SERCOM);
  pinPeripheral (MCP2515_SO, PIO_SERCOM);
  ...
  const uint16_t errorCode = can.begin (settings, [] { can.isr () ; }) ;
  ...
}
```

7 Sending frames

The `ACAN2515Tiny` driver defines three transmit buffers, each of them corresponding to a MCP2515 hardware buffer.

7.1 The `tryToSend` method

```
...
CANMessage message ;
// Setup message
const bool ok = can.tryToSend (message) ;
...
```

You call the `tryToSend` method for sending a message in the CAN network. Note this function returns before the message is actually sent; this function only appends the message to a transmit buffer.

The `idx` field of the message is not used by this driver.

The method `tryToSend` returns:

- `true` if the message has been successfully transmitted to the 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 the driver transmit buffer, it was full.

So it is wise to systematically test the returned value.

A way is to use a global variable to note if the 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 () {
    if (gSendDate < millis ()) {
        CANMessage message ;
        // Initialize message properties
        const bool ok = can.tryToSend (message) ;
        if (ok) {
            gSendDate += 2000 ;
        }
    }
}
```

Another hint is to use a global boolean variable as a flag that remains `true` while the message 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 = can.tryToSend (message) ;
    if (ok) {
        gSendMessage = false ;
    }
}
...
}

```

7.2 Driver transmit buffer size

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

```

ACAN2515TinySettings settings (QUARTZ_FREQUENCY, 125 * 1000) ;
settings.mTransmitBufferSize = 30 ;
const uint16_t errorCode = can.begin (settings, [] { can.isr () ; }) ;
...

```

A zero size is valid: calling the `tryToSend` method returns `true` if the `TXB0` register is empty, and `false` if it is full.

7.3 The `transmitBufferSize` method

The `transmitBufferSize` method returns the allocated size of the driver transmit buffer:

```

const uint8_t s = can.transmitBufferSize () ;

```

7.4 The `transmitBufferCount` method

The `transmitBufferCount` method returns the current message count of the driver transmit buffer:

```

const uint8_t n = can.transmitBufferCount () ;

```

7.5 The `transmitBufferPeakCount` method

The `transmitBufferPeakCount` method returns the peak message count of the driver transmit buffer:

```
const uint8_t max = can.transmitBufferPeakCount () ;
```

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

So, when `transmitBufferPeakCount()` returns a value lower or equal to `transmitBufferSize()`, it means that calls to `tryToSend` have always returned `true`, and no overflow occurs on driver transmit buffer.

8 Retrieving received messages using the `receive` method

There are two ways for retrieving received messages :

- using the `receive` method, as explained in this section;
- using the `dispatchReceivedMessage` method (see [section 10 page 20](#)).

This is a basic example:

```
void loop () {
    CANMessage message ;
    if (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 loop () {
    CANMessage message ;
    if (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.

8.1 Driver receive buffer size

By default, the driver receive buffer size is 32. You can change it by setting the `mReceiveBufferSize` property of `settings` variable before calling the `begin` method:

```
ACAN2515TinySettings settings (QUARTZ_FREQUENCY, 125 * 1000) ;  
settings.mReceiveBufferSize = 100 ;  
const uint16_t errorCode = can.begin (settings, [] { can.isr () ; }) ;  
...
```

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

8.2 The `receiveBufferSize` method

The `receiveBufferSize` method returns the size of the driver receive buffer, that is the value of the `mReceiveBufferSize` property of `settings` variable when the `begin` method is called.

```
const uint8_t s = can.receiveBufferSize () ;
```

8.3 The `receiveBufferCount` method

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

```
const uint8_t n = can.receiveBufferCount () ;
```

8.4 The `receiveBufferPeakCount` method

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

```
const uint8_t max = can.receiveBufferPeakCount () ;
```

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

- submitting an `ACAN2515AcceptanceFilter` array to the `ACAN2515Tiny::begin` method.

The `ACAN2515AcceptanceFilter` array defines the values that the `ACAN2515Tiny::begin` method sets to the `RXFi` acceptance filter registers.

Four functions are available for managing filters:

- `standard2515Mask` and `extended2515Mask` functions for defining `RXMi` value;
- `standard2515Filter` and `extended2515Filter` functions for defining `RXFi` value.

`RXMi` and `RXFi` values you handle are `ACAN2515Mask` class instances, that provides four `uint8_t` properties: `mSIDH`, `mSIDL`, `mEID8`, `mEID0`. They correspond to the `MCP2515` registers. If you want, you can set directly these properties, without using the above functions.

Filter remote and data frames. The `MCP2515` filters do not handle the `RTR` bit: for example, you cannot specify you want to accept data frames and discard remote frames. This should be done by your code.

Multiple filter matches. From DS20001801H, section 4.5.4 page 34: *If more than one acceptance filter matches, the `FILHITn` bits will encode the binary value of the lowest numbered filter that matched. For example, if filters, `RXF2` and `RXF4`, match, the `FILHITn` bits will be loaded with the value for `RXF2`. This essentially prioritizes the acceptance filters with a lower numbered filter having higher priority. Messages are compared to filters in ascending order of filter number. This also ensures that the message will only be received into one buffer. This implies that `RXB0` has a higher priority than `RXB1`.*

The `MCP2515` filters cannot be disabled, so all mask registers can be taken into account during the acceptance of a message. For example, if `MCP2515` filters are defined with the `RXM0`, `RXF0`, `RXF1` registers, leaving `RXM1` equal to 0 provides the transfer to `RXB1` of all messages discarded by `RXF0` and `RXF1`.

For dealing with all situations, the `ACAN2515Tiny::begin` method accepts three prototypes.

No filter.

```
ACAN2515TinySettings settings (QUARTZ_FREQUENCY, 125 * 1000) ;
const uint16_t errorCode = can.begin (settings, [] { can.isr () ; }) ;
```

No filter is provided, `RXM0` and `RXM1` are set to 0, enabling the acceptance of all messages by `RXB0`.

One filter.

For example:

```
ACAN2515TinySettings settings (QUARTZ_FREQUENCY, 125 * 1000) ;
const ACAN2515Mask rxm0 = extended2515Mask (0x1FFFFFFF) ;
const ACAN2515AcceptanceFilter filter [] = {
    {extended2515Filter (0x12345678), receive0} // RXF0
} ;
const uint16_t errorCode = can.begin (settings,
                                     [] { can.isr () ; },
                                     rxm0, // Value set to RXM0 register
                                     filter, // The filter array
                                     1) ; // Filter array size
```

Here, one type of message is accepted, extended (data or remote) frames with an identifier equal to 0x12345678. This defines explicitly RXM0 and RXF0; for disabling acceptance by RXF1, it is set with RXF0 value; RXM1 is set with RXM0 value, and the RXF2 to RXF5 registers are set with the RXF0 value. No message will be accepted by RXB1 filters.

The definition of a filter is associated with a call back function – here `receive0`. This function is called indirectly when the `dispatchReceivedMessage` method is called – see [section 10 page 20](#).

Two filters. For example:

```
ACAN2515TinySettings settings (QUARTZ_FREQUENCY, 125 * 1000) ;
const ACAN2515Mask rxm0 = extended2515Mask (0x1FFFFFFF) ;
const ACAN2515AcceptanceFilter filters [] = {
    {extended2515Filter (0x12345678), receive0}, // RXF0
    {extended2515Filter (0x18765432), receive1} // RXF1
} ;
const uint16_t errorCode = can.begin (settings,
                                     [] { can.isr () ; },
                                     rxm0, // Value set to RXM0 register
                                     filters, // The filter array
                                     2) ; // Filter array size
```

Here, two types of message are accepted, extended (data or remote) frames with an identifier equal to 0x12345678 or 0x18765432. This defines explicitly RXM0, RXF0 and RXF1; RXM1 is set with RXM0 value, and the RXF2 to RXF5 registers are set with the RXF1 value. No message will be accepted by RXB1 filters.

Three to five filters. For example, with four filters:

```
ACAN2515TinySettings settings (QUARTZ_FREQUENCY, 125 * 1000) ;
const ACAN2515Mask rxm0 = extended2515Mask (0x1FFFFFFF) ;
const ACAN2515Mask rxm1 = standard2515Mask (0x7FF, 0, 0) ;
const ACAN2515AcceptanceFilter filters [] = {
    {extended2515Filter (0x12345678), receive0}, // RXF0
    {extended2515Filter (0x18765432), receive1}, // RXF1
    {standard2515Filter (0x567, 0, 0), receive2}, // RXF2
    {standard2515Filter (0x123, 0, 0), receive3} // RXF3
} ;
const uint16_t errorCode = can.begin (settings,
                                     [] { can.isr () ; },
                                     rxm0, // Value set to RXM0 register
                                     rxm1, // Value set to RXM1 register
                                     filters, // The filter array
                                     4) ; // Filter array size
```

Four types of message are accepted, extended (data or remote) frames with an identifier equal to 0x12345678 or 0x18765432, and standard (data or remote) frames with an identifier equal to 0x567 or 0x123. The RXF4 and RXF5 registers are set with the RXF3 value.

Six filters.

```
ACAN2515TinySettings settings (QUARTZ_FREQUENCY, 125 * 1000) ;
```

```

const ACAN2515Mask rxm0 = extended2515Mask (0xFFFFFFFF) ;
const ACAN2515Mask rxm1 = standard2515Mask (0x7FF, 0, 0) ;
const ACAN2515AcceptanceFilter filters [] = {
    {extended2515Filter (0x12345678), receive0}, // RXF0
    {extended2515Filter (0x18765432), receive1}, // RXF1
    {standard2515Filter (0x567, 0, 0), receive2}, // RXF2
    {standard2515Filter (0x123, 0, 0), receive3}, // RXF3
    {standard2515Filter (0x777, 0, 0), receive4}, // RXF4
    {standard2515Filter (0x3AB, 0, 0), receive5} // RXF5
} ;
const uint16_t errorCode = can.begin (settings,
                                     [] { can.isr () ; },
                                     rxm0, // Value set to RXM0 register
                                     rxm1, // Value set to RXM1 register
                                     filters, // The filter array
                                     6) ; // Filter array size

```

Six types of message are accepted, all filter registers are explicitly defined.

9.2.1 Extended frames acceptance

The `extended2515Mask` and `extended2515Filter` functions helps you to define extended frame filters. Extended frame filters test extended identifier value.

The acceptance criterion is⁷:

$$\text{acceptance_mask} \& (\text{received_identifier} \text{ nXOR } \text{acceptance_filter}) == 0$$

where `&` is the bit-wise *and* operator, and `nXOR` is the *not xor* bit-wise operator.

Accepting all extended frames.

```
const ACAN2515Mask rxm0 = extended2515Mask (0) ;
```

No extended frame identifier bit is tested, all extended frames are accepted.

Accepting individual extended frames.

```
const ACAN2515Mask rxm0 = extended2515Mask (0xFFFFFFFF) ;
```

All extended frame identifier bits are tested, only extended frames whose identifiers match the filters are accepted.

Accepting several identifiers. The bits at 0 of the mask correspond to bits that are not tested for acceptance. For example:

```
const ACAN2515Mask rxm0 = extended2515Mask (0x1FFFFFFF) ;
```

If you define an acceptance filter by `extended2515Filter (0x12345608)`, any extended frame with an identifier equal to `0x123456x8` is accepted.

⁷See DS20001801H, section 4.5 *Message Acceptance Filters and Masks*, page 33.

9.2.2 Standard frames acceptance

The `standard2515Mask` and `standard2515Filter` functions help you to define extended frame filters. Standard frame filters test standard identifier value, first and second data byte.

The acceptance criterion is⁸:

```
acceptance_mask & ((received_identifier, data_byte0, data_byte1) nXOR acceptance_filter) == 0
```

where `&` is the bit-wise *and* operator, and `nXOR` is the *not xor* bit-wise operator.

Accepting all standard frames, without testing data bytes.

```
const ACAN2515Mask rxm0 = standard2515Mask (0, 0, 0) ;
```

Accepting individual standard frames, without testing data bytes.

```
const ACAN2515Mask rxm0 = standard2515Mask (0x7FF, 0, 0) ;
```

All standard frame identifier bits are tested, only standard frames whose identifiers match the filters are accepted.

Accepting several identifiers, without testing data bytes. The bits at 0 of the mask correspond to bits that are not tested for acceptance. For example:

```
const ACAN2515Mask rxm0 = standard2515Mask (0x70F, 0, 0) ;
```

If you define an acceptance filter by `standard2515Filter (0x40A, 0, 0)`, any standard frame with an identifier equal to `0x4xA` is accepted.

Filtering from first data byte. The second argument of `standard2515Mask` specifies first data byte filtering. For example:

```
const ACAN2515Mask rxm0 = standard2515Mask (0x70F, 0xFF, 0) ;
```

If you define an acceptance filter by `standard2515Filter (0x40A, 0x54, 0)`, any standard frame with an identifier equal to `0x4xA` and first byte equal to `0x54` is accepted.

Empty standard frame. An empty standard frame (without any data byte) is accepted, the filtering condition on the first data byte is ignored (see `loopbackFilterDataByte` sample sketch).

10 The dispatchReceivedMessage method

Sample sketch: the `loopbackUsingFilters` shows how using the `dispatchReceivedMessage` method.

Instead of calling the `receive` method, call the `dispatchReceivedMessage` method in your `loop` function. It calls the call back function associated with the matching filter.

If you have not defined any filter, do not use this function, call the `receive` method.

⁸See DS20001801H, section 4.5 *Message Acceptance Filters and Masks*, page 33.

```
void loop () {
    can.dispatchReceivedMessage () ; // Do not use can.receive any more
    ...
}
```

The `dispatchReceivedMessage` method handles one message at a time. More precisely:

- if it returns `false`, the driver receive buffer was empty;
- if it returns `true`, the driver receive buffer was not empty, one message has been removed and dispatched.

So, the return value can be used for emptying and dispatching all received messages:

```
void loop () {
    while (can.dispatchReceivedMessage ()) {
    }
    ...
}
```

If a filter definition does not name a call back function, the corresponding messages are lost.

The `dispatchReceivedMessage` method has an optional argument – `NULL` by default: a function name. This function is called for every message that passes the receive filters, with an argument equal to the matching filter index:

```
void filterMatchFunction (const uint8_t inFilterIndex) {
    ...
}

void loop () {
    can.dispatchReceivedMessage (filterMatchFunction) ;
    ...
}
```

You can use this function for maintaining statistics about receiver filter matches.

11 The ACAN2515Tiny::begin method reference

11.1 The ACAN2515Tiny::begin method prototypes

There are three `begin` method prototypes:

```
uint16_t ACAN2515Tiny::begin (const ACAN2515TinySettings & inSettings,
                              void (* inInterruptServiceRoutine) (void)) ;
```

```
uint16_t ACAN2515Tiny::begin (const ACAN2515TinySettings & inSettings,
                              void (* inInterruptServiceRoutine) (void),
```

```

        const ACAN2515Mask inRXM0,
        const ACAN2515AcceptanceFilter inAcceptanceFilters [],
        const uint32_t inAcceptanceFilterCount) ;

uint16_t ACAN2515Tiny::begin (const ACAN2515TinySettings & inSettings,
                             void (* inInterruptServiceRoutine) (void),
                             const ACAN2515Mask inRXM0,
                             const ACAN2515Mask inRXM1,
                             const ACAN2515AcceptanceFilter inAcceptanceFilters [],
                             const uint32_t inAcceptanceFilterCount) ;

```

11.2 Defining explicitly the interrupt service routine

In this document, the *interrupt service routine* is defined by a lambda expression:

```
const uint16_t errorCode = can.begin (settings, [] { can.isr () ; } ) ;
```

Instead of a lambda expression, you are free to define the *interrupt service routine* as a function:

```

void canISR () {
    can.isr () ;
}

```

And you pass canISR as argument to the begin method:

```
const uint16_t errorCode = can.begin (settings, canISR) ;
```

11.3 The error code

The ACAN2515Tiny::begin method returns an error code. The value 0 denotes no error. Otherwise, you consider every bit as an error flag, as described in [table 2](#). An error code could report several errors. The ACAN2515Tiny class defines static constants for naming errors.

Bit	Static constant Name	Link
0	kNoMCP2515	section 11.3.1 page 23
1	kTooFarFromDesiredBitRate	section 11.3.2 page 23
2	kInconsistentBitRateSettings	section 11.3.3 page 23
3	kINTPinIsNotAnInterrupt	section 11.3.4 page 23
4	kISRIsNull	section 11.3.5 page 23
5	kRequestedModeTimeOut	section 11.3.6 page 23
6	kAcceptanceFilterArrayIsNULL	section 11.3.7 page 24
7	kOneFilterMaskRequiresOneOrTwoAcceptanceFilters	section 11.3.8 page 24
8	kTwoFilterMasksRequireThreeToSixAcceptanceFilters	section 11.3.9 page 24

Table 2 – The ACAN2515Tiny::begin method error code bits

11.3.1 kNoMCP2515

The `ACAN2515Tiny::begin` method checks accessibility by writing and reading back the `CNF1_REGISTER` first with the `0x55` value, then with the `0xAA` value. This error is raised when the read value is different from the written one. It means that the MCP2515 cannot be accessed via SPI.

11.3.2 kTooFarFromDesiredBitRate

This error occurs when the `mBitRateClosedToDesiredRate` property of the `settings` object is `false`. This means that the `ACAN2515TinySettings` constructor cannot compute a CAN bit configuration close enough to the desired bit rate. For example:

```
void setup () {  
    ACAN2515TinySettings settings (QUARTZ_FREQUENCY, 1) ; // 1 bit/s !!!  
    // Here, settings.mBitRateClosedToDesiredRate is false  
    const uint16_t errorCode = can.begin (settings, [] { can.isr () ; }) ;  
    // Here, errorCode contains ACAN2515Tiny::kCANBitConfigurationTooFarFromDesiredBitRate  
}
```

11.3.3 kInconsistentBitRateSettings

The `ACAN2515TinySettings` constructor always returns consistent bit rate settings – even if the settings provide a bit rate too far away the desired bit rate. So this error occurs only when you have changed the CAN bit properties (`mBitRatePrescaler`, `mPropagationSegment`, `mPhaseSegment1`, `mPhaseSegment2`, `mSJW`), and one or more resulting values are inconsistent. See [section 12.3 page 29](#).

11.3.4 kINTPinIsNotAnInterrupt

The pin you provide for handling the MCP2515 interrupt has no interrupt capability.

11.3.5 kISRIsNull

The interrupt service routine argument is `NULL`, you should provide a valid function.

11.3.6 kRequestedModeTimeOut

During configuration by the `ACAN2515Tiny::begin` method, the MCP2515 is in the *configuration* mode. At this end of this process, the mode specified by the `inSettings.mRequestedMode` value is requested. The switch to this mode is not immediate, a register is repetitively read for checking the switch is done. This error is raised if the switch is not completed within a delay between 1 ms and 2 ms.

11.3.7 kAcceptanceFilterArrayIsNull

The `ACAN2515Tiny::begin` method you have called names the `inAcceptanceFilters` argument, but it is `NULL`.

11.3.8 kOneFilterMaskRequiresOneOrTwoAcceptanceFilters

The `ACAN2515Tiny::begin` method you have called names the `inRXM0` argument (but not `inRXM1`), you should provide the value 1 or 2 to the `inAcceptanceFilterCount` argument.

11.3.9 kTwoFilterMasksRequireThreeToSixAcceptanceFilters

The `ACAN2515Tiny::begin` method you have called names the `inRXM0` and the `inRXM1` arguments, you should provide the value 3 to 6 to the `inAcceptanceFilterCount` argument.

12 ACAN2515TinySettings class reference

Note. The `ACAN2515TinySettings` class is not Arduino specific. You can compile it on your desktop computer with your favorite C++ compiler. In the <https://github.com/pierremolinaro/acan2515-dev> GitHub repository, a command line tool is defined for exploring all CAN bit rates from 1 bit/s and 20 Mbit/s for a 16 MHz quartz: 63810 bit rates are valid, and 29 are exact. It also checks that computed CAN bit decompositions are all consistent, even if they are too far from the desired baud rate.

12.1 First ACAN2515TinySettings constructor: computation of the CAN bit settings

The constructor of the `ACAN2515TinySettings` has two mandatory arguments: the quartz frequency, and the desired bit rate. It tries to compute the CAN bit settings for this bit rate. If it succeeds, the constructed object has its `mBitRateClosedToDesiredRate` property set to `true`, otherwise it is set to `false`. For example:

```
const uint32_t QUARTZ_FREQUENCY = 16 * 1000 * 1000 ; // 16 MHz
void setup () {
    ACAN2515TinySettings settings (QUARTZ_FREQUENCY, 1 * 1000 * 1000) ; // 1 Mbit/s
    // Here, settings.mBitRateClosedToDesiredRate is true
    ...
}
```

Of course, with a 16 MHz quartz, 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 727 kbit/s. You can check the result by computing actual bit rate, and the distance from the desired bit rate:

```
const uint32_t QUARTZ_FREQUENCY = 16 * 1000 * 1000 ; // 16 MHz
void setup () {
    ...
}
```



```

ACAN2515TinySettings settings (QUARTZ_FREQUENCY, 727 * 1000) ; // 727 kbit/s
Serial.print ("mBitRateClosedToDesiredRate: ") ;
Serial.println (settings.mBitRateClosedToDesiredRate) ; // 1 (--> is true)
Serial.print ("actual bit rate: ") ;
Serial.println (settings.actualBitRate ()) ; // 727272 bit/s
Serial.print ("distance: ") ;
Serial.println (settings.ppmFromDesiredBitRate ()) ; // 375 ppm
...
}

```

The actual bit rate is 727,272 bit/s, and its distance from desired bit rate is 375 ppm. “ppm” stands for “part-per-million”, and 1 ppm = 10^{-6} . In other words, 10,000 ppm = 1%.

By default, a desired 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 third argument of ACAN2515TinySettings constructor:

```

const uint32_t QUARTZ_FREQUENCY = 16 * 1000 * 1000 ; // 16 MHz
void setup () {
    ...
    ACAN2515TinySettings settings (QUARTZ_FREQUENCY, 727 * 1000, 100) ;
    Serial.print ("mBitRateClosedToDesiredRate: ") ;
    Serial.println (settings.mBitRateClosedToDesiredRate) ; // 0 (--> is false)
    Serial.print ("actual bit rate: ") ;
    Serial.println (settings.actualBitRate ()) ; // 727272 bit/s
    Serial.print ("distance: ") ;
    Serial.println (settings.ppmFromDesiredBitRate ()) ; // 375 ppm
    ...
}

```

The third 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 actual bit to be exactly the desired bit rate:

```

const uint32_t QUARTZ_FREQUENCY = 16 * 1000 * 1000 ; // 16 MHz
void setup () {
    ...
    ACAN2515TinySettings settings (QUARTZ_FREQUENCY, 500 * 1000, 0) ; // 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
    ...
}

```

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

```

const uint32_t QUARTZ_FREQUENCY = 16 * 1000 * 1000 ; // 16 MHz
void setup () {
    ...
    ACAN2515TinySettings settings (QUARTZ_FREQUENCY, 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 ()) ; // 10,100 ppm
    ...
}

```

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

```

const uint32_t QUARTZ_FREQUENCY = 16 * 1000 * 1000 ; // 16 MHz
void setup () {
    ...
    ACAN2515TinySettings settings (QUARTZ_FREQUENCY, 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 ()) ; // 10,100 ppm
    Serial.print ( "Bit rate prescaler: " ) ;
    Serial.println (settings.mBitRatePrescaler) ; // BRP = 1
    Serial.print ( "Propagation segment: " ) ;
    Serial.println (settings.mPropagationSegment) ; // PropSeg = 6
    Serial.print ( "Phase segment 1: " ) ;
    Serial.println (settings.mPhaseSegment1) ; // PS1 = 5
    Serial.print ( "Phase segment 2: " ) ;
    Serial.println (settings.mPhaseSegment2) ; // PS2 = 6
    Serial.print ( "Resynchronization Jump Width: " ) ;
    Serial.println (settings.mSJW) ; // SJW = 4
    Serial.print ( "Triple Sampling: " ) ;
    Serial.println (settings.mTripleSampling) ; // 0, meaning single sampling
    Serial.print ( "Sample Point: " ) ;
    Serial.println (settings.samplePointFromBitStart ()) ; // 68, meaning 68%
    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 desired 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 `mPhaseSegment1` value, and decrement the `mPhaseSegment2` value in order to sample the CAN Rx pin later.

```
const uint32_t QUARTZ_FREQUENCY = 16 * 1000 * 1000 ; // 16 MHz
void setup () {
    ...
    ACAN2515TinySettings settings (QUARTZ_FREQUENCY, 500 * 1000) ; // 500 kbit/s
    Serial.print ("mBitRateClosedToDesiredRate: ") ;
    Serial.println (settings.mBitRateClosedToDesiredRate) ; // 1 (--> is true)
    settings.mPhaseSegment1 ++ ; // 5 -> 6: safe, 1 <= PS1 <= 8
    settings.mPhaseSegment2 -- ; // 5 -> 4: safe, 2 <= PS2 <= 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:

$$\begin{aligned}
 1 &\leq \text{mBitRatePrescaler} \leq 64 \\
 1 &\leq \text{mSJW} \leq 4 \\
 1 &\leq \text{mPropagationSegment} \leq 8 \\
 \text{Single sampling: } 1 &\leq \text{mPhaseSegment1} \leq 8 \\
 \text{Triple sampling: } 2 &\leq \text{mPhaseSegment1} \leq 8 \\
 2 &\leq \text{mPhaseSegment2} \leq 8 \\
 \text{mSJW} &< \text{mPhaseSegment2} \\
 \text{mPhaseSegment2} &\leq \text{mPropagationSegment} + \text{mPhaseSegment1}
 \end{aligned}$$

Resulting actual bit rate is given by:

$$\text{Actual bit rate} = \frac{\text{QuartzFrequency} / 2}{\text{mBitRatePrescaler} \cdot (1 + \text{mPropagationSegment} + \text{mPhaseSegment1} + \text{mPhaseSegment2})}$$

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

$$\text{Sampling point (single sampling)} = 100 \cdot \frac{1 + \text{mPropagationSegment} + \text{mPhaseSegment1}}{1 + \text{mPropagationSegment} + \text{mPhaseSegment1} + \text{mPhaseSegment2}}$$

$$\text{Sampling first point (triple sampling)} = 100 \cdot \frac{\text{mPropagationSegment} + \text{mPhaseSegment1}}{1 + \text{mPropagationSegment} + \text{mPhaseSegment1} + \text{mPhaseSegment2}}$$

12.2 Second ACAN2515TinySettings constructor: explicit CAN bit settings

New in release 1.0.4. This ACAN2515TinySettings constructor defines explicitly CAN bit settings. For example, see the TinyLoopBackDemoBitRateSettings sketch :

```
const uint32_t QUARTZ_FREQUENCY = 16 * 1000 * 1000 ; // 16 MHz
void setup () {
  ACAN2515TinySettings settings (QUARTZ_FREQUENCY, // For computing actual bit rate
                                4, // Bit rate prescaler, 1...64
                                5, // Propagation Segment, 1...8
                                5, // Phase Segment1, 1...8
                                5, // Phase Segment2, 2...8
                                4) ; // SJW, 1...4
  ...
}
```

This constructor requires six arguments :

1. inQuartzFrequency: the quartz frequency (uint32_t); note the quartz frequency is only used for computing actual bit rate;
2. inBitRatePrescaler: the bit rate prescaler (uint8_t);
3. inPropagationSegment: the propagation segment (uint8_t);
4. inPhaseSegment1: the phase segment 1 (uint8_t);
5. inPhaseSegment2: the phase segment 2 (uint8_t);
6. inSJW: the Synchronization Jump Width (uint8_t).

By default, *single sampling* is selected. Set mTripleSampling to true is you want *triple sampling*.

Respect the MCP2515 constraints:

$$1 \leq \text{inBitRatePrescaler} \leq 64$$

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

$$1 \leq \text{inPropagationSegment} \leq 8$$

$$\text{Single sampling: } 1 \leq \text{inPhaseSegment1} \leq 8$$

$$\text{Triple sampling: } 2 \leq \text{inPhaseSegment1} \leq 8$$

$$2 \leq \text{inPhaseSegment2} \leq 8$$

$$\text{inSJW} < \text{inPhaseSegment2}$$

$$\text{inPhaseSegment2} \leq \text{inPropagationSegment} + \text{inPhaseSegment1}$$

Call the CANBitSettingConsistency method ([section 12.3 page 29](#)) for checking your bit setting is consistent. Note the ACAN2515Tiny::begin method does this.

You can use this constructor for several reasons:

- you need a specific bit setting that the algorithm of the previous constructor cannot provide;
- you want to save program memory.

The algorithm of the previous constructor requires 32-bit arithmetic, that is expensive for a 8-bit processor as the Arduino Uno's one. The [table 1 page 3](#) lists the program sizes of the TinyLoopBackDemo and TinyLoopBackDemoBitRateSettings sketches, for several platforms. The Teensy 3.5 settings are: USB Serial, 120 MHz, Smallest code with LTO.

A starting point for obtaining the bit setting parameters is to execute the first constructor and note the values it provides. For example, run the TinyLoopBackDemo sketch, it displays in the serial monitor the bit setting values that you can then use in the TinyLoopBackDemoBitRateSettings sketch.

You can also write a program for your desktop computer: the ACAN2515TinySettings class is not Arduino specific.

12.3 The CANBitSettingConsistency method

This method checks the CAN bit decomposition (given by mBitRatePrescaler, mPropagationSegment, mPhaseSegment1, mPhaseSegment2, mSJW property values) is consistent.

```
const uint32_t QUARTZ_FREQUENCY = 16 * 1000 * 1000 ; // 16 MHz
void setup () {
    ...
    ACAN2515TinySettings settings (QUARTZ_FREQUENCY, 500 * 1000) ; // 500 kbit/s
    Serial.print ("mBitRateClosedToDesiredRate: ") ;
    Serial.println (settings.mBitRateClosedToDesiredRate) ; // 1 (--> is true)
    settings.mPhaseSegment1 = 0 ; // Error, mPhaseSegment1 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 – see [table 3](#).

The ACAN2515TinySettings class defines static constant properties that can be used as mask error. For example:

```
public: static const uint32_t kBitRatePrescalerIsZero = 1 << 0 ;
```

Bit	Error Name	Error
0	kBitRatePrescalerIsZero	mBitRatePrescaler == 0
1	kBitRatePrescalerIsGreaterThan64	mBitRatePrescaler > 64
2	kPropagationSegmentIsZero	mPropagationSegment == 0
3	kPropagationSegmentIsGreaterThan8	mPropagationSegment > 8
4	kPhaseSegment1IsZero	mPhaseSegment1 == 0
5	kPhaseSegment1IsGreaterThan8	mPhaseSegment1 > 8
6	kPhaseSegment2IsLowerThan2	mPhaseSegment2 < 2
7	kPhaseSegment2IsGreaterThan8	mPhaseSegment2 > 8
8	kPhaseSegment1Is1AndTripleSampling	(mPhaseSegment1 == 1) && mTripleSampling
9	kSJWIsZero	mSJW == 0
10	kSJWIsGreaterThan4	mSJW > 4
11	kSJWIsGreaterThanOrEqualToPhaseSegment2	mSJW >= mPhaseSegment2
12	kPhaseSegment2IsGreaterThanPSPlusPS1	mPhaseSegment2 > (mPropagationSegment + mPhaseSegment1)

Table 3 – The ACAN2515TinySettings::CANBitSettingConsistency method error codes

12.4 The actualBitRate method

The actualBitRate method returns the actual bit computed from mBitRatePrescaler, mPropagationSegment, mPhaseSegment1, mPhaseSegment2, mSJW property values.

```
const uint32_t QUARTZ_FREQUENCY = 16 * 1000 * 1000 ; // 16 MHz
void setup () {
    ...
    ACAN2515TinySettings settings (QUARTZ_FREQUENCY, 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 12.3 page 29](#)), the returned value is irrelevant.

12.5 The exactBitRate method

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

```
const uint32_t QUARTZ_FREQUENCY = 16 * 1000 * 1000 ; // 16 MHz
void setup () {
    ...
    ACAN2515TinySettings settings (QUARTZ_FREQUENCY, 727 * 1000) ; // 727 kbit/s
    Serial.print ("mBitRateClosedToDesiredRate: ") ;
    Serial.println (settings.mBitRateClosedToDesiredRate) ; // 1 (--> is true)
    Serial.print ("actual bit rate: ") ;
```

```

Serial.println (settings.actualBitRate ()) ; // 727272 bit/s
Serial.print ("distance: ") ;
Serial.println (settings.ppmFromDesiredBitRate ()) ; // 375 ppm
Serial.print ("Exact: ") ;
Serial.println (settings.exactBitRate ()) ; // 0 (----> false)
...
}

```

Note. If CAN bit settings are not consistent (see [section 12.3 page 29](#)), the returned value is irrelevant.

For a 16 MHz clock, the 28 exact bit rates are: 5 kbit/s, 6250 bit/s, 6400 bit/s, 8 kbit/s, 10 kbit/s, 12500 bit/s, 12800 bit/s, 15625 bit/s, 16 kbit/s, 20 kbit/s, 25 kbit/s, 31250 bit/s, 32 kbit/s, 40 kbit/s, 50 kbit/s, 62500 bit/s, 64 kbit/s, 80 kbit/s, 100 kbit/s, 125 kbit/s, 160 kbit/s, 200 kbit/s, 250 kbit/s, 320 kbit/s, 400 kbit/s, 500 kbit/s, 800 kbit/s, 1000 kbit/s.

For a 10 MHz clock, the 24 exact bit rates are: 3125 bit/s, 4 kbit/s, 5 kbit/s, 6250 bit/s, 8 kbit/s, 10 kbit/s, 12500 bit/s, 15625 bit/s, 20 kbit/s, 25 kbit/s, 31250 bit/s, 40 kbit/s, 50 kbit/s, 62500 bit/s, 78125 bit/s, 100 kbit/s, 125 kbit/s, 156250 bit/s, 200 kbit/s, 250 kbit/s, 312500 bit/s, 500 kbit/s, 625 kbit/s, 1000 kbit/s.

For a 8 MHz clock, the 28 exact bit rates are: 2500 bit/s, 3125 bit/s, 3200 bit/s, 4 kbit/s, 5 kbit/s, 6250 bit/s, 6400 bit/s, 8 kbit/s, 10 kbit/s, 12500 bit/s, 15625 bit/s, 16 kbit/s, 20 kbit/s, 25 kbit/s, 31250 bit/s, 32 kbit/s, 40 kbit/s, 50 kbit/s, 62500 bit/s, 80 kbit/s, 100 kbit/s, 125 kbit/s, 160 kbit/s, 200 kbit/s, 250 kbit/s, 400 kbit/s, 500 kbit/s, 800 kbit/s.

Note an 1 Mbit/s bit rate cannot be performed with a 8 MHz clock.

12.6 The ppmFromDesiredBitRate method

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

```

const uint32_t QUARTZ_FREQUENCY = 16 * 1000 * 1000 ; // 16 MHz
void setup () {
    ...
    ACAN2515TinySettings settings (QUARTZ_FREQUENCY, 727 * 1000) ; // 727 kbit/s
    Serial.print ("mBitRateClosedToDesiredRate: ") ;
    Serial.println (settings.mBitRateClosedToDesiredRate) ; // 1 (--> is true)
    Serial.print ("actual bit rate: ") ;
    Serial.println (settings.actualBitRate ()) ; // 727272 bit/s
    Serial.print ("distance: ") ;
    Serial.println (settings.ppmFromDesiredBitRate ()) ; // 375 ppm
    ...
}

```

Note. If CAN bit settings are not consistent (see [section 12.3 page 29](#)), the returned value is irrelevant.

12.7 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%.

```
const uint32_t QUARTZ_FREQUENCY = 16 * 1000 * 1000 ; // 16 MHz
void setup () {
    ...
    ACAN2515TinySettings settings (QUARTZ_FREQUENCY, 500 * 1000) ; // 500 kbit/s
    Serial.print ( "mBitRateClosedToDesiredRate: " ) ;
    Serial.println ( settings.mBitRateClosedToDesiredRate ) ; // 1 (--> is true)
    Serial.print ( "Sample point: " ) ;
    Serial.println ( settings.samplePointFromBitStart () ) ; // 68 --> 68%
    ...
}
```

Note. If CAN bit settings are not consistent (see [section 12.3 page 29](#)), the returned value is irrelevant.

12.8 Properties of the ACAN2515TinySettings class

All properties of the `ACAN2515TinySettings` class are declared public and are initialized ([table 4](#)). The default values of properties from `mDesiredBitRate` until `mTripleSampling` corresponds to a CAN bit rate of `QUARTZ_FREQUENCY / 64`, that is 250,000 bit/s for a 16 MHz quartz.

Property	Type	Initial value	Comment
<code>mQuartzFrequency</code>	<code>uint32_t</code>	<code>QUARTZ_FREQUENCY</code>	
<code>mDesiredBitRate</code>	<code>uint32_t</code>	<code>QUARTZ_FREQUENCY / 64</code>	
<code>mBitRatePrescaler</code>	<code>uint8_t</code>	2	See section 12.1 page 24
<code>mPropagationSegment</code>	<code>uint8_t</code>	5	See section 12.1 page 24
<code>mPhaseSegment1</code>	<code>uint8_t</code>	5	See section 12.1 page 24
<code>mPhaseSegment2</code>	<code>uint8_t</code>	5	See section 12.1 page 24
<code>mSJW</code>	<code>uint8_t</code>	4	See section 12.1 page 24
<code>mTripleSampling</code>	<code>bool</code>	false	See section 12.1 page 24
<code>mBitRateClosedToDesiredRate</code>	<code>bool</code>	true	See section 12.1 page 24
<code>mOneShotModeEnabled</code>	<code>bool</code>	false	See section 12.8.1 page 33
<code>mRequestedMode</code>	<code>RequestedMode</code>	<code>NormalMode</code>	See section 12.8.2 page 33
<code>mRolloverEnable</code>	<code>bool</code>	true	See section 12.8.3 page 33
<code>mReceiveBufferSize</code>	<code>uint8_t</code>	32	See section 8.1 page 15
<code>mTransmitBufferSize</code>	<code>uint8_t</code>	16	See section 7.2 page 13

Table 4 – Properties of the `ACAN2515TinySettings` class

12.8.1 The `mOneShotModeEnabled` property

This boolean property corresponds to the `OSM` bit of the `CANCTRL` control register. It is false by default.

12.8.2 The `mRequestedMode` property

This property defines the mode requested at this end of the configuration: `NormalMode` (default value), `ListenOnlyMode`, `LoopBackMode`.

12.8.3 The `mRolloverEnable` property

This boolean property corresponds to the `BUKT` bit of the `RXB0CTRL` control register. If true (value by default), `RXB0` message will roll over and be written to `RXB1` if `RXB0` is full; if false, rollover is disabled.

13 CAN controller state

Two methods return the receive error counter and the transmit error counter.

13.1 The `receiveErrorCounter` method

```
public: uint8_t receiveErrorCounter (void) ;
```

13.2 The `transmitErrorCounter` method

```
public: uint8_t transmitErrorCounter (void) ;
```