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CANPico MicroPython SDK
Reference Manual

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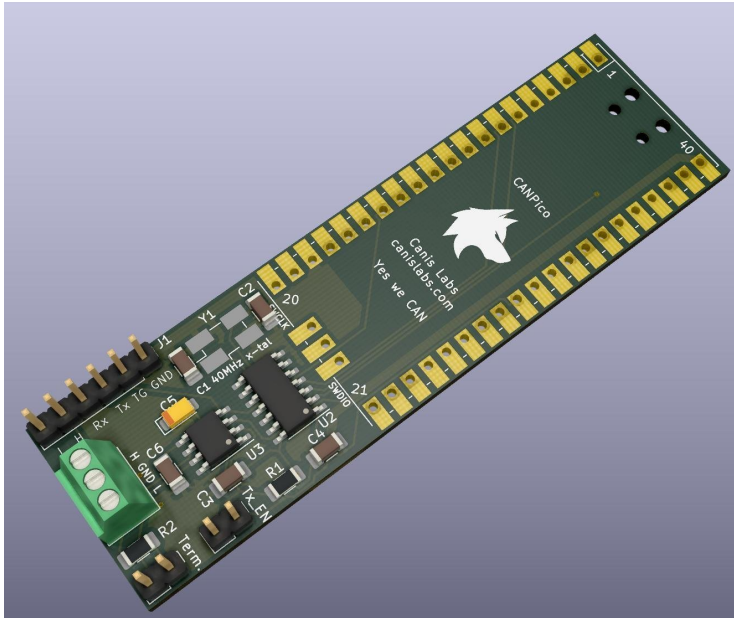
1 Introduction

The CANPico is a 'sock' board designed to connect a Raspberry Pi Pico board to a CAN bus. A Pico board is soldered down on to the upper area of the board and the lower area of the board contains the CAN connectors.



CAN bus is a protocol used in many applications, from trucks to buses to aircraft to agricultural equipment to medical devices to construction equipment and even spacecraft but its most common use is in cars.

This document describes the MicroPython SDK that provides functions for software on the Raspberry Pi Pico to access CAN bus.

WARNING. Connecting the CANPico directly to a vehicle CAN bus comes with risk and should not be undertaken without understanding this risk. Grounding a vehicle chassis through the USB port of a Pico connected to a laptop, PC or USB hub powered from the mains may cause permanent damage to the vehicle's electronics and/or the Raspberry Pi Pico and devices it is connected to. The CAN transceiver will tolerate a ground potential difference ("ground offset") of between -2V/+7V. Connecting pin 2 of the screw terminal to the target system's ground will establish a common ground reference. The CAN bus must be properly terminated (with 120Ω resistors at either end). If the CAN bus is already terminated at both ends then the termination jumper on the CANPico should not be closed. In addition, causing disruption to a vehicle's CAN bus traffic may be interpreted by the vehicle fault management systems as a hardware fault and cause the vehicle to permanently shut down CAN communications with consequent loss of functionality.

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2 Overview

The MicroPython SDK for the CANPico contains two major APIs:

- CAN
- CANHack

The firmware is supplied as a binary file of the form `firmware-` *yyyymmdd*`.uf2` and as a source code patch file against the upstream MicroPython repository (the file `README.txt` contains instructions on how to apply the patch against the MicroPython source). The firmware works on both the CANPico and CANHack boards (in the latter case there is no CAN controller so the CAN API cannot be used).

As well as providing the above APIs there are some other features included in the firmware:

- A second USB serial port is included (so when the Pico connects to a host, two virtual ports are instantiated[1]).
- A new GPIO FLIH (First Level Interrupt Handler); this is to ensure that the CAN interrupts are handled as quickly as possible to avoid frames being lost.
- An implementation of the MIN (Microcontroller Interconnect Network) protocol[2].

The drivers create four queues in RAM and use interrupt handlers to keep these up to date:

- A 128 entry FIFO of all the received frames (optionally also error frames)
- A 32 entry priority-ordered transmit queue (mapped into the CAN controller's hardware priority queue)
- A 32 entry FIFO transmit queue (the head of the FIFO is kept in the priority queue)
- A 128 entry transmit event queue (that records when a frame was transmitted)

[1]By default these would be `/dev/ttyACM0` and `/dev/ttyACM1` on a machine running Linux
[2] See `https://github.com/min-protocol/min`

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3 CAN API

The CAN API is included in the `rp2` module and consists of the following classes:

- The `CAN` class provides control and status of the CAN controller
- The `CANFrame` class encapsulates CAN frames, which are either created in software or by receiving them from the CAN controller hardware
- The `CANError` class encapsulates CAN error frames, which are created receiving them from the CAN controller hardware
- The `CANID` class describes a CAN ID: every CAN frame has a CAN ID, but many frames can have the same ID
- The `CANIDFilter` class describes how a CAN controller should identify and accept CAN frames based on their CAN ID

3.1 `CAN` – CAN controller

`class CAN` ([, *profile=BITRATE_500K_75*] [, *id_filters=None*] [, *hard_reset=False*] [, *mode=NORMAL*] [, *brp=None*] [, *tseg1=10*] [, *tseg2=3*] [, *sjw=2*] [, *recv_errors=False*] [, *tx_open_drain=False*])

Represents CAN controller hardware.

For the CANPico board there is a single CAN controller but other supported hardware may support more than one instance of this class.

The CANHack board has no CAN controller and the `RuntimeError` exception will be raised.

Parameters

- **profile** (*int*) – The profile for the CAN bus bit rate (see Profiles).
- **id_filters** – A dictionary mapping integers to `CANIDFilter` instances (see ID filtering)
- **hard_reset** (*bool*) – Set to True to reset the CAN controller at the lowest level (equivalent to power-on reset)
- **mode** (*int*) – Request the mode for the CAN controller (see Modes)
- **brp** (*int*) – Baud rate prescaler; if this parameter is set then the profile parameter is overridden and *brp*, *tseg1*, *tseg2* and *sjw* are used to directly set the bit rate of the controller.
- **tseg1** (*int*) – TSEG1
- **tseg2** (*int*) – TSEG2
- **sjw** (*int*) – SJW
- **recv_errors** (*bool*) – If False then error frames are discarded and not placed in the receive FIFO

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- **tx_open_drain** (*bool*) – If True then the TX pin of the MCP2517/18FD is set to open drain

Raises

- `TypeError` – if the key/value pairs in *id_filters* are not int/instances of `CANIDFilter`
- `RuntimeError` – if the controller hardware is not connected via SPI

A value of *None* for *id_filters* sets up the CAN controller to accept all incoming frames.

Open drain for the controller's TX pin allows the CAN transceiver's input pin to be driven by a GPIO pin. Open drain mode should not be selected if the controller is put into a mode where it will drive its TX pin to dominant (i.e. it's only appropriate if in offline or listen-only modes).

Methods

send_frame (*frame* [, *fifo=False*])

Queue a frame for transmission on the CAN bus.

Parameters

- **frame** (`CANFrame`) – The CAN frame to send
- **fifo** (*bool*) - Whether the queue the frame in the FIFO queue (see section 3.6)

Returns *None*

Raises

- `TypeError` – if frame is not an instance of `CANFrame`.
- `ValueError` – if there is insufficient room in the queues

send_frames(*frames* [, *fifo=False*)

Send a collection of CAN frames on the bus

Parameters

- **frames** (`CANFrame`) – A list of CAN frames to send
- **fifo** (*bool*) – Whether the queue the frames in the FIFO queue (see section 3.6)

Returns *None*

Raises

- `TypeError` – if frames is not a list of `CANFrame` instances
- `ValueError` – if there is insufficient room in the queues

recv([, *limit=RX_FIFO_SIZE*] [, *as_bytes=False*])

Receive CAN remote, data and error frames

Parameters

- **limit** (*int*) – The maximum number of frames to remove from the FIFO (defaults to the entire FIFO)

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- **as_bytes** (*bool*) – If True then returns a block of bytes representing the frames

Returns a list of `CANFrame` and `CANError` instances or a block of bytes representing the CAN frames received since the last call to *recv* (up to a maximum of *limit* frames)

Return type list or *bytes*

The list is ordered by the order of CAN frame reception into the receive FIFO and the frames are removed from the FIFO. If no frames have been received then an empty list is returned. An element in the list is *None* if there are one or more missing frames because the FIFO was full at that point.

The block of bytes contains a binary representation of the frames, ordered by the order of CAN frame reception into the receive FIFO, and the frames are removed from the FIFO. If no frames have been received then a zero-length block of bytes is returned.

This function can be polled regularly to return the frames received. The *as_bytes* option is to allow the frames to be converted into a standard bytes format for transmission over a network connection for processing elsewhere.

recv_pending()

Number of CAN frames in the receive FIFO

Returns the number of CAN frames pending in the receive FIFO (including any elements of type *None*)

Return type *int*

recv_tx_events([, *limit=TX_EVENT_FIFO_SIZE*] [, *as_bytes=False*])

Get frame transmission events

Parameters

- **limit** (*int*) – The maximum number of transmit events to remove from the transmit event FIFO (defaults to the entire FIFO)
- **as_bytes** (*bool*) – If True then returns a block of bytes representing the transmit events

Returns a list of transmit events or a block of bytes representing the transmit events since the last call (up to a maximum of limit frames)

Return type list or *bytes*

The tuple in a list element has the following contents:

- If the first element is *EVENT_TYPE_TRANSMITTED_FRAME* then the next two elements are a frame tag and the timestamp of start-of-frame
- If the first element is *EVENT_TYPE_OVERFLOW* then the next two elements are a count of the number of dropped transmit events and a

timestamp of the start-of-frame of the first transmit event that was dropped.

recv_tx_events_pending()

Number of transmit events in the event FIFO

Returns the number of events in the event FIFO (including any elements of type *None*)

Return type *int*

get_status()

Status of CAN controller

Returns a tuple of four elements: a bool indicating bus off state, a bool indicating error passive state an int representing the Transmit Error Counter, and an int representing the Receive Error Counter

Return type tuple

get_send_space([*fifo=False*])

Number of slots for CAN frames in the transmit priority queue or FIFO

Returns the space in the transmit FIFO (if *fifo* is *False*) else the space in the transmit priority queue

Return type *int*

get_time()

Current time

Returns The value of the free-running timer used for timestamping transmitted and received CAN frames

Return type *int*

The time is represented by an incrementing integer that wraps around to 0.

get_time_hz()

Returns The number of ticks per second of the timestamp timer

Return type *int*

This function can be used to automatically adjust to different timestamp timers.

set_trigger([*on_error=False*] [, *on_canid=None*] [, *as_bytes=None*])

Set the conditions for a pulse on the TRIG pin.

This method sets the trigger system running, putting a pulse on the TRIG pin when certain conditions are seen. These including seeing a CAN error (enabled by setting *on_error* to *True*), matching a specific CAN ID (by setting *on_canid* to an instance of `CANID`) or by a frame matching a more complex template of ID, DLC and data field (by setting trigger to a block of bytes).

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Parameters

- **on_error** (bool) – Whether trigger when an error occurs
- **on_canid** (`CANID`) – If not *None* then trigger when a given CAN ID is received from the bus
- **as_bytes** (bytes) – If not *None* a block of bytes that sets a trigger based on CAN ID, DLC and data fields (see section 3.10 for a definition of the byte format)

Returns *None*

Raises

- `TypeError` – if *on_canid* is not an instance of `CANID` or *as_bytes* is not an instance of bytes
- `ValueError` – if both *on_canid* and *as_bytes* are specified or the *as_bytes* parameter is not bytes in a specific format

A pulse will be placed on the TRIG pin on the CANPico board each time the event occurs. An external logic analyzer tool can use this to trigger. A trigger set by trigger or *on_canid* will only trigger for frames passing through the ID acceptance filters (see section 3.7).

clear_trigger()

Disables the trigger

Returns *None*

After this is called there will be no more pulses on the TRIG pin until a new trigger is set via a new call to *set_trigger*().

pulse_trigger()

Puts a pulse on the TRIG pin

Returns *None*

This method allows application software in MicroPython to directly trigger a logic analyzer.

Modes

The table below gives the controller modes.

Mode	Description
NORMAL	Normal CAN 2.0 mode
LISTEN_ONLY	Listens to CAN RX but never sets CAN TX to dominant
ACK_ONLY	Like listen-only but will generate a dominant bit for ACK
OFFLINE	Sets up the controller pins but keeps the controller off the bus

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Profiles

The table below gives the CAN bit rate settings for the valid profiles.

Profile	Bit rate (Kbit/sec)	Sample point (%)
BITRATE_500K_75	500	75
BITRATE_250K_75	250	75
BITRATE_125K_75	125	75
BITRATE_1M_75	1000	75
BITRATE_500K_50	500	50
BITRATE_250K_50	250	50
BITRATE_125K_50	125	50
BITRATE_1M_50	1000	50
BITRATE_2M_50	2000	50
BITRATE_4M_90	4000	90
BITRATE_2_5M_75	2500	75
BITRATE_2M_80	2000	80

The bit rates above 1Mbit/sec are non-standard and experimental.

Queue sizes

The following table gives the sizes of the various queues.

Queue	Size	Pre-defined constant
Receive FIFO	128	*RX_FIFO_SIZE*
FIFO-ordered transmit	32	*TX_FIFO_SIZE*
Priority-ordered transmit	32	*TX_QUEUE_SIZE*
Event FIFO	128	*TX_EVENT_FIFO_SIZE*

3.2 `CANFrame` – CAN frame

class CANFrame(*canid*, [, *data=None*] [, *remote=False*] [, *tag*=0] [, *dlc=None*])

Represents a CAN frame for transmission or reception. A `CANFrame` instance is created either directly in order to transmit a frame, or is returned from the *recv*() call.

Parameters

- **canid** (`CANID`) – The CAN ID of the frame
- **data** (bytes) – The payload of the CAN frame
- **remote** – Set to True if the frame is a remote frame
- **tag** – An integer value that is returned along with a timestamp as a transmit event
- **dlc** – Set the specific DLC value to send on the wire

Raises

- `ValueError` – if the length of the data field is greater than 8 or greater than 0 if remote is *True* or there is mismatch between DLC and the data length
- `TypeError` – if data is not of type bytes or if *canid* is not an instance `CANID`

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Methods

is_remote()

Returns *True* if the frame is a remote frame

Return type bool

get_canid()

Returns the frame's CAN ID

Return type `CANID`

get_id()

Returns the numeric arbitration ID as an integer value of the frame's CAN ID

Return type int

is_extended()

Returns *True* if the CAN frame has an extended 29-bit ID

Return type *bool*

This is the equivalent function to the *is_extended*() method of `CANID`. Note that the CAN protocol specifies that an extended ID of 0x100 and a standard ID of 0x100 are not the same and are arbitrated differently (the top 11 bits of an extended ID are arbitrated against the 11 bits of a standard ID).

get_data()

Returns the frame's payload; remote frames return zero bytes

Return type *bytes*

get_dlc()

Returns the frame's DLC value

Return type int

get_timestamp()

Returns the frame's timestamp

Return type int

The timestamp returns *None* when a frame is created through its constructor. If the frame is returned via *recv*() then the timestamp is an integer representing the time of start-of-frame when it was received. If a frame is queued for transmission then the timestamp is the time of the start-of-frame when it was successfully transmitted.

The timestamp can also be used to determine if a frame queued for transmission has been sent.

The current time in the CAN controller is returned by the *get_time*() call.

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get_index()

Returns the frame's ID filter index

Return type int

The filter index is the key value of the ID filter that matched in the CAN controller's ID filtering system (see section 3.7). If the frame was not returned via *recv*() then this call returns *None*. The filter index is a fast way to identify the received frame.

static from_bytes(*block*)

Parameters

- **block** (*bytes*) – A block of bytes representing list of CAN frames

Returns a list of instances of `CANFrame` specified by a block of bytes

Return type list

Raises

- `ValueError` – if the length of block is not an integer multiple of the CAN frame binary format
- `TypeError` – if block is not of type *bytes*

This is a factory method that takes a block of bytes in a specific binary format and returns a list of `CANFrame` instances representing the frames specified by those bytes.

Examples

In all the examples, the classes are assumed to have been imported and a CAN controller initialized like this:

```
>>> from rp2 import *
>>> c = CAN()
```

(This initializes the CAN controller to the defaults, which includes setting the bit rate to 500kbit/sec)

To send a CAN frame with a payload:

```
>>> f = CANFrame(CANID(0x123), data=b'hello')
>>> c.send_frame(f)
>>>
```

This sends a CAN frame with a standard ID of 0x123 and a 5 byte payload of 68 65 6c 6c 6f.

3.3 `CANError` — CAN error frame

class CANError

Represents a CAN error frame. Instances are returned from the *recv*() method.

Methods

get_timestamp()

Returns the error frame's timestamp

Return type int

If the error frame is returned via *recv*() then the timestamp is an integer representing the time when the error occurred. This is less accurate than remote and data frame timestamps due to the variability in fetching the time from the controller. The timestamp is 0 if an error frame is created through its constructor.

The current time in the CAN controller is returned by the *get_time*() call.

is_crc_error()

Returns *True* if the error was a CRC error

Return type bool

is_stuff_error()

Returns *True* if the error was a stuff error

Return type bool

is_form_error()

Returns *True* if the error was a form error

Return type bool

is_bit1_error()

Returns *True* if the error was a bit error where a recessive was sent but a dominant received

Return type bool

is_bit0_error()

Returns *True* if the error was a bit error where a dominant was sent but a recessive received

Return type bool

is_bus_off()

Returns *True* if the controller is now Bus Off

Return type bool

3.4 `CANID` — CAN identifier

class CANID(*canid* [*, extended=False*])

Represents a CAN identifier. A `CANID` instance is created either directly or is returned from the *get_canid*() call.

Parameters

- **canid** (*int*) – The CAN identifier of the frame

- **extended** (*bool*) – Set to *True* if the ID is a 29-bit identifier.

Raises

- `ValueError` – if *canid* is not in the range 0..0x7ff (when extended is *False*) or 0..0x1fffffff (when extended is *True*).

Methods

is_extended()

Indicates if the CAN ID is a standard 11-bit ID or an extended 29-bit ID.

Returns *True* if the CAN ID is a 29-bit identifier

Return type bool

get_id()

Returns the integer value of the CAN ID

Returns the frame's CAN ID represented as an integer

Return type int

get_id_filter()

Returns a CAN ID filter that accepts this (and only this) ID

Returns the ID filter for the CAN ID

Return type `CANIDFilter`

3.5 `CANIDFilter` — CAN ID acceptance identifier

class CANIDFilter([*filter=None*])

Represents a CAN ID filter to select which incoming frames match.

Parameters

- **filter** (*str*) – The filter mask string describing the ID to match, or *None* to match all 11- and 29-bit identifiers

Raises

- `ValueError` – if the length of the filter string is not 11 or 29 characters long or contains characters other than 'X', '1' or '0'
- `TypeError` – if filter is not of type *str*

The filter is a character string that defines the ID matching to take place. It is composed of only 'X', '1' or '0' and must be 11 or 29 characters long. A 'X' character means "don't care", a '1' means "Must be 1" and '0' means "Must be 0".

Examples

The following gives an ID filter that accepts all CAN frames:

```
>>> filter = CANIDFilter()
```

To accept all frames with 11-bit identifiers:

```
>>> filter = CANIDFilter(filter='XXXXXXXXXXX')
```

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To accept all CANOpen 'Transmit SDO' frames:

```
>>> filter = CANIDFilter(filter='1101XXXXXXX')
```

3.6 FIFO transmission

The CAN arbitration phase selects the highest priority frame to transmit. A well-designed CAN controller will perform internal arbitration on the same basis: it will enter into bus arbitration its highest priority frame. The drivers of the MCP2517/18FD configure it for a priority queue of 32 frames. But when two frames with the same ID are queued then the order that the hardware chooses to send a frame will typically be arbitrary, and this might not be good enough in some cases. For example, a block message made up from multiple CAN frames must be transmitted in the correct order.

To support this the drivers create an additional FIFO priority queue. At any point in time the frame at the head of the FIFO queue will be in the priority queue. Once a FIFO frame is transmitted on the CAN bus, the drivers will copy in the next frame in the FIFO queue, and so on.

Note that the FIFO queue for the MCP2517/18FD is implemented in software: there is a hardware FIFO queue provided by the controller but it suffers from priority inversion[3] with respect to the priority queue.

3.7 ID filtering

The CAN protocol engine of a CAN controller receives every frame but in most applications the host software does not need to see all these frames. Instead, ID filters are used to filter out unwanted frames. The MCP2517/18FD allows 32 ID filters. The matching filter is included in the `CANFrame` instance when the frame is received. ID filters are matched in order, so filter 0 is matched first, down to 31. If no filters are specified then a default 'match all frames' filter is defined.

See `CANIDFilter` for more information on creating ID acceptance filters.

3.8 Controller specifics

The Microchip MCP2517/18FD CAN controller has the following hardware-specific behaviors:

- The number of ID acceptance filters is limited to 32, and key values in the *id_filters* dictionary must be in the range 0..31.
- The number of frames in the transmit priority queue is limited to 32.
- The controller will automatically attempt to recover from a Bus Off state (which requires the controller to see 127 idle periods of 11 recessive bits each).
- Pending outgoing CAN frames will be discarded when entering Bus Off.

In addition there are specifics of the MCP2517/18FD driver:

- The number of frames in the FIFO queue that feeds into the hardware priority queue is limited to 32.

[3] See `https://kentindell.github.io/2020/06/29/can-priority-inversion` for more details on this common but important CAN driver problem

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- The free-running timestamp counter is a 32-bit integer counting microseconds.

The CAN bit time parameters *brp*, *tseg1*, *tseg2* and *sjw* are intepreted to be one less than their actual values (e.g. setting *brp* to 0 means /1, a value of 3 means /4, and so on). Together they specify a CAN bit time:

- The *brp* parameter specifies the prescaler for the 40MHz clock to give the CAN time quanta clock
- A CAN bit time is 3 + *tseg1* + *tseg2*
- The sample point for a bit is 2 + *tseg1*

For example, for 500kbit/sec and a 75% sample point the settings are:

- *brp* = 4, i.e. 40MHz / 5 = 8MHz time quanta clock (1 time quantum = 125ns)
- *tseg1* = 10 and *tseg2* = 3, i.e. a CAN bit time of 3 + 10 + 3 = 16 time quanta or 2000ns = 2µs per bit
- Sample point of 2 + 10 = 12 / 16, or 0.75

3.9 Examples

3.9.1 Getting started: hardware

The first thing to get right with sending frames on a CAN bus is to have a receiver device. If there is no other device on the CAN bus then there is nothing to generate the ACK bit in a CAN frame to acknowledge it, and the sender will keep sending the original frame again and again and the frame will never be marked as sent (so it will never get a transmit timestamp and never be removed from the transmit queue). Obviously one way to have two devices is to send frames between a pair of CANPico boards.

The other thing that is important is that the CAN bus must be terminated with the standard termination resistor, ideally at either end of the bus. The CANPico board has a jumper to include a termination resistor, so if a pair of CANPico boards are on the bus they can be at either end with the jumpers closed.

3.9.2 Getting started: MicroPython API

The whole MicroPython API can be imported from the `rp2` module with:

Standard REPL

```
>>> from rp2 import *
```

where >>> is Python REPL command line prompt.

An instance of a CAN controller is created with:

Standard REPL

```
>>> c = CAN()
```

This initializes the CAN controller on the board with the default profile (500kbit/sec, 75% sample point) and sets up the ID filtering to receive all frames (some examples will re-initialize the CAN controller with different settings)

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To create a CAN frame to send:

Sender REPL

```
>>> f = CANFrame(CANID(0x123), data=b'hello')
```

This creates a 5 byte frame to send on the bus.

An instance of `CANID` can be created directly (this is useful if creating a new frame with the same ID as an existing frame):

Sender REPL

```
>>> canid = frames[0].get_canid()
>>> canid
CANID(id=S123)
```

A frame can be sent with the *send_frame*() call:

Sender REPL

```
>>> c.send_frame(f)
```

The frame can be checked to see when it was sent:

Sender REPL

```
>>> f.get_timestamp()
86152095
```

The frame is received at another CANPico board using *recv*():

Receiver REPL

```
>>> frames = c.recv()
>>> frames
[CANFrame(CANID(id=S123), dlc=5, data=68656c6c6f,
timestamp=83501487)]
```

This returns a list (in this example) containing a single CAN frame. The payload of the frame can be obtained with the *get_data*() call:

Receiver REPL

```
>>> frames[0].get_data()
b'hello'
```

The arbitration ID can be obtained with *get_arbitration_id*():

Receiver REPL

```
>>> hex(frames[0].get_arbitration_id())
'0x123'
```

And whether it has an extended ID can be found with *get_arbitration_id*():

Receiver REPL

```
>>> frames[0].is_extended()
False
```

The timestamp of the frame (according to the receiver board's clock) can be obtained by reading its timestamp with the *get_timestamp*() call:

Receiver REPL

```
>>> frames[0].get_timestamp()
3327067
```

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The offset between the two timestamps can be used to synchronize clocks (a common technique is for the transmitter to send a 'follow-up frame' with its timestamp so that the receiver can compute a clock delta).

3.9.3 The `canpico.py` examples file

The file `canpico.py` is a module that contains helpful setup code and examples, and is used here to illustrate the API. It is generally invoked from the Python REPL command line like this:

Standard REPL

```
>>> from canpico import *
>>> c = CAN()
>>> cp = CANPico(c)
```

The module code itself brings in the entire CAN API and useful functions like *delay_ms*() but the CAN controller must be created outside of the module. In the above, `cp` is the instance of the `CANPico` examples class and is used to invoke a particular function. The rest of the examples will refer to `c` and `cp` assuming they have been created using the code above.

3.9.4 A simple bus monitor

It's very easy to create a bus monitor in Python and the `CANPico` class contains the following method:

CANPico code

```
# Simple CAN bus monitor
def mon(self):
   while True:
        frames = self.c.recv()
        for frame in frames:
            print(frame)
```

The simple monitor can be run like this:

Receiver REPL

```
>>> from canpico import *
>>> c = CAN()
>>> cp = CANPico(c)
>>> cp.mon()
```

This prints a representation of each frame (including timestamp) as it is received (because this runs in Python, and because the time for code to print to the Python REPL promt is much longer than a CAN frame, this little monitor will not be able to keep up with a fully loaded CAN bus at 500kbit/sec).

We can transmit some frames from another board. Here we make ten frames with ID 0x100 and a single byte payload:

Sender REPL

```
>>> frames = [CANFrame(CANID(0x100), data=bytes([i])) for i in
range(10)]
>>> len(frames)
10
>>> c.send_frames(frames)
```

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The receiver then shows those frames:

Receiver REPL

```
>>> cp.mon()
CANFrame(CANID(id=S100), dlc=1, data=00, timestamp=374052889)
CANFrame(CANID(id=S100), dlc=1, data=04, timestamp=374053005)
CANFrame(CANID(id=S100), dlc=1, data=03, timestamp=374053121)
CANFrame(CANID(id=S100), dlc=1, data=08, timestamp=374053239)
CANFrame(CANID(id=S100), dlc=1, data=09, timestamp=374053355)
CANFrame(CANID(id=S100), dlc=1, data=07, timestamp=374053472)
CANFrame(CANID(id=S100), dlc=1, data=05, timestamp=374053588)
CANFrame(CANID(id=S100), dlc=1, data=02, timestamp=374053706)
CANFrame(CANID(id=S100), dlc=1, data=06, timestamp=374053826)
CANFrame(CANID(id=S100), dlc=1, data=01, timestamp=374053944)
```

Note that the frames did not get sent in FIFO order. This is because the MCP2517/18FD (and nearly all other CAN controllers) will select the highest priority frame (i.e. the one with the lowest ID) to send from a priority queue, but if two frames have the same priority then the tie is broken arbitrarily. This is not what we want if the frames contain parts of a bigger block message. Fortunately, we can fix that by using the *fifo* option when sending:

Sender REPL

```
>>> c.send_frames(frames, fifo=True)
```

Now the monitor shows the second batch of ten frames arriving in true FIFO order:

Receiver REPL

```
>>> cp.mon()
CANFrame(CANID(id=S100), dlc=1, data=01, timestamp=582017001)
CANFrame(CANID(id=S100), dlc=1, data=02, timestamp=582017397)
CANFrame(CANID(id=S100), dlc=1, data=03, timestamp=582017719)
CANFrame(CANID(id=S100), dlc=1, data=04, timestamp=582017873)
CANFrame(CANID(id=S100), dlc=1, data=05, timestamp=582018025)
CANFrame(CANID(id=S100), dlc=1, data=06, timestamp=582018179)
CANFrame(CANID(id=S100), dlc=1, data=07, timestamp=582018333)
CANFrame(CANID(id=S100), dlc=1, data=08, timestamp=582018485)
CANFrame(CANID(id=S100), dlc=1, data=09, timestamp=582018637)
```

3.9.5 Frame queueing

The transmit queue and transmit FIFO have only 32 slots so it is possible to overrun the transmit buffer, and the exception *ValueError* is raised if there is no space in the queue for the queued frame. One way to overcome this is to catch the exception and keep re-trying, for example by defining a function that only returns when the frame transmit has succeeded:

CANPico method

```
def always_send(self, f):
    while True:
        try:
            self.c.send_frame(f)
            return
        except:
            pass
```

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Alternatively, the *get_send_space*() call can be used to see how many buffer slots are free:

CANPico method

```
def always_send2(self, f):
    while True:
        if self.c.get_send_space() > 0:
            self.c.send_frame(f)
            return
```

A burst of many frames can then be sent with:

Sender REPL

```
>>> for i in range(10000):
...     f = CANFrame(CANID(0x123), data=pack('>I', i))
...     cp.always_send(f)
```

The above code creates and sends frames where the frame number is packed into a 4-byte payload in big-endian format (using the standard Python `pack` method of the `struct` module).

The firmware runs fast enough to fill the controller and for the CAN bus to be completely flooded with frames. But note that MicroPython uses a heap, so there may sometimes be delays due to garbage collection.

The last frame *queued* will have a payload of 00 00 27 0F but this may not be the last frame *transmitted*: when more than one frame has the same CAN ID then the hardware may choose arbitrarily which frame to enter into arbitration. This is something to watch out for with CAN systems: if an application transmits a frame periodically then it is best to check if the previous instance was sent already and only queue if it has been sent, ensuring that only one instance of the frame is in the controller. For example:

Sender REPL

```
>>> i = 0
>>> f = CANFrame(CANID(0x123), data=pack('>I', i))
>>> c.send_frame(f)
>>> while True:
...     delay_ms(10)
...     i += 1
...     if f.get_timestamp() is not None:
...         f = CANFrame(CANID(0x123), data=pack('>I', i))
...         c.send_frame(f)
```

In the above example, every 10 milliseconds the frame becomes due to be re-queued, and a check is made to see if the timestamp is set. If it has been then the frame is re-queued, but if it hasn't been then the sending is skipped for this period. In mission critical real-time systems an analysis of the worst-case latencies on the network is done to prove that in normal circumstances the frame will always have won arbitration and be sent by the time it is due to be sent again and if not then a genuine error (rather than a transient overload) has occurred.

3.9.6 Time syncing

A simple way to show the clocks at a sender and receiver is for the sender to obtain its own timestamp and send that in a follow-up message. The receiver can then see the sender's clock and its own clock for the same message. At the sender we use the following functions from the example code:

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CANPico method

```
def send_wait(self, f):
    self.c.send_frame(f)
    while True:
        if f.get_timestamp() is not None:
            return
```

CANPico method

```
def fup(self, f):
    return CANFrame(CANID(0x101), data=pack('>I', f.get_timestamp()))
```

CANPico method

```
def heartbeat(self):
    f = CANFrame(CANID(0x100))
    while True:
        self.send_wait(f)
        f2 = self.fup(f)
        self.c.send_frame(f2)
        sleep(1)
```

The *send_wait*() function queues a frame and waits until it has been sent. The *fup*() function creates a follow-up message from the sent frame and the *heartbeat*() function sends a heartbeat pair of frames.

The receiver runs a function that interprets the follow-up message with the timestamp:

CANPico method

```
def drift(self):
    self.c.recv()  # Clear out old frames
    ts = None  # Don't know the first timestamp yet
    while True:
        frames = self.c.recv()
        for frame in frames:
            if frame is not None:
                if frame.get_arbitration_id() == 0x100:  # First
                    ts = frame.get_timestamp()
                if frame.get_arbitration_id() == 0x101:  # Follow-up
                    sender_ts = unpack('>I', frame.get_data())[0]
                    if ts is not None:
                        print(sender_ts - ts)
```

At the sender a timing heartbeat pair can be sent every 1 second like this:

Sender REPL

```
>>> cp.heartbeat()
```

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The frames look like this when *mon*() is running on the receiver:

Receiver REPL

```
>>> cp.mon()
CANFrame(CANID(id=S100), dlc=0, data=*, timestamp=984513569)
CANFrame(CANID(id=S101), dlc=4, data=40a7c451, timestamp=984513885)
CANFrame(CANID(id=S100), dlc=0, data=*, timestamp=985513933)
CANFrame(CANID(id=S101), dlc=4, data=40b707f3, timestamp=985514249)
CANFrame(CANID(id=S100), dlc=0, data=*, timestamp=986514305)
CANFrame(CANID(id=S101), dlc=4, data=40c64b9d, timestamp=986514623)
CANFrame(CANID(id=S100), dlc=0, data=*, timestamp=987514677)
CANFrame(CANID(id=S101), dlc=4, data=40d58f48, timestamp=987515001)
CANFrame(CANID(id=S100), dlc=0, data=*, timestamp=988515053)
CANFrame(CANID(id=S101), dlc=4, data=40e4d2f6, timestamp=988515375)
CANFrame(CANID(id=S100), dlc=0, data=*, timestamp=989515421)
CANFrame(CANID(id=S101), dlc=4, data=40f4169c, timestamp=989515747)
CANFrame(CANID(id=S100), dlc=0, data=*, timestamp=990515799)
CANFrame(CANID(id=S101), dlc=4, data=41035a4c, timestamp=990516125)
```

Running *drift*() on the receiver and *heartbeat*() on the sender outputs something like this on the receiver:

Receiver REPL

```
>>> cp.drift()
82836029
82836034
82836037
82836040
82836043
```

This shows the offset between the clocks and that the clocks are drifting apart at about 3µs per second (i.e. about 3ppm), which is pretty good for a pair of crystals.

3.9.7 Bit rate profiles

To use a different bus bit rate use the profile parameter:

```
>>> c = CAN(profile=CAN.BITRATE_250K_75)
```

There are some profiles that are higher than the maximum 1Mbit/sec but they may not work on the CAN bus cabling (the 4Mbit/sec is particularly unstable).

3.9.8 ID acceptance filtering

We can put a simple ID filtering scheme in place for the receiving board:

Receiver REPL

```
>>> filter0 = CANIDFilter(filter='1001XXXXXXX')
>>> filter1 = CANIDFilter(filter='XXXXXXXXXXXXXXXXXXXXXXXXX0000')
>>> filter31 = CANIDFilter()
>>> id_filters = {0: filter0, 1: filter1, 31: filter31}
>>> c = CAN(id_filters=id_filters)
```

All received frames will still be put into the receive FIFO because *filter31* is a catch-all, but they will be assigned an index value according to the *id_filters* dictionary above.

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So on the sending board we can send this frame:

Sender REPL

```
>>> f = CANFrame(CANID(0x11111110, extended=True))
>>> f
CANFrame(CANID(id=E11111110), dlc=0, data=*)
>>> c.send_frame(f)
```

At the receiver we then pick up the frames as normal:

Receiver REPL

```
>>> frames = c.recv()
>>> frames[0]
CANFrame(CANID(id=E11111110), data=*)
```

The acceptance filters are set to accept all frames into the receive FIFO, but frames with an 11-bit ID where the top four bits are 0b1001 will have an index tag of 0 (accessed by the frame's *get_index*() method), frames with an extended ID where the bottom four bits are 0 will get an index tag of 1 and all other frames will get an index tag of 31.

The index of the above received frame will be set according to the first matching acceptance filter, in this case *filter1* which was assigned a key of 1 in the *id_filters* dictionary:

Receiver REPL

```
>>> frames[0].get_index()
1
```

These tags can be used to quickly identify a frame for further processing. The filters can also be used to eliminate unwanted traffic from ending up in the receive FIFO. For example, to only receive 11-bit standard ID frames the following ID filter can be used and applied when the controller is initialized:

Receiver REPL

```
>>> id_filters = {0: CANIDFilter('XXXXXXXXXXX')}
>>> c = CAN(id_filters=id_filters)
```

An instance of `CANID` has a method to return a specific ID filter that matches just that ID, so if an application does not need to receive more than 32 frames then the ID acceptance filtering system can be used to directly identify the frame to the application (the frame's index value can used to to index a list, a much faster operation than hashing the full CAN ID). For example:

Receiver REPL

```
>>> idf1 = CANID(0x123).get_id_filter()
>>> idf2 = CANID(0x400).get_id_filter()
>>> idf3 = CANID(0x401).get_id_filter()
>>> c = CAN(id_filters={1: idf1, 2: idf2, 3: idf3})
```

Each received frame can be processed very quickly: the frame's tag can be used to index into a list of functions that are defined to process a specific frame.

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3.9.9 Errors

Error frames are by default not added into the receive FIFO. This default can be overridden when initializing the CAN controller:

Receiver REPL

```
>>> c = CAN(recv_error=True)
```

An item in the receive FIFO that's an error is an instance of `CANError`, and an overflow indicator (which indicates that the receive FIFO ran out of space and error and normal frames were dropped) is returned as *None*.

3.9.10 Setting DLC

The DLC for a frame is set automatically by default, but the CAN specification says that DLC values 8-15 are equivalent, and it is possible to set a DLC to a value greater than 8 for a frame with an 8 byte payload. The following transmits a frame with a DLC of 14:

Sender REPL

```
>>> f = CANFrame(CANID(0x123), data=bytes([0] * 8), dlc=14)
>>> len(f.get_data())
8
>>> c.send_frame(f)
```

This can be useful for penetration testing to check that a device doesn't just use the DLC of a received frame as a loop bound.

3.9.11 Remote frames

Remote frames can be sent at follows:

Sender REPL

```
>>> f = CANFrame(CANID(0x123), remote=True)
>>> c.send_frame(f)
```

At the receiver a remote frame is received in the normal way:

Receiver REPL

```
>>> frame = c.recv()[0]
>>> frame
CANFrame(CANID(id=S123), dlc=0, data=R, timestamp=2715883559)
>>> frame.is_remote()
True
```

Note that the CAN specification requries that all remote frames of the same ID must have the same agreed-upon DLC value (otherwise a ‘doom loop’ of repeated error and retransmissions could occur).

3.9.12 Bus logging

The firmware is fast enough to log frames arriving at a high rate. Here we send a burst of 300 frames as fast as possible.

At the receiver we will pick up the first 300 frames:

Receiver REPL

```
>>> frames = []
>>> while len(frames) < 300:
...     frames += c.recv()
```

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Now we can send a burst of 300 frames as fast as possible:

Sender REPL

```
frames = [CANFrame(CANID(i)) for i in range(300)]
>>> len(frames)
300
>>> for frame in frames:
...     cp.always_send(f)
```

Note that if the frames are printed to the terminal then the frames cannot be logged without dropping frames: it takes much longer to print a frame than it takes for CAN to receive it (even on a fast PC: for example, the BUSMASTER software cannot keep up printing frames in a GUI under Windows).

The receiver quits the while loop once it gets the 300 frames:

Receiver REPL

```
>>> frames = []
>>> while len(frames) < 300:
...     frames += c.recv()
>>> len(frames)
300
>>> print(frames[-1])
CANFrame(CANID(id=S12b), dlc=0, data=*, timestamp=3839015741)
>>> int(0x12b)
299
```

3.9.13 Setting up a trigger for a logic analyzer

To trigger only when a certain CAN ID is seen use the *set_trigger*() method:

Receiver REPL

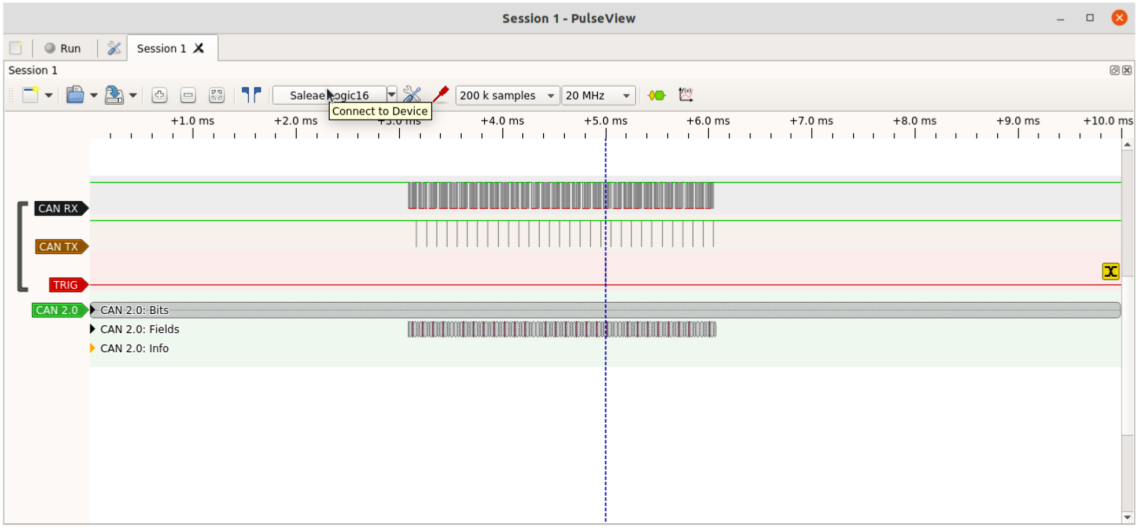
```
>>> c.set_trigger(on_canid=CANID(0x412))
```

On the sending side we can create some traffic:

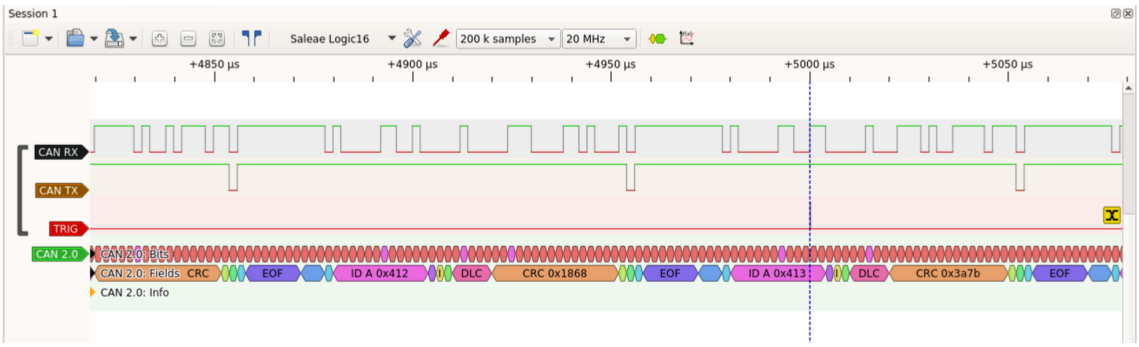
Sender REPL

```
>>> frames = [CANFrame(CANID(i + 0x400)) for i in range(30)]
>>> c.send_frames(frames)
```

This produces a burst of frames and one of them is the one being looked for (a frame with standard ID 0x412). A logic analyzer or oscilloscope can be set to trigger on a rising edge on the TRIG pin on the CANPico board:



Zooming in to the trace shows the frame we are looking for:



There is a short delay (in this case about 50µs) between the end of the frame being looked for and the trigger pulse due to this trigger being generated in software. The trigger should be set up with a pre-trigger buffer large enough to contain a frame. Here the logic analyzer has plenty of memory and the entire burst of frames we sent can be seen.

The logic analyzer software used in the examples above is the Sigrok PulseView tool with the Saleae Logic 16 and the `can2` protocol decoder[4].

3.10 Trigger byte format

The trigger can be set using a block of 27 bytes, with the following format:

Byte	Bits	Description
0	7	If 1 then a CAN error frame will also fire the trigger
	6:0	*Reserved* (must be set to 0)
1:4	29	IDE mask (1 = "must match", 0 = "don't care")
	28:18	CIDA mask (for each bit, 1 = "must match", 0 = "don't care)
	17:0	CIDB mask (for each bit, 1 = "must match", 0 = "don't care)
5:8	29	IDE match (1 = extended ID, 0 = standard ID)
	28:18	CIDA value
	17:0	CIDB value (only used if IDE match = 1)
9	7:4	*Reserved* (must be set to 0)
	3:0	DLC mask (for each bit, 1 = "must match", 0 = "don't care)
10	7:4	*Reserved* (must be set to 0)
	3:0	DLC value
11:18	7:0	Data byte mask (for each bit, 1 = "must match", 0 = "don't care)
19:26	7:0	Data byte value

The trigger will fire if the error trigger is set or if all the fields in the CAN frame with must-match mask bits are set to the corresponding trigger values. If the frame has a payload of less than 8 bytes then the data byte value of the CAN frame is undefined.

[4] For more details about this protocol decoder see `https://kentindell.github.io/can2/`

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4 CANHack toolkit

The CANHack toolkit is software that bit-bangs the minimal parts of the CAN protocol to mount various attacks on a CAN bus. It is designed to demonstrate how easy it is with just software access to a pair of GPIO pins connected to RX and TX of a CAN transceiver to attack a CAN bus right down at the protocol level, with many attacks that are invisible to a simple bus monitor operating at the CAN frame level. In essence, any device on CAN that can be compromised (e.g. via a buffer overrun remote execution vulnerability) can mount these attacks on the bus.

It has been ported to the MicroPython SDK and will run on either of the CANPico and CANHack hardware boards to drive GPIO pins that are connected to a CAN transceiver (the CANPico and CANHack boards use the same GPIO pins for TX, RX and TRIG).

The CANHack toolkit is provided as a single class `CANHack`.

4.1 `CANHack` — CANHack toolkit

class CANHack([*bitrate=500*])

Initializes the CANHack toolkit.

If running on a CANPico, this constructor must be called after the CAN controller TX output is put into open drain mode (by setting the CAN controller *tx_open_drain* parameter to *True*).

Raises

- `ValueError` – if *bit_rate* is not one of 500, 250, or 125

Methods

set_frame([*can_id=0x7ff*] [, *remote=False*] [, *extended=False*] [, *data=None*] [, *set_dlc=False*] [, *dlc=0*] [, *second=False*])

Set the specified frame buffer.

The frame buffer is an internal buffer in RAM in the toolkit that pre-defines the bit sequence for a CAN frame (pre-calculating where the stuff bits go, etc.)

This function pre-computes the layout of a CAN frame into a frame buffer inside the toolkit (it will set the shadow frame buffer is second is *True* because the Janus Attack[5] requires two separate CAN frames).

This method must be called prior to mounting an attack: the pre-computed bit pattern in the frame buffer is used to synchronize the attack on a targeted frame.

Parameters

- **can_id** (*int*) – An 11-bit or 29-bit integer representing the CAN ID of the frame
- **remote** (*bool*) – True if the frame is a remote frame

[5] For more details on the Janus Attack see `https://kentindell.github.io/2020/01/20/new-can-hacks/`

- **extended** (*bool*) – True if can_id is a 29-bit CAN identifier
- **data** (*bytes*) – The payload of the CAN frame
- **set_dlc** (*bool*) – True if the DLC should be set to a specific value
- **dlc** (*int*) – the value of DLC if set_dlc is True
- **second** (*bool*) – True if this call is setting the shadow frame in preparation for the Janus Attack

Raises

- `ValueError` – if the *dlc* value is > 15 or if the payload is more than 8 bytes or *remote* is *True* and *data* is set

Returns *None*

get_frame([, *second=False*])

Return details of the specified frame buffer.

Parameters

- **second** (*bool*) – *True* if the details of the shadow frame buffer should be returned

Return type tuple

Raises

- `ValueError` – if the selected frame buffer has not been set by a prior call to *set_frame*()

The method returns an 8-element tuple of:

- A string representing the frame bitstream (including stuff bits) with '1' and '0' characters for the bits
- A string representing where the stuff bits are located (with 'X' being a stuff bit and '–' being a data bit)
- The integer index of the last arbitration bit in the bitstream
- The integer index of the last DLC bit in the bitstream
- The integer index of the last data bit in the bitstream
- The integer index of the last CRC bit in the bitstream
- The integer index of the last EOF bit in the bitstream
- A 15-bit integer of the CRC of the frame

send_frame([*timeout=50000*] [, *second=False*] [, *retries*=0])

Send a frame on the CAN bus.

Parameters

- **timeout** (*int*) – A value for how long we wait for bus idle before giving up
- **second** (*bool*) – True if the frame should come from the shadow frame buffer

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- **retries** (*int*) – the number of times to try again to send the frame after loss of arbitration or error

Raises

- `ValueError` – if the selected frame buffer has not been set by a prior call to *set_frame*()

This function sends the specified frame on the CAN bus. It waits for the bus to become idle and then starts transmitting, following the CAN protocol for arbitration. If it loses arbitration or detects an error then it tries again, up to a maximum set by retries.

This function can mount a traditional spoof attack on the bus where the frame pretends to be from another node, avoiding the 'doom loop' problem with this being mounted from a standard CAN controller (the 'doom loop' happens if the spoof frame and the legitimate frame happen to win arbitration at the same time: an error will be raised and arbitration will re-start and his will continue in a loop until one of the devices has gone error passive or bus-off).

The timeout value is used as a limit on spin looping and depends on the target CPU. For the RP2040 in the Raspberry Pi Pico a timeout value of 3440000 is one second of real-time.

send_janus_frame([*timeout=50000*] [, *sync_time=0*] [, *split_time=0*], [, *retries=0*])

Sends the specified Janus frame on the CAN bus.

It waits for the bus to become idle and then starts transmitting, following the CAN protocol for arbitration. If it loses arbitration or detects an error then it tries again, up to a maximum set by *retries*.

A Janus frame is a CAN frame with two different contents, specified by the frame buffer and shadow frame buffer. It must have the same ID and be the same number of bits long, which means it must have the same number of stuff bits (although they can be in different places).

Parameters

- **timeout** (*int*) – The timeout (a value of 3440000 corresponds to one second)
- **sync_time** (*int*) – The number of clock ticks to wait to ensure controllers have synced (0 has a special meaning of 1/4 of a CAN bit time)
- **split_time** (*int*) – The number of clock ticks from the start of the bit before the second CAN bit value is set (0 has a special meaning of 5/8th of a CAN bit time)
- **retries** (*int*) – the number of times to try to send the frame after loss of arbitration or error

Raises

- `ValueError` – if either frame buffer has not been set by a prior call to *set_frame*()

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spoof_frame([*timeout*=50000] [, *overwrite=False*] [, *retries=0*])

Target a frame and send a spoof version.

Parameters

- **timeout** (*int*) – The time to wait for the targeted frame to appear before giving up (a value of 3440000 corresponds to one second)
- **overwrite** (*bool*) – Once the targeted frame has been detected, overwrite the remainder with the selected spoof frame
- **retries** (*int*) – the number of times to try to send the frame after loss of arbitration or error

Returns *None*

Raises

- `ValueError` – if the frame buffer has not been set by a prior call to *set_frame*()

If *overwrite* is *True* then the spoof frame is written over the top of the targeted frame. If the targeted sender is error passive then it will not be able to signal an error frame and other controllers will receive only the spoofed version of the frame. If *overwrite* is set to *False* then the spoof frame is entered into arbitration immediately following the end of the targeted frame.

error_attack([*repeat*=2] [, *timeout*=50000])

Repeatedly destroy a targeted frame with error frames.

Parameters

- **timeout** (*int*) – The time to wait for the targeted frame to appear before giving up (a value of 3440000 corresponds to one second)
- **repeat** (*int*) – the number of times to repeat the attack

Returns *True* if the timeout occurred, *False* otherwise

Return type bool

Raises

- `ValueError` – if the frame buffer has not been set by a prior call to *set_frame*()

A CAN frame with the targeted frame's ID must be set using the *set_frame*() before calling this method. When the ID of the targeted CAN frame has been seen then an error is generated (six dominant bits) and all CAN controllers go into error handling. The error delimiter is targeted for further repeating of the attack. With this approach a targeted node can quickly be driven into the error passive or bus-off state.

double_receive_attack([*repeat*=2] [, *timeout=50000*])

Cause a targeted frame to be received twice.

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Parameters

- **timeout** (*int*) – The number of bit times to wait for the targeted frame to appear before giving up
- **repeat** (*int*) – the number of times to repeat the attack

Returns *True* if the timeout occurred, *False* otherwise

Return type bool

Raises

- `ValueError` – if the frame buffer has not been set by a prior call to *set_frame*()

A CAN frame with the targeted frame's ID must be set using the *set_frame*() before calling this method. When the ID of the targeted CAN frame has been seen then an error is generated at the last bit of the EOF field, after the receivers have accepted the CAN frame but before the transmitter has marked it as sent. This causes the transmitter to signal an error and retransmit the frame, leading to it being received twice.

freeze_doom_loop_attack([*repeat=2*] [, *timeout=2000000*])

Freeze the bus after a targeted frame has been successfully transmitted.

Parameters

- **timeout** (*int*) – The number of bit times to wait for the targeted frame to appear before giving up
- **repeat** (*int*) – the number of times to repeat the attack

Returns *None*

Raises

- `ValueError` – if the frame buffer has not been set by a prior call to *set_frame*()

A CAN frame with the targeted frame's ID must be set using the set_frame() before calling this method. When the ID of the targeted CAN frame has been seen then an overload frame is generated after the last bit of the EOF field, after the receivers have accepted the CAN frame and the transmitter has marked it as sent. This causes the controllers to enter the overload frame recovery mode (like error recovery, except the error counters are not incremented). At the end of the error delimiter, another overload frame is generated until the number in the repeat parameter is reached.

set_can_tx([*recessive=True*])

(*Hardware diagnostic method*) Set the CAN TX pin to recessive or dominant.

Parameters

- **recessive** (*bool*) – Set to *True* if the TX pin should be set recessive (i.e. high)

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Returns *True* if CAN RX was recessive, *False* otherwise

Return type bool

This is intended for diagnostics to check that the TX and RX pins have been identified and connected correctly.

square_wave()

(*Hardware diagnostic method*) Drive the CAN TX pin for 160 CAN bit times with a square wave with a 50:50 duty cycle and a frequency of half the CAN bit rate.

The purpose of this function is for hardware bring-up to check that the CAN TX pin is driven correctly.

Return type *None*

loopback()

(*Hardware diagnostic method*) Wait for a falling edge on CAN RX and then drive the TRIG pin with the value of CAN RX for 160 bit times.

The purpose of this function is for hardware bring-up to check that the CAN RX pin is connected correctly.

Return type *None*

get_clock()

(*Hardware diagnostic method*) Get the current time.

The purpose of this function is to check that the free-running counter has been initialized properly and is counting correctly. **Note**: this is the free-running counter used internally by the CANHack toolkit to measure time and is not the same as the timer inside the CAN controller on the CANPico board used for timestamping.

Parameters

Returns the current time in pre-scaled CPU clock ticks

Return type int

reset_clock()

(*Hardware diagnostic method*) Reset the free-running counter to zero.

Return type *None*

send_raw()

(*Hardware diagnostic method*) Send the raw bitstream of a CAN frame on the CAN TX pin.

Return type *None*

Raises

- `ValueError` – if the frame buffer has not been set by a prior call to *set_frame*()

The CAN frame to send must have been set with a call to set_frame() before calling this method. This call does not enter into CAN arbitration or participate in the

CAN protocol, it merely sends a sequence of bits to the pin. Consequently the CAN bus must be idle when this function is called.

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