Controller Area Network SDK API with CryptoCAN *for* Python on CANPico

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CryptoCAN class

Creating

```
cc = CryptoCAN(transmit=False,
               encryption_key=HSM.SHE_KEY_1,
               authentication_key=HSM.SHE_KEY_2,
               b_flag=0,
               anti_replay=False,
               alt_freshness=False,
               no_encrypt=False)
```

Note
- `b_flag` is measured from the least-significant CAN ID bit
- `encryption_key` key slot must be set in the HSM
- `authentication_key` key slot must be set in the HSM with the `KEY_USAGE` flag set
- `HSM` must be initialized

Sending

```
cc.create_frames(frame,
                 freshness=0)
```

Note
- `frame` is an instance of `CANFrame`
- `freshness` is a 31-bit unsigned integer
- Returns a list with A and B instances of `CANFrame`
- Raises an exception if an HSM error

Status

```
cc.get_status()
```

Returns Last return code of a CryptoCAN API call

CryptoCAN error codes

```
CC_ERC_NO_ERROR
CC_ERC_FIRST_FRAME
CC_ERC_VERIFY_FAILED
CC_ERC_SHE_ERROR
CC_ERC_FRAME_SYNC
CC_ERC_RANGE
CC_ERC_ID
CC_ERC_REPLAY
```

Receiving

```
cc.receive_frame(frame,
                 freshness=0,
                 alt_freshness=0)
```

Note
- `frame` is an instance of `CANFrame`
- `freshness` is a 31-bit unsigned integer
- `alt_freshness` is a 31-bit unsigned integer
- Returns An instance of `CANFrame` if decoded OK
- Raises an exception if an HSM error

HSM class

Initializing

```
h = HSM(secret_key=None)
```

Note
- `secret_key` must be None or 16 `bytes`
- Factory reset if `secret_key` is not `None`

Key management

```
h.load_key(m1,
           m2,
           m3)
```

Note
- `m1` must be 16 `bytes` of M1
- `m2` must be 32 `bytes` of M2
- `m3` must be 16 `bytes` of M3
- Returns a 2-tuple of:
  - M4 (32 `bytes`)
  - M5 (16 `bytes`)

```
h.load_plain_key(bytes)
h.export_ram_key()
```

Returns
- A 5-tuple of:
  - M1 (16 `bytes`)
  - M2 (32 `bytes`)
  - M3 (16 `bytes`)
  - M4 (32 `bytes`)
  - M5 (16 `bytes`)

Encryption

```
h.enc_ecb(plaintext,
          key=SHE_KEY_1)
```

Note
- `plaintext` must be 16 `bytes`
- Returns 16 `bytes` of ciphertext

```
h.dec_ecb(ciphertext,
          key=SHE_KEY_1)
```

Note
- `ciphertext` must be 16 `bytes`
- Returns 16 `bytes` of plaintext

Authentication

```
h.generate_mac(message,
               key=SHE_KEY_1)
```

Note
- `message` must be a multiple of 16 `bytes`
- Returns 16 `bytes` of MAC
- Key must not have VERIFY_ONLY property set
- Key must have KEY_USAGE property set

```
h.verify_mac(message,
             mac,
             mac_length=128,
             key=SHE_KEY_1)
```

Note
- `message` must be a multiple of 16 `bytes`
- `mac` must be 16 `bytes`
- `mac_length` must be between 0 and 128
- Key must have KEY_USAGE property set
- Returns `True` if MAC verified

SHE key numbers

```
SHE_SECRET_KEY
SHE_MASTER_ECU_KEY
SHE_BOOT_MAC_KEY
SHE_KEY_1
SHE_KEY_2
SHE_KEY_3
SHE_KEY_4
SHE_KEY_5
SHE_KEY_6
SHE_KEY_7
SHE_KEY_8
SHE_KEY_9
SHE_KEY_10
SHE_RESERVED
SHE_RAM_KEY
```

SHE error codes

```
SHE_ERC_NO_ERROR
SHE_ERC_SEQUENCE_ERROR
SHE_ERC_KEY_NOT_AVAILABLE
SHE_ERC_KEY_INVALID
SHE_ERC_KEY_EMPTY
SHE_ERC_MEMORY_FAILURE
SHE_ERC_BUSY
SHE_ERC_GENERAL_ERROR
SHE_ERC_KEY_WRITE_PROTECTED
SHE_ERC_KEY_UPDATE_ERROR
SHE_ERC_RNG_SEED
```

Random numbers

```
h.init_rng()
h.rnd(as_int=False)
```

Returns
- If `as_int` is `True` then returns a 128 bit integer
- If `as_int` is `False` then returns 16 `bytes`

```
h.extend_seed(entropy=bytes)
```

Debugging

```
h.backdoor_set_key(key=SHE_KEY_1,
                   key_value,
                   authentication_key=False,
                   store_keys=False)
```

Note
- `key_value` must be 16 `bytes`
- If `authentication_key` is `True` then sets KEY_USAGE property
- If `store_keys` is `True` then keys are written to NVRAM
- Backdoor API call only for development with a software HSM
- `authentication_key` must be:
  - `True` if key used for CryptoCAN MAC
  - `False` if key used for CryptoCAN encryption

CAN class

Starting controller

```
c = CAN(profile=CAN.CAN_BITRATE_500K_75,
        id_filters=None,
        hard_reset=False,
        brp=None,
        tseg1=10,
        tseg2=3,
        sjw=2,
        recv_errors=False,
        mode=CAN.NORMAL,
        tx_open_drain=False,
        reject_remote=True,
        rx_callback_fn=None,
        recv_overflows=False)
```

Note
- `id_filters` is a {integer: `CANIDFilter`} dictionary
- If `brp` is defined then profile is overridden
- `rx_callback_fn` is a Python function called from the ISR with the received `CANFrame`
- Set `tx_open_drain=True` if `CANHack` used

Bit rates

```
CAN_BITRATE_500K_75
CAN_BITRATE_250K_75
CAN_BITRATE_125K_75
CAN_BITRATE_1M_75
CAN_BITRATE_500K_50
CAN_BITRATE_250K_50
CAN_BITRATE_125K_50
CAN_BITRATE_1M_50
CAN_BITRATE_2M_50
CAN_BITRATE_4M_90
CAN_BITRATE_2_5M_75
CAN_BITRATE_2M_80
CAN_BITRATE_500K_875
CAN_BITRATE_250K_875
CAN_BITRATE_125K_875
CAN_BITRATE_1M_875
CAN.CAN_BITRATE_CUSTOM
```

Modes

```
CAN_MODE_NORMAL
CAN_MODE_LISTEN_ONLY
CAN_MODE_ACK_ONLY
CAN_MODE_OFFLINE
```

Triggers

```
c.set_trigger(on_error=False,
              on_canid=None,
              as_bytes=None,
              on_tx=False,
              on_rx=True)
```

Note
- `as_bytes` is None or type `bytes`
- `on_can_id` is None or `CANID` (`as_bytes` overrides)

```
c.clear_trigger()
c.pulse_trigger()
```

Time

```
c.get_time()
c.get_time_hz()
```

Sending frames

```
c.send_frame(frame, fifo=False)
c.send_frames([frame], fifo=False)
c.recv_tx_events(limit=CAN.CAN_TX_EVENT_FIFO_SIZE,
                 as_bytes=False)
```

Returns
- list of `CANFrame` instances sent, `CANOverflow`
- or `bytes`

```
c.recv_tx_events_pending()
```

Receiving frames

```
c.recv(limit=CAN.CAN_RX_FIFO_SIZE,
       as_bytes=False)
```

Returns
- list of `CANFrame`, `CANError`, `CANOverflow`
- or `bytes`

```
c.recv_pending()
```

Status

```
c.get_status()
```

Returns 4-tuple of (*bus off*, *error passive*, *TEC*, *REC*)

CANFrame class

Making

```
frame = CANFrame(can_id,
                 data=None,
                 remote=False,
                 tag=0,
                 dlc=None)
```

Note
- `can_id` is a `CANID`
- `data` is of type `bytes`
- `tag` is an integer
- DLC defaults to length of `data` if `dlc` not set

```
CANFrame.from_bytes(bytes)
```

Note returns a list of `CANFrame`

Reading

```
frame.get_data()
frame.get_dlc()
frame.get_tag()
frame.get_timestamp()
```

Note returns `None` if not sent or received yet

```
frame.get_index()
```

Note returns index of acceptance ID filter

```
frame.is_remote()
frame.is_extended()
frame.get_arbitration_id()
frame.get_canid()
```

Note returns `CANID`

Printing

```
>>> f = CANFrame(CANID(0x123), data=b'hello')
>>> print(f)
CANFrame(CANID(id=S123), dlc=5, data=68656c6c6f)
```

S = 11-bit CAN ID, E = 29-bit CAN ID; * = 0 byte payload, R = remote frame

CANHack class

Creating

```
ch = CANHack(bit_rate=500)
```

Note `bit_rate` can be 500, 250 or 125

Frames

```
ch.set_frame(can_id=0x7ff,
             remote=False,
             extended=False,
             data=None,
             set_dlc=False,
             dlc=0
             second=False
             no_ack=False)
```

Note
- DLC set by default from `data` length
- `data` is 0..8 `bytes`
- `second` sets the Janus attack alternative value

```
ch.print_frame()
ch.send_frame(timeout=50000000,
              second=False,
              retries=0,
              repeat=1)
```

Bus Off and Error Passive attacks

```
ch.error_attack(repeat=2,
                timeout=50000000)
```

Note Attacks the frame set with `set_frame()`

Freeze Doom Loop attack

```
ch.freeze_doom_loop_attack(repeat=2,
                           timeout=50000000)
```

Note Attacks the frame set with `set_frame()`

Double Receive attack

```
ch.double_receive_attack(repeat=2,
                         timeout=50000000)
```

Note Attacks the frame set with `set_frame()`

Janus attack

```
ch.send_janus_frame(sync_time=50,
                    split_time=155,
                    timeout=50000000,
                    retries=0)
```

Note
- `split_time` default is 62.5% (bit time is 249)
- `sync_time` default is 20%
- `timeout` default is about 17 seconds

Spoof attacks

```
ch.spoof_frame(timeout=50000000,
               overwrite=False,
               sync_time=0,
               split_time=0,
               second=False,
               retries=0,
               loopback_offset=93)
```

Note
- if `second` is `True` then will spoof using a Janus frame
- if `overwrite` is `True` then sends an error passive spoof
- `loopback_offset` only used if `overwrite` is `True`

Diagnostics

```
ch.set_can_tx(recessive=False)
```

Returns `True` if RX is recessive

```
ch.send_square_wave()
```

Note Sends a square wave on TX for 160 bit times

```
ch.loopback()
```

Note
- Waits for falling edge then transmits on TX
- what is read on RX for 160 bit times

CANIDFilter class

Making

```
filter = CANID(filter_str=None)
```

Note `filter_str` is 11 or 29 '1', '0' or 'X' characters

CANError class

Reading

```
error.get_timestamp()
error.is_crc_error()
error.is_stuff_error()
error.is_form_error()
error.is_ack_error()
error.is_bit1_error()
error.is_bit0_error()
error.is_bus_off()
```

CANID class

Making

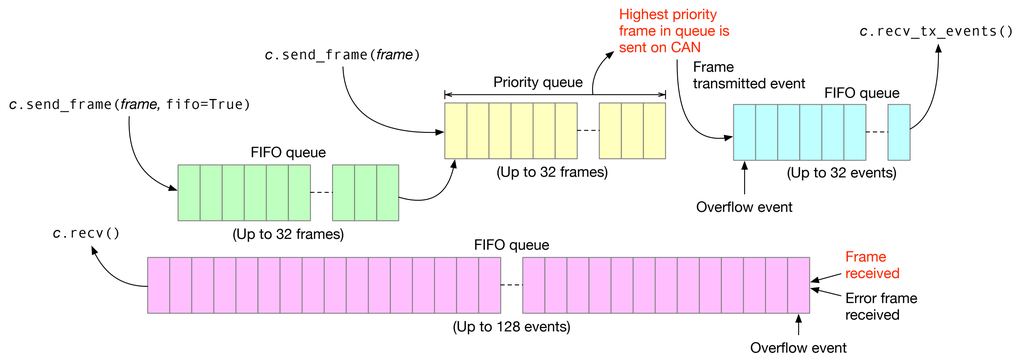
```
id = CANID(arbitration_id, extended=False)
```

Reading

```
id.is_extended()
id.get_arbitration_id()
id.get_id_filter()
```

Returns a `CANIDFilter` matching the ID

Queues



CANOverflow class

Reading

```
overflow.get_timestamp()
overflow.get_frame_cnt()
overflow.get_error_cnt()
```

Example: Send and receive a CAN frame

Sender

```
>>> from rp2 import *
>>> c = CAN()
>>> f1 = CANFrame(CANID(0x122), b='hello')
>>> c.send_frame(f1)
>>> f2 = CANFrame(CANID(0x123), b='world')
>>> c.send_frame(f2)
```

Receiver

```
>>> from rp2 import *
>>> c = CAN()
>>> frames = c.recv()
>>> frames[0]
CANFrame(CANID(id=S122), dlc=5, data=68656c6c6f, timestamp=2053479727)
>>> frames[1]
CANFrame(CANID(id=S123), dlc=5, data=776f726c64, timestamp=2056890118)
```

Example: Only listen to a J1939 CAN bus

```
>>> p = CAN_BITRATE_250K_875
>>> c = CAN(mode=CAN_MODE_LISTEN_ONLY, profile=p)
```

Example: Send CAN frames in FIFO order

```
>>> c = CAN()
>>> f1 = CANFrame(CANID(0x123), b='hello')
>>> f2 = CANFrame(CANID(0x123), b='world')
>>> c.send_frames([f1, f2], fifo=True)
```

Example: Set acceptance ID filters for CANOpen nodes 9 and 10

```
>>> id9 = CANIDFilter('XXXX0001001')
>>> id10 = CANIDFilter('XXXX0001010')
>>> c = CAN(id_filters=[id9, id10])
```

Example: Factory reset the HSM with a lucky secret key

```
>>> from rp2 import HSM
>>> h = HSM(secret_key=bytes([0x88] * 16)
```

Receive: define a receive frame ISR callback

```
>>> def cb(f):
...  printf(f)
>>> c = CAN(rx_callback_fn=cb)
>>>
CANFrame(CANID(id=S123), dlc=5, data=68656c6c6f, timestamp=153981122)
```

Example: Set key 9 and make it an encryption key

```
>>> h = HSM()
>>> k = HSM.SHE_KEY_9
>>> kv = unhexlify('fc67bedac6755ba07365c7195a45c72e')
>>> h.backdoor_set_key(key=k, key_value=kv)
```

Example: Set key 10 and make it an authentication key

```
>>> h = HSM()
>>> k = HSM.SHE_KEY_10
>>> kv = unhexlify('4b65e7947ea6c179e2ec8ebd79c87d3e')
>>> h.backdoor_set_key(key=k, key_value=kv, authentication_key=True)
```

Example: Encrypt a block with a key

```
>>> h = HSM()
>>> t = unhexlify('00112233445566778899aabbccddeeff')
>>> ct = h.enc_ecb(plaintext=t, key=HSM.SHE_KEY_9)
>>> hexlify(ct)
b'13a4ea3282a9ea8c2c6d5f6f7c632c22'
```

Example: Decrypt a block with a key

```
>>> h = HSM()
>>> k = HSM.SHE_KEY_9
>>> ct = unhexlify('13a4ea3282a9ea8c2c6d5f6f7c632c22')
>>> pt = h.dec_ecb(ciphertext=ct, key=k)
>>> hexlify(pt)
b'00112233445566778899aabbccddeeff'
```

Example: Send and receive CryptoCAN messages

Sender

```
>>> h = HSM()
>>> c = CAN()
>>> e = HSM.SHE_KEY_9
>>> a = HSM.SHE_KEY_10
>>> tx = CryptoCAN(encryption_key=e, authentication_key=a, transmit=True)
>>> f = CANFrame(CANID(0x122), data=b'hello')
>>> frames = tx.create_frames(f)
>>> c.send_frames(frames)
>>> f = CANFrame(CANID(0x122), data=b'world')
>>> frames = tx.create_frames(f)
>>> c.send_frames(frames)
```

Receiver

```
>>> h = HSM()
>>> c = CAN()
>>> e = HSM.SHE_KEY_9
>>> a = HSM.SHE_KEY_10
>>> rx = CryptoCAN(encryption_key=e, authentication_key=a)
>>> while True:
...     frames = c.recv()
...         for f in frames:
...             rx.receive_frame(f)
...
CANFrame(CANID(id=S122), dlc=5, data=776f726c64,timestamp=383201659)
```