canbus_analyzer-Copy1

March 26, 2021

By @Virus_Friendly

[1]:
```python
import base64
import json
import matplotlib
import pandas
import time
```

[2]:
```python
def find_frame(data):
    begin = -1

    if data[:2] != b'\x10\x02':
        for i in range(1, len(data)-7):
            if data[i:i+4] == b'\x10\x03\x10\x02':
                begin = i+2
                break
    else:
        begin = 0

    return(begin)
```

[3]:
```python
def parse_frame(data):
    padding = find_frame(data)

    if find_frame(data) == -1:
        display('Bad Frame')
        display(data)
        return None

    data = data[padding:]

    if data[5+data[3]:data[3]+7] != b'\x10\x03':
        if find_frame(data[5+data[3]:]) == -1:
            display('Frame Length Fail')
            return None

        # This data uses 0x1002 to symbolize start of frame and 0x1003 to␣
↪symbolize the end of frame
```

```
        # To protect against 0x1003 being included in the datastream and␣
↪misinterpreted as an end of frame
        # The device escapes 0x10 as 0x1010. Thus 0x1003 will become 0x101003.
        # This causes our length checks to fail, so we must detect them and␣
↪de-escape the 0x1010 sequence

        frags = list()
        frag_start = 0

        for x in range(2, 5+data[3]+find_frame(data[5+data[3]:])):
            if data[x:x+2] == b'\x10\x10' and x >= frag_start:
                padding=padding+1
                frags.append(data[frag_start:x+1])
                frag_start = x+2

        if 0 < frag_start < len(data):
            frags.append(data[frag_start:])

        y=b''.join(frags)

        if (len(y) < 3) or (len(y) < y[3]+5) or (len(y) < y[3]+7) or (y[y[3]+5:
↪y[3]+7] != b'\x10\x03'):
            display('bad frame not repaired')
            display(data[:5+data[3]+find_frame(data[5+data[3]:])])
            display(y[:data[3]+7])
            return None

        data=y

    n2kframe = dict()
    n2kframe['start'] = data[0:2]
    n2kframe['cmd'] = data[2]
    n2kframe['len'] = data[3]

    if n2kframe['cmd'] == 147:
        n2kframe['priority'] = data[4]
        n2kframe['pgn'] = int.from_bytes(data[5:8], 'little')
        n2kframe['dst'] = data[8]
        n2kframe['src'] = data[9]
        n2kframe['timestamp'] = int.from_bytes(data[10:14], 'little')
        n2kframe['datalen'] = data[14]

        if n2kframe['datalen'] > n2kframe['len']-11:
            display("Data Length Fail")
            return None

        pgndata = list()
        for byte in data[15:15+n2kframe['datalen']]:
            pgndata.append('{:02x}'.format(byte))

        n2kframe['data'] = ','.join(pgndata)
        n2kframe['crc'] = data[4+n2kframe['len']]
    else:
        unk_bytes = list()

        for byte in data[4:5+n2kframe['len']]:
            unk_bytes.append('{:02x}'.format(byte))

        n2kframe['data'] = ','.join(unk_bytes)

        for label in ['priority', 'pgn', 'dst', 'src', 'timestamp', 'datalen',␣
↪'crc']:
            n2kframe[label] = ''

    n2kframe['end'] = data[5+n2kframe['len']:5+n2kframe['len']+2]

    return n2kframe, n2kframe['len']+7+padding
```

[4]:
```
def parse_frames(data):
    begin = 0
    n2kframes = list()

    begin = find_frame(data)

    frame_no = 0

    while(True):
        if begin < 0:
            print("Could not find next frame")
            break
        elif begin > len(data)-7:
            break

        parsed_data = parse_frame(data[begin:])

        if parsed_data == None:
            # print ("Bad frame at %s, finding next frame" % frame_no)
            begin=begin+7+find_frame(data[begin+7:])
            continue

        (frame, length) = parsed_data
        n2kframes.append(frame)
        begin=begin+length
        frame_no = frame_no+1

    return n2kframes
```

[5]:
```
def parse_timestamp(timestamp):
    epoch = timestamp/1000.0
    millsec = timestamp%1000
    epoch_str = time.strftime('%Y-%m-%d-%H:%M:%S', time.gmtime(epoch))
    return "%s.%d" % (epoch_str, millsec)
```

[6]:
```
def parse_log(logfile):
    lines = None
    capture = b''
    maxtime = 0

    with open(logfile) as n2klog:
        lines = n2klog.read().splitlines()

    for line in lines:
        log=json.loads(line)

        if int(log["milliunixtimestamp"]) >= maxtime:
            if 0 == maxtime:
                display(f"First timestamp: {int(log['milliunixtimestamp'])}")

            maxtime=int(log["milliunixtimestamp"])
        else:
            print("!!!!OUT OF SEQUENCE LOG!!!!!")
            print(maxtime, int(log["milliunixtimestamp"]))

        data = base64.b64decode(log['data'])
        capture = capture+data

    display(f"Last timestamp: {maxtime}")

    return pandas.DataFrame(parse_frames(capture))
```

[7]:
```
n2k_logs = list()
print("first log")
n2k_logs.append(parse_log('NMEA2000PacketCapture.log'))
```

```
first log

'First timestamp: 1596659569526'


'Last timestamp: 1596659850800'
```

```
'Frame Length Fail'
```

[8]:
```
for n2k_log in n2k_logs:
    display(n2k_log[n2k_log.src == 16])
```

```
              start  cmd  len priority    pgn  dst  src timestamp datalen  \
15     b'\x10\x02'  147   19        3  61184    0   16    317823       8
41     b'\x10\x02'  147   19        3  61184    0   16    317873       8
55     b'\x10\x02'  147   19        3  61184    0   16    317923       8
68     b'\x10\x02'  147   19        3  61184    0   16    317973       8
86     b'\x10\x02'  147   19        6  65271  255   16    318022       8
...            ...  ...  ...      ...    ...  ...  ..       ...     ...
91281  b'\x10\x02'  147   19        6  65271  255   16    598963       8
91282  b'\x10\x02'  147   19        6  65280  255   16    598964       8
91284  b'\x10\x02'  147   19        3  61184    0   16    598965       8
91304  b'\x10\x02'  147   19        3  61184    0   16    599015       8
91317  b'\x10\x02'  147   19        3  61184    0   16    599065       8

                          data  crc          end
15     00,7d,7d,00,00,00,06,00  244  b'\x10\x03'
41     00,7d,7d,00,00,00,06,00  194  b'\x10\x03'
55     00,7d,7d,00,00,00,06,00  144  b'\x10\x03'
68     00,7d,7d,00,00,00,06,00   93  b'\x10\x03'
86     ff,ff,ff,ff,6c,01,ff,ff  189  b'\x10\x03'
...                        ...  ...          ...
91281  ff,ff,ff,ff,6c,01,ff,ff    2  b'\x10\x03'
91282  50,6c,01,ff,ff,d4,ff,ff  209  b'\x10\x03'
91284  01,7d,7d,00,00,00,06,00  110  b'\x10\x03'
91304  01,7d,7d,00,00,00,06,00   60  b'\x10\x03'
91317  01,7d,7d,00,00,00,06,00    9  b'\x10\x03'

[7289 rows x 12 columns]
```

Canbus Layout

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|S| ID                    |R|E| ID (continued)                  |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+

SAE J1939 Overlay
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|S| Pri |R|D|PDU Format |R|E|PF | PDU Specific  | Source Address|
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
NMEA2000 PGN1 Overlay (PDU Format < 0xF0
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|S| Pri |R| PGN1        |R|E|P1 | Dest Address  | Source Address|
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+

NMEA2000 PGN2 Overlay
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|S| Pri |R| PGN2        |R|E| PGN2 (Continued)  | Source Address|
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

We can reconstitue the Canbus ID using te NMEA2000 Priority, PGN, Source Address, and optional Destination Address

[9]:
```
target_pgns = [61184,65280,65281]
```

[10]:
```
can_maps = list()
can_ids = list()

for pgn in target_pgns:
    pgn_data = n2k_log[n2k_log.pgn == pgn]

    for x in range(len(pgn_data)):
        can_id = pgn
        pri, dst, src = pgn_data[['priority','dst', 'src']].iloc[x]

        if (pgn&0xFFFF) < 0xF000:
            can_id = can_id + dst

        can_id = can_id + (pri << 18)
        can_id = src + (can_id << 8)

        if can_id not in can_ids:
            can_ids.append(can_id)
            can_map=dict()
            can_map["can_id"] = can_id
            can_map["can_id (hex)"] = hex(can_id)
            can_map["pgn"] = pgn
            can_map["priority"] = pri
            can_map["dst"] = dst
            can_map["src"] = src
            can_maps.append(can_map)

canbus_map = pandas.DataFrame(can_maps)
display(canbus_map.sort_values(by=['src']))
```

```
       can_id can_id (hex)    pgn  priority  dst  src
4   216989712   0xcef0010  61184         3    0   16
```

```
10  419364880   0x18ff0010  65280          6  255   16
2   216989728    0xcef0020  61184          3    0   32
6   419364896   0x18ff0020  65280          6  255   32
12  419365152   0x18ff0120  65281          6  255   32
1   216989744    0xcef0030  61184          3    0   48
7   419364912   0x18ff0030  65280          6  255   48
11  419365168   0x18ff0130  65281          6  255   48
8   419364913   0x18ff0031  65280          6  255   49
13  419365169   0x18ff0131  65281          6  255   49
3   216989746    0xcef0032  61184          3    0   50
5   216989760    0xcef0040  61184          3    0   64
9   419364928   0x18ff0040  65280          6  255   64
0   216989761    0xcef0041  61184          3    0   65
```

One clue that these are not NMEA2000 or SAE J1939 messages is that several of them are destined for address 0, which is the Actisense probe.

[11]:
```
can_rows = list()

for n2k_log in n2k_logs:
    for pgn in target_pgns:
        pgn_data = n2k_log[n2k_log.pgn == pgn]
        #rows = pgn_data.iterrows()

        for x in range(len(pgn_data)):
            #row = next(rows)
            can_id = pgn
            pri, dst, src, timestamp, data = pgn_data[['priority','dst', 'src',␣
↪'timestamp', 'data']].iloc[x]

            if (pgn&0xFFFF) < 0xF000:
                can_id = can_id + dst

            can_id = can_id + (pri << 18)
            can_id = src + (can_id << 8)

            can_row=dict()
            can_row["can_id"] = can_id
            can_row["timestamp"] = timestamp
            can_row["data"] = data
            can_rows.append(can_row)

canbus_log = pandas.DataFrame(can_rows)
display(canbus_log)
```

```
         can_id  timestamp                     data
0     216989761     317786  0f,00,00,ff,ff,ff,ff,00
```

```
1      216989744     317790  04,00,7d,00,00,01,06,00
2      216989728     317799  00,3f,00,ff,30,ff,05,00
3      216989746     317807  00,00,7d,00,0f,01,05,00
4      216989712     317823  00,7d,7d,00,00,00,06,00
...          ...        ...                      ...
60525  419365152     599028  00,b4,01,00,87,00,85,00
60526  419365169     599029  1f,01,21,00,ff,07,00,00
60527  419365168     599059  4d,0e,20,00,ff,07,00,00
60528  419365169     599078  1f,01,21,00,ff,07,00,00
60529  419365152     599079  00,b4,01,00,87,00,85,00

[60530 rows x 3 columns]
```

[12]:
```python
data_widths=list()

for can_id in canbus_log.sort_values(by=['can_id']).can_id.unique():
    devicelog = canbus_log[canbus_log.can_id == can_id]
    data_width=dict()
    data_width["can_id"] = can_id
    data_width["num_unique_values"] = len(devicelog.data.unique())
    data_width["total_values"] = len(devicelog)
    data_width["start_time"] = devicelog.timestamp.iloc[0]
    data_width["end_time"] = devicelog.timestamp.iloc[-1]
    data_width["timelength"] = (devicelog.timestamp.iloc[-1]) - (devicelog.
 ↪timestamp.iloc[0])
    data_widths.append(data_width)

display(pandas.DataFrame(data_widths))
```

```
       can_id  num_unique_values  total_values  start_time  end_time  \
0   216989712                 23          5607      317823    599065
1   216989728                154          5607      317799    599076
2   216989744                138          5608      317790    599058
3   216989746                 30          5608      317807    599077
4   216989760                  3          5602      317835    599086
5   216989761                  1          5603      317786    599087
6   419364880                  8          1121      318023    598964
7   419364896                111          5607      317799    599077
8   419364912                  7          1122      317821    598989
9   419364913                  7          1122      317839    599008
10  419364928                  2          1100      317854    598976
11  419365152                239          5607      317800    599079
12  419365168                239          5608      317790    599059
13  419365169                 52          5608      317808    599078

    timelength
0       281242
```

```
1         281277
2         281268
3         281270
4         281251
5         281301
6         280941
7         281278
8         281168
9         281169
10        281122
11        281279
12        281269
13        281270
```

The data field in canbus messages can contain multiple data groups known as signals. By analyzing the entropy of the data field, we can make assumptions of how the signals are grouped.

Typically, the value printed is the number of different values (in hex) seen in that byte.

Data bytes that have only a single value can still provide useful information.

- If the signle value is 0, this is represented as 'ZZ' to allow for quickly identifying leading zeros.
- If the single value is 0xff, this is represented as 'XX' since this oftens signals invalid or unsused fields.
- Other wise, this byte is effectively a constant and represented as 'CC'

[13]:
```
for can_id in canbus_log.sort_values(by=['can_id']).can_id.unique():
    canid_log = canbus_log[canbus_log.can_id == can_id]
    signals = list()

    for x in range(8):
        signals.append(list())

    for datas in canid_log.data:
        data = datas.split(',')

        if len(data) > 8:
            print("data is unexpectedly long")

        for x in range(8):
            if data[x] not in signals[x]:
                signals[x].append(data[x])

    sgn_fmt = list()

    for signal in signals:
        if len(signal) == 1:
            if signal[0] == 'ff':
                sgn_fmt.append('XX')
            elif signal[0] == '00':
                sgn_fmt.append('ZZ')
            else:
                sgn_fmt.append('CC')
        else:
            sgn_fmt.append(hex(len(signal))[2:].zfill(2))

    display(str(can_id) + '     ' + ' '.join(sgn_fmt))
```

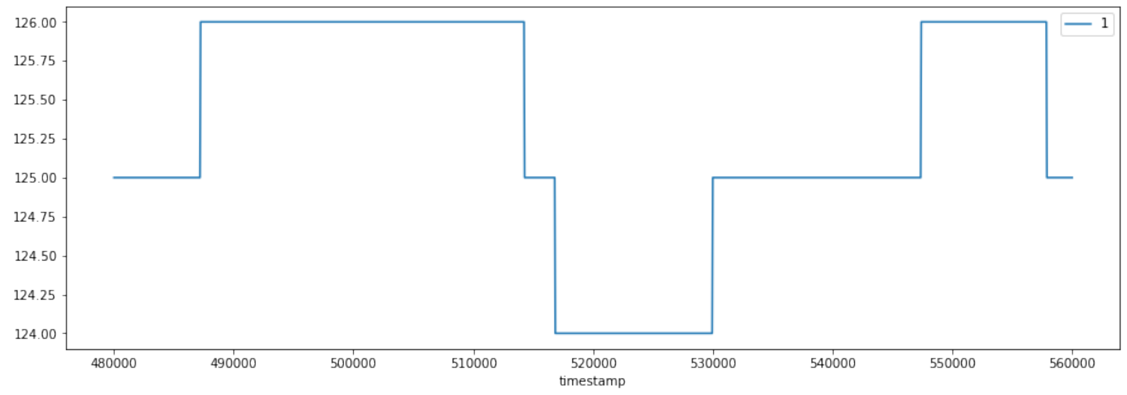
```
'216989712     05 03 03 ZZ ZZ ZZ 0b ZZ'


'216989728     03 CC 83 XX 02 XX 03 ZZ'


'216989744     03 71 03 ZZ ZZ CC 03 ZZ'


'216989746     04 19 02 ZZ 02 CC 03 ZZ'


'216989760     03 ZZ ZZ XX XX XX XX ZZ'


'216989761     CC ZZ ZZ XX XX XX XX ZZ'


'419364880     CC 08 CC XX XX CC XX XX'


'419364896     CC 0a CC 54 ZZ XX XX CC'


'419364912     CC 02 02 02 ZZ XX CC 02'


'419364913     CC 02 02 02 ZZ XX CC 02'


'419364928     CC ZZ 02 ZZ CC XX XX XX'


'419365152     52 CC 8a 03 6f 04 8f 04'


'419365168     91 08 02 ZZ 9b 08 75 71'


'419365169     28 05 02 ZZ 29 05 18 19'
```

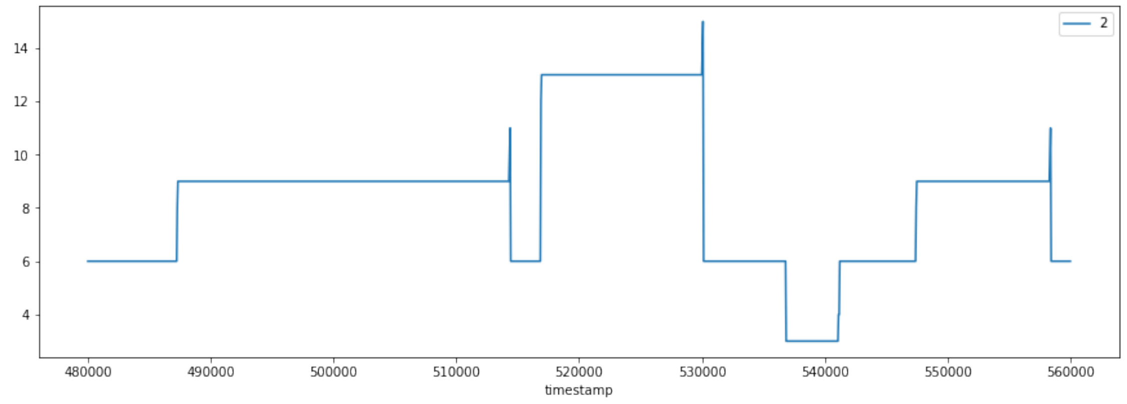
0 1 2 3 4 5 6 7 +-+-+-+-+-+-+-+-+ | 0|0 0| 0| 216989712 +-+-+-+-+-+-+-+-+ |c c| |x|c|x|c 0| 216989728 +-+-+-+-+-+-+-+-+ |0 0|c 0|c c|c 0| 216989744 +-+-+-+-+-+-+-+-+ |c| |c 0 0|c|c 0|

216989746 +-+-+-+-+-+-+-+-+ |c 0 0|x x x x|0| 216989760 +-+-+-+-+-+-+-+-+ |c 0 0|x x x x|0| 216989761 +-+-+-+-+-+-+-+-+

[14]:
```
# All activity occurs between these timestamps

#START_TIME = 23121358
#END_TIME = 23192867

START_TIME = 480000
END_TIME = 560000
```

[15]:
```
#  0 1 2 3 4 5 6 7
# +-+-+-+-+-+-+-+-+
# |      0|0 0|  0| 216989712
# +-+-+-+-+-+-+-+-+

canid_log = canbus_log[canbus_log.can_id == 216989712]
signal_log = list()

for x in range(len(canid_log)):
    signals = (canid_log.data.iloc[x]).split(',')

    signal = dict()
    signal["timestamp"] = canid_log.timestamp.iloc[x]

    if (signal["timestamp"] < START_TIME) or (signal["timestamp"] > END_TIME):
        continue

    #signal["1"] = int(''.join([signals[3],signals[2],signals[1],signals[0]]),␣
 ↪16)
    signal["1"] = int(''.join([signals[1]]), 16)
    signal["2"] = int(''.join([signals[7],signals[6]]), 16)


    signal_log.append(signal)

for signal in ['1','2']:
    pandas.DataFrame(signal_log).plot(x='timestamp', y=signal,figsize=(15,5))
```

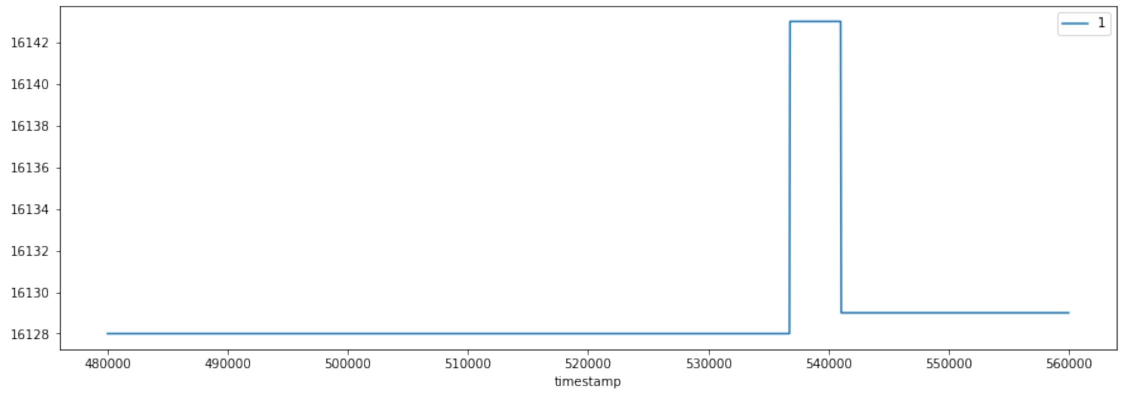


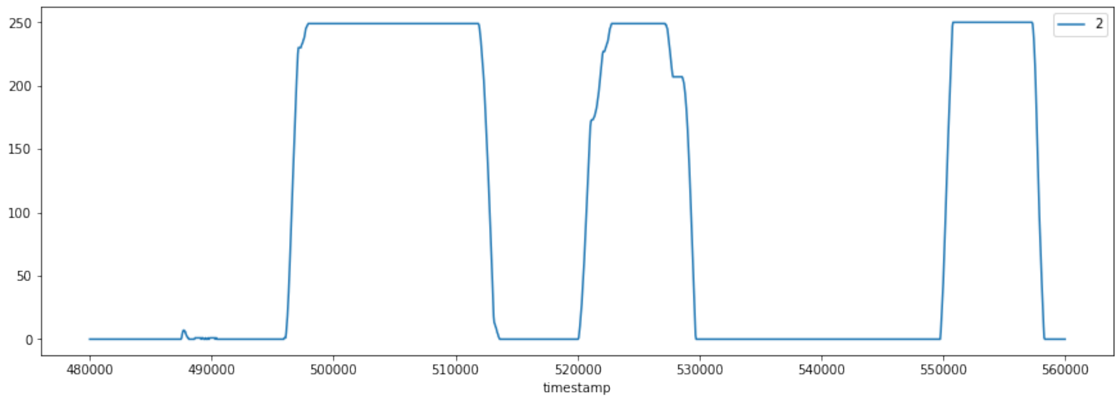


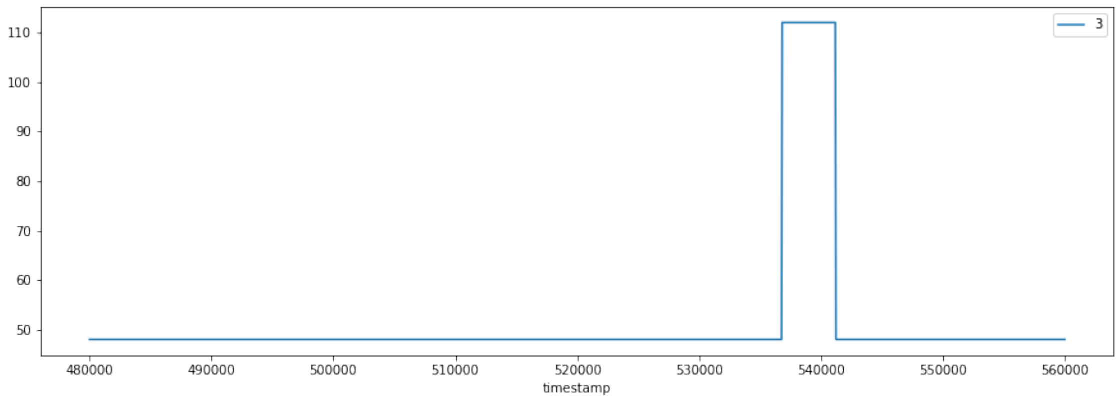
[16]:
```
canid_log = canbus_log[canbus_log.can_id == 216989712]

for x in range(len(canid_log)):
    signals = (canid_log.data.iloc[x]).split(',')

    y = int(''.join([signals[1]]), 16)

    if y < 125:
        #display(y)
        canid, ts, data = canid_log.iloc[x]
        display(data)
        break
```

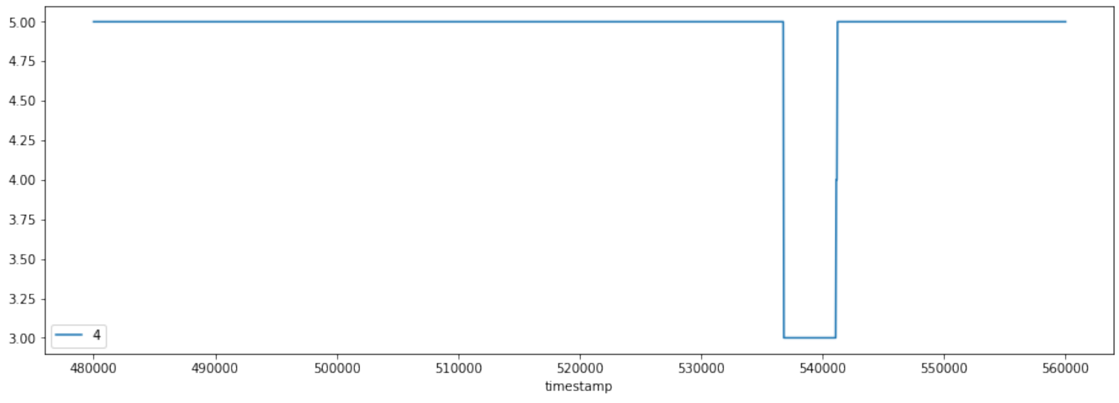
```
'00,7c,7d,00,00,00,06,00'
```

[17]:
```
#  0 1 2 3 4 5 6 7
# +-+-+-+-+-+-+-+-+
# |   | |x| |x|   | 216989728
# +-+-+-+-+-+-+-+-+-+

canid_log = canbus_log[canbus_log.can_id == 216989728]
signal_log = list()

for x in range(len(canid_log)):
    signals = (canid_log.data.iloc[x]).split(',')

    signal = dict()
    signal["timestamp"] = canid_log.timestamp.iloc[x]

    if (signal["timestamp"] < START_TIME) or (signal["timestamp"] > END_TIME):
        continue

    signal["1"] = int(''.join([signals[1],signals[0]]), 16)
    signal["2"] = int(signals[2], 16)
    signal["3"] = int(signals[4], 16)
    signal["4"] = int(''.join([signals[7],signals[6]]), 16)

    signal_log.append(signal)

for signal in ['1','2','3','4']:
    pandas.DataFrame(signal_log).plot(x='timestamp', y=signal,figsize=(15,5))
```



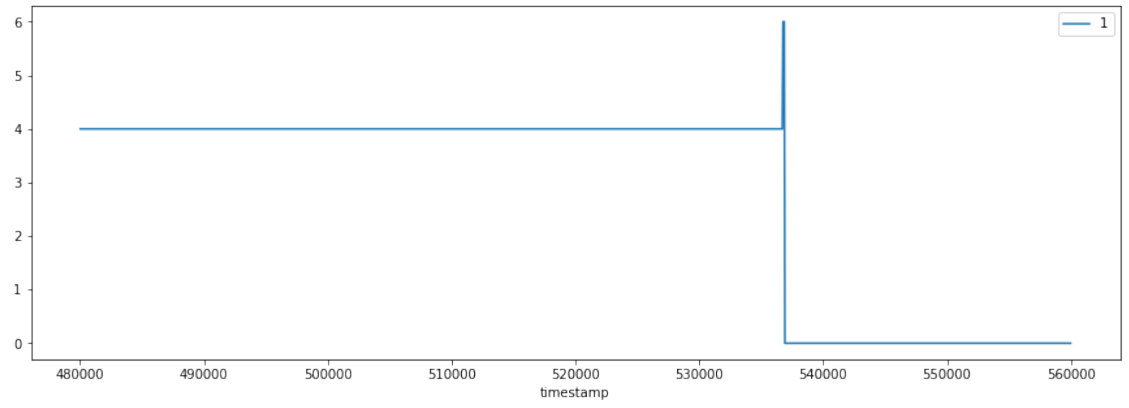


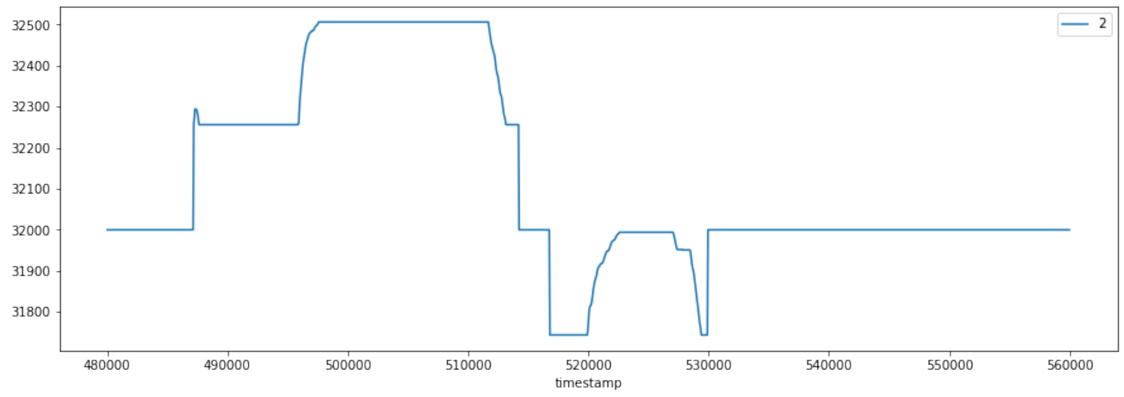


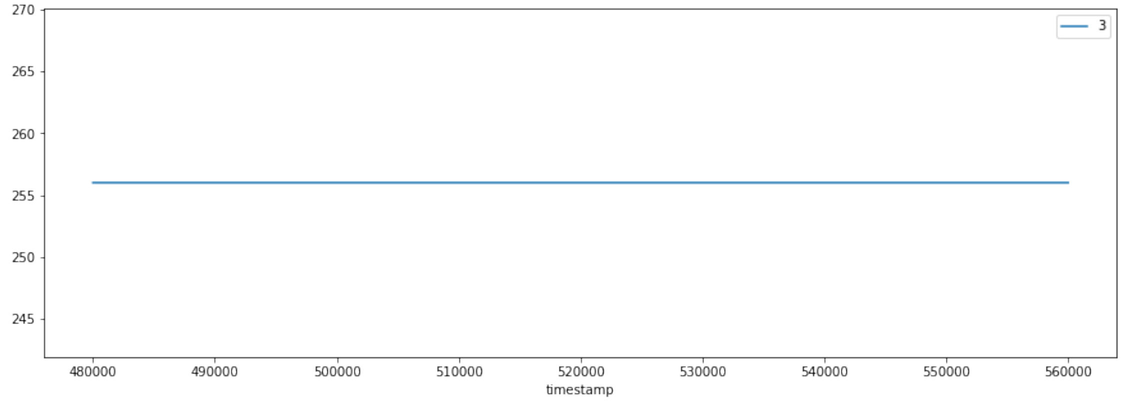


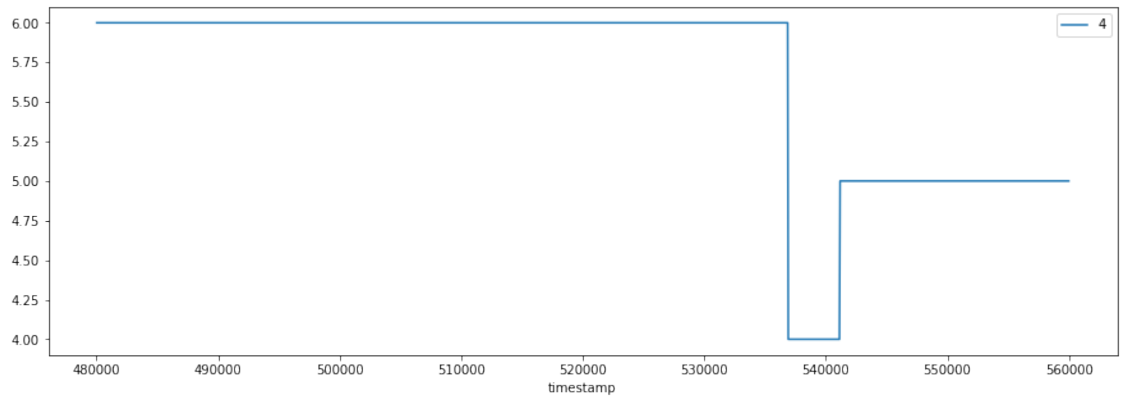
[18]:
```
#  0 1 2 3 4 5 6 7
# +-+-+-+-+-+-+-+-+
# | |       |c|   | 216989744
# +-+-+-+-+-+-+-+-+
```

```python
canid_log = canbus_log[canbus_log.can_id == 216989744]
signal_log = list()

for x in range(len(canid_log)):
    signals = (canid_log.data.iloc[x]).split(',')

    signal = dict()
    signal["timestamp"] = canid_log.timestamp.iloc[x]

    if (signal["timestamp"] < START_TIME) or (signal["timestamp"] > END_TIME):
        continue

    signal["1"] = int(signals[0], 16)
    signal["2"] = int(''.join([signals[3],signals[2],signals[1]]), 16)
    signal["3"] = int(''.join([signals[5],signals[4]]), 16)
    signal["4"] = int(''.join([signals[7],signals[6]]), 16)

    signal_log.append(signal)

for signal in ['1','2','3','4']:
    pandas.DataFrame(signal_log).plot(x='timestamp', y=signal,figsize=(15,5))
```







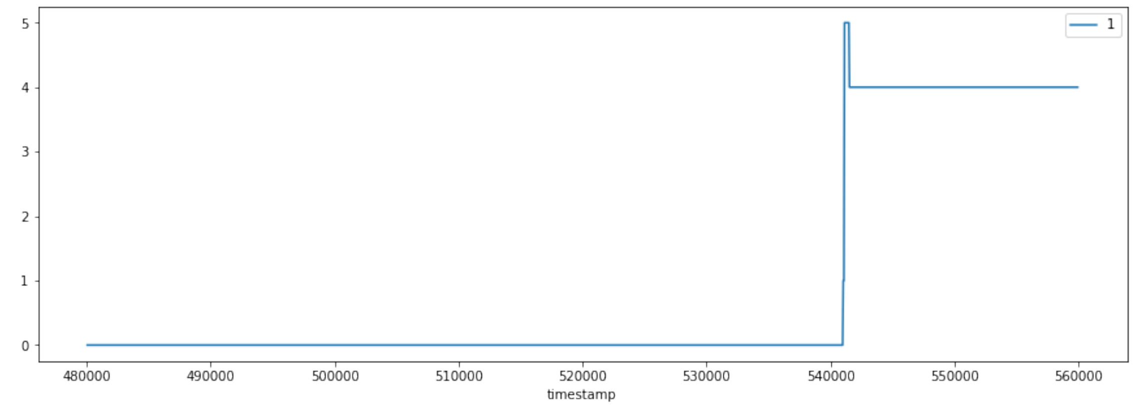


[19]:
```
canid_log = canbus_log[canbus_log.can_id == 216989744]

for x in range(len(canid_log)):
    signals = (canid_log.data.iloc[x]).split(',')
    y = int(''.join([signals[3],signals[2],signals[1]]), 16)

    if y > 32500:
        canid, ts, data = canid_log.iloc[x]
        display(canid, data)
        break
```

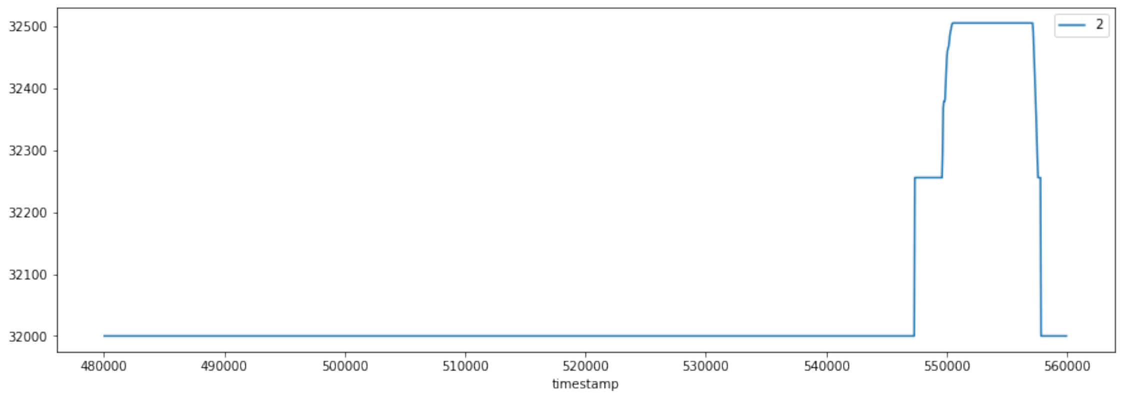
```
216989744
```

```
'04,f7,7e,00,00,01,06,00'
```

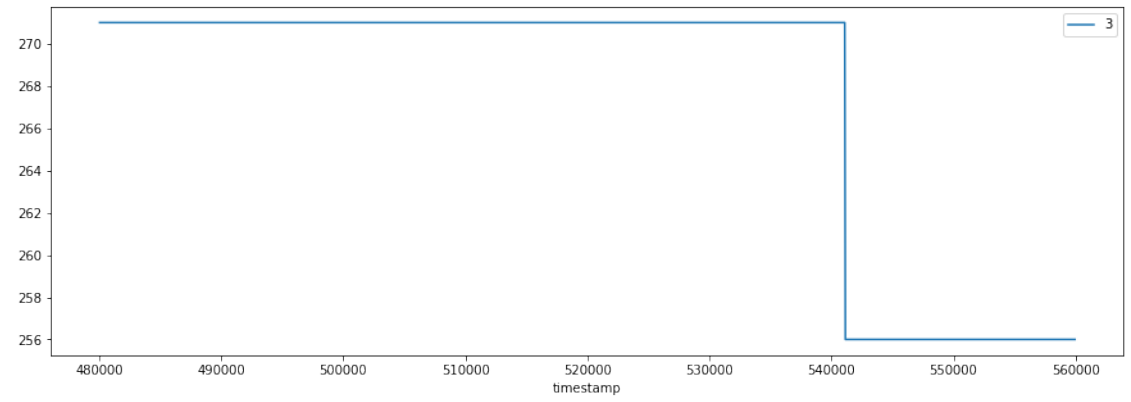
[20]:
```
#  0 1 2 3 4 5 6 7
# +-+-+-+-+-+-+-+-+
# | |     |   |   | 216989746
# +-+-+-+-+-+-+-+-+

canid_log = canbus_log[canbus_log.can_id == 216989746]
signal_log = list()

for x in range(len(canid_log)):
    signals = (canid_log.data.iloc[x]).split(',')

    signal = dict()
    signal["timestamp"] = canid_log.timestamp.iloc[x]

    if (signal["timestamp"] < START_TIME) or (signal["timestamp"] > END_TIME):
        continue

    signal["1"] = int(signals[0], 16)
    signal["2"] = int(''.join([signals[3],signals[2],signals[1]]), 16)
    signal["3"] = int(''.join([signals[5],signals[4]]), 16)
    signal["4"] = int(''.join([signals[7],signals[6]]), 16)

    signal_log.append(signal)

for signal in ['1','2','3','4']:
    pandas.DataFrame(signal_log).plot(x='timestamp', y=signal,figsize=(15,5))
```



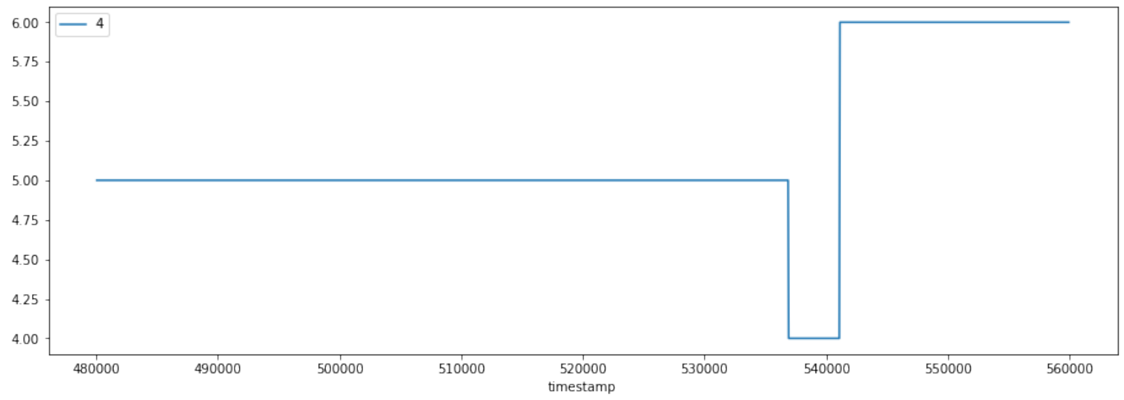
1
timestamp



2
timestamp



3
timestamp

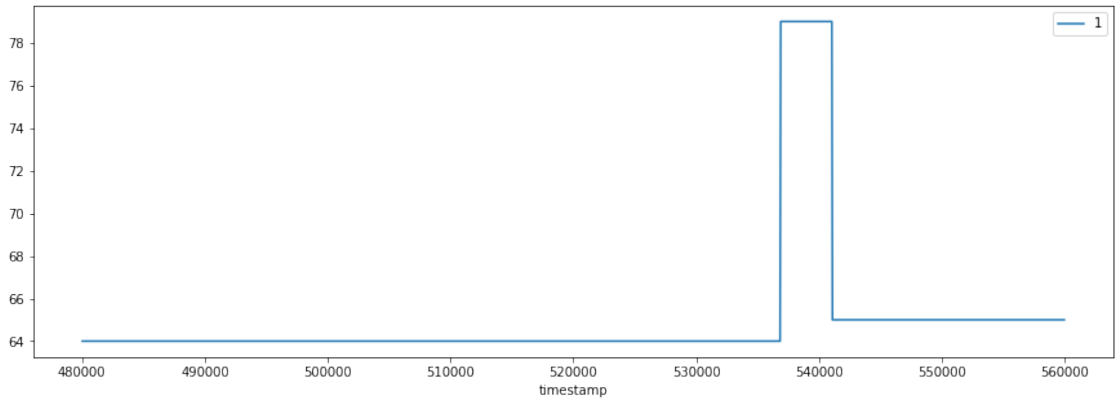


[21]:
```
canid_log = canbus_log[canbus_log.can_id == 216989746]

for x in range(len(canid_log)):
    signals = (canid_log.data.iloc[x]).split(',')

    y = int(''.join([signals[3],signals[2],signals[1]]), 16)

    if y == 32000:
        #display(y)
        canid, ts, data = canid_log.iloc[x]
        display(canid, data)
        break
```

```
216989746
```

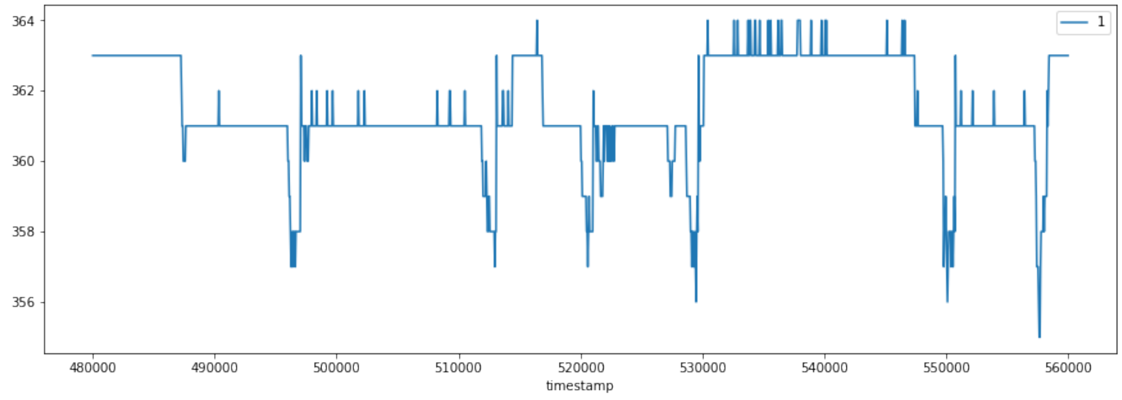
```
'00,00,7d,00,0f,01,05,00'
```

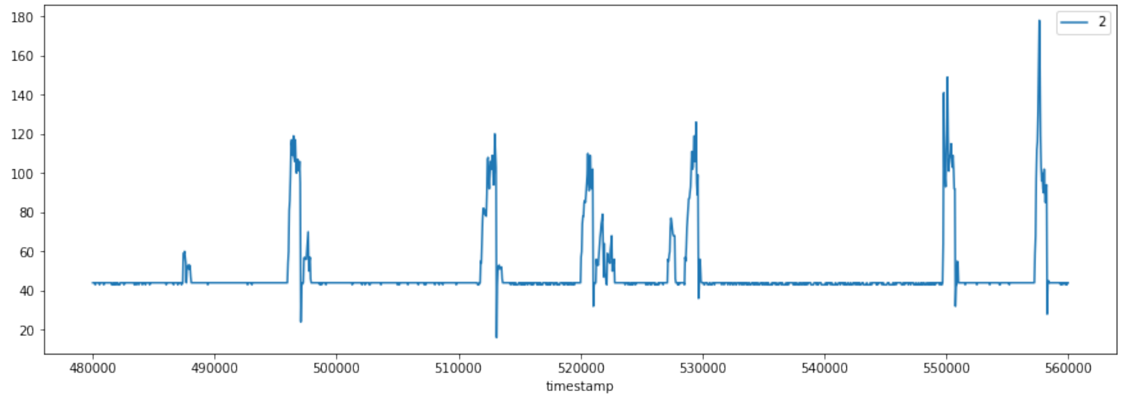
[22]:
```
#  0 1 2 3 4 5 6 7
# +-+-+-+-+-+-+-+-+
# |     |x x x x|c| 216989760
# +-+-+-+-+-+-+-+-+

canid_log = canbus_log[canbus_log.can_id == 216989760]
signal_log = list()

for x in range(len(canid_log)):
    signals = (canid_log.data.iloc[x]).split(',')

    signal = dict()
    signal["timestamp"] = canid_log.timestamp.iloc[x]

    if (signal["timestamp"] < START_TIME) or (signal["timestamp"] > END_TIME):
        continue

    signal["1"] = int(''.join([signals[2],signals[1],signals[0]]), 16)

    signal_log.append(signal)

for signal in ['1']:
    pandas.DataFrame(signal_log).plot(x='timestamp', y=signal,figsize=(15,5))
```



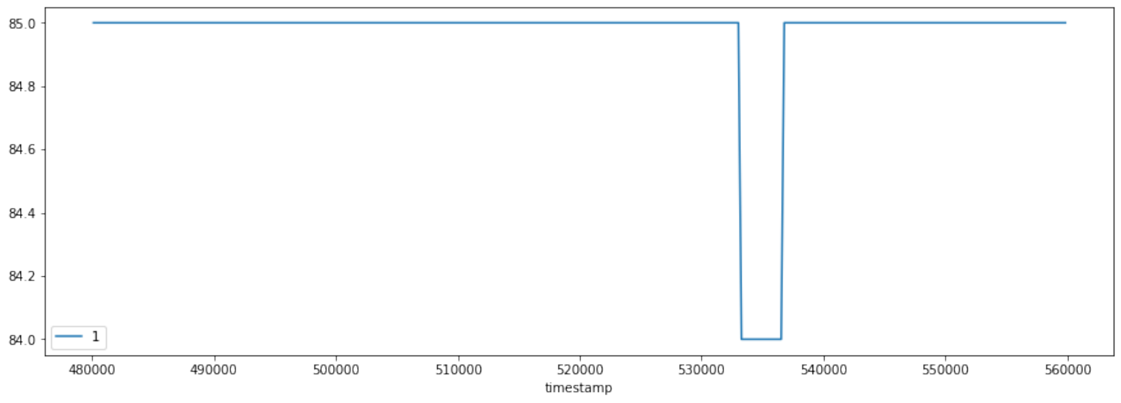
[23]:
```
#  0 1 2 3 4 5 6 7
# +-+-+-+-+-+-+-+-+
# |c c c|x x x x|c| 216989761
# +-+-+-+-+-+-+-+-+
```

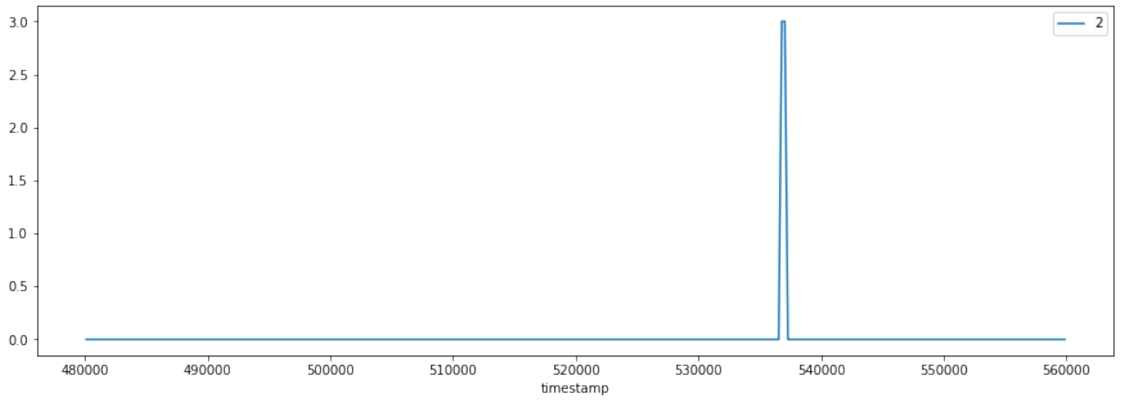
[24]:
```
#  0 1 2 3 4 5 6 7
# +-+-+-+-+-+-+-+-+
# |c|   |   |x x|c| 419364896
# +-+-+-+-+-+-+-+-+

canid_log = canbus_log[canbus_log.can_id == 419364896]
signal_log = list()

for x in range(len(canid_log)):
    signals = (canid_log.data.iloc[x]).split(',')

    signal = dict()
    signal["timestamp"] = canid_log.timestamp.iloc[x]

    if (signal["timestamp"] < START_TIME) or (signal["timestamp"] > END_TIME):
        continue

    signal["1"] = int(''.join([signals[2],signals[1]]), 16)
    signal["2"] = int(''.join([signals[4],signals[3]]), 16)

    signal_log.append(signal)

for signal in ['1','2']:
    pandas.DataFrame(signal_log).plot(x='timestamp', y=signal,figsize=(15,5))
```

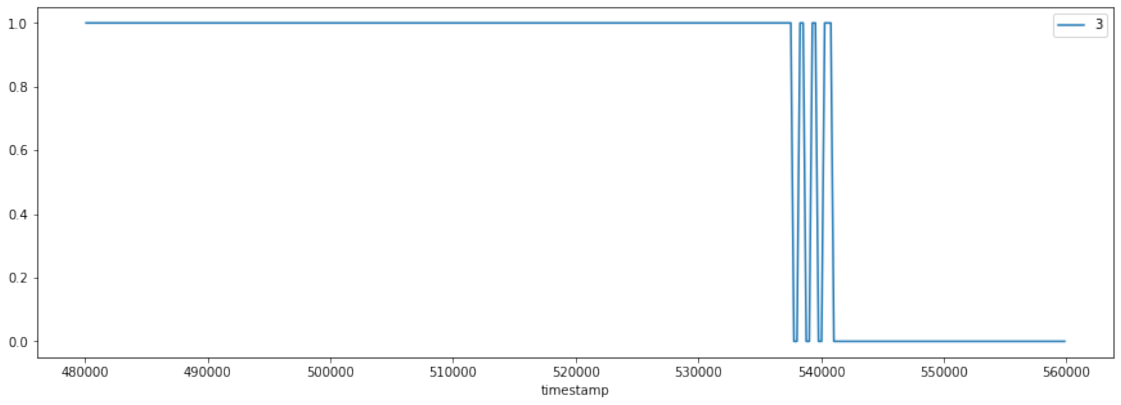


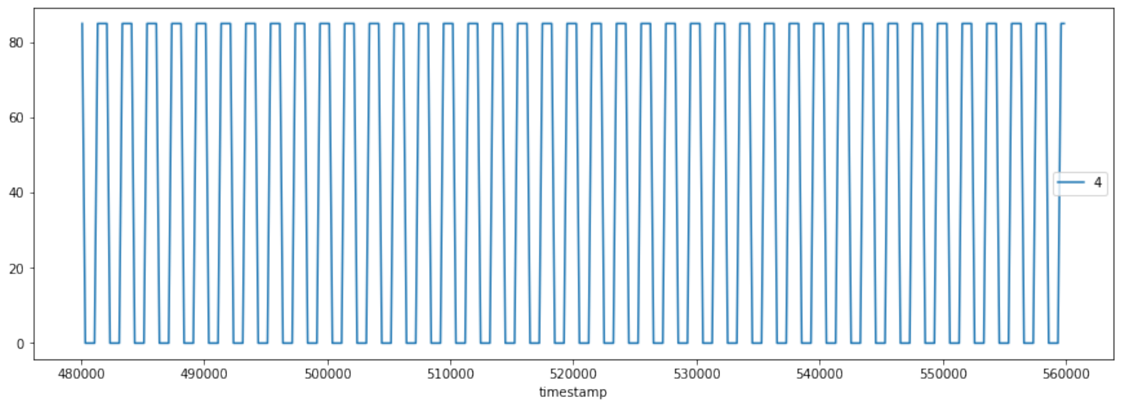


[25]:
```
#  0 1 2 3 4 5 6 7
# +-+-+-+-+-+-+-+-+
# |c| | |   |x|c| | 419364912
# +-+-+-+-+-+-+-+-+

canid_log = canbus_log[canbus_log.can_id == 419364912]
signal_log = list()

for x in range(len(canid_log)):
    signals = (canid_log.data.iloc[x]).split(',')
    signal = dict()
    signal["timestamp"] = canid_log.timestamp.iloc[x]

    if (signal["timestamp"] < START_TIME) or (signal["timestamp"] > END_TIME):
        continue

    signal["1"] = int(signals[1], 16)
    signal["2"] = int(signals[2], 16)
    signal["3"] = int(''.join([signals[4],signals[3]]), 16)
    signal["4"] = int(signals[7], 16)

    signal_log.append(signal)

for signal in ['1','2','3','4']:
    pandas.DataFrame(signal_log).plot(x='timestamp', y=signal,figsize=(15,5))
```

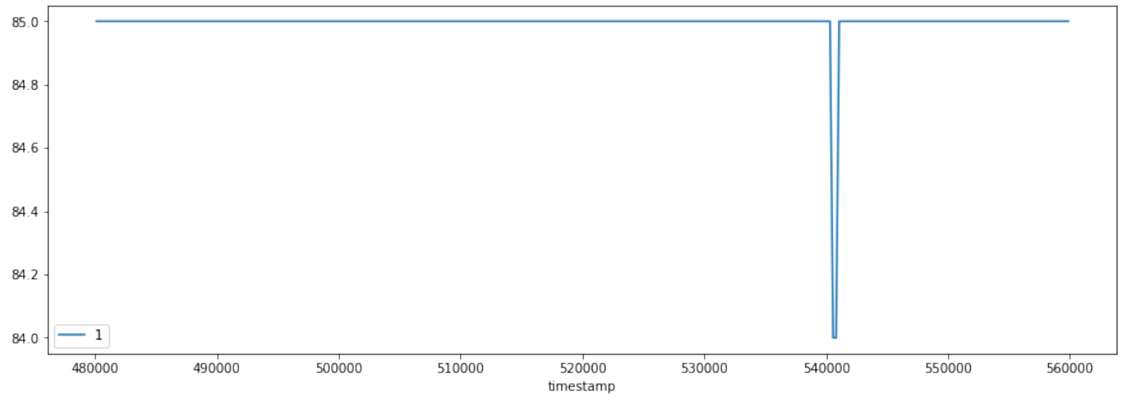


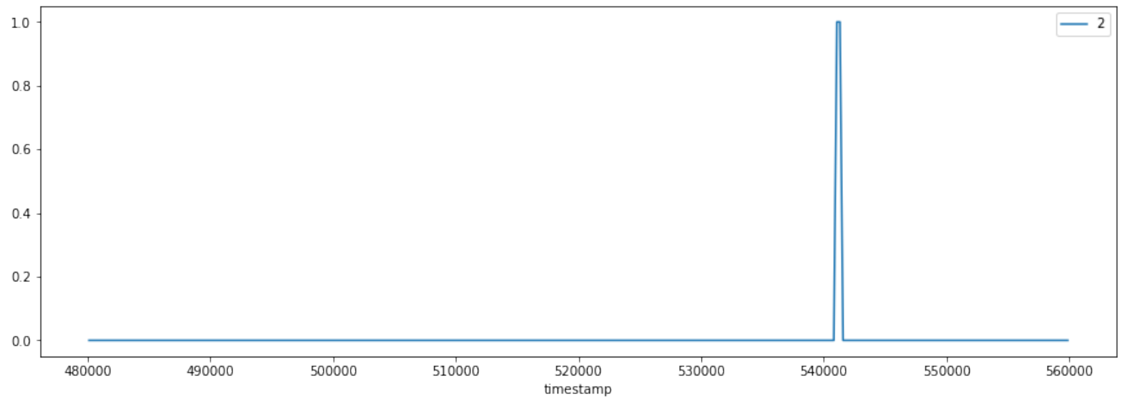


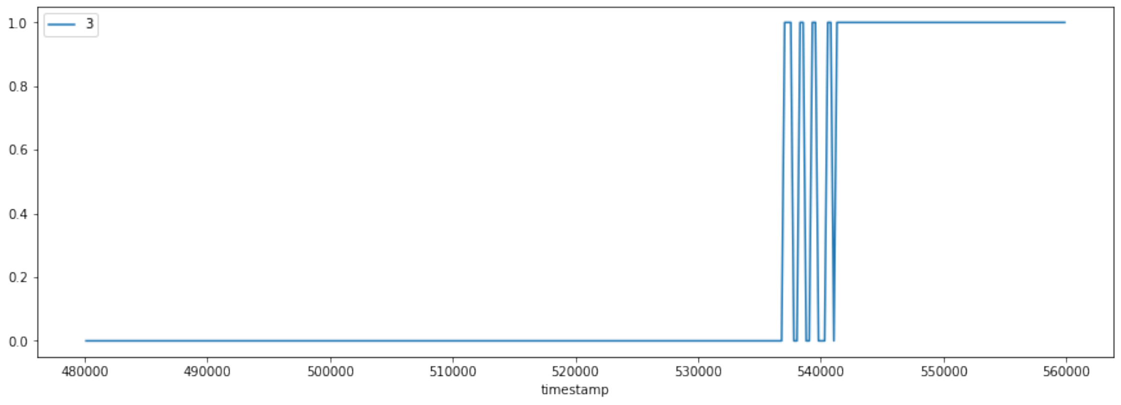


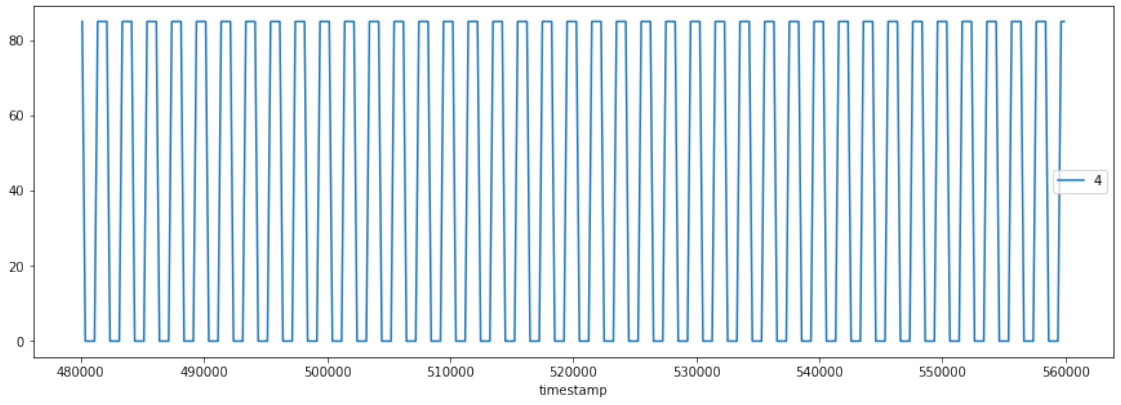


[26]:
```
#  0 1 2 3 4 5 6 7
# +-+-+-+-+-+-+-+-+
# |c| | |   |x|c| | 419364913
# +-+-+-+-+-+-+-+-+

canid_log = canbus_log[canbus_log.can_id == 419364913]
signal_log = list()

for x in range(len(canid_log)):
    signals = (canid_log.data.iloc[x]).split(',')

    signal = dict()
    signal["timestamp"] = canid_log.timestamp.iloc[x]

    if (signal["timestamp"] < START_TIME) or (signal["timestamp"] > END_TIME):
        continue

    signal["1"] = int(signals[1], 16)
    signal["2"] = int(signals[2], 16)
    signal["3"] = int(''.join([signals[4],signals[3]]), 16)
    signal["4"] = int(signals[7], 16)

    signal_log.append(signal)

for signal in ['1','2','3','4']:
    pandas.DataFrame(signal_log).plot(x='timestamp', y=signal,figsize=(15,5))
```

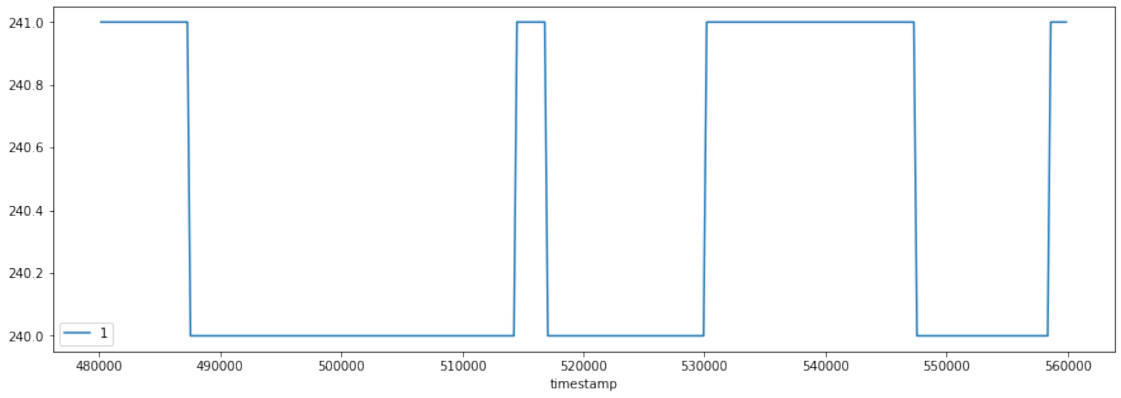




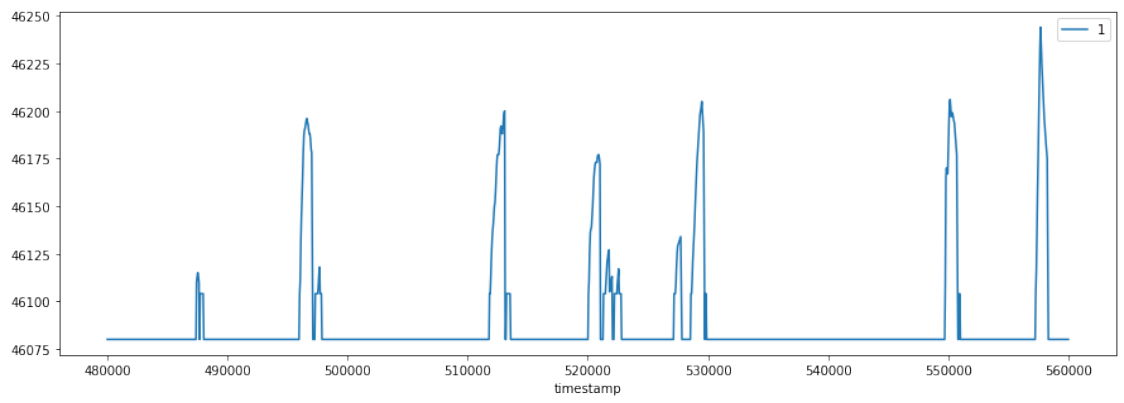


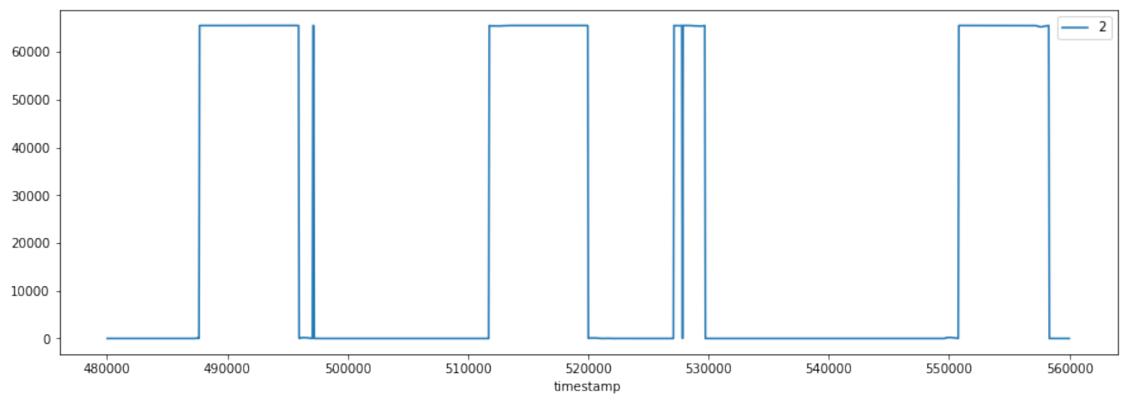


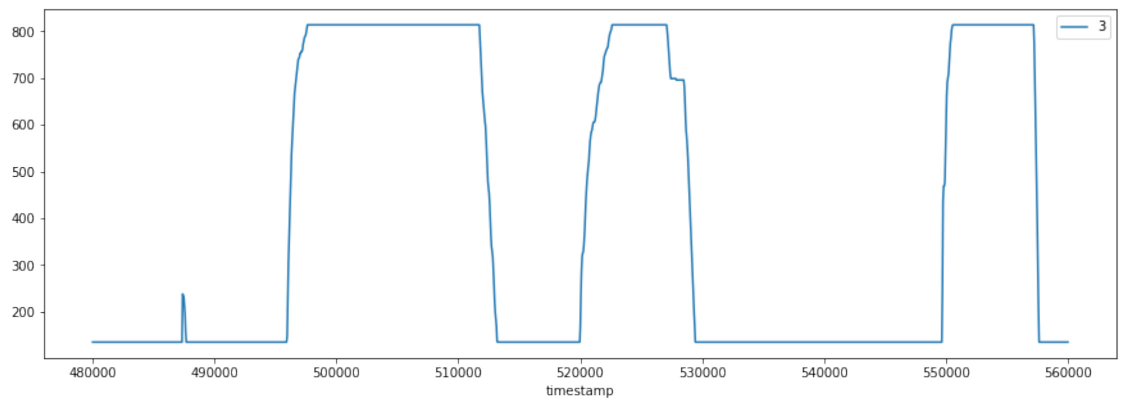
[27]:
```
#  0 1 2 3 4 5 6 7
# +-+-+-+-+-+-+-+-+
# |c c|   |c|x x x| 419364928
# +-+-+-+-+-+-+-+-+

canid_log = canbus_log[canbus_log.can_id == 419364928]
signal_log = list()

for x in range(len(canid_log)):
    signals = (canid_log.data.iloc[x]).split(',')

    signal = dict()
    signal["timestamp"] = canid_log.timestamp.iloc[x]

    if (signal["timestamp"] < START_TIME) or (signal["timestamp"] > END_TIME):
        continue

    signal["1"] = int(''.join([signals[3],signals[2]]), 16)
    signal_log.append(signal)

for signal in ['1']:
    pandas.DataFrame(signal_log).plot(x='timestamp', y=signal,figsize=(15,5))
```

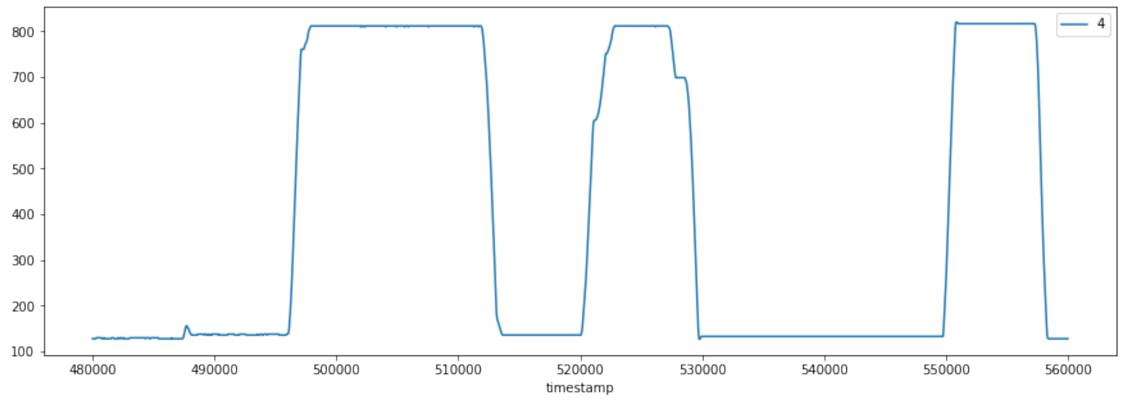


[28]:
```
#  0 1 2 3 4 5 6 7
# +-+-+-+-+-+-+-+-+
# |   |   |   |   | 419365152
# +-+-+-+-+-+-+-+-+

canid_log = canbus_log[canbus_log.can_id == 419365152]
signal_log = list()

for x in range(len(canid_log)):
    signals = (canid_log.data.iloc[x]).split(',')

    signal = dict()
    signal["timestamp"] = canid_log.timestamp.iloc[x]

    if (signal["timestamp"] < START_TIME) or (signal["timestamp"] > END_TIME):
        continue

    signal["1"] = int(''.join([signals[1],signals[0]]), 16)
    signal["2"] = int(''.join([signals[3],signals[2]]), 16)
    signal["3"] = int(''.join([signals[5],signals[4]]), 16)
    signal["4"] = int(''.join([signals[7],signals[6]]), 16)

    signal_log.append(signal)

for signal in ['1','2','3','4']:
    pandas.DataFrame(signal_log).plot(x='timestamp', y=signal,figsize=(15,5))
```


46250
46225
46200
46175
46150
46125
46100
46075
480000
490000
500000
510000
520000
530000
540000
550000
560000
timestamp
1


60000
50000
40000
30000
20000
10000
0
480000
490000
500000
510000
520000
530000
540000
550000
560000
timestamp
2

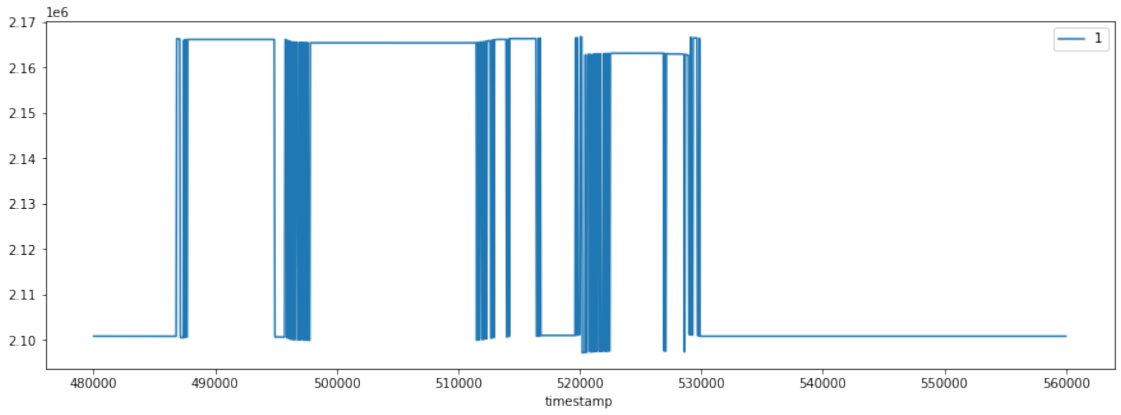

800
700
600
500
400
300
200
480000
490000
500000
510000
520000
530000
540000
550000
560000
timestamp
3

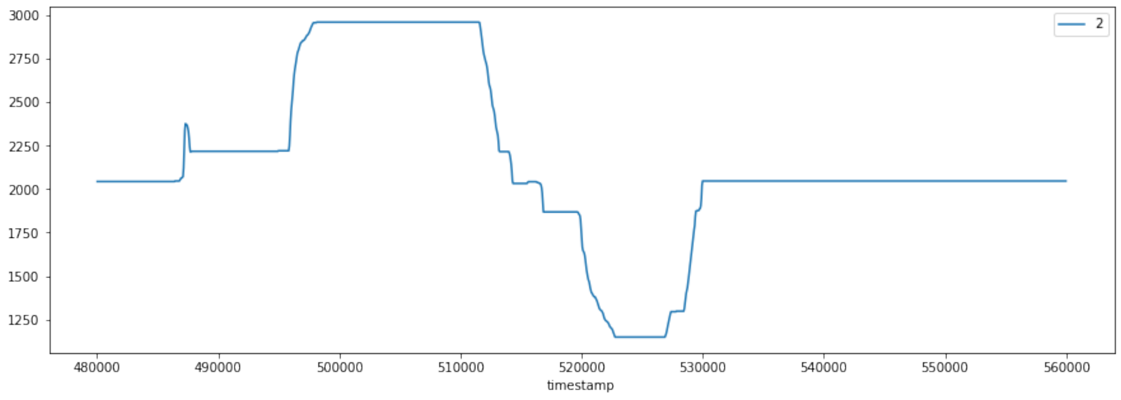


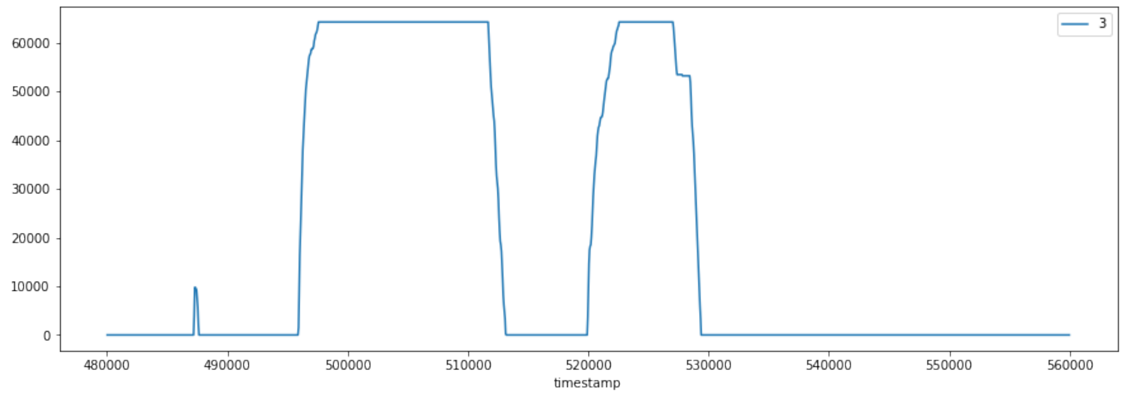
[29]:
```python
canid_log = canbus_log[canbus_log.can_id == 419365152]

for x in range(len(canid_log)):
    signals = (canid_log.data.iloc[x]).split(',')

    y = int(''.join([signals[7],signals[6]]), 16)

    if y < 130:
        #display(y)
        canid, ts, data = canid_log.iloc[x]
        display(data)
        break
```

```
'00,b4,04,00,87,00,80,00'
```

[30]:
```python
#  0 1 2 3 4 5 6 7
# +-+-+-+-+-+-+-+-+
# |       |   |   | 419365168
# +-+-+-+-+-+-+-+-+

canid_log = canbus_log[canbus_log.can_id == 419365168]
signal_log = list()

for x in range(len(canid_log)):
    signals = (canid_log.data.iloc[x]).split(',')

    signal = dict()
    signal["timestamp"] = canid_log.timestamp.iloc[x]

    if (signal["timestamp"] < START_TIME) or (signal["timestamp"] > END_TIME):
        continue
    signal["1"] = int(''.join([signals[3],signals[2],signals[1],signals[0]]),␣
↪16)
    signal["2"] = int(''.join([signals[5],signals[4]]), 16)
    signal["3"] = int(''.join([signals[7],signals[6]]), 16)

    signal_log.append(signal)

for signal in ['1','2','3']:
    pandas.DataFrame(signal_log).plot(x='timestamp', y=signal,figsize=(15,5))
```



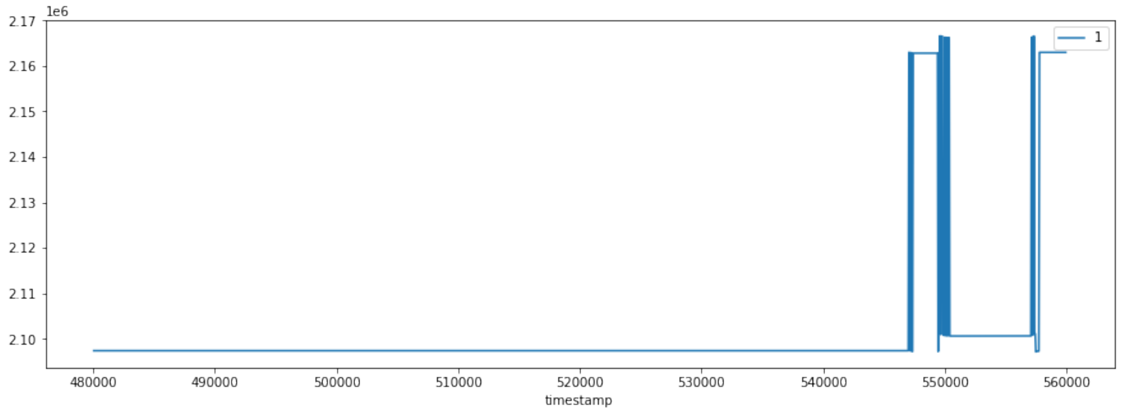


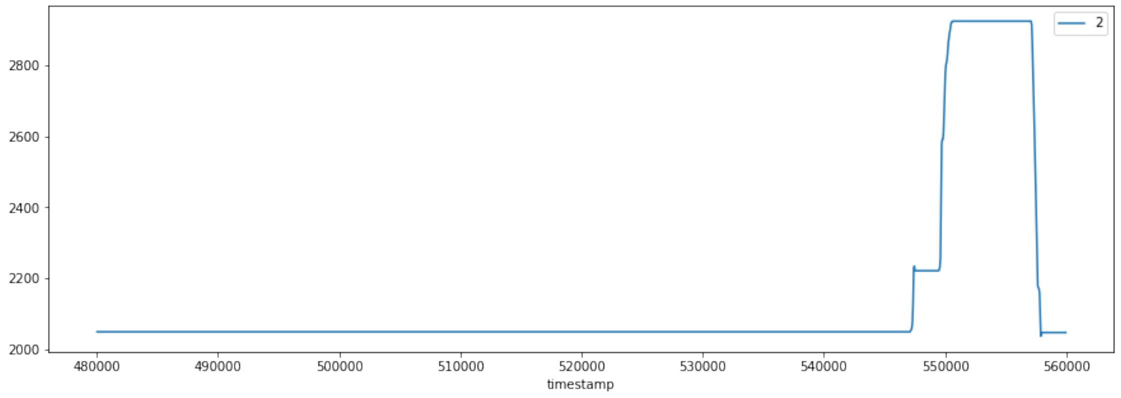


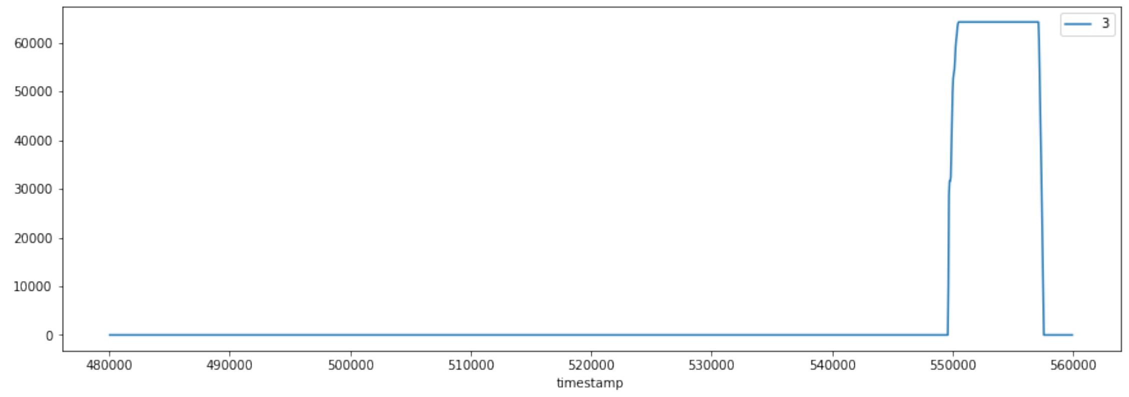
[31]:
```python
canid_log = canbus_log[canbus_log.can_id == 419365168]

for x in range(len(canid_log)):
    signals = (canid_log.data.iloc[x]).split(',')

    y = int(''.join([signals[7],signals[6]]), 16)

    if y == 0:
        #display(y)
        canid, ts, data = canid_log.iloc[x]
        display(data)
        break
```

```
'50,0e,20,00,fc,07,00,00'
```

[32]:
```python
#   0 1 2 3 4 5 6 7
# +-+-+-+-+-+-+-+-+
# |       |   |   | 419365169
# +-+-+-+-+-+-+-+-+

canid_log = canbus_log[canbus_log.can_id == 419365169]
signal_log = list()

for x in range(len(canid_log)):
    signals = (canid_log.data.iloc[x]).split(',')

    signal = dict()
    signal["timestamp"] = canid_log.timestamp.iloc[x]

    if (signal["timestamp"] < START_TIME) or (signal["timestamp"] > END_TIME):
        continue
    signal["1"] = int(''.join([signals[3],signals[2],signals[1],signals[0]]),␣
↪16)
    signal["2"] = int(''.join([signals[5],signals[4]]), 16)
    signal["3"] = int(''.join([signals[7],signals[6]]), 16)

    signal_log.append(signal)

for signal in ['1','2','3']:
    pandas.DataFrame(signal_log).plot(x='timestamp', y=signal,figsize=(15,5))
```







Based on the data and timeline I've been able to create a model where each "Control Station" sends its throttle and enable signals to the "Control Unit" which determines which "Control Station" is enabled and sends its throttle information for the shift unit and actuators.

- 216989712 Shift Control
- 216989728 "Control Unit" enable & throttle
- 216989744 First "Control Station" enable & throttle
- 216989746 Second "Control Station" enable & throttle
- 216989760 "Control Unit" enable
- 216989761 Unknown
- 419364896 "Control Unit" (Needs more research)
- 419364912 First "Control Station" enable
- 419364913 Second "Control Station" enable
- 419364928 "Control Unit" Unknown
- 419365152 "Control Unit" throttle
- 419365168 First "Control Station" throttle
- 419365169 Second "Control Station" throttle