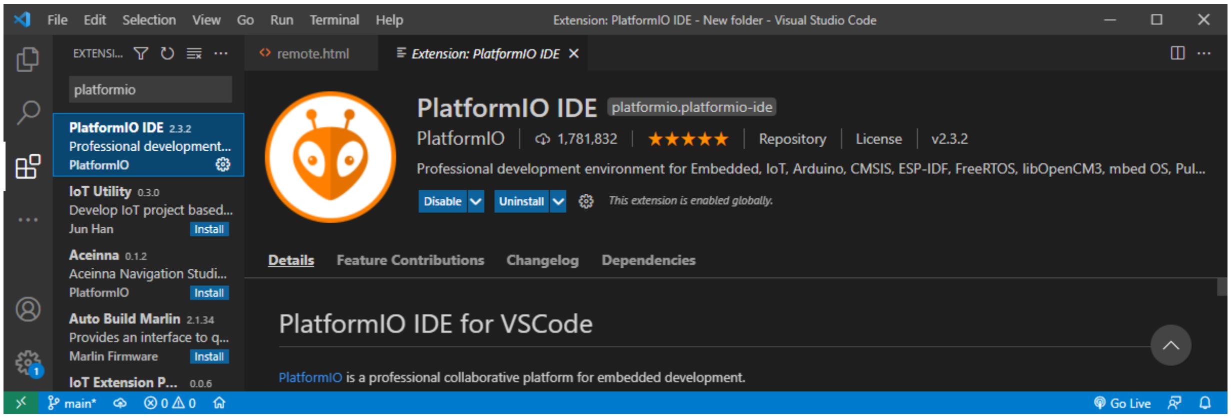
Contents

Lab 5 – Teleoperation

This lab will demonstrate how to configure the MacBot to drive based on user keyboard input. This will be done by writing a script to communicate with the motor controller firmware and forward the velocity commands generated from the teleop_twist_keyboard ROS package.

Motor Driver Firmware

With the assumption that the reader has gone through the process of loading firmware to the ESP32-based boards using the PlatformIO IDE, they must open their PlatformIO environment.



Professional development environment for Embedded, IoT, Arduino, CMSIS, ESP-IDF, FreeRTOS, libOpenCM3, mbed OS, Pul...

This extension is enabled globally.

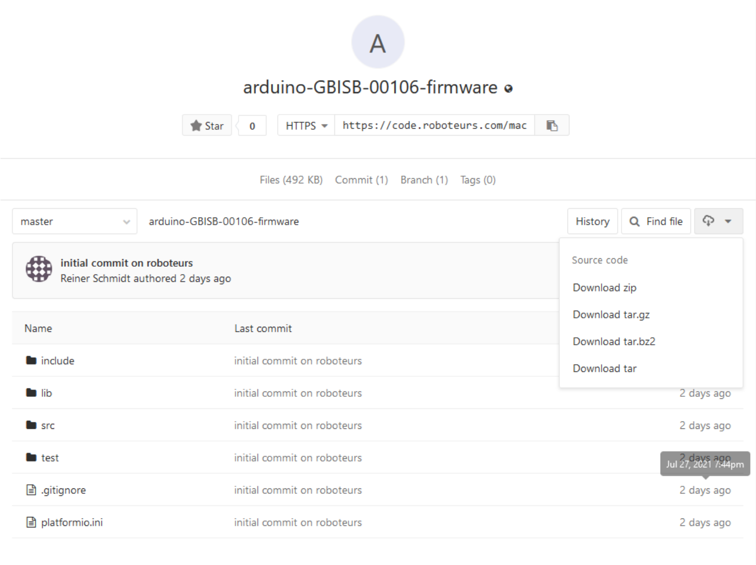
PlatformIO IDE for VSCode

PlatformIO is a professional collaborative platform for embedded development.

Next, navigate to the following repository:

https://code.roboteurs.com/maciot-libs/arduino-GBISB-00106-firmware

Download and extract it into the PlatformIO workspace being used for this lab.



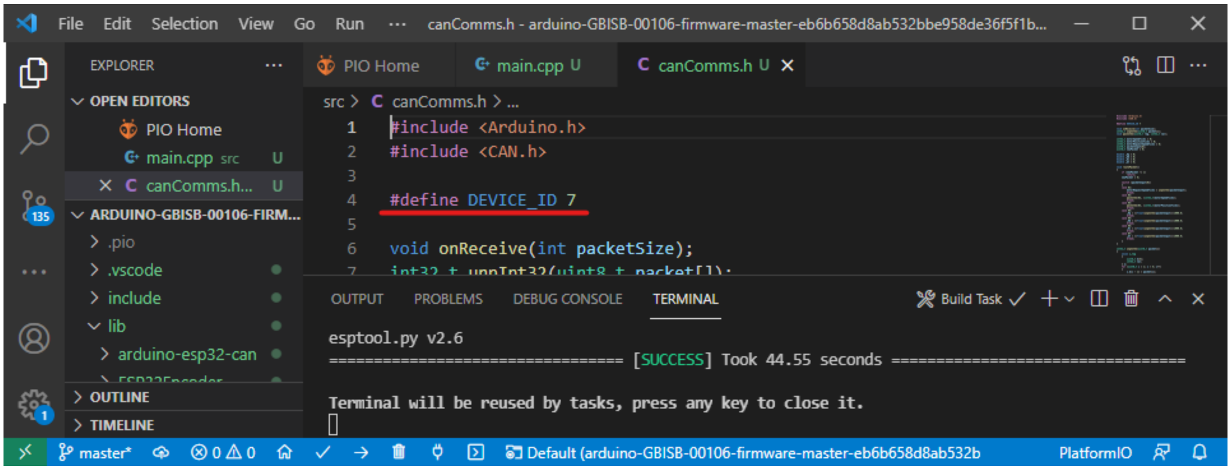
initial commit on roboteurs
Reiner Schmidt authored 2 days ago

Name	Last commit	
include	initial commit on roboteurs	
lib	initial commit on roboteurs	2 days ago
src	initial commit on roboteurs	2 days ago
test	initial commit on roboteurs	2 days ago
.gitignore	initial commit on roboteurs	2 days ago
platformio.ini	initial commit on roboteurs	2 days ago

Open the source folder and notice three key files:

- canComms.h
- motor.h
- main.cpp

Open canComms.h in VSCode:



```
#include <Arduino.h>
#include <CAN.h>

#define DEVICE_ID 7

void onReceive(int packetSize);
int32_t unpInt32(uint8_t packet[]);
```

```
esptool.py v2.6
================================= [SUCCESS] Took 44.55 seconds =================================

Terminal will be reused by tasks, press any key to close it.
```

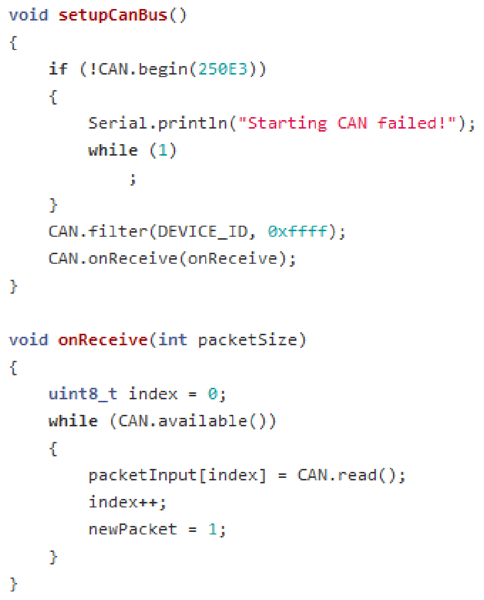
The routePacket() function first checks the newPacket variable. It acts as an update request flag. If equal to 1, it returns immediately.

Ensure that the device ID for each module is unique. Ex. if left is 7, set the right module's device ID to 8.

The switch-case statement looks at the first byte. This first byte categorizes the array payload as either a speed value, PID gain value or a value to be written to the CAN bus.

```
void routePacket()
{
    if (newPacket != 1)
        return;
    newPacket = 0;

    switch (packetInput[0])
    {
    case 01:
        motorRequestSpeedTicks = unpInt32(packetInput);
        break;
    case 02:
        pasInt32(02, (int32_t)motorSpeedTicks);
        break;
    case 03:
        pasInt32(03, (int32_t)motorPositionTicks);
        break;
    case 04:
        _Kp = ((float)unpInt32(packetInput))/1000.0;
        break;
    case 05:
        _Kd = ((float)unpInt32(packetInput))/1000.0;
        break;
    case 06:
        _Ki = ((float)unpInt32(packetInput))/1000.0;
        break;
    case 07:
        _dt = ((float)unpInt32(packetInput))/1000.0;
        break;
    }
}
```

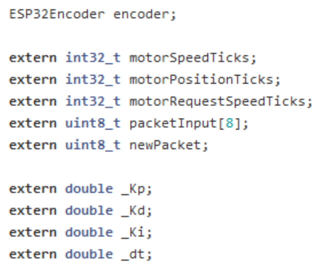
The setupCanBus() function checks to see if a CAN bus connection has been made. If not, it enters a NOP loop. If is, it sets up the device ID then initializes the receive callback function.



```
void setupCanBus()
{
    if (!CAN.begin(250E3))
    {
        Serial.println("Starting CAN failed!");
        while (1)
            ;
    }
    CAN.filter(DEVICE_ID, 0xffff);
    CAN.onReceive(onReceive);
}

void onReceive(int packetSize)
{
    uint8_t index = 0;
    while (CAN.available())
    {
        packetInput[index] = CAN.read();
        index++;
        newPacket = 1;
    }
}
```

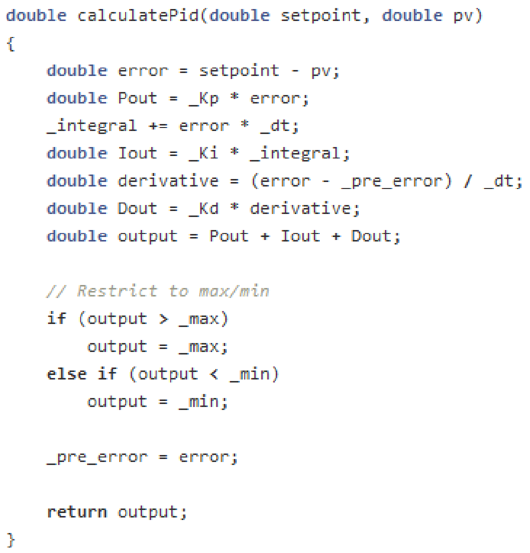
The onReceive() function replaces the data loaded into the packetInput buffer then toggles the request update flag named newPacket.

Open motor.h in VSCode:



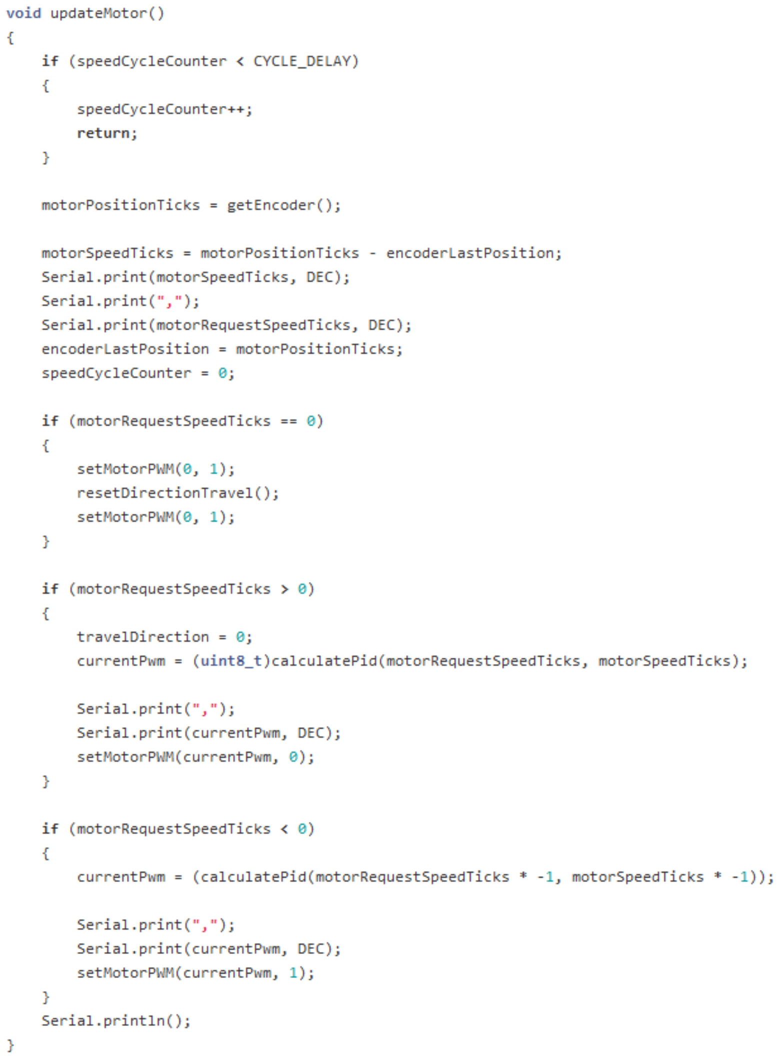
```
ESP32Encoder encoder;

extern int32_t motorSpeedTicks;
extern int32_t motorPositionTicks;
extern int32_t motorRequestSpeedTicks;
extern uint8_t packetInput[8];
extern uint8_t newPacket;

extern double _Kp;
extern double _Kd;
extern double _Ki;
extern double _dt;
```

An ESP32Encoder object is globally constructed.



```
double calculatePid(double setpoint, double pv)
{
    double error = setpoint - pv;
    double Pout = _Kp * error;
    _integral += error * _dt;
    double Iout = _Ki * _integral;
    double derivative = (error - _pre_error) / _dt;
    double Dout = _Kd * derivative;
    double output = Pout + Iout + Dout;

    // Restrict to max/min
    if (output > _max)
        output = _max;
    else if (output < _min)
        output = _min;

    _pre_error = error;

    return output;
}
```

The calculatePid() function calculates the output using the global PID values.

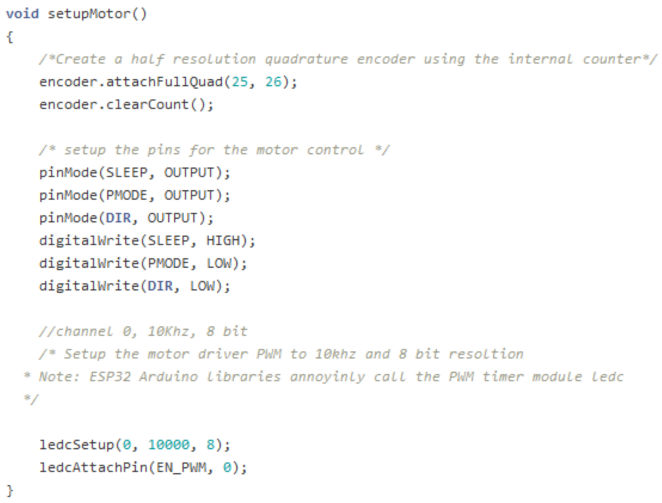


```
void updateMotor()
{
    if (speedCycleCounter < CYCLE_DELAY)
    {
        speedCycleCounter++;
        return;
    }

    motorPositionTicks = getEncoder();

    motorSpeedTicks = motorPositionTicks - encoderLastPosition;
    Serial.print(motorSpeedTicks, DEC);
    Serial.print(",");
    Serial.print(motorRequestSpeedTicks, DEC);
    encoderLastPosition = motorPositionTicks;
    speedCycleCounter = 0;

    if (motorRequestSpeedTicks == 0)
    {
        setMotorPWM(0, 1);
        resetDirectionTravel();
        setMotorPWM(0, 1);
    }

    if (motorRequestSpeedTicks > 0)
    {
        travelDirection = 0;
        currentPwm = (uint8_t)calculatePid(motorRequestSpeedTicks, motorSpeedTicks);

        Serial.print(",");
        Serial.print(currentPwm, DEC);
        setMotorPWM(currentPwm, 0);
    }

    if (motorRequestSpeedTicks < 0)
    {
        currentPwm = (calculatePid(motorRequestSpeedTicks * -1, motorSpeedTicks * -1));

        Serial.print(",");
        Serial.print(currentPwm, DEC);
        setMotorPWM(currentPwm, 1);
    }
    Serial.println();
}
```

The updateMotor() function will return immediately if the CYCLE_DELAY has not been reached yet.

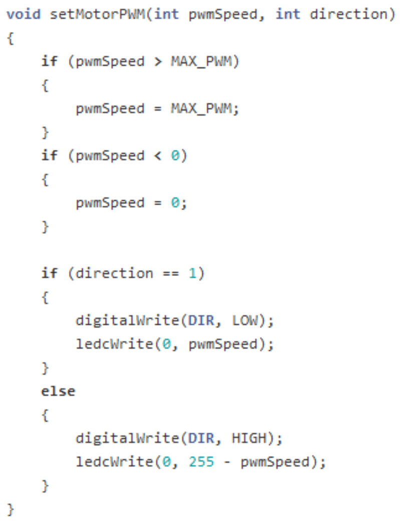
It then sets updated motor position values.

The IF statements check the direction of the motor and changes the channel on the motor controller that it writes the PWM value to in order to achieve that reversed spin direction.



```
void setupMotor()
{
    /*Create a half resolution quadrature encoder using the internal counter*/
    encoder.attachFullQuad(25, 26);
    encoder.clearCount();

    /* setup the pins for the motor control */
    pinMode(SLEEP, OUTPUT);
    pinMode(PMODE, OUTPUT);
    pinMode(DIR, OUTPUT);
    digitalWrite(SLEEP, HIGH);
    digitalWrite(PMODE, LOW);
    digitalWrite(DIR, LOW);

    //channel 0, 10Khz, 8 bit
    /* Setup the motor driver PWM to 10khz and 8 bit resoltion
  * Note: ESP32 Arduino libraries annoyinly call the PWM timer module ledc
  */

    ledcSetup(0, 10000, 8);
    ledcAttachPin(EN_PWM, 0);
}
```

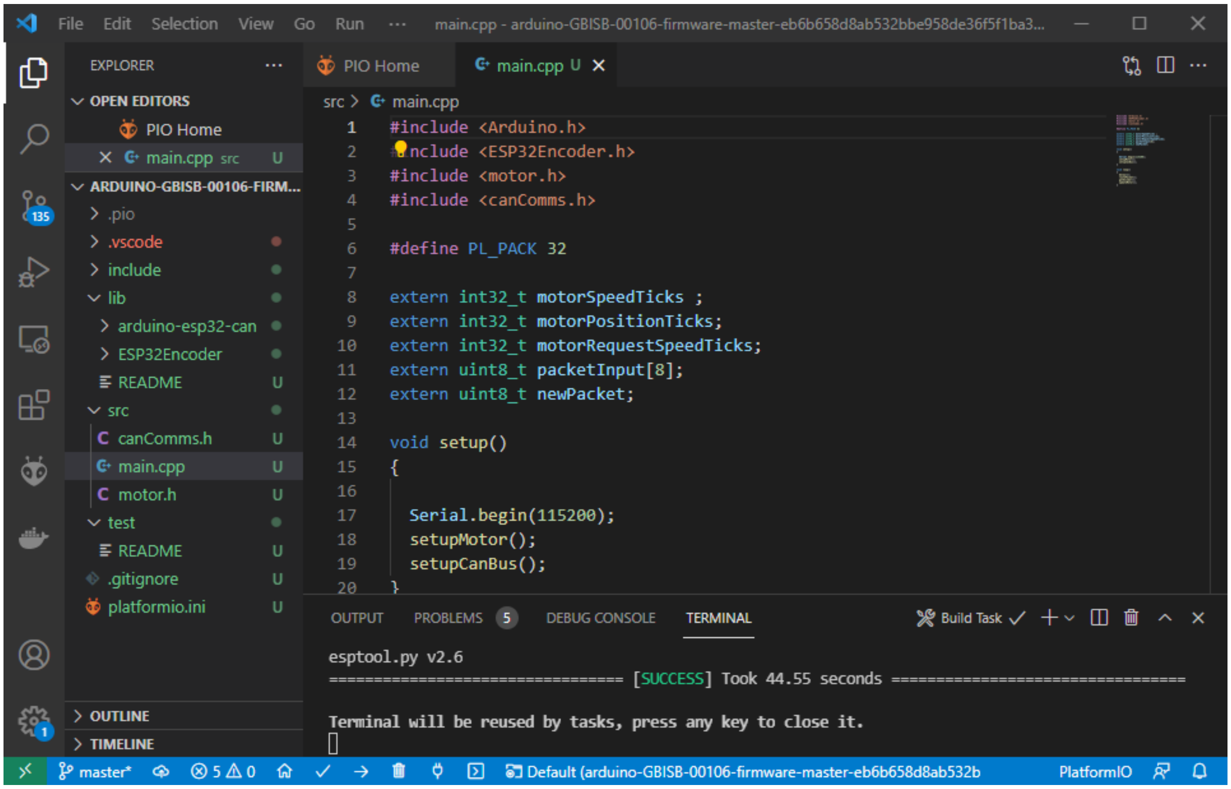
The setupMotor() function initializes the I/O pins and writes an initial value to them.



```
void setMotorPWM(int pwmSpeed, int direction)
{
    if (pwmSpeed > MAX_PWM)
    {
        pwmSpeed = MAX_PWM;
    }
    if (pwmSpeed < 0)
    {
        pwmSpeed = 0;
    }

    if (direction == 1)
    {
        digitalWrite(DIR, LOW);
        ledcWrite(0, pwmSpeed);
    }
    else
    {
        digitalWrite(DIR, HIGH);
        ledcWrite(0, 255 - pwmSpeed);
    }
}
```

The setMotorPWM() function corrects the PWM output to be within an acceptable threshold.

Open main.cpp in VSCode.



```
#include <Arduino.h>
#include <ESP32Encoder.h>
#include <motor.h>
#include <canComms.h>

#define PL_PACK 32

extern int32_t motorSpeedTicks ;
extern int32_t motorPositionTicks;
extern int32_t motorRequestSpeedTicks;
extern uint8_t packetInput[8];
extern uint8_t newPacket;

void setup()
{

  Serial.begin(115200);
  setupMotor();
  setupCanBus();
}
```

```
esptool.py v2.6
================================ [SUCCESS] Took 44.55 seconds ================================

Terminal will be reused by tasks, press any key to close it.
```

The main() function is set up as a super-loop that calls the required functions every millisecond.

```
void setup()
{

  Serial.begin(115200);
  setupMotor();
  setupCanBus();
}

void loop()
{
  delay(1);
  routePacket();
  getEncoder();
  updateMotor();
}
```

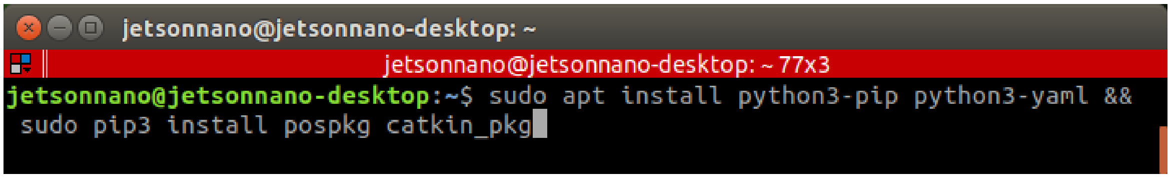
ROS Teleop Script

Now it is necessary to write a script that can communicate with the teleop_twist_keyboard node and forward those commands to devices on the CAN bus. This script can either be created in a catkin package or an existing one.

The teleop_twist_keyboard node publishes messages of type geometry_msgs::Twist, which contains linear and angular components.

Package Setup

First, ensure that the necessary libraries are installed.


jetsonnano@jetsonnano-desktop: ~
jetsonnano@jetsonnano-desktop: ~ 77x3

```
jetsonnano@jetsonnano-desktop:~$ sudo apt install python3-pip python3-yaml &&
 sudo pip3 install pospkg catkin_pkg
```

sudo apt-get install python3-pip python3-yaml sudo pip3 install rospkg catkin_pkg

Next, navigate to the scripts directory of your target package.

cd ~/catkin_ws/src

catkin_create_pkg macbot_teleop rospy roscpp std_msgs …

cd macbot_teleop

mkdir scripts

cd scripts

Serializer Library

```
import struct
class typeSerializer(object):

    '''
    Serializer
    s '''
    def _packUint32(self, val):
        return list(struct.pack("I", val))

    def _packInt32(self, val):
        return list(struct.pack("i", val))

    def _packFloat(self, val):
        return list(struct.pack("f", val))

    '''
    Deserializer
    s '''
    def _unpackUint32(self, data):
        return struct.unpack("I", bytes(data))

    def _unpackInt32(self, data):
        return struct.unpack("i", bytes(data))

    def _unpackFloat(self, data):
        return struct.unpack("f", bytes(data))
```

The typeSerializer library acts as a compatibility layer that allows Python code to communicate with the motor drivers. It is essential because while C/C++ is a strongly typed language (ei. Variables are explicitly declared as native sizes and formats such as signed int's, unsigned int's, long int's), Python is dynamically typed. This means that Python decides how to interpret and handle data on the behalf of the developer.

So, the motor driver firmware is designed to expect one particular format but may receive another. Not knowing this, the motor driver firmware would end up misinterpreting the information it is receiving.

Main Script

```
class GoroboMotorDriver(object):

    def_init_(self, id):
        self.id = id
        self.typeSer = typeSerializer.typeSerializer()
        self.bus = can.interface.Bus(channel='can0',
bustype='socketcan')
        self.us = 1

    def sendRecvPacket(self, packet, recv=False, send=True):
        msg = can.Message(
            arbitration_id=self.id,
            data=packet,
            is_extended_id=False
        )
        if send:
            try:
                for i in range(0, 10):
                    self.bus.send(msg)
                    break
            except can.CanError as e:
```

```python
                if str(e) == "Transmit buffer full":
                    time.sleep(0.020)
                else:
                    raise Exception("Unhandled can bus error", e)
                    quit()  # Fool proof exit
        time.sleep(0.01)
        if not recv:
            return
        try:
            data = self.bus.recv(1.0)
        except Exception as e:
            print("Error on receiving", e)
        return data

    def _makePacket(self, reg, data=None):
        outData = []
        outData.append(reg)
        if data == None:
            outData += [0, 0, 0, 0]
        else:
            outData += data
        outData += [0, 0, 0]
        if len(outData) != 8:
            raise ValueError(
                "Packet length is different than 8, this should be
impossible")
        return outData

    def _unpackPacket(self, data):
        return data[1:5]

    def getPositionTicks(self):
        msg = self.sendRecvPacket(
            self._makePacket(
                3
            ),
            recv=True
        )
        return self.typeSer._unpackInt32(
            self._unpackPacket(msg.data)
        )[0], True

    def getSpeedTicks(self):
        msg = self.sendRecvPacket(
            self._makePacket(
                2
            ),
            recv=True
        )
        return self.typeSer._unpackInt32(
            self._unpackPacket(msg.data)
        )[0], True

    def setTargetSpeedTicks(self, speedTicks=0):
        outBytes = self.typeSer._packInt32(speedTicks)
        self.sendRecvPacket(
            self._makePacket(
                1,
                outBytes
            )
        )
        return 0, True

    def setControlPidP(self, val=0):
        outBytes = self.typeSer._packInt32(val)
        self.sendRecvPacket(
            self._makePacket(
                4,
                outBytes
            )
        )
        return 0, True

    def setControlPidI(self, val=0):
        outBytes = self.typeSer._packInt32(val)
        self.sendRecvPacket(
            self._makePacket(
                6,
                outBytes
            )
        )
        return 0, True

    def setControlPidD(self, val):
        outBytes = self.typeSer._packInt32(val)
        self.sendRecvPacket(
            self._makePacket(
                5,
                outBytes
            )
        )
        return 0, True

    def setControlPidT(self, val):
        outBytes = self.typeSer._packInt32(val)
        self.sendRecvPacket(
            self._makePacket(
                7,
                outBytes
            )
        )
        return 0, True
```

```
case 01:
    motorRequestSpeedTicks = unpInt32(packetInput);
    break;
case 02:
    pasInt32(02, (int32_t)motorSpeedTicks);
    break;
case 03:
    pasInt32(03, (int32_t)motorPositionTicks);
    break;
case 04:
    _Kp = ((float)unpInt32(packetInput))/1000.0;
    break;
case 05:
    _Kd = ((float)unpInt32(packetInput))/1000.0;
    break;
```

```
class GoroboDynamics(object):

    def_init__(self, motors):
        self.wd = 0.265  # meters
        self.ticksPerMeter = 10762.0
        self.updateRateOfMotor = 20.0  # HZ
        self.maxV = 0.1
        self.maxR = 0.1
        self.motors = motors
        self.timeout = 2
        self.dataUpdateFromRemote = False

        for motor in self.motors:
            motor.setControlPidP(100)
            motor.setControlPidI(1000)
            motor.setControlPidD(850)
            motor.setControlPidT(2000)

        self.timeoutThread = threading.Thread(target=self.checkTimeout)
        self.timeoutThread.daemon = True
        self.timeoutThread.start()

    def checkTimeout(self):
        while 1:
            if self.dataUpdateFromRemote != True:
                print("Timeout, setting wheels to zero")
                self.move(0, 0)
            self.dataUpdateFromRemote = False
            time.sleep(self.timeout)

    def solveWheelSpeed(self, speed):
        # calculate the speed to ticks in meters per second
        preSpeed = self.ticksPerMeter * speed
        return preSpeed/self.updateRateOfMotor
    def solveRotation(self, rotation):
        # calculate central articulation speed
        return self.wd/2.0 * 2.0 * 3.14159 * rotation  # m/s wheel
velocity

    def solveSpeeds(self, vx, rz):
        # calculate the speeds
        if abs(vx) > self.maxV:
            print("max input velocity exceeded")
            return (0, 0)
        if abs(rz) > self.maxR:
            print("max input velocity exceeded")
            return (0, 0)

        rot = self.solveRotation(rz)
        rightVel = vx + rot
        leftVel = vx - rot
        leftTickVel = int(self.solveWheelSpeed(leftVel) * -1.0)
        rightTickVel = int(self.solveWheelSpeed(rightVel))

        return (rightTickVel, leftTickVel)

    def move(self, vx, rz):
        wheelSpeedTicks = self.solveSpeeds(vx, rz)
        self.motors[0].setTargetSpeedTicks(wheelSpeedTicks[0])
        self.motors[1].setTargetSpeedTicks(wheelSpeedTicks[1])




if___name__== "_main__":

    motorLeft = GoroboMotorDriver(id=7)
    motorRight = GoroboMotorDriver(id=8)
    goDyn = GoroboDynamics((motorLeft, motorRight))
    def onMessageCallback(data):

        try:
            goDyn.dataUpdateFromRemote = True
            goDyn.move(data.linear.x, data.angular.z)
        except Exception as e:
            print("failed to process the move command")
            print(e)

rospy.init_node("listener", anonymous=True)
rospy.Subscriber("cmd_vel", Twist, onMessageCallback)
rospy.spin()
```

```
case 06:
        _Ki = ((float)unpInt32(packetInput))/1000.0;
        break;
    case 07:
        _dt = ((float)unpInt32(packetInput))/1000.0;
        break;
```