Specs and architecture V1.0

1. Physical
   1. Overall

* Dimensions
  + intérieur chassis = 53 x 85
  + H axe roue avant = 9 cm, roue arrière = 12cm
  + Chassis OK sauf
* Largeur de coupe 45 cm
* Vitesse 0,5 m/s
* Surface de coupe = 800m² / heure
  1. Motors
* 12V
* 310rpm @ no load
* @ maximal efficiency 270rpm, 2A, 0.7Nm
* stall tork 3,4Nm, < 6.5A
  1. Battery
* 1 hour autonomy @ 50% DoD
* Motors @ max efficiency = 8A
* 16Ah required
  1. Navigation
* <https://www.sunearthtools.com/fr/tools/distance.php>
  1. Wiring
* MU – 40 pins IDE compatible (do not use 80, they short cut grounds together)
* TP board (2560 – data pin IDE 2x18, 27 pins on right, 26 pins on left)
* Decoder board (2560 – data pin IDE 2x18, 27 pins on right, 26 pins on left)
* IDE connector male = 69830-040LF (040 means 40 pins) – LF means Sn coating
* IDE connector female = 71600-040LF (040 means 40 pins) – LF means Sn coating

1. Architecture HW and key functions
   1. Overview

* Main unit (Pi) – I2C bus to TP (Traction and Position), ES (Environment Sensors) and BC (Battery Control)
  + Pi to manage connection with wifi dedicated AP for the front end
* Traction and position control board (Arduino Mega) – SPI to sub boards
  + Compass (serial 5V)
  + GPS (SPI)
  + Decoders board (Arduino MEGA 2560 5V +SPI)
  + Motor drivers (GPIO direct)
* Environment sensors board (Arduino tbd) – direct to sensors
  + US sensor
  + Others (?)
* Battery control board (tbd)
  1. Main unit key functions
* MU1 - Webserver for HMI
* MU2 - Time reference
* MU3 - Maintain status database
* MU4 - Calculate trajectories
* MU5 - Drives Traction and position board (I2C-1 0x01)
* MU6 - Drives environment sensors (I2C-1 0x02)
* MU7 – Drives Battery control board (I2C-1 0x03)
  1. Traction and Position control board key functions

I2C-1 slave, I2C-2 master

* TP0 – manage emergency stop – (tbc, could go direct from MU to shorten execution loop, short circuit HW failures)
* TP1 – receive and decode order from MU

Order can be a segment (distance, speed) or a turn (target heading)

{“type”:”segment/turn”, ‘id”:1, “distance”:3512 (in ticks), “speed”:100 as a byte, / “target\_heading”:180 as a byte}

* TP2 – calculate PWM x4 to execute order and set them
* TP3 – poll encoders (SPI) frequency = 0,1s
* TP4 – poll compass (serial) = 0,1s
* TP5 – poll GPS (SPI) - tbc
* TP6 – adjust PWM to deliver order = 0,1s
* TP7 – feedback actual status (distance (ticks), speed (ticks/s), heading (byte), tetapoint (deg/s as a byte), powerx4) to MU (SPI) = 1s
  + 1. Decoders
  + D1 – read (interrupt) encoder ticks

Interrupt overhead = 2,93 micros before + 2,18 micros after = 5,1125 microsec in total + interrupt instructions time (ATmega 328 16Mhz) + 4,78 microsec for a digital read or 1 microsec for a register read = 7 microsec – say x2 for overhead = 14 microseconds. Will get 5\*70=350 interrupts per second per encoder (ie 1,400 interrupts /second) => 4,900 microseconds = 5 miliseconds per second (0,5% per encoder). Sounds OK !

@ 350 interrupts

Cycle = 3ms

* + - Interrupt management: 14microsec x4 = 56microsec
    - I2C reading for 4 x2 bytes = 1ms (source: compass test) @ 10hz => 1ms/30 = 30microsec
* CPU load of 86microsec / 3ms = 2,8% = ok
  + - Leadtimewise, I2C to be executed between external interrupts. Need to manage 1,400 interrupts / second => one every 0,7ms.
    - => external interrupts likely to be delayed during I2C processing.  
      Mega Board (5V) able to manage 6+ external interrupts. Need to confirm the queeing of interrupt will not delay I2C call forever + latching – Confirmed
  + D2 – count / decount based on direction

Interrupt on encoderA (raising), check encoderB for level and increment/decrement – direct port read

* + D3 – provides value since last poll

One board (Mega) reads all interrupts. Latch triggered based on SPI interrupt, value

* + 1. Compass
  + C1 – provides heading

serial call from TP board every 0.1s

* + 1. GPS

tbd

* + 1. Motors drivers
  + MD1 – sets direction

Basic execution of PT sketch

* + MD2 – execute PWM

Basic execution of PT sketch

* 1. Sensors board

tbd

1. Detailed specifications
   1. A. Main Unit

* Map
  + Name
  + 4 corners GPS coordinates x4
  + [blocks] = square of 0.5m x 0.5m = authorized or not (+ a date of update + a source of update ?)
  + Position of the block (x/y, GPS, needed or just using indexes in map \* size)
* Rover
  + Routing
  + Position and speed
  + Status variables
* Routing
  + Name
  + Type (move or mow)
  + Perimeter [waypoints] in case of move perimeter = 2 points (origin and destination)
  + Segment
  + Speed = one overall or one per segment (?)
* Segment
  + byte segment\_type; //0 in case rotation, 1 in case straight
  + unsigned short segment\_id;
  + long target\_ticks;
  + byte target\_bearing;
  + byte target\_speed;
* Waypoint
  + Position (x,y)
  + GPS coordinates (to be matched with x,y)
    1. MU1 - Webserver for HMI
* Main HMI page
  + Status block P1 (MVP)
    - Position X,Y
    - Speed
    - Heading
    - Errors & warnings messages
  + Status block P2
    - Position visible on a map
    - State of ICE engine
    - Battery level
    - Traction power
  + File load block (MVP)
    - Active routing / area info – text box
    - Select & load routing / area button
  + Actions block (MVP)
    - Start / pause / resume
  + Actions block (P2)
    - Emergency stop - button
    - Manual operations – button
* Manual operations page (V2)
  + - Go to base - button
    - Adjust base speed (50-100%)
    - Manual remote control (to store waypoints and manual test)
    - Store way point
    - Tbc - Stop ICE engine
* Waypoints / mown\_area upload dialog box
  + - select file from local drive dialog box
    - upload, check structure, confirm, place in relevant directory and make active or raise exception
* Active waypoints / area selection dialog box
  + - list of available files in each category (2 boxes)
    - make active
    1. MU2 - Time reference – need to be confirmed
    2. MU3 - Maintain status database

Query TP status (1Hz, I2C bus) and load sql database

Calculated x, y, heading, PWML, PWMR, calculated speedx, calculated speedy

Query BMS status (1Hz, I2C bus) load sql database:

Battery level, battery temperature

Query SB status (1Hz, I2C bus) load SQL database:

tbc

* + 1. MU 4 – Calculate trajectories

2 modes = waypoints and area to be mowed

* + - 1. Way points
  + Load waypoints

Waypoints file structure (tbc)

{{“type”:”waypoints”},{“name”:“toto”},{“status”:”valid/invalid/unknown”}}

{{x,y},

…

{x,y}}

* + Calculate segments
    - Seg0\_origin=starting point
    - Draw straight line to next way point
    - Current\_block = next crossed block
    - Check for forbidden blocks (block crossed + 3x3 around)
    - If ok Segi\_end = current\_block else Segi\_end = last\_block
    - Add waypoint @ 90° left + 3 blocks from last ok block
  + Play segments (MU5)
    - 1. Mowed area mode

Based on and random action within mowed area

* + load mown\_area

Mown\_area file structure

{{“type”:”area”},{“name”:“toto”},{“status”:”valid/invalid/unknown”}}

{{x,y},

…

{x,y}}

* + head towards mowed\_area
    - Find closest point of mowed\_area as waypoint 1
    - Calculate route (waypoint mode)
    - Enter into mowed\_area
  + Mowing trajectory algorithm
    - To be implemented – check for forbidden blocks and redesign mowed area to exclude them
    - Alternative 1
      * Generate random heading with heuristic based on maximum number of unmowed blocks
      * Calculate waypoint as intersection of heading and mowed\_area border
      * Go back 1 block
      * Turn by random heading generated based on heurisitic
    - Alternative 2
      * Generate inner border of mowed area moving all waypoints by one block towards the inner (need to manage narrow areas)
      * Mow along this line
      * Repeat same logic
    1. MU5 – Drive TP board

Send first segment then when segment completed, send next segment.

TP to report on position every 1 second (possible optimizations moving to 0.5s in a later stage).

Segment structure:

* Type
* id
* # ticks
* Bearing cible
* Speed
  + 1. MU6 - Drives environnement sensors (SPI 2) TBC
  1. TP functionalities
     1. TP1 – receives and decodes order from MU (SPI bus)

Order can be a segment (distance, speed), a turn (target heading)

{“type”:”segment/turn”, “distance”:1.0, “speed”:100, / “target\_heading”:180}

* + 1. TP2 – calculate PWM x4 to execute order and set them

If (order[“type”]=”segment”) Set all PWM=100

TO DO add a learning process because straingth line maybe different from equal to 100

If (order[“type”]=”turn”) Set right\_pwm=50 & right\_pwm=-50

* + 1. TP3 – poll encoders (I2C slave) frequency = 0,1s

Timer interrupt retrieve EC data (# of ticks since last latch for each wheel - 1 tick = 3,1e-3 m). @full speed (5 rps and 70 ticks per round) expected reported ticks in [-35;35] => [-70;70] or [0;140] = will fit one byte on I2C.

Use only one 4 byte variable for the 4 counters (?) vs 4 bytes

Algo:

* + Receives I2C read instruction
  + Copy ticks counters (4 bytes) and set them to 128 with a bit operation
  + Read millis time
  + Calculate delta millis as a byte
  + Send 5 bytes to I2C bus
    1. TP4 – poll compass (I2C slave) = 0,1s

I2C read duration = 1 ms

Timer interrupt retrieve compass data = current heading

* + 1. TP5 – poll GPS - tbd
    2. TP6 – adjust PWM to deliver order
* Execute after TP 4 or TP 5 (Encoder ticks and compass available every 0,1s)
* Check if segment is completed (distance < 2,5 cm or heading <2°):
  + Reset counters
  + Check go ahead received from MU
  + Start next segment
* Check if segment is expected to be completed in next iteration (distance < PWM \* 5 cm or heading < 5°):
  + If yes : report segment completed
  + Set PWM to 50% of current \*4
* Straight line management (forward and backward)
  + If max (current gap; abs(sumof(current gap and previous gap))) between slowest left and slowest right >= 2 ticks (6% deviation):
    - slowdown fastest side (function of the gap tbd)
    - Reset current gap #fixed so do not carry forward
  + Else if sumof(current gap and previous gap)=0 :
    - Reset current gap #current and previous cancel out => do not carry forward
  + If gap between front and rear
    - Slowdown slipping wheel to slowest wheel of the corresponding/both side(s)
  + If no gap front rear and abs(sum(current gap – previous gap) <=1:
    - Increase speed by 10% on all
  + Former\_gap=current\_gap
* Rotation management
  + Pour un chassis de 60 x 90, circonférence cercle circonscrit = 3,4m => vitesse de rotation ~ 52°/seconde => roation à faire mi-vitesse soit 26°/s soit avec une fréquence de 5hz sur le compas une resolution de l’ordre de 5,2° qui est 2x la precision du compas.
  + Check if abs(current\_heading - target\_heading) < 10° then PWM=25%
    1. TP7 – feedback actual status (position (x,y), heading, teta\_point) to MU (I2C-1) every 1s
* Calculate x, y, vx, vy, teta\_point
  + x, y in milimeters [-1e6, +1e6] => need a long [-2e9; +2e9] (4 bytes) – int are 2 bytes [-32k to +32k]
  + vx, vy in mm/s => [-500,+500] => int (2 bytes)
  + teta\_point in 0,1 deg/s @max speed = 52°/s => [-520;+520] => int = ok
* Report on I2C-1 bus - position (x,y), heading, speedL, speed R
  1. Sensors board

To be confirmed

1. Data model
   1. Overall data model

Long = 4 bytes, int = 2 bytes

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Data | Type | Unit | Origin | MU | TP | ES | BC |
| delta\_encoder\_tick\_FR/FL/RR/RL | byte | none | encoder |  | x |  |  |
| delta\_millis | byte | Ms | encoder |  | x |  |  |
| x\_decoded | long | Mm | TP | x | x |  |  |
| y\_decoded | long | Mm | TP | x | x |  |  |
| vx\_decoded | Int | mm/s | TP | x | x |  |  |
| vy\_decoded | Int | mm/s | TP | x | x |  |  |
| Bearing | byte | 360/255° | TP | x | x |  |  |
| Teta\_point | Int | 0,1 °/s | TP | x | x |  |  |
| x\_GPS | long | Mm | TP | x | x |  |  |
| y\_GPS | long | Mm | TP | x | x |  |  |
| Vx\_GPS | Int | mm/s | TP | x | x |  |  |
| Vy\_GPS | Int | mm/s | TP | x | x |  |  |
| lat\_GPS | Tbd |  | TP | x | x |  |  |
| long\_GPS | Tbd |  | TP | x | x |  |  |
| Power | Int | mA | TP | x | x |  |  |
| ice\_status | byte | 0/1 | MU | x |  |  |  |
| Message | String (140) |  | TP | x | x |  |  |
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* 1. Data model per board

1. SW architecture
   1. Main Unit software
      1. Front web app

* Based on Flask framework
* 3+1 Front end pages
* Classes
  + Rover
    - Data (x, y, speedx, speedy, messages, ice\_status, battery\_level, traction\_power)
    - Methods
      * query\_dbstatus
      * get\_status
      * save\_status
      * set\_routing – question to clarify how to pass it
      * emergency\_stop()
      * set\_speed()
      * Manual mode functions – not clear how to pass instructions real time to the motors in current architecture (manual\_forward(meters), manual\_backward(meters), manual\_turn\_right(degrees), manual\_turn\_left(degrees), set\_speed())
  + Routing
    - Data: type, list of waypoints
    - Methods: check, save, load\_from\_disk,
    1. Back end
    2. Data management

Class Routing()

* datas

mode, routing, next\_step

* functions

Class GPS()

Data

Functions

Initialization

launch webserver

mower=Mower()

while routing is not set :

pass

mower.create\_routing()

main loop

mower.get\_info()

check database for new orders

mower.calculate\_next\_step()

mower.execute()

2.4 Communication protocol

http

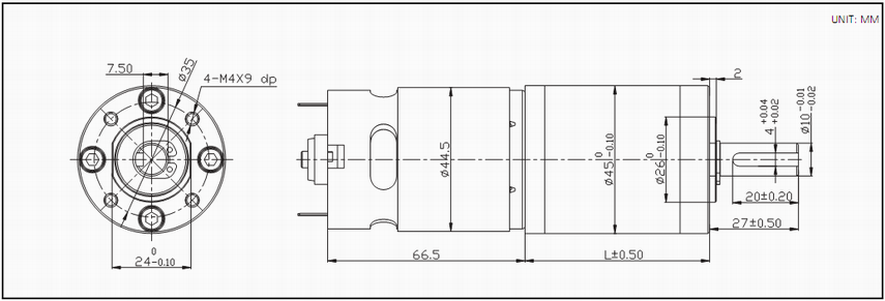
Robot connects to wifi

Robot Web server - Webpage of the robot

**Gear Ratio**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Gear Ratio Stage | 1 | 2 | 3 | 4 | 5 |
| Gear Ratio | 4 | 10 | 32 | 139 | 700 |
|  | 13.7 | 50 | 188 | 977 |
|  | 19 | 71 | 264 | 1367 |
|  |  | 100 | 369 | 1911 |
|  |  |  | 516 | 2672 |
| Gearbox Length(L)mm | 33.6 | 45 | 56.20 | 67.50 | 78.8 |

**Dimensions**



**Reference**

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| MODEL | VOLTAGE | | NO LOAD | | AT MAX EFFICIENCY | | | AT STALL | |
| OPERATION     RANGE | NOMINAL | SPEED | CURRENT | SPEED | CURRENT | TORQUE | CURRENT | TORQUE |
| r/min | mA | r/min | A | kg.cm | A | kg.cm |
| HT-POG45-12 900 | 9-15V | 12VDC | 900 | ≤450 | 810 | ≤2.0 | 2.3 | ≤6.5 | 8.6 |
| HT-POG45-12 450 | 9-15V | 12VDC | 450 | ≤450 | 360 | ≤2.0 | 6 | ≤6.5 | 24 |
| HT-POG45-12 166 | 9-15V | 12VDC | 166 | ≤450 | 122 | ≤2.0 | 11 | ≤6.5 | 44 |
| HT-POG45-12 88 | 9-15V | 12VDC | 88 | ≤450 | 70 | ≤2.0 | 18 | ≤6.5 | 76 |
| HT-POG45-12 63 | 9-15V | 12VDC | 63 | ≤450 | 46 | ≤2.0 | 26 | ≤6.5 | 100 |
| HT-POG45-12 45 | 9-15V | 12VDC | 45 | ≤450 | 33 | ≤2.0 | 36 | ≤6.5 | 150 |
| HT-POG45-12 32 | 9-15V | 12VDC | 32 | ≤450 | 23.5 | ≤2.0 | 51 | ≤6.5 | 200 |
| HT-POG45-12 24 | 9-15V | 12VDC | 24 | ≤450 | 15.8 | ≤2.0 | 68 | ≤6.5 | 300\* |
| HT-POG45-12 17 | 9-15V | 12VDC | 17 | ≤450 | 11 | ≤2.0 | 86 | ≤6.5 | 300\* |
| HT-POG45-12 12 | 9-15V | 12VDC | 12 | ≤450 | 8 | ≤2.0 | 120 | ≤6.5 | 300\* |

Remark:  
1, The speed and torque are adjustable .   
2, The gearbox can match other DC motors .  
3, Shaft can be customized .   
4, The voltage can be 6v,9v, 12v, 24v.  
5, This gear motor can be equipped with encoders .  
6, Terminals support : cables and connectors available.