Requirements Set 11

Main specs:

Max. Robot weight: 800 gr

Nominal speed: 100 mm/s

Cost of material & components: max. 300 € (assume that an in-house 3D printer is available)

Footprint shape: Circular

Footprint size: 25-35 cm

Obstacles:

Gaps of 6 cm

Darkness

PCB specs:

To be clarified – keep a box of 20x25x10 cm^3 reserved for PCBs

Tasks:

Min. runtime: 15min

Line-Tracking capability

RC capability (also supply proper remote control)

Give acoustic feedback (70 -75 dB)

DESIGN OVERVIEW

- Platform: Circular robot with 2 helical 3D-printed wheels (black TPU - **Thermoplastic Polyurethane — flexible, rubber-like 3D printing filament**)
- Drive: 2x Stepper motors (likely Pololu #2267 SY42STH38-1684A, 0.36 Nm)
- Weight: 800 g (max)
- Speed target: 100 mm/s
- 3D structure: Fusion360 model confirms twin screw drive with low clearance
- Battery: 12V proposed, 15 min runtime
- Control: Atmega328P + nRF24L01P
- Sensing: VL53L1 (ToF), CNY70 (line), IIM-42652 (IMU), buzzer (70–75 dB)

PHYSICAL CALCULATIONS

Step 1: Define Requirements

Target speed = 0.1 m/s (100 mm/s)
Helix pitch (measured or estimated) = 2 cm = 0.02 m
Robot mass = 0.8 kg
Wheel radius = 6 cm = 0.06 m
Surface type = linoleum or carpet friction coefficient μ=0.4

Step 2: Calculate Required RPM

We assume 1 full revolution of the helix moves the robot forward by 1 pitch length.

$$\text{Revolutions per second (RPS)} = \frac{Linear\ speed}{Helix\ pitch} = \frac{0.1}{0.02} = 5\ \text{rev/sec}$$

helix pitch = the axial distance (i.e., forward movement along the wheel's centerline) that the thread travels in one full 360° rotation around the wheel.

the axial distance (i.e., length along the wheel) between two full revolutions of the helix — that's the pitch

$$\text{RPM} = 5 * 60 = 300\ \text{RPM}$$

Step 3: Calculate Normal Force per Wheel

Assume equal weight distribution across two wheels:

$$F_N = \frac{m * g}{2} = 3.924\ \text{N}$$

Step 4: Calculate Friction Force (Required to Move)

$$F_{friction} = \mu \cdot F_N = 0.4 * 3.924 = 1.57\ \text{N}$$

Step 5: Calculate Required Torque per Wheel

$$\tau = F * r = 1.57 * 0.06 = 0.0942\ \text{Nm}$$

Apply safety margin (1.5×):

$$\tau_{safe} = 0.0942 * 1.5 = 0.1413 \text{ Nm}$$

Step 6: Convert RPM to Angular Velocity

$$\omega = \frac{2\pi * RPM}{60} = 2\pi * 300 / 60 = 31.42 \text{ rad/s}$$

Step 7: Calculate Mechanical Power per Motor

$$P = \tau * \omega = 0.1413 * 31.42 = 4.44 \text{ W per motor}$$

Total for 2 motors:

$$P_{motors} = 8.88 \text{ W}$$

ELECTRICAL POWER CALCULATIONS

Step 8: System Power Budget

Power Budget Table

We calculate the power P of each component using the formula:

$$P = V \cdot I$$

Component	V	A	W	Notes
ATmega328P MCU	5.0	0.020	0.10	Powered from 5V rail
nRF24L01P RF module	3.3	0.012	0.04	Powered from 3.3V rail
VL53L1X ToF sensor	2.8	0.019	0.05	Direct 2.8V rail or onboard LDO
TP4056 charger module	5.0 (input)	1.000	5.00	During charging
MT3608 (regulator loss)	12.0	0.01	0.12	Estimated conversion overhead
IIM-42652 IMU	3.3	0.007	0.023	Motion tracking

CNY70 IR sensor	5.0	0.018	0.09	IR emitter + transistor
Buzzer (passive)	5.0	0.030	0.15	Approx. 75 dB
2x Pololu Stepper Motors	2.8	3.4	9.52	Two motors: 1.7 A × 2

Total Power = 24.613 W

Step 9: Energy Required for 15 Minutes

Convert 15 min to hours:

$$E = 24.613 * 0.25 = 6.15325 \text{ Wh}$$

Step 10: Calculate Battery Capacity at 12V

$$C = \frac{6.15325}{12} = 512.77 \text{ mAh}$$

Add 30% safety margin:

$$C_{safe} = 666.6 \text{ mAh}$$

Battery required: **12 V, at least 670 mAh**