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Design and Analysis of a 4-Wheeled Wireless RF Controlled Robot

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Abstract: This paper presents the design, development, and analysis of a small wireless remote-controlled robot using a 27 MHz RF communication system. The robot is powered by a 3.7 V, 2000 mAh lithium-ion battery and utilizes four geared DC motors (300 RPM, 500 mA each) for locomotion. The system is designed to carry a weight of approximately 500 grams.

The robot is developed to make quality education available for underprivileged children at village vernacular medium schools. The wheeled bot is made using waste materials considerably reducing the cost which is easily affordable by the schools.

Key aspects such as motor torque, battery discharge rate, RF communication range, and mechanical feasibility are analyzed. The results demonstrate that the selected components provide sufficient torque, acceptable battery life, and reliable short-range wireless control, making the system suitable for educational and hobby applications.

Index Terms **-** RF Robot, Geared DC Motor, Torque Analysis, Battery Discharge, Wireless Control

I. INTRODUCTION

Robotics provides an effective way of introducing students to practical concepts such as wireless communication, motor control, mechanical motion, and battery-powered systems. A remotely operated robot is particularly useful for this purpose because its operation can be observed directly while the underlying electrical and mechanical principles remain simple enough to understand. The present work describes the development of a compact four-wheeled robot that can be operated wirelessly using a radio-frequency control system.

The proposed robot uses a 27 MHz RF transmitter and receiver to establish communication between the operator and the robot. Four geared DC motors are employed to produce the movement of the wheels. Each motor is rated at 300 RPM with a current requirement of approximately 500 mA. The four-motor arrangement provides the driving capability needed for the robot and also allows the available torque to be distributed through the wheels.

An important consideration in this work is affordability. The robot is intended as an educational model that can be used in schools, including village vernacular medium schools where access to expensive robotic kits may be limited. For this reason, waste materials are used wherever practical in the construction of the robot body. This reduces the material cost while still allowing the main principles of a wheeled robotic system to be demonstrated.

The electrical power is supplied by a 3.7 V, 2000 mAh lithium-ion battery. Battery selection is important because the operating time of a wireless robot depends on the power consumed by its motors and control circuit. For the proposed arrangement, the estimated operating duration is about 35–45 minutes. This makes the robot suitable for classroom demonstrations, basic experiments, and short educational activities.

The mechanical capability of the robot is examined using the motor torque and the approximate robot weight. The robot is designed around a weight of about 500 g. Each motor provides approximately 0.06 Nm of torque, giving an approximate combined torque of 0.24 Nm for four motors. These values are considered to determine whether the selected motors can provide adequate movement for the intended structure.

In addition to torque, the main forces acting on the robot are considered. The analysis includes the weight of the robot, the normal reaction from the supporting surface, the driving force produced by the wheels, and friction opposing movement. Considering these factors gives a basic understanding of the mechanical feasibility of the design.

Therefore, the proposed system combines low-cost construction with wireless operation and a simple four-wheel drive arrangement. The work focuses on examining the selected components and determining whether they provide adequate torque, useful battery operating time, and reliable short-range wireless control for educational and hobby applications.

I. Methodology

The development procedure was organized around four main aspects: construction of the mechanical platform, selection of the electrical components, implementation of wireless control, and evaluation of the robot's performance. The approach was kept simple so that the resulting system could be reproduced and understood easily in an educational environment.

a. Mechanical arrangement: The robot uses four wheels mounted on a lightweight body. Its approximate total weight is 500 g. Four geared DC motors are used to drive the wheels. Each motor has a rated speed of 300 RPM and a current rating of approximately 500 mA. Waste materials are incorporated into the body construction to reduce the overall cost.

b. Power and electrical arrangement: A 3.7 V, 2000 mAh lithium-ion battery is used as the main power source. The battery supplies the electrical energy required by the motors and the wireless control arrangement. The expected operating duration is considered while assessing the suitability of the battery for the intended application.

c. Wireless control: The robot is operated through a 27 MHz RF transmitter and receiver. Commands are transmitted from the user side through the RF transmitter, while the receiver placed on the robot accepts the transmitted control information. The received commands are used to control the movement of the robot, providing wireless operation without a physical control cable.

d. Torque evaluation: The torque capability of the drive system is estimated from the torque available from an individual motor. The torque of one motor is approximately 0.06 Nm. With four motors, the combined torque is approximately 0.24 Nm. This value is used as an indicator of the available driving capability of the robot.

e. Force consideration: A free-body representation is used to identify the important forces acting on the robot. The weight acts downward, the supporting surface produces a normal reaction, the motor-wheel system produces the driving force, and friction acts opposite to motion. These forces are considered when discussing the mechanical feasibility of the robot.

f. Battery assessment: Battery performance is evaluated in terms of the expected operating time. For the selected 3.7 V, 2000 mAh battery, the estimated backup is approximately 35–45 minutes. This provides a practical duration for short demonstrations and educational activities.

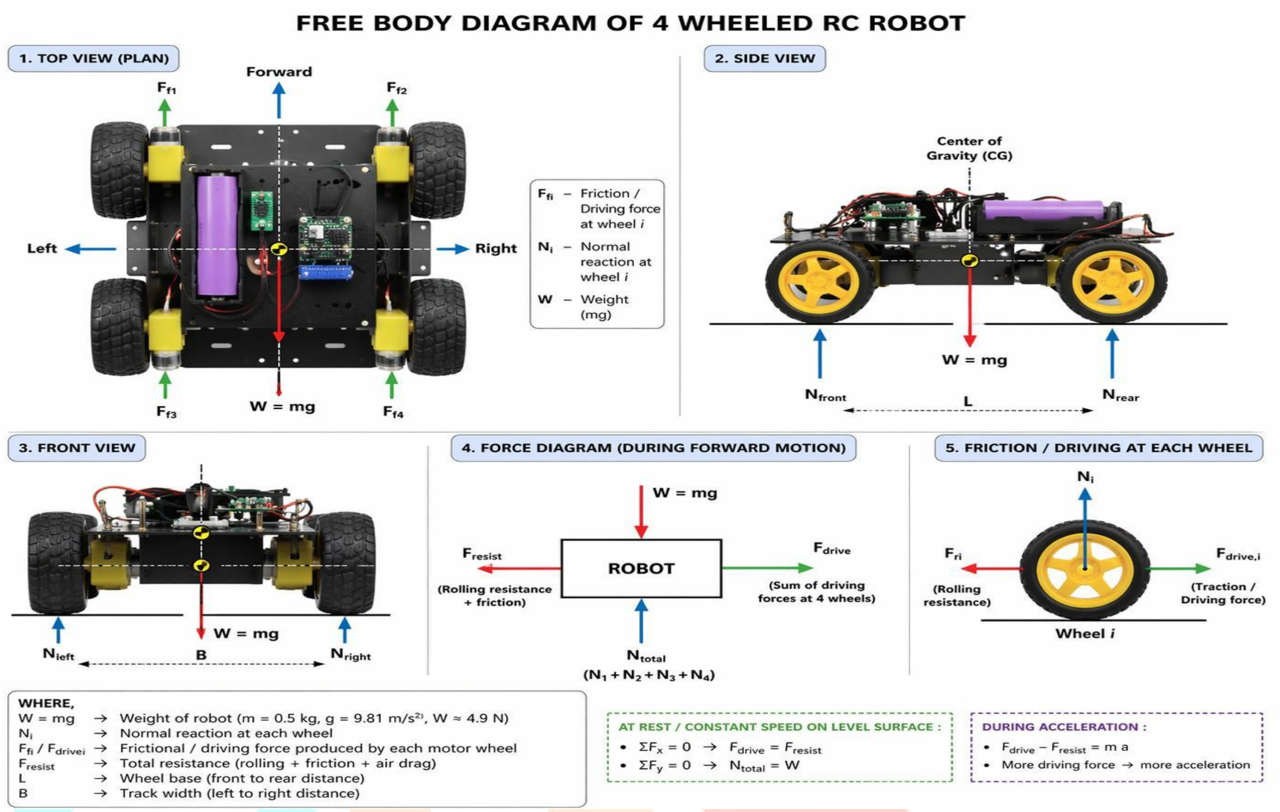

Figure 1. Free body diagram of 4 wheeled RC Robot

II. CALCULATION AND SYSTEM DESCRIPTION

1. DC Motor speed and torque calculation

Given: 1. Motor speed=300 rpm (no load)
2. Voltage = 3-6 volts
3. Current= 500mA (0.5A) per motar
4. Number of Motors =4

a. Angular speed calculation:

$$\omega = \frac{2\pi N}{60}$$

$$\omega = \frac{2\pi \ X \ 100}{60}$$

$$\omega = 31.42 \ rad/sec$$

b. Linear speed calculation

D = Wheel Diameter = 70mm

$$V = \frac{\pi D N}{60}$$

$$V = \frac{\pi \ X \ 70 \ X \ 100}{60}$$

$$V = 1099.55 \text{ mm/s}$$

c. Torque Estimation

Electrical Power per meter

$$P = V \ X \ I$$

$$P = 3.7 \ X \ 0.5$$

$$P = 1.85 \ Watts$$

$$\text{Torque,} \quad T = \frac{P}{\omega} = \frac{1.85}{31.42} = 0.05 \text{ Nm}$$

$$T \cong 0.06 \ Nm$$

$$\text{Total Torque} = 4 \text{ X } 0.06 = 0.24 \text{ Nm}$$

2. **Battery Discharge Time Calculation:**
Given: 1. Battery = 2000 mAh =2A
2. Each Motor = 0.5 A
3. Total number of Motors =4
Total Motor Current, I = 4 X 0.5 = 2A

Considering,
RF Module + Losses = 0.225 A
Total = 2+0.225 =2.225 A

Battery backup Time

$$t = \frac{Battery\ capacity}{Total\ current} = \frac{2}{2.225} = 0.8989$$

$$\text{t} = 0.8989\ X\ 60\ X\ (1-0.2)$$

$$\text{t} = 43\ min$$

Note : here 0,2 is 20% motor friction and drive losses, ie, considering 80% Motor efficiency.

3. **RF Transmitter and Receiver Calculation**
Basic parameters: 1. Frequency = 27MHz
2. Range = 10m
3. Power Source = 3V

a. Wavelength Calculation

$$\lambda = \frac{c}{f} = \frac{3\ X\ 10^8}{27\ X\ 10^6} = 11.1\ m$$

b. Antenna length (Quarter Wave)

$$\text{L} = \frac{\lambda}{4} = \frac{11.1}{4} = 2.75\ m$$

(In practical the antennas will be shorter so the range also reduces)

c. Power Consideration
Typical transmission current = 20-50 mA
Battery life of transmitter:

$$\text{t}= \frac{2000}{50} = 40\ hours\text{(approximately)}$$

4. **RF Transmitter and Receiver Calculation**
a. Robot Weight :
Mass = 0.5 to 0.6 kg
Force acting on the earth due to it s mass = 0.6 * 9.81 = 5.886 kg

b. Usage of Gear Motors :
Overall Torque Requirement
Each motor supports = 5.886 / 4 =1.4715 N
Here, wheel radius = 3.5 cm = 0.035 m

$T_{required}$ = F*r
= 1.4715*0.035
= 0.0515 N-m

Now, here it's clear from the above calculation Point(1) and Point (4) that the Torque available at the motors is more than the Torque required to drive the robot. Hence, the torque is sufficient.

Necessity for using Gear motors and not the regular DC motor :
The gear motor of 300 rpm, without the gearbox has a free no load rpm of 3000. Here the speed(rpm) has increased 10 times, so consequently if the torque is inversely proportional to speed, then the toque gets redu=uced nearly 10 times which will not be sufficient enough to run the robot.

Result and discussion

The developed robot was evaluated using the main electrical and mechanical parameters selected during the design. The evaluation focused on motor speed, torque, total driving torque, battery operating time, and the overall weight of the robot.

The four geared DC motors operate at a rated speed of 300 RPM. The approximate torque available from one motor is 0.06 Nm. When the four motors are considered together, the resulting approximate total torque is 0.24 Nm. For the intended robot weight of about 500 g, this available torque indicates that the selected motor arrangement is suitable for the proposed movement requirements.

The power source used for the robot is a 3.7 V, 2000 mAh lithium-ion battery. The estimated battery backup is approximately 35–45 minutes. This operating period is adequate for the type of short-duration demonstrations and basic educational activities for which the robot is intended.

The mechanical behavior is examined by considering the forces acting on the four-wheeled structure. The weight of the robot is balanced by the normal reaction from the surface, while the motors provide the driving force through the wheels. Friction acts against the movement. These factors form the basis for assessing whether the selected mechanical arrangement can support the intended operation.

Table 1. Performance Table

Parameter	Value
Motor speed	300 RPM
Torque per motor	0.06 Nm
Total torque	0.24 Nm
Battery life	35–45 min
Robot weight	500 g

The combined results indicate that the selected components are appropriate for the proposed low-cost robotic platform. The four motors provide the required torque for the intended structure, while the estimated battery backup offers useful operating time. The RF arrangement provides the required wireless control, and the use of waste materials supports the low-cost objective. Overall, the analysis supports the feasibility of the robot for educational and hobby applications.

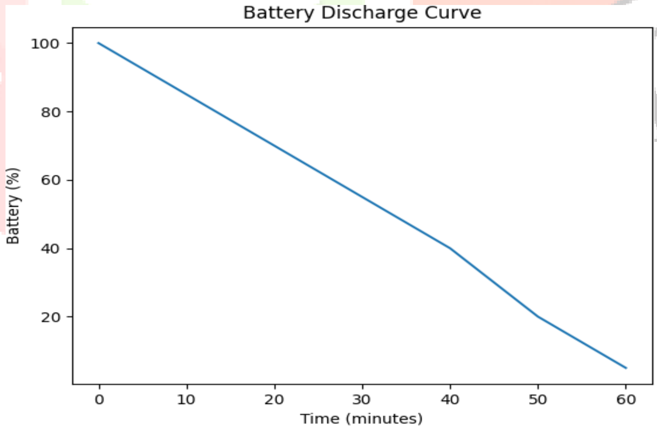

Figure 2. Battery Discharge Curve

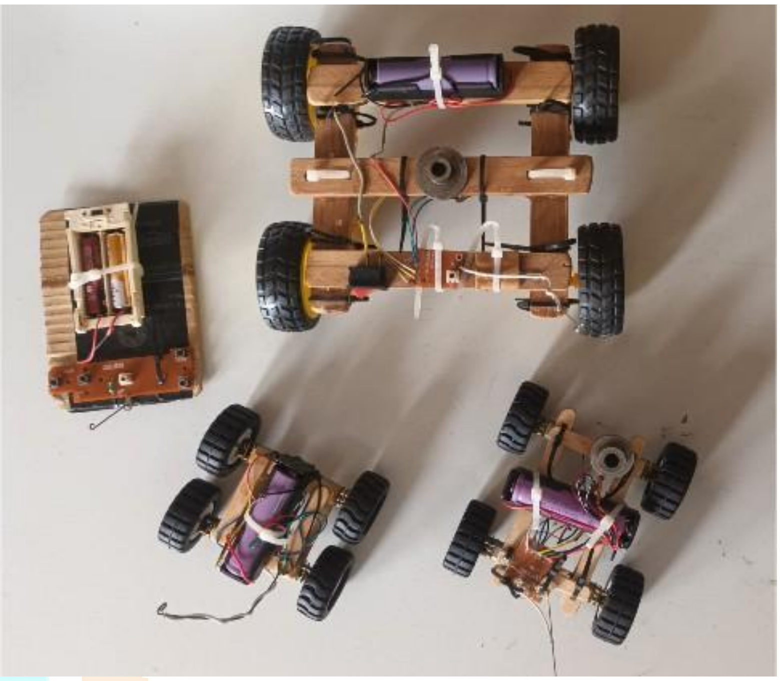

Figure 3. 4-In-house developed Wheeled Wireless RF Controlled Robot

III. Conclusion

The four-wheeled RF-controlled robot was developed as a simple and economical platform for demonstrating basic robotics and wireless control. The design combines four 300 RPM geared DC motors, a 27 MHz RF transmitter-receiver arrangement, and a 3.7 V, 2000 mAh lithium-ion battery. The calculated torque is approximately 0.06 Nm per motor and 0.24 Nm for the four motors together, while the estimated battery backup is 35–45 minutes for an approximate robot weight of 500 g.

The force considerations involving weight, normal reaction, driving force, and friction support the mechanical feasibility of the proposed structure. The use of waste materials further reduces construction cost and makes the system more suitable for resource-limited educational environments. Based on the available analysis, the proposed robot provides a practical low-cost platform for introducing students to wireless communication, motor control, and fundamental robotic systems.

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