

Design and Implementation of an RF-Controlled Rocker-Bogie Mechanism for Multi-Terrain Navigation and Tactical Defense Applications

Tejas Chaudhari, Sanket Deshmukh, Machchhindra J.Garde

Department of Electronics Engineering
SSVPS' BSD College of Engineering, Dhule

Abstract: This paper details the design, mechanical configuration, and electronic architecture of a multi-terrain Rocker-Bogie mobility mechanism. The system leverages a six-wheel configuration driven by 100 RPM DC gear motors to achieve efficient obstacle traversal and step-climbing capabilities without traditional suspension springs. Power delivery is managed via a 12V Lithium-Ion battery pack configured by connecting three individual cells in series. System navigation and operational commands are transmitted wirelessly using a 433 MHz RF Module coupled with HT12E/HT12D encoder-decoder ICs and an integrated relay switching network. Empirical testing validates that the system effectively navigates highly irregular topographies, climbs inclines up to 45 degrees, and supports tactical payloads such as laser targeting modules and AV recording equipment. The design offers a low-cost, scalable framework for military operations, material handling, and hazardous exploration.

Keywords: Genetic Algorithm (GA), selective harmonic elimination, dc sources.

I. INTRODUCTION

Efficient material transport and vehicle navigation across uneven or vertical topographies present a substantial engineering challenge. Standard transportation methods, such as industrial lifts, require significant power footprints, structural permanence, and high maintenance costs. Manual material handling on steep or broken inclines introduces a high risk of musculoskeletal injuries for workers. Standard material-handling solutions, like conventional two-wheeled hand trolleys, perform optimally only on flat, planar surfaces. When pushed or pulled over steps, ledges, or highly unyielding terrains, standard wheel-and-axle frameworks fail due to high shock loads and shifting centers of gravity.

To resolve these mobility limitations, robotic platforms have increasingly turned to suspension systems capable of maintaining continuous ground contact. At the forefront of this methodology is the Rocker-Bogie mechanism, originally engineered for planetary exploration rovers due to its ability to clear obstacles larger than its wheel diameter. This project adapts the Rocker-Bogie mechanism for earth-bound applications, focusing heavily on tactical defense, hazardous reconnaissance, and off-road freight handling. The vehicle operates wirelessly via an RF transmitter-receiver pair, enabling operators to guide the vehicle safely through hostile or unstable spaces from a distance.

II. LITERATURE REVIEW

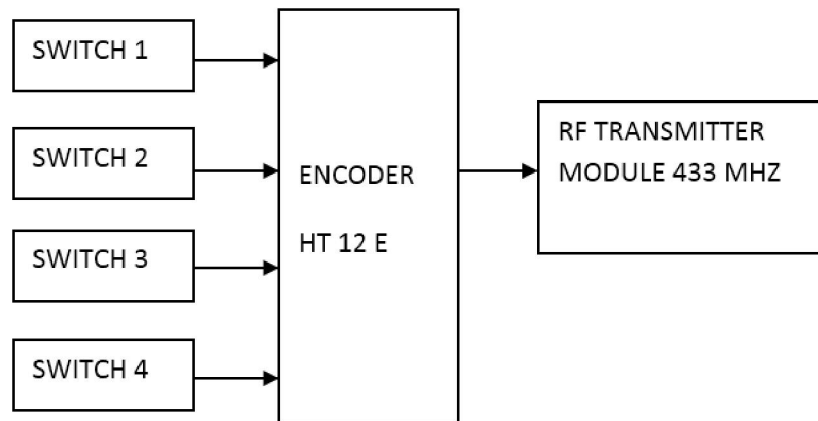
Planetary surface exploration has heavily driven the development of highly compliant mobile robots. NASA pioneered the use of the six-wheeled Rocker-Bogie suspension system on a series of historical Mars missions, including the Sojourner rover (1997), Spirit and Opportunity (2004), and the Curiosity rover (2011). Curiosity, a 900 kg mobile laboratory, successfully scaled obstacles between 60 to 75 cm using an autonomous path-planning vision framework paired with a robust Rocker-Bogie chassis. The absence of springs or springs-and-dampers prevents the vehicle from snapping back when clearing ledges, distributing weight equally across all six driving wheels. Commercial entities, such

as Astrobotic Technology Inc., have similarly refined these lunar and Martian suspension designs to support commercial payload delivery and high-resolution 3D terrain scanning. Modern structural engineering research emphasizes integrating Taguchi and Grey-based optimization algorithms to fine-tune structural geometries, allowing these modular chassis variants to climb stairs with distinct overhangs. Recent laboratory prototypes demonstrate stable navigation over inclines up to 45 degrees. However, historical data indicates a critical physical threshold: standard scale models experience tracking failures on step runs shorter than 375 mm (15 inches), establishing clear parameters for further wheel geometry optimization.

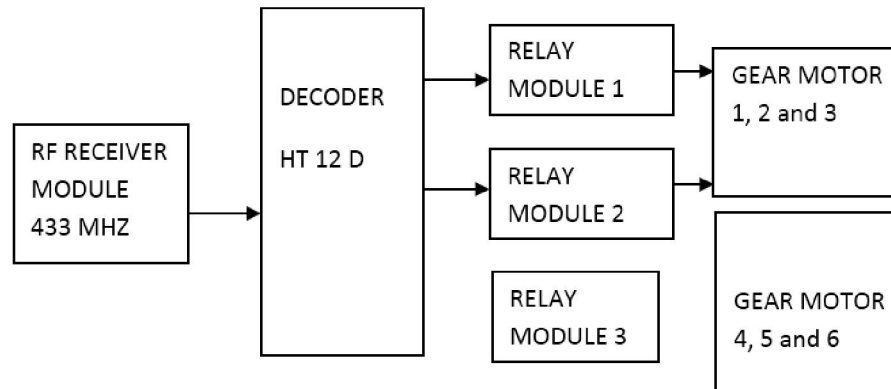
III. METHODOLOGY

The mechanical skeleton consists of two symmetric Rocker-Bogie assemblies mounted on opposite sides of the central chassis body. The primary link (the rocker) is pinned to the chassis using a central pivot, while the secondary link (the bogie) pivots at the terminal end of the rocker arm. This arrangement ensures that as one side encounters an obstacle, the forces are distributed through a differential linkage, keeping the central chassis level. The system is fully motorized, featuring six high-torque 100 RPM DC gear motors directly coupled to the wheel hubs. The electronics rely on a balance of biasing resistors (10kΩ, 470kΩ, 47kΩ, and 1kΩ configurations) paired with standard 1N4148 diodes for signal routing and protection. Switching execution is driven by four BC558 PNP transistors powering a four-channel 12V SPDT relay module.

1] RF TRANSMITTER



2] RF RECEIVER



Wireless Control Logic & Circuit Action:

Block Diagram & System Logic: The electronic control loop is structurally segregated into two autonomous hardware subsystems: the Wireless RF Transmitter Command Unit and the Wireless RF Receiver/Motor Driver Array.

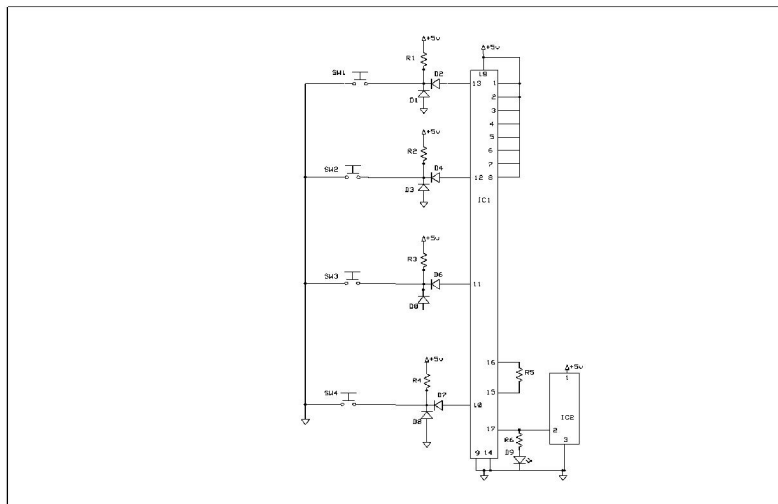
Wireless Transmitter Logic: The interface features four dedicated push-to-on switches (SW1 to SW4). When an operator presses a switch, it completes the path to ground, pulling the corresponding input data pin on the HT12E Encoder IC low. The encoder converts this parallel input state into a continuous serial data stream outputted through Pin 17. This stream directly modulates the 433 MHz RF Transmitter Module, radiating the command data as an electromagnetic wave via its antenna.

Wireless Receiver & Motor Driver Array: The radiated electromagnetic signal is captured by the antenna of the 433 MHz RF Receiver Module, which down-converts the wave back into a serial electrical stream. This serial stream enters Pin 14 of the HT12D Decoder IC. The decoder verifies the transmission security address bits; upon validation, it updates its four parallel output latch pins (Pins 10–13). These latches drive the bases of the BC558 PNP transistors, switching the 12V Relays to route current from the battery pack to the six DC gear motors.

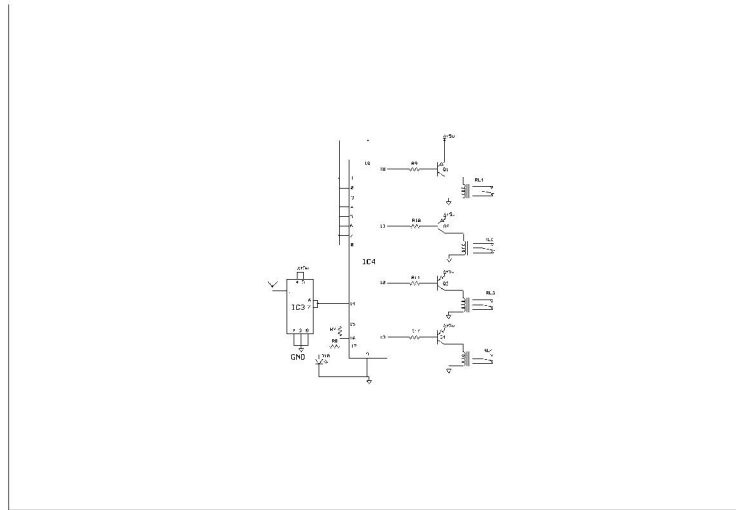
Detailed Circuit Action: The primary transmitter stage centers around IC1 (HT12E). Inputs on Pins 10, 11, 12, and 13 are pulled high using 10k Ω biasing resistors (R1–R4) to prevent floating logic states. Pressing a navigation switch overrides the pull-up resistor, forcing the pin to 0V. The internal oscillator of the encoder is regulated by a 470k Ω resistor (R5) connected across Pins 15 and 16. The generated serial sequence passes to the data pin of IC2 (RF TX), which operates on a +5V regulated rail. At the receiver chassis, IC3 (RF RX) outputs the demodulated serial stream to Pin 14 of IC4 (HT12D). The decoder's internal clock reference is set by a 47k Ω resistor (R8) across Pins 15 and 16. When valid data updates the output latches (Pins 10–13), it drops the base voltage of the corresponding BC558 transistor (Q1–Q4) through a 1k Ω limiting resistor (R9–R12). This activates the transistor, energizing the coil of the target relay (RL1–RL4). The relay contacts switch the heavy 12V DC rail to change the rotation direction or activation states of the left (Motors 1, 2, 3) and right (Motors 4, 5, 6) wheel groups.

IV. CIRCUIT DIAGRAM:

A) RF TRANSMITTER



B| RF RECEIVER



Power Subsystems, Performance:

Core Energy Storage: Lithium-Ion Subsystem While traditional systems rely on heavy lead-acid or bulky nickel-cadmium chemistries, this design uses a high-energy-density Lithium-Ion (Li-Ion) battery pack. The battery subsystem is constructed by wiring three 18650 cylindrical cells in series, producing a nominal operating voltage of 11.1V to 12.6V at full charge.

Li-Ion chemistry uses the reversible reduction of lithium ions between a carbon-graphite anode and a transition metal oxide cathode to achieve superior energy density and low self-discharge rates. To prevent the risks associated with volatile organic carbonate electrolytes, the cell block is monitored by integrated over-charge and deep-discharge protection circuits. The discharge duration (T) is governed by the structural power law:
$$(T) = \frac{\text{Battery Capacity (Ah)}}{\text{Total Motor Current Load (A)}}$$
 By maintaining a tight discharge profile where cell levels do not drop below 3.0V per cell under load, the power subsystem provides uniform torque to the 100 RPM motors without thermal runaway or performance drops.

System Payload Integration: Laser & AV Systems To support tactical defense applications, the chassis carries a high-radiance Semiconductor Laser Diode and an active AV recording webcam module. **Laser Targeting:** The integrated laser diode produces spatially and temporally coherent monochromatic light. Because of this high spatial coherence, the laser beam maintains tight collimation over long distances. This allows the system to mark targets or measure structural clearances accurately during exploration. **AV Reconnaissance:** The onboard AV webcam streams real-time, 360° visual data back to the base station. This gives operators immediate visual feedback during multi-terrain navigation, allowing them to adjust paths safely around obstacles.

Advantages, Disadvantages, & Applications

Advantages: Maintains structural wheel contact over highly uneven terrain. Low cost due to standard IC components. Eliminates complex wiring harnesses through mechanical link stabilization. Low maintenance footprint without springs or hydraulic dampers. **Disadvantages:** Requires periodic battery recharges. Speed is restricted to maintain climbing stability. **Application Areas:** Defensive patrolling in hostile zones, industrial material transport across multi-level facilities, and urban search-and-rescue operations.

V. FUTURE MODIFICATIONS & CONCLUSIONS

The current prototype demonstrates the core capabilities of the Rocker-Bogie chassis layout. Future iterations will replace manual RF switching with autonomous GPS waypoint tracking navigation and an ultrasonic sensor array for automatic obstacle charting. Integrating an SMS transceiver node will also allow the platform to text status alerts directly to remote monitoring stations. In conclusion, this project provides a reliable, cost-effective framework for multi-terrain robotic navigation. By combining the mechanical compliance of the Rocker-Bogie chassis with modern Li-Ion energy storage and simple RF control logic, the system functions as a highly capable platform for tactical defense, industrial freight routing, and hazardous exploration.

REFERENCES

- [1] B.Vilox.T.Nguyen Sojourner on Mars and Lessons for Future Planetary Rovers, ICES, 1997.
- [2] National Aeronautics and Space Administration (NASA) Mars Exploration Rover Landings Press Kit (January 2004)
- [3] P.E. Sandin, Robot Mechanisms and Mechanical Devices Illustrated (Mc GrawHill-New York-2003)
- [4] Farritor S., Haccot S., Dubowsky S., "Physics based Planning for Planetary exploration" proceedings for 1998 IEEE International Conference on Robotics and Automation.
- [5] Chottinjer J.E, 1992, "Simulation of six wheeled Martian rover called Rocker Bogie", MSt thesis the Ohio State University, Columbus, Ohio