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CASE STUDY REPORT

BEAM ROBOTICS

XCSHA -3

INTRODUCTION TO MEACHINE LEARNING

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Introduction:

BEAM robotics—standing for Biology, Electronics, Aesthetics, and Mechanics—is a minimalist approach to building autonomous robots. Instead of relying on microcontrollers and complex programming, BEAM robots use simple analog circuits, recycled components, and direct sensor-to-actuator connections to generate behavior.

Typical BEAM robots include photovores (light-seeking robots), symets (simple solar-powered movers), and walkers. They are designed with the philosophy of "form follows function", favoring simplicity, ruggedness, and low power consumption. Central to BEAM is the Nv neuron circuit, which mimics biological neurons by producing pulses and time-based signals that drive motors and behaviors.

History of BEAM Robotics:

- Late 1980s–1990s: BEAM robotics was pioneered by Mark W. Tilden at the University of Waterloo and later at Los Alamos National Laboratory. He promoted BEAM as "living machines" inspired by biology and physics.

- 1992: A.K. Dewdney introduced BEAM robots ("photovores") in Scientific American, sparking widespread hobbyist interest.

- 1990s–2000s: BEAM spread through communities, workshops, and companies such as Solarbotics, which released kits and reference circuits like the Miller Solar Engine (MSE).

- Philosophical Roots: BEAM's emphasis on reactive, layered behaviors parallels Rodney Brooks' subsumption architecture, which showed that simple reactive behaviors can yield complex, lifelike outcomes.

Literature Review:

Foundational Works

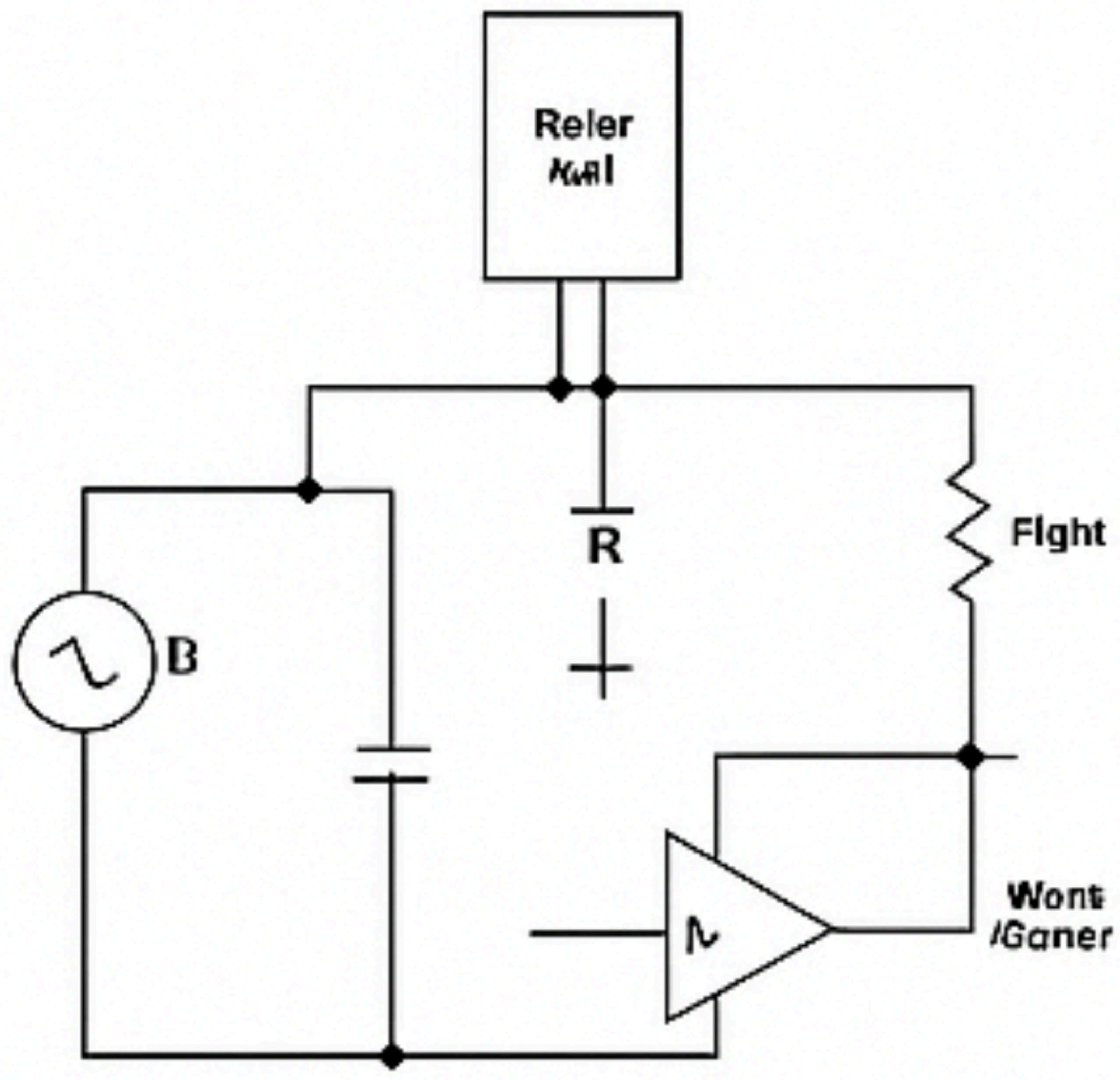
- Junkbots, Bugbots & Bots on Wheels (Hrynkiw & Tilden, 2002): The definitive hands-on BEAM guide, with practical circuits and scavenged parts.

- Solarbotics BEAM Reference Library: Provides detailed documentation of BEAM circuits such as solar engines and Nv neurons.

Principles of BEAM Robotics:

1. Direct coupling: Sensors feed actuators directly, minimizing processing layers.
2. Nv neurons: RC-based timing circuits mimic biological spiking neurons to control motor patterns.
3. Energy-first design: Solar engines harvest energy and release it in bursts, ensuring ultra-low-power autonomy.
4. Form follows function: Robot behavior emerges from the integration of mechanical design and circuitry.

Diagram:



BEAM Photovore Circuit

Problem Statement:

Modern robotics often relies heavily on microcontrollers, complex programming, and high-power electronics to achieve autonomous behavior. While effective, this approach can make robots expensive, energy-hungry, and difficult for beginners to build or maintain. In contrast, BEAM robotics provides a minimalist alternative that uses simple analog circuits, solar energy, and recycled parts to create lifelike, autonomous machines without programming.

Lack of formal benchmarking against microcontroller-based robots in terms of energy efficiency and robustness.
Limited availability of modern component replacements for obsolete BEAM circuits (e.g., 1381 supervisors).
Scattered documentation that makes it difficult for newcomers to replicate or study BEAM designs systematically.

Introduction:

BEAM Robotics (Biology, Electronics, Aesthetics, and Mechanics) is a field of robotics that focuses on simple, efficient, and nature-inspired robot designs. Unlike traditional programmable robots, BEAM robots often rely on analog circuits, solar power, and minimalist designs to achieve tasks such as movement, sensing, and interaction with the environment.

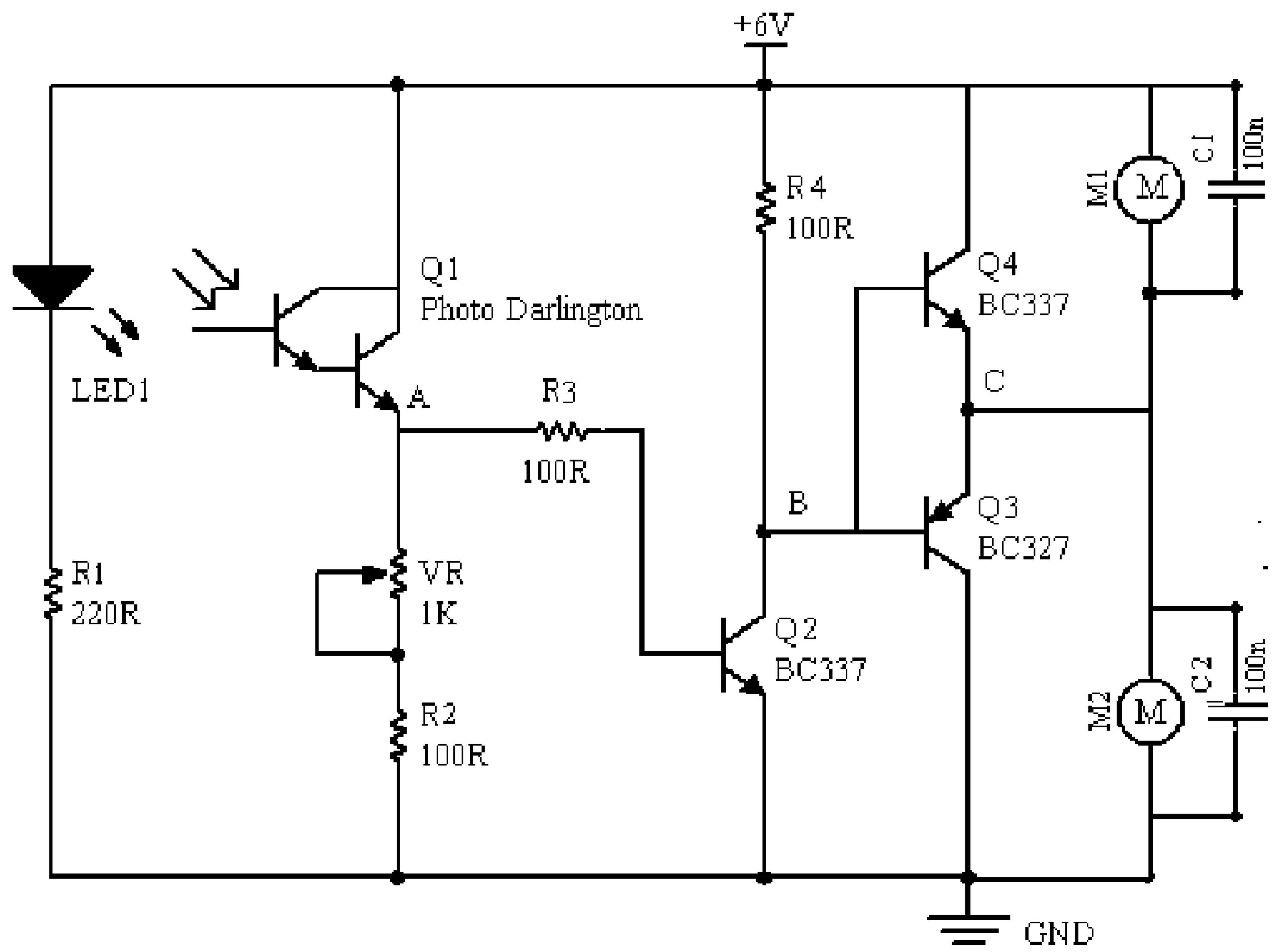
This case study explores two types of BEAM robots

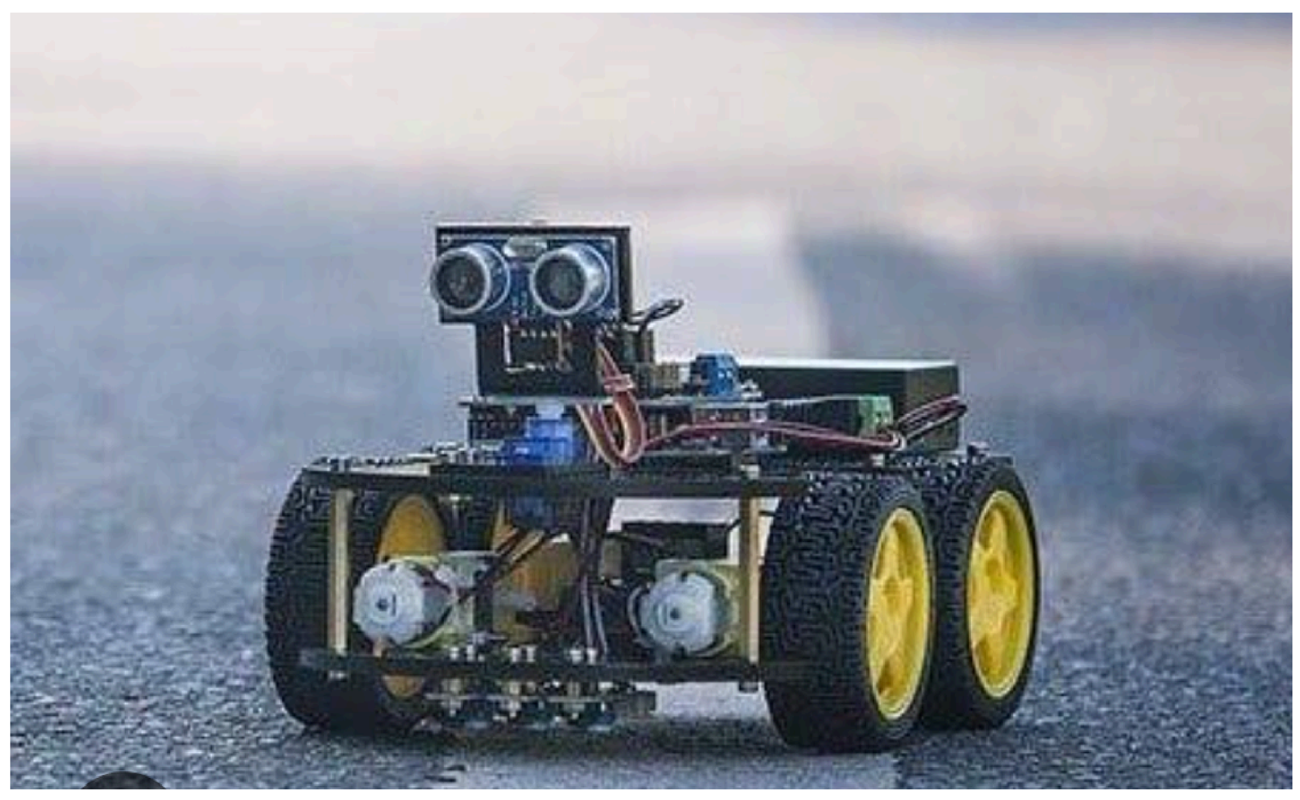
1. Straight-Line Robots
2. Obstacle-Avoiding Robots

1. Straight-Line BEAM Robots

Straight-line BEAM robotsaredesigned to move in a single linear path. Their primary function is to travel forward without deviation using very simple circuitry.

Circuit diagram :

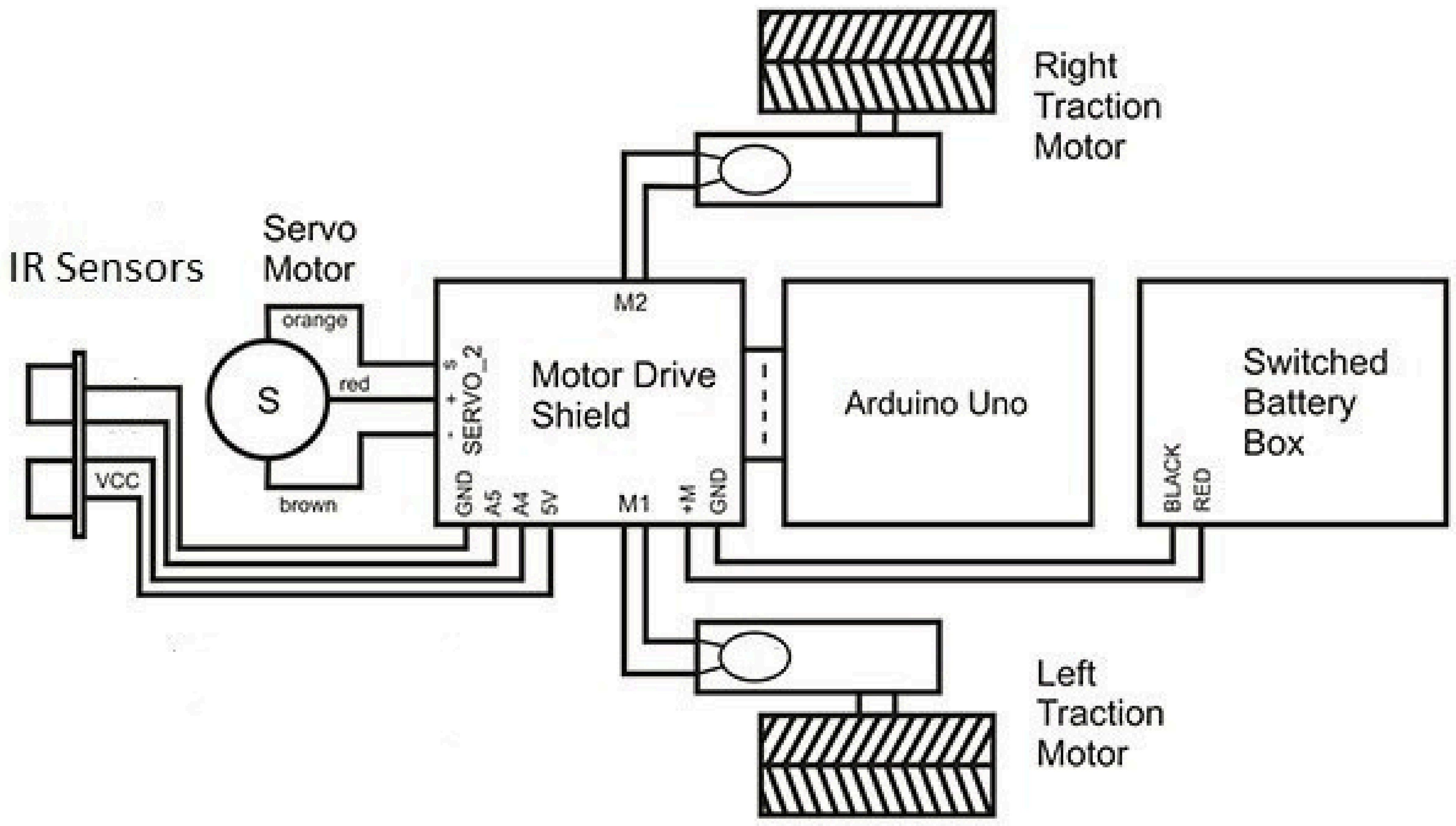




Working principle:

The capacitor charges through the solar cell and resistor. When sufficient voltage is reached, it triggers the transistor Q1, allowing current to flow to the motor. This results in periodic bursts of forward motion, enabling straight-line travel.

Block diagram:



Applications:

- Educational projects for beginners.
- Demonstrations of BEAM principles in workshops.
- Simplemotion demonstrations powered by solar energy.

Advantages:

- Simple construction.
- Low cost and energy-efficient.
- Illustrates capacitor charging and transistor switching concepts.

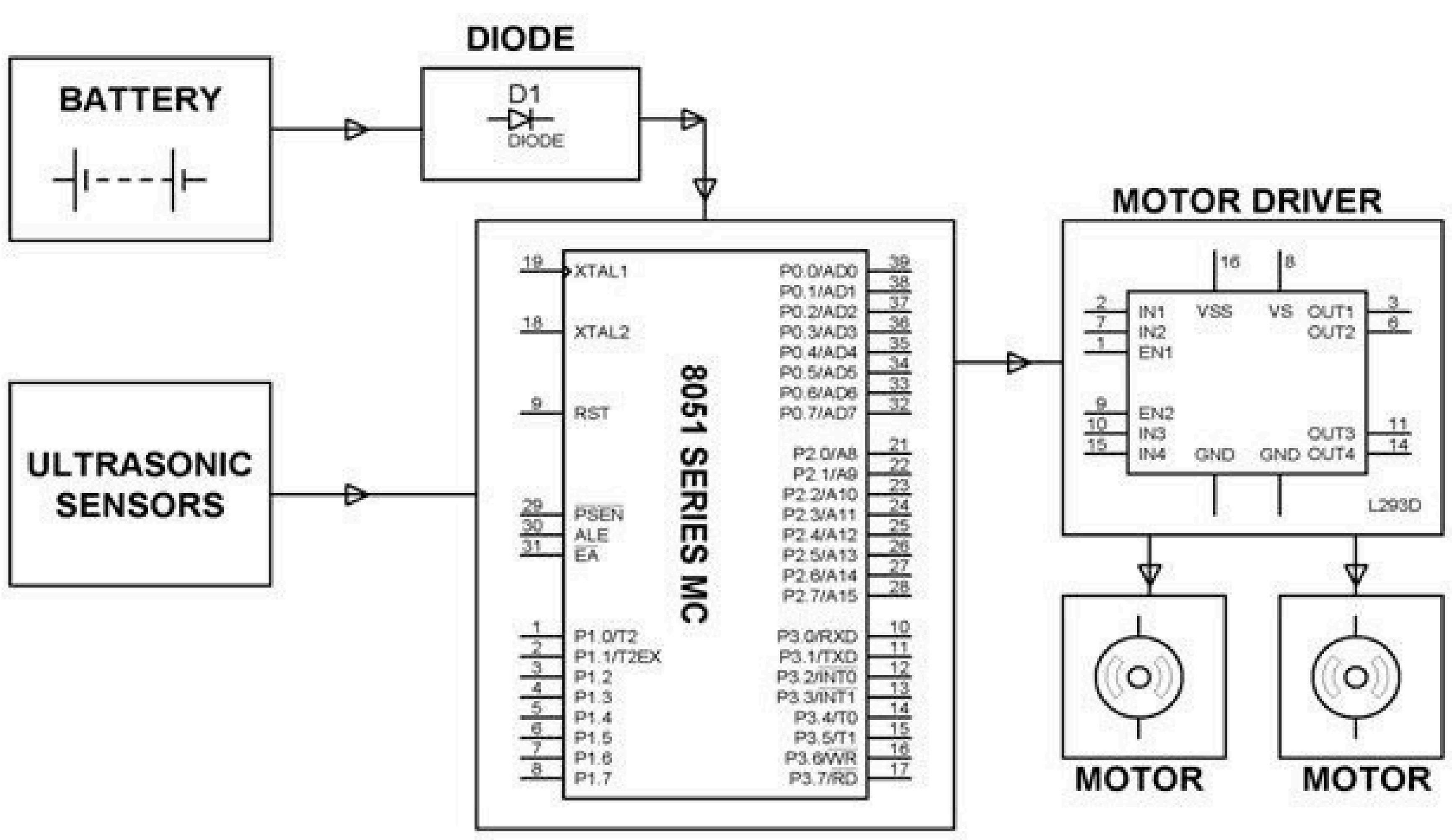
Limitations:

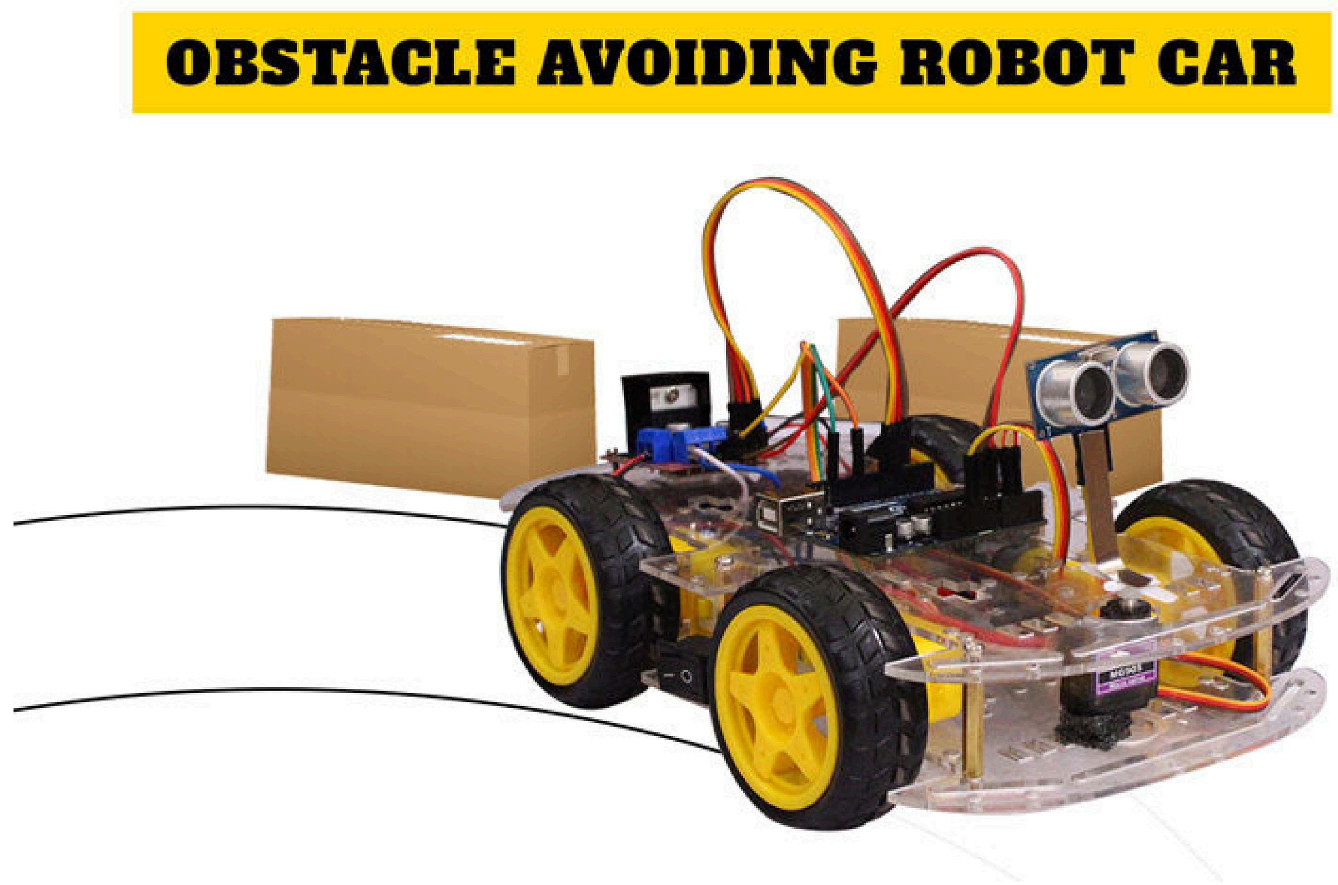
- Cannot adapt to obstacles.
- Limited to controlled or open environments.

2. Obstacle-Avoiding BEAM Robots

Obstacle-avoiding BEAM robots are designed to detect and navigate around objects in their path. The circuit introduces additional feedback elements to alter motor behavior when obstacles are encountered.

Circuit diagram :

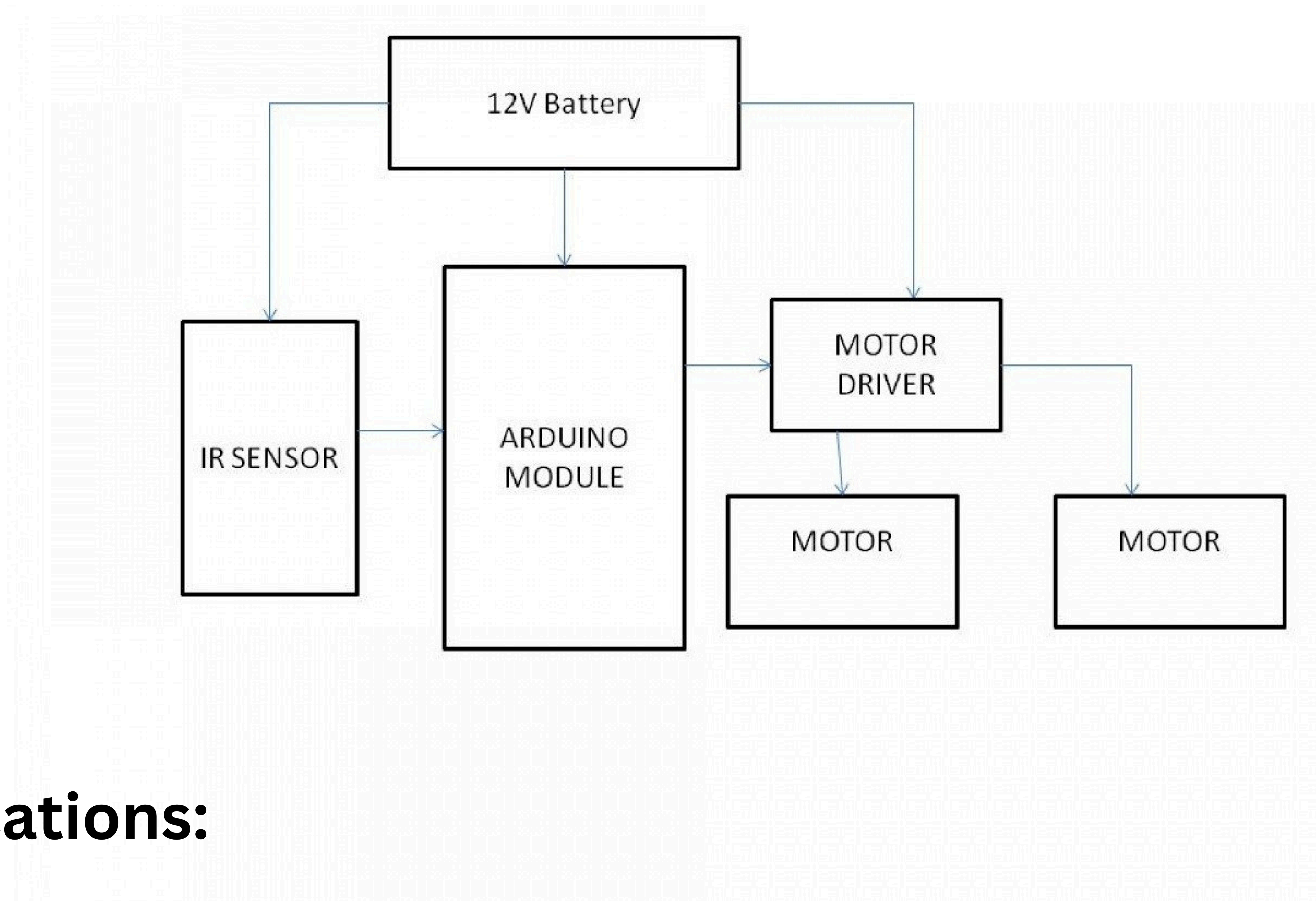




Working principle:

The timing network charges and triggers the transistor as in the straight-line robot, but the added feedback resistor alters the motor response when obstacle sensors (such as whiskers or bump switches) interact. When an obstacle is detected, the motor response changes direction or stops briefly, allowing avoidance.

Block diagram :



Applications:

- Exploration in unknown environments.
- Demonstrations of autonomous navigation.
- Foundation for more advanced adaptive robots.

Advantages:

- Capable of adapting to environmental changes.
- Demonstrates feedback-based motion control.
- Good for learning autonomous robot design principles.

Limitations:

- Limited intelligence compared to microcontroller-based robots.
- Works best in simple obstacle scenarios.

solution :

To overcome the lack of benchmarking, a simple evaluation framework can be developed to compare BEAM and microcontroller-based robots on energy efficiency, runtime, and robustness using standardized tasks like line-following or obstacle avoidance. For the issue of obsolete components, modern replacements and adapter modules can be identified and documented, ensuring that classic BEAM circuits remain buildable with widely available parts. Finally, to tackle scattered documentation, a structured open-source handbook with step-by-step guides, annotated circuits, and simulation files can be created, making BEAM robotics more accessible and reproducible for learners and hobbyists.

Conclusion:

Both straight-line and obstacle-avoiding BEAM robots demonstrate robotics fundamentals using minimalist analog circuits. The straight-line robot showcases basic energy storage and release concepts for simple forward motion. The obstacle-avoiding robot introduces adaptive behavior using feedback, making it more versatile and interactive. Together, these designs provide excellent educational value and highlight the BEAM philosophy of simplicity, efficiency, and biomimicry.