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CASE STUDY REPORT

BEAM ROBOTICS

XCSHA -3

INTRODUCTION TO MACHINE LANGUAGE

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INTRODUCTION:

BEAM (Biology, Electronics, Aesthetics, Mechanics) robotics is a field of robotics that uses simple analog circuits and minimal processing to mimic natural behaviors of living organisms. Unlike advanced microcontroller-based robots, BEAM robots rely on solar cells, motors, and simple sensors to interact with the environment.

- This case study examines two BEAM robots:
- Obstacle-Avoiding Robot (navigates around barriers)
- Straight-Line Robot (moves in a fixed direction)

HISTORY OF BEAM ROBOTICS:

Origin (1980s – 1990s)

BEAM robotics was developed by Mark W. Tilden, a robotics physicist.

In the late 1980s, while working at the University of Waterloo (Canada), Tilden wanted to design robots that were simple, low-cost, and energy-efficient, unlike expensive computer-controlled robots.

2. Philosophy

Inspired by biology and natural creatures (insects, animals, plants).

Focused on minimalism: using analog circuits instead of microcontrollers.

Goal: show that complex behaviors can emerge from simple systems.

3. Development (1990s)

Tilden created many famous BEAM robots, such as photovores (light-seeking robots) and walkers (insect-like robots).

The robots were often solar powered, using “solar engines” (circuits that stored solar energy and released it to motors).

BEAM gained popularity among hobbyists, students, and researchers.

4. Spread and Popularity (2000s)

BEAM robotics became a big part of educational kits and DIY robotics.

Simple BEAM robots were sold as toys and science projects.

Robotics clubs and competitions included BEAM robot challenges.

LITERATURE REVIEW:

Core Circuit Archetypes

Solar engines (SE): charge–dump circuits that store energy (capacitor) and periodically release it to motors; foundational for ultra-low-power walkers/symets.

Nv "neurons" / relaxation oscillators: simple transistor networks that generate motor timing and left/right alternation for walkers and steerers.

H-bridges & driver stages: discrete transistor/MOSFET stages for bidirectional motor control without microcontrollers.

PRINCIPLES OF BEAM ROBOTICS:

Simplicity: Achieve lifelike behavior with the fewest components possible.

Decentralization: No central brain; behavior emerges from local sensor–motor interactions.

Energy efficiency: Often solar-powered, designed for low energy consumption.

Robustness: Few components = fewer chances of failure; robots keep working in rough conditions.

Adaptivity: Robots react directly to their environment without pre-programmed logic.

PROBLEM STATEMENT — BEAM STRAIGHT-LINE ROBOT:

Create a BEAM straight-line robot that travels as close to a straight path as possible using matched motors and a simple analog driver/solar engine—no digital control or feedback loops.

Objectives:

1. Minimize lateral drift via mechanical symmetry and electrical balancing.

2. Ensure smooth energy delivery (e.g., solar engine storage/trigger tuning).

3. Document how mechanical tolerances affect drift.

Constraints: purely analog; identical (or trimmed) motors; fixed wheel/axle geometry; low mass.

Success Criteria (measurable):

- Lateral drift ≤10 cm over 5 m on a flat surface;
- Repeatability: ≤20% variance across five runs;
- Continuous operation >20 min on ambient light/battery.

INTRODUCTION:

BEAM (Biology, Electronics, Aesthetics, Mechanics) robotics is a branch of robotics that focuses on building simple, efficient, and biologically inspired robots using analog circuits and minimal components. Unlike microcontroller-based robots, BEAM robots rely on direct sensor-to-motor connections and solar or battery power to achieve lifelike behaviors.

A Straight-Line BEAM Robot is a fundamental design that demonstrates how simple analog circuitry, balanced mechanics, and minimal energy can be combined to achieve stable directional movement without programming. This design is particularly valuable in education and research, as it shows how symmetry and low-power electronics can be used to replicate purposeful behavior in robotics.

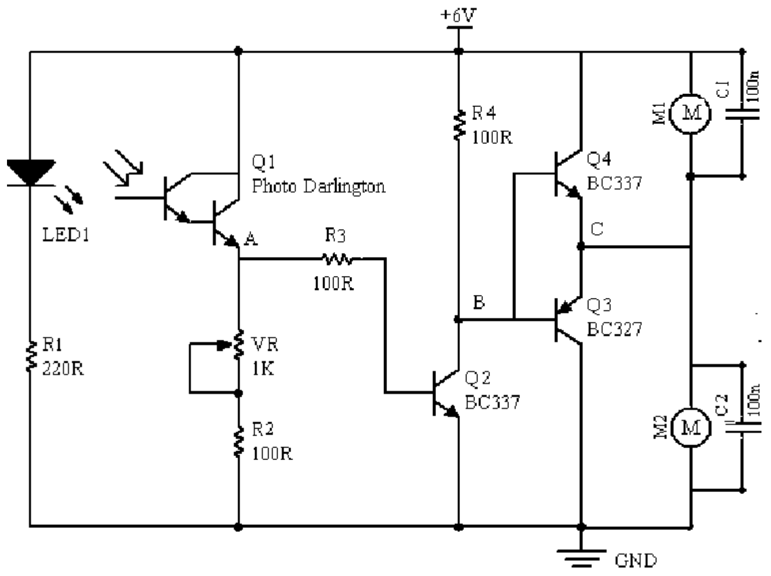
This case study explores two types of BEAM robots:

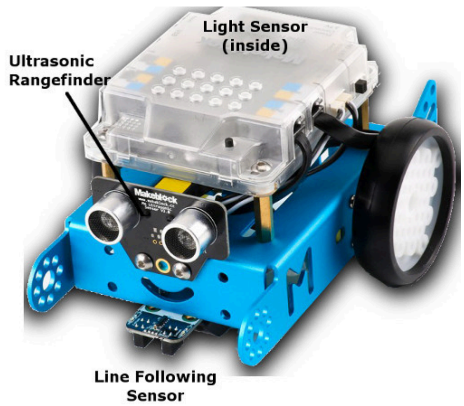
- Obstacle-Avoiding Robot
- Straight-Line Robot

1.STRAIGHT-LINE ROBOT:

A BEAM robot designed to travel in a stable straight path using mechanical symmetry and balanced motor control. It demonstrates how purposeful motion can be achieved without programming or microcontrollers.

CIRCUIT DIAGRAM:

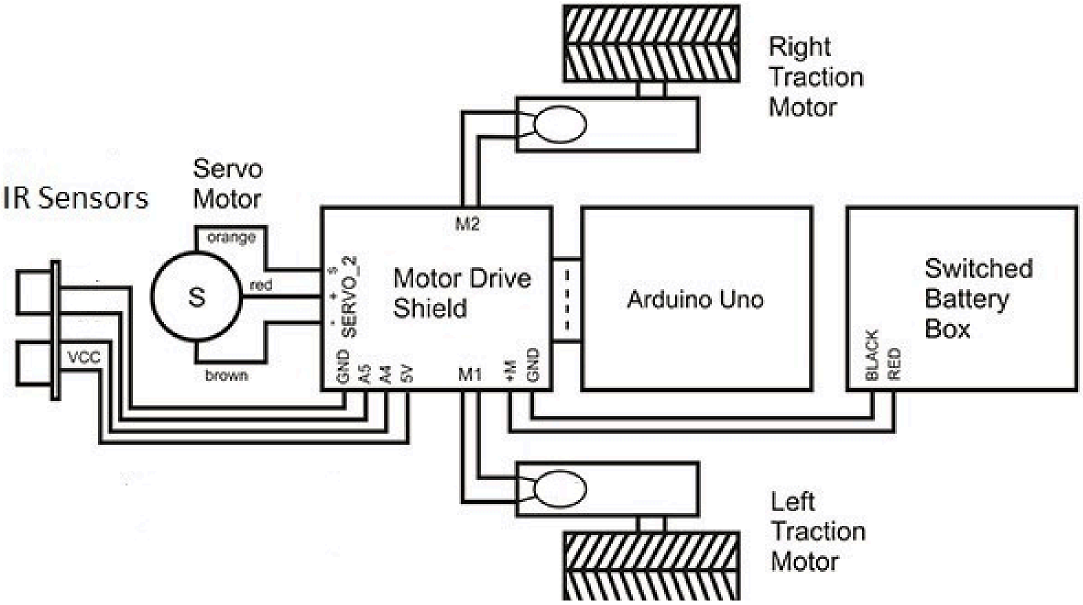




WORKING PRINCIPLE:

The BEAM straight-line robot operates on the principle of mechanical and electrical symmetry. It is powered either by a solar cell with a simple solar engine circuit or by a small battery. The stored energy is released to two identical DC motors, each connected to a wheel on either side of the robot. Since both motors receive equal voltage and current, they rotate at nearly the same speed and torque, which drives the robot forward in a straight path. The mechanical design ensures proper alignment of wheels and axles, while electrical balancing (such as resistors or trimming) compensates for minor mismatches between the motors. Unlike microcontroller-based robots, the BEAM straight-line robot does not rely on programming or feedback systems; instead, its straight motion emerges naturally from the symmetry of its design and the equal distribution of power

BLOCK DIAGRAM:



APPLICATIONS:

Educational tool – helps students understand basic robotics, electronics, and mechanics without programming.

Research prototypes – used in bio-inspired robotics and energy-efficient mobility studies.

Demonstrations & exhibitions – shows how simple circuits can achieve purposeful motion.

Toy and hobby projects – simple, low-cost robots for hobbyists.

Solar-powered vehicles – small models to demonstrate renewable energy applications.

ADVANTAGES:

Simplicity – requires very few components, easy to build and maintain.

Low cost – inexpensive compared to microcontroller-based robots.

Energy efficient – often solar powered, with very low power consumption.

Durable and robust – fewer electronic parts means fewer chances of failure.

Programming-free – works without coding, purely based on analog circuits.

LIMITATIONS:

Limited intelligence – cannot adapt beyond its fixed straight-line behavior.

No feedback system – drift correction is only mechanical/electrical, not dynamic.

Dependent on motor and wheel matching – small differences cause deviation.

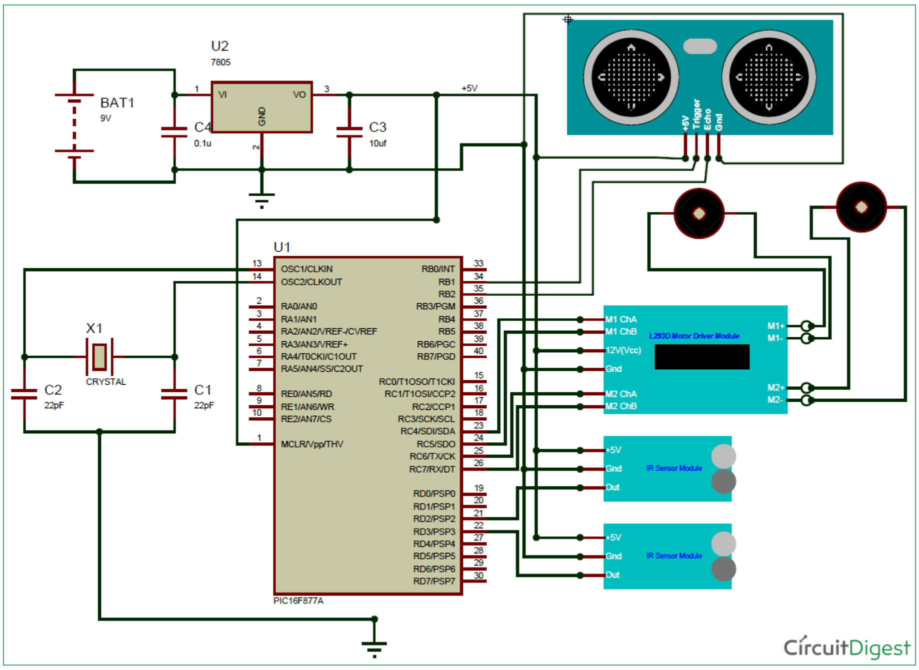
Restricted functionality – cannot perform complex tasks or navigation.

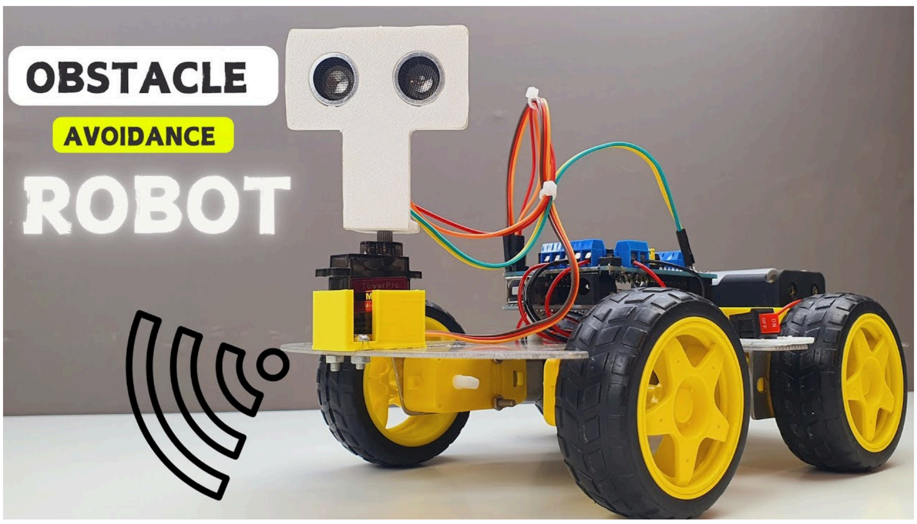
Surface dependent – works best on smooth, even floors; performance drops on rough terrain.

2.OBSTACLE-AVOIDING BEAM:

A BEAM robot designed to travel in a stable straight path using mechanical symmetry and balanced motor control. It demonstrates how purposeful motion can be achieved without programming or microcontrollers.

CIRCUIT DIAGRAM:

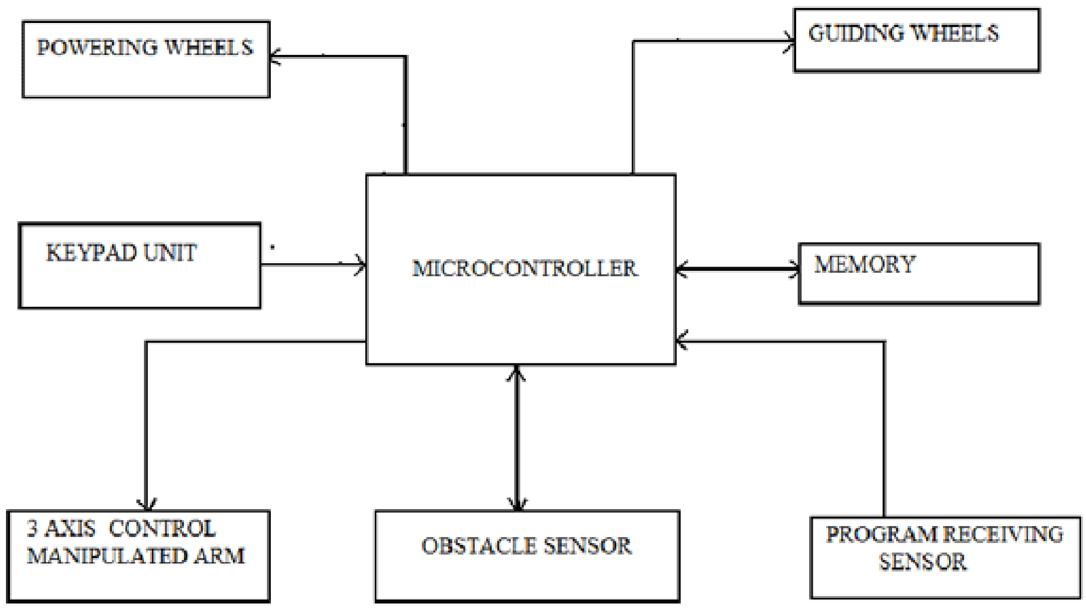




WORKING PRINCIPLE:

The BEAM obstacle-avoiding robot uses simple sensors like whiskers or light detectors connected directly to its motors. When an obstacle is detected, the circuit changes motor movement so the robot turns away. Once clear, both motors run forward again. The robot avoids obstacles through analog reflex circuits without any programming.

BLOCK DIAGRAM:



APPLICATIONS:

Educational kits and learning tools

Hobby and DIY robotics projects

Demonstrations of bio-inspired behavior

Small solar-powered robots and prototypes

ADVANTAGES:

Simple and low-cost design

Energy-efficient (often solar powered)

Durable and robust with few components

No programming required

LIMITATIONS:

Limited intelligence and adaptability

Cannot perform complex tasks

Behavior fixed by circuit design

Sensitive to mechanical or motor mismatches

SOLUTION:

The solution for the BEAM Straight-Line and Obstacle-Avoiding Robots relies on simple analog circuits and minimal components to achieve purposeful motion. The Straight-Line Robot uses a solar engine or battery to power two identical DC motors, and its mechanical symmetry in wheel size, axle alignment, and weight distribution ensures stable forward movement. Minor differences between motors can be corrected using resistors or trimming adjustments, eliminating the need for programming or feedback systems. The Obstacle-Avoiding Robot, on the other hand, is equipped with tactile whiskers or light sensors directly connected to the motor drivers. When an obstacle is detected, the circuit alters the motor operation, causing the robot to turn away, and resumes forward motion once the path is clear. Both robots demonstrate how behavior can emerge from simple sensor–motor interactions without the use of microcontrollers.

CONCLUSION:

In conclusion, this case study shows that BEAM robotics is an effective approach for creating adaptive and purposeful robotic behaviors using minimal components. The Straight-Line Robot highlights stable, energy-efficient motion achieved through mechanical and electrical symmetry, while the Obstacle-Avoiding Robot demonstrates reflexive adaptation to the environment. Although these robots have limitations in intelligence and task complexity, they are highly valuable for educational purposes, hobby projects, and basic research, illustrating how bio-inspired principles, simplicity, and low-power analog circuits can replicate lifelike behavior in robots.