Hybrid Control of a Simple Walking Autonomous Robot

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Abstract

A very simple walking robot based on the BEAM (Biology Electronics Aesthetics Mechanics) model of design and control was developed. This robot uses a simple design based on single neurons to drive servo motors and propel the vehicle quickly across many surfaces. This paper describes the design steps and results of this robot.

1. Introduction

Robots are great tools. They do repetitive tasks flawlessly and cheaply. Robots do things that humans would rather not or cannot do, and an application growing in popularity is using them for exploration and mapping. Whether the robot is mapping a mine field or doing science on Mars, the robot consists of two main parts; the base of the robot and the brain of the robot. The base consists mainly of the systems dealing with locomotion and the brains will do the science, mapping or other needed tasks. The base generally requires a good bit of processing power to control the motors and obstacle sensors. A better robot would use a smart base; one that can take care of itself, yet is still controllable to some extent. For this proof of concept project, a simple smart base was created using BEAM technology. The base was controlled by a simple radio control unit as well as an ATtiny2313 programmable chip.

2. BEAM Robotics

BEAM is considered a small hobby branch of robotics. Created by Mark Tilden, BEAM robotics is based on the concept of using biology as an inspiration for robotics [1-6]. The goal is to create autonomous robots controlled by simple logic chips instead of processors. To get a four-legged, two-motored robot to walk is generally no easy task. Making it walk in a straight line isn't incredibly hard; however, adding other behaviors such as turning and reversing while adjusting to motor strain would soon take more time than it is worth to program. To conquer these problems, BEAM robots of the walking variety use NV neurons. Instead of a robot whose brain is directly attached to its legs, BEAM robots have no brain at all and use a ring of NV neurons to simulate a spinal cord.

3. Implementation

Neurons are linked and looped together to form a grounded bicore. The grounded bicore is a reflexive circuit with outputs that oscillate inversely. This is a very simple circuit that on its own cannot do a lot, but the simplicity of the circuit hides the complexity of its function. Placing a gearmotor between the outputs will cause it to spin back and forth with a roughly 50 percent duty cycle. The tolerance of the capacitors and the resistors can throw off this duty cycle a bit, making the motor spin more in one direction than the other. Investigating this behavior, it was found that the load on the motor would also cause a change in the duty cycle. This is caused by the motor changing the amount of current pulled by the motor on each half-turn. This allows the robot to become reactive to its environment. The circuit will spin the motor in such a way that the path of least resistance is followed. This allows the robot to pick the best walking gait for different surfaces it may encounter on the fly. Try programming that in as little time as it takes to breadboard this circuit.

Combining the two resistors in the circuit to create a “floating bicore” makes it more reactive to the load of the motor. Attaching another (slave) bicore to the output of the first (master) bicore allows control of a second motor. These two motors are all that is needed to build a simple walking BEAM robot. Tracing the timing of this circuit, the slave motor will move approximately 90 degrees out of phase with the master.

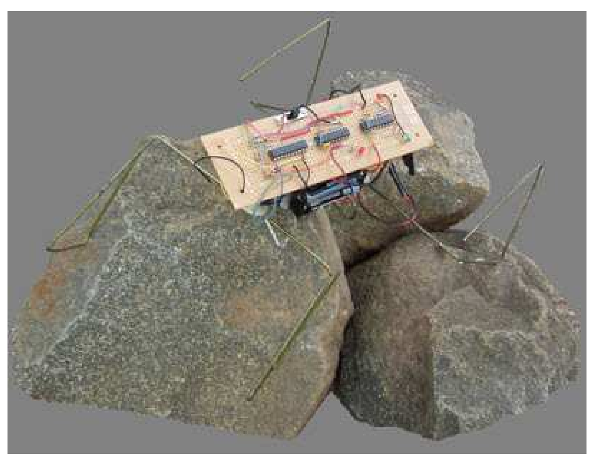

Figure 1: The finished robot in action

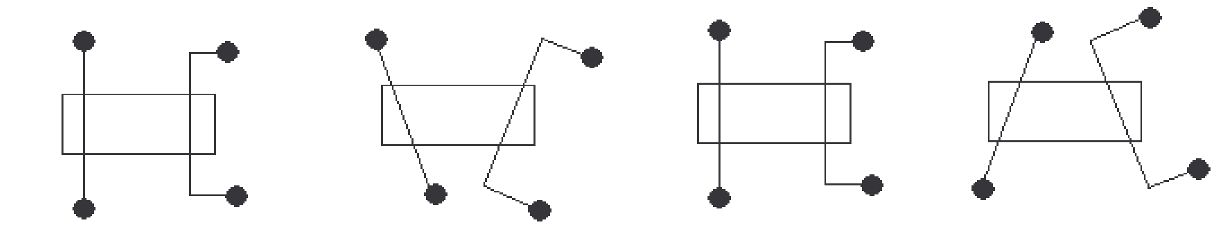

Figure 2: Diagonal appendages move together

A smart base for a robot would need sensors to help it avoid obstacles. This robot will use a simple dual bi-directional inverting multiplexer designed by BEAM builder Tom Gray. If either of the sensors are hit, it will cause the robot to reverse and turn in the opposite direction of the stimulus. Hitting both reverse sensors at once causes the robot to reverse straight back.

Leg mechanics become a big deal at this point. The legs must be arranged in such a way that the oscillation of the motors cause the desired movement in the robot. Mark Tilden's papers "The Design of 'Living' Biomech Machines:" and "Controller for a Four Legged Walking Machine" shed a lot of light on this subject. The diagonal appendages move in the same direction at the same time, as shown in Figure 2.

The front legs pull the body up slightly, and the back legs simply propel the robot forward. This is achieved by allowing the back legs to oscillate parallel to the ground and setting the front legs at about a 35 degree angle as shown in Figure 3 [5]. This gives the robot pulling power with the front motor, while also picking the front of the robot off the ground so the back legs can move forward.

For forward directional control, signals will be introduced into the master bicore. By putting an assembly of opposing diodes in series with resistors and switches in parallel with the master timing resistor, the robot will turn left or right while going forward when the appropriate sensor is hit. At this point the base, a complete autonomous BEAM robot with full directional control has been finished (see Figure 4).

To give other circuits access to the sensors, a Maxim MAX394 was added with its switches in parallel with the mechanical sensors to interface the control circuits. (Figure 4) A CD4016 would have been a better choice, but the Maxim chip was used based on availability. The control circuits used here are an RF controller and an ATtiny2313.

The RF controller used in this proof of concept was a hacked mini RC car toy. The receiver was tested and modified slightly. The outputs were buffered using a 74HC14 and the whole assembly was treated as a black box and was connected to the MAX394 inputs. When a button was pushed on the transmitter, the corresponding output on the receiver went high, triggering the switch in the MAX394.

When connected to the AtTiny2313, the mechanical sensors can be disconnected from the BEAM base and rerouted to the inputs of the AtTiny, thus allowing the AtTiny to use the sensor information directly in the program it is running. The outputs of the AtTiny are connected to the inputs of the MAX394 to control the BEAM base. Since timing isn't a big issue, the internal AtTiny oscillator is used.

4. Conclusions

This proof of concept works quite well. While only one control method can be used at a time, it proves the premise that a smart base controlled by either pre-programmed or RF signals.

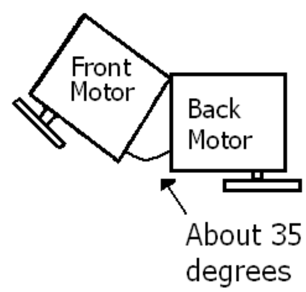

Figure 3: Mechanical relationship between motors.

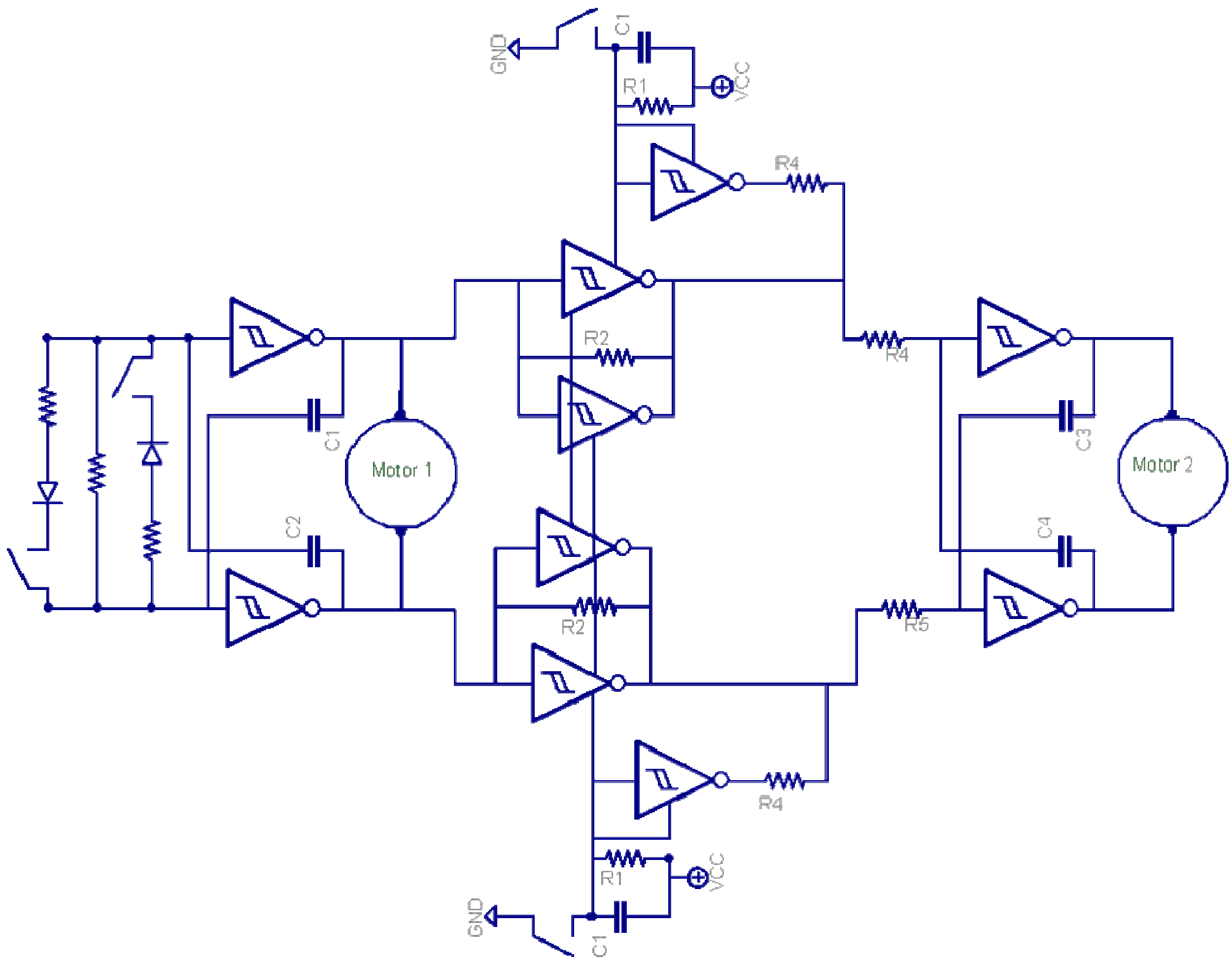

Figure 4: The complete BEAM base

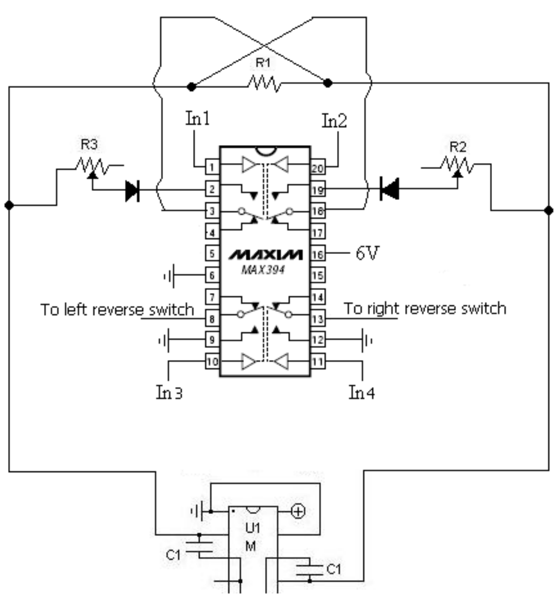

Figure 5: Inputs of the MAX394 are connected to the outputs of the control circuits

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- Tom Gray http://beamdream.solarbotics.net/
- Al Celetti, Wilf Righter, Paul T. Barton, Solarbotics.com and everyone at the Yahoo BEAM group
  http://groups.yahoo.com/group/beam/

5. References

[1] Solarbotics, Inc., "Connecting Nv Nets" http://bftgu.solarbotics.net/starting_nvnet_connect.html

[2] Wilf Righter, "Tom Gray's Junkbot Walker", http://www.solarbotics.net/library/circuits/bot_walker_grayJunkbot.html

[3] Mark Tilden, "Design of Living Biomech machines", http://www.solarbotics.net/library/pdflib/pdf/DesignOfLivingBiomechMechns.pdf

[4] Susanne Still and Mark Tilden, "Control for a Four Legged Walking Machine"

http://www.solarbotics.net/library/pdflib/pdf/stirling97_still_tilden.pdf

[5] Solarbotics Scoutwalker III http://www.solarbotics.com/products/k_w3/

[6] James M. Conrad, and Mark van Dijk, "BEAMStiquito," *Circuit Cellar Ink*, pp. 10-12, Issue 120, July 2000.

Additional Suggested Reading:

“The Suspended Bicore (for Dummies)” By: Wouter Brok http://www.solarbotics.net/library/pdflib/pdf/suspbicr.pdf

"Autonomous Biomorphic Robots as Platforms for Sensors" By: Mark Tilden, Brosl Hasslacher, Ronnie Mainieri, and John Moses http://www.solarbotics.net/library/pdflib/pdf/auto_bio_rob_platforms.pdf

"Coupled Bicores, Firts Experiments" By: Wouter Brok http://www.solarbotics.net/library/pdflib/pdf/brok_coupled_bicores.pdf

"Living Machines" By: Mark Tilden and Brosl Hasslacher http://www.solarbotics.net/library/pdflib/pdf/living_machines.pdf

"On the Reliability of Nervous (NV) Nets" By: Valeriu Beiu, Jan R. Frigo, and Kurt R. Moore
http://www.solarbotics.net/library/pdflib/pdf/nv_net_reliability.pdf