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DESIGN AND DEVELOPMENT OF LINE FOLLOWING ROBOTS USING H-BRIDGE CONTROL HARDWARE AND AT 89C2051 MICROCONTROLLER WITH DIFFERENTIAL STEERING SYSYEM

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ABSTRACT

The line following robot, operates as the name specifies. It is programmed to follow a dark line on a white background and detect turns or aviations and modify the motors appropriately. The sensor is an array of commercially available IR reflective type sensors. The core of the robot is the ATMEL microcontroller. The direction control is provided by 2 I/O pins. The H-Bridge motor driving/control chip takes these signals and translates it into current direction entering the motor armature. The motors require separate supply for operation. In this system, each back wheel has a dedicated motor while the front wheels are free to rotate. To move in a straight line, both the motors are given the same voltage (same polarity).

These signals (from each photo-reflective sensor) are given to the output of the microcontroller. The control has 4 modes of operation, turn left/right and move left/right. The actual action is caused by controlling the direction of the two motors (the two back wheels), thus causing a turn. The actual implementation is a behavior based (neural) control with the sensors providing the inputs. The robot can also be programmed to find the line by pseudo-random movements.

Keywords: H-Bridge Motor Control, ATMEL Microcontroller, IR.Sensors , Crystal Oscillator .

1. INTRODUCTION

The word "robot" originates from the Czech word for forced labour. Robots are electronic devices intended to perform a desired function. Robots may never make it to our kitchens or living rooms as personal slaves, but they certainly have made their way to the manufacturing industry, aero-space industry, and yes to the work benches of robotic hobbyists. Robots are now working in dangerous places, such as nuclear disposal, space explorers, fire fighting, etc. Robots have the potential to change our economy, our health, our standard of living, our knowledge and the world in which we live. As the technology progresses, we are finding new ways to use robots. Each new use brings new hope and possibilities, but also potential dangers and risks. Robotics is not only a science, but it is also an art. The robot, we build reflect the ideas and personalities we portray. There are many different versions of robots that can be made. From turtle robots to vehicles like the Mars rovers to rovers like R2-D2. From walkers that have anywhere from 1 to 10 legs to robotic arms to androids. Whatever you can dream, you can create. We have seen how ants always travel in a line, following an invisible route in search of food, or back home. How on roads we follow lanes to avoid accidents and traffic jams. Ever thought about a robot which follows line? A perfect or near perfect mimic of mother-nature? After all the purpose of robotics is to recreate in terms of machines what we see around to solve a problem or fulfill a requirement.

1.2. RELIABILITY

In the industry carriers are required to carry products from one manufacturing plant to another which are usually in different buildings or separate blocks. Conventionally, carts or trucks were used with human drivers. Unreliability and inefficiency in this part of the assembly line formed the weakest link. The project is to automate this sector, using carts to follow a line instead of laying railway tracks which are both costly and an inconvenience.

2.2 CCD cameras

The first idea was to use optical imaging (CCD cameras) to see the line. This was later given up due to various reasons including complexity and unavailability of components. Later a choice was made to use sensors which solved most of the problems pertaining to complexity. The resistor values used in the sensor were experimentally determined rather than theoretical mathematical design calculations. This was done as the data sheets of the proximity sensor was not available anywhere and most of the parameters had to be determined experimentally. The chip is used as it was a much better option than forming an H-Bridge out of discrete transistors, which would make the design unstable and prone risk of damage. The ATMEL microcontroller was used as it is the only device we have a full practical knowledge about, and most of all a RISC processor which are better suited for real-time operations. Extra hardware was added to let the robot know if it is on a surface or not. This helps it from not running off a table or preserving battery if manually lifted off the floor. Software was coded, deciding on a few algorithms and few tiny details which gradually got the robot to do what was required..

3.1. THE DIFFERENTIAL STEERING SYSTEM

The differential steering system is familiar from ordinary life because it is the arrangement used in a wheelchair. Two wheels mounted on a single axis are independently powered and controlled, thus providing both drive and steering. Additional passive wheels (usually casters) are provided for support. Most of us have an intuitive grasp of the basic behavior of a differential steering system. If both drive wheels turn in tandem, the robot moves in a straight line. If one wheel turns faster than the other, the robot follows a curved path. If the wheels turn at equal speed, but in opposite

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directions, the robot pivots.

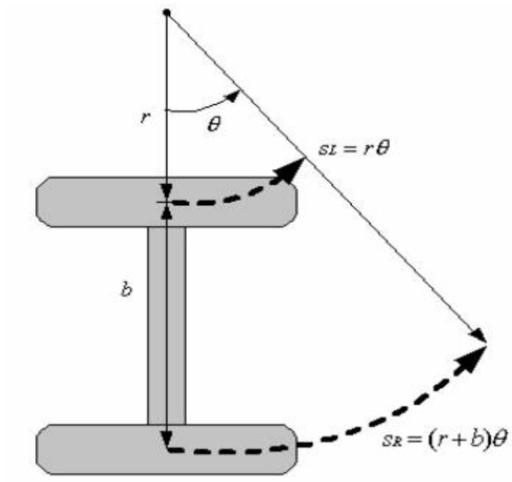

Figure 3.1: The Differential steering model

$$s_L = r\theta$$
$$s_R = (r+b)\theta$$
$$s_M = (r+b/2)\theta$$

Which gives the displacement (distance traveled) for the left and right wheels respectively, is the turn radius for the inner (left) wheel, is the distance between wheels (from center-to-center along the length of the axle), and is the angle of the turn

$$\theta_{radians} = \theta_{degrees}(\pi/180)$$

axle. In this discussion, we will treat the axle's center point as the origin of the simulated robot's frame of reference. Once we've established the simple geometry for the differential steering system, it is easy to develop algorithms for controlling the robot's path. Note, though, that we did make an important simplifying assumption: the wheels maintain a steady velocity. We neglected the effects of acceleration. If the wheels are allowed to accelerate, the curve which describes the robot's trajectory can become much more complicated. When working with very light robots, where the mass (and inertia) of the platform is small, we can often get away with treating changes in speed as nearly instantaneous. The path that the robot follows will not be truly circular, but it will be close enough for many applications. For larger and heavier robots, of course mass is important and acceleration must be considered. If the right wheel is moving at a velocity of VR and the left wheel at a velocity of VL, then the following equation can be derived.

$$\theta(t) = (v_R - v_L)t/b$$

Where a positive θ implies counter-clockwise rotation; the above equation clearly shows that the angle of the turn can be increased by either, Increasing the difference in the wheel's velocities (VR – VL), or Keep the wheels at the different velocity for a longer time (t)

All this while b remains constant; in the line following robot, both these parameters are dynamically changed by the sensors in order to keep the robot on the line.

3.1. D.C. MOTORS

Figure 3.2 Geared D.C. Motor

Geared D.C. motors were used which can operate in the range from 0V to ±12V. The D.C. motors have a speed of 2400rpm and a torque of 15 gm-cm. The gears decrease the speed to 30rpm at 6V and thus considerably increasing the torque so that the robot can carry the load of its frame and the lead-acid battery. Two such motors are used in the rear of the robot, and a dummy castor is fixed to the front to stabilize the robot.

Several characteristics are important when selecting DC motors and these can be split into two specific categories..

Characteristic	Value
Operating Voltage:	6V to 12V
Operating Current:	2A Max. (Stall)
Speed:	2400 rpm
Torque:	30 gm-cm

Table 3.1 specifications of the motors

As noticed in the Table 3.1 the torque provided can hardly move 30gm of weight around with wheel diameter of about 2cm. This is a fairly a huge drawback as the robot could easily weigh about a kg. This is accomplished by gears which reduce the speed (2400 rpm is highly impractical) and effectively increase the torque. If the speed is reduced by using a gear system by a factor of ρ then the torque is increased by the same factor.

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3.3. H-BRIDGE MOTOR CONTROL

An H bridge is an electronic circuit that enables a voltage to be applied across a load in either direction. These circuits are often used in robotics and other applications to allow DC motors to run forwards or backwards. Most DC-to-AC converters (power inverters), most AC/AC converters, the DC-to-DC push–pull converter, most motor controllers, and many other kinds of power electronics use H bridges. In particular, a bipolar stepper motor is almost invariably driven by a motor controller containing two H bridges DC motors are generally bi-directional motors. But once the motors are fixed, control becomes tricky. This is done using the H-Bridge. The Direction of Rotation is shown in Table 3.2

A	B	C	D	ACTION
1	0	0	1	CLOCKWISE
0	1	1	0	COUNTER-CLOCKWISE
0/1	0/1	1/0	1/0	BRAKE
ANY OTHER STATE				FORBIDDEN

Table 3.2 Direction of rotation

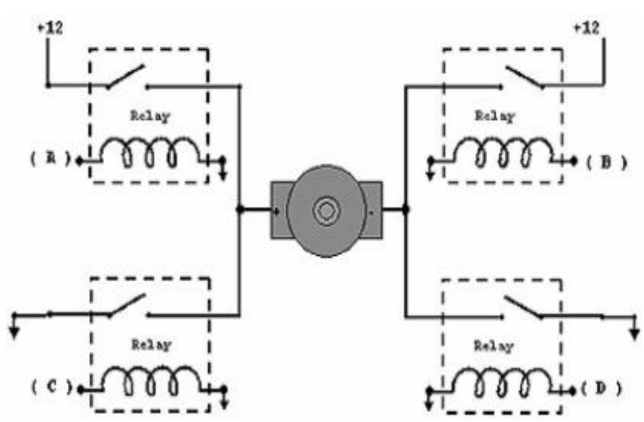

Figure 3.2: The H-Bridge Using Relays

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The H-Bridge using relays are shown in the Figure 3.3. It has four relays A,B,C & D. and are all connected to the motors

The Explanation is simple, If A & D are turned on, then the current flows in the direction shown in the figure 3.3

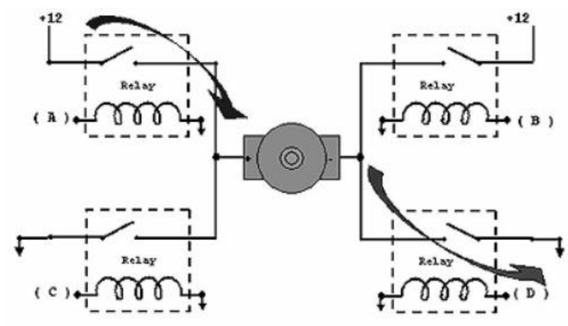

Figure 3.3: Clockwise rotation

If B & C are turned on, then the motor rotates in counter clockwise direction as shown in figure 3.4

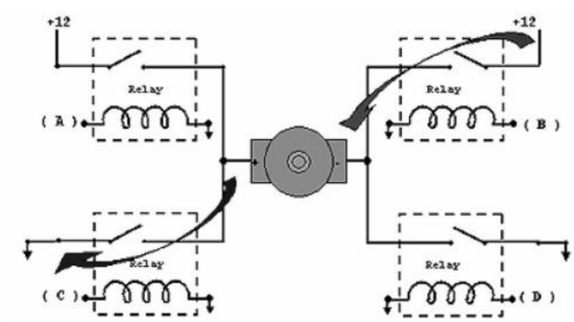

Figure 3.4: Counter-Clockwise rotation

The two upper circuits, the motor resists turning, so we effectively have a breaking mechanism. The same is true if we turn on both of the lower circuits. because the motor is a generator and turns to generates a voltage. If the terminals of the motor are connected (shorted), then the voltage generated counteracts the motors freedom to turn. It is as if we are applying a similar but opposite voltage to the one generated by the motor being turned. In other words, it acts like a brake.

Any other state like A & C = ON or B & D = ON will cause a direct path to ground causing a very high current to pass through the relays thus causing a burnt fuse (if it exists).The following Figure 3.5 shows an H-Bridge using only transistors.

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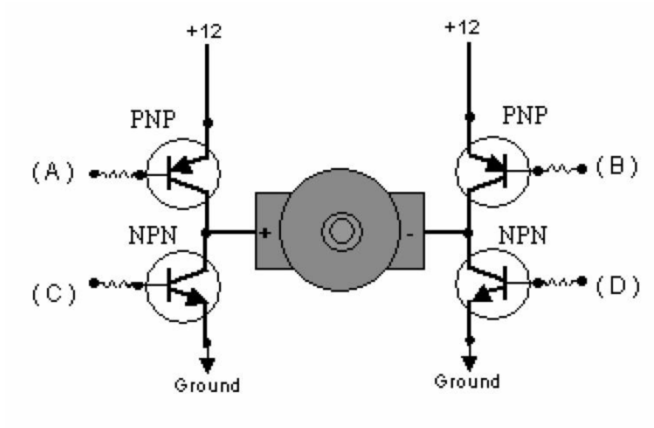

Figure 3.5: H-Bridge using transistors.

Usually, the above circuitry can be used only for direction control. The same direction rules apply, but now the motor will behave as per the direction control only when a '1' is given to the EN input. Usually protection diodes are also incorporated across the transistors to catch the back voltage that is generated by the motor's coil when the power is switched on and off. This fly-back voltage can be many times higher than the supply voltage! If diodes are not used, the transistors have a good chance to get burnt.

3.4. AT 89C2051 MICROCONTROLLER

The ATMEL microcontrollers are a group of 8 – bit microcontrollers of RISC (Reduced Instruction Set Computer) architecture. It has various features few of which are given below. Microcontroller Core Features of 4K Bytes of In-System Reprogrammable Flash Memory – Endurance: 1,000 Write/Erase Cycles and Fully Static Operation: 0 Hz to 24 MHz, Three-Level Program Memory Lock and 128 x 8-Bit Internal RAM.

Peripheral Features

Port 1

Port 1 is an 8-bit bidirectional I/O port with internal pull-ups. The Port 1 output buffers can sink/source four TTL inputs. When 1s are written to Port 1 pins they are pulled high by the internal pull-ups and can be used as inputs. As inputs, Port 1 pins that are externally being pulled low will source current (I_{IL}) because of the internal pull-ups. P1 is used as an input port.

Port 2

Port 2 is an 8-bit bidirectional I/O port with internal pull-ups. It emits the high-order address byte during fetches from external program memory and during accesses to external data memory that use 16-bit addresses .In this application it uses strong internal pull-ups When emitting 1s. During accesses to external data memory that use 8-bit addresses, Port 2 emits the contents of the P2 Special Function Register. P2 is used as an output port.

Port 3

Port 3 is an 8-bit bidirectional I/O port with internal pull-ups. Port1, Port2 and Port 3 also receive some control signals for Flash programming and verification.P3 is used as an switch. The Line following robot was programmed using the FLASH programmer.

4. DESIGN AND IMPLEMENTATION

4.1 HARDWARE COMPONENT

The main component is the AT 89C2051 microcontroller. The schematic is divided into two sections; one the Sensor Array Board, and the other the motor-control or main board. In addition to the line follower robot circuit a detector circuit is also added along with it in the hardware part. This is basically used for detecting any object on its path and it produces a beep sound. The given supply 12V is converted into 5V using regulator LM7805 and supply to the complete circuit, except transistor T3 and the lamp L1, for which 12V potential developed across capacitors C2 is used. Diode D3 protects the circuit against wrong supply polarity.

4.2. BLOCK DIAGRAM

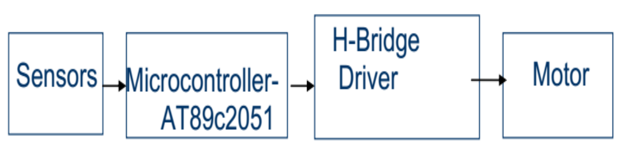

Figure 4.1: Block Diagram of the Line Following Robot

The clock frequency is provided by one 12 MHz crystal which is connected across the OSC1 & OSC2 pins as shown. This provides an instruction execution time of $1\,\mu$ s. Motors on a robot consume most of the power. For most of them, each DC motor typically consumes 1.5W on the average. For differential steering, two DC motors consume up to 3W. The logic components typically draw a total of about 80mA. Even at a supply voltage of 12V, the logic component only consumes 1W. If we assume the whole robot consume 5W, it requires 4500J of energy to last 15 minutes. If we use a 12V battery, it must have a capacity of 4500J/12V=375Asec or 104mAH. This may imply that getting a battery of 150mAH is sufficient. Unfortunately, the discharge curve of a 150mAH will not sustain the required voltage for 15 minutes. An IC voltage regulator unit contains all the circuitry required in a single IC. Thus there are no discrete components and the circuitry needed for reference source, the comparator and control elements are fabricated on a single chip. Even over load and short-circuit protection mechanism is integrated into the IC. IC voltage regulators are designed to provide either a fixed positive or negative voltage, or an adjustable voltage which can be set for a range between two voltage levels.

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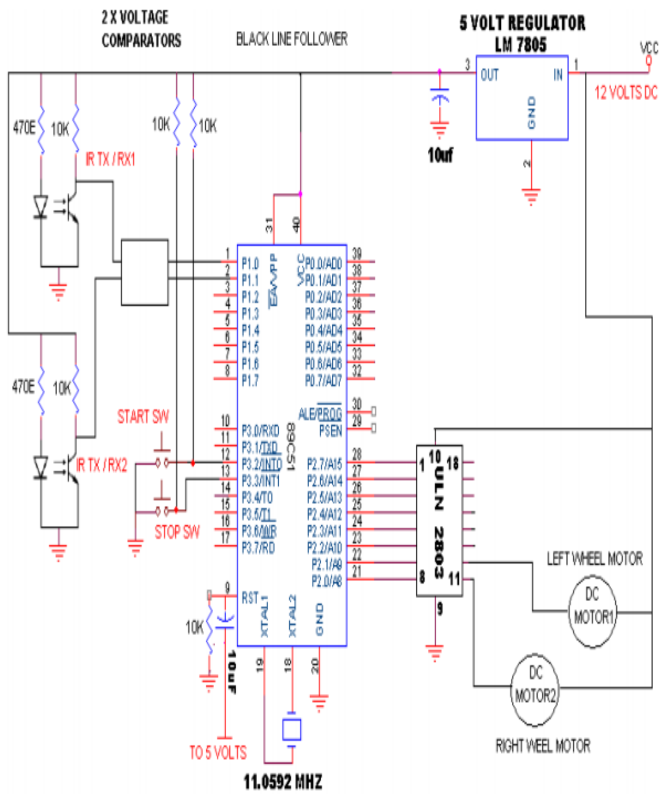

Figure 4.2 Circuit Diagram

4.3 CRYSTAL OSCILLATOR

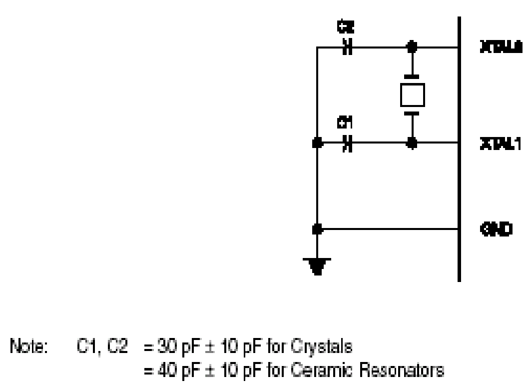

Figure 4.3 Crystal oscillator

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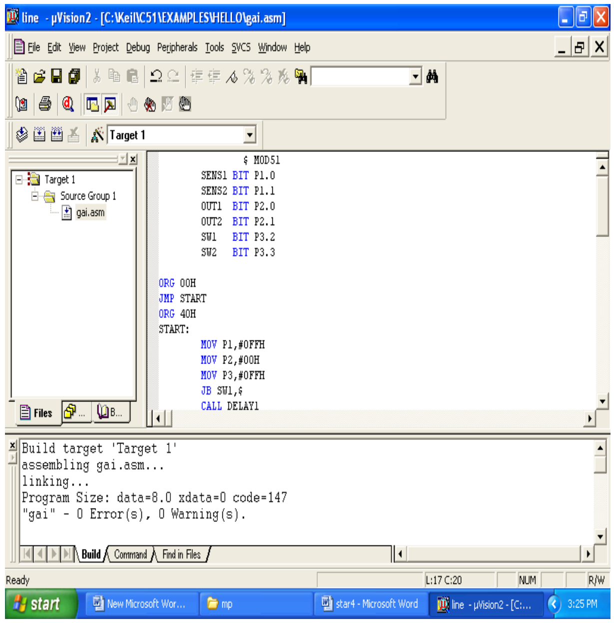
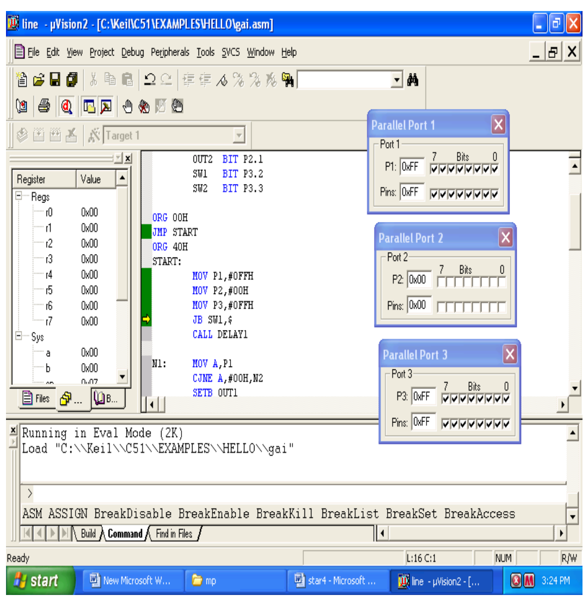
5. SIMULATION RESULTS



OUTPUT IN DIFFERENT CASES

CASE: 1 This is the basic execution of our program when start pin is enable.



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CASE:2

Here the program is being executed when the input is given in port 1 and the corresponding output pin enabled in port 2.

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