Microcontroller Based Infrared Tracking Device In 2D Motion

Mrinmoy Sengupta (B.Tech)

ABSTRACT

The objective of the project is to construct a mobile vehicle that has the capability to track IR signals emitted from a source and propel itself in the direction of that source. It was planned that the vehicle shall be a two wheeled device the rotation of the wheels of which is controlled by the direction from which the IR signals are received. The brain of the entire assembly that shall control and coordinate the rotation of the wheels is a microcontroller chip named AT89S52.

The vehicle has an important application as an automatic fire extinguisher with the ability to track the IR emitted from a fire and thereby locate it. As a future modification of this project it is decided that a proper fire extinguishing mechanism shall be installed in the vehicle which shall get triggered at a certain distance from the fire so as to extinguish it.

INDEX TERMS

Comparator, Driver, Infrared, Motor, Microcontroller, Sensor

1. INTRODUCTION:

A Microcontroller (sometimes abbreviated µC, uC or MCU) is a small computer on a single integrated circuit containing a processor core, memory, and programmable input/output peripherals. Program memory in the form of NOR flash or OTP ROM is also often included on chip, as well as a typically small amount of RAM. Microcontrollers are designed for embedded applications, in contrast to the microprocessors used in personal computers or other general purpose applications.

Microcontrollers are used in automatically controlled products and devices, such as automobile engine control systems, implantable medical devices, remote controls, office machines, appliances, power tools, and toys. By reducing the size and cost compared to a design that uses a separate microprocessor, memory, and input/output devices, microcontrollers make it economical to digitally control even more devices and processes.

Infrared (IR) light is electromagnetic radiation with a wavelength longer than that of visible light. These wavelengths correspond to a frequency range of approximately 430 to 1 THz and include most of the thermal radiation emitted by objects near room temperature. Infrared technology has evolved over the years. Infrared imaging is used extensively for military and civilian purposes.

Military applications include target acquisition, surveillance, and night vision, homing and tracking. Non-military uses include thermal efficiency analysis, remote temperature sensing, short-ranged wireless communication, spectroscopy, and weather forecasting. Infrared astronomy uses sensor-equipped telescopes to penetrate dusty regions of space, such as molecular clouds; detect objects such as planets, and to view highly red-shifted objects from the early days of the universe. Microscopically, IR light is typically emitted or absorbed by molecules when they change their rotational-vibrational movements.

1.1 PROJECT OBJECTIVE:

The project deals with the construction and working of a basic infrared navigation system. The purpose of the system is to track the signals from any IR source and follow those signals so as to cause the movement of the system towards the source. It is also the objective of the project to detect obstacles in the course of its movement towards the source and avoid those.

1. Mrinmoy Sengupta has completed B.Tech in Electronics and Instrumentation from Techno India, Saltlake. He is currently working as an assistant system engineer-trainee for Tata Consultancy Services Ph No.-+919836328637, E-mail. mrin.phylectro@gmail.com

2. METHODOLOGY:

2.1 PROBLEM DEFINITION:

The system under question shall be a fully automated microcontroller based embedded system in the form of a robotic vehicle. The navigation is based on the transmission of IR signals of a specific frequency from a particular direction so that the vehicle moves towards that direction.

The primary challenge of the project is to convert the Infrared radiation to Analog voltage signal which in turn will be fed to the microcontroller through an Analog to Digital Converter (ADC). The output from the microcontroller will finally drive the motors necessary for the locomotion of the vehicle.

2.2 PLANNING AND APPROACH:

The basic working principle of the robotic vehicle is quite simple. There are three sensors oriented at a spatial difference in orientation of 90°. So the three sensors are supposed to receive the IR radiations coming from the centre, left and right direction. Accordingly the motors of the robot will turn causing the robot to move towards the direction of the IR source. It must be mentioned here that the forward movement of the vehicle has only been considered so no IR sensors are being incorporated into the circuit to sense any signal coming from the back of the vehicle.
In case any obstacle is present in the path of the robot, the IR signals from those directions shall be blocked. Accordingly the robot shall turn in the direction from where it still receives the IR signal i.e. where there is no obstacle.
The input signals from the three sensors via the comparator circuit shown above shall be fed to three input pins of a certain port of the microcontroller. The logic of the flowchart deciding the movement of the robot shall be burnt in the form of an appropriate program into the controller. The output from the microcontroller although logically correct is not enough to drive a 12V dc motor. So I used a motor driver chip L293D that steps up the voltage level from the microcontroller output in order to drive the motor.

2.2.1 PROJECT DESIGN

The project design basically consists of three sections-

1. The sensor- This part senses the incoming infra red radiations from the transmitter/source. The sensor must be capable of detecting the IR signals emitted by the source and generate a corresponding analog output voltage.

2. The controller- A variety of control mechanisms can be used for the purpose of controlling this vehicle. However due to time and space restrictions it was decided to use a microcontroller for the purpose. The microcontroller generates suitable control signals to guide the vehicle in the proper direction depending upon the output of the sensor receiving the IR radiation.

3. The driver- This portion is required to bring about a proper interfacing between the microcontroller and the DC motors. It steps up the output signal from the microcontroller to a fairly large level for driving the motors.

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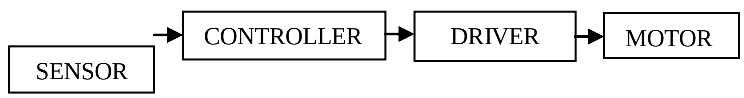

2.2.2 A GENERAL DESCRIPTION OF THE COMPONENTS USED

IR SENSOR:

IR (infrared) sensors detect infrared light. The IR light is transformed into an electric current, and this is detected by a voltage or amperage detector.

COMPARATOR:

A voltage comparator is a device used for the comparison of two voltage levels. The output of the comparator indicates which of the two input voltages is greater. Hence it is a switching device, giving an output voltage when one input voltage is larger and another output voltage when the other input voltage is larger. An OP AMP can be used as a comparator by operating it in the open-loop condition and applying the two voltages to be compared to the inverting and non-inverting inputs. If the voltage to the non-inverting input terminal slightly exceeds the voltage to the inverting terminal the OP AMP quickly switches to the maximum positive and in the vice versa to the maximum negative.

MICROCONTROLLER:

8051 microcontroller is a 40 pin chip .The advantage of using a microcontroller is the factor that no separate I/O

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interfacing devices need to be incorporated in the circuit. The microcontroller as we know has an 8 bit microprocessor along with I/O devices. The pin configurations are listed below:

1-8: **Port1-** each of these pins can be used as ether input or output according to the needs.

Pins 1 and 2 have special functions associated with timer2.

9: **Reset Signal -** A high on this input halts the MCU and clears all the registers.

10-17: **Port3-** As port 1 each of these pins can be used as universal input or output.

10: RXD-Serial input for asynchronous communication

11: TXD- serial output for asynchronous communication.

12-13-input for interrupt 0 and 1

14-15- clock input of counter 0 and 1

16-17- signal for writing and reading

18-19- Input and output of internal oscillator.

20: Ground

21-28: **Port2-** If external memory is not present pins of port2 act as universal input/output. If external memory is present , this is the location of the higher address byte.

29: **PSEN-**Microcontroller activates this bit upon each reading of byte from program memory.

30: Before each reading of the external memory microcontroller sends the lower bytes of the address register to port0 and activates the output ALE.

31: A low on this pin designates the port2 and port3 for transferring address regardless of the presence of internal memory.

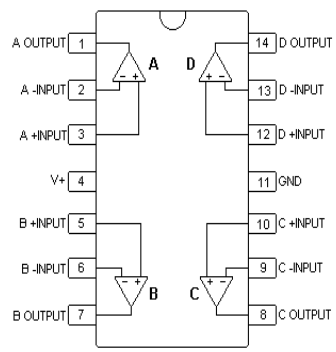
32-39: **Port0-** Similar to port the pins of port 0 can be used as universal input/output if external memory is not used. In case of external memory, this behaves as the lower bit of address.

40: Power

DRIVER:

The output signal from a microcontroller ranges between 0 and 5V. It is impossible to drive a 12V motor with this output because of the difference in voltage levels. So a device is required that shall step up the voltage level from 5V to 12V so that the motors can be operated with it. Such a device is called a motor driver. The internal circuit of any motor driver IC reveals the fact that a motor driver simply functions as a buffer switch. On one terminal of the switch 12V is supplied. The input signal of 5V to the driver functions as the controlling parameter of the switch. In the presence of this signal the switch closes to transmit the 12V to the other terminal of the switch that is connected with the motor. Upon receiving this 12V signal the motor turns. Apart from this, the driver protects the microcontroller from the back emf produced by the rotating motors. This protection is necessary because such a back emf might erase the program from the microcontroller completely.

Fig1.Internal circuit of LM324



MOTOR:

DC motors are in countless consumer electronic devices from CD players to computers to radio-controlled airplanes. There are many different kinds of DC motors, but they all work on the same principle. They turn current into pulses of magnetism, which they use to turn a rotor. There are many different kinds of electric motors namely brushed dc motors and brushless dc motors.

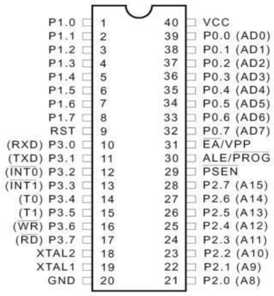
Basically motors are generators, and one can be converted into the other. When motors operate they produce an emf, just like generators do. It is called a back emf, and does not immediately appear when they are initially turned on. The back emf works to reduce the current in the loop, thus slowing the motor down, and gets larger as the speed of the motor increases. This causes the power requirements of the motor to also increase, especially under loads that are very large. This contributes to energy waste and inefficiency in their operation.

That is exactly why a driver is needed. It blocks the back emf produced by the motor from interfering with the microcontroller program.

2.2.3 DETAILS OF THE COMPONENTS TO BE USED IN THE PROJECT:

HL538AA51: This part senses the incoming infra red radiations from the transmitter/source. The sensor

(HL538AA51) must be capable of detecting the signals of a specific frequency emitted by the source.



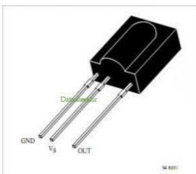


Fig 2. Pin Configuration of IR sensor HL538AA51

LM324: LM324 is a 14 pin chip consisting of 4 comparators, each of them compares the voltage signal obtained as an output from TSOP 1738 with a reference voltage (+5volts) and provides a steady output to the microcontroller.

The comparator basically acts as an Analog to Digital Converter (ADC) thus providing steady +5V as logic 1 to the microcontroller and 0V as logic 0.

Microcontroller Input Port 1	Microcontroller Input Port 2	Status
0	0	Static Stop
0	1	Clockwise
1	0	Anticlockwise
1	1	Dynamic Stop

TABLE 1. TRUTH TABLE FOR MOTOR ROTATION BY L293D

AT89S52:

The AT89S52 is a low-power, high-performance CMOS 8-bit microcontroller with 8K bytes of in-system programmable Flash memory. The device is compatible with the industry-standard 80C51 instruction set and pinout. The on-chip Flash allows the program memory to be reprogrammed in-system or by a conventional nonvolatile memory programmer.
AT89S52 is a powerful microcontroller which provides a highly flexible and cost-effective solution to many embedded control applications.

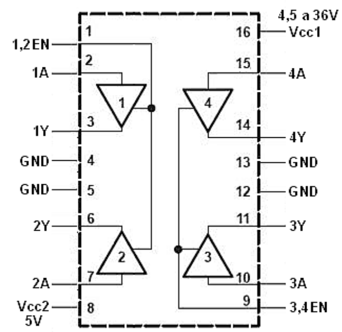


Fig 3. Internal circuit of L293D

The AT89S52 provides the following standard features: 8K bytes of Flash, 256 bytes of RAM, 32 I/O lines, Watchdog timer, two data pointers, three 16-bit timer/counters, a six-vector two-level interrupt architecture, a full duplex serial port, on-chip oscillator and clock circuitry The control strategy is fed by burning a suitable program into the microcontroller.

L293D:

The component available as an IC functions as the driver for the DC motor.
This is a 16 pin device capable of driving two motors simultaneously in reversible direction.
The IC is helpful in two ways:
I) It can drive the motors at a voltage much higher than the input voltage applied to its input terminals.
II) It provides sufficient protection against any sort of back emf caused during the motor stop which may otherwise erase the microcontroller program or may damage other circuit components.
L293D can drive motor in reversible direction. The following table shows the truth table for clockwise and anticlockwise rotation of the motors with respect to the inputs provided to the driver.

Fig 4.Pin configuration of AT89S52

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7805:

7805 is a voltage regulator which receives voltage between 9-12 volts and provides 5 volts steady supply to the circuit components.

2.2.3 CIRCUIT DESIGN:

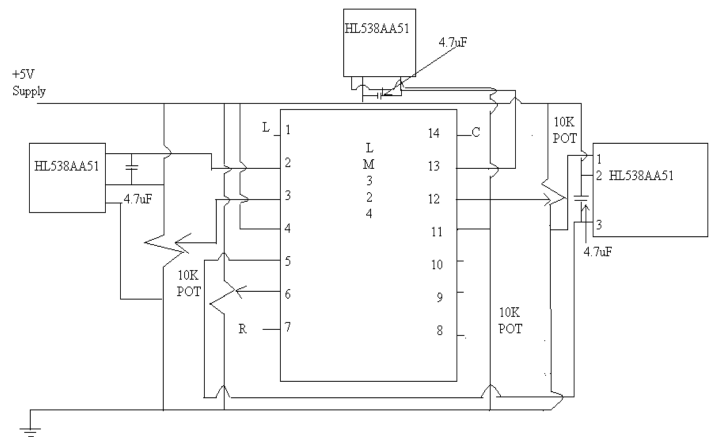

Fig 5. IR sensor and comparator circuit

The above circuit diagram represents the IR receiver we employed in our circuit. The comparator chip LM324 used in the circuit has four comparators. Out of those we used only three namely (1,2,3),(5,6,7),(12,13,14). The numbers in the brackets indicate the pin numbers of the two inputs and one output of each of the comparators. So we have three such sets indicating the three comparators we used to sense Left, Right and Center movement respectively.

It should also be mentioned here that the comparator functions as an Analog to Digital converter here with the threshold value being adjusted by the 10K pots.

The microcontroller receives the output of the three comparators for left, center and right movement at pins 10, 11, 12 respectively. These are the input pins of the microcontroller AT89S52 under question. The output pins of the controller for controlling the two motors are pins 1, 2 respectively. Pin 1 is used to control the right motor while pin 2 is used to control the left motor. The connection for the driver is entailed in the figure.

Certain factors of importance which had to be considered while preparing the circuit designs are briefly discussed below.

The output of the IR sensor is obtained from pin no. 3. In the OFF state i.e. when no IR signals are received, the output voltage is roughly 5V. In the ON state the output voltage drops to about 0.14V. This output pin of the sensor is connected to the inverting terminal of the comparator. The pot is connected to the non inverting terminal. It is adjusted so that its output voltage becomes precisely 3.61V.

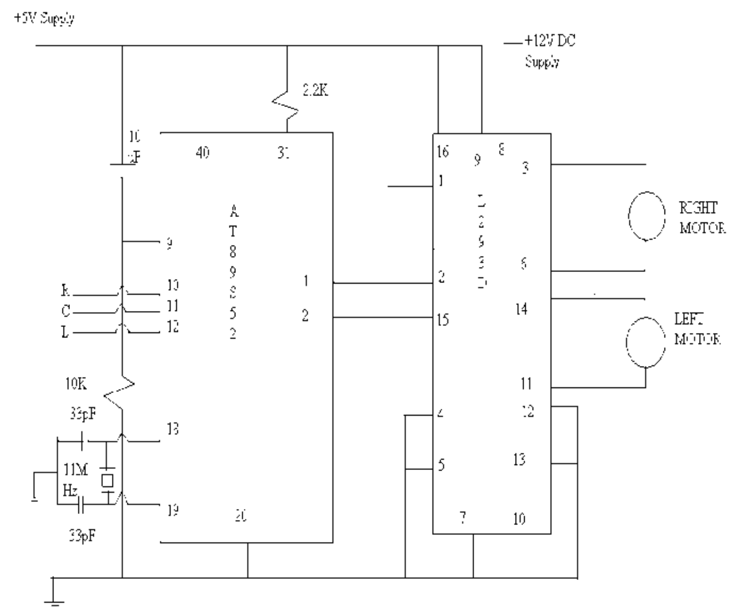

Fig 6.Microcontroller and driver circuit

So in the OFF state as the non inverting terminal voltage becomes less than the inverting terminal voltage the comparator output stays 0V which denotes logic 0.

In the ON state the sensor output and hence the non inverting terminal voltage becomes 0.01V. Clearly in such a situation the inverting terminal voltage of 3.61V obtained from the pot becomes greater than the non inverting terminal voltage. Consequently, an output voltage of 3.8V is obtained from the comparator which denotes logic 1 and is supplied to the microcontroller.

The microcontroller is provided with a logical HIGH signal at pin 31 i.e. EA/Vpp to represent the fact that the program is accessed from the internal ROM and no external access is required. Power on reset circuitry is employed using a resistance capacitance circuit of 10K and 10uF respectively. The timing pulses generated by this RC circuit to the reset pin exist for an appropriately proper duration of time such that the microcontroller gets reset every time the power is turned ON in the circuit.

Although a motor can be made to turn in both directions using the L293D driver chip, but to keep things simple we involved only unidirectional rotation of the motor. This direction is clockwise. As mentioned in the previous table a bit combination of 0 and 1 is needed by the driver at its input to make such a rotation possible. The 0 and 1 need to given in pins 7and 2 respectively for the right motor and in pins 10 and 15 respectively for the left motor.

Pins 7 and 10 are permanently clamped to the ground i.e. logical 0. The pins 2 and 15 are connected to the pins 1 and 2 of the microcontroller which carry the outputs of the right and left motor respectively.

2.3.2MICROCONTROLLER PROGRAM

Following the above control strategy and obviously by making a few modifications such as introduction of the delays etc., the program is prepared. This program as given below is burned using a burner into the microcontroller.

=====MAIN PROGRAM=======

MEMORY LOCATION	HEX CODE	OPCODE	REMARKS
0000		ORG 0000H	START THE PROGRAM FROM MEMORY LOCATION 0000 H
0000	759000	MOV P1,#00H	CLEAR PORT1
0003	75B000	MOV P3,#00H	CLEAR PORT3
0006	20B12C	S: JB P3.1,CENTER	JUMP TO CENTER SUBROUTINE WHEN PORT BIT 3.1 IS SET
0009	1148	ACALL D	CALL OUTER DELAY SUBROUTINE
000B	20B009	JB P3.0,RIGHT	JUMP TO RIGHT SUBROUTINE WHEN PORT BIT 3.0 IS SET
000E	1148	ACALL D	CALL OUTER DELAY SUBROUTINE
0010	20B213	JB P3.2,LEFT	JUMP TO LEFT SUBROUTINE WHEN PORT BIT 3.2 IS SET
0013	1148	ACALL D	CALL OUTER DELAY SUBROUTINE
0015	80EF	SJMP S	SHORT JUMP TO MEMORY LOCATION 0006 H

====LEFT MOVEMENT/RIGHT MOTOR======

MEMORY LOCATION	HEX CODE	OPCODE	REMARKS
0017	D290	RIGHT: SETB P1.0	PORT BIT1.0 IS SET
0019	114D	ACALL D1	CALL INNER DELAY SUBROUTINE
001B	30B002	JNB P3.0,C1	
001E	80F7	SJMP RIGHT	SHORT JUMP TO MEMORY LOCATION 001E H
0020	C290	C1: CLR P1.0	CLEAR PORT BIT1.0
0022	114D	ACALL D1	CALL INNER DELAY SUBROUTINE
0024	80E0	SJMP S	SHORT JUMP TO MEMORY LOCATION TO 0006 H

====RIGHTMOVEMENT/LEFT MOTOR======

MEMORY LOCATION	HEX CODE	OPCODE	REMARKS
0026	D291	LEFT: SETB P1.1	PORT BIT1.1 IS SET
0028	114D	ACALL D1	CALL INNER DELAY SUBROUTINE
002A	30B202	JNB P3.2,C2	
002D	80F7	SJMP LEFT	SHORT JUMP TO MEMORY LOCATION 0026 H
002F	C291	C2: CLR P1.1	CLEAR PORT BIT1.1
0031	114D	ACALL D1	CALL INNER DELAY SUBROUTINE
0033	80D1	SJMP S	SHORT JUMP TO MEMORY LOCATION TO 0006 H

==CENTER MOVEMENT/BOTH MOTORS==

MEMORY LOCATION	HEX CODE	OPCODE	REMARKS
0035	D290	CENTER:SETB P1.0	PORT BIT1.0 IS SET
0037	D291S	SETB P1.1	PORT BIT1.1 IS SET
0039	114D	ACALL D1	CALL INNER DELAY

			SUBROUTINE
003B	30B102	JNB P3.1,C3	
003E	80F5	SJMP CENTER	SHORT JUMP TO MEMORY LOCATION 0035 H
0040	C290	C3: CLR P1.0	CLEAR PORT BIT1.0
0042	C291	CLR P1.1	CLEAR PORT BIT1.1
0044	114D	ACALL D1	CALL INNER DELAY SUBROUTINE
0046	80BE	SJMP S	SHORT JUMP TO MEMORY LOCATION TO 0006 H

========**OUTER DELAY**===========

MEMORY LOCATION	HEX CODE	OPCODE	REMARKS
0048	790F	D: MOV R1,#0FH	MOVE THE VALUE 0F H TO R1
004A	D9FE	D2: DJNZ R1,D2	DECREASE R1 AND JUMP TO 004A H AFTER EACH DECREMENT TILL R1 BECOMES ZERO
004C	22	RET	RETURN TO MAIN PROGRAM

=========**INNER DELAY**==============

MEMORY LOCATION	HEX CODE	OPCODE	REMARKS
004D	7D0F	D1: MOV R5,#0FH	MOVE THE VALUE 0F H TO R5
004F	7B32	H4: MOV R3,#32H	MOVE THE VALUE 32H TO R3
0051	7C32	H2: MOV R4,#32H	MOVE THE VALUE 32H TO R4
0053	DCFE	H3: DJNZ R4,H3	DECREASE R4 AND JUMP TO 0053 H AFTER EACH DECREMENT TILL R4 BECOMES ZERO
0055	DBFA	DJNZ R3,H2	DECREASE R3 AND JUMP TO 0051 H AFTER EACH DECREMENT TILL R3 BECOMES ZERO
0057	DDF6	DJNZ R5,H4	DECREASE R5 AND JUMP TO 004F H AFTER EACH DECREMENT TILL R5 BECOMES ZERO
0059	22	RET	RETURN TO MAIN PROGRAM
		END	END THE PROGRAM

2.2.4 SOME PHOTOGRAPHS OF MY WORKING CIRCUIT

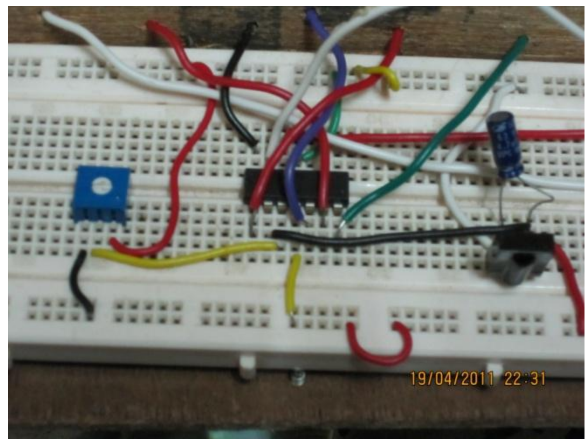

Fig 7.A picture of our IR receiver circuit

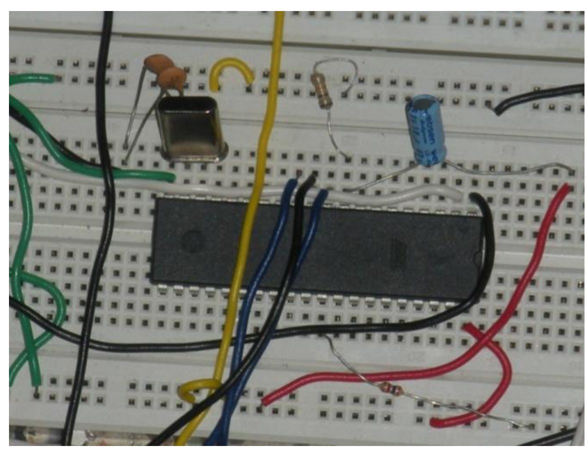

Fig 8.A picture of our microcontroller circuit

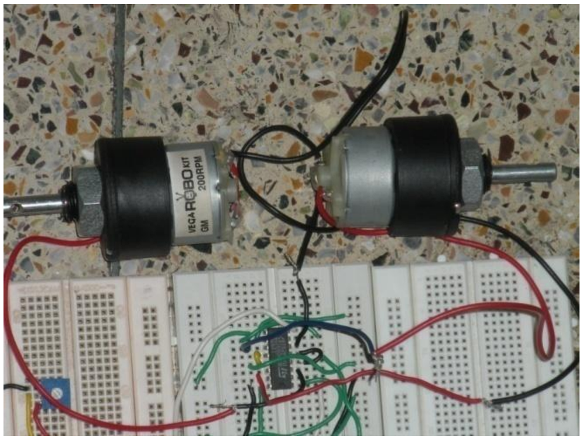

Fig 9.A picture of the driver circuit

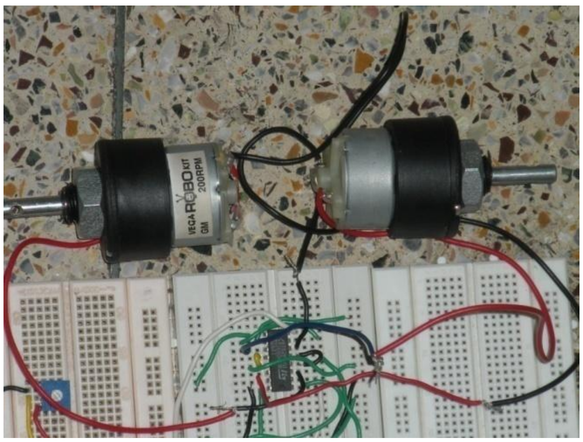

Fig 10.A picture of our entire circuit consisting of the three sensors, one comparator, microcontroller and driver

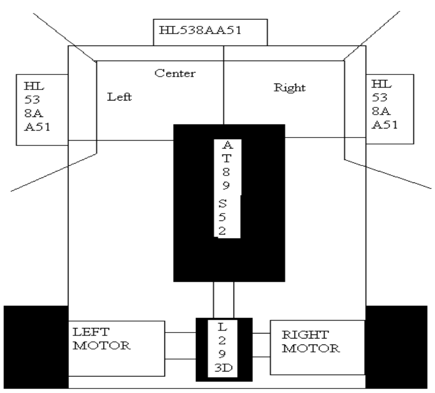

Fig 11.A Pictographic representation of the vehicle

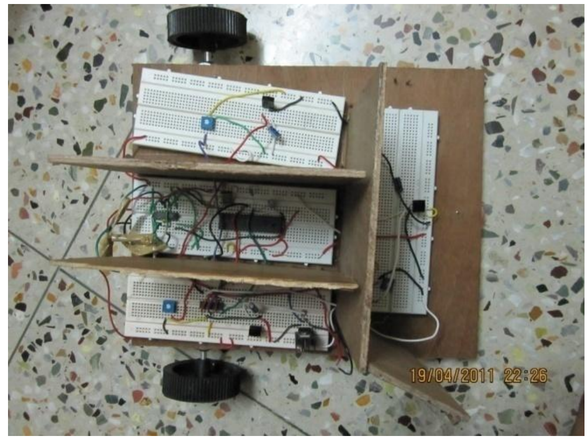

Fig 12.A Photograph of the working design of the vehicle

3. TESTING

To check the capability of the device I tested it with a Sony DVD Remote where I found that my device has the capability of catching signal up to 15 feet having no barrier in the way. Another thing came to my notice while conducting this test is there are interference of the signals in the right, left and centre sensors. So I decided to use guard between the sensors to effectively detect the direction.

Since a large number of components were driven from single 5V supply extracted from a7805 chip, some abrupt voltage drops were observed during testing. These drops became more frequent on using a 9V battery. So in its stead a 12V supply from an SMPS was used. The voltage was found to be quite uniform throughout the circuit in that case.

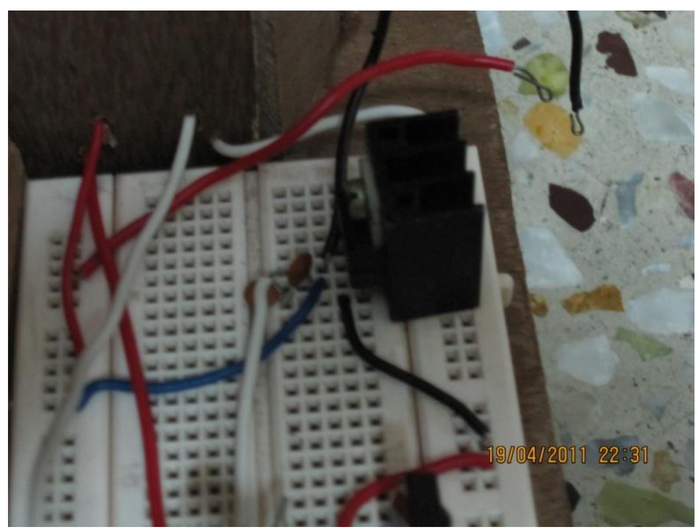

Fig13. A Photograph of the voltage supply block of the circuit. The large black structure is the7805 voltage regulator plotted with the heat sink. The red wire with the bare end is to be connected to ground while the black one is to be connected to 12V supply from an SMPS.

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4. MEASUREMENTS, RESULTS AND A DISCUSSION

After the fabrication of the entire circuit was completed it was tested using a remote as mentioned in the previous section. While testing, the outputs of the different blocks of the circuit were measured using a multimeter.

The measurements of the final design are briefly tabulated in the following table:

<table>
<tr><td>Component</td><td colspan="2">Input Voltage</td><td colspan="2">Input Current</td><td>Output Voltage</td><td>Output Current</td></tr>
<tr><td>IR Sensor</td><td colspan="2"></td><td colspan="2"></td><td>0.01V</td><td>1.13mA</td></tr>
<tr><td rowspan="2">Comparator</td><td>IR Sensor</td><td>0.01V</td><td>IR Sensor</td><td>1.13mA</td><td rowspan="2">3.8V</td><td rowspan="2">46.2mA</td></tr>
<tr><td>Pot</td><td>3.61V</td><td>Pot</td><td>15.4mA</td></tr>
<tr><td>Microcontroller</td><td colspan="2">2.94V</td><td colspan="2">40mA</td><td>4.25V</td><td>0.14mA</td></tr>
<tr><td>Driver</td><td colspan="2">4.11V</td><td colspan="2">0.14mA</td><td>9.98V</td><td>-------</td></tr>
</table>

TABLE 2. MEASUREMENT RESULTS

The input voltage of the IR sensor is not mentioned since it does not receive any input voltage apart from its supply voltage. The sensor receives IR radiations as its input.

It must be noted that all the above data were tabulated while the concerned component was not connected with the next component in the circuit. When such a connection is made a certain quantity of voltage drop occurs that leads to a reduction in voltage and current levels as from the data given above.

All the above measurements were made while sensors were excited with IR radiations emitted from a remote.

The circuit was found to function effectively good till a distance of roughly 20 feet which is actually the range of the IR sensors. However in proper synchrony with the nature of IR rays, the sensor functions appropriately only when it is maintained in a proper line of sight of the IR source. The sensor fails to detect the IR if an obstacle gets in between the source and the sensor.

As previously mentioned in the microcontroller program, the subroutines are mentioned in the following order: Center-> Right -> Left. This only implies the fact that they will also be executed in the same order. So in a situation where the IR source is placed at a certain angle such that the center sensor fails to receive any signal, initially the motors will turn following the left or right subroutine as the case applies till the center sensor exactly faces the source. Following this the center subroutine shall be executed that will propel the vehicle towards the source. But in case where center sensor receives the signal first the motor will go straight since the center subroutine is placed first. So the bottom line is that given a choice first the center subroutine shall be executed. However in any other case the left or right subroutine shall be executed till a point where only the center subroutine can be executed. This is precisely the point where only the center sensor receives the IR signals while the left and right do not. It is ensured by the presence of appropriate separators between the three sensors.

The response time of the system is found to be reasonably fast within limits of experimental error. After making all the measurements and correcting all the occurring errors to the maximum extent possible, the breadboard circuit was finally installed in the vehicle. The circuit spanned an area of four breadboards. As planned initially the vehicle was a two wheeled one with the two motors controlling the wheels. Apart from the two wheels, a flywheel is placed in the front end of the vehicle to bring about a balance as well as guide the vehicle in the proper direction.

5. CONCLUDING REMARKS

The final working model was found to be a successful one. Theoretically a lot of applications of the project could be thought of. One among them is an automatic fire tracker and extinguisher. It is a similar vehicle employing the same technology to track fires by following the IR signals emitted by the fire.

The principle of the system can be equally applied for the purpose of solar tracking. It is a technique by which the solar panels exposed to sunlight automatically turn themselves as the position of the sun changes in the sky so as to maintain a proper perpendicular alignment between the Sun's rays and the panel surface for the entire duration of time for which the Sun stays in the sky.

REFERENCES

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