Design Analysis of a GSM/RF-Based Remote Controlled Robotic Car

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Abstract:
In years past, the motion of wireless robotic vehicles has been restricted by limited distance of control, line-of-sight control and interference which is mainly caused by the use of Infra-Red and Radio Frequency circuits for the remote control of the robot. This paper presents a solution to such problem whereby a GSM/RF based remote control system is used to control a robotic car. This is done in such a way that to control the robot, the user makes a phone call to the phone attached to the robot which automatically answers the call.During the phone call, the user can control the robotic car with the keys on the phone. Hence the user can control the robotic car from anywhere no matter the distance without interference so far as the robotic car can be seen by the user. The design methodology involves four stages, namely: power supply unit, the input unit, the control unit and the output unit. The performance evaluation of the designed work after series of tests was very satisfactory.
Keywords: GSM, Robotic Car, Remote, Control, DTMF

I. Introduction

Before the emergence of GSM technology, Infrared (IR) and Radio frequency (RF) communication systems had been the prevalent wireless remote control systems. These systems made wireless remote control possible but certain drawbacks limit their efficiency **(Bedini, 1999).** The problem of IR systems had always been the line-of-sight control. Control cannot be possible without the controller and the robot facing each other. This makes communication over obstacles and barriers quite impossible. Limited range for control is also an issue for this system. The RF remote control system also has the disadvantage of limited range of control. Frequency Interference with other nearby RF control systems is also a problem for this system.

This paper focuses on the design analysis of a GSM/RF-based remote controlled Robotic Car with password protection system .

II. Related Works

In the work published by Robolab Technologies (online) on IR Controlled Robotic Vehicle, a robotic car with infrared TV remote controller was constructed. The car was able to move in all four directions but the IR remote control limits its efficiency as it could not be controlled with an object blocking its line-of-sight from the controller. The robotic car was also not controllable from a considerable far distance.

Dharmani (2009) on IR Remote Controlled Car, used an IR Remote system to control a robotic car which uses two PWM channels of ATmega8 microcontroller for controlling the speed and direction of the car. Although speed control of the car was made possible the car was unable to make a turn. Poor range of control and line-of-sight alignment was also a problem.

In the work published by Sourangsu Banerji (2013) on Design and Implementation of an Unmanned Vehicle using a GSM Network without Microcontroller, Sourangsu Banerji proposed a model to remotely control an unmanned vehicle using DTMF technology without the use of a microcontroller. In this model, a DTMF decoder (MT8870) was used to decode the DTMF signals. The output of the decoder was fed directly to an L293D motor driver IC which drives two dc motors. The vehicle was expected to move in all four directions. The model has the advantage of reduced circuit complexity and manpower to program the microcontroller but the absence of a microcontroller made it nearly impossible for a password protection system, sensors and wireless camera system to be included.

Similar works by Gupta et al (2013) on Design and Implementation of Mobile Operated Toy Car by DTMF and Ranu Kaushik and Renuka Singh (2013) on GSM Mobile Controlled Robotic Car were able to control a robotic car using DTMF signals with the use of a microcontroller. In these works, the received tone is processed by an ATmega16 microcontroller with the help of DTMF decoder MT8870. The decoder decodes the DTMF signal into its binary equivalent and this is sent to the microcontroller programmed to take a decision for a particular input and outputs its decision to the motor drivers in order to drive the robot forward, backward, left or right. In situations where there is no GSM network connecting these robots cannot be controlled hence there is need to add an alternative way for controlling the robotic car..

III. Design Methodology and Analysis

This section presents the list of the various components used in the individual blocks put together to form this work.

3.1 Block Diagram

Robotic car System has both hardware and software part, the figure 1 shows the block diagram of the work.
The circuit made use of an embedded system and wireless module in controlling several loads. The circuit has four sections, power supply unit, the input unit, the control unit and the output unit.

3.2 Design Analysis of circuit

The circuit for the GSM remote controlled Robotic Car is shown in Fig. 2. The detail circuit diagram for the entire idea is shown in Fig 3.

3.2.1 Power supply unit

This made up of a dc battery, voltage regulator and a power indicator. The circuit diagram is shown in fig .4. (Circuit diagram drawn and copied from Proteus environment).

The battery used is a 12Vdc battery with current rating 0f 6.5 amp. A filter capacitor of 100uf is connected in parallel to filter off noise from the battery supply. Two voltage regulators were used 7805 and 7812. The 7805 regulator is used to supply 5 volt to the microcontroller, 74244 IC, HT12D IC and the RF receiver. The 7812 is used to supply 12 volt to the relays.

A light emitting diode is connected to the 7805 voltage regulator via a limiting resistor connected in series to it. The resistor limit the amount of current entering the light emitting diode. The light emitting diode is used as an indicator to show that there is power in the circuit. The value of the resistor is gotten from the calculation below.

$$V = V_d \ I_R$$

$$V = Supply\ voltage$$

$$V_d = Operating\ voltage\ of\ of\ light\ emitting\ diode\ (LED_S)$$

$$I = Allowable\ current\ through\ the\ LED_S\ (20mA)$$

$$R = Limiting\ current\ \mathrm{Re}\,sistor$$

$$V = 5_v$$

$$V_d = 2_v$$

$$I = 20mA$$

$$\therefore R = \frac{V - V_d}{I} = \frac{5 - 2}{20mA} = \frac{3}{20\ x\ 10^{-3}} = \frac{3\ x\ 1000}{20}$$

$$R = 150\Omega$$

100 ohms resistor was used in place of 150 ohms due to unavailability of the 150 ohms resistor.

3.2.2 Remote control unit

This consists of a matrix keypad that inputs a digital signal into the microcontroller. The microcontroller sends an eight bit signal via an RF module to the receiver circuit. The diagram is as shown in figure 3.

The circuit made use of an encoder IC that encode the eight bit from the microcontroller with its address bits and send this code to the receiver unit via the RF transmitter, within a frequency of 434 MHz (the carrier frequency of the RF module), 12 bit data (four bits from the microcontroller, eight bit from the address of the encoder IC) is sent via this transmission line. The values and component and circuit diagram were gotten from the manufacturer datasheet. (AT89C52 Datasheet,2014).

3.2.3 DTMF Unit

This comprises of the DTMF decoder and an octal buffer. This is the point where signal is received and decoded to output the required signal to the microcontroller unit. The phone will be set to auto-answer and its keypad turn on and set to the highest volume. Each corresponding key in the keypad have a distinct tone that is been converted by the DTMF decoder IC (mt8870) to four digit binary tones (Dialab.com, 2014). Differenntial Input Configuration For Mt8870

The input arrangement of the MT8870 provides a differential input amplifier as well as a bias source (V_{ref}) which is used to bias the input at mid rail. Provision is made for connection of a feedback resistor to the op amp (GS) for adjustment of gain.

C_1 = 10nF, R_1 = 100kΩ , R2 = 10kΩ ,Voltage gain = R1/R , = 100/10 = = 10

Therefore the op amp has a voltage gain of 10

- **INPUT IMPEDANCE**

$Z_{in} = \sqrt{[R_1^2 + (1/wc)^2]}$

Where Z_{in} is the input impedance, R1 is the input resisto, W is the angular frequency , C is the lowest DTMF frequency (685MHZ) (sourangsu Banerji, 2013)

$= {}^2\sqrt{(100\times10^3)^2 + 1/(2\times3.142\times685\times10\times10^{-9})^{2=}} = {}^2\sqrt{(1\times10^{10}) + (539692651)}$

$= 102663.0 = \approx 100k$

3.2.4 Control Unit

The microcontroller is the power house of the circuit. It receives input from the DTMF circuit and the remote control via the RF transmitter and receiver.

The microcontroller use is a 40pin IC from Atmel 89c52. Port 1 of the microcontroller is connected to the DTMF decoder and the decoder IC from the RF receiver. Each of this send a code in four bits, which the microcontroller processes and execute the command (Phonescoope.com,2014).

3.2.5 Output Unit

These sections consist of the relay driver and the motor. The relays are switched on and off via transistors. The circuit diagram of the output unit is shown in Fig 5.

The calculation used for the transistor to drive the relay is shown below.

The transistors take input from the microcontroller via a 74244 output for high signal strength. An NPN TIP41 transistor is used in this project to drive (switch) the relays ON and OFF.

For the transistor configuration, since the transistor is biased to saturation

$V_{CE} = 0, When\ the\ transistor\ is\ ON$

$This\ implies\ that\ V^+$

$$= I_C R_C + V_{CE} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 3.1 V_{IN} = I_B R_B + V_{BE} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 3.2$$

$$h_{fe} = \frac{I_C}{I_B} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 3.3$$

$$R_B = \frac{V_{IN} - V_{BE}}{I_B} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 3.3$$

$Where;\ I_C = collector\ current$, $I_B = Base\ Current$, $V_{IN} = input\ voltage$

$V_{CE} = collector\ emitter\ voltage$, $h_{fe} = current\ gain$.

$V^+ = supply\ voltage$

The switching is done by a transistor (TIP41) *npn* transistor. It has a gain of β=100, maximum collector current of 200*mA*.

Analysis for the relays switching;

Required voltage, $V = 12V$, Coil resistance, $R = 400\Omega$, From ohms law, the required current can be calculated. Required current, $I_C = \frac{V}{R} = \frac{12}{400} = 0.03A = 30mA$

$$From\ Equ.3.10;\ I_B = \frac{I_C}{\beta}$$,

$$= 300\mu A From\ Equ.3.3\ the\ Base\ resistor;\ R_B = \frac{12 - 0.7}{300 \times 10^{-6}} = 3.7k\Omega$$

3.3 SOFTWARE DESIGN FRAMEWORK

The program is written in assembly language and assembled using MIDE-51.The program is burned into AT89c52 microcontroller.

3.3.1 ALGORITHM

This section contains the working algorithm which was used in the construction of the unmanned vehicle

Start

Step 1-> assign port1 and port3 as the input and port2 as output

Step 2-> load port1 into register (A) and load port3 into register (R1)
Step 3-> enter selection routine (while loop)

Under the loop read input ports and test received using compare instruction.

I. If 1 is pressed on the keypad, left motor stops and right motor reverse.
II. If 2 is pressed on the keypad, both left and right motors moves forward.
III. If 3 is pressed on the keypad, left motor stops and right moves reverse.
IV. If 4 is pressed on the keypad, left motor stops and right motor moves forward.
V. If 5 is pressed on the keypad, both motor stops.
VI. If 6 is pressed on the keypad, right motor stops and left motor moves forward.
VII. If 8 is pressed on the keypad, both motor moves backwards. If any other key is pressed the motors, the motors will remain in their initial position.

3.3.2 PROGRAM FLOW CHART

Fig .6 shows the program flow chart for the developed algorithm.

RESULTS AND DISCUSSION

4.1.1 TESTING OF THE DTMF CONTROL SYSTEM

In DTMF there are 16 distinct tones. Each tone is the sum of two frequencies: one from a low and one from a high frequency group. There are four different frequencies in each group. Your phone only uses 12 of the possible 16 tones. In most conventional phones, there are only 4 rows (R1, R2, R3 and R4) and 3 columns (C1, C2 and C3). The rows and columns select frequencies from the low and high frequency groups respectively. The exact values of the frequencies are listed in table 1. An LED blinks to indicate if there is transmission at the sending end and also if the receiver is receiving any signal at receiving end.

These tones from each button of the mobile phone are assigned to a specific function in the circuit.

4.1.2 TESTING OF THE REMOTE CONTROL VIA RF

The remote control system made used of an RF circuit to transmitter and receiver system. A 4x4 matrix keypad is used to input signal or send codes to the receiver circuit each key is assigned to do a specific operation as shown in Table 3. An LED blinks to indicate if there is transmission at the sending end and also if the receiver is receiving any signal.

4.2 RESULT

The results from the test carried out on the completed design are shown in Table 4 and Table 5.

4.3 DISCUSSION

The movement of the car when a key when is pressed is as shown in Tables 1 and 2. These movements are achieved by the ON and OFF states of the drivers which control the motors.

i. **Backward Left movement:** This occurs when the drivers (relays and transistors) controlling the left motor of the wheel is switch OFF and the drivers controlling the right wheel is put on counter clockwise (reversed). This is achieved with Button 1 of DTMF and Key 1 of remote control. Fig.7
ii. **Forward Movement:** In this case both motors turn clockwise to achieve this movement. This movement occurs when button 2 of DTMF or Key 2 of remote control. Fig8
iii. **Backward Right Movement:** This movement is achieved with DTMF button 3 and Key 3 of remote control. The right motor is stopped while the left motor is on reverse. Fig .9
iv. **Forward Left Movement:** The robotic car is seen to move forward-left when DTMF button 4 or Key 4 of remote control is pressed. The right motor turns clockwise while the left motor is still. Fig 10
v. **Stop:** The robotic car stops moving when both motors are made to halt by pressing DTMF button 5 or remote control Key 5 or switching OFF the robotic car. Fig 11
vi. **Forward Right Movement:** When either the DTMF button 6 or remote control Key 6 is pressed, the right motor goes OFF and the left motor turns clockwise. This results in the car turning forward right. Fig 14
vii. **Backward movement:** This occurs when DTMF button 8 and remote control button 8 is pressed, both motors move anti clockwise hence the car reverses. Fig. 13. Fig 14. Shows the fabricated work.

IV. CONCLUSION

In this project, the robotic car is controlled by a mobile phone that makes a call to the mobile phone attached to the robotic car. In the course of a call, if any button is pressed, a tone corresponding to the button pressed is heard at the other end of the call. The robotic car is also controlled by an RF remote controller with an encoder and a decoder IC.

This is a wireless controlled Robotic car hence the limitation of wire is completely overcome by using latest technology of mobile phones. However, there are still lots of scopes to improve the stability and ability of this system. The mobile phone that makes a call to mobile phone stacked in the car act as a remote. The RF remote serves as an alternative control when there is no network. It is undoubtedly true that, this model can be a very significant device in case of information acquisition from remote areas where direct interference of human being is quite impossible hence it would be a very crucial topic to do further research on.

REFERENCES

AT89C52 Datasheet, [online] Available from: www.alldatasheet-pdf/pdf/56216/ATMEL/AT89C52.html [Accessed 2/03/2014]

Bedini, S.A 1999, "The Role of Automata In The History Of Technology"

Brief History Of Artificial Intelligence [online]. Available from: www.aaai.org/AITopic/

Dharmani C.C., Design with microcontrollers: IR Remote Controlled Car (PWM motor control using ATmega8) [online] Available from:www.dharmanitech.com/2009/01/ir-remotecontrolied-car-pwm-motor.html?m=1.[Accessed 08/01/2014].

Dialab.com, DTMF [online] Available from: www.dialab.com/sound/dtmf.html. [Accessed 7/01/2014]

Dowling, K. 1999, What is robotics?[online]

DTMF Signal History [online] Available from: www.specialtyansweringservice.net/dtmf-signal-history.html. [Accessed 08/01/2014]

Gupta, Sabuj S., Arman R.O Mohammad S.H. and Nahid H.S., "Design & Implementation of Mobile Operated Toy Car by DTMF, International Journal of Scientific Research Publications, Vol. 3, Issue-1, 2013. ISSN 2250.

Phonescoope.com, DTMF [online] Available from: phonescoop.com/glossary/term?gid=206 [Accessed 10/1/2014].

Robolab Technologies, IR controlled Robot [onliine]. Available from: Robolabtechnology.com/robots.php. [Accessed 07/01/2014].

Sourangsu Banerji, "Design and Implementation of an Unmanned Vehicle Using a GSM Network Without Microcontrollers". Journal of Electrical Engineering, 2013.

Specialansweringservice.net, What is DTMF? [online] Available from: www.specialansweringservice.net. [Accessed 08/01/2014].

Ranu Kaushik and Renuak Singh, " Gsm Mobile Conrol Robo Car". 2nd conference in intelligent computing and communication, 2013. ISBN9788175157538.

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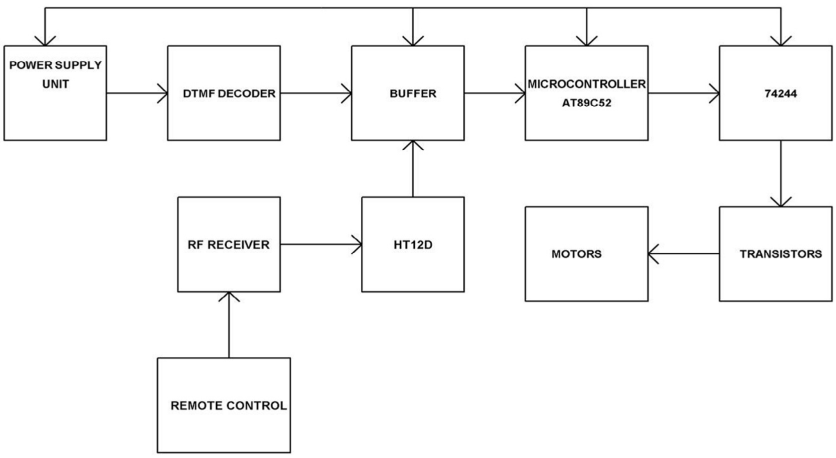

Fig 1 Block diagram of GSM/Remote Controlled Based Robotic Car

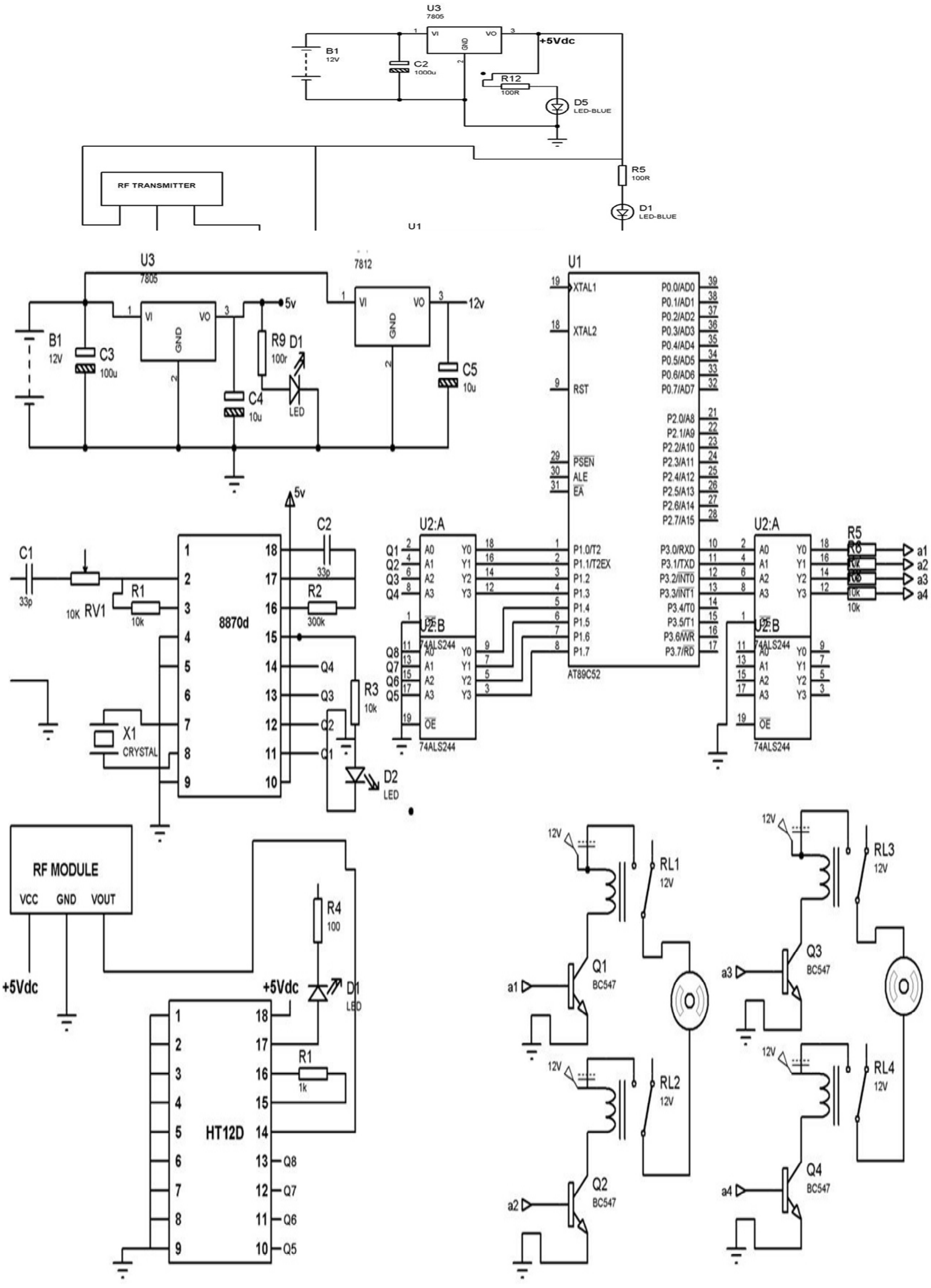

Fig 3: Circuit Diagram of Remote Control

Table 1 DTMF Keypad Frequencies (with Sound Clip)

Frequency	1209Hz	1336Hz	1477Hz
697Hz	1	2	3
770Hz	4	5	6
852Hz	7	8	9
941Hz	*	0	#

Table 2 DTMF Function Buttons

Buttons	Functions
Button 1	Move Backward Left
Button 2	Move Forward
Button 3	Move Backward Right
Button 4	Move Forward Left
Button 5	Stop
Button 6	Move Forward Right
Button 8	Move Backward
Button 7	Not Used
Button 9	Not Used
Button 0	Not Used
Button *	Not Used
Button #	Not Used

Table 3 RF Remote Control Function Keys

Keys	Functions
Key 1	Move Backward Left
Key 2	Move Forward
Key 3	Move Backward Right
Key 4	Move Forward Left
Key 5	Stop
Key 6	Move Forward Right
Key 8	Move Backward
Key 7	Not Used
Key 9	Not Used
Key 0	Not Used
Key A	Not Used
Key B	Not Used
Key C	Not Used
Key D	Not Used
Key Stop	Not Used
Key Enter	Not Used

Table 4 result from DTMF Control

S/N	DTMF COMMAND	LED 1	LED 2	CAR MOVEMENT	RESULT
1	Button 1	Blinks	ON	Backward left turn	The car moved back and made a turn left achieved. The result is expected.
2	Button 2	Blinks	ON	Straight forward movement	The resultant action is expected.
3	Button 3	Blink	ON	Backward right	A back left turn is expected and it is achieved.
4	Button 4	Blink	ON	Forward left	The car moved front and turned left.
5	Button 5	Blinks	ON	No movement	The car stops as expected.
6	Button 6	Blinks	ON	Forward right	A turn was made as expected.
7	Button 8	Blink	ON	Backward movement	A straight backward movement was achieved the result is expected.

Table 5 Result from Remote Control

S/N	REMOTE CONTROL COMMAND	LED 3	LED 2 and LED 4	CAR MOVEMENT	RESULT
1	Key 1	Blinks	ON	Backward left turn	The car moved back and made a turn left achieved. The result is expected.
2	Key 2	Blinks	ON	Straight forward movement	The resultant action is expected.
3	Key 3	Blinks	ON	Backward right	A back left turn is expected and it is achieved.
4	Key 4	Blinks	ON	Forward left	The car moved front and turned left.
5	Key 5	Blinks	ON	No movement	The car stops as expected.
6	Key 6	Blinks	ON	Forward right	A turn was made as expected.
7	Key 8	Blinks	ON	Backward movement	A straight backward movement was achieved the result is expected.

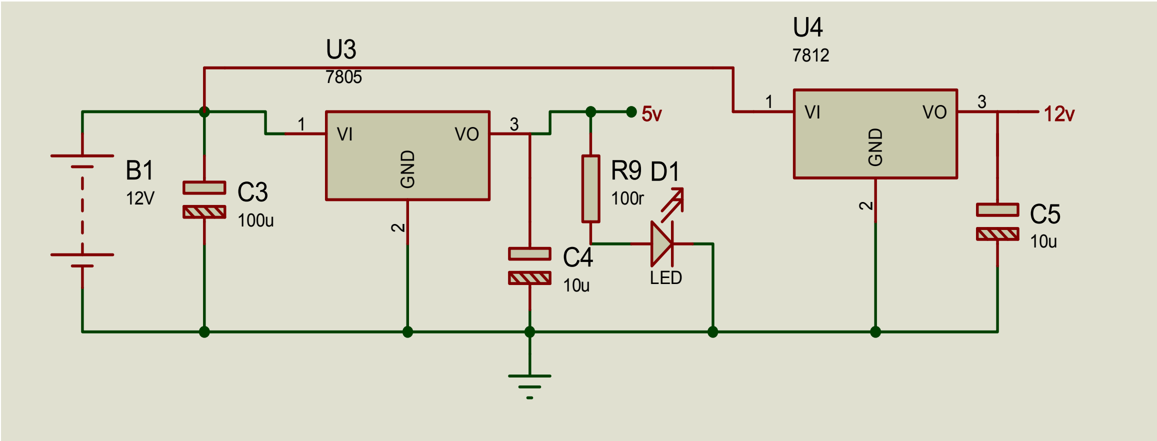

Fig 4 circuit diagram of the power supply

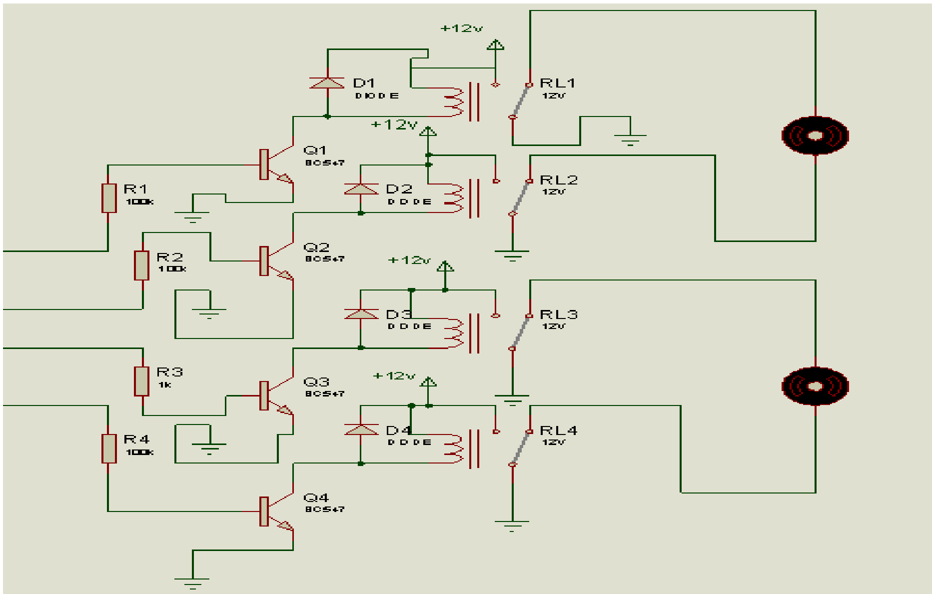

Fig. 5 Circuit Diagram of the Output Unit

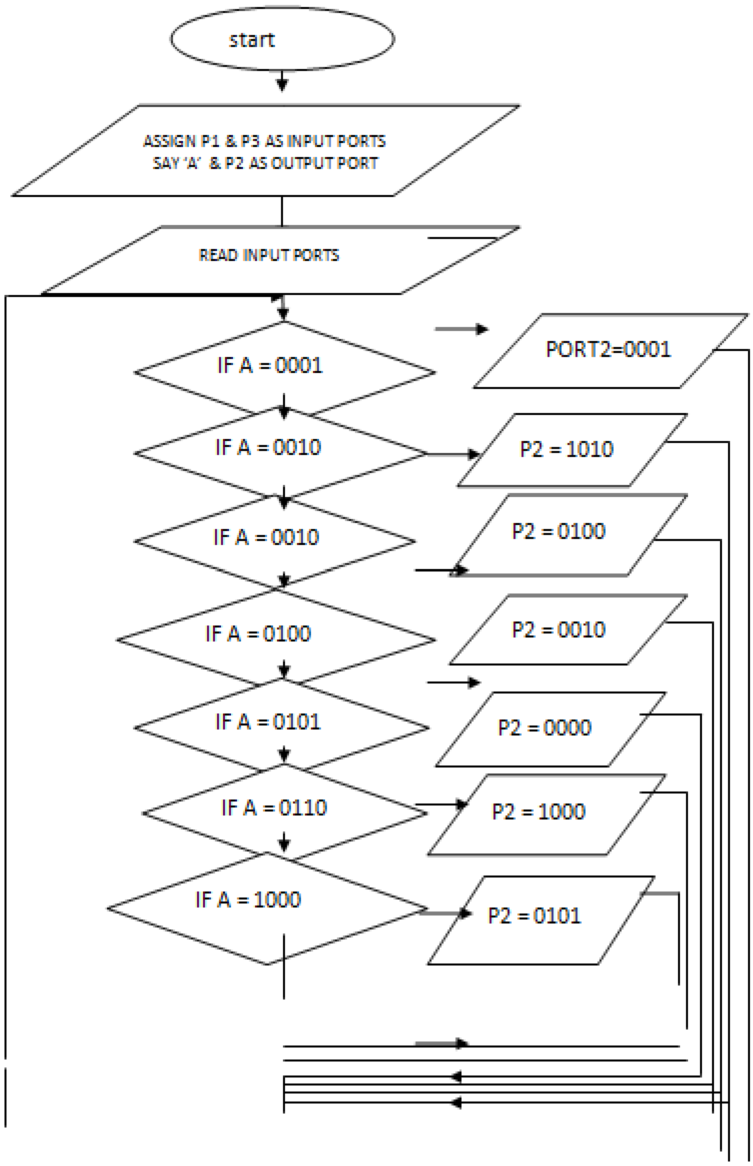

Fig 6:: Flow chart of the Algorithm

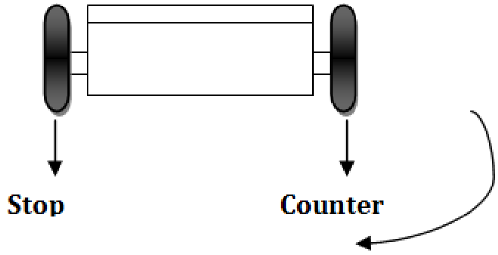

Figure 7: Backward Left movement of robotic car

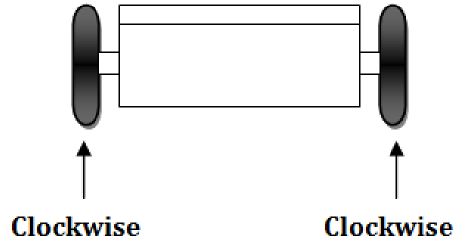

Figure 8: Forward Movement of Robotic car

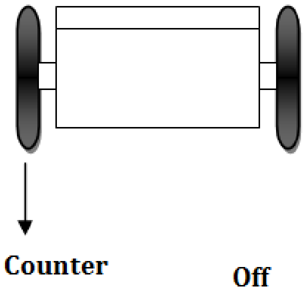

Figure 9: Backward Right Movement of robotic car

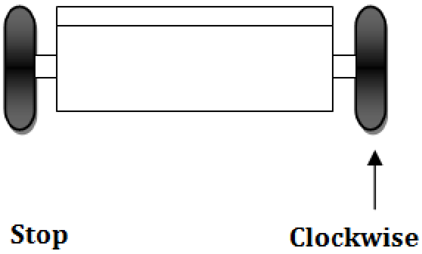

Figure 10: Forward Left Movement

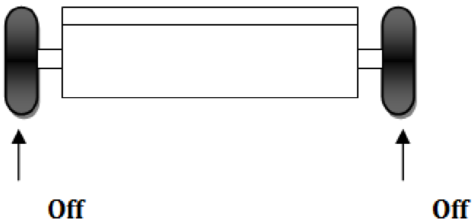

Figure 11: Halt state of the robotic car

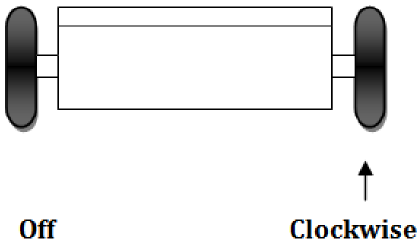

Figure 12.Forward Right movement of the robotic car

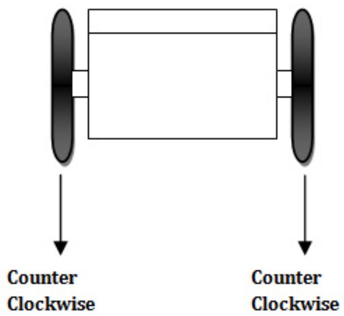

Figure 13: Backward Movement of Robotic Car

Fig 14: Fabricated GSM/RF based Robotic Circuit