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Design and Fabrication of RF-Controlled Pick and Place Robotic Vehicle

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Abstract— *Robotic arm is an important subset of a robot and it is defined as an electromechanical machine controlled by electronic or computer programming. They find use in tasks that are extremely hazardous or impossible for humans such as drilling, spraying, lifting heavy objects, welding, and rescue mission among others. This paper presents an RF-controlled pick and place robotic vehicle design and fabrication methodology. The components in the fabrication are: RF transceiver modules, encoder and decoder ICs, microcontroller, voltage regulator, servo motors, motor driver, battery and other electronic components and materials. The outcome is a prototype with a weight of about 1.35kg, having a dimension of 25.5cm, 20.5cm, 45.0cm, as length, breath and height respectively. The vehicle can be controlled at a maximum distance of 100m by the RF remote and perform the desired operation (pick and place of small objects) smoothly*.

Keywords— *Robotic arm, microcontroller, RF transceiver, vehicle, programming, Arduino, encoder ICs, decoder ICs, servo motor*.

I. Introduction

Robots are electromechanical machines controlled by electronic or computer programming. They can be classified into three types, namely: autonomous, semi-autonomous and remotely controlled [1]. They find use in tasks that are extremely hazardous or impossible for humans. A robotic arm has similar functions to the human arm, it is one an essential part of a robot. As a subset of a robot, robotic arm can be used separately in tasks such as drilling, spraying, lifting heavy objects, welding and rescue mission among others [2] [3] [4]. A stand-alone robotic arm is usually fabricated by using servomotors, micro-controllers, mechanical and electronic components [5].

The main advantages of robotic arm are simplicity, increased operation speed, increased productivity and efficiency, precision, and ease of hazardous material shifting. ATMEGA micro-controller family have been used extensively in various robotic arm fabrication in the past due to their simplicity and effectiveness in control and coordination operations. Robotics as a field integrates electrical engineering, mechanical engineering, control engineering, signal analysis, computing and artificial intelligence. Robot institute of America defined robot as a multifunctional manipulator invented to move materials, specialized devices and tools via variable programmed motions. This mechanism can be reprogrammed and used for performing various tasks [6].

Environmental Interaction is an important objective in robot development, and it is established by a gripping device (the arm) or end effectors. As earlier mentioned, robotic arm is similar to human arm which has several joints for motion, controlled through synapses from the brain. By inference, the robotic arm has several mechanical joints for motion, controlled by signals from the programmed micro-processor.

II. Review of Related Works

Robotics has achieved success in several fields such as medicine, military, education, archaeology, and manufacturing. It can be defined as a field that gives birth to machines that performs work humans find dangerous or undesirable [7]. Robots can perform monotonous tasks accurately, cheaply and faster than humans [8]. The programming languages for robot control are: Motion Control Language, Variable Assembly Language, Interactive Reader Language, Arc Macro Language among others [9]. Automatic operation (automation) is paramount in robotics. This is achieved through the use of programmable logic controllers. Most automobile manufacturing industries use robots for painting, assembly, handling parts, making spot welding etcetera, for accurate and fast work. Advanced software is used in robot programming, this makes diagnosis easy and faster which greatly reduces downtime and improves efficiency and cost-effectiveness [10].

Most works on robotic arm utilizes ATMEGA 8 microcontroller with Arduino programming to interface potentiometer (which converts mechanical motion into electrical signals) and servomotors. The circuitry of the hand-held control converts the analogue electric signals from the potentiometer into digital signals (pulses) for onward transmission to the servomotors which translates the pulses to movement of the arm [11]. The major objectives of robot fabrication are: use in hostile and contaminated areas, nuclear power plants operation to lessen human exposure to hot,

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oxygen-deficient and radiation environment. Wheeled and track vehicles are the most popular configurations of mobile robots [12].

III. System Design and Specification

The method employed in this design and fabrication of remote-controlled pick and place robotic vehicle (PPVR) is based on the operational characteristics and features of the RF transceiver, microcontroller, Servomotors, electronic circuitry and the software programming of the microcontroller. The pick and place portion consists of the Remote Control (Transmitter) Section and the Pick and Place Robot (PPR) Receiver Section.

3.1 Re8mote Control (Transmitter) Section

The remote-control section consists of RF transmitter module fitted with an Antenna, encoder, 12V alkaline battery and the keypad interfaced with the microcontroller as depicted in Figure 1. When a key is pressed, the value is converted to a 4-digit binary which is in turn outputted as parallel data to the encoder. The encoder performs conversion to serial data of its inputted parallel data and feeds this to the transmitter, which transmits the serial data.

The PPRV is remotely controlled with just few buttons or switches on a keypad. When the required buttons are pressed, it transmits command signal to the robot to make it move in any direction to achieve the task of picking and placing objects. This is achieved by RF communication modules (Transmitter and Receiver). Figure 2 and Figure 3 show the transmitter module and the remote-control respectively.

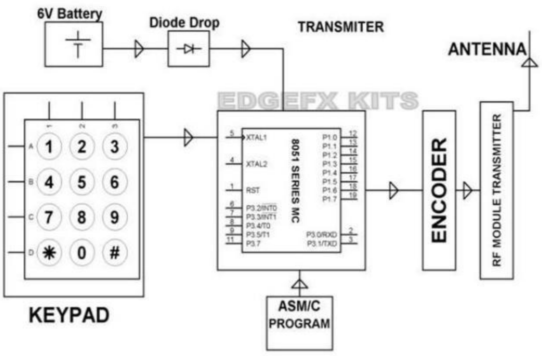

Fig. 1. Block Diagram of a Remote-Control Section [13]

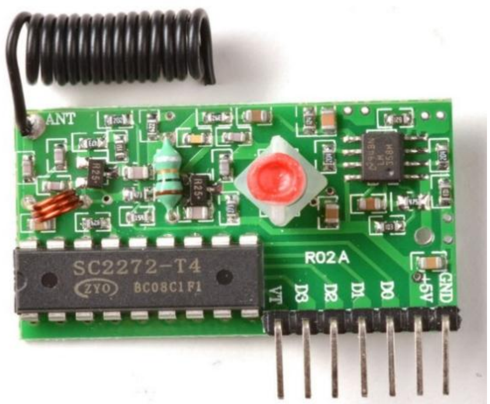

Fig. 2. The transmitter module

Fig. 3. The Remote control

3.2 Transmitter Circuit Diagram

In the transmitter section circuit displayed in Figure 4, there are 4 switches used in the circuit for controlling the robotic arm pick & place operation and vehicle movement. Also, one of the switches is used for the turning on and off the remote control. The diode in the circuit uses binary language with the help of the logic gates to instruct the receiver to perform tasks. Transmitter uses an encoder IC, PT2262 to encode voltage signals in binary language, this connects to the switches.

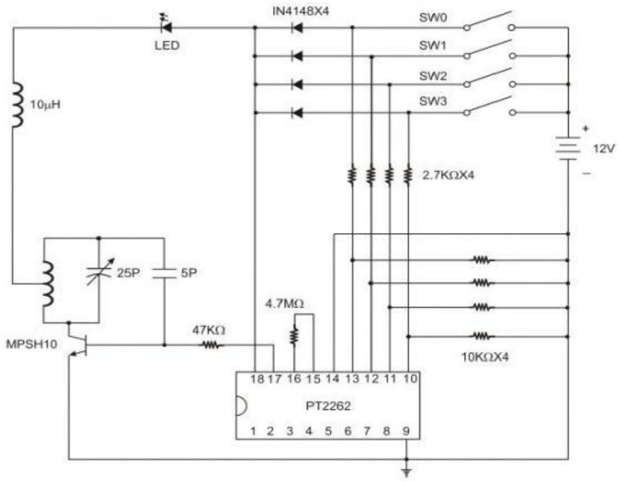

Fig. 4. Internal Circuitry of PT2262

3.3 PPR Receiver Module

The PPR section consists of robotic arm located on a moving chassis. The vehicle can move in different terrains and surfaces regardless of how smooth or rough it is. The robot uses two servo motors for chassis operation and another two servo motors for the arm operation. The arm comprises of an arm assembly with a jaw, which can only move up and down. The two motors for the arm assembly, one for the up and down movement and the other for jaw opening and closing. For motor control, Atmega328 micro controller and motor driver IC were used.

The input control signal originates from the remote control and transmitted to be received and decoded in the microcontroller for onward transmission to actuators (servo motors) in the system. Figure 5 show the block diagram of the pick and place robot module.

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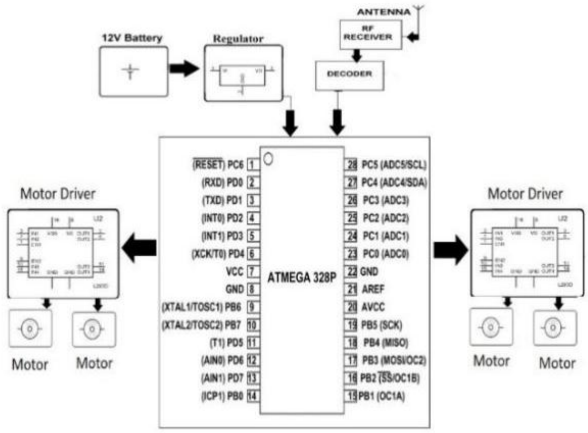

Fig. 5. Pick and Place Robot Module Block Diagram [14]

3.3.1 Robotic Arm Design

The robotic arm with gripper termination has five degrees of freedom with a rotating base that rests on the upper region of the vehicle as depicted in Figure 6. The base has a servo motor that allows cyclic movement at the base, another motor is located at the shoulder, this allows for upward and downward movement of the arm. The last servo motors allow for the gripping of objects by the end effector. Free Body Diagram of the robotic arm Operational of robot arm is depicted in Fig. 6 with the servos designated as S1, S2, S3 and S4.

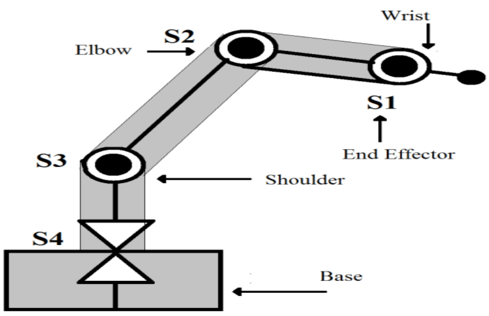

Fig. 6. Free Body Diagram of the robotic arm [15]

3.3.2 Operational of robot arm

The strength of these servo motors varies directly as the load the arm can lift, this implies that overloading the arm can lead to system damage or failure.

3.3.3 Circuit design for development of PPR

The microcontroller performs the task of forward, reverse, left, and right movement of the robotic arm and the gripper. User sends the control signal through RF module, this is received and executed by the robot according to the programming. Atmega-328P is a low power highly efficient 8-bit AVR microcontroller which has the ability to convert analogue signals from sensors and other electronic components to digital signals. The Circuit Diagram of a PPR Vehicle is depicted in Figure 7. The microcontroller sends signals to the RF module using Rx-Tx Serial UART interface. Roving Networks manufactured RF module is used. Atmega328P has higher code memory and RAM, is faster and executes instructions in a clock cycle which makes it preferable to standard 8051 and other high-speed variants.

Furthermore, AVRs have internally calibrated clock option, this in many cases result in no need for a crystal and availability of two extra port pins. They have inbuilt circuitry for ADC, SPI, I2C, UART, internal oscillators and internal pull up registers. AVR also possess L&H 8bit registers, which makes performing primitive 16bit operations possible by breaking down the data in to H and L 8-bit values. ATMEA-328 has the ability to convert analogue signals from sensors and other electronic components to digital signals.

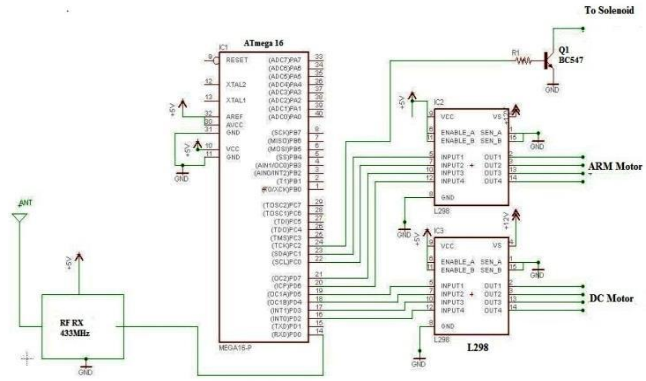

Fig. 7. Circuit Diagram of a Pick & Place Robotic Vehicle

3.4 Hardware Implementation

The hardware implementation of remotely controlled PPR comprises of microcontroller, Servo motor, RF communication modules, voltage regulator and power supply.

3.4.1 Microcontroller (ATMEGA-328P)

The ATMEGA-328p Microcontroller is a single-chip microcontroller from series Atmel which belongs to the mega AVR series. It is a highly efficient and cost-effective type of microcontroller. It's an AVR RISC that denotes reduced instruction set. ATmega8 is CMOS, low-powered AVR, 8-bit microcontroller manufactured by Atmel. It executes instructions by using single clock cycle. It has a throughput of about 1MIPS per MHz, this allows the designed systems with ATMEGA-328p to have optimal power consumption against the processing speed. Figure 8 shows the pin-out diagram of ATMEGA-328p

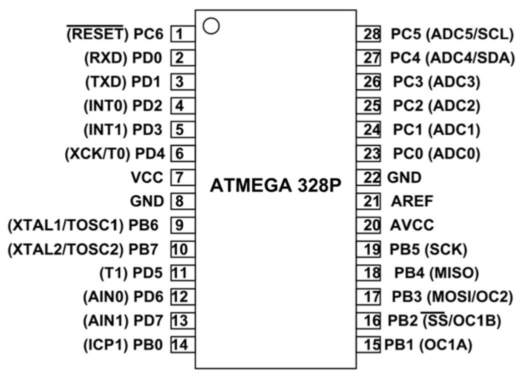

Fig. 8. Pin-out Diagram of ATMEGA-328p

3.4.2 Voltage regulator (LM7805)

Lm7805 is an IC with three terminals which performs the function of producing a fixed voltage of 5V as output when the input voltage is between 7.2 and 35V. A regulated fixed

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voltage is important to prevent intermediate logic levels that can result in malfunctioning of ICs used. 78xx series ICs are fixed voltage regulators with xx indicating the fixed voltage output of the ICs. The ICs has a provision for heat sink addition which is useful if the input voltage is greater than 7.5V. This is because the excess voltage is dissipated as heat.

The schematic in Figure 9 depicts how to connect a 7805 IC, pin 1 is connected to the input voltage terminal to produce an output voltage at pin 3. The neutral of both the output and input are connected to pin 2. Figure 9 and 10 show the pin-out and internal circuitry of LM7805

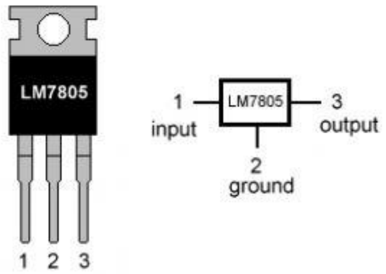

Fig. 9. Pin-out of LM7805

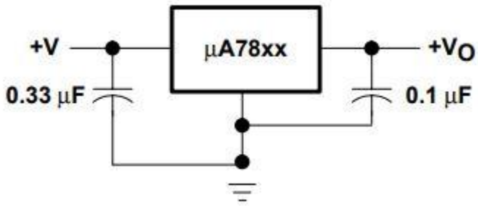

Fig. 10. Internal Circuitry of LM7805

To prevent power loss, the input voltage to the IC is limited to 7.2V and maintained at this level. This is because in design, circuitry voltage fluctuation could be fatal to electronic components and most especially Microcontrollers.

3.4.3 Servo motor (SM)

SM uses a servo mechanism that senses errors and uses the information to feedback and correct the motor's performance. They are DC motors fortified with servo mechanism to precisely control angular movement of the motor. The limit of rotation for a servo is 180^0, this is constrained to some fixed angles. They usually find use in robotic arms and legs, RC toys and sensor scanners. The specifications of Servomotor used are: Weight- 55g, Dimension- 40.7*19.7*42.9mm, Stall torque- 10kg/cm, Operating speed-0.20sec/60degree (4.8v), Operating voltage 4.8-7.2V and Temperature range 0-55 degrees. PWM is used for the control signal of servo motors

SM is precisely controlled unlike conventional DC motors, they come with three wires, for power, control and neutral respectively. Servo controller regulates the power drawn to energize the motor. SMs are designed for precise tasks and do not freely rotate like standard DC motor. Control signal is received by the SMs which depicts the output position to turn the motor in the right direction as determined by the position sensor. For an SM, a neutral pulse keeps the shaft of the servo in the centre, a positive pulse determines the shaft's position. The control command is used to move and keep to a position opposing external forces. SM retains its position if there is no control signal and resists external forces to move it from the position. Picture depicting SM is depicted in Figure 11.

Fig. 11. Servo motor

3.4.4 Motor driver (L293D)

L293D is an IC of 16pins with eight pins on either side devoted to regulating 2 DC motors simultaneously in both directions. It consists of two pins for input of each motor with an enable pin per motor. It is otherwise called an H-BRIDGE and one of the popular 16-Pin Motor Driver IC used mainly to drive motors. A single L293D IC is capable of running two DC motors at the same time; also, the route of each motor can be independently controlled. Figure 12 and 13 show the physical diagram and internal circuitry of L293D, respectively. The microcontroller output current is very low as compared to motor current requirement. 1 Amp is required as motor current while micro controller output current is in the interval of milliamps. Therefore, microcontroller can't directly drive motors. Hence, a driver is needed in-between the controller and motor. The motor driver used here is called as L293D. It consists of four channels with each motor requiring two channels each for control. Therefore, we need one L293D for controlling of wheel motors and other one is for the controlling the motors of robot arm. It can increase the voltage output up to 36v from 4.5v.

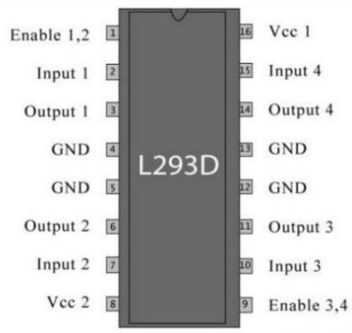

Fig. 12. Physical Diagram of Motor Driver

The IC operates on the Half H-Bridge principle, which is a set-up used to run two motors simultaneously in clock wise and anti-clockwise direction. The circuit configuration to achieve this is described in Figure 13. All the Ground pins should be grounded. The IC consist of two power pins, the first is the Vss (Vcc1) that delivers the voltage for the IC to function, which is to be connected to +5V. The other is Vs (Vcc2) which delivers the voltage for running the motors, based on the motor's specification. This pin can be connected to voltages between 4.5V to 36V, +12V is connected to in this work.

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The pins, enable 1, 2 and Enable 3, 4 are used as Motor 1 and 2 Enable Input pins respectively. Both motors will most likely operate simultaneously, hence, both of these pins are held high by default through connection to a +5V supply. Input pins 1 and 2 are used for Motor 1 control while pins 3 and 4 are for Motor 2 control. The pins are connected to microcontroller to control the direction and speed of the motor. The input pins can be toggled to control the motors.

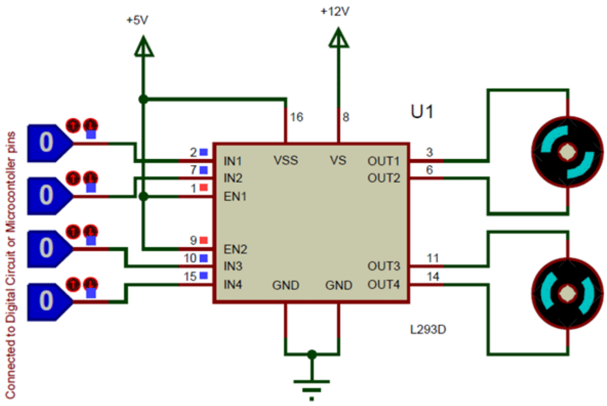

Fig. 13. Internal Circuitry of L293D

3.4.5 The remote-control decoder (PT2272)

PT2272 is a remote-control decoder in conjunction with PT2262 which utilizes CMOS Technology. It is a 12-bit tri-state address pins which provides 531,441 or 312 address codes. The large volume of address codes leads to reduction in occurrence of unauthorized code scanning possibilities and code collision. PT2272 is available in various options to fit into different application need such as momentary or latch output type and variable number output data pins.

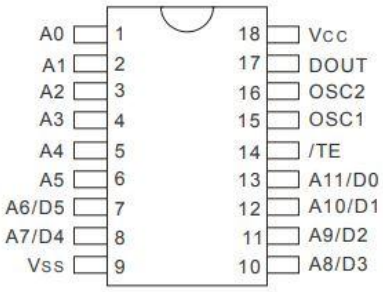

Fig. 14 Pin-out diagram of PT2272

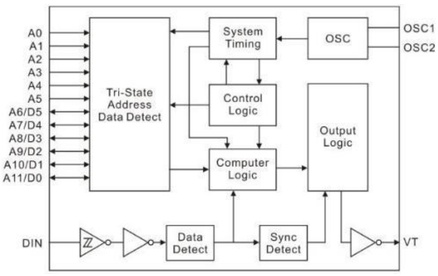

Fig. 15 Internal Circuitry of PT2272

PT2272 decodes the received signal and fed the output into DIN pin. The signal is deciphered into code words which include data, the address and sync bits. The bits of the decoded address are matched with the input pin address bits to drive the appropriate motor in the required direction. Figure 14 and 15 show the pin-out diagram and internal circuitry.

3.4.6 Battery

Microcontroller stepper motor control is paramount in the fabrication, hence not much attention is given to power supply section. Rechargeable batteries of 12V, 500mA was used, the output of this battery is fed into the LM7805 which gives an output of +5V that is required to power the control unit section. The battery type used is a rechargeable type that consist of electrochemical cells which can be discharged, charged into load, and recharged several times.

4.0 Software Implementation

Software is a set of algorithms, procedures, programs, and its documentation in relation to the operation of a data processing system. In this work, software is used to achieve the aim of this work which is RF control of a pick and robotic vehicle. Arduino IDE: Arduino hardware uses a Wiring-based programming language, it is akin to C++ with some adjustments, also a Processing-based IDE. Arduino is programmed with Arduino IDE that has been develop using Java and based on Processing, avr-gcc, and other open-source software.

IV. CONCLUSIONS

The image of the PPR Vehicle is depicted in Figure 16. This prototype is an RF controlled motorized PPR with a weight of about 1.35kg, having a dimension of 25.5cm, 20.5cm, and 45.0cm as length, breath and height respectively. The vehicle can be control at a maximum distance of 100m by the RF remote and perform the desired operation (pick and place of small objects) smoothly. The robotic vehicle can successfully pick an object of maximum weight of 0.8kg without any difficulty or complexity.

Fig. 16. Image of the Prototype Pick and Place Robotic Vehicle

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