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Cost Effective Implementation of a Human Arm Emulator

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Abstract— ***Dangerous work environments, like nuclear reactors and chemical plants, pose a threat to human life by the ways of injuries or fatalities. RoboArm is a simple and highly cost efficient electromechanical model, which copies a human being's hand movements. It is controlled remotely via an infrared beam, which is generated by using infrared light emitting diodes, which sense a human being's hand movements. This circuit has been designed to emulate two dimensional hand movements successfully. The actions which can be mimicked include a forward and backward motion as well as a grabbing action is achieved using electromagnets.***

Index Terms— ***Electromechanical, Infrared, Low cost, Phototransistor, Robotic arm***

I. INTRODUCTION

The integration of electronics and mechanics is used in a plethora of industries ranging from medicine to nuclear sciences. RoboArm has been made to achieve remote manipulations of robotic movements using highly effective low cost technology. This human arm emulator resembles the human arm with all mechanical and electronic circuit support enabling it to copy gestures and movements. In order to overcome the limitations of primitive wired technology, RoboArm implements wireless communication between the user and the electromechanical arm.

II. PRINCIPLE

In order to enable the RoboArm to emulate human movements, infrared transmitters and receivers are used to send signals from the human arm to the robotic arm. Infrared radiation (IR) is electromagnetic radiation with a wavelength between 0.7 and 300 µm. Infrared is widely used in communication and control systems due to ease of generation and its immunity to electromagnetic interference.

The robotic arm applies an algorithm on the signal received and accordingly copies the movements. Infrared (IR) LEDs are attached to the forearm, back arm and finger, which continuously transmit an IR modulated beam. Three photo transistors are strapped to the forearm and back arm, and one on the finger to regulate the movements of the robotic arm.

The fore arm and back arm of the RoboArm are driven by DC motor via a motor driver IC. This motor driver is in turn controlled by a microcontroller as per the signals received from the photo transistors. The finger movement is done through a plunger movement with the help of electromagnet, which is controlled by the microcontroller.

Any change in the position of the IR beam will produce an error signal as per the sensors (photo transistors) and this signal is given to the microcontroller. The microcontroller sets the corresponding motor to drive and thus the RoboArm follows our movements effectively.

III. SECTIONAL OVERVIEW

In order to generate continuous square waves of frequency of about 38 KHz, IC 555 is used in astable multivibrator mode. The generated square wave is given to TR Darlington pair transistors, which increases the current driving capability of the generated beam in the transmitter and drives the IR light emitting diodes (LED). Three LEDs are placed on the forearm, back arm and finger. The output of the IR LEDs is an IR beam which is transmitted continuously at the frequency of the generated square wave.

Figure 1. Transmitter Section

The beam sent by the transmitter is received by the receiver section. There are in all seven IR sensors (phototransistors) to sense the beam. There are three sensors on back arm, three on fore arm and one on the finger. The signals from the IR sensors are given to the microcontroller 89c2051. The signals received from the sensors are processed as per the program and the algorithm [Section V] stored in the microcontroller memory. Then microcontroller produces signals which are given to the motor driver IC L293. This IC can drive two motors as per the signals received at its input from µc 89c2051.

There are two 12 V, 2 pole permanent magnet DC motors on the mechanical arm; one for the fore arm and one for the back arm movements. These motors are completely controlled by the motor driver. The plunger depicts the movements of the finger. It uses the electromagnet which is energized and controlled by the microcontroller.

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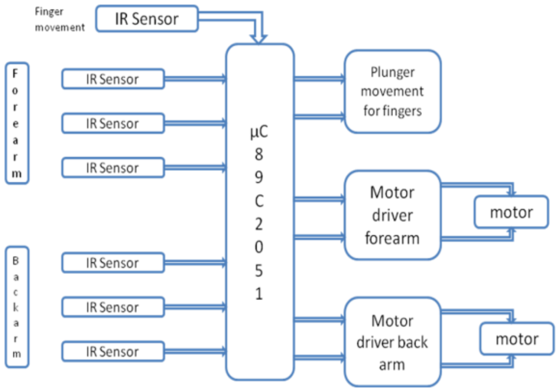

Figure 2. Receiver Section

IV. OPERATION

The transmitter circuit comprises of three IR LEDs [Section III]. Whereas, the phototransistors and microcontroller form the receiver section on the RoboArm [Section III].

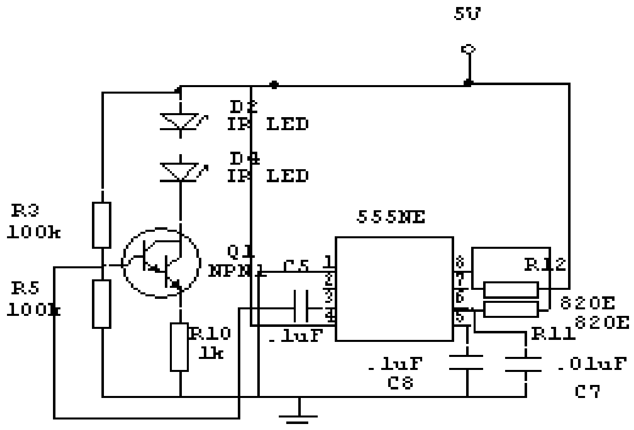

Figure 3. IR Beam Transmitter Circuit.

RoboArm implements simple principles of infrared. The transmitter section is worn on human arm. It consists of three IR transmitters; one back arm, one on fore arm and the last one for the finger movements. Figure 3 shows the transmitter circuit diagram. The transmitter section continuously transmits IR beam at about 38 KHz. This is done by using IC 555 as astable multivibrator and its output frequency is controlled by RC time constant. Then the generated IR beam is given to the Darlington pair transistor which increases the current carrying capability of the generated IR beams. Then this beam is transmitted via infrared LEDs. The range of this IR LEDs is about 2 to 3 meters. Also the transmitted beam is in line of sight i.e. in straight line.

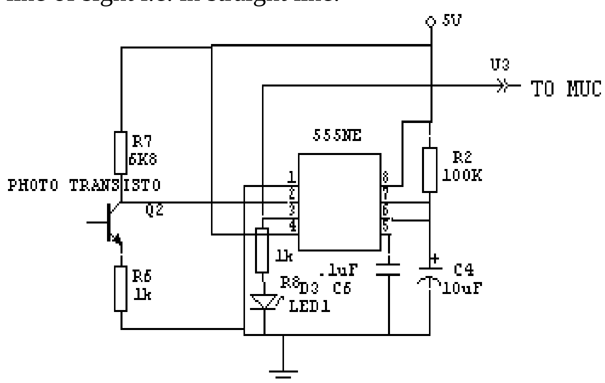

Figure 4. IR Beam Receiver Section

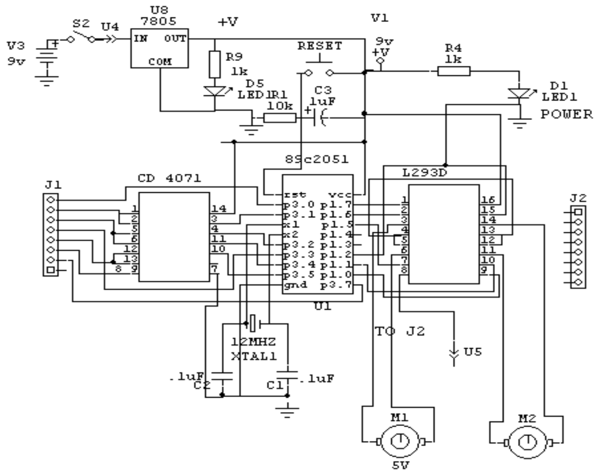

Figure 5. Microcontroller Circuitry

Then the transmitted beam is received by the receiver section. There are in all three receiver sensors; one at back arm, one at fore arm and the last one on the palm of the robot. The fore arm and the back arm sections consist of three IR sensors i.e. left, middle and right. Figure 4 shows the circuit diagram of the receiver section. Here, the receiver consists of phototransistors as the IR sensors. As soon as the IR beam falls on the photo transistor it conducts and generates signals which are used to trigger IC 555 via a load resistance of 6.8KΩ. Here IC 555 is used as monostable multivibrator. So the output of the IC (pin no 3) goes high as per RC time constant i.e. for the duration T=R*C=100kΩ*10µf=1 second.

Thus, this generated pulse is fed to microcontroller. Figure 5 shows the microcontroller circuit. It is fed via IC 4071CD Quad 2 inputs OR GATE IC. Both the inputs of all four OR gates are shorted and the output is taken. While the signals from middle sensor of both the arm and from finger sensor are connected directly to the µc. The signals are received on port 3 of 89c2051.The output of the µc are given through port1 to drive the motor driver IC L293. The µc generates signals to drive the motor via motor driver as per the signals received in the receiver section. The program in the µc takes care of the changes and produces drive signal on port1.6 for forward and port1.5 for reverse movements of the back arm. And for the fore arm movements' µc drives signals on port1.1 for forward and port1.2 for reverse action.

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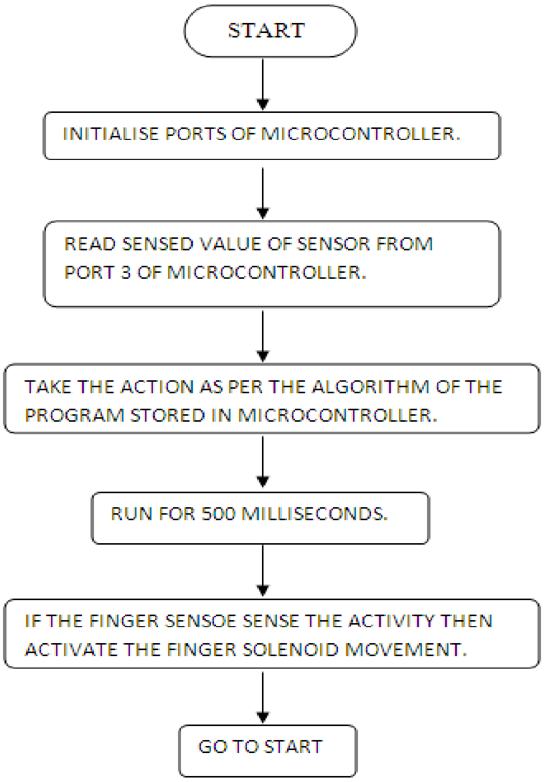

Flowchart 1. Steps to Program the Microcontroller

The outputs are taken from μc and are given to motor driver IC. Here L293 motor driver IC is used which has the capability to drive two motors. The outputs are from pin no. 3 and pin no. 6 of L293 for forward and reverse movements of the of back arm motor; and pin no. 11 and pin no. 14 of L293 for forward and reverse movements of the fore arm motor. μc generates signal on port1.4 to drive the plunger for finger movements.

V. ALGORITHM

The basic algorithm of the program is shown in the table i.e. **Table 1.** The forward or backward movements of any of the two motors are done following the algorithm of the program which is stored in the flash memory of the microcontroller.

The algorithm is as follows:

	Left sensor	Middle sensor	Right sensor	Forward movement	Backward movement
0	0	0	0	1	1
1	0	0	1	0	1
2	0	1	0	1	1
3	0	1	1	0	1
4	1	0	0	1	0
5*	1	0	1	1	1
6	1	1	0	1	0
7	1	1	1	1	1

Table 1. Conditions Used to Program the Microcontroller

The movement of the motor i.e. either forward or backward is controlled by the above given algorithm. When the sensed value is sent to the microcontroller it takes the appropriate decision and generates control signals to motor driver to drive the either of two or both the motors. The fifth condition is impossible as when both left and right sensors are sensing the signals it cannot be possible that the middle sensor is not receiving any input from the transmitter. So, this condition cannot be carried out, as the condition never occurs.

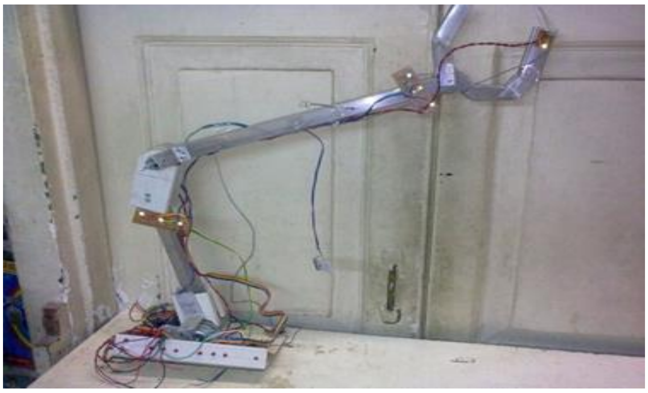

Figure 6. Actual Implementation of the RoboArm Receiver

VI. CONCLUSION

RoboArm provides the cost efficient solution with extremely simple circuitry for arm movements to be emulated in two dimensions. The alignment of the IR beam and phototransistors need to be monitored. The implementation of RoboArm provides an overview to achieving remote control over systems and processes using simple reception and transmission of IR beams.

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