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Comparative Analysis of Stepper Motor Drivers

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Abstract— This paper deals with the transformation of manual sphere gap apparatus used for measuring breakdown voltage of insulating materials such as air into automatic displacement of sphere gap achieved by the use of stepper motor and microcontroller ATmega16A. The manual apparatus involves the risk of accidents due to human negligence and also more human labors. The main objective of this paper is to enhance safety by panel operation. The work has been divided into two part. In the first part, simulation is done using . PROTEUS software and in the second part the model is implemented in hardware. Both the software and hardware results are verified accordingly.

Keywords- *ATmega16A,ULN2003,LM555*

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I. INTRODUCTION

Stepper motors are used in numerous applications where there is need of controlling the motion. This is due to the robust structure of stepper motor, absence of brushes and better control capability. These motors have excellent response to starting, stopping and reversing. Speed control of machine is the most vital and important part in any industrial organization. Stepper motors are also called as stepping motors or step motors. [1] Pulses needed by the stepper motor can be given either through IC555 or using microcontroller. The pulses generated by either of these are not capable enough to drive the stepper motor and hence a driver is needed. In this project the work has been implemented both by IC555 and microcontroller. A microcontroller is a small computer on a single integrated circuit containing a processor core, memory, and programmable input/output peripherals. Microcontrollers are designed for embedded applications, in contrast to the microprocessors used in personal computers or other general purpose applications [2]. In this project we have used ATmega16A IC from programmable flash memory, static RAM of 1 KB and EEPROM of 512 Bytes ATmega16A is a 40 pin microcontroller. The driver circuit used for LM555 is Johnson counter IC4017 and for microcontroller is ULN2003.Unipolar stepper motor with six wires is used out of which four wires are connected to the output pins of driver IC and two wires are made common. In this way pulses are given to stepper motor and the stepper motor rotates with desired step angle. The speed of the motor is inversely proportional to the pulse delay given to the four phases of stepper motor. The pulses are generated with the help of microcontroller 8051. There are 32 I/O (input/output) lines which are divided into four 8-bit ports designated as PORTA, PORTB, PORTC and PORTD. In this manner, we have achieved the automatic displacement of stepper motor without the involvement of user and making the apparatus more reliable.

II. METHODOLOGY

A. The methodology for stepper motor driving circuit is by using IC555. Firstly power is given through battery source to timer IC 555. The pulse generated by LM 555 is not capable enough to drive the stepper motor hence for this circuit driver IC 4017 is used which amplifies the current pulses. These pulses are now given to stepper motor which then drives in required step angle.

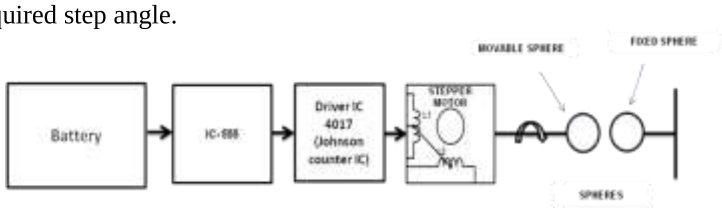

Fig. Sphere gap displacement using LM555 IC

B. The methodology for stepper motor driving circuit using Microcontroller . Firstly power is given through battery source to microcontroller 8051. ATmega16A is used for generating pulses in this circuit. The pulse generated by this microcontroller is not capable enough to drive the stepper motor hence for this circuit driver ULN2003A is used which amplifies the current pulses. These pulses are now given to stepper motor which then drives in required step angle.

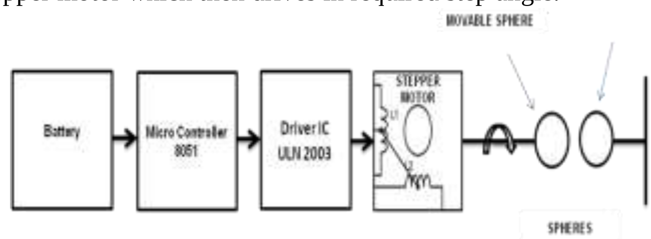

Fig. Sphere gap displacement using Microcontroller

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III. STEPPER MOTOR

A stepper motor is an electromechanical device which converts electrical pulses into discrete mechanical movements. The shaft or spindle of a stepper motor rotates indiscrete step increments when electrical command pulses are applied to it in the proper sequence. The motors rotation has several direct relationships to these applied input pulses. The sequence of the applied pulses is directly related to the direction of motor shafts rotation. The speed of the motor shafts rotation is directly related to the frequency of the input pulses and the length of rotation is directly related to the number of input pulses applied.

A unipolar stepper motor has two windings per phase, one for each direction of magnetic field.Since in this arrangement a magnetic pole can be reversed without switching the direction of current, the commutation circuit can be made very simple (eg. a single transistor) for each winding.Typically, given a phase, one end of each winding is made common: giving three leadsper phase and six leads for a typical two phase motor [7].

Table : Technical specifications of unipolar stepper motor

TERMS	SPECIFICATIONS
Rated Voltage	12V
Rated current/phase	0.6A
Number of phase	4
DC Coil Resistance	3.6 Ω
Step Angle	30
Inductance	4.7mH
Holding Torque	210mNm
Detent Torque	7.9mNm
Mass	150g

IV. TYPES OF STEPPER MOTOR DRIVERS

A. Stepper Motor Driver Using IC555 & Johnson Counter

IC 555 timer is a well-known component in the electronic circles. The timer got its name from the three 5 kilo-ohm resistor in series employed in the internal circuit of the IC.IC 555 timer is a one of the most widely used IC in electronics and is used in various electronic circuits for its robust and stable properties. It works as square-wave form generator with duty cycle varying from 50% to 100%, Oscillator and can also provide time delay in circuits. The 555 timer got its name from the three 5k ohm resistor connected in a voltage-divider pattern which is shown in the figure below. The full internal circuit consists of over more than 16 resistors, 20 transistors, 2 diodes, a flip-flop and many other circuit components.

The 555 timer comes as 8 pin DIP (Dual In-line Package) device. There is also a 556 dual version of 555 timer which consists of two complete 555 timers in 14 DIP and a 558 quadruple timer which is consisting of four 555 timer in one IC and is available as a 16 pin DIP in the market.

An Astable Circuit has no stable state - hence the name "astable". The output continually switches state between high and low without any intervention from the user, called a 'square' wave. This type of circuit could be used to give a mechanism intermittent motion by switching a motor on and off at regular intervals.

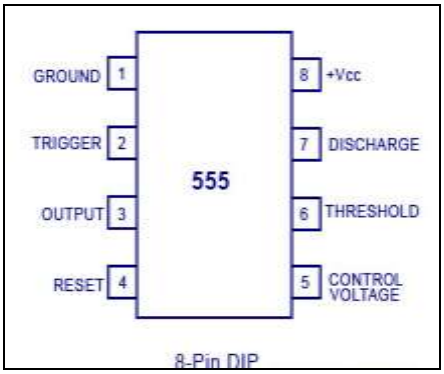

Fig. Pin description of LM555

By selecting the proper values for R_A, R_B and C, the output can be manipulated into a square wave.

The "high" time is given through the equation-

$T_{Hign} = 0.693(R_A + R_B).C$ --------------------------------- (1)

"low" time is given by-

$T_{Low} = 0.693(R_B).C$ --------------------------------------- (2)

The Duty Cycle is thus given through the equation-

$D = (R_A + R_B)/ (R_A + 2R_B)$. ---------------------------- (3)

Another important piece of information is the frequency. It is given by-

$1/(T_{High}+ T_{Low})$ or $1.44/((R_A+ R_B)C)$. ---------------- (4)

In this the important thing is only the third formula. We can see that the frequency is inversely related to R_B (which is 1K+220k POT in the circuit). So if R_B increases then the frequency decreases. And so if the pot is adjusted to increase the resistance in the branch the frequency of clock decreases. The clock generated by 555 timer is fed to DECADE BINARY counter. Now the decade binary counter counts the number of pulses fed at the clock and lets the corresponding pin output go high. For example if the event count is 2 then Q1 pin of counter will be high and if 6 is count the pin Q5 will be high. This is similar to binary counter however the counting will be in decimal (ie., 1 2 3 4…. 9) so if the count is seven only Q6 pin will be high. In binary counter Q0, Q1 and Q2 (1+2+4) pins will be high. These outputs are fed to transistor to drive the stepper motor in orderly way. In this circuit, it can be observed that the RESET connected to Q2 before is now moved to Q4 and the opened Q2 and Q3 pins are connected to another two transistors to get a four pulse driving set to run the four stage stepper motor. So it is clear that we can drive up to ten stage stepper motor. However one should move the RESET pin up in order so to fit in driving transistors in place.

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The 4017 decade counter has ten outputs which go HIGH in sequence when a source of pulses is connected to the CLOCK input and when suitable logic levels are applied The 4017 is an extremely useful device for project word and is used in the Games Timer and in various DOCTRONICS construction kits including the Light Chaser and the Matrix Die. When you are familiar with the 4017, you will be able to think of lots of useful applications. Internally, the 4017 contains five bistable subunits. These are interconnected in a pattern known as a Johnson counter. The outputs of the bistables are decoded to give the ten individual outputs.

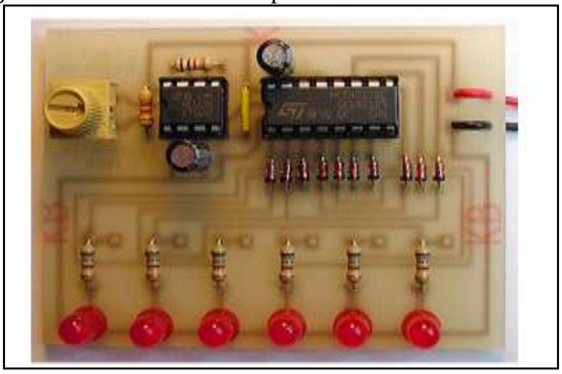

Fig Johnson counter IC 4017

B. Stepper Motor Driver using Mocrocontroller

Stepper motors are used in numerous applications where there is need of controlling the motion. This is due to the robust structure of stepper motor, absence of brushes and better control capability. These motors have excellent response to starting, stopping and reversing. Speed control of machine is the most vital and important part in any industrial organization. In this paper, the speed control of stepper motor is achieved using microcontroller ATmega16A. For sending pulses to the stepper motor driver, microcontroller is used. Since microcontroller is not able to provide sufficient current to drive the stepper motor, Darlington transistor ULN2003 is used. This microcontroller is used both to control the speed as well as position of the motor.[1] [2] Actually speed is inversely proportional to delay between pulses of consecutive phases. The aim of this work is to adjust the distance between sphere gaps using stepper motor drive. The sphere gap apparatus has two spheres connected to it. The position of one sphere is fixed while the position of other is adjusted. There are two objectives here. One is to develop a low cost driver circuit. The second objective is the control and calibration of the sphere gap apparatus. Fulfilment of both the objectives leads to an integrated system for displacing the sphere gap apparatus. The shaft of the stepper motor is coupled to the spheres.

The ATmega16A is a low-power CMOS 8-bit microcontroller based on the Atmel AVR enhanced RISC architecture. By executing powerful instructions in a single clock cycle, the ATmega16A achieves throughputs approaching 1MIPS per MHz allowing the system designer to optimize power consumption versus processing speed.

Table . Ratings of various components used.

Sr.No.	Components	Rating
1	Microcontroller 8051(ATmega16A used)	5.5V, 0.6mA(active mode), 0.2mA(Idle mode)
2	ULN2003	50V,500mA
3	Resistor (10KΩ)	10KΩ
4	Capacitor	10μF
5	Crystal oscillator	16MHZ

a. ATmega16A microcontroller

The ATmega16A is a low-power CMOS 8-bit microcontroller based on the Atmel AVR enhanced RISC architecture. By executing powerful instructions in a single clock cycle, the ATmega16A achieves throughputs approaching 1MIPS per MHz allowing the system designer to optimize power consumption versus processing speed.

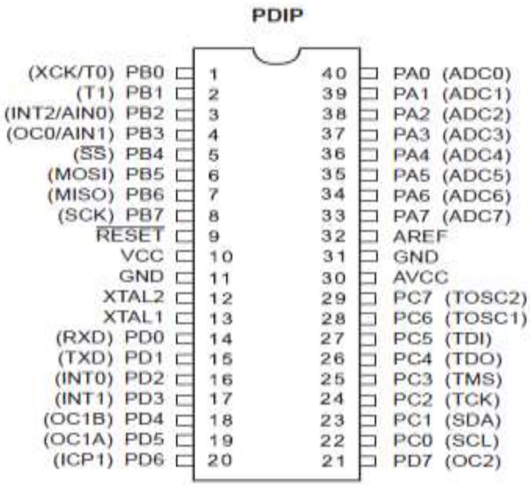

Fig. Pin Configuration of ATmega16A

b. *ULN2003 Driver IC*

The ULN2003A is an array of seven NPN Darlington transistors capable of 500mA, 50V output. In the same family are ULN2002A, ULN2004A, as well as ULQ2003A and ULQ2004A, designed for different logic input levels. The ULN2003 is known for its high-current, high-voltage capacity. The drivers can be paralleled for even higher current output. Even further, stacking one chip on top of another, both electrically and physically, has been done. Generally it can also be used for interfacing with a stepper motor, where the motor requires high ratings which cannot be provided by other interfacing devices.

Fig. Pin Configuration of ULN2003

V. HARDWARE CIRCUIT USING IC555

The clock generated by 555 timer is fed to DECADE BINARY counter. Now the decade binary counter counts the number of pulses fed at the clock and lets the corresponding pin output go high. For example if the event count is 2 then Q1 pin of counter will be high and if 6 is count the pin Q5 will be high. In binary counter Q0, Q1 and Q2 (1+2+4) pins will be high. These outputs are fed to transistor to drive the stepper motor in orderly way.In this circuit, it can be observed that the RESET connected to Q4 and the opened Q0, Q1 Q2 and Q3 pins are connected to four transistors to get a four pulse driving set to run the four stage stepper motor. We can drive up to ten stage stepper motor. However one should move the RESET pin up in order so to fit in driving transistors in place.The diodes are placed here to protect the transistors from inductive spiking of the stepper motor winding. If these are not placed one might risk blowing the transistors. Greater the frequency of pulses, greater the chance of blow up without diodes.

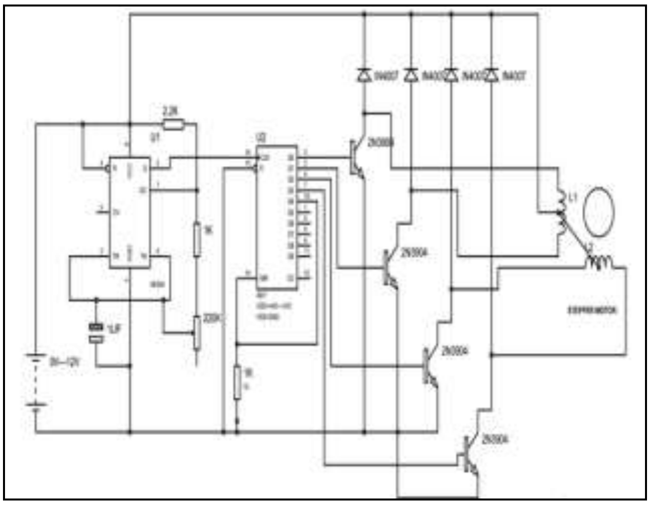

Fig Stepper Motor Control using IC555 Circuit Diagram

VI. SOFTWARE CIRCUIT USING PROTEUS

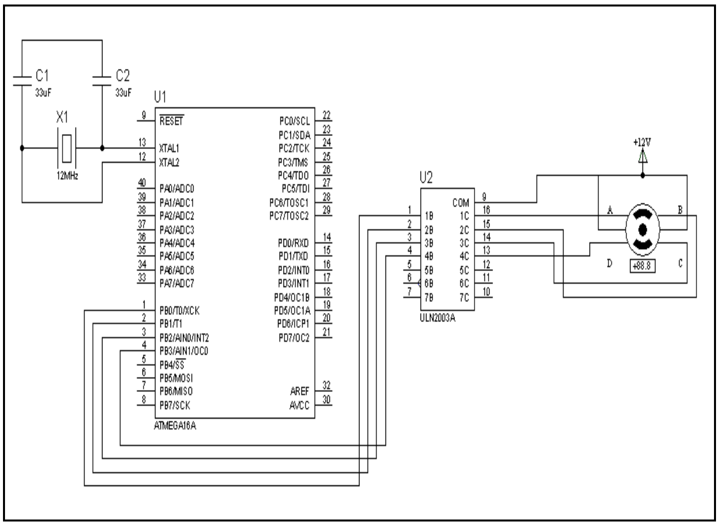

Fig. Stepper Motor Control using Microcontroller

Proteus (Processor for Text Easy to Use) is a fully functional, procedural programming language created in 1998 by Simone Zanella. Proteus incorporates many functions derived from several other languages: C, BASIC, Assembly, Clipper/dBase; it is especially versatile in dealing with strings, having hundreds of dedicated functions; this makes it one of the richest languages for text manipulation. Proteus was designed to be practical (easy to use, efficient, complete), readable and consistent.

Its strongest points are:

i. powerful string manipulation;
ii. comprehensibility of Proteus scripts;.

The language can be extended by adding user functions written in Proteus or DLLs created in C/C++. Digital Oscilloscope software is used burn microcontroller. Digital Oscilloscope is a software debugger and simulator. It is the debugger connected to a hardware system. Programs are run on the target hardware rather than in the virtual microcontroller in your PC. The Kiel debugger DScope will communicate with the Intel RISM monitor contained in the EPROM on the USB board. The COM port will be dependent on your configuration and the speed is 9600 baud.

VII. RESULT

i. HARDWARE RESULT OF IC 555

Fig. Output waveform of IC555

This is the output waveform of IC555 obtained on CRO. These pulses are now given to the stepper motor driver for amplification as these pulses are not sufficient to drive the stepper motor.

Fig. Non inverted output of driver

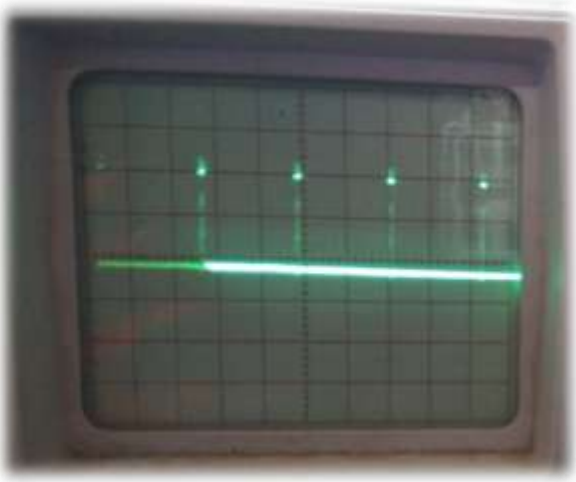

Fig. Inverted output driver

ii. SOFTWARE RESULTS USING PROTEUS

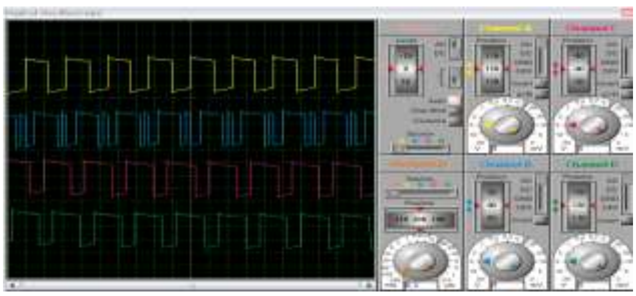

Fig. Pulses for Forward rotation waveforms

The above figure shows the forward rotation for four different phases of the six wire unipolar stepper motor. Different color represents different phases of the stepper motor.

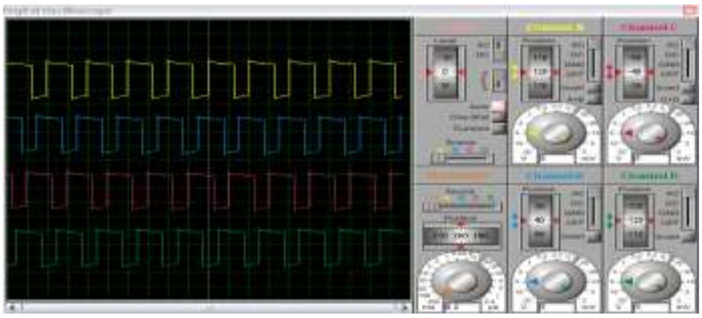

Fig. Pulses for Reverse rotation waveforms

iii. HARDWARE RESULTS MICROCONTROLLER

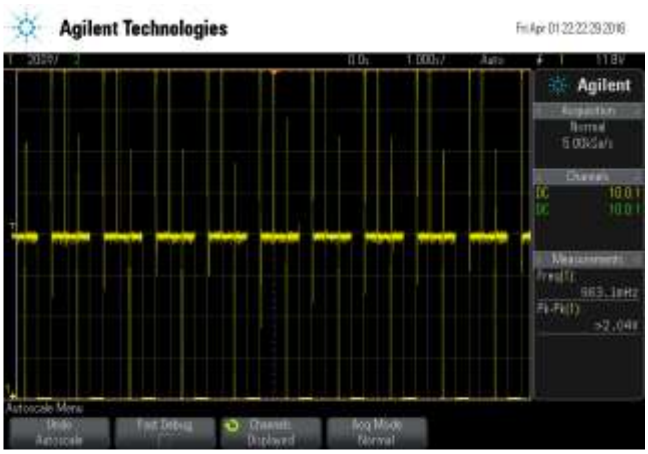

Fig. Pulses for forward rotation waveforms

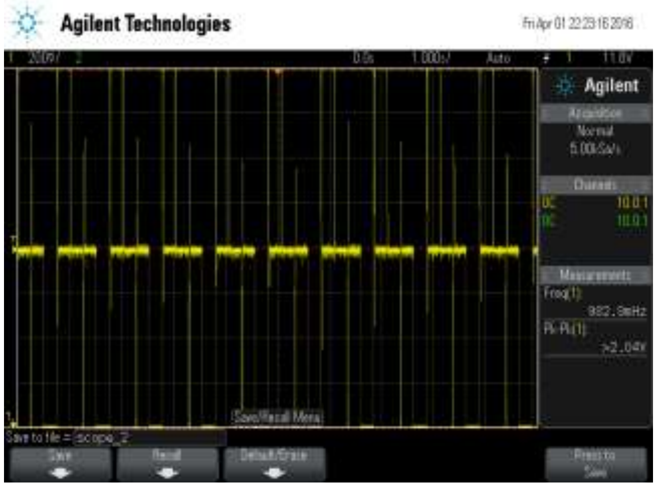

Fig. Pulses for Reverse rotation waveforms

VIII . CONCLUSION

It has been observed that stepper motor driven by microcontroller has a precise control in forward & reverse direction as compared to IC555 driver.

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