DEVELOPMENT OF A ROTARY TABLE FOR DOMESTIC USE

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Abstract: A rotary table is a device that aids in precision work mainly in manufacturing industries. There has however been little research done in the development of rotary table for domestic use. The major trend has been to design rotary table to be used in machineries. In view of the above, a prototype of a rotary table for domestic use was designed and developed. The rotary table was developed using a PIC16F84 microcontroller, a synchronous step motor, transmitter and receiver circuit and also a power circuit, an assembly code was written. The design is cost effective, uses readily available materials and finds economic usage in homes, offices and can be used by the elderly.

Keywords: Domestic, microcontroller, receiver, rotary table, synchronous step motor, transmitter

Introduction

A mechanical rotary table can be defined as a work positioning device used in metalworking. It aids in precision work. It enables the operator to drill or cut work at exact intervals around a fixed (usually horizontal or vertical) axis (Kylie, 2015). The idea of rotary table has always been used for milling machine and lathe machine in which the tools are arranged in an orderly manner so that when an operation is to be performed with a tool, the rotary table rotates the tool to the appropriate position for the tool to perform the required operation.

This idea started in the fifties when manual rotary tables were being produced by various industries, it then moved from the completely manually operated rotary table to digital round about units. The development of numerically controlled rotary table took place in the seventies (Walter, 2014). The rotary table finds usefulness in several fields of engineering. The rotary table is used in the lathe machine, milling machine, for drilling of oil, for accumulating and packing products like dietary tablets, sachets among many other uses. The rotary table also has some benefits in terms of milling and lathe operations, the rotary table allows multiple faces to be accessed without moving the work piece out of a fixture, and it also reduces the operation time of these machine processes per job. Also for the accumulating and packing of products, it reduces production time, it reduces cost in terms of manpower, and it increases productivity (Cletus, 2005).

In the course of the research on the development of a rotary table, it was discovered that the main area of application was for industrial purposes, while domestic usage were neglected (Nirav and Vakhari, 2014). Problem of passing across items (e.g. files, utensils) across a round table in a large dinning setting or conference, in the case of dependent people (e.g. aged or disabled) has been a great challenge over the years. It is pertinent therefore to develop a rotary table that will meet most household domestic needs. This can also be applicable to use in an office environment.

The aim of this work is to develop a rotary table that will find major application in domestic and office use. The objectives are to simulate the model of the rotary table using Autodesk inventor with the specified dimensions, then proceeding to the physical model of the work, which is construction of the table, programming of the software that the microcontroller will use and then designing of the power circuit, transmitter and receiver circuits.

The motivation behind this work was a rotary table developed for a Susan called "lazy Suzy". The lazy Susan (also called lazy Suzy) is a rotating tray that is placed on a table in order to aid in food distribution. They were made from glass materials, wood or plastic. They find their usage in sharing dishes among diners seated around a circular table (Levine, 2010). About sixty years ago, there was huge development in the Chinese restaurant industry. This development was about the furniture known as "lazy Susan" table. Throughout the 1950s, Chinese restaurants were known to be dirty and overcrowded. The introduction of lazy Susan tables brought about a transformation towards refined and spacious restaurants. Although Chinese foods were not as popular then as it is today, lazy Susan's tables still made a great impact throughout the decades. Lazy Susan were viewed as a Chinese tradition in the decades that followed (Daniel, 2014).

A rotary table is an automatic moveable table that supports a work piece and slides or pivots into and out of the machining centre (Vasantraoadam and Hargunde, 2015). Computer numerical control (CNC) rotary table is a work holding device used on machining centres to position the component in desired angle to do multi-face operation in one setup. A rotary table can be designed to accommodate heavy loads. When they are designed with a worm wheel, they tend to have the characteristics of longer life and accuracy. Rotary tables are mostly used indexing and in angular increments. They can be used in multiple operations. They consist of a circular steel plate, spindles, a drive system, and pins that hold parts in proper place. Rotary tables have fixed or adjustable indexing angles (Chapman, 2002).

In 1983 the development of the Derrick Drilling Machine (DDM) started to replace the conventional way of rotating the drill string with a rotary table known as "Kelly rotary table". This model was released in 1984 with 650 ton load rating, popularly known as DDM 650 DC. It was designed mainly for offshore installations. Later, in 1987, a 500/600 DC specification was released. This was hydraulically driven. Further need for increased torque capacity lead to a two-gear version of 500/650 DC and 650 DC to be both released in 1989. In 1993 the extreme two - motor DDM 650 frontier was introduced into the market, developing 2.100 Hp and 8.800 N.m torque output (Pinka *et al.*, 1996).

Materials and Methods

To achieve these aims and objectives, the following steps of methods were carried out:

The Autodesk inventor model was designed and simulation of the rotary table was effected. The simulation will enable the drive constraint to be determined.

The program to be uploaded on the microcontroller was written.

The table was constructed to determined dimension.

The power circuit, transmitter and receiver circuit were designed and connected.

The hardware components were fixed unto the table.

Design process

The design process is made up of four modules below:

a. Transmitter circuit

b. Receiver circuit

c. Power supply circuit

d. Microcontroller and switching circuit

These phases are explained as follows:

Transmitter circuit

The transmitter circuit is made of a carrier frequency and a modulating signal. Two different modulating frequencies of 500 Hz and 1 KHz are used to control the directions of the table. The modulating signal is generated using a 555 timer, whilst the carrier signal is generated on the HC-12 (wireless serial transceiver) module.

The 555 timer (used for timed and pulse generation) oscillator frequency is given by

$$F = \frac{1.44}{(R_A+2R_B)C} \quad (1)$$

From Equation (1)

$$R_A = \frac{1.44}{fC} - 2R_B \quad (2)$$

For $f = 1kHz$, Set $R_B = 2.2\ k\Omega, C = 100\,nF$

From Equation (1)

$$R_A = \frac{1.44}{1\ kHz \times 100\ nF} - (2 \times 2.2\ k\Omega)$$

$$R_A = R_2 = 10\ k\Omega$$

For $f = 500\ Hz$, Set $R_B = 2.2\ k\Omega, C = 100\,nF$

From Equation (1)

$$R_A = \frac{1.44}{500\ Hz\ \times 100\ nF} - (2 \times 2.2\ k\Omega)$$

$$R_A = VR_2 = 24.4\ k\Omega$$

Figure 1 shows the circuit diagram of the transmitter:

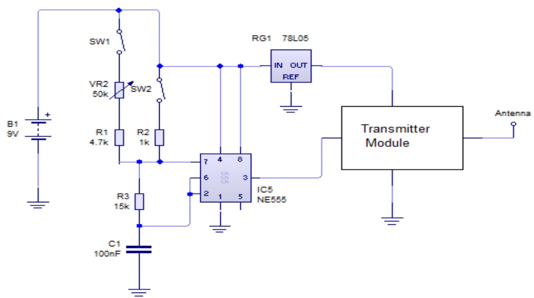

Fig. 1: Transmitter circuit

The specification of the transmitter circuit is itemized below

Transmitter Specifications

Working frequency: 433.4 MHz to 473.0 MHz

Supply voltage: 3.2V to 5.5VDC

Communication distance: 1,000m in the open space

Serial baud rate: 1.2 Kbps to 115.2 Kbps（default 9.6 Kbps）

Receiving sensitivity: -117dBm to -100dBm

Transmit power: -1 dBm to 20 dBm

Interface protocol: UART/TTL

Operating temperature: -40℃ to +85℃

Dimensions: 27.8 x 14.4 x 4 mm

Receiver circuit

The radio frequency receiver uses HC-12 receiver module (sold as a transceiver pair) and NE567 PLL (tone/pulse locked loop) decoder. The signal is first demodulated from the receiver module before being decoded. Once the high frequency is received, the decoding takes place. The receiver and decoder circuit is shown in Fig. 2

The frequency of the internal VCO (voltage-controlled oscillator) is given by

$$F = \frac{1.1}{RC} \quad (3)$$

Set $C = 100\,nF \quad for\ F = 500\ Hz,$

From Equation (3)

$$R = \frac{1.1}{FC}$$

$$R = \frac{1.1}{500 \times 100\ e^{-9}}\ \Omega = 22K$$

47K pre-set was used and tuned to lock the transmitter signal. Values of C_2 and C_4 were given from applications data sheet for the NE567. The schematic diagram of the receiver circuit is shown in Fig. 2

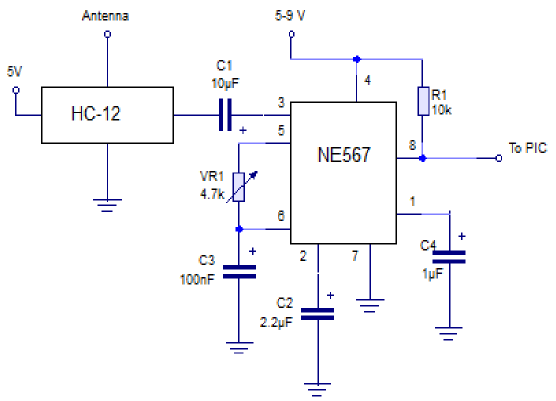

Fig. 2: Receiver circuit diagram

Power supply circuit

The wireless rotating table uses a 5V DC power supply rail. The need for power supply circuit is to provide the voltage and current requirements for the circuit since all the electronic components work with DC voltages. The required dc voltage and current of the power supply for the project is dependent on the component specifications and the nature of circuits to be powered.

The following requirements were estimated for circuit components and motor requirements.

Power supply requirements

Supply Voltage : DC 5V

Maximum Current: 2A

The maximum current is estimated based on the receiver circuits and the requirement for the stepper motor. The PIC microcontroller used can operate on a supply voltage from 3-6 V DC; whereas the DC motor operates on 5V DC.

For the power circuit design, the following calculations were carried out

From formula of electric charge, $Q = IT$;

$CV = IT$ (Since $Q = IT$) (4)

Where C is the Capacitance
V is the Voltage
I is the Current (A)
T is the period of one cycle of AC waveform.

From Equation (4) $C = I\frac{t}{V}$

$\rightarrow C = I\frac{dt}{dV}$ (5)

Since C is proportional to the current and inversely proportional to the ripple gradient of the power supply.
The peak unregulated voltage is given by

$V_{peak} = V_{rms} \times \sqrt{2}$ (6)

Where V_{rms} is the AC voltage stepped down on the transformer;
Hence, considering a peak voltage of 12V dc

From Equation (6) $V_{rms} = \frac{12\ V}{\sqrt{2}} = 8.$

$8 \cong 9\ V\ ac$

This implies that a step down transformer of 9V at 1.5A

From Equation (5) $C = I\frac{dt}{dV}$

$I = 1.5A$ as required from PSU requirement for design $dt = 0.01\ s$ (this is the time duration of the duty cycle of half the waveform).
dV = ripple factor.
If the ripple factor is set to 20% of the peak voltage,
$dV = 2.4\ V$.
Hence from equation (5)
C = 6250 uF.
A preferred value of 6800 uF was used.

Figure 3 shows the power supply design circuit design.

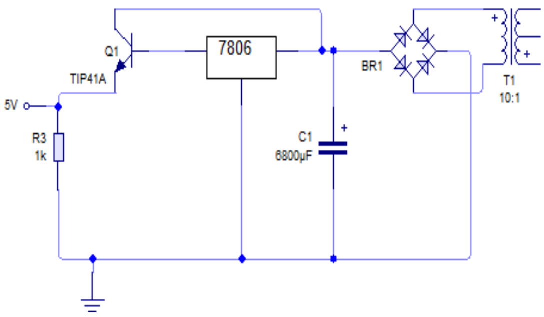

Fig. 3: Power supply circuit

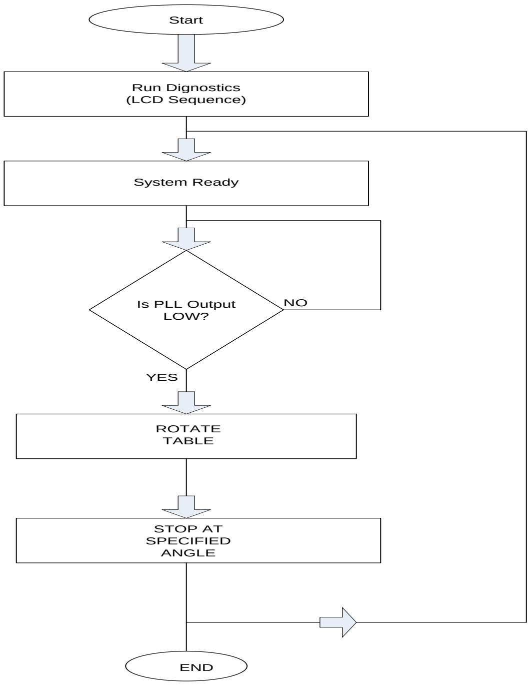

Fig. 4: Program flow chart

Microcontroller and switching circuit

The microcontroller circuit uses a PIC microcontroller. The function is to control speed and direction of the table, as well as write to the LCD (liquid crystal display). Once the system is switched ON, a series of diagnostics is run and displayed on the LCD, then the LCD displays the prompt, “System Activated, Scanning and ready” Once this is displayed, the PORT A0 and PORTA1 (as shown in Fig. 5) inputs of the microcontroller are scanned for a LOW signal. This is because the PLL decoder has an active LOW output and would be LOW once a frequency is detected. The rotation is controlled using a stepper motor, controlled by a receiver circuit.

Figure 4 shows the microcontroller program flowchart. The microcontroller connected to the stepper motor circuit is shown in Fig. 5.

Principle of operation

The microcontroller based rotating table developed uses a PIC microcontroller to control the speed and direction of a synchronous-step motor attached to a rotating shaft of the table. The transmitter circuit has two switches to select two different frequencies (500 Hz and 1 kHz). These frequencies are used to modulate the 455 MHz carrier frequency of the wireless transceiver module. The receiver module receives the wireless signal and demodulates the frequency using IC1 and IC2. IC1 & IC2 are Phase Locked Loop frequency decoders with internal VCO set at the modulating frequency of the transmitter. Only the frequencies lock in phase, decoding action takes place and a low signal is sent to A0 input of PORTA and A1input (depending on if the signal is for speed or direction control).The PICI6F84 microcontroller generates a sequence of pulses that controls the speed of the motor using a phase angle technique via an opto-coupler connected to the gate of a TRIAC (three-electrode semiconductor device). As the pulse width is varied, the phase angle changes and the speed of the motor varies. An LCD display connected to the microcontroller displays vital information on the sequence of rotation of the motor.

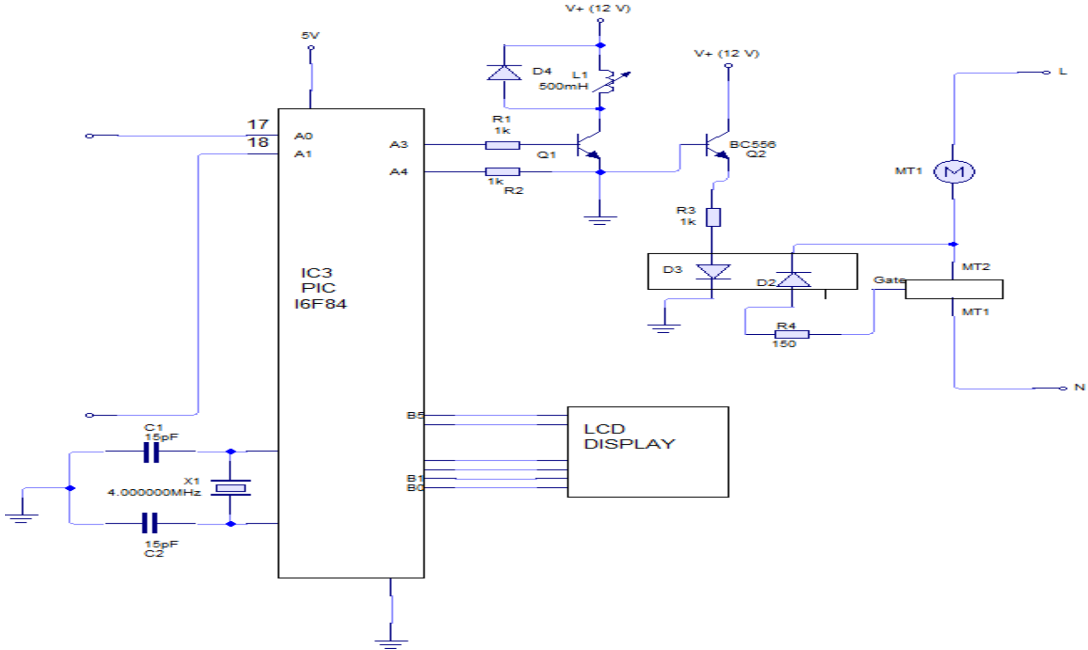

Fig. 5: Microcontroller connected to stepper motor circuit

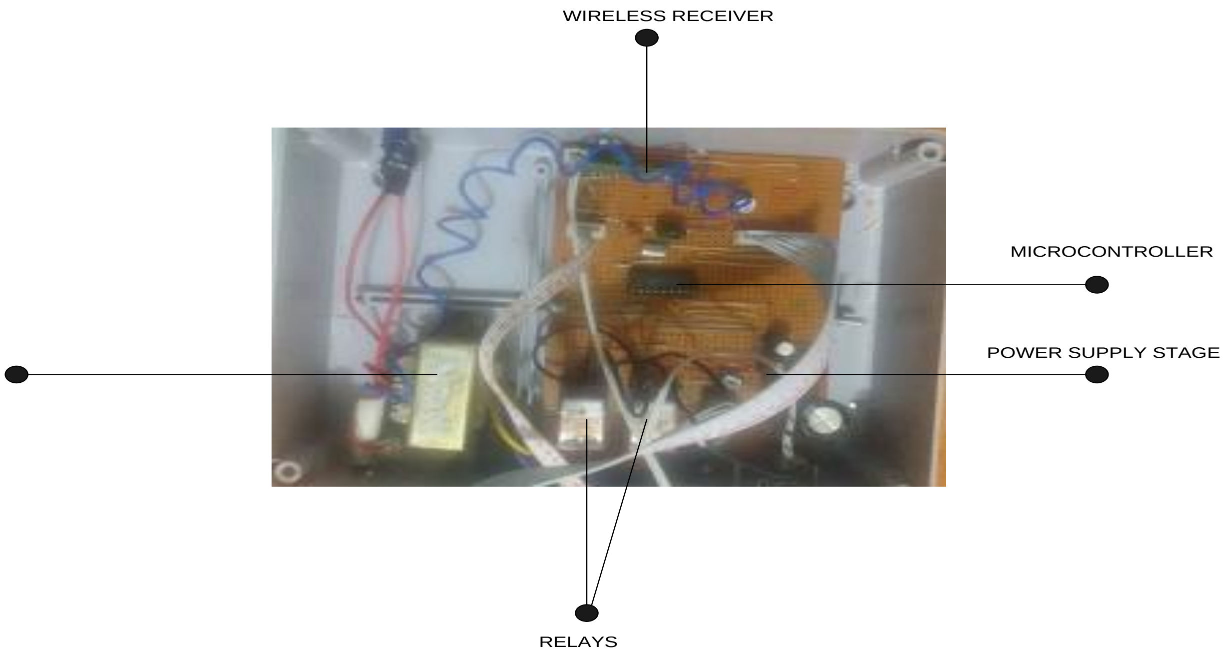

Fig. 6: Components layout

Implementation

The implementation of this project was done on the breadboard. The power supply was first derived from a bench power supply to confirm the workability of the components before the power supply circuit was soldered. The circuits were tested sequentially on the breadboard; this activity preceded the final soldering done on the vero board. The various components in the circuits were soldered in sequence to meet desired workability of the project. Fig. 6 shows the components layout on the vero board

The second phase of the project construction is the casing of the project. This project was coupled to a plastic casing. Fig. 7 shows the Transmitter and receiver circuit soldered and packaged.

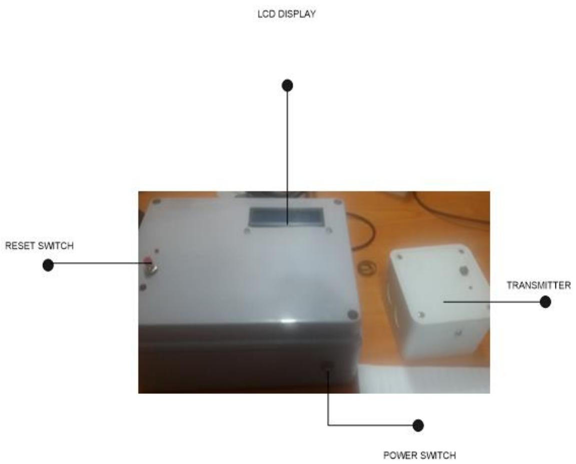

Fig. 7: Packaging

Figure 8 shows the constructed rotary table in its finished state.

Fig. 8: The rotary table in its finished state

Conclusions

The project which is the development of a rotary table was designed considering some factors such as economic application, design economy, availability of components and research materials, efficiency, compatibility and portability and also durability. The fabrication of parts was done by using locally available materials. The design of the microcontroller controlled rotary table involved research in both digital design and construction.

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