Digital Resistance Box: An Approach to Generate Desired Value of Resistance by Automatically Varying the Potentiometer

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***Abstract*—Resistor combinations are being frequently used by scientists and researchers to get the desired value of resistance. In literature; this is achieved either by connecting the resistors in various combinations or by manual tuning of potentiometers; which is quite tedious. Moreover; resistance value is compromised with another close available value most of the time. In the present work; an attempt is done to design a digital resistance box that provides the desired value of resistance by simply entering the value through a digital keypad. In the presented approach; a microcontroller is used to control the servo motor; on which the potentiometer is mounted. The resistance of the potentiometer get varied by servo motor; which is controlled by a microcontroller. The microcontroller is programmed to control the servo motor using binary search computational algorithm. Experimental results represent the efficacy of the proposed approach to generate the desired value of resistance.**

Keywords—Resistance; Servomotor; Microcontroller; Potentimeter

I. INTRODUCTION

Resistor is an electrical component which has the property to resist the flow of electrons which are used in circuits to limit the current flow.

Resistors can be connected in different configuration to generate different values of resistances. Series Combination: When resistors are connected in parallel; the total amount of resistance across two terminals is equivalent to the sum of all individual resistances. Parallel Combination: When resistances are connected in parallel; the equivalent resistance is equal to the reciprocal of the sum of reciprocal of all individual resistances connected in parallel.

According to the requirement of circuits different values of resistances are needed which may be obtained either by connecting resistors in Series; Parallel or Both. But the task may prove complex and time taking for some values of resistances.

Later; Digital Potentiometer IC [5] or Digital Resistor was introduced which works in similar way as Normal Mechanical potentiometer but instead of mechanical action it uses digital signals and switches. A resistor ladder i.e. a string of small resistors in series is used. At every step of the ladder; an electronic switch is present. Only one switch is closed at the same time and in this way the closed switch determines the 'wiper' position and the resistance ratio. The amount of steps in the ladder determines the resolution of the digital pot.

The previous approaches are either based on customization of resistance by the manufacturing company or the series or parallel combination of various resistances to generate the desired value of resistance. All the above mentioned methods need manual computations; to generate the desired value of resistances.

A solution is provided in the presented approach; which is fully automatic and can be used to generate a large range of resistances without manual computation. In the presented work; a Resistance Box is designed; which provides the required value of resistance across its two terminals by varying the potentiometer. The potentiometer is automatically controlled by Servo Motor [6]; which is controlled by Arduino. The programming is done using binary search computational algorithm. The overview of the presented approach is shown in figure 1.

The rest of the paper is organized as follows: Section 2 describe the brief of various components used to generate the resistance. Section 3 describes the binary approach used to control the servo motor. The experimental setup and results of the presented approach are listed in Section 4. Finally; conclusion and future scope are mentioned in Section 5.

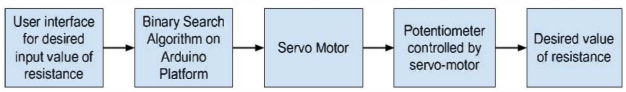

Fig. 1: Overview of the Proposed Approach

II. COMPONENTS OF THE PRESENTED APPROACH

A. Potentiometer

A potentiometer is a three terminal resistor with turning contact that form a voltage divider and if two terminals are used it act as a variable resistor. They are used in many places like audio control; amplifiers; etc.

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The potentiometer taper can be linear or logarithmic there is no standard notation for these two type of tapers and there is another type of type of taper also which is anti-logarithmic in nature.

Fig. 2: Single-turn Potentiometer

B. *Servo Mechanism*

This system is an automatic closed control system which contains three basic elements

1. A controlled device
2. Sensor
3. Feedback system

The device is controlled by the feedback system. A feedback signal is produced by subtracting the output signal with the input reference signal which produces an error signal. This error signal is fed to the controller so as to reduce the error. The error persists until the output is not equal to the input; once the error is zero the desired output is obtained.

C. *Servo Motor*

A servo motor is a DC motor (AC in special cases) along with various other elements which includes a small DC motor; gear mechanism and an intelligent circuitry.

The gear mechanism provide the high torque by reducing the rpm of the DC motor which is gives it a more practical use.

Fig. 3: Servo Motor

Servo motors are rotary actuators that are used for precision control of angular rotation of the shaft. These motors are fed with PWM (Pulse Width Modulation) as control signal. The angular rotation of the shaft depends on the duty cycle of the PWM. The motor can sweep a maximum angle of 180 degrees. The pulse width of the PWM may vary from 500us to 2000us corresponding to-90 degrees to +90 degrees from the centre point of reference. The servo motor expects a control pulse after every 20ms.

D. *Arduino*

Arduino is an open source hardware project based on microcontroller board design. Arduino boards consists of ATMEL AVR microcontrollers specifically the ATmega8; ATmega168; ATmega328; ATmega1280 and ATmega2560.

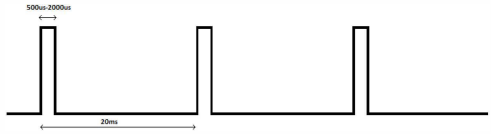

Fig. 4: Pulse Train for Servo Motor

III. BINARY SEARCH ALGORITHM

Binary search algorithm has been popularly used in computer vision field due to its capability of finding the exact match in a sorted array. The same approach is adopted in the present approach to search the desired value of resistance on a potentiometer. The fascinating feature of binary search is that it search the desired value by scanning the half data rather than complete set of data and hence named as Half-Interval Search. Another interesting feature of binary search is the computation complexity; which is O(log(n)); where n represents number of elements in the array. Due to involvement of log in computation; it is also known as logarithmic search.

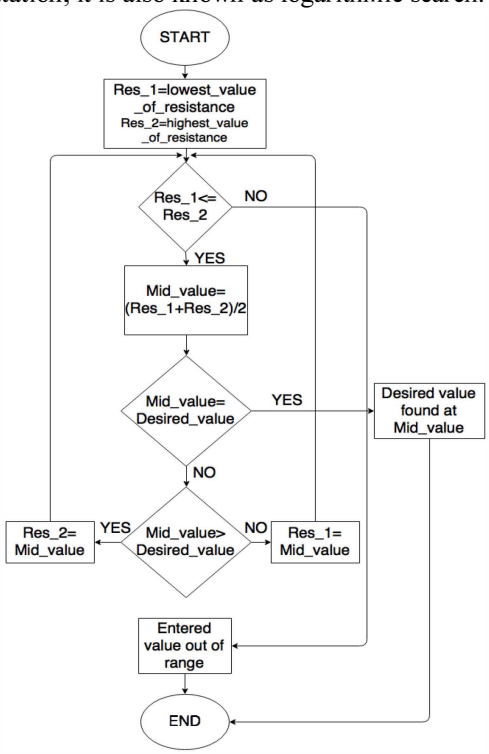

Fig. 5: Flowchart of the Proposed Algorithm

The binary search algorithm can be well explained using a Block diagram. The middle value of the potentiometer resistance is considered as the reference of the binary decision. Block Diagram for Application of Binary Search in Digital resistance box is shown in Fig. 3.

The binary search algorithm is an iterative process; where two comparisons are performed at each iteration. The middle value of the resistances is compared with the desired value of resistance and if the condition is satisfied then the position of the resistance is returned. If the condition is not satisfied then the desired value is compared with the new middle value of the resistance of upper and lower range. On each iteration; one half is eliminated and search is continued on the other half. This results in decrease in computations at each iteration. In the proposed approach; the programming of Arduino is done based on binary search algorithm.

IV. Experimental Setup and Results

Experimental setup for the proposed approach is well presented in fig.6. The desired value of resistance is entered through digital keypad. Using Binary Search Algorithm the value is obtained by varying potentiometers through Arduino Controlled Servo Motors. During the estimation of desired resistance; the potentiometer is isolated from the application circuit to achieve isolation.

The desired resistance is provided across the two terminals of device which can then be used in any other internal circuit. The isolation of the resistive device during resistance building is necessary because the feedback mechanism used to achieve the desired resistance value will interfere with the application circuit. This isolation can be provided through a switching mechanism between application circuit and the resistance box. The switching mechanism may include a transistor [7] or a electromagnetic switch (relay) [8].

Pseudo Code

```
START:
Input (Desired_Val);
Isolation (ON);
Max = 180;
Min = 0;
Loop:
Mid_pos      = (Max + Min) / 2;
Servo (Mid_pos);
Curr_res = calculate_resistance ();
err = abs(Desired_Val – Curr_res)*100/Desired_Val;
if err < 10
Isolation (“OFF”);
Exit loop;
else if Curr_res>Desired_Val
Max = Mid_pos;
else
Min = Mid_pos;
End loop;
EXIT
```

Each device shows its own pros and cons. Transistor is a much faster switching device but any leakage current through transistor can interfere with the application circuit. In contrast; the electromagnetic switch makes or breaks the feedback circuitry physically thus ensuring no interference in application circuit due to resistance box. But making/breaking feedback circuitry may take longer time as it is a physical switch.

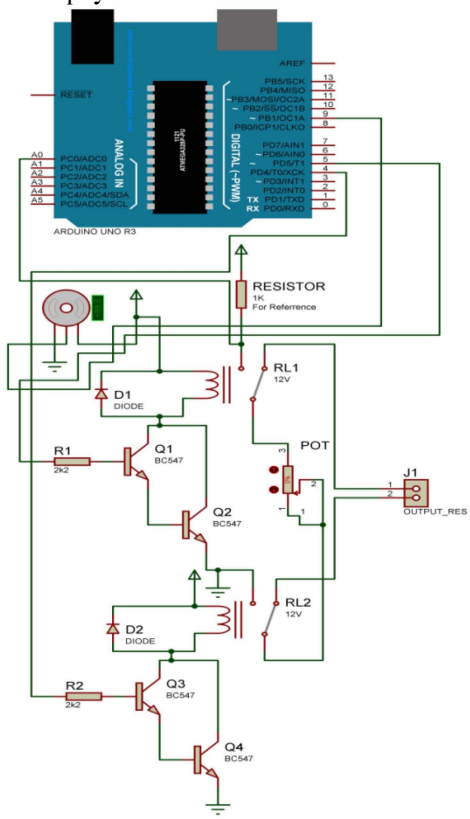

Fig. 6: Circuit Diagram of the Proposed Approach

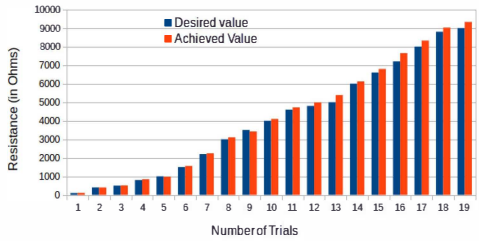

Fig. 7: Comparison between Desired and Achieved Resistances

V. Conclusion and Future Scope

The presented work is typically designed for designing resistances by controlling potentiometer viper automatically. The binary search algorithm is adopted for generating the desired value of resistance. The mean square error of the proposed approach is very small proving the efficacy of the proposed approach. Moreover; the proposed approach help in automatic control of potentiometer avoiding the tedious task of manual setting

of potentiometer. The time taken by the proposed approach further prove the applicability of the proposed approach in real time.

In future; more than one potentiometers can be used in cascade to improve the range and efficiency of the device. Potentiometers of different value ranges can be connected in series and the efficiency can be improved to 1 Ohm and the range can be extended to Mega Ohms.

The precision and accuracy of the Resistance box is also limited by the resolution of the ADC [1][2] that we use. For an Analog to Digital Convertor of 8-bit resolution; the maximum number of unique readings that we can take is only 256. But if we increase the resolution of the ADC; we can achieve a higher precision for the resistance box. So using a 10-bit; 12-bit or even higher resolution; we can design a system with much higher accuracy. Thus; the limitations of the resistance box is correlated with the resolution of the ADC.

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