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# DC Motor Synchronization Speed Controller Based on Microcontroller

*Aamir Shahzad, Muhammad Kashif, Tariq Munir and Maogang He*

## Abstract

In this chapter, we report the design and fabrication of an improved speed synchronizer device in which two dc motors has been controlled on different sequences programmed by microcontroller. Depending on the programmed software, the device is used to command a rolling of machines, synchronizes the dc motors speed, and displays the result on liquid crystal display (LCD). Flash memory of the microcontroller is used to program for controlling this device where permanent memory is needed to store different parameters (codes for motor speed, LCD display, ratio control, and rotary encoder's feedback). The present simulation gives new reliable results with better performance for the speed and direction than the earlier available synchronizers. It has been shown that the speed and direction are dependent on both the ratio setting and frequency of encoder in two dc motors speed synchronizer. It is shown that this device is applicable for controlling, monitoring, and synchronizing identical processes and can be implemented in multiple domains, from textile industry and home control applications to industrial instruments.

**Keywords:** speed synchronizer, liquid crystal display, microcontroller, dc motors speed

## 1. Introduction

Nowadays, the advancements in industrial automation research technology and the desires on performance and feature in manufacture processes have become in complex and integrated innovation systems. Speed synchronizers have various applications in many control industrial processes (textile, chemical, marine, etc.) and have shown a vital role in control system design and optimization. The speed synchronizer is cost-effective and highly efficient device and it works as a bridge between two (or multiple) independent drives for many control applications with a suitable value of ratio control. The synchronization units are appropriate for different type of drives (DC, AC, Servo, etc.) that are adjustable in speed and direction under influence of speed reference signal of the 0–5 volts [1]. The significant results of using synchronizer is to reduce the working and fabricating cost in designing new control devices in terms of reducing the time and minimizing the ambiguity in going process modernization at the small level to manufacturing scale. Recent advances in microelectronics and algorithm design including information

technology have brought significant changes in speed and motion control technology. As a result, the predictive advancement, broadly useful, practical approach for the speed and motion control is an enduring target of greatly of the industrial automation technologist both in science and engineering developments [2].

The earlier variable speed drive was mechanical type and was used a variable pitch diameter pulley. This drive is still in operation but for clear reasons are not in common uses in practical and industrial applications nowadays. Recently, the three significant kinds of electronically variable speed drives are used in present industrial machines. Firstly, the brush style dc motor is almost the totally used adjustable speed drive on blow molding machineries. Alternative current (AC) adjustable frequency and AC motor drives for blow molding technologies are used and replaced which is second kind of variable speed drives. Thirdly, the brush dc drive has been replaced with Brushless dc drive [3]. The direction, speed and power of an AC or dc motor can be controlled with the help of electronic device called as variable speed drive. Variable frequency AC drives provide processing requirements and several familiar industrial appliances for example pumps, fans and conveyors in a variety of working situations. The dc drives have various development applications and they can used to command material handling and processing machine such as metals, mining, printing, and other industries. In industrial automation increases gradually and many applications need directional and positional control simultaneously [3, 4].

Over the past two decades, numerous measurements of speed and direction control synchronization have been studied [5–11]. The revolving mechanical arrangements form a significant and singular class of systems that, with or without the interaction through some coupling, demonstrate synchronized motion (or speed motors), for instance the case of rotating machinery in manufacture plants, power generators, wrapping of cloth in many textile industrial applications and unbalanced rotors in milling machines [12]. The synchronization of revolving systems and electromechanical arrangements was reported by Blekhman et al. [13]. Subsequently, the teleoperated master-slave systems were developed by Dubey et al. [14], and by Lee and Chung [15]. Shortly after, the Brunt [16] and Liu et al. [17] were designed multifinger robot-hands, multirobot systems and multi-actuated platforms. Only a few years later, Huijberts et al. calculated synchronization of rotating bodies and electromechanical systems [18]. For the medical applications, the master-slave teleoperated systems were used in surgical procedure giving rise to more accurate and less enveloping surgical treatment measures [19, 20]. In case of aerospace applications, the synchronization approaches were employed to reduce the error of the relevant manner in developments of satellites [21, 22]. The case of group formation of multiple robotic vehicles is addressed in [23]. Mirza and Hussain published their work of speed asynchronization mode of dc motors in the regime of nonlinear process through selective position of feedback and integral control for textile industry [1]. Since then, speed synchronizers have provided a key automation tool in process industries, medicine, material science, plasma process engineering, and aerospace science and multiphase and thermal transport processes [9–11].

In this study, a speed synchronizer based on microcontroller for controlling and monitoring the speed of two dc motors, which is our particular motivation. Embedded system is a system that has a microcomputer or microcontroller inside which can reads the input, process them and gives the feedback according to the preprogram condition. Embedded systems are designed to do some specific tasks and have minimal requirements for memory and program length [24]. The application of microcontrollers with designed algorithm, dc drives, and complex programmable logic devices (CPLD) in factory automation motivates the development of

computer integrated manufacturing systems. In textile industry many processes require speed synchronization of more than one motors involved in the process. Rolling of cloth should be synchronized with the speed of weaving spindle to avoid damage and similarly motors-speed synchronization is vital in a conveyor-belt driven by multiple motors. The digitally controlled dc machines (or motors) can have much aggravated phenomena owing to poor sampling period selection [1, 7]. The role of synchronization control not only involves in practical and industrial applications, however, there are many physical phenomena that may be explored through synchronization control theory [12].

The objective of presented article is to design and implement of an advanced digital speed control synchronizer using ATMEL-based microcontroller and dc drives. A digital speed (or motion) control algorithm has been developed for the synchronization control of two motors, which can easily be extended to control of multiple motors. The designed speed and motion control system is based on a digital torque drive for dc motors with encoder interface. This article presents the algorithm for design implementation of a speed and motion control and to examine the understanding of synchronization efficiency for industrial application. Additionally, this design and numerical approach is different from those used in the earlier studies. The calculations are performed for a wide domain of synchronization control parameters for the drives. In order to characterize the performance of the project, the different parameters of synchronization control have been studied and analyzed, so that the systems working may be enhanced.

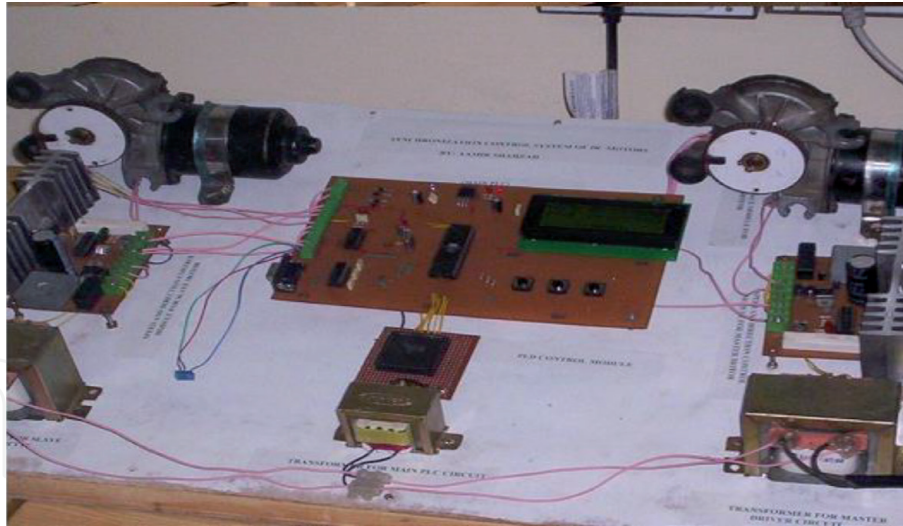
## 2. Methodology and design

### 2.1 The PROTOS framework

The circuitry was designed for the synchronization control of two dc motors using commercially available devices and components. There are two main parts in the system, which are hardware and software development. The schematic design for the system and components testing in standalone state are include in hardware development. While the software skill developed including drive circuit connection establishment and improvements to algorithm. Some assumptions are made in the prototype system and recommendations or future improvements are suggested [25]. In order to utilize facilities and advantages of both microcontrollers along with their standard features and programming resources and CPLD along with their flexibility to implement additional hardware arrangements for interfacing or progress of computational performance, we need to set a number of this design system purposes the PROTOS system should fulfill.

An experimental dc motor synchronization control system based on microcontroller has been developed and its design implemented for control automation of two dc motors as shown in **Figure 1**. This controller can command two drives one byte external port; these outputs take values depending of the inputs states. One port states are displaying on a 16 characters, 4/2 lines material liquid crystal display (LCD) display. The ATmega8535 has a 13-bit program counter capable of addressing an  $8\text{ k} \times 14$  program memory space [26]. In this experiment an attempt has been made to fabricate and study a circuit that is able to control and monitor the synchronization control of two dc motors. The basic proposal was to design a synchronizer to ensure its performance equivalent to dedicated industrial synchronizers designed by marketable big companies. The synchronizer based on ATmega8535 microcontroller hardware was divided into six major modules; power supply module, dc motor speed and direction control module, encoder interface module for two dc





**Figure 1.**  
*Prototype snap for synchronization control system for two dc motors.*

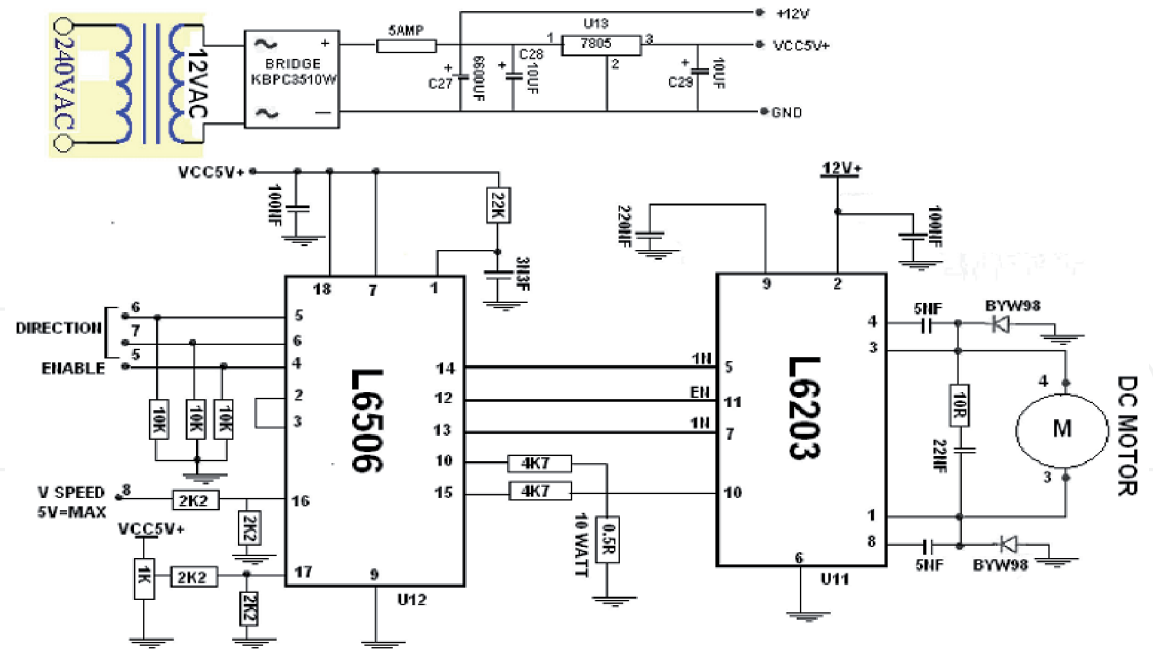
motors, central processing unit (CPU) and control module, speed synchronization graphic interface module and LCD display module. In order to develop the project the following methodology has followed: the theory of microcontroller, logic control devices, encoder, dc motor, circuit diagrams, operation and its function has been studied in detail [7–15, 26–29]. The first step was to draw a schematic diagram of the hardware in a software package called Protel, according to circuit diagrams [5, 6]. The encoder circuit design has been made on computer and its film developed in printing press and finally its hard fitting with sensor has been made accordingly. A fitting of dc motor shaft coupled with encoder has been made for sensing motor position, direction and whole system fitted on separate wooden board. After completing the circuit of encoder interface unit, the program has been written in VHDL programming language of CPLDs family. The written program has been debugger using active VHDL simulator and downloaded according to the application with the help of programmer such as control sensing and monitor motion or position of motors [29, 30].

After completing the circuit of CPU and control unit, the program has been written in C-51 programming language of MCS-51 microcontroller family. The written program has been debugger using simulator AVS-51 and downloaded according to the application with the help of downloader ATmega8535 such as synchronization of two dc motors. Check the performance and error of microcontroller, and CPLD ICs has debugger the written program and circuits through respective simulators and check timing signals on different pins and finally monitor programs of both ICs.

## 2.2 Measurement scheme using microcontroller and CPLD

The schematic circuit diagram (CPU and control module) of the microcontroller scheme is given in **Figure 2**. The hardware and software for CPU and control unit are to be contained within the microcontroller. Design of the CPU and control hardware was tested using the ATmega8535 development board and breadboard. The power supply was then tested and found to be functional. After the first programming the microprocessor was configured to use the external oscillator [26–30]. Testing of the communication between the Atmel chip and other chips in the circuit design was successful using the communication protocol designed. Switching between two voltage levels required the use of the microcontroller on board comparator. It was





**Figure 3.**  
*Schematic diagram for speed and direction control module for two dc motor.*

of the L6203 and ground its terminal. We have used the sunbber circuit very close to the output connections of the device L6203 which was fabricated by the series of resister (R) and capacitor (C). Moreover, each power output connection and ground terminal was connected with the help of one diode (BYW98). An appropriate big capacitor was used and linked close to the supply pin of the device L6203, when the power supply cannot sink current properly. It is important that a capacitor at pin 17 of the L6506 allows the system application work smoothly. The L6506 was proposed for work with double bridge drivers, such as the device L6203 to drive dc motors. The major purpose of the device (L6203) was to detect and monitor the current in each of the load windings (dc motors). The dual chopper was run using a general on chip oscillator. An ordinary on chip oscillator was used to drive the dual chopper and it wad regulated the working frequency for the pulse width modulated drive. The sunbber circuit on pin 1 sets the working frequency which was calculated as:

$$f = \frac{1}{0.69RC}, \text{ where } R > 10 \text{ K} \quad (2)$$

The oscillator gives signals to set the two flip flops which in turn cause the outputs to trigger the drive. The current in the load winding (dc motor) attained the computerized programmed peak point, then the voltage across the sense resister becomes equivalent to the reference voltage ( $V_{ref}$ ) signal which leads to the comparator readjusts its flip flop interrupting the drive current until the next oscillator signal appears. A suitable choice of the value of reference voltage ( $V_{ref}$ ) and sense resister were used to program the peak current for each dc motor. It was examined that the ground noise issues in multiple arrangements has been avoided by synchronizing the oscillators. This was done by the oscillator output of the master device was connected to the sync pins of each of the devices and the R/C pin of the unused oscillators was grounded [7–11].

### 3. Results and discussion

A control system is designed and fabricated using microcontroller and CPLD from the point of simplicity and cost effectiveness to act as speed synchronization

and direction control for two (or multiple) dc motors, already shown in **Figure 1**. The presented system was tested running the two motors for the long period of time and in different environments. It is observed that the synchronization system was worked to expectation. Some calibration of the analogy to digital conversion (ADC) in the control circuit module was necessary and this was done using software. Calibration had to account for the voltage drop across the resistor in series with the control trigger and motor response. The calibration improved the speed range available to the driver circuit of dc motors, confirming the earlier results [1, 7–11]. Once dc motors were running on synchronization mode it was expected that contact noise between the motor brushes and due to the power signals would cause incorrect speeds. Therefore, the error checking software has been included in order to diagnose the erroneous signals, and it is important that this was found not to be a problem. It was noted that there were periodic speed control but unusual cases of erroneous speed behavior. The graphic interface unit has two zones of synchronization, one for when graphic interface unit has its middle value of indications (green-indications), the two motors has same speed, this mode was called synchronization of motors. On the other hand, the second zone of graphic interface has its end value of indications (red-indications), shows that the speeds of two motors were not in same phase. This feature adds realism to the synchronization control system of dc motors by using software.

### 3.1 Principle of operation: Positional synchronization and ratio control

All operation was based on setting an analogue synchronization between the speed and direction control modules first. This has been achieved by feeding a common speed reference voltage to the drives and tuning the drive speeds in order to get them into an approximate synchronism. A ratio agreement was significant for the slave drive. This analogue pre-synchronization was matched the two speeds within an error range of approximately 0.8%, confirming the earlier results of Ref. [31]. Presently, the digital synchronization has to balance for the analogue speed errors in order to get an absolute, angular and positional synchronization with no drift and no cumulative displacement of the motor shafts. This required a digital feedback of the angular shaft position of the drives. In our case, incremental shaft encoders (e.g., encoder simulation from a resolver system) were used for this feedback purpose.

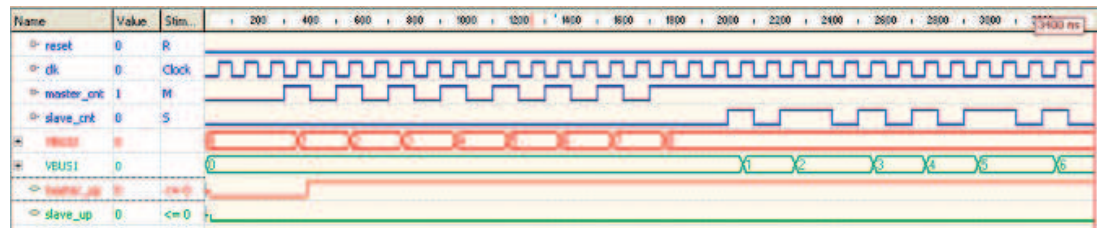
The synchronizer (CPU and encoder modules) was continuously checked the two shaft positions and immediately responded by an analogue correction signal when an angular error started to appear. This analogue correction signal, added to the slave's reference with the correct polarity, was maintained the shaft positions of master and slave inline. The synchronized speed of developed system was monitored by using LCD. It was noted that the synchronizer responds within only microseconds to each individual encoder pulse and the slave was practically have no chance to drift away. We have been adopted the way to generate feed forward signal (FFS) given in Ref. [31]. Currently, this FFS was generated internally from the frequency of the master encoder and no external voltage was applied to the analogue input. It was observed that the encoder frequency always represents the real actual speed of the master. Moreover, a FFS was needed to run the drives, and no external correction voltage was added to receive the total slave speed reference. It was significant that the digital FFS used here was higher than at maximum speed, for encoder frequencies [7, 8, 31].

### 3.2 Simulation results

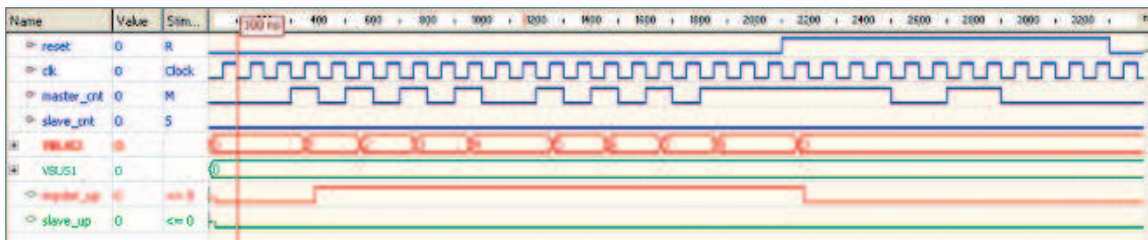
In this section, the simulation measurements of encoder interface with motors by using the Cypress and Wrap software were presented. The calculations of



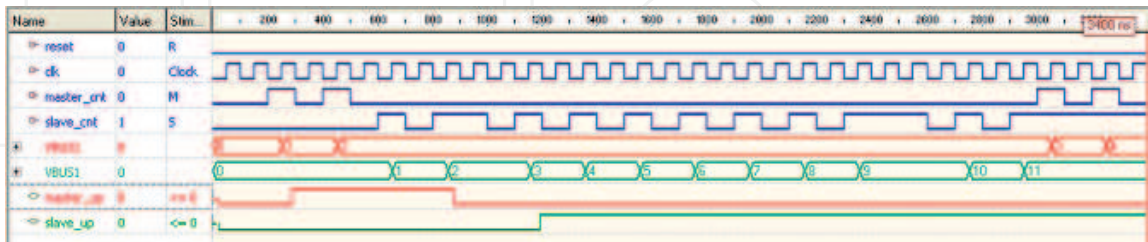
simulated waveforms with each module for implementation of CPLD (CY7C374i) were shown. Also, this subsection describes the implementation of C-code of AVR ATmega8535 microcontroller. The compiler software simulator has been used for both functional and timing simulation [29, 30]. For functional simulation, the written code was simulated before synthesis. After fitting (CPLDs) or place, simulate the design using the same original test bench as a test fixture, but with logic and routing delays added. In case of any major problems which have made an assumption on the device specification that was incorrect, or has not measured some aspect of the signal required to/ from the programmable logic device. Consequently, we have collected data on the problem and go back to the drawing (or behavioral) board. The output master up, reset, slave up and mixed simulation waveforms for encoder interface with motor for synchronization control of dc motors are shown in **Figures 4–7**. These presented timing waveforms show a successful prototype of a synchronization control system for dc motors. The designed system was



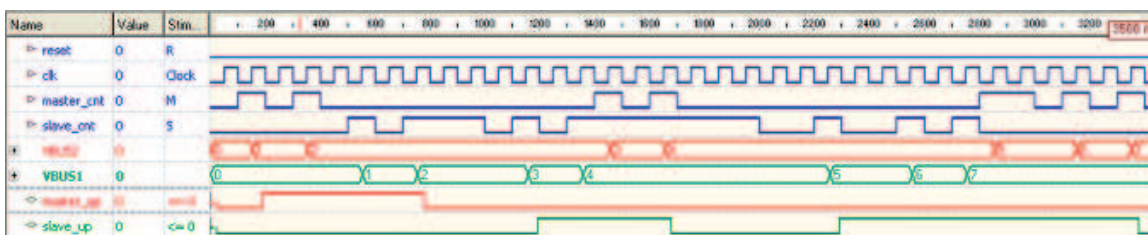
**Figure 4.**  
*Master up timing simulated wave form for encoder interface with motors.*



**Figure 5.**  
*Reset timing simulated wave form for encoder interface with motors.*



**Figure 6.**  
*Slave up timing simulated wave form for encoder interface with motors.*



**Figure 7.**  
*Mixed timing simulated wave form for encoder interface with motors.*

demonstrated the advantages of a synchronization control system over an analog system and improved the possibility for security when data mentioned on graphic interface module, challenge and competition when synchronization of dc motors speed required in industry, especially in textile.

#### 4. Summary

An experimental dc motor synchronization control based on microcontroller has been developed and its design implemented for the purpose of simplicity and cost effectiveness to act as power converter, master and slave controller. The main functions that each drive performs were readily programmable. The drives were forced into coordination and synchronization by some sort of software mechanism which was also implemented by programming. The speed synchronization was provided with the help of the FFS technique on the LCD. The designing of a synchronizer system to control the direction and speed of a geared dc motor has been successfully employed in this chapter. The dc motors have speed control facilities which show that speed and direction of rotation can be changed at any time to meet new situation. The hardware of the proposed system was interfaced with computer using RS232 serial communication port, for future communications. It is concluded that the dc motors were ideally suited to a multitude of industrial including textile and marine applications in which variable speed high torque are required. In addition, systems present in other applications, which include industrial equipment such as fan drives, ship propulsion and steel rolling mills, can be synchronized by a proposed design with proper modifications. This paper gives a platform for further development in the field of industrial use of dc motors.

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#### Abbreviations

LCD	liquid crystal display
AC	alternative current
CPLD	complex programmable logic devices
CPU	central processing unit
ADC	analog to digital conversion
FFS	feed forward signal

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