Three-Dimensional Loading Bridge

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***Abstract*—This project is a three-dimension loading bridge and aims to move an object 'O' from an initial point $(x_1,\ y_1, z_1)$ to a final point (x_2, y_2, z_2) to solve some transporting problems. The linear motion in the loading bridge is transformed from rotational motion, which is originally produced from a DC motor, using a screw and nut mechanism. We drive these motors using a simple H-bridge with its attaching protection circuit. As a control method for this system, we use a personal computer (PC) as a control unit, specifically, we use universal serial bus (USB) to interface the PC with the motor driver. Finally, we use C# language to program the manual and automatical modes.**

I. Introduction

The project based on a design for a loading bridge which moves in three dimensions. This loading bridge has three coordinates (x, y, z) . Thus, we can save time , efforts and also we can work more safe as well as the flexibility can be partially guaranteed in the workplace. The project consists of two fixed and parallel bridges which are linked to a moving bridge that are perpendicular on them. The loading bridge has three motors to represent three degree of freedom in the space as shown in Figure (1).

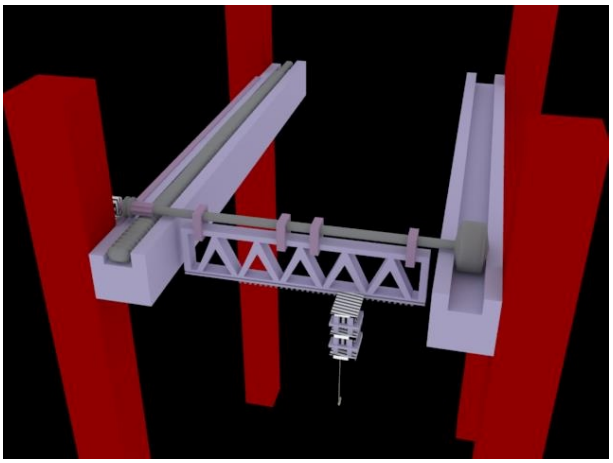

Fig. 1. Project design

There are some useful previous projects that were done at Palestine Polytechnic University/ College of Engineering and Technology as an introduction of this work such as [1] and [2]. These projects have given us general thinking about defining the position of the DC motor and their control using PC. Other useful project was done at TU-Muenchen [3] which helps us in the manual control of the loading bridge.

The true model of this bridge can be used in several industries that causes risks on human life in terms of transporting in workplaces, such as biomedical chemistry. Movements in x (width), y, (length) and z (depth) are defined as a moving path using this load bridge.

The cornerstone of this project is using a well suited motor that moves the object a desired position. Although there are several types of motors, but not all, are suitable to be used in this system, thus we have to carefully choose them.

The remaining sections of this paper are organized as follows. Section II gives the basic principle of the electronic circuit of the project. This circuit is summarized using a block diagram. Section III introduces the protection issues that must be taken in the consideration in the electrical circuit in addition the usage of the suitable driving motor in the project. Section IV explains the circuit, the devices and their usage that are used interfacing circuit between the driver and the control unit while Section V will conclude the report.

II. Project Setup

The simple electronic system of the loading bridge can be built using the following subsystems: Power supply, motors' drivers, protection system for the motors, positioning circuits, control unit (e.g. Personal Computer "PC") and interfacing circuits as shown in Figure (2).

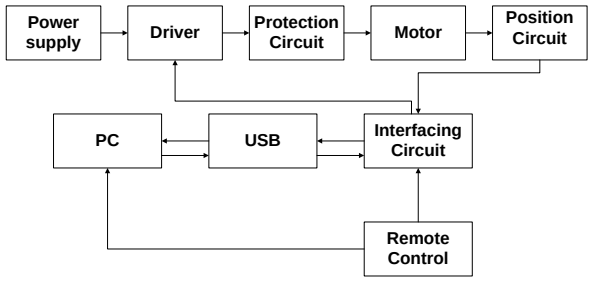

Fig. 2. Project block diagram

In the following we describe each subsystem.

1) Power Supply: In our project, the power supply contains transformer, rectifier, filter and regulator as shown in Figure (3).

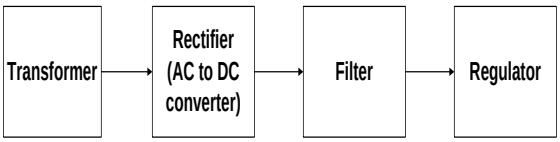

Fig. 3. Power supply block diagram

- Transformer: The transformer is used to couple the alternating current (AC) input voltage from the source to the second part (rectifier) as show in Figure (4). The coupling has two advantages. First, it allows the source voltage to be step down (from 220 V to 12 V). Second, the AC source is electrically isolated from rectifier, therefore a shock hazards in the secondary circuit will be prevented . Eq. (1) shows that the output voltage is equal the primary

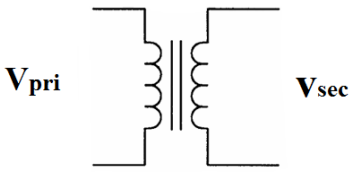

Fig. 4. Electrical transformer

(input) voltage divided by the transformer ratio. The ratio of the transformer that will be used $n = 18.3$ [4].
From basic AC circuit we recall that the voltage of the transformer equals the turn ratio n. The Secondary voltage can be expressed using Eq. (1) and the apparent power can be expressed using Eq. (2).

$$V_{Sec} = \frac{V_{Pri}}{n}, \tag{1}$$

$$S = V_{Sec} \times I_{Sec} = 12 \times 17 = 204 \quad \text{VA} \tag{2}$$

where V_{Sec}, V_{Pri} and S are the secondary voltage, primary voltage and apparent power, respectively.

- AC to DC converter: The AC rectifier converts the voltage signal using full-wave rectifiers (bridge). After transforming the source voltage into 12 V_{rms}, we need to deal with direct current (DC). A bridge rectifier carry out this function. The bridge rectifier uses four diodes as shown in Figure (5). When the input cycle is positive, the diodes D_1 and D_3 are forward-biased and pass current, in this case D_2 and D_4 are reverse biased. otherwise the input cycle is negative, the D_2 and D_4 are forward biased and pass current in the reverse direction. The output voltage can determine in Eq. (3):

$$V_{O(Avg)} = \frac{2(V_{Sec} - 2V_D)}{\pi} \tag{3}$$

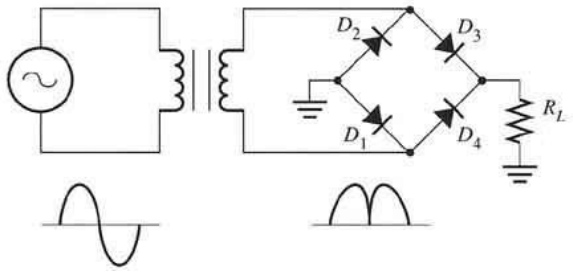

Fig. 5. Full-wave bridge rectifier

where $V_{O(Avg)}$ and V_D are the output average voltage and the diode barrier potential, respectively.

- Capacitor: The output voltage which comes from the rectifier needs to be suppressed to convert to DC current. This filtration is done by a coupling filter (capacitor) since a ripple voltage due to rectification process can be resulted. The output waveform will have less ripples as show in Figure (6) [4].

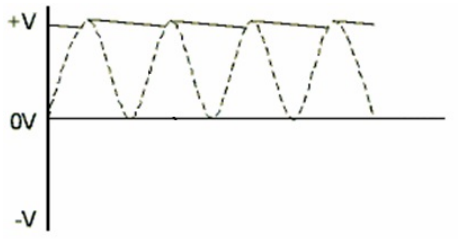

Fig. 6. The output voltage using filter

- IC Regulator: Since the output of the capacitor is not constant (pure DC) we use an IC regulator to stabilize the current. Figure (7) shows the position of coupling regulator in the power supply. We use the IC regulator of the number 7812 that results 12 V [4].

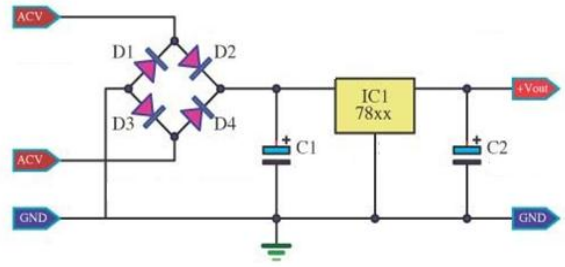

Fig. 7. IC regulator

- Driver: For the direction control of the DC motors, we use H-bridges, which is an electronic circuit that enables

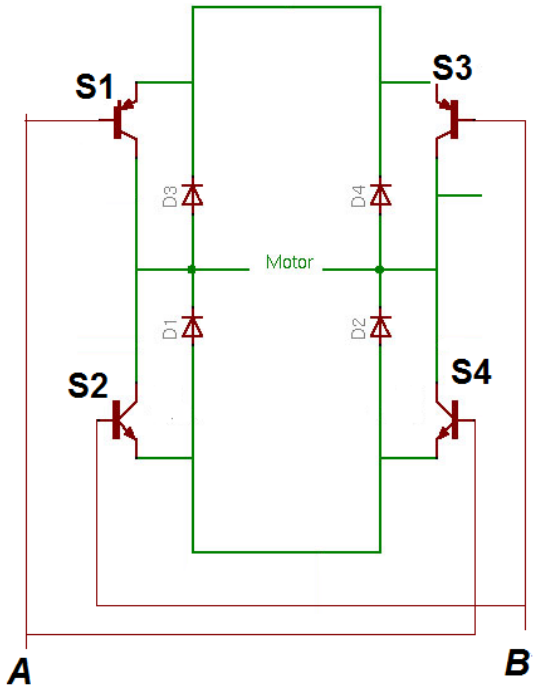

Fig. 8. H-bridge

TABLE I
TRUTH TABLE FOR DC MOTOR USING H-BRIDGE.

A	B	S_1	S_2	S_3	S_4	Motor
0	0	ON	OFF	ON	OFF	OFF
0	1	OFF	ON	ON	OFF	CCW
1	0	ON	OFF	OFF	ON	CW
1	1	OFF	ON	OFF	ON	OFF

a voltage to be applied across a load in either direction. It consists four bipolar junction transistors or MOSFETs as shown in Figure (8). These transistors allow DC motors to run clockwise direction (CW) or counter clockwise direction (CCW) as needed [5]. Both of transistor S_1 and S_3 are PNP and they should be low activated (logic 0, i.e. 0 V) . On the other hand S_2 and S_4 are NPN and they should be high activated (logic , i.e. 12 V). Table(1) show the direction of rotation the motor for power supply into the points A and B points [5].

III. PROTECTION CIRCUIT

Overload relays are specialized circuit breakers used with motors to protect the them from hazards that are caused by overload or electrical faults which allow harmless temporary overloads (such as motor starting) without disrupting the circuit. In addition, it will trip and open a circuit if current is high enough to cause motor damage over a period of time as well as it can be reset once the overload is removed. An overload relay consists of a sensor that is connected between the power supply and the motor as show in Figure (9). While the motor is running the current flows through the overload relay, the extra current will cause the overload relay to be tripped at a predetermined level and then the circuit between the power source and the motor will be opened. After a predetermined amount of time, the overload relay can be reset. When the cause of the overload has been identified and corrected, the motor can be reset [5].

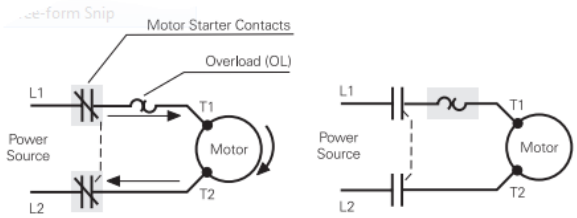

Fig. 9. Overload in a motor circuit

Again, it consists of a small heater element wired in series with the motor and a bi-metal strip that can be used as a trip lever. The bi-metal strip is made of two dissimilar metals bonded together. The two metals have different thermal expansion characteristics, so the bi-metal strip bends at a given rate when heated. Under normal operating conditions, the heat that is generated by the heater element will be insufficient to cause the bi-metal strip to bend enough to trip the overload relay as show in Figure (10) [5].

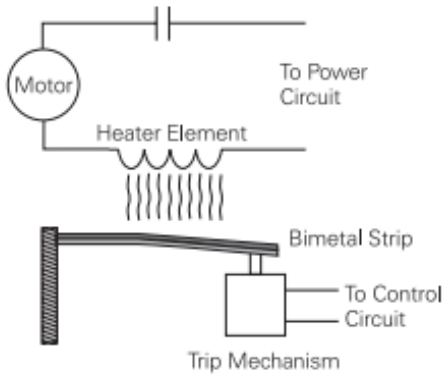

Fig. 10. Interrupt the motor using a thermal overload

In an overload condition, the current rises, so the heat also rises. The heat generated from the heater will cause the bi-metal strip to bend until the mechanism is tripped(stopping the motor) [5].

On the other hand, the direct current (DC) motor is a device used to convert electrical energy to mechanical energy. DC motor are also categorized into several types in terms of excitation circuit which are separately excited, shunt excited , series excited, compounded and permanent-magnet excited DC motor (PMDC). The last type of the DC motor has poles that are made from permanent magnets. The stator magnetic flux remains essentially constant at all levels of armature current, and therefore the speed verse torque curve of the PM motor is linear over an extended range. In general, the PMDC motor

has the several advantages; it is easier than other motors in terms of control, their maximum torque is found at zero speed, they produce zero torque at their maximum speed and they develop their maximum power at 50% of their maximum speed At 50% of maximum speed, they produce 50% of their maximum torque, At maximum power, they are no more than 90% efficient [5]

A digital encoder is a device that converts motion into a sequence of digital pulses. By counting a single bit or by decoding a set of bits, the pulses can be converted to relative or absolute position measurements [6]. This encoder designed to produce a digital word that distinguishes N distinct positions of the shaft. For example, if there are 8 tracks, the encoder is capable of producing 256 distinct positions (the number of bit corresponds to the number of track as show in Figure(11).

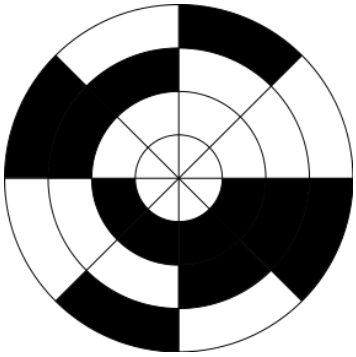

Fig. 11. Encoder with three track

When the conductor of the signal which put to the track on the black of the region , it send a number one to the computer, and when it in the white region send a number zero to the computer [6]. The Encoder cannot indicate the direction of rotation by the pulses that generated , to solve it the computer basedon foradd or decrease the distance that the motor is move about the which bits is active (ex. If the bin's that move forward is active ,the computer is add the distance.

IV. Interfacing Circuit

In our project, the interfacing circuit of the loading bridge is connected with PC using universal serial port (USB). We connect the nine inputs that come from the control switches (mechanical switches to control the motor direction) and the encoders which are used to detriment the speed and position of the motor in radius, which means tree inputs from the encoders and six input from the remote switches, to a "parallel to serial" device (e.g., IC-SN74LS165) that is shown in Figure(12) [7].

We connect six the outputs, that are the rotation and directions of the motors, i.e., three motors with two possible direction for each of them. to a the outputs of "serial to parallel" device (e.g. IC-GD74LS164) that is shown in Figure(13).

The universal serial port (USB) of the PC drives the interfacing circuit according a especial program that was written with C# language [8]. This language was highly adapted to be used industrial application, since it is improved language

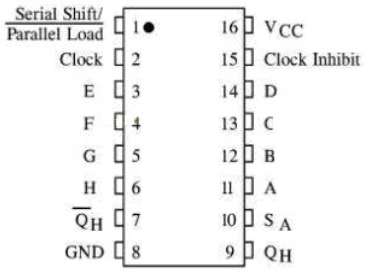

Fig. 12. IC parallel to serial

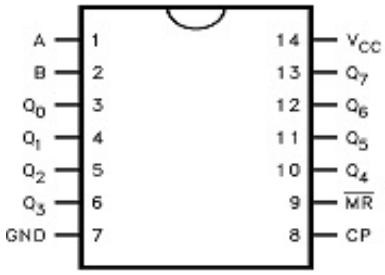

Fig. 13. IC serial to parallel

in comparison to the existing ones and contains many useful functions that are fitted to our applications in this project. This program enables the user to move the object 'O' from a predetermined point P_1 to a desired point P_2 in two ways. The first one is manual, i.e. without determining the desired point P_2 and the user uses the program to move the object only by pressing the remote switches. The second way is automatic, i.e., the user does not need to use the remote switches, but needs only to determine the location of the desired point P_2 in advance using a especial in the written program.

V. Conclusion

In this project, we designed and implemented a simple prototype of a three-dimensional loading bridge. We used simple technology in machines and electronic. In this technology, we use simple mechanical switches for the manual control, bipolar junction transistors (BJT-NPN and BJT-PNP) with their protection circuits, electrical transformer attached with rectification, filtration and regulation stages, electrical PMDC motor, operational amplifiers, serial to parallel converter, parallel to serial converter, three-bit encoder and PC with a USB port. We use a C# framework to write a especial program for the manual and automatic control of the prototype. With this loading bridge prototype, one can move an object from an initial point to other using two methods; manually and automatically. This means the moving track can be determined either using manual or automatic ways, respectively. In manual case we need only with remote switches but in automatic way we need to specify the target point the we need using cartesian coordinate and with respect to the initial known coordinate. As a future outlook to this project, one can improve the accuracy

for both the mechanical and electrical systems, so that we can use it as a laboratory unit for doing control experiments.

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