MINISTRY OF EDUCATION AND SCIENCE OF UKRAINE
National University “Zaporizhzhia Polytechnic”

LABORATORY GUIDELINES

in the discipline
“Embedded Computer System”

for students of specialty 123 “Computer Engineering”
according to the educational program “Specialized Computer Systems”

for all forms of education

2023

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CONTENT

1 LABORATORY WORK № 1
PROTEUS DESIGN SUITE

The purpose of the work: to learn how to create embedded systems in the Proteus Design Suite software.

1.1 Theoretical Information

Proteus Design Suite is a software package for electronic design automation (EDA) that is widely used by engineers, students, and hobbyists for designing, simulating, and prototyping electronic circuits.

Proteus Design Suite includes two main software applications: Proteus Schematic Capture and Proteus PCB Layout. Proteus Schematic Capture is a tool for drawing and editing electronic schematics, while Proteus PCB Layout is used to design printed circuit boards (PCBs).

One of the main features of Proteus Design Suite is its ability to simulate circuit designs in real-time using virtual instruments and components. This enables designers to test and verify the functionality of their designs before physically prototyping them, saving time and reducing costs.

Proteus Design Suite also includes a large library of components and models, as well as support for third-party libraries and custom component creation. Additionally, it offers a wide range of export options for sharing designs with other software tools, as well as an integrated 3D viewer for visualizing PCB designs in 3D.

Overall, Proteus Design Suite is a powerful and versatile software package that provides a comprehensive set of tools for electronic design and simulation

1.2 Progress

1.2.1 First, download and install Proteus Demo software (https://www.labcenter.com/downloads/) on your computer.

The Proteus Professional demonstration is intended for prospective customers who wish to evaluate our professional level products. It includes all features offered by the professional system including netlist based PCB design with auto-placement, auto-routing and graph based simulation.

Pay attention!

– No time limit on PCB Layout evaluation, 14 day on Microcontroller Simulation.

– Extensive set of sample designs included to help you evaluate all aspects of the software.

– You can write your own software to run on existing sample designs for evaluation purposes.

– You can only print Schematics and Layouts from the sample designs.

– You cannot save your work.

– You cannot simulate your own microcontroller designs.

1.2.2 Once you have installed Proteus, open the software.

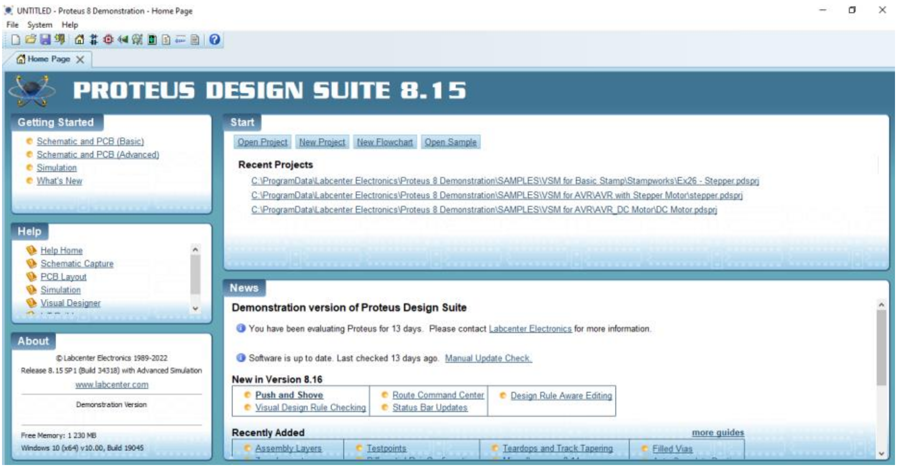


Figure 1.1 - Proteus Demo software

1.2.3 Click on "New Project" to create a new project.

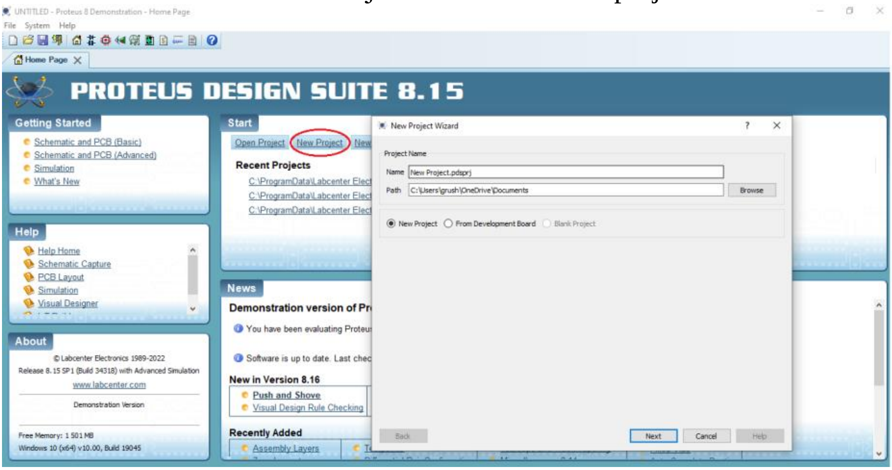


Figure 1.2 – New Project Window

1.2.4 Next, select the type of project you want to create. You can choose between Schematic Capture, PCB Layout, or both.

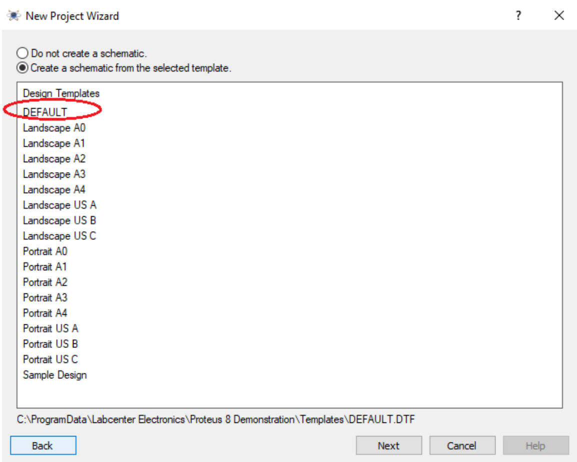


Figure 1.3 – New Project Wizard (Step 1)

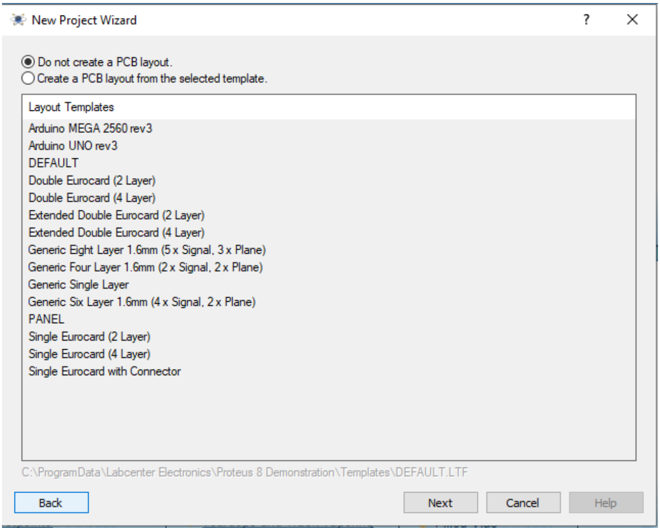


Figure 1.4 – New Project Wizard (Step 2)

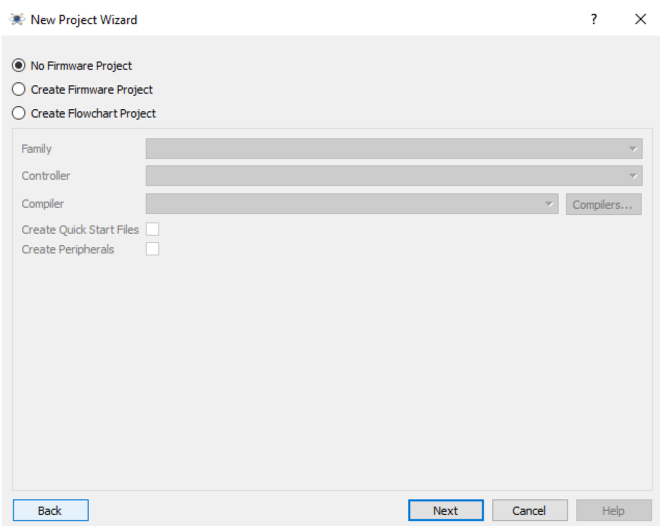


Figure 1.5 – New Project Wizard (Step 3)

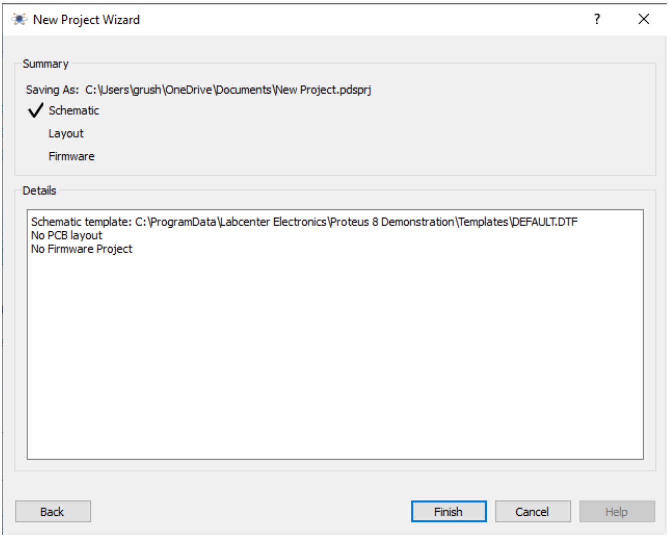


Figure 1.6 – New Project Wizard (Step 4)

1.2.5 After selecting the project type, you can start adding components to your design. You can use the built-in library or create your own custom components.

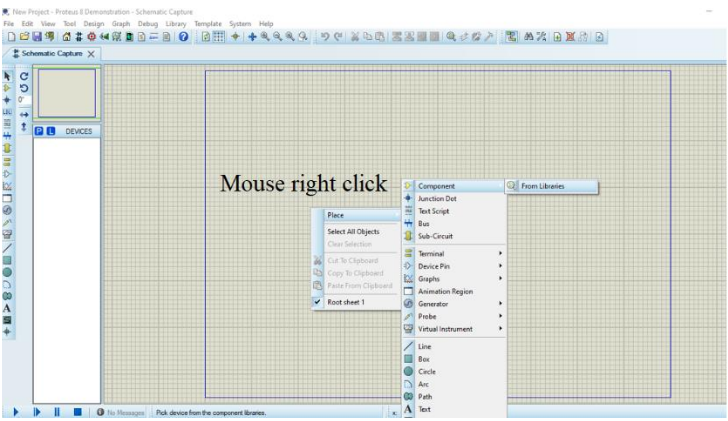


Figure 1.7 – Adding components

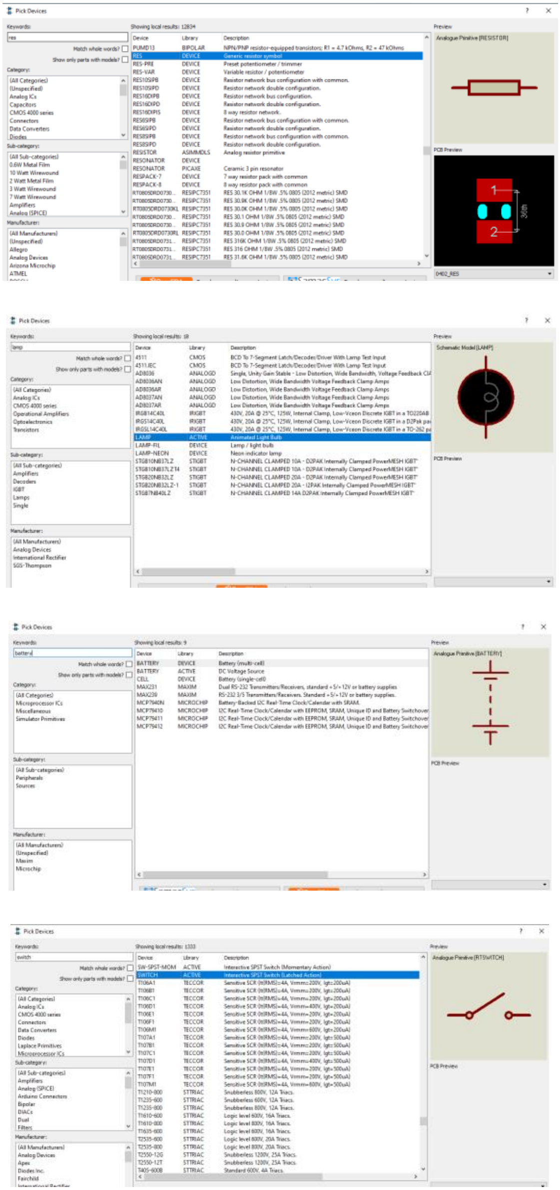


Figure 1.8 – Components library

1.2.6 Once you have added all the necessary components, you can connect them using wires or buses.

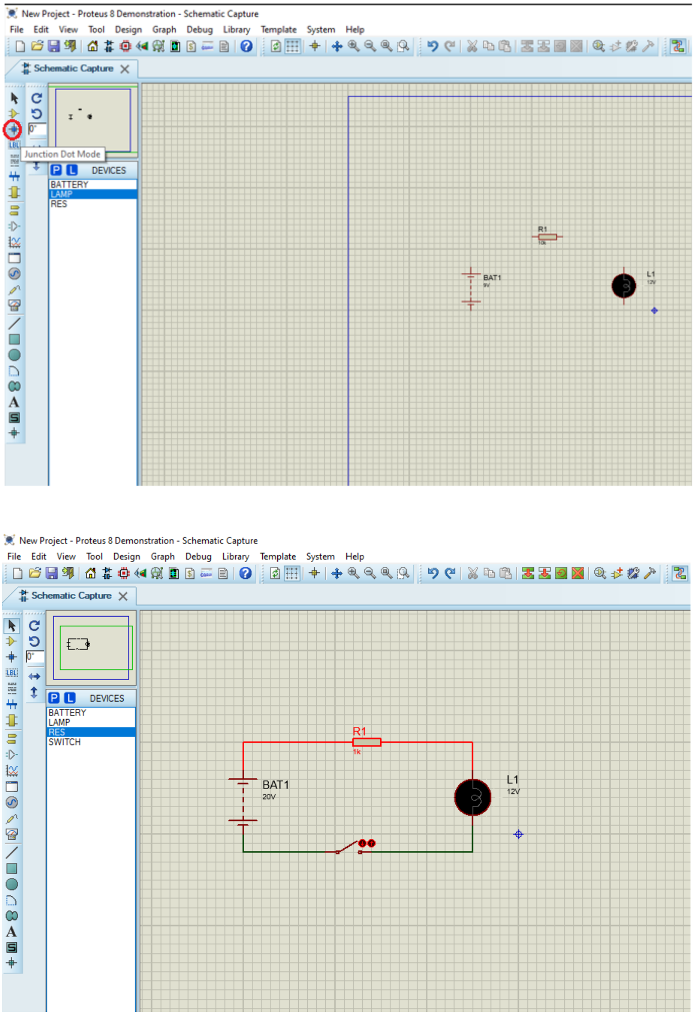
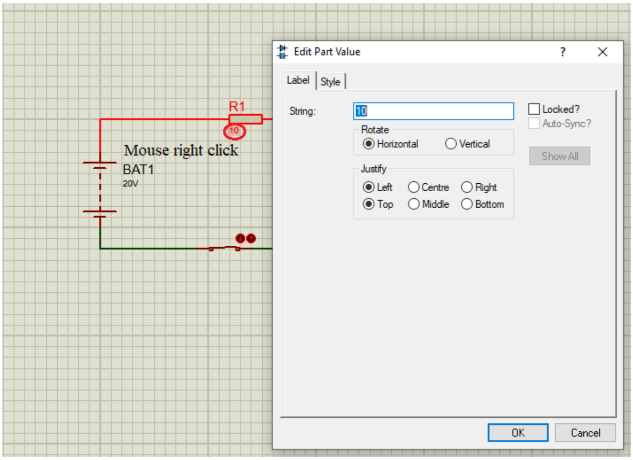


Figure 1.9 – Connection of components

1.2.7 You can change the parameters of the elements (Fig. 1.10).



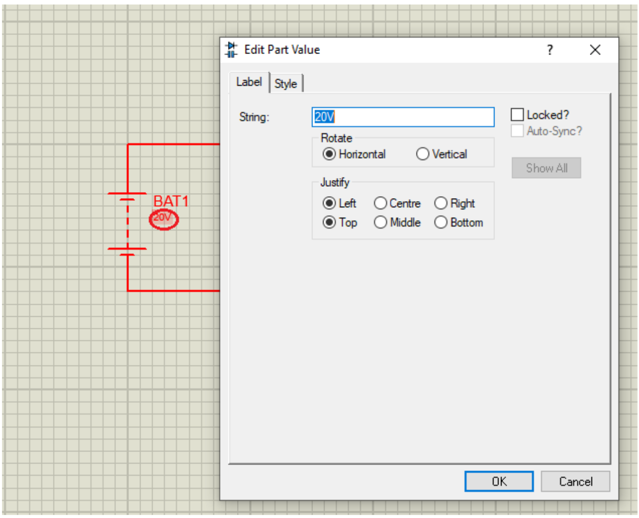
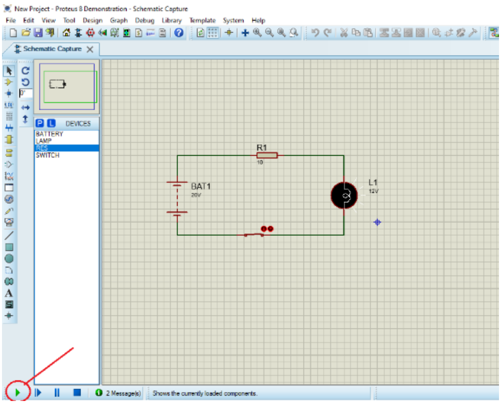


Figure 1.10 – Changing element parameters

1.2.8 You can simulate your design by clicking on the “Play” button in the toolbar. This will launch the simulation environment where you can test and debug your design.



1.3 Tasks to Complete

1.3.1 Perform all the actions described in paragraph 1.2;
1.3.2 Show result (the lamp should be on when the switch is turned on).

1.4 Contents

The report should have the following components:
– title page;
– the purpose of the work;
– the result of the tasks;
– the answers to review questions.

1.5 Review Questions

1.5.1 How do you create a new project in Proteus?
1.5.2 How do you add a new component to your circuit design in Proteus?

1.5.3 How do you connect multiple components in your circuit design in Proteus?

1.5.4 How do you simulate your circuit design in Proteus?

1.5.5 How do you troubleshoot errors in your circuit design in Proteus?

1.5.6 How do you run code on a microcontroller in Proteus?

1.5.7 How do you view the results of your simulation in Proteus?

1.5.8 How do you export your circuit design from Proteus to other software or hardware platforms?

1.5.9 How do you save your project in Proteus and access it later?

1.5.10 How do you use online resources to learn more about using Proteus?

2 LABORATORY WORK №2
DIRECT CURRENT MOTOR CONTROL

The purpose of the work: to study of the principles of operation and control of a direct current motor.

2.1 Theoretical Information

A direct current (DC) motor is any of a class of rotary electrical motors that converts DC electrical energy into mechanical energy. The most common types rely on the forces produced by induced magnetic fields due to flowing current in the coil. Nearly all types of DC motors have some internal mechanism, either electromechanical or electronic, to periodically change the direction of current in part of the motor.

A DC motor's speed can be controlled over a wide range, using either a variable supply voltage or by changing the strength of current in its field windings. Small DC motors are used in tools, toys, and appliances. The universal motor, a lightweight brushed motor used for portable power tools and appliances can operate on direct current and alternating current. Larger DC motors are currently used in propulsion of electric vehicles, elevator and hoists, and in drives for steel rolling mills. The advent of power electronics has made replacement of DC motors with AC motors possible in many applications.

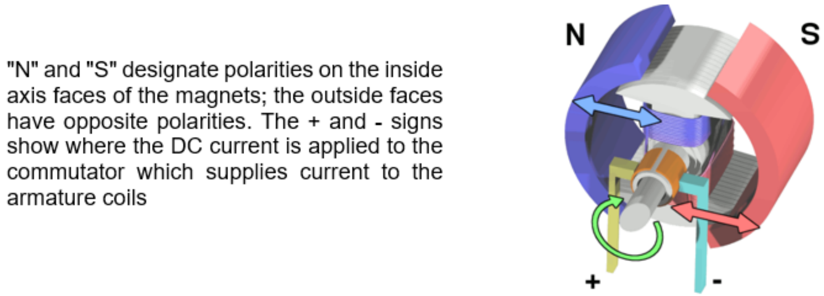


Figure 2.1 - Workings of a brushed electric motor with a two-pole rotor (armature) and permanent magnet stator

Advantages of a brushed DC motor include low initial cost, high reliability, and simple control of motor speed. Disadvantages are high maintenance and low life-span for high intensity uses. Maintenance involves regularly replacing the carbon brushes and springs which carry the electric current, as well as cleaning or replacing the commutator. These components are necessary for transferring electrical power from outside the motor to the spinning wire windings of the rotor inside the motor.

Brushed

Brushes are usually made of graphite or carbon, sometimes with added dispersed copper to improve conductivity. In use, the soft brush material wears to fit the diameter of the commutator, and continues to wear. A brush holder has a spring to maintain pressure on the brush as it shortens. For brushes intended to carry more than an ampere or two, a flying lead will be molded into the brush and connected to the motor terminals. Very small brushes may rely on sliding contact with a metal brush holder to carry current into the brush, or may rely on a contact spring pressing on the end of the brush. The brushes in very small, short-lived motors, such as are used in toys, may be made of a folded strip of metal that contacts the commutator.

Brushless

Typical brushless DC motors use one or more permanent magnets in the rotor and electromagnets on the motor housing for the stator. A motor controller converts DC to AC. This design is mechanically simpler than that of brushed motors because it eliminates the complication of transferring power from outside the motor to the spinning rotor. The motor controller can sense the rotor's position via Hall effect sensors or similar devices and can precisely control the timing, phase, etc., of the current in the rotor coils to optimize torque, conserve power, regulate speed, and even apply some braking. Advantages of brushless motors include long life span, little or no maintenance, and high efficiency. Disadvantages include high initial cost, and more complicated motor speed controllers. Some such brushless motors are sometimes referred to as "synchronous motors" although they have no external power supply to be synchronized with, as would be the case with normal AC synchronous motors.

DC Motor Speed Control in Series Types

It can be categorized into two types and those are:

– Armature Controlled Technique;

– Field Controlled Technique.

The armature controlled technique is further classified into three types:

– Armature Controlled Resistance;

– Shunted Armature Control;

– Armature Terminal Voltage.

Armature Controlled Resistance

This technique is most widely employed where the regulating resistance has a series connection with that of the motor supply. The below Figure explains this.

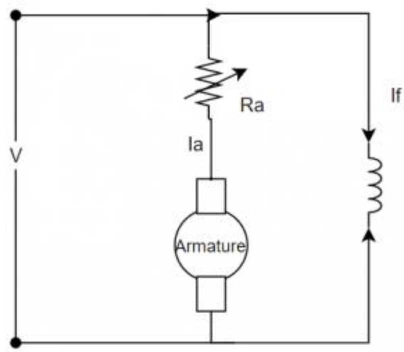


Figure 2.2 - Armature Resistance Control

The power loss that happens in the DC series motor's controlling resistance can be ignored because this regulating technique is mostly used for a long period in order to decrease the speed at the time of light loading scenarios. It is a cost-effective technique for persistent torque and mainly implemented in driving cranes, trains, and other vehicles.

Shunted Armature Control

Here, the rheostat will be in both series and shunting connection with the armature. There will be a change in the voltage level which is applied to the armature and this varies by changing the series rheostat. Whereas the change in excitation current takes place by changing the shunt rheostat. This technique of controlling speed in DC motor is not so costly because of significant power losses in speed regulation resistances. The speed can be regulated to some extent but not above the normal level of speed.

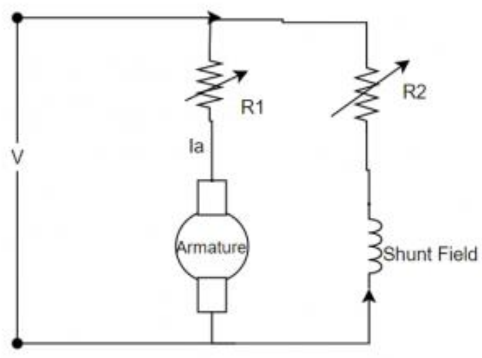


Figure 2.3 - Shunted Armature DC Motor Speed Control Method

Armature Terminal Voltage

The speed of a DC series motor can also be done through power supply to the motor using an individual varied supply voltage, but this approach is costly and not extensively implemented.

The field-controlled technique is further classified into two types:

– Field Diverter;

– Controlling of tapped field (Tapped field control).

Field Diverter Technique

This technique makes use of a diverter. The flux rate which is across the field can be decreased by shunting some part of the motor current across the series field. The lesser is the resistance of the diverter, the field current is less. This technique is utilized for more than the normal range of speeds and is implemented across electric drives where the speed increases when there is a decrease in load.

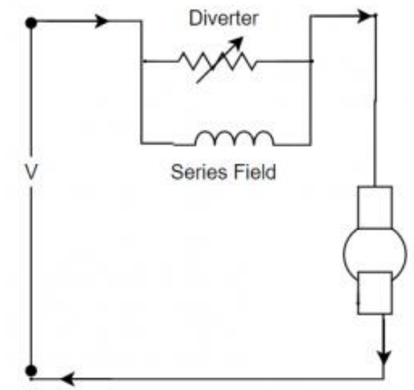


Figure 2.4 - Field Diverter DC Motor Speed Control

Controlling of Tapped Field

Here also, with the reduction of flux, the speed will be increased and it is accomplished by reducing the field winding turns from where the flow of current takes place. Here, the number of tapping's in the field winding is taken out and this technique is used in electric tractions.

2.2 Tasks to Complete

2.2.1 Assemble the circuit according to Fig. 2.6 in Proteus. Check the work. If a power source is connected to a circuit with a motor, the motor will rotate.

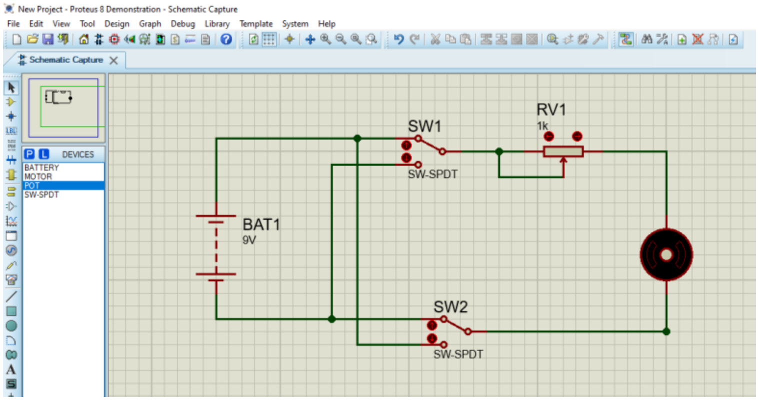


Figure 2.5 - Circuit example

2.2.2 Change the scheme according to the task by option (the option is selected by the number in the group list).

Table 2.1 - Task options

Option	Task
1, 9, 17	The circuit contains 3 motors, 2 of which rotate clockwise, and the third rotates counterclockwise. All motors rotate at the same speed.
2, 10, 18	The circuit contains 3 motors, 2 of which rotate counterclockwise, and the third rotates clockwise. All motors rotate at the same speed.
3, 11, 19	The circuit contains 3 motors, 2 of which rotate clockwise, and the third rotates counterclockwise. The third motor has a lower rotation speed.
4, 12, 20	The circuit contains 3 motors, 2 of which rotate counterclockwise, and the third rotates clockwise. The second and third motors have a lower rotation speed.
5, 13, 21	The circuit contains 4 motors, 2 of which rotate clockwise, and 2 - counterclockwise. All motors rotate at the same speed.

6, 14, 22	The scheme contains 4 motors, the first and fourth rotate clockwise, and the second and third rotate counterclockwise. The third and fourth motors have a lower rotation speed.
7, 15, 23	The circuit contains 3 motors, 2 of which rotate counterclockwise, and the third rotates clockwise. All motors rotate at different speeds.
8, 16, 24	The scheme contains 4 motors, the first and fourth rotate clockwise, and the second and third rotate counterclockwise. The third and fourth motors have a lower rotation speed.

2.3 Contents

The report should have the following components:
– title page;
– the purpose of the work;
– the result of the tasks;
– the answers to review questions.

2.4 Review Questions

2.4.1 What is a DC motor?
2.4.2 How does a DC motor work?
2.4.3 What are the components of a DC motor?
2.4.4 What is the difference between a DC motor and an AC motor?
2.4.5 What are the advantages of using a DC motor?
2.4.6 What are the disadvantages of using a DC motor?
2.4.7 What are the applications of DC motors?
2.4.8 How do you control the speed of a DC motor?
2.4.9 What is the difference between a brushed and brushless DC motor?
2.4.10 How do you maintain a DC motor?

3 LABORATORY WORK № 3
STEPPER MOTOR

The purpose of the work: to study of the principles of operation and control of a stepper motor.

3.1 Theoretical Information

A stepper motor is a type of electric motor that rotates in small, precise steps rather than continuously like a traditional electric motor. It is a digital motor that can accurately control its position and speed.

Stepper motors are often used in applications where precise motion control is required, such as in robotics, CNC machines, 3D printers, and industrial automation. They are also commonly used in consumer electronics, such as camera lenses, DVD drives, and printers.

A stepper motor consists of a rotor and stator, with the rotor typically having a series of teeth that align with magnetic poles on the stator. When current is applied to the stator, the magnetic field causes the rotor to move in small steps, with each step being controlled by the current sequence applied to the stator.

There are several types of stepper motors, including bipolar and unipolar motors, which differ in the way their coils are wired. Bipolar motors require more complex control circuits, but they typically provide higher torque and precision. Unipolar motors are easier to control, but they tend to have lower torque and precision.

Stepper motors can be controlled using a microcontroller or specialized stepper motor driver circuit. The control circuit sends signals to the motor to step in a specific direction and at a specific speed. The number of steps taken by the motor can be controlled by the number of pulses sent to the control circuit.

Overall, stepper motors are a popular choice for applications requiring precise motion control due to their accuracy, repeatability, and ease of control.

Unipolar Stepper Motor

A unipolar stepper motor has four fixed coils arranged around a magnetized rotor, as shown below. Typically, the coils are arranged in two centre tapped pairs, on opposing sides of the motor.

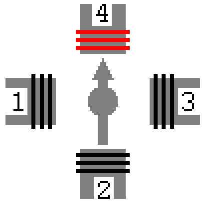


Figure 3.1 - The principle of unipolar stepper motor operation

Driving current through any coil will cause the rotor magnet to be attracted to it, and by sequencing the drive current though each coil in turn, the motor can be made to rotate continuously. Higher torque can be achieved if two coils are energized at a time, and by alternating between one and two coil drive states, a half stepping mode can be realized.

Driving current through any coil will cause the rotor magnet to be attracted to it, and by sequencing the drive current though each coil in turn, the motor can be made to rotate continuously. Higher torque can be achieved if two coils are energized at a time, and by alternating between one and two coil drive states, a half stepping mode can be realized.

As mentioned above, the stepper motor model does not simulate second order (acceleration) effects within the motor. Instead, we assume that the rotor arm is light relative to the forces acting upon it, and that maximum rotational velocity for a given rotor position and applied voltage is attained instantly.

The schematic model is shown in Fig. 3.2.

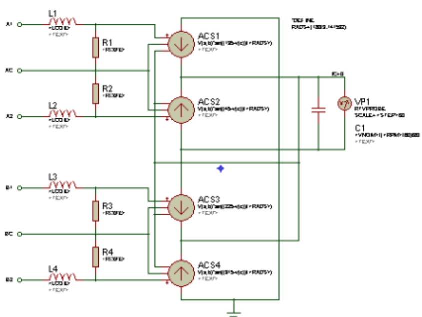


Figure 3.2 - The schematic model of unipolar stepper motor

This corresponds with mechanical reality as follows:

– L1-L4 and R1-R4 model the electrical properties of the drive coils;

– the force acting on the rotor is the sum of the forces generated by the currents flowing through the drive coils. The force is proportional to the current, and also depends on the current absolute position of the rotor. For a typical motor design, this involves a sine law, with the force changing sign as the rotor passes either side of the coil position. When the rotor is dead in line with a particular coil, there is no force since sin(0) == 0.

Strictly speaking, we should integrate these torque forces to get the angular velocity, and also generate back-emfs in each drive coil according to the current rotor velocity and absolute position. However, if we assume that the rotor is light, and that the maximum rotational velocity is achieved instantly, it is reasonable to say that the rotor velocity is simply proportional to the drive voltage.

This is achieved electrically by arbitrary controlled sources ACS1-4 which generate output currents as a function of coil drive voltage and the angular position.

– these currents are summed and integrated by capacitor C1 to generate a voltage representing absolute rotor position. This voltage is normalized to a 90° step angle, so that the forces generated by the four coils can be computed directly;

– voltage probe VP1 scales the value for the step angle (i.e. applies a gearing ratio) and feeds the result to the animated rotor model.

Bipolar Stepper Motor

A bipolar stepper motor is essentially the same as a unipolar stepper motor except that the opposing coils are wired in parallel and therefore the device has just four terminals.

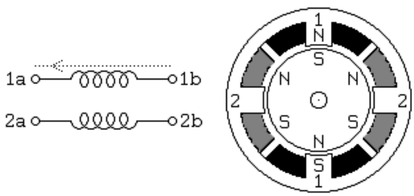


Figure 3.3 - The model of bipolar stepper motor

The motor must be driven using circuitry that can drive current through each pair of coils in either direction. This is achieved using an H-Bridge driver for each coil – this can be most easily implemented using bridge driver ICs such as the L298 or L6201/2/3 for which behavioural simulator models are also provided.

The properties and theory of operation of the bipolar stepper motor model are almost identical to those of the unipolar stepper motor model.

3.2 Tasks to Complete

3.2.1 Assemble the circuit according to Fig. 3.4 in Proteus. Check the work. If a power source is connected to a circuit with a motor, the motor will rotate.

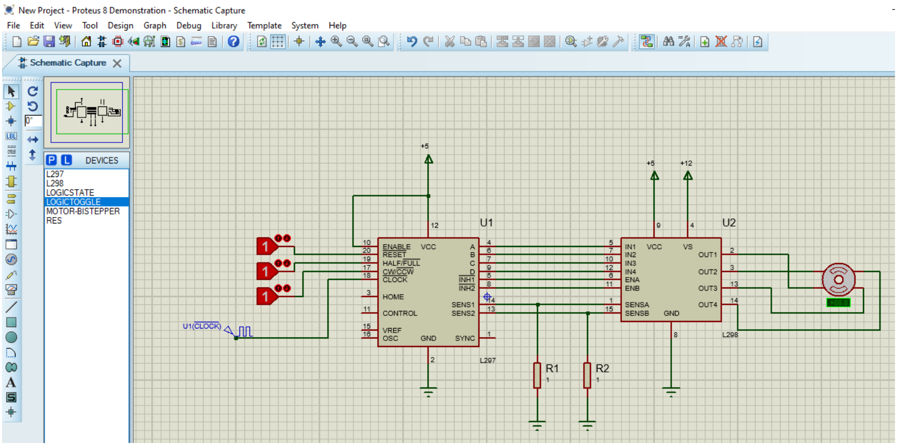


Figure 3.4 – Bipolar stepper motor control circuit

3.2.2 Start and investigate the operation of the circuit. Specify the necessary screens in the report.

3.2.3 Find the datasheet for the L297 and L298 chips. Provide the necessary information in the report. Understand the principle of their work, inputs and outputs. Understand the principle of operation of the scheme as a whole. Write in the report.

3.3 Contents

The report should have the following components:
– title page;
– the purpose of the work;
– the result of the tasks;
– the answers to review questions.

3.4 Review Questions

3.4.1 What is a bipolar stepper motor, and how does it differ from a unipolar stepper motor?

3.4.2 How does the L297 stepper motor controller chip operate, and what features does it offer for controlling stepper motors?

3.4.3 What is the purpose of the L298 motor driver chip, and how does it interface with the L297 controller to drive a bipolar stepper motor?

3.4.4 What are some common applications for bipolar stepper motors, and what advantages do they offer over other types of motors?

3.4.5 What is microstepping, and how can it improve the precision and accuracy of stepper motor motion control?

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