

DC POWER SUPPLY SIMULATOR

An Educational Laboratory Simulator for DC Power Supply

**Report Submitted to
IGS-CES**

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Abstract

Simulators are excellent illustrative tools that provide facets such as hands on experience of a real world system. Such simulators have enormous efficacy in education where critical thinking and decision making skills can be infused with great effectiveness. These simulators allow students to polish various competencies ranging from application to analysis and from synthesis to evaluation. In this project, a simulator is proposed from the area of electronics. The simulator targets junior to senior level electrical engineering students.

1. Introduction:

Computers and information technology have increased educational opportunities and opened the doors to new instructional methods. Today's educator and student have adopted technology as a normal part of their curriculum. One common adaptation is for the instructors to create a website or WebCT course folder for their course, which may contain the instructor's PowerPoint lectures, course handouts, streaming audio/video lectures, and a list of links, which may further aid the student in understanding the material. Interactive learning content revolutionizes the way topics can be traditionally taught. The use of multimedia, rich-graphics, animations, simulations, and virtual environments offer students a way to visualize and actively engage with the content which is otherwise presented to them in a static and passive manner, via textbook and lectures.

This type of new content material is invaluable to disciplines like the engineering and sciences, where visualization coupled to understanding cause and effects of concepts are the heart to mastering the material. Traditional learning materials are not effective resources to support this type of learning, since students repeatedly struggle with the same difficult concepts. Interactive learning content requires a different pedagogical approach from traditional materials. The effective design of interactive learning content includes identifying and utilizing how a technological approach (animation, interactivity, or simulation) can help the student understand the phenomenon, engaging them in active learning environments. This design is then coupled strongly to a usable interface and clear pedagogical goals for the student to grasp. The result is an integration of technology and pedagogy into a new vehicle for teaching: high-quality interactive learning content that is an *Interactive Educational Simulator*. If a picture is worth a thousand words, and an animation is one thousand pictures, the net worth of simulations and virtual environments is priceless.

The nature of the interactive simulation environment provides students to make numerous attempts in a relatively short period of time and quickly see the consequences of their decision and strategies without the fear of failure or breaking of equipments. Interactive

simulation models allow students to see the subject dynamics with all dimensions which helps to explain complex situations in a more comprehensive way. With this respect it improves students' practical competencies; such as critical-thinking, decision-making and management skills. As Checkland (1989) states, "...soft systems methodology is a learning, not an optimizing system."

Obviously, Simulators' are not a substitute for more formal approaches of teaching theories and methods of a particular subject. However, it complements these approaches and hence can prove to be extremely effective. An exciting feature of this simulator is that students concentrate on decision-making. It is this intensity that gives the simulator the richness and teaching effectiveness.

To achieve the goal of integrating course material and a platform where students can experiment with the concepts introduced in the lectures, we have developed a DC power supply Simulator, as a part of a course module. One reason that Electronic circuits are harder to understand than basketballs is that one can learn about basketballs by watching them, whereas voltage and current are not directly visible, and must be measured indirectly with meters and oscilloscopes. This lack of visibility impedes learning about circuits in many ways, not only in lab work, but also in communication about circuits in the classroom and in paper or electronic documents. In addition, without a way to mentally visualize circuits, it can be more difficult to gain an intuitive understanding of circuit operation. Thus the Simulator developed will assist the students to visualize the dynamics to various circuits and test the effects of various decisions they can make on the outcome of their circuits.

The simulator is machine-independent and thus open to wide use. The Visio 2003, Photoshop and Macromedia Flash and Action Script (Flash scripting language) capability of Flash allowed us speedy development and user-friendly presentation. The integration of a web-based simulator, multimedia materials, reference, and feedback creates an effective course environment.

Literature survey

Using new media and information technology in the classroom can not only make studying more attractive to the student, but might make also teaching much easier [1], [2]. Especially in engineering classes complex technical problems have to be presented in a way which is easy to follow and understand.

Simulators in education are becoming widespread and a plenty of literature is available. The realization of the effectiveness of these simulators is growing Literature on specific simulators are presented below

Projects using Java applets in different fields of engineering [3], [4], [5], [6] and for simulation in power electronics [7], [8], [9] can be found on the Internet in a Growing number.

In [4], A Java applet that performs graphical convolution of continuous-time signals on the screen is presented to aid in teaching, where a student can select from provided signals or draw a signal with mouse. A combination of Java Script, RealAudio, and technical presentation on the screen, and Java applets to complement classroom lectures.

In [10], A new platform-independent Simulation tool for education in power electronics and electrical machines has been introduced. The Java-applets inserted into the HTML text are written for interactive animation, controller design and simulation with an easy-to-use self-explaining graphical user interface.

In [11], an example of E-Learning for an effective introduction into the space vector theory for three-phase PWM converter systems and electrical machines is given. The E-Learning software focusing on space vector calculus is part of iPES (Interactive Power Electronics Seminar) that is available on the Internet at www.ipes.ethz.ch. iPES is a collection of Java applets for interactive animation and simulation of power electronic systems that is used in addition to more conventional teaching in the basic power electronics course at the ETH Zurich.

In [12], a Web/DVD-based Multimedia Architecture Simulator and courseware have been developed for a course module entitled “Multimedia Architectures.” The goal of this module is to study architectural enhancements to microprocessors to support multimedia applications. The courseware provides lecture material including audio/video lecture recordings and slides, references to relevant websites, a search engine, and various Java applets and the Multimedia Architecture Simulator: The Simulator is Web/DVD-based and runs on-line.

In [13], the virtual oscilloscope has been created within the scope of a master's thesis at the Department of Communication Science at the Institute for Language and Communication of Technical University Berlin. You can operate the oscilloscope as you would operate a real one. You can attach and detach signal cables. Simulation contains the original sounds of switches and wheels.

In [14], an analog cathode ray oscilloscope simulator has been developed to permit students to practice with a good simulator, experiment step by step with the concept he or she is learning, and to allow interaction with the teacher via a normal Internet TCP/IP connection.

In [15], paper presents a tutoring system for the ear domain in medical education as an application of the Interactive Simulation based multimedia system (InterSim). The InterSim approach is based on the principles of cognitive apprenticeship. It enables exploration of the subject domain and acquisition of both domain knowledge and skills through multimedia based interactions, especially interactive simulations. With its main focus on cognitive skills acquisition, the system adapts to user actions and supports learning activities with intelligent assistance in the form of guidance and dynamic feedback as well as system assessed testing.

In [16], an educational simulator (e-SCAT) for switched-mode power converter has been developed that has new algorithm and user-friendly interface to encourage students to learn more concerning the field of Switched-mode power converter.

This educational simulator has features as follows:

(1) Remarkably high simulation speed (2) User-friendly circuit editor
(3) Visible oscilloscope window (4) Automatic determination of states and sequence mode (5) Indication of equivalent circuit for each state

In [17], the application of simulators in teaching digital electronics is discussed. Educational simulator software package employed are discussed and examples of practical exercises used with students are presented. The advantages and disadvantages of the simulator approach are compared with conventional courses.

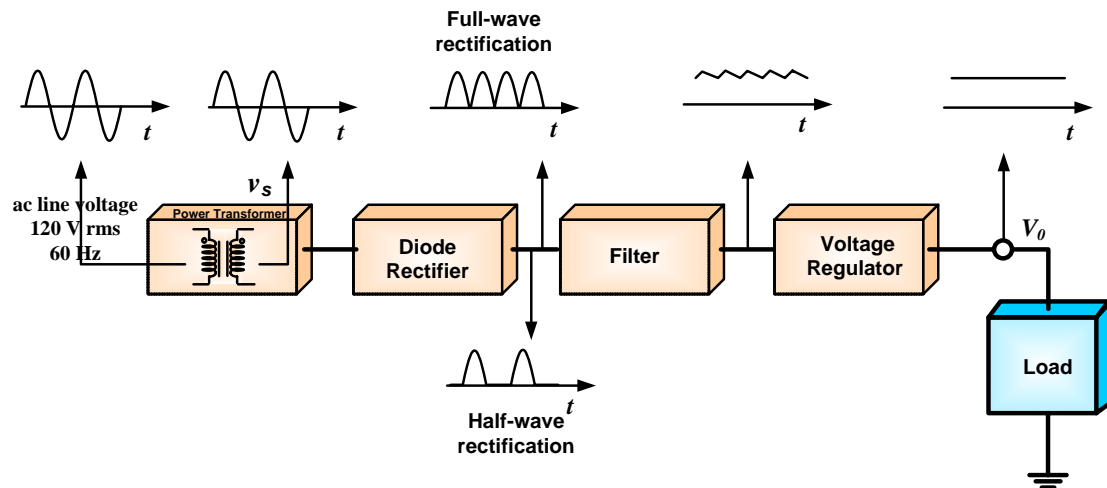
In [18], A glucose and insulin simulator, was completed to fulfill a senior design project and is available for educational purposes through the World Wide Web. The simulator allows user to make modifications in diet and insulin regimen for 40 different pre-programmed "patients" or to create a patient with custom-designed specifications. Multiple simulations can be run in order to compare the results of changes in diet and/or insulin regimen. The results of two different simulations can be displayed on the same graph.

Introduction to DC Power Supply

The objective of the simulator is to reacquaint students with the fundamentals of AC (alternating current) and DC (direct current) voltages as well as introduce students to the basics of AC to DC conversion through the use of diode rectifiers

The dc **power supply** converts the standard 120V /220V, ac available at wall outlets into a constant dc voltage (usually in the range of 5 to 20 V). It is one of the most common electronic circuits that you will find. The dc voltage produced by a power supply is used to power all types of electronic circuits, such as television receivers, mobiles, stereo systems, VCRs, CD players and most laboratory equipments

A basic block diagram for complete power supply is shown in figure below. The first block in a dc power supply is the **power transformer**. It consists of two separate coils wound around an iron core that magnetically couples the two windings. The **primary winding** having N_1 turns, is connected to the 120-V ac supply; and the **secondary winding**, having N_2 turns, is connected to the circuit of the dc power supply. Thus, an ac voltage V_s of $120(N_2/N_1)$ volts (rms) develops between the two terminals of the secondary windings. By selecting the appropriate turns ratio (N_1/N_2) for the transformer, the designer can step the line voltage down to the value required to yield the particular dc voltage output of the supply. For instance, a secondary voltage of 8-V rms may be appropriate for a dc output of 5 V. This can be achieved with a 15:1 turns ratio.



In addition to providing the appropriate sinusoidal amplitude for the dc power supply, the power transformer provides electrical isolation between the electronic equipment and the power-line circuit. This isolation minimizes the risk of electric shock to the equipment user.

The **diode rectifier** can be either a half-wave rectifier or a full-wave rectifier (center-tape and bridge). The rectifier converts the ac input sinusoid V_s to a unipolar pulsating output,

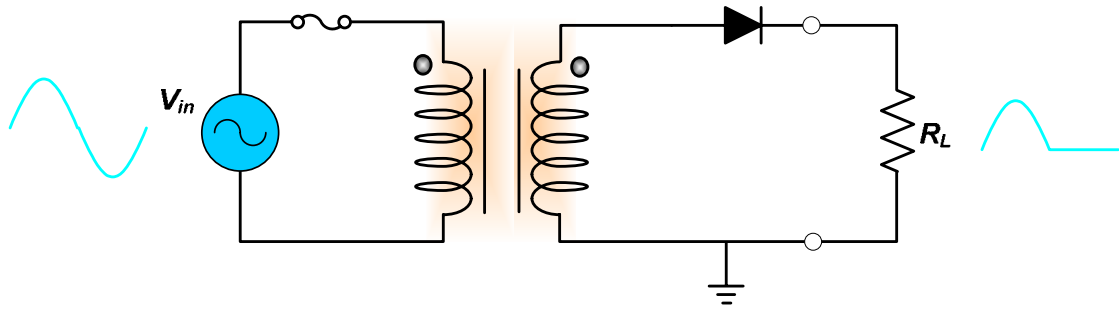
which is half-wave or full-wave rectified as shown in figure above. Although this waveform has nonzero average or dc-component, its pulsating nature makes it unsuitable as a dc source for electronic circuits, hence the need for a filter. The variation in the magnitude of the rectifier output is considerably reduced by the filter block in Figure above.

The output of the rectifier filter, though much more constant than without the filter, still contains a time-dependent component, known as **ripple**. To reduce the ripple and to stabilize the magnitude of the dc output voltage of the supply against variations caused by change in load current a voltage regulator is employed. Regulators vary from a single device (zener shunt regulator) to more complex integrated circuits. The load block is a circuit or device for which the power supply is producing the dc voltage and load current.

We will not use regulators in our simulator as the regulators maintain a constant voltage at the output. We want to give more control to the students to play with different values of capacitors to reduce the ripple to acceptable level this will increase the learning of students.

Half-wave Rectifier

The easiest rectifier to understand is the half wave rectifier. It is simply a diode and a load as shown in Figure.

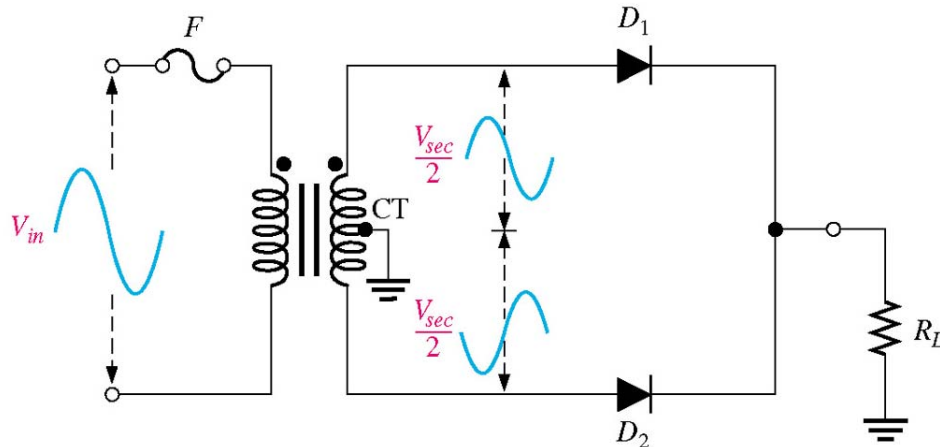


Let's examine what happens during one cycle of the input voltage using ideal model for diode. When the sinusoidal input voltage (V_{in}) goes positive, the diode is forward-biased and conducts current through the load resistor. The current produces an output voltage across the load R_L , which has the same shape as the positive half-cycle of the input voltage.

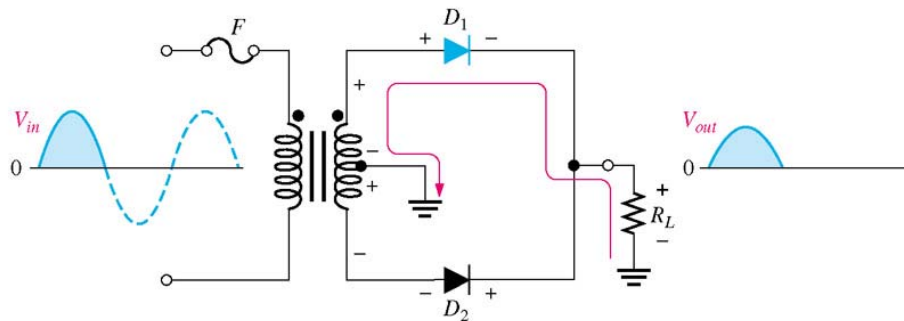
When the input voltage goes negative during the second half of its cycle, the diode is reverse-biased. There is no current, so the voltage across the load resistor is 0V as shown. The net result is that only positive half-cycle of the ac input voltage appears across the load. Since, the output does not change polarity, it is pulsating dc voltage.

The Center-Tapped Full-Wave Rectifier

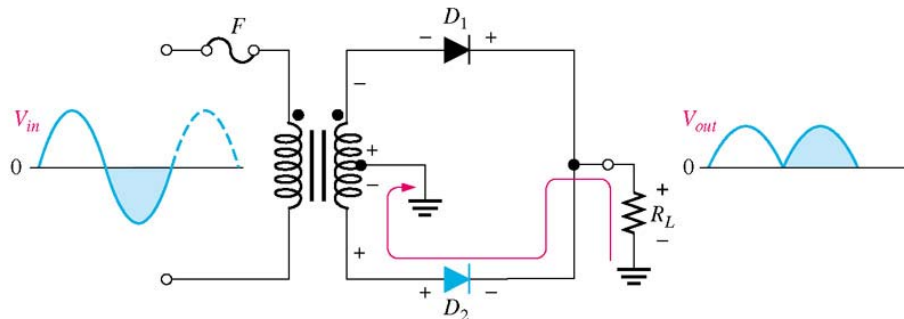
A center-tapped rectifier is a type of full-wave rectifier that uses two diodes connected to the secondary of a center-tapped transformer, as shown in the figure 1. The input voltage is coupled through the transformer to the center-tapped secondary. Half of the total secondary voltage appears between the center tap and each end of the secondary winding as shown.



For positive half-cycle of the input voltage, the polarities of the secondary voltages are as shown in figure (a).



(a) During positive half-cycles, D_1 is forward-biased and D_2 is reverse-biased.



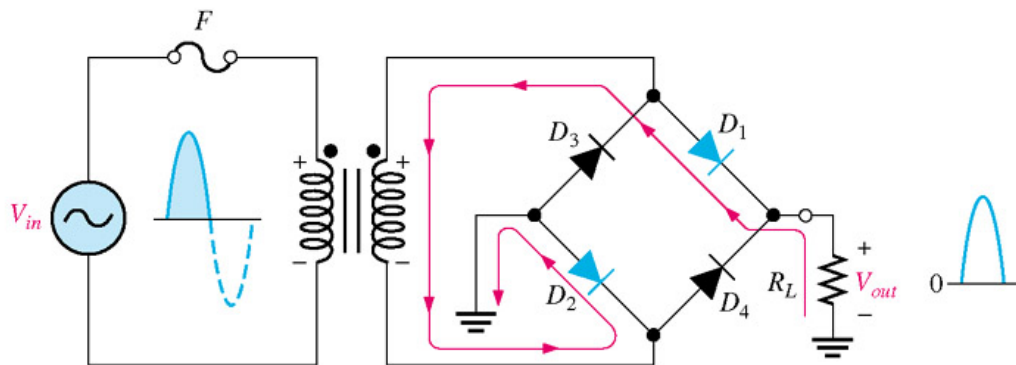
(b) During negative half-cycles, D_2 is forward-biased and D_1 is reverse-biased.

This condition forward-biases diode D_1 and reverse-biases diode D_2 . The current path is through D_1 and the load resistor R_L , as indicated. For the negative half cycle of the input voltage, the voltage polarities on the secondary are as shown in figure (b). This condition reverse biases D_1 and forward-biases D_2 . The current path is through D_2 and R_L , as indicated. Because the output current during both positive and negative portions of the input cycle is in the same direction through the load, the output voltage developed across the load resistor is a full-wave rectified dc voltage.

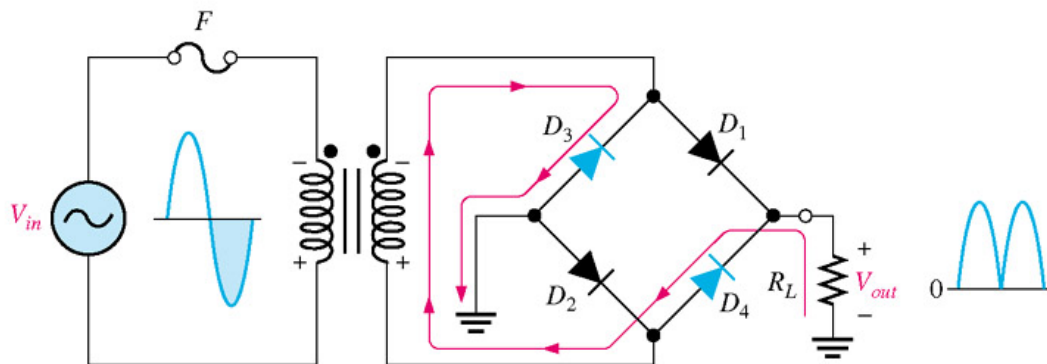
The Bridge Full-wave Rectifier

An alternative implementation of the full-wave rectifier is as shown in figure. The circuit known as the bridge rectifier because of the similarity of its configuration to that of the Wheatstone bridge, does not require a center-tapped transformer, distinct advantage over a Full-wave center-tapped rectifier. The bridge rectifier however requires four diodes as compared to two in the previous circuit. This is not much of a disadvantage, as diodes are inexpensive and one can buy a diode bridge in one package.

The bridge rectifier operates as follows: during the positive half cycles of the input voltage diodes D_1 and D_2 are forward-biased and conduct current in the direction shown in figure (a). A voltage is developed across R_L which looks like the positive half of the input cycle. During this time diodes D_3 and D_4 are reverse-biased.



(a) During positive half-cycle of the input, D_1 and D_2 are forward-biased and conduct current. D_3 and D_4 are reverse-biased.



(b) During negative half-cycle of the input, D_3 and D_4 are forward-biased and conduct current. D_1 and D_2 are reverse-biased.

When the input cycle is negative as shown in figure (b), diodes D_3 and D_4 are forward-biased and conduct current in the same direction through R_L as during the positive half cycle. During negative half-cycle, D_1 and D_2 are reverse-biased. A full wave rectified output voltage appears across R_L as a result of this action.

Although the rectification stage makes the sine wave voltage to be positive for both full-wave bridge and Center-tapped, the rectifier's result is not as "flat" a DC value as we would like to have from a reliable voltage source. The capacitor is included to help smooth out the ripples that result in the output from the rectification stage. Recall that the voltage across a capacitor cannot change instantaneously, but rather it requires a certain amount of time before it is fully charged. Large capacitance values help suppress the quickly changing voltage from the rectifier and result in a flatter DC value being supplied to the load. Typical power supply designs use relatively large capacitor values (greater than 1000 μF).

Following sections describe the simulator developed & feedback received from EE faculty:

DC power Supply Simulators

The dc **power supply** converts the standard 120V /220V, ac available at wall outlets into a constant dc voltage (usually in the range of 5 to 20 V). It is one of the most common electronic circuits that you will find. The dc voltage produced by a power supply is used to power all types of electronic circuits, such as television receivers, mobiles, stereo systems, VCRs, CD players and most laboratory equipments.

In the developed Simulator, the power supply consists of a transformer, a rectifier circuit and a filter. The objective of the simulator is to reacquaint students with the fundamentals of AC (alternating current) and DC (direct current) voltages as well as introduce students to the basics of AC to DC conversion through the use of diode rectifiers

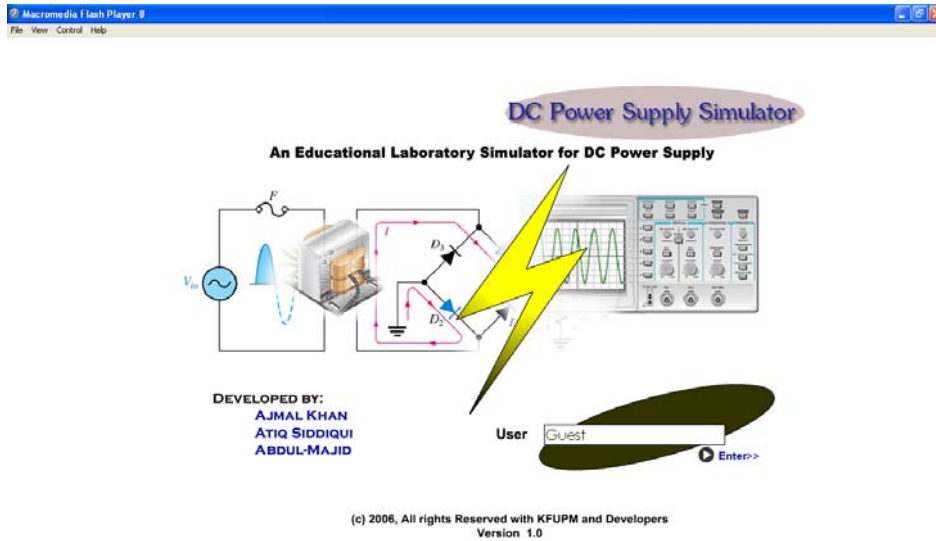
The screen shots of the developed Simulator 'DC Power Supply Simulators' are attached.

Game Development and Interface

The game is developed in Macromedia Flash 8. The programming is done in Actionscript. The suite was selected because of its excellent animation and graphical abilities along with the programming capabilities provided by scripting language known as Actionscript.

Title Screen

Showing the name of the Simulator with an icon and a field for the name of the user.



Information Screen

On this screen students will find an introduction of the DC power supply Simulator its working and objectives.

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Full-wave rectification

Half-wave rectification

ac line voltage 120 V rms 60 Hz

Power Transformer

Diode Rectifier

Filter

Voltage Regulator

Load

V_s

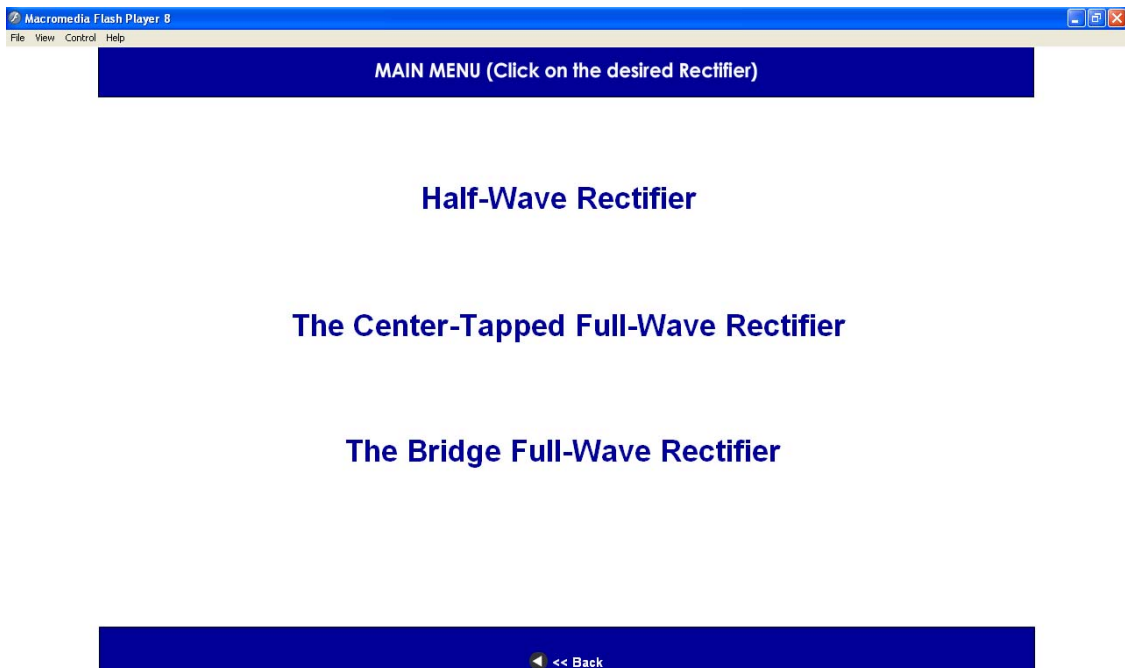
V_L

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Rectifier Circuit screen

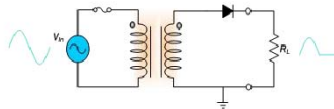
The students after browsing through the introduction can now proceed to the individual rectifiers as shown below.



Here the student can proceed with their choice of rectifier depending on their level of understanding of the subject. The three screens shown below will help student understand the background information about halfwave, fullwave and bridge rectifier.

Half-Wave Rectifier

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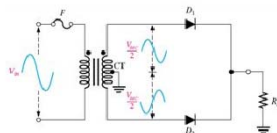
Let's examine what happens during one cycle of the input voltage using ideal model for diode. When the sinusoidal input voltage (V_{in}) goes positive, the diode is forward-biased and conducts current through the load resistor. The current produces an output voltage across the load R_L , which has the same shape as the positive half-cycle of the input voltage.

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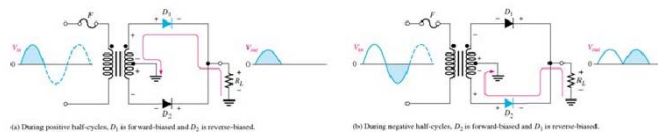
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The Center-Tapped Full-Wave Rectifier

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For positive half-cycle of the input voltage, the polarities of the secondary voltages are as shown in Figure 2(a).



This condition forward-biases diode D_1 and reverse-biases diode D_2 . The current path is through D_1 and the load resistor R_L , as indicated. For the negative half cycle of the input voltage, the voltage polarities on the secondary are as shown in Figure 2(b). This condition reverse biases D_1 and forward-biases D_2 . The current path is through D_2 and R_L , as indicated. Because the output current during both positive and negative portions of the input cycle is in the same direction through the load, the output voltage developed across the load resistor is a full-wave rectified DC voltage.

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Macromedia Flash Player 8

The Bridge Full-wave Rectifier

An alternative implementation of the full-wave rectifier is as shown in Figure. The circuit is known as the **bridge rectifier** because of the similarity of its configuration to that of the Wheatstone bridge, does not require a center-tapped transformer, distinct advantage over a full-wave center-tapped rectifier. The bridge rectifier however requires four diodes as compared to two in the previous circuit. This is not much of a disadvantage, as diodes are inexpensive and one can buy a diode bridge in one package.

The bridge rectifier operates as follows: during the positive half cycles of the input voltage diodes D_1 and D_2 are forward-biased and conduct current in the direction shown in Figure 4(a). A voltage is developed across R_L which looks like the positive half of the input cycle. During this time diodes D_3 and D_4 are reverse-biased.

(a) During positive half-cycle of the input, D_1 and D_2 are forward-biased and conduct current. D_3 and D_4 are reverse-biased.

(b) During negative half-cycle of the input, D_3 and D_4 are forward-biased and conduct current. D_1 and D_2 are reverse-biased.

When the input cycle is negative as shown in Figure 4 (b), diodes D_3 and D_4 are forward-biased and conduct current in the same direction through R_L as during the positive half cycle. During negative half-cycle, D_1 and D_2 are reverse-biased. A full wave rectified output voltage appears across R_L as a result of this action.

Although the rectification stage makes the sine wave voltage to be positive for both full-wave bridge and Center-tapped, the rectifier's result is not as "flat" a DC value as we would like to have from a reliable voltage source. The capacitor is included to help smooth out the ripples that result in the output from the rectification stage. Recall that the voltage across a capacitor cannot change instantaneously, but rather it requires a certain amount of time before it is fully charged. Large capacitance values help suppress the quickly changing voltage from the rectifier and result in a flatter DC value being supplied to the load. Typical power supply designs use relatively large capacitor values (greater than 1000 μF).

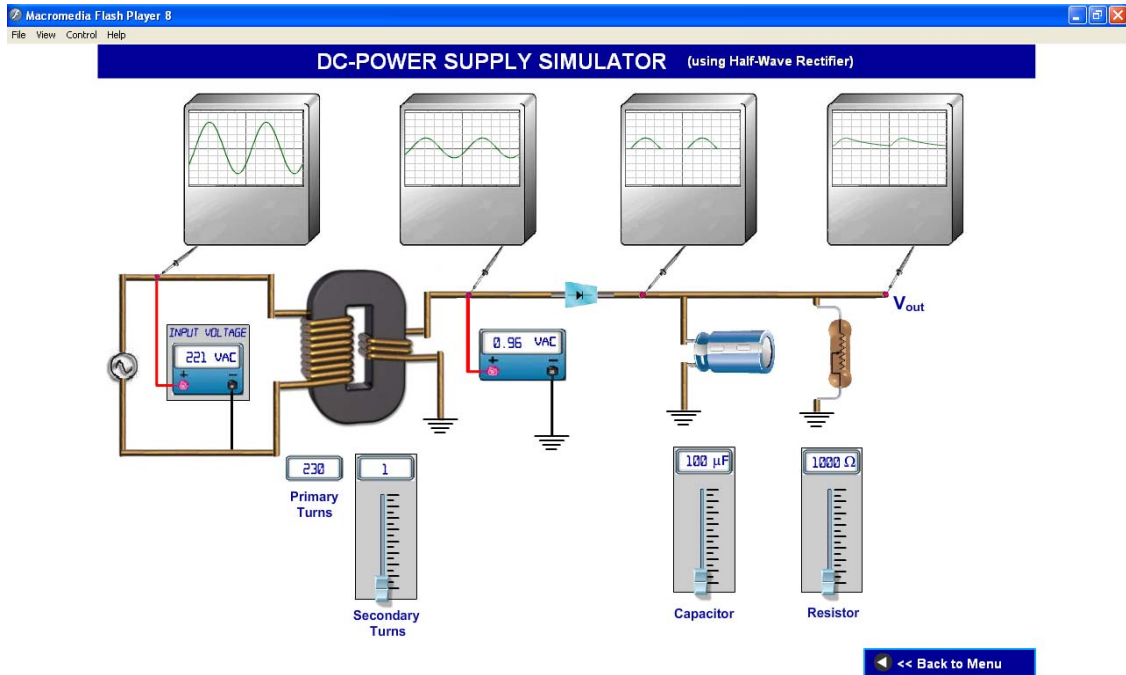
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From the above three screen student will have the option of going forward and backward between theory and simulator to clear their understanding and relate with the simulator.

Working of simulator

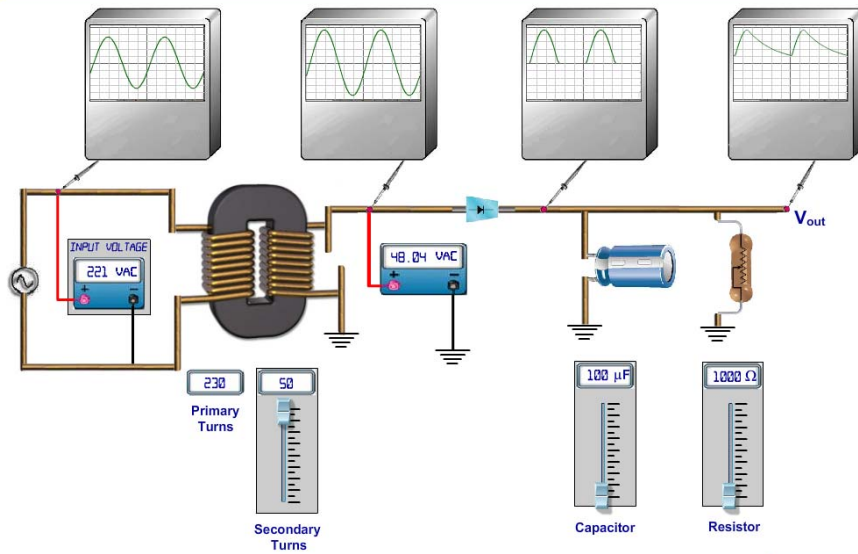
1. Half wave rectifier

The half wave rectifier screen is as shown in figure. As seen from the screen that we have developed it such that every time the student login he will get random input which will enhance his learning for different supply input. We have fixed primary winding turns to 230 (to get step down) turns and secondary turns can be varied using a slider the secondary voltage is displayed on the oscilloscope screen and also the value of the secondary voltage is displayed on digital multimeter as shown below.



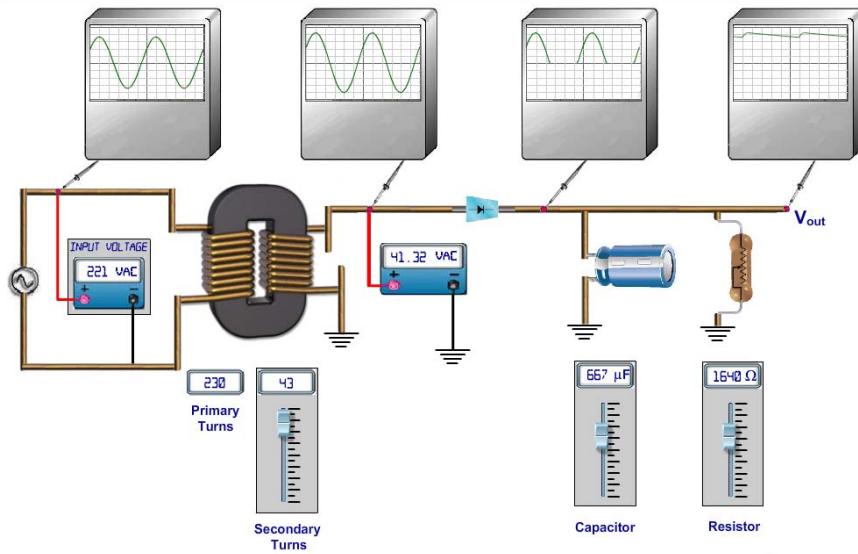
The student can play with the slider of the secondary turn and he can see the effect in secondary voltage, rectified output and also on ripple voltage of the half wave rectifier (see screen snap shots below). In the output part of the half wave wave rectifier the student can understand how to minimize the ripple by varying the capacitance and resistance slider on the oscilloscope.

DC-POWER SUPPLY SIMULATOR (using Half-Wave Rectifier)



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DC-POWER SUPPLY SIMULATOR (using Half-Wave Rectifier)

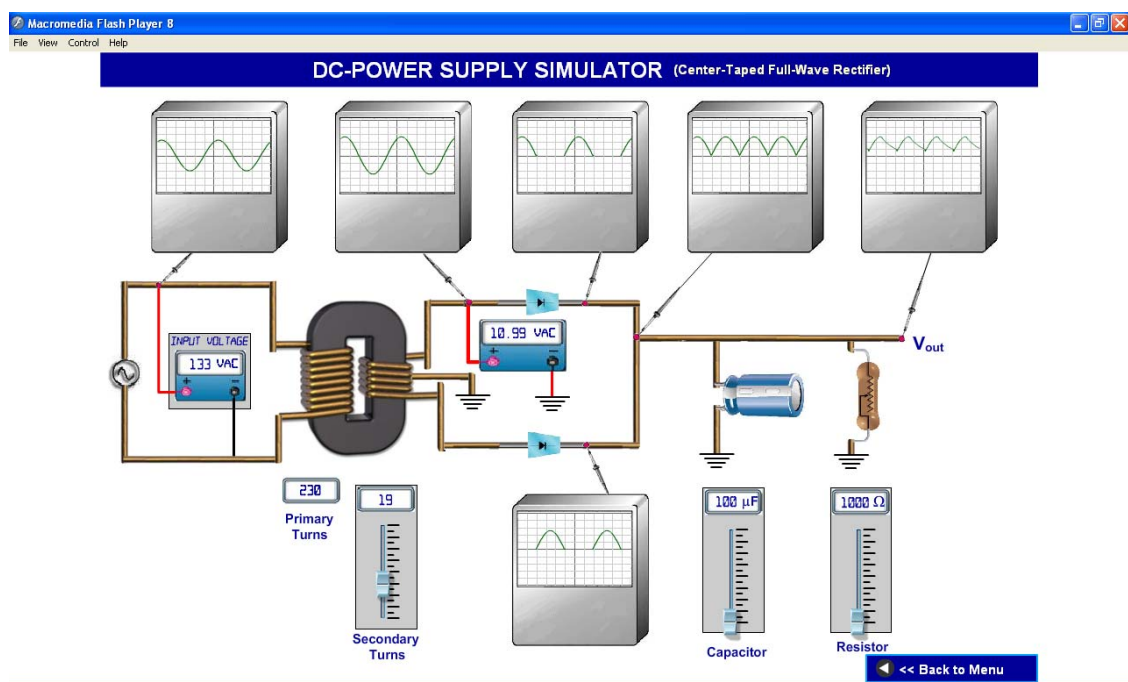


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The full wave and Bridge rectifier

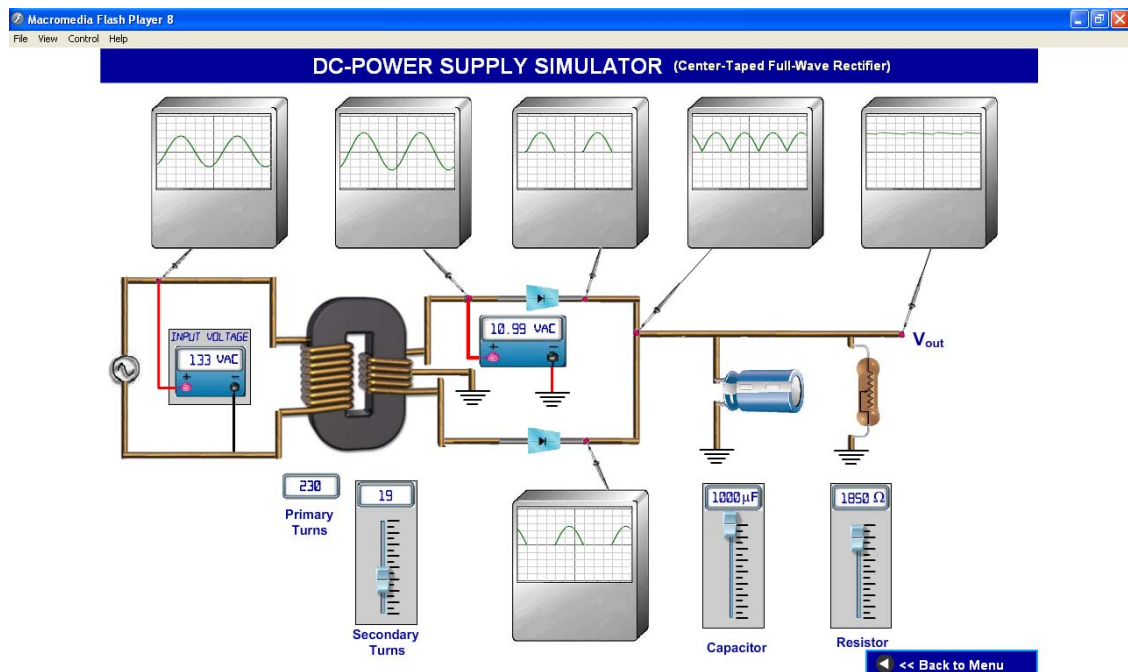
We have developed center-tap full wave and bridge full wave rectifier for students to understand the difference between their working and advantage and disadvantage of each one.

Center-tap full wave Rectifier



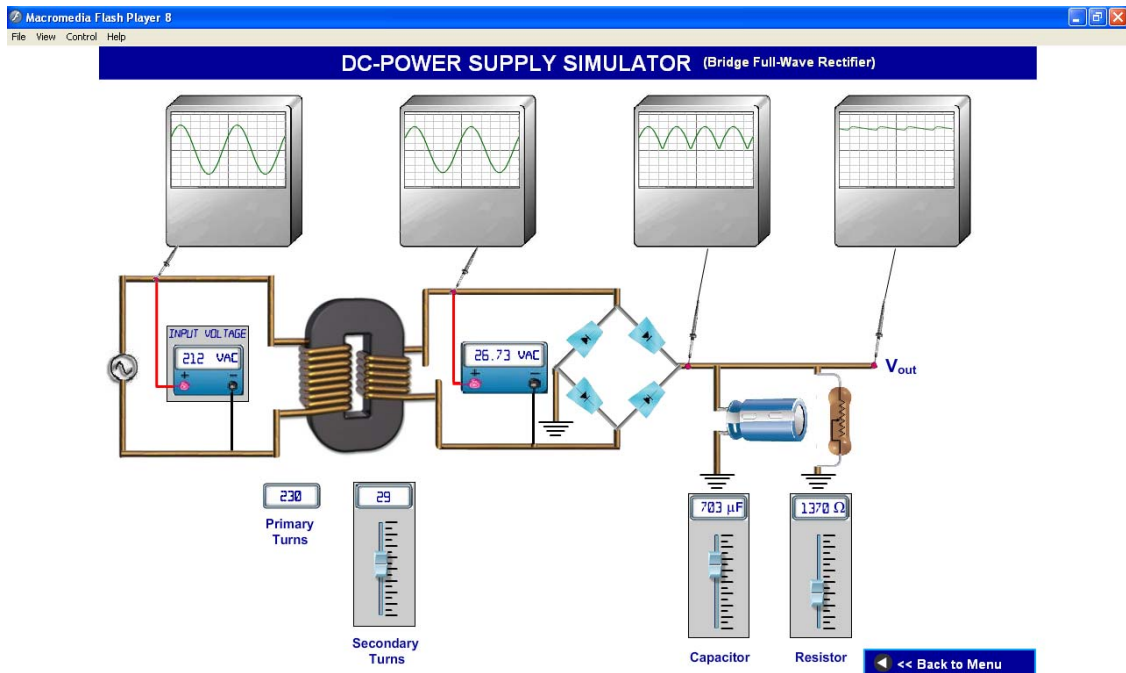
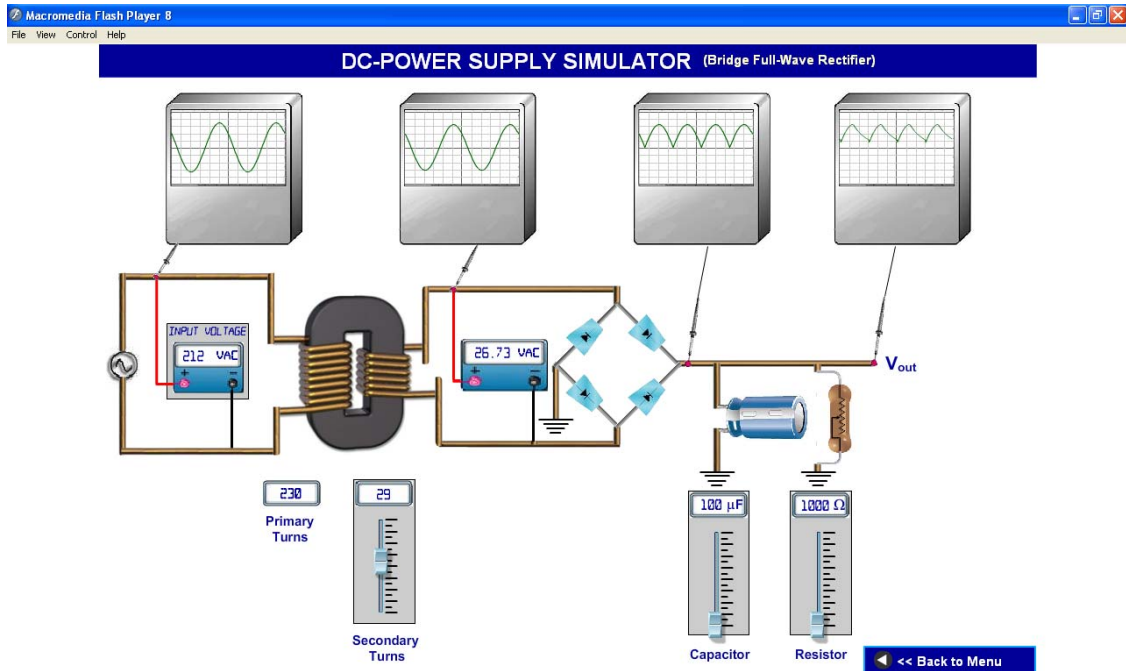
The center-tap full wave rectifier further enhances the students understanding. The student can see real-time display of two waveform 180 degree out of phase because of center-tap transformer, its worth to mention here that student will never get the opportunity of viewing the secondary, rectified, filtered, and 180 degree shifted waveform due to center-tap transformer, coupled with the opportunity of reducing or enhancing the ripple by varying the filter capacitor and resistor (see snap shot of filter effect below). From the snap shot shown below one can see that student can increase the

value of capacitance and resistance thus decreasing the discharge time and achieving almost constant voltage which is the requirement of DC power supply.



Bridge full wave rectifier

Here the student will learn about how 4 diodes can be used to get full wave rectification when there is no center-tap transformer which is much more practical than full wave center-tap as the four diode pack is available commercially. Note that in all simulators the input is random. The snap shot shown below will clear the same concept discussed for full wave center-tap rectifier



Faculty Feedback:

The simulator was also shown to the faculty of EE to get their feedback. The survey results can be summarized than as follows:

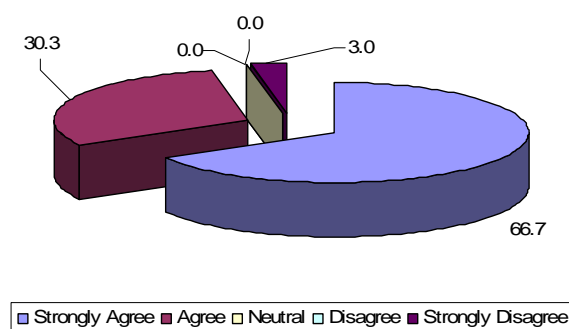
1. The faculty overall ‘strongly agreed’ that the simulator is related to the basic EE courses.
2. The simulator was suggested to be supplementing the courses
3. They were of the opinion that the simulator will enhance the learning and understanding of the students.
4. The appreciated the graphics, navigations and the concept and language of the information screens.

Student Survey:

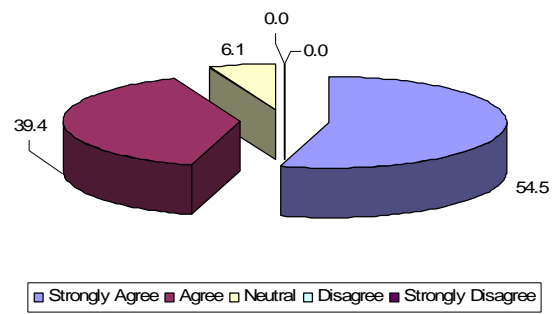
A survey with the students was conducted to get feedback on various aspects of this simulator. A questionnaire was prepared (Appendix A). Results of the survey are reported as follows:

The students showed interest in the simulator and found it to be related with their course work. Their response to question 9 showed that they want to see such kind of simulators in all other courses. The students suggested that the simulator may enhance their learning and understanding. A few suggested that such simulators give confidence as failure with real equipment may cause material loss while they can experiment with many variations with such simulators.

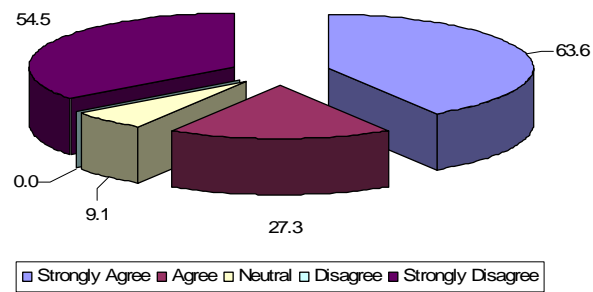
The results and verbal and written feedback shows that the students appreciate the graphics and found the navigation system to be very easy. The results also suggests that the idea of information screen showed ‘read before use’ as opposed to ‘use first than read’ behavior of a user.



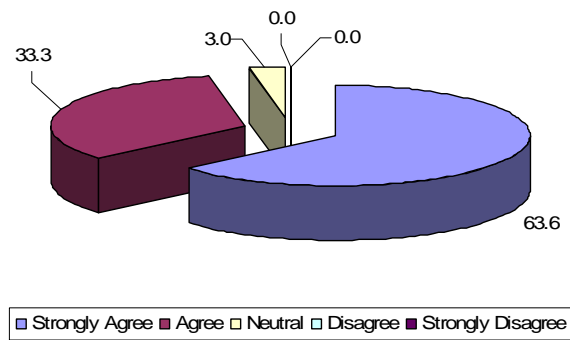
Question 1



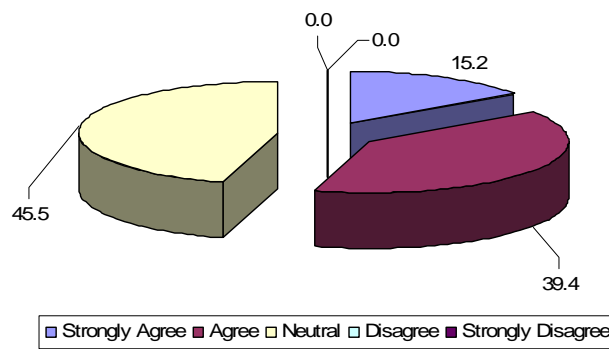
Question 2



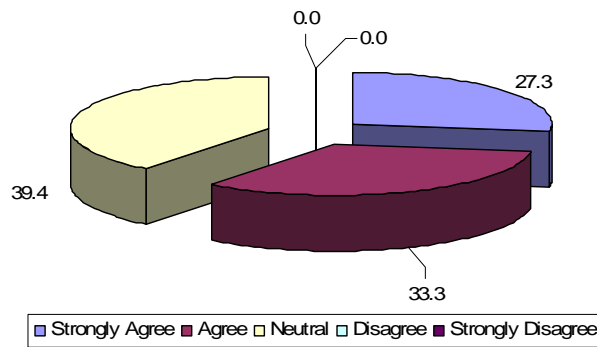
Question 3



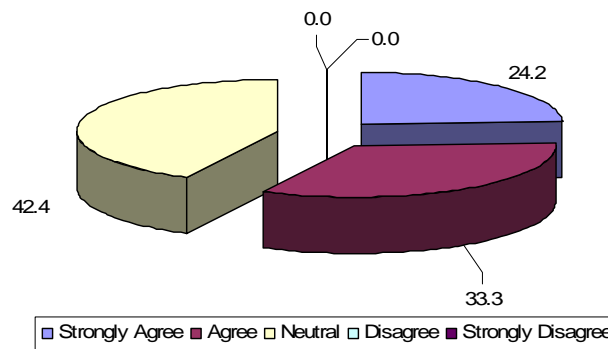
Question 4



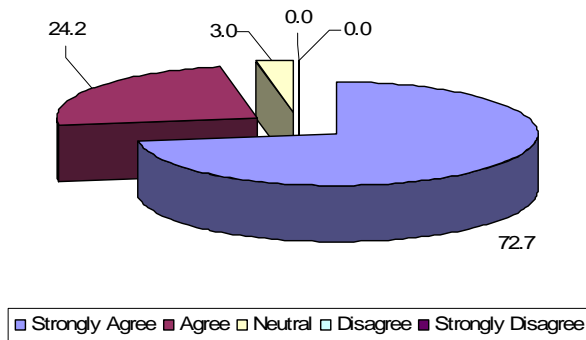
Question 5



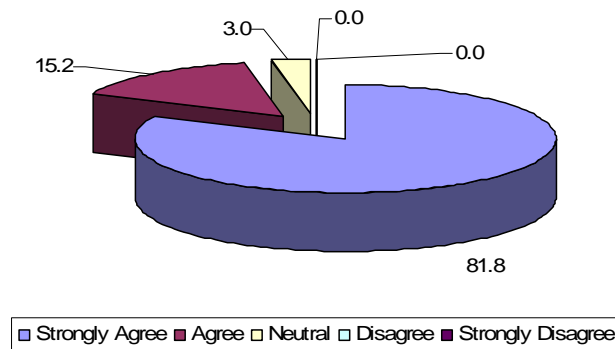
Question 6



Question 7



Question 8



Question 9

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