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E-LEARNING SYSTEM FOR DESIGN AND CONSTRUCTION OF AMPLIFIER USING TRANSISTORS

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ABSTRACT

This paper proposes a novel e-Learning system for the comprehensive understanding of electronic circuits with transistors. The proposed e-Learning system allows users to learn a wide range of topics, encompassing circuit theories, design, construction, and measurement. Given the fact that the amplifiers with transistors are an integral part of almost all the electronic equipments, a fundamental knowledge of the design and construction of transistor circuits is highly imperative in the field of technology education. To this end, the proposed system serves as an effective educational tool for learning practical electronic circuits. The usefulness and effectiveness of the proposed system were evaluated by 10 university students in an actual class. The positive responses provided by all the students indicate the usefulness of the proposed system.

KEYWORDS

Electronic circuit, bipolar transistor, e-Learning, circuit construction, SPICE simulation

1. INTRODUCTION

Teaching and learning electronic circuits are important elements in the field of technology education. Recently, several education systems have been developed to improve the students' understanding of the concepts of electronic circuits. These so-called e-Learning systems for electrical circuit analysis (Weyten et.al, 2009) and the circuit design of the amplifier with a bipolar transistor (Assaad et. al, 2009) facilitate understanding of the fundamental theories and analysis of simple circuits. A learning kit to help beginners understand the functioning of various components in the electrical circuit was developed (Reisslein et. al, 2013). However, these conventional systems are based on all-purpose or ready-made learning tools and are suitable for only specific circuits within a subject area. Moreover, these systems are not designed to promote the learning of circuit construction and experiments, although the ability to understand and construct electronic circuits is highly imperative for acquiring extensive knowledge of the technologies. The educational support system, which was proposed to overcome the disadvantages of the conventional learning tools, involves experiments on the circuit construction of an active filter and a simple sound processor with operational amplifiers (Takemura, 2013). However, the abovementioned system has the following disadvantages:

- The system is suitable for constructing only simple circuits with operational amplifiers.
- It is necessary to provide comprehensive studies for the users to acquire deeper insights on the process.

In general, understanding of transistor circuits is difficult for beginners, as the designing of the circuit demands knowledge of complicated theories and analysis. Given the fact that the amplifier with a transistor is an integral part of almost all electronic equipments, a comprehensive understanding of transistor circuits is essential in the field of technology education. To this end, this paper aims to develop an e-Learning system that is capable of providing comprehensive studies on electronic circuits in terms of (a) circuit theories, (b) analysis, (c) design, (d) construction, (e) measurement, and (f) evaluation.

2. TECHNICAL FEATURES OF THE PROPOSED SYSTEM

Figure 1 shows the schematic illustration of the proposed e-Learning system that aims to provide comprehensive studies in the aspects of (a)–(f) described in Section 1. This system consists of individual computers of the users and a remote education system that runs online. The individual learners in the network learn the comprehensive topics of circuits described in Subsections 2.1 and 2.2.

2.1 Web-based Learning of Circuit Theories and Design

This section describes the new functionality of the proposed system that performs an important role in the designing the construction of the circuit. First, learners download the manuals and the datasheets necessary for understanding the theories and analysis methods for designing and constructing circuits. The datasheets of the circuit devices, which are necessary to grasp the characteristics and rated values of devices, are provided by the manufacturers. Based on the required circuit design, the learner uploads the details of the designed circuit (e.g., the components used in the circuit and calculated parameters) to the remote education system. The remote education system evaluates the designed circuit and specifies the errors in the circuit by comparing with the details and specifications of the designed circuit prepared by an instructor.

2.2 Circuit Construction and Experiments

Based on the circuit design using the technique described in Subsection 2.1, the learner constructs the actual circuit on a breadboard and transmits an image of the constructed circuit to the remote education system. The remote education system performs image processing to recognize the circuit construction and translates its structure into a general circuit description language (Simulation Program with Integrated Circuit Emphasis; SPICE) (Rabaey, 2012). This SPICE translation technique simulates the working of the circuit and enables virtual measurement without real measurement equipment. Furthermore, it can also identify the incorrect components in the circuit (Takemura, 2013). Moreover, the circuit translation and simulation techniques adopted in this system are important for improving the efficiency of experiments and preventing the occurrence of serious accidents, such as electric shocks and fires. Depending on the required purpose and environment (e.g., virtual laboratories and e-Learning), individual learners can choose a preferred mode from the following learning modes: (1) virtual circuit making (VCM), (2) real circuit making (RCM), and (3) the mixed mode (Takemura, 2013). To construct the virtual circuits with transistors using VCM, this study added new virtual circuit components to the database of the remote education system. In addition to these features that are available in the preceding systems, the proposed system includes new functionalities for performing web-based experiments using virtual measurements. Using this function, a user can learn the characteristics and the working of the constructed circuit. The remote education system also evaluates the characteristics of the circuit constructed by the user, such as the amplification ratio and frequency bandwidth.

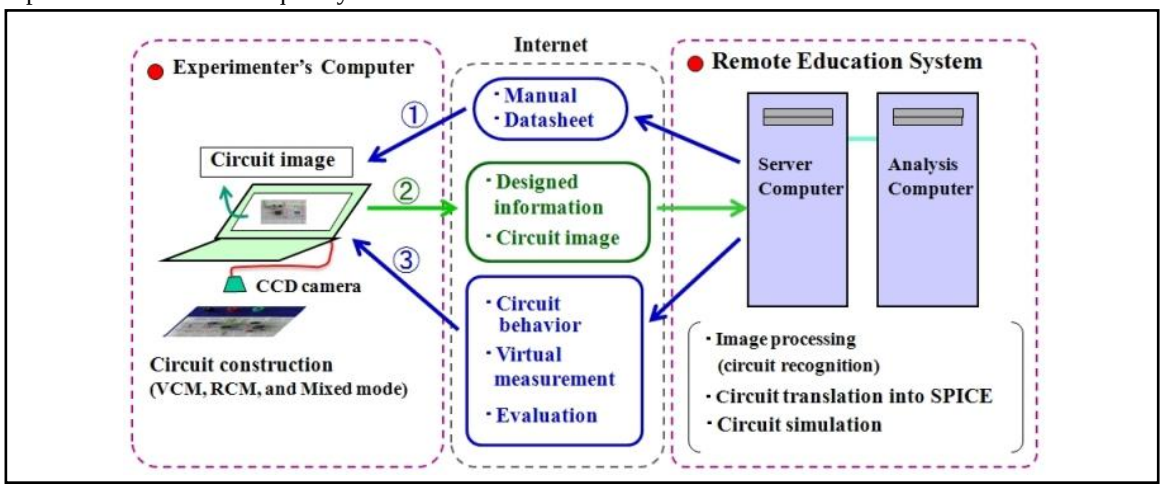

Figure 1. Schematic of the proposed e-Learning system.

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3. METHODOLOGY FOR EVALUATING THE PROPOSED SYSTEM

The effectiveness of the proposed system was evaluated by 10 undergraduate students, who do not have much knowledge and experience of circuit making, in an actual class at the Tokyo University of Agriculture and Technology (TUAT). Each student learned the comprehensive topics of a transistor amplifier according to the steps described in the following subsections.

3.1 Preliminary Learning of a Transistor Circuit

An NPN transistor consists of two N-type semiconductors separated by a P-type semiconductor, forming three terminals, namely, emitter, collector, and base. As shown in Figure 2(a), the currents to the base and collector are symbolized as I_B and I_C, respectively. The learner constructs the circuit shown in Figure 2(a) using an NPN transistor (2SC1815). By selecting the preferred mode of virtual measurement (VCM, RCM, or the mixed mode), the user can measure the V_{CE}–I_C characteristics shown in Figure 2(b). The learner studies the following features of the transistors using the virtual measurements of the proposed system:

- When a voltage V_{CC} is applied between the collector and the emitter and a current I_B flows to the base, an NPN transistor allows a current I_C.
- The amount of I_C depends on the amount of I_B.

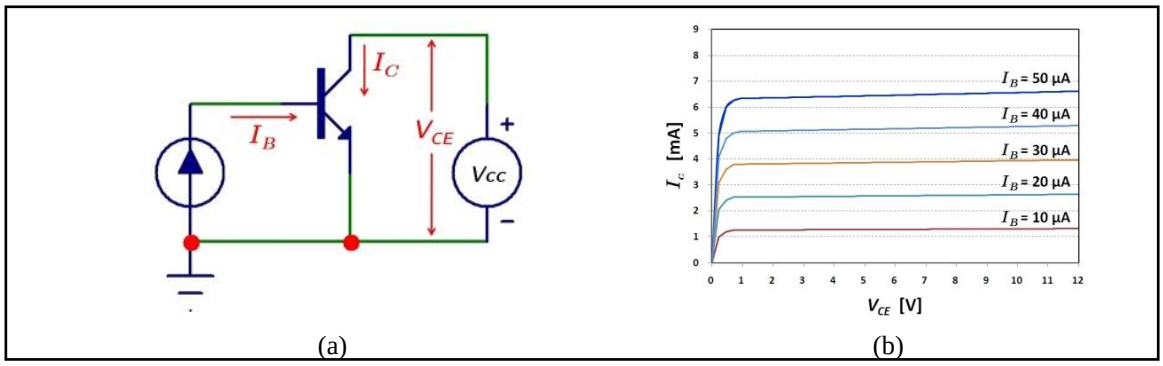

Figure 2. Static characteristics of an amplifier with a transistor; (a) circuit diagram, and (b) V_{CE}–I_C characteristics.

3.2 Learning of an Amplifier with a Transistor

To design and evaluate the usability of the functionalities provided in the proposed e-Learning system, individual students learn the comprehensive topics (described in Section 1) of the amplifier with the transistor (2SC1815) shown in Figure 3(a). Figure 3(b) indicates the components and currents necessary for designing the amplifier. To acquire comprehensive knowledge on the working of the amplifier, individual students were required to complete the topics (1)–(6), where a part of the manual to design the circuit, the characteristics to find the operating point of the amplifier, and a part of the web-based input form for evaluating the designed circuit are shown in Figure 4(a)–(c), respectively:

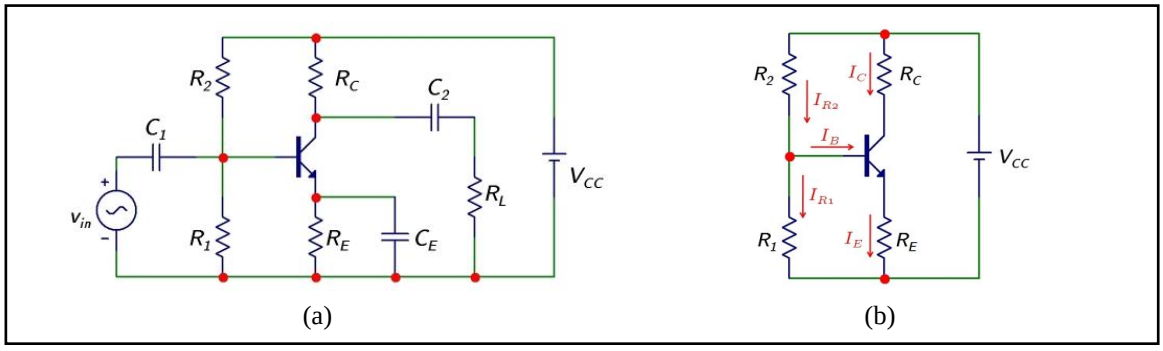

Figure 3. Small signal-amplifier with a transistor: (a) circuit diagram, and (b) DC equivalent circuit.

(1) Let the collector current I_C and the current amplification degree h_{FE} be 5 mA and 125, respectively. Using the manual and the datasheet, calculate the necessary currents and determine the operating point P.
(2) Upload the designed information to the remote education system using the web-based input form and check the correctness of the designed circuit based on the evaluation scheme included in the proposed system.
(3) Construct the circuit using the preferred mode (VCM, RCM, or the mixed mode).
(4) If the system indicates wrong parts on the image of the constructed circuit, make the necessary changes.
(5) Using the function of virtual measurements, plot the input and output voltage signals and the frequency characteristics of the constructed circuit.
(6) Using the function of virtual measurements, measure the voltage amplification ratio, gain, and bandwidth of the constructed amplifier and evaluate them using the system.

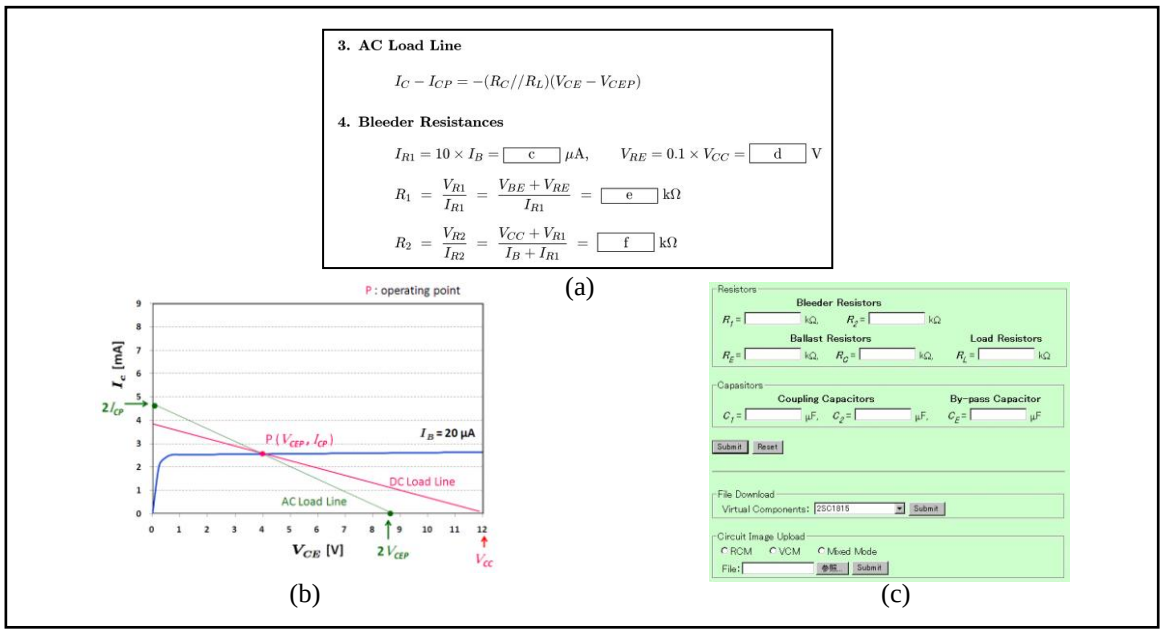

Figure 4. (a) Operating point and load lines that are indicated on V_{CE}–I_C characteristics, (b) manual to calculate the circuit parameters, and (c) input forms to submit the information of the designed circuit.

4. RESULTS AND DISCUSSION

Ten undergraduate students at TUAT evaluated the proposed system through the experiments described in Section 3. Figures 5(a) and (b) show the virtual circuit constructed using VCM and the physical circuit constructed using RCM, respectively. The remote education system of the proposed e-Learning system provided the SPICE information for constructed circuits that were obtained from the circuit translation technique. As shown in Figures 5(c) and (d), individual students learned the working of the circuit designed by them, in terms of the output signal and frequency characteristics, through the virtual measurement technique. Moreover, the system allowed the experimenter to construct the large-scale circuit (multistage amplifier) using the mixed mode of the system. Figures 5(e) and (f) show the constructed multistage amplifier and the working of the amplifier, respectively. Individual students submitted their opinions to the remote education system. The following positive responses, validating the usefulness and effectiveness of the proposed system, were obtained from all students:

- The web-based learning of circuit theories and analysis of transistors were effective because the complicated calculations pertaining to the circuit design were instructed explicitly.
- The comprehensive studies of transistor circuits using the e-Learning system were instructive because the system allowed learning of both theories and experiments.

- The choice of three modes of circuit construction (VCM, RCM, or the mixed mode) provided by the e-Learning system enables users to select a preferred mode depending on the environment.

However, the following technical suggestions were suggested for the improvement of the system:

- The usefulness of this e-Learning system would be much greater if the circuit translation technique is also made applicable to the circuit constructed on a printed circuit board.
- Improvements are expected in the e-Learning system for learning digital circuits.

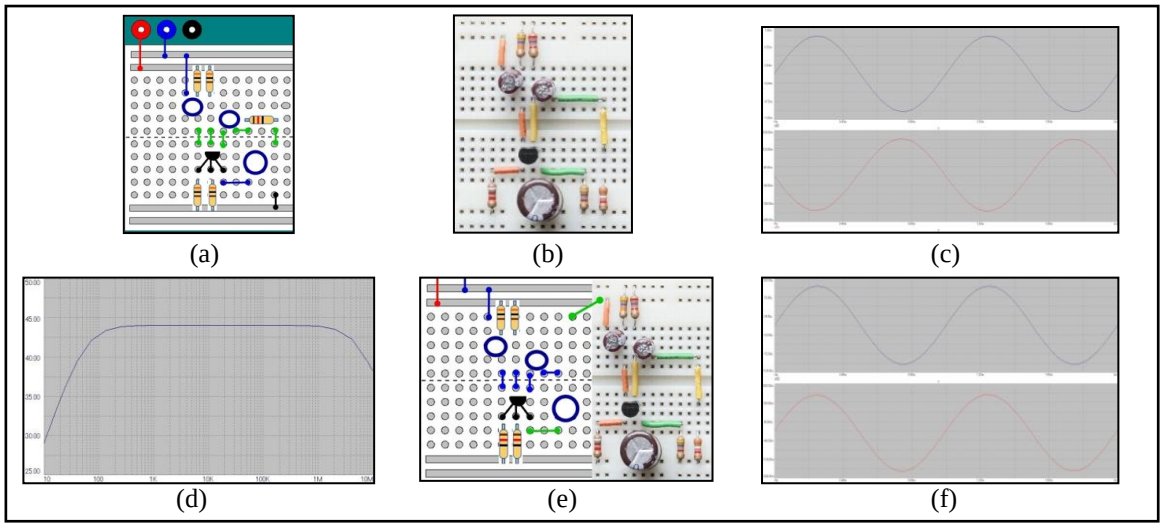

Figure 5. (a) Virtual circuit constructed using VCM and (b) physical circuit constructed using RCM. (c) Results of the virtual measurements of the constructed circuit showing the input and output signals and (d) frequency characteristics. (e) Constructed multistage amplifier and (f) its working.

5. CONCLUSION

This paper proposes a novel e-Learning system that aids in the learning of electronic circuits with transistors. The proposed system enables users to understand the comprehensive theories and experiments pertaining to electronic circuits. The usefulness and effectiveness of the proposed system were verified by 10 undergraduate students, who served as experimenters on the system, in an actual university class. Positive responses, which pertain to the effectiveness and efficiency of the proposed system, were obtained from all the students. The technical suggestions from the users (Section 4) are necessary for improving the usefulness of the proposed system.

ACKNOWLEDGMENT

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