



**NONRESIDENT  
TRAINING  
COURSE**

**SEPTEMBER 1998**



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# **Navy Electricity and Electronics Training Series**

## **Module 3—Introduction to Circuit Protection, Control, and Measurement**

**NAVEDTRA 14175**

Although the words “he,” “him,” and “his” are used sparingly in this course to enhance communication, they are not intended to be gender driven or to affront or discriminate against anyone.

## PREFACE

By enrolling in this self-study course, you have demonstrated a desire to improve yourself and the Navy. Remember, however, this self-study course is only one part of the total Navy training program. Practical experience, schools, selected reading, and your desire to succeed are also necessary to successfully round out a fully meaningful training program.

**COURSE OVERVIEW:** To introduce the student to the subject of Circuit Protection, Control, and Measurement who needs such a background in accomplishing daily work and/or in preparing for further study.

**THE COURSE:** This self-study course is organized into subject matter areas, each containing learning objectives to help you determine what you should learn along with text and illustrations to help you understand the information. The subject matter reflects day-to-day requirements and experiences of personnel in the rating or skill area. It also reflects guidance provided by Enlisted Community Managers (ECMs) and other senior personnel, technical references, instructions, etc., and either the occupational or naval standards, which are listed in the *Manual of Navy Enlisted Manpower Personnel Classifications and Occupational Standards*, NAVPERS 18068.

**THE QUESTIONS:** The questions that appear in this course are designed to help you understand the material in the text.

**VALUE:** In completing this course, you will improve your military and professional knowledge. Importantly, it can also help you study for the Navy-wide advancement in rate examination. If you are studying and discover a reference in the text to another publication for further information, look it up.

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## **Sailor's Creed**

“I am a United States Sailor.

I will support and defend the Constitution of the United States of America and I will obey the orders of those appointed over me.

I represent the fighting spirit of the Navy and those who have gone before me to defend freedom and democracy around the world.

I proudly serve my country's Navy combat team with honor, courage and commitment.

I am committed to excellence and the fair treatment of all.”

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# NAVY ELECTRICITY AND ELECTRONICS TRAINING SERIES

The Navy Electricity and Electronics Training Series (NEETS) was developed for use by personnel in many electrical- and electronic-related Navy ratings. Written by, and with the advice of, senior technicians in these ratings, this series provides beginners with fundamental electrical and electronic concepts through self-study. The presentation of this series is not oriented to any specific rating structure, but is divided into modules containing related information organized into traditional paths of instruction.

The series is designed to give small amounts of information that can be easily digested before advancing further into the more complex material. For a student just becoming acquainted with electricity or electronics, it is highly recommended that the modules be studied in their suggested sequence. While there is a listing of NEETS by module title, the following brief descriptions give a quick overview of how the individual modules flow together.

**Module 1, *Introduction to Matter, Energy, and Direct Current***, introduces the course with a short history of electricity and electronics and proceeds into the characteristics of matter, energy, and direct current (dc). It also describes some of the general safety precautions and first-aid procedures that should be common knowledge for a person working in the field of electricity. Related safety hints are located throughout the rest of the series, as well.

**Module 2, *Introduction to Alternating Current and Transformers***, is an introduction to alternating current (ac) and transformers, including basic ac theory and fundamentals of electromagnetism, inductance, capacitance, impedance, and transformers.

**Module 3, *Introduction to Circuit Protection, Control, and Measurement***, encompasses circuit breakers, fuses, and current limiters used in circuit protection, as well as the theory and use of meters as electrical measuring devices.

**Module 4, *Introduction to Electrical Conductors, Wiring Techniques, and Schematic Reading***, presents conductor usage, insulation used as wire covering, splicing, termination of wiring, soldering, and reading electrical wiring diagrams.

**Module 5, *Introduction to Generators and Motors***, is an introduction to generators and motors, and covers the uses of ac and dc generators and motors in the conversion of electrical and mechanical energies.

**Module 6, *Introduction to Electronic Emission, Tubes, and Power Supplies***, ties the first five modules together in an introduction to vacuum tubes and vacuum-tube power supplies.

**Module 7, *Introduction to Solid-State Devices and Power Supplies***, is similar to module 6, but it is in reference to solid-state devices.

**Module 8, *Introduction to Amplifiers***, covers amplifiers.

**Module 9, *Introduction to Wave-Generation and Wave-Shaping Circuits***, discusses wave generation and wave-shaping circuits.

**Module 10, *Introduction to Wave Propagation, Transmission Lines, and Antennas***, presents the characteristics of wave propagation, transmission lines, and antennas.

**Module 11**, *Microwave Principles*, explains microwave oscillators, amplifiers, and waveguides.

**Module 12**, *Modulation Principles*, discusses the principles of modulation.

**Module 13**, *Introduction to Number Systems and Logic Circuits*, presents the fundamental concepts of number systems, Boolean algebra, and logic circuits, all of which pertain to digital computers.

**Module 14**, *Introduction to Microelectronics*, covers microelectronics technology and miniature and microminiature circuit repair.

**Module 15**, *Principles of Synchros, Servos, and Gyros*, provides the basic principles, operations, functions, and applications of synchro, servo, and gyro mechanisms.

**Module 16**, *Introduction to Test Equipment*, is an introduction to some of the more commonly used test equipments and their applications.

**Module 17**, *Radio-Frequency Communications Principles*, presents the fundamentals of a radio-frequency communications system.

**Module 18**, *Radar Principles*, covers the fundamentals of a radar system.

**Module 19**, *The Technician's Handbook*, is a handy reference of commonly used general information, such as electrical and electronic formulas, color coding, and naval supply system data.

**Module 20**, *Master Glossary*, is the glossary of terms for the series.

**Module 21**, *Test Methods and Practices*, describes basic test methods and practices.

**Module 22**, *Introduction to Digital Computers*, is an introduction to digital computers.

**Module 23**, *Magnetic Recording*, is an introduction to the use and maintenance of magnetic recorders and the concepts of recording on magnetic tape and disks.

**Module 24**, *Introduction to Fiber Optics*, is an introduction to fiber optics.

Embedded questions are inserted throughout each module, except for modules 19 and 20, which are reference books. If you have any difficulty in answering any of the questions, restudy the applicable section.

Although an attempt has been made to use simple language, various technical words and phrases have necessarily been included. Specific terms are defined in Module 20, *Master Glossary*.

Considerable emphasis has been placed on illustrations to provide a maximum amount of information. In some instances, a knowledge of basic algebra may be required.

Assignments are provided for each module, with the exceptions of Module 19, *The Technician's Handbook*; and Module 20, *Master Glossary*. Course descriptions and ordering information are in NAVEDTRA 12061, *Catalog of Nonresident Training Courses*.

Throughout the text of this course and while using technical manuals associated with the equipment you will be working on, you will find the below notations at the end of some paragraphs. The notations are used to emphasize that safety hazards exist and care must be taken or observed.

### **WARNING**

AN OPERATING PROCEDURE, PRACTICE, OR CONDITION, ETC., WHICH MAY RESULT IN INJURY OR DEATH IF NOT CAREFULLY OBSERVED OR FOLLOWED.

### **CAUTION**

AN OPERATING PROCEDURE, PRACTICE, OR CONDITION, ETC., WHICH MAY RESULT IN DAMAGE TO EQUIPMENT IF NOT CAREFULLY OBSERVED OR FOLLOWED.

### **NOTE**

An operating procedure, practice, or condition, etc., which is essential to emphasize.



# INSTRUCTIONS FOR TAKING THE COURSE

## ASSIGNMENTS

The text pages that you are to study are listed at the beginning of each assignment. Study these pages carefully before attempting to answer the questions. Pay close attention to tables and illustrations and read the learning objectives. The learning objectives state what you should be able to do after studying the material. Answering the questions correctly helps you accomplish the objectives.

## SELECTING YOUR ANSWERS

Read each question carefully, then select the BEST answer. You may refer freely to the text. The answers must be the result of your own work and decisions. You are prohibited from referring to or copying the answers of others and from giving answers to anyone else taking the course.

## SUBMITTING YOUR ASSIGNMENTS

To have your assignments graded, you must be enrolled in the course with the Nonresident Training Course Administration Branch at the Naval Education and Training Professional Development and Technology Center (NETPDTC). Following enrollment, there are two ways of having your assignments graded: (1) use the Internet to submit your assignments as you complete them, or (2) send all the assignments at one time by mail to NETPDTC.

**Grading on the Internet:** Advantages to Internet grading are:

- you may submit your answers as soon as you complete an assignment, and
- you get your results faster; usually by the next working day (approximately 24 hours).

In addition to receiving grade results for each assignment, you will receive course completion confirmation once you have completed all the

assignments. To submit your assignment answers via the Internet, go to:

<http://courses.cnet.navy.mil>

**Grading by Mail:** When you submit answer sheets by mail, send all of your assignments at one time. Do NOT submit individual answer sheets for grading. Mail all of your assignments in an envelope, which you either provide yourself or obtain from your nearest Educational Services Officer (ESO). Submit answer sheets to:

COMMANDING OFFICER  
NETPDTC N331  
6490 SAUFLEY FIELD ROAD  
PENSACOLA FL 32559-5000

**Answer Sheets:** All courses include one “scannable” answer sheet for each assignment. These answer sheets are preprinted with your SSN, name, assignment number, and course number. Explanations for completing the answer sheets are on the answer sheet.

**Do not use answer sheet reproductions:** Use only the original answer sheets that we provide—reproductions will not work with our scanning equipment and cannot be processed.

Follow the instructions for marking your answers on the answer sheet. Be sure that blocks 1, 2, and 3 are filled in correctly. This information is necessary for your course to be properly processed and for you to receive credit for your work.

## COMPLETION TIME

Courses must be completed within 12 months from the date of enrollment. This includes time required to resubmit failed assignments.

## **PASS/FAIL ASSIGNMENT PROCEDURES**

If your overall course score is 3.2 or higher, you will pass the course and will not be required to resubmit assignments. Once your assignments have been graded you will receive course completion confirmation.

If you receive less than a 3.2 on any assignment and your overall course score is below 3.2, you will be given the opportunity to resubmit failed assignments. **You may resubmit failed assignments only once.** Internet students will receive notification when they have failed an assignment--they may then resubmit failed assignments on the web site. Internet students may view and print results for failed assignments from the web site. Students who submit by mail will receive a failing result letter and a new answer sheet for resubmission of each failed assignment.

## **COMPLETION CONFIRMATION**

After successfully completing this course, you will receive a letter of completion.

## **ERRATA**

Errata are used to correct minor errors or delete obsolete information in a course. Errata may also be used to provide instructions to the student. If a course has an errata, it will be included as the first page(s) after the front cover. Errata for all courses can be accessed and viewed/downloaded at:

<http://www.advancement.cnet.navy.mil>

## **STUDENT FEEDBACK QUESTIONS**

We value your suggestions, questions, and criticisms on our courses. If you would like to communicate with us regarding this course, we encourage you, if possible, to use e-mail. If you write or fax, please use a copy of the Student Comment form that follows this page.

## **For subject matter questions:**

E-mail: n315.products@cnet.navy.mil  
Phone: Comm: (850) 452-1001, ext. 1728  
DSN: 922-1001, ext. 1728  
FAX: (850) 452-1370  
(Do not fax answer sheets.)  
Address: COMMANDING OFFICER  
NETPDTC N315  
6490 SAUFLEY FIELD ROAD  
PENSACOLA FL 32509-5237

## **For enrollment, shipping, grading, or completion letter questions**

E-mail: fleetservices@cnet.navy.mil  
Phone: Toll Free: 877-264-8583  
Comm: (850) 452-1511/1181/1859  
DSN: 922-1511/1181/1859  
FAX: (850) 452-1370  
(Do not fax answer sheets.)  
Address: COMMANDING OFFICER  
NETPDTC N331  
6490 SAUFLEY FIELD ROAD  
PENSACOLA FL 32559-5000

## **NAVAL RESERVE RETIREMENT CREDIT**

If you are a member of the Naval Reserve, you will receive retirement points if you are authorized to receive them under current directives governing retirement of Naval Reserve personnel. For Naval Reserve retirement, this course is evaluated at 5 points. (Refer to *Administrative Procedures for Naval Reservists on Inactive Duty*, BUPERSINST 1001.39, for more information about retirement points.)

## Student Comments

**Course Title:** *NEETS Module 3*  
*Introduction to Circuit Protection, Control, and Measurement*

**NAVEDTRA:** 14175 **Date:** \_\_\_\_\_

**We need some information about you:**

Rate/Rank and Name: \_\_\_\_\_ SSN: \_\_\_\_\_ Command/Unit \_\_\_\_\_

Street Address: \_\_\_\_\_ City: \_\_\_\_\_ State/FPO: \_\_\_\_\_ Zip \_\_\_\_\_

**Your comments, suggestions, etc.:**

<p><b>Privacy Act Statement:</b> Under authority of Title 5, USC 301, information regarding your military status is requested in processing your comments and in preparing a reply. This information will not be divulged without written authorization to anyone other than those within DOD for official use in determining performance.</p>
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NETPDTC 1550/41 (Rev 4-00)

# CHAPTER 1

## CIRCUIT MEASUREMENT

### LEARNING OBJECTIVES

Learning objectives are stated at the beginning of each chapter. These learning objectives serve as a preview of the information you are expected to learn in the chapter. The comprehensive check questions are based on the objectives. By successfully completing the NRTC, you indicate that you have met the objectives and have learned the information. The learning objectives are listed below.

Upon completion of this chapter you will be able to:

1. State two ways circuit measurement is used, why in-circuit meters are used, and one advantage of out-of-circuit meters.
2. State the way in which a compass reacts to a conducting wire including the compass reaction to increasing and decreasing dc and ac high and low frequencies.
3. State how a d'Arsonval meter movement reacts to dc.
4. State the purpose of a rectifier as used in ac meters.
5. State the meaning of the term "damping" as it applies to meter movements and describe two methods by which damping is accomplished.
6. Identify average value as the value of ac measured and effective value (rms) as the ac value indicated on ac meter scales.
7. Identify three meter movements that measure dc or ac without the use of a rectifier.
8. State the electrical quantity measured by an ammeter, the way in which an ammeter is connected in a circuit, and the effect of an ammeter upon a circuit.
9. Define ammeter sensitivity.
10. State the method used to allow an ammeter to measure different ranges and the reason for using the highest range when connecting an ammeter to a circuit.
11. List the safety precautions for ammeter use.
12. State the electrical quantity measured by a voltmeter, the way in which a voltmeter is connected in a circuit, the way in which a voltmeter affects the circuit being measured, and the way in which a voltmeter is made from a current reacting meter movement.
13. Define voltmeter sensitivity.
14. State the method used to allow a voltmeter to measure different ranges and the reason for using the highest range when connecting a voltmeter to a circuit.

15. Identify the type of meter movement that reacts to voltage and the most common use of this movement.
16. List the safety precautions for voltmeter use.
17. State the electrical quantity measured by an ohmmeter, the second use of an ohmmeter, and the way in which an ohmmeter is connected to a resistance being measured.
18. State the method used to allow an ohmmeter to measure different ranges and the area of an ohmmeter scale that should be used when measuring resistance.
19. State the two types of ohmmeters and the way in which each can be identified.
20. List the safety precautions for ohmmeter use.
21. State the primary reason for using a megger and the method of using it.
22. Identify normal and abnormal indications on a megger.
23. List the safety precautions for megger use.
24. State how a multimeter differs from other meters, the reason a multimeter is preferred over separate meters, and the way in which a multimeter is changed from a voltage measuring device to a current measuring device.
25. State the reason the ac and dc scales of a multimeter differ, the reason for having a mirror on the scale of a multimeter, and the proper way of reading a multimeter using the mirror.
26. List the safety precautions for multimeter use.
27. State the purpose of a hook-on type voltmeter.
28. State the electrical quantity measured by a wattmeter and a watt-hour meter.
29. Identify the two types of frequency meters.
30. Identify the type of meter and interpret the meter reading from scale presentations of an ammeter; a voltmeter; an ohmmeter; a megger; a multimeter (current, voltage, and resistance examples); a wattmeter; a watt-hour meter; and a frequency meter (vibrating reed and moving-disk types).

## **CIRCUIT MEASUREMENT**

This chapter will acquaint you with the basics of circuit measurement and some of the devices used to measure voltage, current, resistance, power, and frequency. There are other quantities involved in electrical circuits, such as capacitance, inductance, impedance, true power, and effective power. It is possible to measure any circuit quantity once you are able to select and use the proper circuit measuring device. You will NOT know all there is to know about circuit measuring devices (test equipment) when you finish this chapter. That is beyond the scope of this chapter and even beyond the scope of this training series. However, more information on test equipment is provided in another portion of this training series.

A question which you might ask before starting this chapter is "Why do I need to know about circuit measurement?"