Lesson Plans for Module 12207-16

# Control Valves, Actuators, and Positioners

**Module One (12207-16)** introduces different types of control valves, actuators, and positioners. Due to the variety of devices in use in various industries, instrumentation trainees require a strong grounding in this subject. They will also learn about the different control technologies used in remotely managing valves. Finally, they will learn how to identify valve characteristics through markings and nameplate information.

## Objectives

**Learning Objective 1**

- Identify and describe various types of control valves, actuators, and positioners.
  a. Identify and describe the operation of various types of control valves.
  b. Identify and describe actuators and their key operating features.
  c. Identify and describe the operation of various positioners.
  d. Identify and explain the importance of factors related to valve selection.
  e. Identify and describe valve markings and nameplate information.

## Performance Tasks

**Performance Task 1 (Learning Objective 1)**

- Install a positioner on a control valve.

**Performance Task 2 (Learning Objective 1)**

- Locate bridgewall markings on a globe valve and determine the stem and packing orientation.

**Performance Task 3 (Learning Objective 1)**

- Identify different actuators and positioners from instructor-provided drawings or during a field survey.

## Teaching Time: 15.0 hours

(Six 2.5-Hour Sessions)

Session time may be adjusted to accommodate your class size, schedule, and teaching style.

## Prerequisites

*Core Curriculum*, *Instrumentation Level One*, and *Instrumentation Level Two*.

## Before You Begin

As you prepare for each session, allow sufficient time to review the course objectives, content, visual aids, including the PowerPoint® presentation, and these lesson plans, and to gather the required equipment and materials. Consider the time required for demonstrations, laboratories, field trips, and testing.

Using your access code, download the module exams and Performance Profile Sheets from **www.nccerirc.com**. The passing score for submission into NCCER's Registry is 70% or above for the module exam; performance testing is graded pass or fail.

## Safety Considerations

This module requires that trainees work with tools and potentially energized equipment. Safety must be emphasized at all times. Trainees should be carefully observed to ensure that they wear the proper PPE, follow safe practices, and give due respect to unseen hazards. Any deficiencies must be corrected to ensure future trainee safety. All practice sessions and Performance Tasks must be completed under your direct supervision.

## Classroom Equipment and Materials

Whiteboard
Markers
Pencils and paper
*Instrumentation Level Three* PowerPoint® Presentation
DVD player or a computer with a DVD drive
LCD projector and screen
Computer with internet access
Review Questions answer key
Copies of the module examination (for paper-based exams) and Performance Profile Sheets
Globe valve
Gate or knife valve
Ball valve
Plug valve
Butterfly valve
Needle valve
Pneumatic or electric valve actuator
Pneumatic, analog, or smart valve positioner
Example globe valves with bridgewall markings
Example valves with nameplates

## Equipment and Materials for Laboratories and Performance Testing

Appropriate PPE to include the following:
- Safety glasses
- Work gloves
- Proper footwear as designated by the instructor or training facility provider
- Hearing protection as designated by the instructor or training facility provider
- Hard hat as designated by the instructor or training facility provider

Control valve with compatible positioner
Appropriate mounting hardware
Common hand tools
Selection of globe valves with bridgewall markings
Drawings showing a variety of actuators and positioners in a process environment

## Additional Resources

This module presents thorough resources for task training. The following resource material is suggested for further study.


*ANSI/ISA-5.1-2009*. 2009. Research Triangle Park, NC: International Society of Automation.

*ANSI/ISA Standard S75.01, Flow Equations for Sizing Control Valves*. 2007. Research Triangle Park, NC: International Society of Automation.

*Control Valve Handbook.* Fourth Edition. 2005. Fisher Emerson Process Management. Marshalltown, IA: Fisher Controls International LLC.
**http://www.documentation.emersonprocess.com/groups/public/documents/book/cvh99.pdf**

*Control Valves: Practical Guides for Measurement and Control (Practical Guide Series)*. Guy Borden, Jr. (editor). 1998. Research Triangle Park, NC: International Society of Automation.

*Instrument Engineers Handbook, Volume 2: Process Control and Optimization*. Béla G. Lipták (editor). Fourth Edition. 2006. Boca Raton, FL: CRC Press.

*Instrument Engineers Handbook, Volume 3: Process Software and Digital Networks*. Béla G. Lipták and Halit Eren (editors). Fourth Edition. 2012. Boca Raton, FL: CRC Press.


Instructors are also encouraged to locate additional audiovisual aids available on the internet, make personal videos, and take still pictures related to the subject matter and add them to the PowerPoint® presentations throughout the program.

## Session Outline for 12207-16

# Control Valves, Actuators, and Positioners

The Lesson Plan for this module is divided into six 2.5-hour sessions.
This time includes 10 minutes for administrative tasks and a 10-minute break per session.

## Session One

Session One introduces trainees to valve types and operation. They will learn the advantages and disadvantages to each major type as well as the situations in which each is used. This session covers Sections 1.0.0 through 1.1.7.

1. Show the Session One PowerPoint® presentation.
2. Use the Kickoff Activity to get trainees engaged and give them an idea of what they will learn from this module.
3. Identify the various types of control valves.
4. Describe each valve's basic operation and its advantages and disadvantages.

## Session Two

Session Two introduces valve actuators and positioners. The different technologies behind each type are addressed, as is the reason for using a given type in a particular situation. This session covers Sections 1.2.0 through 1.3.5.

1. Show the Session Two PowerPoint® presentation.
2. Use the Kickoff Activity to introduce trainees to the idea of remote control and the need for more sophisticated control methods in certain situations.
3. Describe the operation of a valve actuator and identify the major technologies used for this purpose.
4. Identify the three failure modes of a valve/actuator combination.
5. Explain the purpose of a valve positioner and list the three main types commonly used.

## Session Three

Session Three introduces valve configurations and the criteria used in selecting them. Although instrumentation technicians usually do not select valves on their own, they should have a basic understanding of the process. Trainees will also learn to read bridgewall markings and nameplates in order to identify the characteristics of a particular valve. This session covers Sections 1.4.0 through 1.5.5.

1. Show the Session Three PowerPoint® presentation.
2. Use the Kickoff Activity to help trainees recognize common symbols used in valve, actuator, and positioner situations as well as recognize the variations that are possible across industry.
3. Discuss the factors involved in valve selection and sizing.
4. Explain how to interpret globe valve flow and bridgewall markings in order to understand the valve's basic properties.
5. Describe other valve properties that can be determined from nameplate information.

## SESSIONS FOUR AND FIVE

Sessions Four and Five are laboratory sessions devoted to the practice and completion of Performance Tasks 1, 2, and 3.

1. Note that no PowerPoint® presentations are associated with these laboratory sessions.
2. Demonstrate how to properly install a positioner on a control valve.
3. Demonstrate how to locate bridgewall markings on a globe valve and determine the stem and packing orientation.
4. Identify different actuators and positioners from instructor-provided drawings or during a field survey.
5. Have trainees practice and/or complete the requirements of Performance Tasks 1, 2, and 3 in these hands-on sessions.

## SESSION SIX

Session Six is a review and testing session. Have the trainees complete the Module Review questions. Alternatively, these may be assigned as homework at the end of Session Five. Go over the answers to the Review Questions in class prior to the exam and answer any questions that the trainees may have.

1. Have trainees complete the module exam. Any outstanding performance testing must be completed during this session as well.
2. Record the testing results on the Registration of Training Modules form and submit the form to your Training Program Sponsor.

**Materials Checklist for 12207-16, Control Valves, Actuators, and Positioners**

| Equipment and Materials | | | | | |
|---|---|---|---|---|---|
| **Personal protective equipment:** | | Pneumatic or electric valve actuator | | Control valve with compatible positioner | |
| Safety glasses | | Pneumatic, analog, or smart valve positioner | | Appropriate mounting hardware | |
| Work gloves | | Example globe valves with bridgewall markings | | Common hand tools | |
| Proper footwear as designated by the instructor or training facility provider | | Example valves with nameplates | | Selection of globe valves with bridgewall markings | |
| Hearing protection as designated by the instructor or training facility provider | | | | Drawings showing a variety of actuators and positioners in a process environment | |
| Hard hat as designated by the instructor or training facility provider | | | | | |
| Whiteboard/chalkboard | | | | | |
| Markers/chalk | | | | | |
| Pencils and paper | | | | | |
| *Instrumentation Level Three* PowerPoint® Presentation Slides | | | | | |
| DVD player or a computer with a DVD drive | | | | | |
| LCD projector and screen | | | | | |
| Computer with internet access | | | | | |
| Module Review answer key | | | | | |
| Copies of the module examination (for paper-based exams) and Performance Profile Sheets | | | | | |
| Globe valve | | | | | |
| Gate or knife valve | | | | | |
| Ball valve | | | | | |
| Plug valve | | | | | |
| Butterfly valve | | | | | |
| Needle valve | | | | | |

To the extent possible, and as required for performance testing, provide a selection of the tools listed for each session; alternatively, photos may be used to teach tool identification.

Lesson Plans for Module 12205-16

# Detectors, Secondary Elements, Transducers, and Transmitters

**Module Two (12205-16)** introduces the first four components of the instrumentation chain in process control applications. Trainees will learn about sensing devices used for measuring different parameters, and transducers used to convert information into different forms as required by the application. Information on transmitters and the differences between traditional designs and modern smart transmitters is also provided.

## Objectives

### Learning Objective 1

- Identify and describe the first four components common to most process control channel applications and the relevant standards and elements.
  a. Identify the first four common instrument and process control channel components.
  b. Define key terms related to instrumentation and process control.
  c. Describe measurement standards and elements.

### Learning Objective 2

- Identify various detectors and explain how they operate.
  a. Identify and describe the operation of various temperature detection devices.
  b. Identify and describe the operation of various pressure detection devices.
  c. Identify and describe the operation of various level detection devices.
  d. Identify and describe the operation of various flow detection devices.

### Learning Objective 3

- Identify various transducer types and explain how they operate.
  a. Identify and describe the operation of I/P and P/I transducers.
  b. Identify and describe the operation of metallic and pressure strain gauges.
  c. Identify and describe the operation of other transducers.

### Learning Objective 4

- Identify various transmitter types and explain how they operate.
  a. Identify and describe the operation of force-balance differential pressure pneumatic transmitters.
  b. Describe the application of force-balance transmitters to temperature, pressure, level, and flow measurement.
  c. Identify and describe the operation of electronic transmitters.

## Performance Tasks

**Performance Task 1 (Learning Objective 2)**

- Identify various thermocouple types using a multifunction calibrator and a calibrated heat source.

**Performance Task 2 (Learning Objective 2)**

- Identify at least three instructor-chosen thermocouples by color code.

**Performance Task 3 (Learning Objective 4)**

- Connect a communication device to a smart transmitter and document the existing settings.

## Teaching Time: 25.0 hours

(Ten 2.5-Hour Sessions)

Session time may be adjusted to accommodate your class size, schedule, and teaching style.

## Prerequisites

*Core Curriculum*, *Instrumentation Level One*, and *Instrumentation Level Two*

## Before You Begin

As you prepare for each session, allow sufficient time to review the course objectives, content, visual aids, including the PowerPoint® presentation, and these lesson plans, and to gather the required equipment and materials. Consider the time required for demonstrations, laboratories, field trips, and testing.

Using your access code, download the module exams and Performance Profile Sheets from **www.nccerirc.com**. The passing score for submission into NCCER's Registry is 70% or above for the module exam; performance testing is graded pass or fail.

## Safety Considerations

This module requires that trainees work with tools and potentially energized equipment. Safety must be emphasized at all times. Trainees should be carefully observed to ensure that they wear the proper PPE, follow safe practices, and give due respect to unseen hazards. Any deficiencies must be corrected to ensure future trainee safety. All practice sessions and Performance Tasks must be completed under your direct supervision.

## Classroom Equipment and Materials

Whiteboard
Markers
Pencils and paper
*Instrumentation Level Three* PowerPoint® Presentation
DVD player or a computer with a DVD drive
LCD projector and screen
Computer with internet access
Review Questions answer key
Copies of the module examination (for paper-based exams) and Performance Profile Sheets
Detectors
Transducers
Amplifiers
Transmitters
Modern smart transmitter containing all four functions
Example instruments with measurement scales
Bimetallic strip thermostat
Thermocouples
Digital multimeter
Thermocouple extension wire
Pressure gauges or capsules
Capacitance level detector
Orifice plate
Venturi tube
Pitot tube
Magnetic flowmeter
Ultrasonic flowmeter
I/P and/or P/I transducers
Individual strain gauges
Example transducer
Various pneumatic and/or analog transmitters
Smart transmitter
Smart transmitter field communicator

## Equipment and Materials for Laboratories and Performance Testing

Appropriate PPE, to include the following:
- Safety glasses
- Work gloves
- Proper footwear as designated by the instructor or training facility provider
- Hearing protection as designated by the instructor or training facility provider
- Hard hat as designated by the instructor or training facility provider

Selection of thermocouples with color codes
Thermocouple color code chart appropriate to the provided thermocouples
Multifunction calibrator
Calibrated heat source
Smart transmitter
Field communicator

## Additional Resources

This module presents thorough resources for task training. The following resource material is suggested for further study.

*Instrumentation*, Franklyn W. Kirk, Thomas A. Weedon, and Philip Kirk. Fifth Edition. 2010. Orland Park, IL: American Technical Publishers.

*Power-Plant Control and Instrumentation: The Control of Boilers and HRSG Systems*, David Lindsley. 2000. London: The Institution of Electrical Engineers.

*Overview of Measurement Systems and Devices*, M.T. Tham. Newcastle University. 1996–2009. **http://lorien.ncl.ac.uk/ming/procmeas/measintr.htm**

*The Condensed Handbook of Measurement and Control*, N.E. Battikha. Third Edition, 2006. Research Triangle Park, NC: The International Society of Automation.

Dwyer Instruments Inc. website, **www.dwyer-inst.com**

Emerson Electric Company website, **www.emerson.com**

Omega Engineering website, **www.omega.com**

Instructors are also encouraged to locate additional audiovisual aids available on the internet, make personal videos, and take still pictures related to the subject matter and add them to the PowerPoint® presentations throughout the program.

Session Outline for 12205-16

# Detectors, Secondary Elements, Transducers, and Transmitters

The Lesson Plan for this module is divided into ten 2.5-hour sessions.
This time includes 10 minutes for administrative tasks and a 10-minute break per session.

## Session One

Session One introduces the first four components in the instrument chain. These will be addressed individually, although in many systems, they are combined in various ways. This session covers Sections 1.0.0 through 1.1.4.

1. Show the Session One PowerPoint® presentation.
2. Use the Kickoff Activity to get trainees engaged and give them an idea of what they will learn from this module.
3. Describe the initial four components of the instrumentation and process control chain.
4. Point out that components are often combined in different ways, making a large variety of instrumentation scenarios possible.

## Session Two

Session Two introduces key terms related to instrumentation and the measuring process. The way in which these concepts affect instrument use will be addressed. This session covers Sections 1.2.0 through 1.3.7.

1. Show the Session Two PowerPoint® presentation.
2. Use the Kickoff Activity to help trainees understand the difference between accuracy and precision, two commonly confused terms.
3. Introduce instrumentation and measurement terminology, differentiating between the key concepts of accuracy, precision, sensitivity, responsiveness, and reproducibility.
4. Discuss measurement error, listing and distinguishing the different types of error and their sources.
5. Discuss the concept of standards, including primary, secondary, and working. Emphasize the crucial idea of traceability in calibration.

## Session Three

Session Three introduces specific sensors used in measuring common process parameters. Temperature and pressure measurement technologies will be examined and compared. This session covers Sections 2.0.0 through 2.2.5.

1. Show the Session Three PowerPoint® presentation.
2. Use the Kickoff Activity to demonstrate how mechanical temperature measurement using the bimetallic strip principle works.
3. Introduce the most common temperature sensing devices, including bimetallic strips, thermocouples, and RTDs.
4. Discuss the different types of thermocouples and the color code systems used to identify them.
5. Introduce pressure-measuring technologies, discussing the various ways in which pressure can be determined.

## Session Four

Session Four introduces specific sensors used in measuring common process parameters. Level and flow measurement technologies will be examined and compared. This session covers Sections 2.3.0 through 2.4.6.

1. Show the Session Four PowerPoint® presentation.
2. Use the Kickoff Activity to introduce the ultrasonic method of measuring flow.
3. Introduce level detection devices, including both everyday ones and more exotic methods, such as nuclear level detection.
4. Introduce flow detection devices, covering the science behind the way in which they work.

Session Outline for 12205-16

# Detectors, Secondary Elements, Transducers, and Transmitters

## Session Five

Session Five introduces transducers of various types and explains how they are used to convert information into an equivalent form that is more useful than the original. This session covers Sections 3.0.0 through 3.3.2.

1. Show the Session Five PowerPoint® presentation.
2. Use the Kickoff Activity to acquaint trainees with industrial process equipment sales literature and other sources of information.
3. Introduce the I/P and P/I transducers and discuss how they convert information between electrical and pneumatic forms.
4. Discuss strain gauges, the way in which they operate, and the uses to which they are put in measurement.
5. Address other kinds of transducers, including those that involve pressure and acceleration measurement and make use of piezoelectric crystals to perform the transducer operation.

## Session Six

Session Six introduces transmitter technology. Transmitter operation and types are examined. Modern digital and smart transmitters are compared to more traditional types. This session covers Sections 4.0.0 through 4.3.3.

1. Show the Session Six PowerPoint® presentation.
2. Use the Kickoff Activity to clarify how traditional mechanical transmitters work. This subject may be confusing if the trainees have not worked with this technology before.
3. Discuss the operation of traditional mechanical/pneumatic transmitters.
4. Explain how traditional transmitters work in various common measurement settings.
5. Address electronic, digital, and smart transmitters, emphasizing the advantages that smart transmitters confer on plant management.
6. Summarize the major communication networks and protocols used by industrial smart technology.

## Sessions Seven through Nine

Sessions Seven through Nine are laboratory sessions devoted to the practice and completion of Performance Tasks 1, 2, and 3.

1. Note that no PowerPoint® presentations are associated with these laboratory sessions.
2. Demonstrate how to identify various thermocouple types using a multifunction calibrator and a calibrated heat source.
3. Demonstrate how to identify at least three instructor-chosen thermocouples by color code.
4. Demonstrate how to connect a communication device to a smart transmitter and document the existing settings.
5. Have trainees practice and/or complete the requirements of Performance Tasks 1, 2, and 3 in these hands-on sessions.

## Session Ten

Session Ten is a review and testing session. Have the trainees complete the Module Review Questions. Alternatively, these may be assigned as homework at the end of Session Nine. Go over the answers to the Review Questions in class prior to the exam and answer any questions that the trainees may have.

1. Have trainees complete the module exam. Any outstanding performance testing must be completed during this session as well.
2. Record the testing results on the Registration of Training Modules form and submit the form to your Training Program Sponsor.

**Materials Checklist for Module 12205-16, Detectors, Secondary Elements, Transducers, and Transmitters**

| Equipment and Materials | | | | | |
|---|---|---|---|---|---|
| **Personal protective equipment:** | | Modern smart transmitter containing all four functions | | Selection of thermocouples with color codes | |
| Safety glasses | | Example instruments with measurement scales | | Thermocouple color code chart appropriate to the provided thermocouples | |
| Work gloves | | Bimetallic strip thermostat | | Multifunction calibrator | |
| Proper footwear as designated by the instructor or training facility provider | | Thermocouples | | Calibrated heat source | |
| Hearing protection as designated by the instructor or training facility provider | | Digital multimeter | | Smart transmitter | |
| Hard hat as designated by the instructor or training facility provider | | Thermocouple extension wire | | Field communicator | |
| Whiteboard | | Pressure gauges or capsules | | | |
| Markers | | Capacitance level detector | | | |
| Pencils and paper | | Orifice plate | | | |
| *Instrumentation Level Three* PowerPoint® Presentation | | Venturi tube | | | |
| DVD player or a computer with a DVD drive | | Pitot tube | | | |
| LCD projector and screen | | Magnetic flowmeter | | | |
| Computer with internet access | | Ultrasonic flowmeter | | | |
| Review Question answer key | | I/P and/or P/I transducers | | | |
| Copies of the module examination (for paper-based exams) and Performance Profile Sheets | | Individual strain gauges | | | |
| Detectors | | Example transducer | | | |
| Transducers | | Various pneumatic and/or analog transmitters | | | |
| Amplifiers | | Smart transmitter | | | |
| Transmitters | | Smart transmitter field communicator | | | |

To the extent possible, and as required for performance testing, provide a selection of the tools listed for each session; alternatively, photos may be used to teach tool identification.

# Instrumentation Electrical Circuitry

**Module Three (12305-16)** covers the crucial topic of basic DC and AC electrical theory. Understanding these concepts is essential for instrumentation personnel since many instruments are electrical or electronic. This module addresses the foundational concepts and laws of DC voltage, current, and resistance. AC electricity is introduced and compared to DC. Electrical technology as applied to signals and sensors is briefly examined.

## Objectives

### Learning Objective 1

- Describe resistive circuits and explain how to apply Ohm's law and Kirchhoff's laws.
  a. Describe series, parallel, and series-parallel resistive circuits.
  b. Explain how to apply Ohm's law to different circuit types.
  c. Explain how to apply Kirchhoff's laws to determine current and voltage values.

### Learning Objective 2

- Identify key characteristics of alternating current and explain resistance, inductance, capacitance, and power concepts.
  a. Identify key characteristics of alternating current.
  b. Describe alternating current phase relationships.
  c. Explain resistance in alternating-current circuits.
  d. Explain inductance in alternating-current circuits.
  e. Explain capacitance in alternating-current circuits.
  f. Explain power in alternating-current circuits.

### Learning Objective 3

- Describe direct-current power supplies and testing methods.
  a. Describe direct-current power supplies.
  b. Describe how to select and test a direct-current power supply.

### Learning Objective 4

- Describe the primary types of electronic instrumentation signals.
  a. Describe analog signals and explain how they are used.
  b. Describe digital signals and explain how they are used.
  c. Describe how PLCs interact with instrumentation signals.

### Learning Objective 5

- Describe common applications for instrumentation circuitry.
  a. Describe temperature applications using an RTD bridge.
  b. Describe pressure applications using a strain-gauge bridge.
  c. Describe remote level applications.

## Performance Tasks

**Performance Task 1 (Learning Objective 1)**

- Calculate the resistance range of three resistors using their color bands. Using a multimeter, measure the actual resistance of each resistor and determine if it is within the specified tolerance.

**Performance Task 2 (Learning Objective 1)**

- Connect three resistors in series and calculate the total nominal resistance using the color bands and the appropriate formula. Using a multimeter, measure the actual total series resistance and compare it to the calculated value.

**Performance Task 3 (Learning Objective 1)**

- Connect three resistors in parallel and calculate the total nominal resistance using the color bands and the appropriate formula. Using a multimeter, measure the actual total parallel resistance and compare it to the calculated value.

## Teaching Time: 25.0 hours

(Ten 2.5-Hour Sessions)

Session time may be adjusted to accommodate your class size, schedule, and teaching style.

## Prerequisites

*Core Curriculum*, *Instrumentation Level One*, and *Instrumentation Level Two*

## Before You Begin

As you prepare for each session, allow sufficient time to review the course objectives, content, visual aids, including the PowerPoint® presentation, and these lesson plans, and to gather the required equipment and materials. Consider the time required for demonstrations, laboratories, field trips, and testing.

Using your access code, download the module exams and Performance Profile Sheets from **www.nccerirc.com**. The passing score for submission into NCCER's Registry is 70% or above for the module exam; performance testing is graded pass or fail.

### Safety Considerations

This module requires that trainees work with tools and potentially energized equipment. Safety must be emphasized at all times. Trainees should be carefully observed to ensure that they wear the proper PPE, follow safe practices, and give due respect to unseen hazards. Any deficiencies must be corrected to ensure future trainee safety. All practice sessions and Performance Tasks must be completed under your direct supervision.

## Classroom Equipment and Materials

Whiteboard

Markers

Pencils and paper

*Instrumentation Level Three* PowerPoint® Presentation

DVD player or a computer with a DVD drive

LCD projector and screen

Computer with Internet access

Calculators

Inductors

Capacitors

Linear DC power supply

Switching DC power supply

Example PLC analog and digital modules

RTD

Multimeter

Single unbonded strain gauge

Pressure sensor/DP cell

Level sensor

Module Review answer key

Copies of the module examination (for paper-based exams) and Performance Profile Sheets

## Equipment and Materials for Laboratories and Performance Testing

Appropriate PPE to include the following:

- Safety glasses
- Work gloves
- Proper footwear as designated by the instructor or training facility provider
- Hearing protection as designated by the instructor or training facility provider
- Hard hat as designated by the instructor or training facility provider

Selection of resistors (¼ or ½W, 5 percent tolerance)

Multimeters

Calculators

Resistor color code charts

## Additional Resources

This module presents thorough resources for task training. The following resource material is recommended for further study.


*Electronics Fundamentals: Circuits, Devices, & Applications*, Thomas L. Floyd. Eighth Edition. 2009. New York, NY: Prentice Hall.

*Introduction to Electric Circuits*, Richard C. Dorf and James A. Svoboda. Ninth Edition. 2013. Hoboken, NJ: Wiley.

*Measurement and Control Basics*, Thomas A. Hughes. Fifth Edition. 2014. Research Triangle Park, NC: International Society of Automation.

*Principles of Electric Circuits: Electron Flow Version*, Thomas L. Floyd. Ninth Edition. 2009. New York, NY: Prentice Hall.


Instructors are also encouraged to locate additional audiovisual aids available on the Internet, make personal videos, and take still pictures related to the subject matter and add them to the PowerPoint® presentations throughout the program.

# Session Outline for 12305-16

# Instrumentation Electrical Circuitry

The Lesson Plan for this module is divided into ten 2.5-hour sessions.
This time includes 10 minutes for administrative tasks and a 10-minute break per session.

## Session One

Session One introduces basic DC electrical theory by discussing the two fundamental circuit types: series and parallel. This idea is extended to combination circuits that contain both series and parallel sections. The equations for calculating circuit resistance in each type are examined. This session covers Sections 1.0.0 through 1.1.3.

1. Show the Session One PowerPoint® presentation.
2. Use the Kickoff Activity to get trainees engaged and give them an idea of what they will learn from this module.
3. Review resistance and introduce the concept of a multi-resistance circuit.
4. Examine series circuits as well as the formula for calculating total circuit resistance.
5. Examine parallel circuits as well as the formulas for calculating total circuit resistance.
6. Introduce series-parallel circuits and the redrawing techniques that make its elements more apparent.
7. Discuss how to calculate the total circuit resistance of a series-parallel circuit.

## Session Two

Session Two explores one of the most fundamental and useful laws of electricity, Ohm's law. The three forms of the law are presented and their uses explored. Ohm's law is then used to help analyze series, parallel, and series-parallel circuits. This session covers Sections 1.2.0 through 1.2.3.

1. Show the Session Two PowerPoint® presentation.
2. Use the Kickoff Activity to review Ohm's law and encourage the trainees to think of it not just as equations but as relationships between the three electrical parameters.
3. Introduce Ohm's law and explain how the three forms allow for any one electrical parameter to be calculated from the other two.
4. Apply Ohm's law to determine circuit current and voltage drops in series circuits.
5. Apply Ohm's law to determine circuit current and individual branch currents in parallel circuits.
6. Apply Ohm's law to analyze series-parallel circuits.

## Session Three

Session Three extends the trainees' understanding by adding Kirchhoff's two laws as the means by which series and parallel circuits can be further analyzed. Trainees will learn to create loop equations and use them to understand how current and voltage behave in the circuit. This session covers Sections 1.3.0 through 1.3.3.

1. Show the Session Three PowerPoint® presentation.
2. Use the Kickoff Activity to introduce the trainees to Kirchhoff's laws.
3. Introduce Kirchhoff's current law (KCL) and Kirchhoff's voltage law (KVL).
4. Clarify how signs are determined when writing KCL and KVL equations.
5. Demonstrate how to write loop equations.

## SESSION FOUR

Session Four moves a step deeper into fundamental electrical principles by looking at alternating current and comparing its behavior to DC. Waveform terms as well as the average and RMS methods for determining quantities are examined. The concept of phase is introduced. Resistance is extended to include AC. This session covers Sections 2.0.0 through 2.3.0.

1. Show the Session Four PowerPoint® presentation.
2. Use the Kickoff Activity to review the differences between DC and AC.
3. Introduce alternating current and the sine wave.
4. Define and give examples of the various parameters used to describe a sine wave.
5. Discuss the need for a "single" AC voltage or current value in a setting in which the waveform is constantly changing. Introduce average and RMS values as a solution to this problem.
6. Explain phase angles.
7. Discuss resistance in an AC context, comparing it to DC resistance.

## SESSION FIVE

Session Five carries AC theory further by examining its effect on inductive and capacitive circuits. Capacitor and inductor equations are introduced, as is the concept of reactance. Finally, AC power is addressed in contrast to DC power. This session covers Sections 2.4.0 through 2.6.0.

1. Show the Session Five PowerPoint® presentation.
2. Use the Kickoff Activity to review key AC terminology and the sine wave.
3. Introduce inductive circuits by explaining how an AC signal in a coil of wire produces some significant effects.
4. Describe an inductor and explain how its various physical properties influence its circuit behavior. Mention inductive reactance.
5. Introduce capacitive circuits by explaining how an AC signal acting across a capacitor produces some significant effects.
6. Compare a capacitor's behavior under DC and under AC.
7. Introduce the equations used to calculate total capacitance in series and parallel capacitive circuits.
8. Describe capacitor voltage rating, leak resistance, and capacitive reactance.
9. Explore AC power and compare it to DC power.

## SESSION SIX

Session Six examines DC power supply technology. Both linear and nonlinear (switching) supplies are examined. Power supply selection and testing is considered from an instrumentation perspective. This session covers Sections 3.0.0 through 3.2.2.

1. Show the Session Six PowerPoint® presentation.
2. Use the Kickoff Activity to highlight the differences between linear and switching power supplies.
3. Discuss the role that DC power supplies play in instrumentation and control systems.
4. Define linear and nonlinear (switching) power supplies and identify their key qualities.
5. Explain how a DC power supply is selected and tested.

## SESSION SEVEN

Session Seven introduces instrumentation signals. Both analog and digital signals are compared and contrasted. Digital communications with intelligent devices such as PLCs is introduced. This session covers Sections 4.0.0 through 4.3.2.

1. Show the Session Seven PowerPoint® presentation.
2. Use the Kickoff Activity to give the trainees a chance to ask questions about previous material in this module.
3. Survey analog instrumentation signals and explain how they represent physical quantities as electrical voltage or current levels.
4. Discuss the key details of 4–20mA current loops. Describe their limitations.
5. Introduce digital signals and compare them to analog ones.
6. Discuss how PLCs send and receive information in both analog and digital formats.

## SESSION EIGHT

Session Eight discusses a number of common electrical instrumentation technologies, including temperature, pressure, and level sensors. Each is considered from an electrical perspective. Bridge circuits are examined briefly. This session covers Sections 5.0.0 through 5.3.0.

1. Show the Session Eight PowerPoint® presentation.
2. Use the Kickoff Activity to review the Trade Terms introduced in the previous sessions.
3. Explore the RTD temperature sensor by describing its basic principles and features.
4. Introduce the bridge circuit and its role in instrumentation circuits.
5. Discuss strain-gauge pressure sensors and explain how they convert strain into changes of resistance.
6. Examine pressure-based level sensors.

## SESSION NINE

Session Nine is a laboratory session devoted to the practice and completion of Performance Tasks 1, 2, and 3.

1. Note that no PowerPoint® presentation is associated with this laboratory session.
2. Demonstrate how to calculate the resistance range of three resistors using their color bands. Then, compare their measured resistance and see if it comes within the expected tolerance.
3. Demonstrate how to connect three resistors in series and determine their nominal resistance from their color bands. Then, compare the measured circuit value to the calculated value.
4. Demonstrate how to connect three resistors in parallel and determine their nominal resistance from their color bands. Then, compare the measured circuit value to the calculated value.
5. Have trainees practice and/or complete the requirements of Performance Tasks 1, 2, and 3.

## SESSION TEN

Session Ten is a review and testing session. Have the trainees complete the Module Review Questions. Alternatively, these may be assigned as homework at the end of Session Nine. Go over the answers to the Review Questions in class prior to the exam and answer any questions that the trainees may have.

1. Have trainees complete the module exam. Any outstanding performance testing must be completed during this session as well.
2. Record the testing results on the Registration of Training Modules form and submit the form to your Training Program Sponsor.

**Materials Checklist for Module 12305-16, Instrumentation Electrical Circuitry**

| Equipment and Materials | | | | | |
|---|---|---|---|---|---|
| **Personal protective equipment:** | | Inductors | | Selection of resistors (¼ or ½W, 5 percent tolerance) | |
| Safety glasses | | Capacitors | | Multimeters | |
| Work gloves | | Linear DC power supply | | Calculators | |
| Proper footwear as designated by the instructor or training facility provider | | Switching DC power supply | | Resistor color code charts | |
| Hearing protection as designated by the instructor or training facility provider | | Example PLC analog and digital modules | | | |
| Hard hat as designated by the instructor or training facility provider | | RTD | | | |
| Whiteboard | | Multimeter | | | |
| Markers | | Single unbonded strain gauge | | | |
| Pencils and paper | | Pressure sensor/DP cell | | | |
| *Instrumentation Level Three* PowerPoint® Presentation | | Level sensor | | | |
| DVD player or a computer with a DVD drive | | | | | |
| LCD projector and screen | | | | | |
| Computer with Internet access | | | | | |
| Calculators | | | | | |
| Module Review answer key | | | | | |
| Copies of the module examination (for paper-based exams) and Performance Profile Sheets | | | | | |

To the extent possible, and as required for performance testing, provide a selection of the tools listed for each session; alternatively, photos may be used to teach tool identification.

# Lesson Plans for Module 12208-16

# Relays and Timers

**Module Four (12208-16)** introduces electromechanical, electronic, and pneumatic switching through the topic of relays and timers. Trainees will learn about the various types of relays as well as the nomenclature used to describe a relay's behavior and internal arrangement. They will also learn about solid-state switching devices, pneumatic relays, and various kinds of timing relays and clocks.

## Objective

**Learning Objective 1**

- Identify and describe the operation of various types of relays and timers.
  a. Identify and describe the operation of various electromechanical relays.
  b. Identify and describe the operation of solid-state relays.
  c. Identify and describe the operation of pneumatic boosters.
  d. Identify and describe the operation of various timers and time clocks.

## Performance Task

**Performance Task 1 (Learning Objective 1)**

- Select and connect various types of relays and timers to create a functional circuit as directed by the instructor.

## Teaching Time: 10.0 hours

(Four 2.5-Hour Sessions)

Session time may be adjusted to accommodate your class size, schedule, and teaching style.

## Prerequisites

*Core Curriculum*, *Instrumentation Level One*, and *Instrumentation Level Two*

## Before You Begin

As you prepare for each session, allow sufficient time to review the course objectives, content, visual aids, including the PowerPoint® presentation, and these lesson plans, and to gather the required equipment and materials. Consider the time required for demonstrations, laboratories, field trips, and testing.

Using your access code, download the module exams and Performance Profile Sheets from **www.nccerirc.com**. The passing score for submission into NCCER's Registry is 70% or above for the module exam; performance testing is graded pass or fail.

## Safety Considerations

This module requires that trainees work with tools, electrical devices, and potentially energized equipment. Safety must be emphasized at all times. Trainees should be carefully observed to ensure that they wear the proper PPE, follow safe practices, and give due respect to unseen hazards. Any deficiencies must be corrected to ensure future trainee safety. All practice sessions and Performance Tasks must be completed under your direct supervision.

## Classroom Equipment and Materials

Whiteboard

Markers

Pencils and paper

*Instrumentation Level Three* PowerPoint® Presentation

DVD player or a computer with a DVD drive

LCD projector and screen

Computer with Internet access

Reed relay

General-purpose relays of various types

Solid-state relay

Pneumatic booster relay

Dashpot timer relay

Time clock

Solid-state timer

Review Questions answer key

Copies of the module examination (for paper-based exams) and Performance Profile Sheets

## Equipment and Materials for Laboratories and Performance Testing

Appropriate PPE, to include the following:

- Safety glasses
- Work gloves
- Proper footwear as designated by the instructor or training facility provider
- Hearing protection as designated by the instructor or training facility provider
- Hard hat as designated by the instructor or training facility provider

Selection of relays and timers

Appropriate wiring, connectors, and sockets

Suitable power supply

Device to be controlled

## Additional Resources

This module presents thorough resources for task training. The following resource material is suggested for further study.

*Instrument Engineers Handbook, Volume 2: Process Control and Optimization*. Béla G. Lipták (editor). Fourth Edition. 2006. Boca Raton, FL: CRC Press.

*Electrical Motor Controls for Integrated Systems*, Gary Rockis and Glen A. Mazur. Fourth Edition. 2009. Orland Park, IL: American Technical Publishers.

*The Condensed Handbook of Measurement and Control*, N.E. Battikha. Third Edition, 2006. Research Triangle Park, NC: The International Society of Automation.

Dwyer Instruments Inc. website, **www.dwyer-inst.com**

Emerson Electric Company website, **www.emerson.com**

Omega Engineering website, **www.omega.com**

Instructors are also encouraged to locate additional audiovisual aids available on the Internet, make personal videos, and take still pictures related to the subject matter and add them to the PowerPoint® presentations throughout the program.

# Session Outline for 12208-16

# Relays and Timers

The Lesson Plan for this module is divided into four 2.5-hour sessions.
This time includes 10 minutes for administrative tasks and a 10-minute break per session.

## Session One

Session One introduces electromechanical and electronic switching. Various types of electromechanical relays are covered. Trainees will learn about the key electrical parameters of relays, their contact arrangements, and their switching behavior. Solid-state relays are described and compared to electromechanical relays. This session covers Sections 1.0.0 through 1.2.1.

1. Show the Session One PowerPoint® presentation.
2. Use the Kickoff Activity to get trainees engaged and give them an idea of what they will learn from this module.
3. Introduce the different types of electro-mechanical relays and the uses for each major category.
4. Discuss the electrical parameters associated with relays as well as the nomenclature connected with their internal arrangement.
5. Compare solid-state relays with electro-mechanical relays, introducing the places where each technology works best.

## Session Two

Session Two introduces pneumatic relays, repeaters, and boosters. The internal arrangements of these technologies are examined, as well as their uses. Timing relays, clocks, and other delay devices are discussed. Mechanical, electrical, and electronic technologies are compared. This session covers Sections 1.3.0 through 1.4.3.

1. Show the Session Two PowerPoint® presentation.
2. Use the Kickoff Activity to help trainees recognize the need for pneumatic relays, boosters, and repeaters.
3. Discuss pneumatic switching devices and explain the purposes for each type.
4. Examine timing devices, such as timer relays, delay devices, and time clock mechanisms.
5. Compare solid-state timing devices to mechanical and electrical equivalents.

## Session Three

Session Three is a laboratory session devoted to the practice and completion of Performance Task 1.

1. Note that no PowerPoint® presentation is associated with this laboratory session.
2. Demonstrate how to connect relays and timers to create a functional timing circuit.
3. Have trainees practice and/or complete the requirements of Performance Task 1 in this hands-on session.

## Session Four

Session Four is a review and testing session. Have the trainees complete the Module Review Questions. Alternatively, these may be assigned as homework at the end of Session Three. Go over the answers to the Review Questions in class prior to the exam and answer any questions that the trainees may have.

1. Have trainees complete the module exam. Any outstanding performance testing must be completed during this session as well.
2. Record the testing results on the Registration of Training Modules form and submit the form to your Training Program Sponsor.

**Materials Checklist for Module 12208-16, Relays and Timers**

| Equipment and Materials | | | | | |
|---|---|---|---|---|---|
| **Personal protective equipment:** | | Reed relay | | Selection of relays and timers | |
| Safety glasses | | General-purpose relays of various types | | Appropriate wiring, connectors, and sockets | |
| Work gloves | | Solid-state relay | | Suitable power supply | |
| Proper footwear as designated by the instructor or training facility provider | | Pneumatic booster relay | | Device to be controlled | |
| Hearing protection as designated by the instructor or training facility provider | | Dashpot timer relay | | | |
| Hard hat as designated by the instructor or training facility provider | | Time clock | | | |
| Whiteboard | | Solid-state timer | | | |
| Markers | | | | | |
| Pencils and paper | | | | | |
| *Instrumentation Level Three* PowerPoint® Presentation | | | | | |
| DVD player or a computer with a DVD drive | | | | | |
| LCD projector and screen | | | | | |
| Computer with Internet access | | | | | |
| Review Questions answer key | | | | | |
| Copies of the module examination (for paper-based exams) and Performance Profile Sheets | | | | | |

To the extent possible, and as required for performance testing, provide a selection of the tools listed for each session; alternatively, photos may be used to teach tool identification.

# Lesson Plans for Module 12209-16

# Switches and Photoelectric Devices

**Module Five (12209-16)** introduces the many different types of switches encountered in typical industrial settings. Various types of photoelectric devices will be considered in a number of applications. In addition to the standard switch types, trainees will also examine other types of switches, including infrared-detecting, fiber-optic, and proximity sensors.

## Objectives

**Learning Objective 1**

- Identify and describe the operation of various types of switches and photoelectric devices.
  a. Define switches and their various characteristics.
  b. Describe the characteristics of various switch types and styles.
  c. Describe various switch applications.
  d. Identify and describe the operation of photoelectric devices.
  e. Identify and describe the operation of infrared-sensing devices.
  f. Identify and describe the operation of fiber-optic sensors.
  g. Identify and describe the operation of proximity sensors.

## Performance Tasks

**Performance Task 1 (Learning Objective 1)**

- Select and connect various switches into a functional circuit as directed by the instructor.

**Performance Task 2 (Learning Objective 1)**

- Select and connect various photoelectric devices into a functional circuit as directed by the instructor.

## Teaching Time: 10.0 hours

(Four 2.5-Hour Sessions)

Session time may be adjusted to accommodate your class size, schedule, and teaching style.

## Prerequisites

*Core Curriculum*, *Instrumentation Level One*, and *Instrumentation Level Two*

## Before You Begin

As you prepare for each session, allow sufficient time to review the course objectives, content, visual aids, including the PowerPoint® presentation, and these lesson plans, and to gather the required equipment and materials. Consider the time required for demonstrations, laboratories, field trips, and testing.

Using your access code, download the module exams and Performance Profile Sheets from **www.nccerirc.com**. The passing score for submission into NCCER's Registry is 70% or above for the module exam; performance testing is graded pass or fail.

## Safety Considerations

This module requires that trainees work with tools, electrical devices, and potentially energized equipment. Safety must be emphasized at all times. Trainees should be carefully observed to ensure that they wear the proper PPE, follow safe practices, and give due respect to unseen hazards. Any deficiencies must be corrected to ensure future trainee safety. All practice sessions and Performance Tasks must be completed under your direct supervision.

## Classroom Equipment and Materials

Whiteboard

Markers

Pencils and paper

*Instrumentation Level Three* PowerPoint® Presentation

DVD player or a computer with a DVD drive

LCD projector and screen

Computer with internet access

Review Questions answer key

Copies of the module examination (for paper-based exams) and Performance Profile Sheets

Disassembled switch, preferably DPDT

Panel-mounted switches

Float switch

Pressure switch

Limit switch

SCR or TRIAC switch

Photoelectric, direct scanning sensor

Infrared thermometer

Inductive proximity sensor

## Equipment and Materials for Laboratories and Performance Testing

Appropriate PPE, to include the following:

- Safety glasses
- Work gloves
- Proper footwear as designated by the instructor or training facility provider
- Hearing protection as designated by the instructor or training facility provider
- Hard hat as designated by the instructor or training facility provider

Selection of switches

Selection of photoelectric devices

Appropriate wiring, connectors, and sockets

Suitable power supply

Devices to be controlled

## Additional Resources

This module presents thorough resources for task training. The following resource material is suggested for further study.

*Instrument Engineers Handbook, Volume 2: Process Control and Optimization*. Béla G. Lipták (editor). Fourth Edition. 2006. Boca Raton, FL: CRC Press.

*National Electrical Code® Handbook 2014*, Mark W. Earley, Christopher D. Coache, Mark Cloutier, and Gil Moniz. Thirteenth Edition. 2013. Quincy, MA: National Fire Protection Association.

*The Condensed Handbook of Measurement and Control*, N.E. Battikha. Third Edition, 2006. Research Triangle Park, NC: The International Society of Automation.

Dwyer Instruments Inc. website, **www.dwyer-inst.com**

Emerson Electric Company website, **www.emerson.com**

Omega Engineering website, **www.omega.com**

Instructors are also encouraged to locate additional audiovisual aids available on the internet, make personal videos, and take still pictures related to the subject matter and add them to the PowerPoint® presentations throughout the program.

## Session Outline for 12209-16

# Switches and Photoelectric Devices

The Lesson Plan for this module is divided into four 2.5-hour sessions.
This time includes 10 minutes for administrative tasks and a 10-minute break per session.

## Session One

Session One introduces various types of switches. Trainees will learn about switch classifications, contact arrangements, poles, and throws. They will study specific switch types and applications. Various types of electronic switches are also described. This session covers Sections 1.0.0 through 1.3.5.

1. Show the Session One PowerPoint® presentation.
2. Use the Kickoff Activity to get trainees engaged and give them an idea of what they will learn from this module.
3. Introduce essential switch terminology and definitions.
4. Discuss the major switch classifications, including details such as contact arrangements, poles, and throws.
5. Provide an overview of major switch types and applications.
6. Discuss electronic (solid-state) switches and compare them to mechanical ones.

## Session Two

Session Two introduces several different types of specialized switches. Photoelectric switches, used in different sensing situations, will be examined. The use of infrared sensors, motion detectors, and fiber-optic switches is described, and proximity switches are examined. This session covers Sections 1.4.0 through 1.7.0.

1. Show the Session Two PowerPoint® presentation.
2. Use the Kickoff Activity to help trainees understand proximity sensors and their applications.
3. Discuss photoelectric switches and their uses in scanning applications such as conveyor belts.
4. Introduce solar cells as an example of a photoelectric energy conversion device.
5. Discuss infrared sensors and their applications, both as motion detectors and as non-contact temperature sensors.
6. Describe fiber-optic sensors and inductive proximity sensors and how they are used.

## Session Three

Session Three is a laboratory session designated for the practice and completion of Performance Tasks 1 and 2.

1. Note that no PowerPoint® presentation is associated with this laboratory session.
2. Demonstrate how to connect various switches into a functional circuit.
3. Demonstrate how to connect various photoelectric devices into a functional circuit.
4. Have trainees practice and/or complete the requirements of Performance Tasks 1 and 2 in this hands-on session.

## Session Four

Session Four is a review and testing session. Have the trainees complete the Module Review Questions. Alternatively, these may be assigned as homework at the end of Session Three. Go over the answers to the Review Questions in class prior to the exam and answer any questions that the trainees may have.

1. Have trainees complete the module exam. Any outstanding performance testing must be completed during this session as well.
2. Record the testing results on the Registration of Training Modules form and submit the form to your Training Program Sponsor.

**Materials Checklist for Module 12209-16, Switches and Photoelectric Devices**

| Equipment and Materials | | | | | |
|---|---|---|---|---|---|
| **Personal protective equipment:** | | Disassembled switch, preferably DPDT | | Selection of switches | |
| Safety glasses | | Panel-mounted switches | | Selection of photoelectric devices | |
| Work gloves | | Float switch | | Appropriate wiring, connectors, and sockets | |
| Proper footwear as designated by the instructor or training facility provider | | Pressure switch | | Suitable power supply | |
| Hearing protection as designated by the instructor or training facility provider | | Limit switch | | Devices to be controlled | |
| Hard hat as designated by the instructor or training facility provider | | SCR or TRIAC switch | | | |
| Whiteboard | | Photoelectric, direct scanning sensor | | | |
| Markers | | Infrared thermometer | | | |
| Pencils and paper | | Inductive proximity sensor | | | |
| *Instrumentation Level Three* PowerPoint® Presentation | | | | | |
| DVD player or a computer with a DVD drive | | | | | |
| LCD projector and screen | | | | | |
| Computer with internet access | | | | | |
| Review Questions answer key | | | | | |
| Copies of the module examination (for paper-based exams) and Performance Profile Sheets | | | | | |

To the extent possible, and as required for performance testing, provide a selection of the tools listed for each session; alternatively, photos may be used to teach tool identification.

# Lesson Plans for Module 12307-16

# Terminating Conductors

**Module Six (12307-16)** addresses the topic of cable termination. Instrumentation involves many different types of cables carrying a wide variety of signals. In order to keep equipment operating reliably, proper cable termination is essential. This module addresses cable and termination types, tools, termination methods, and testing strategies to deal with problems. The causes of cable failure are also briefly examined.

## Objectives

### Learning Objective 1

- Identify and describe various types of instrumentation cable and their related terminal hardware.
  a. Identify and describe various types of communication cable.
  b. Identify and describe low-voltage connectors and terminals.

### Learning Objective 2

- Explain how to terminate various types of low-voltage cable.
  a. Explain how to terminate cables and conductors with solderless terminals or terminal blocks.
  b. Explain how to terminate coaxial cable.
  c. Identify considerations and installation techniques related to cable and conductor routing.
  d. Identify considerations and installation techniques related to avoiding electromagnetic interference.

### Learning Objective 3

- Explain how to test and troubleshoot cable installations.
  a. Identify common test equipment.
  b. Identify various cable and conductor testing parameters used to determine condition.
  c. Describe cable and conductor troubleshooting techniques.
  d. Identify various types of cable and conductor failures and their potential causes.

## Performance Tasks

**Performance Task 1 (Learning Objective 1)**

- Physically distinguish between various types of cable, including twisted-pair, non-twisted-pair, and coaxial.

**Performance Task 2 (Learning Objective 2)**

- Terminate conductors using crimp connectors.

**Performance Task 3 (Learning Objective 2)**

- Terminate shielded cable.

**Performance Task 4 (Learning Objective 2)**

- Install a coaxial cable connector.

**Performance Task 5 (Learning Objective 3)**

- Test a cable using telephones.

**Performance Task 6 (Learning Objective 3)**

- Inspect a cable for defects and classify any defects found.

## Teaching Time: 20.0 hours

(Eight 2.5-Hour Sessions)

Session time may be adjusted to accommodate your class size, schedule, and teaching style.

## Prerequisites

*Core Curriculum*, *Instrumentation Level One*, and *Instrumentation Level Two*

## Before You Begin

As you prepare for each session, allow sufficient time to review the course objectives, content, visual aids, including the PowerPoint® presentation, and these lesson plans, and to gather the required equipment and materials. Consider the time required for demonstrations, laboratories, field trips, and testing.

Using your access code, download the module exams and Performance Profile Sheets from **www.nccerirc.com**. The passing score for submission into NCCER's Registry is 70% or above for the module exam; performance testing is graded pass or fail.

## Safety Considerations

This module requires that trainees work with tools and potentially energized equipment. Safety must be emphasized at all times. Trainees should be carefully observed to ensure that they wear the proper PPE, follow safe practices, and give due respect to unseen hazards. Any deficiencies must be corrected to ensure future trainee safety. All practice sessions and Performance Tasks must be completed under your direct supervision.

## Classroom Equipment and Materials

Whiteboard

Markers

Pencils and paper

*Instrumentation Level Three* PowerPoint® Presentation

DVD player or a computer with a DVD drive

LCD projector and screen

Computer with Internet access

Samples of UTP cable (multiple categories, if possible)

Samples of STP cable (multiple shield types, if possible)

Samples of coaxial cable (single and quad-shield, if possible)

Examples of UTP and STP terminations

Type 66 or type 110 punchdown block

Examples of coaxial cable terminations

Sample data communications plates, jacks, and connectors

Samples of properly and improperly terminated cables

Terminated screw-terminal, UTP, STP, and coaxial cables/wires

Termination tools (cutter, stripper, crimper, etc.)

Common cable terminations (screw-terminal, UTP, STP, and coaxial)

Unterminated cables/wires

AM radio

Personal computer

Telephone test set

Tone generator and cable toner

Cable tester

Certification field tester

TDR

Additional cable test instruments (if available)

Sample lengths of UTP or coaxial cable 50' or longer

Multimeter

Examples of failed cables

Review Questions answer key

Copies of the module examination (for paper-based exams) and Performance Profile Sheets

## Equipment and Materials for Laboratories and Performance Testing

Appropriate PPE, to include the following:

- Safety glasses
- Work gloves
- Proper footwear as designated by the instructor or training facility provider
- Hearing protection as designated by the instructor or training facility provider
- Hard hat as designated by the instructor or training facility provider

Selection of cables (twisted-pair, non-twisted-pair, coaxial)

Wire and crimp-type connectors

STP cables and terminations

Coaxial cables and terminations

Appropriate termination tools (cutters, strippers, crimpers)

Lengths of UTP cable

Telephone test sets

Examples of terminated cable with a number of defects

## Additional Resources

This module presents thorough resources for task training. The following resource material is suggested for further study.

*Cabling: The Complete Guide to Copper and Fiber-Optic Networking*, 2014. Andrew Oliviero and Bill Woodward. Indianapolis, IN: John Wiley & Sons, Inc.

Telecommunications Industry Association website, **www.tiaonline.org**

Instructors are also encouraged to locate additional audiovisual aids available on the Internet, make personal videos, and take still pictures related to the subject matter and add them to the PowerPoint® presentations throughout the program.

# Session Outline for 12307-16

# Terminating Conductors

The Lesson Plan for this module is divided into eight 2.5-hour sessions.
This time includes 10 minutes for administrative tasks and a 10-minute break per session.

## Session One

Session One introduces the low-voltage cabling used in instrumentation and data communications applications. Different cables types are examined and categorized. Twisted-pair cable is stressed and the different types and shielded varieties are compared. Coaxial cables are discussed as are the various types of cable terminations. This session covers Sections 1.0.0 through 1.2.3.

1. Show the Session One PowerPoint® presentation.
2. Use the Kickoff Activity to get trainees engaged and give them an idea of what they will learn from this module.
3. Introduce low-voltage cable of the types commonly used in instrumentation and data communications.
4. Discuss UTP cable, its categories, and its applications.
5. Discuss STP cable, its nomenclature, and its shielding systems.
6. Describe coaxial cable and the different ways that it's shielded.
7. Present the major categories of crimp, coaxial, and data communications cable terminations.

## Session Two

Session Two focuses on the proper way to terminate different types of cables. Crimp-on and coaxial terminations are stressed. Using the proper tools in the proper way is the key to reliable and long-lasting terminations. This session covers Sections 2.0.0 through 2.2.2.

1. Show the Session Two PowerPoint® presentation.
2. Use the Kickoff Activity to show how improper cable terminations can become a source of major problems.
3. Introduce cable termination tools and the proper way to prepare cables for termination.
4. Describe crimp-on connectors and the tools used to attach them.
5. Discuss the guidelines for crimp-type connections and the proper way to make them.
6. Introduce terminal blocks and the guidelines for cabling to them.
7. Discuss coaxial cable termination and the proper method for attaching each type of connector.

## Session Three

Session Three addresses the subjects of cable inspection and proper routing. Many cabling problems stem from improperly handling them and/or not protecting them from the environment. The issue of electromagnetic interference (EMI) is introduced, along with some of the ways in which it is managed and its effects minimized. This session covers Sections 2.3.0 through 2.4.2.

1. Show the Session Three PowerPoint® presentation.
2. Use the Kickoff Activity to demonstrate the role that a properly grounded shield can play in dealing with EMI.
3. Discuss cable routing and inspection. List common checkpoints used during inspections.
4. Introduce electromagnetic interference and explain how it passes from one cable to another.
5. Summarize common strategies for reducing EMI problems in cables, particularly through routing techniques.
6. Explain how shielded cables should be terminated.

## SESSION FOUR

Session Four surveys the primary tools used for testing cables. Testing as a means of confirming proper termination and routing as well as for diagnosis is addressed. Different types of tools are examined with a focus placed on their proper use. Causes for cable failure are briefly examined. This session covers Sections 3.0.0 through 3.4.3.

1. Show the Session Four PowerPoint® presentation.
2. Use the Kickoff Activity to provide an overview of how a TDR is used to measure cable length as well as to find faults in it.
3. Introduce and summarize the primary cable test instruments, focusing on their basic operation and major applications.
4. Summarize and define the key test parameters used when examining instrumentation and data cabling.
5. Describe common troubleshooting strategies and explain how even simple test instruments, such as a multimeter, can be used for basic fault-finding.
6. Discuss the common causes for low-voltage cable failure.

## SESSIONS FIVE THROUGH SEVEN

Sessions Five through Seven are laboratory sessions devoted to the practice and completion of Performance Tasks 1 through 6.

1. Note that no PowerPoint® presentations are associated with these laboratory sessions.
2. Demonstrate how to distinguish between various types of low-voltage cable, including twisted-pair, non-twisted-pair, and coaxial cable.
3. Demonstrate how to terminate cables using crimp-type connectors. Stress the correct use of the proper tools in this process.
4. Demonstrate how to terminate shielded cable using the proper tools and techniques.
5. Demonstrate how to terminate coaxial cable using the proper tools and techniques.
6. Demonstrate the telephone test set and explain how to use it to perform a basic continuity test on a cable.
7. Demonstrate the steps used to inspect a cable and identify faults. Emphasize determining the probable cause of faults as well, so future problems can be prevented.
8. Have trainees practice and/or complete the requirements of Performance Tasks 1 through 6 in these hands-on sessions.

## SESSION EIGHT

Session Eight is a review and testing session. Have the trainees complete the Module Review Questions. Alternatively, these may be assigned as homework at the end of Session Seven. Go over the answers to the Review Questions in class prior to the exam and answer any questions that the trainees may have.

1. Have trainees complete the module exam. Any outstanding performance testing must be completed during this session as well.
2. Record the testing results on the Registration of Training Modules form and submit the form to your Training Program Sponsor.

**Materials Checklist for Module 12307-16, Terminating Conductors**

| Equipment and Materials | | | | | |
|---|---|---|---|---|---|
| **Personal protective equipment:** | | Samples of UTP cable (multiple categories, if possible) | | Selection of cables (twisted-pair, non-twisted-pair, coaxial) | |
| Safety glasses | | Samples of STP cable (multiple shield types, if possible) | | Wire and crimp-type connectors | |
| Work gloves | | Samples of coaxial cable (single and quad-shield, if possible) | | STP cables and terminations | |
| Proper footwear as designated by the instructor or training facility provider | | Examples of UTP and STP terminations | | Coaxial cables and terminations | |
| Hearing protection as designated by the instructor or training facility provider | | Type 66 or type 110 punchdown block | | Appropriate termination tools (cutters, strippers, crimpers) | |
| Hard hat as designated by the instructor or training facility provider | | Examples of coaxial cable terminations | | Lengths of UTP cable | |
| Whiteboard | | Sample data communications plates, jacks, and connectors | | Telephone test sets | |
| Markers | | Samples of properly and improperly terminated cables | | Examples of terminated cable with a number of defects | |
| Pencils and paper | | Terminated screw-terminal, UTP, STP, and coaxial cables/ wires | | | |
| *Instrumentation Level Three* PowerPoint® Presentation | | Termination tools (cutter, stripper, crimper, etc.) | | | |
| DVD player or a computer with a DVD drive | | Common cable terminations (screw-terminal, UTP, STP, and coaxial) | | | |
| LCD projector and screen | | Unterminated cables/wires | | | |
| Computer with Internet access | | Telephone test set | | | |
| AM radio | | Tone generator and cable toner | | | |
| Personal computer | | Cable tester | | | |
| Multimeter | | Certification field tester | | | |
| Review Questions answer key | | TDR | | | |
| Copies of the module examination (for paper-based exams) and Performance Profile Sheets | | Additional cable test instruments (if available) | | | |
| | | Sample lengths of UTP or coaxial cable 50' or longer | | | |
| | | Examples of failed cables | | | |

To the extent possible, and as required for performance testing, provide a selection of the tools listed for each session; alternatively, photos may be used to teach tool identification.

# Grounding and Shielding of Instrumentation Wiring

**Module Seven (12306-16)** addresses the concept of grounding in instrumentation settings. Grounding carries with it two distinct aspects. First of all, it is necessary to ensure safely operating equipment that minimizes risk for those who use it. Second, grounding is a key facet in dealing with electromagnetic noise and interference in instrumentation systems. Most shielding approaches involve ground connections as a part of their basic operation. Failing to understand grounding can result both in hazardous situations and ones in which a shielding system fails to do its job, leading to unreliable equipment performance.

## Objectives

**Learning Objective 1**

- Define grounding and bonding and describe grounding and bonding techniques.
  a. Describe grounding and bonding and define key terms.
  b. Describe basic grounding components and techniques.
  c. Describe bonding and its purpose.

**Learning Objective 2**

- Describe different types of electromagnetic interference and identify methods to reduce or eliminate its influence.
  a. Describe capacitive-coupled noise.
  b. Describe inductive-coupled noise.
  c. Describe directly-coupled noise.
  d. Describe cable shielding and grounding techniques.

## Performance Tasks

**Performance Task 1 (Learning Objective 1)**

- Identify and explain the function of an equipment ground identified in an instructor-provided drawing.

**Performance Task 2 (Learning Objective 2)**

- Draw an example of a ground loop.

**Performance Task 3 (Learning Objective 2)**

- Identify and explain the function of an equipment shield in an instructor-provided drawing.

## Teaching Time: 10.0 hours

(Four 2.5-Hour Sessions)

Session time may be adjusted to accommodate your class size, schedule, and teaching style.

## Prerequisites

*Core Curriculum*, *Instrumentation Level One*, and *Instrumentation Level Two*

## Before You Begin

As you prepare for each session, allow sufficient time to review the course objectives, content, visual aids, including the PowerPoint® presentation, and these lesson plans, and to gather the required equipment and materials. Consider the time required for demonstrations, laboratories, field trips, and testing.

Using your access code, download the module exams and Performance Profile Sheets from **www.nccerirc.com**. The passing score for submission into NCCER's Registry is 70% or above for the module exam; performance testing is graded pass or fail.

## Safety Considerations

Safety must be emphasized at all times. Trainees should be carefully observed to ensure that they wear the proper PPE, follow safe practices, and give due respect to unseen hazards. Any deficiencies must be corrected to ensure future trainee safety. All practice sessions and Performance Tasks must be completed under your direct supervision.

## Classroom Equipment and Materials

Whiteboard

Markers

Pencils and paper

*Instrumentation Level Three* PowerPoint® Presentation

DVD player or a computer with a DVD drive

LCD projector and screen

Computer with Internet access

Grounding rod

Grounding conductor

Several examples of shielded cables

Backshell connectors with mating connectors

Review Questions answer key

Copies of the module examination (for paper-based exams) and Performance Profile Sheets

## Equipment and Materials for Laboratories and Performance Testing

Appropriate PPE, to include the following if this laboratory is not conducted in a regular classroom:

- Safety glasses
- Work gloves
- Proper footwear as designated by the instructor or training facility provider
- Hearing protection as designated by the instructor or training facility provider
- Hard hat as designated by the instructor or training facility provider

Selection of drawings showing grounding and shields

## Additional Resources

This module presents thorough resources for task training. The following resource material is suggested for further study.

*Grounding and Shielding in Facilities*, Ralph Morrison. 1990. New York, NY: John Wiley & Sons.

*Grounding and Shielding Techniques*, Ralph Morrison. Fourth edition. 1998. New York, NY: John Wiley & Sons.

*National Electrical Code® Handbook 2014*, Mark W. Earley, Christopher D. Coache, Mark Cloutier, and Gil Moniz. Thirteenth Edition. 2013. Quincy, MA: National Fire Protection Association.

Instructors are also encouraged to locate additional audiovisual aids available on the Internet, make personal videos, and take still pictures related to the subject matter and add them to the PowerPoint® presentations throughout the program.

## Session Outline for 12306-16

# Grounding and Shielding of Instrumentation Wiring

The Lesson Plan for this module is divided into four 2.5-hour sessions.
This time includes 10 minutes for administrative tasks and a 10-minute break per session.

## Session One

Session One introduces electrical grounding from the equipment and safety point of view. The function of grounding is to protect operators against accidental contact with dangerous voltages. Different types of grounding systems are considered and the proper way of bonding equipment is addressed. This session covers Sections 1.0.0 through 1.3.1.

1. Show the Session One PowerPoint® presentation.
2. Use the Kickoff Activity to get trainees engaged and give them an idea of what they will learn from this module.
3. Provide an overview of electrical grounding and its associated terminology.
4. Broadly discuss the *NEC*® grounding requirements.
5. Summarize basic grounding concepts and the ways that systems and devices can be grounded.
6. Address bonding and its role in creating a safe electrical system.

## Session Two

Session Two addresses electromagnetic interference and the role that grounding and shielding play in controlling it. Different types and sources of noise are considered. Ways in which noise enters a system are discussed. Cable shielding is explored and the different types of shielding are compared. This session covers Sections 2.0.0 through 2.4.5.

1. Show the Session Two PowerPoint® presentation.
2. Use the Kickoff Activity to help trainees understand shielding systems and the different types of cable shields.
3. Discuss electromagnetic noise and its various forms.
4. Describe the different ways in which noise enters a system.
5. Explain how cable shielding works to control noise.
6. Discuss ground loops and the proper way to terminate a shield.

## Session Three

Session Three is a laboratory session devoted to the practice and completion of Performance Tasks 1, 2, and 3.

1. Note that no PowerPoint® presentation is associated with this laboratory session.
2. Demonstrate how to identify and explain the function of an equipment ground in a drawing.
3. Demonstrate how to draw an example of a ground loop.
4. Demonstrate how to identify and explain the function of an equipment shield in a drawing.
5. Have trainees practice and/or complete the requirements of Performance Tasks 1, 2, and 3 in this hands-on session.

## Session Four

Session Four is a review and testing session. Have the trainees complete the Module Review Questions. Alternatively, these may be assigned as homework at the end of Session Three. Go over the answers to the Review Questions in class prior to the exam and answer any questions that the trainees may have.

1. Have trainees complete the module exam. Any outstanding performance testing must be completed during this session as well.
2. Record the testing results on the Registration of Training Modules form and submit the form to your Training Program Sponsor.

**Materials Checklist for Module 12306-16, Grounding and Shielding of Instrumentation Wiring**

| Equipment and Materials | | | | | |
|---|---|---|---|---|---|
| **Personal protective equipment:** | | Grounding rod | | Selection of drawings showing grounding and shields | |
| Safety glasses | | Grounding conductor | | | |
| Work gloves | | Several examples of shielded cables | | | |
| Proper footwear as designated by the instructor or training facility provider | | Backshell connectors with mating connectors | | | |
| Hearing protection as designated by the instructor or training facility provider | | | | | |
| Hard hat as designated by the instructor or training facility provider | | | | | |
| Whiteboard | | | | | |
| Markers | | | | | |
| Pencils and paper | | | | | |
| *Instrumentation Level Three* PowerPoint® Presentation | | | | | |
| DVD player or a computer with a DVD drive | | | | | |
| LCD projector and screen | | | | | |
| Computer with Internet access | | | | | |
| Review Questions answer key | | | | | |
| Copies of the module examination (for paper-based exams) and Performance Profile Sheets | | | | | |

To the extent possible, and as required for performance testing, provide a selection of the tools listed for each session; alternatively, photos may be used to teach tool identification.

# Lesson Plans for Module 12204-16

# Process Control Theory

**Module Eight (12204-16)** presents the basics of process control theory. Understanding how processes are measured and control decisions are made is crucial to implementing and maintaining the systems that keep processes happening reliably and safely. Trainees will learn about the basic features of control theory. They will examine different types of loop control, along with the advantages and disadvantages of each type. Finally, they will see how typical process measurements are used in control loops.

## Objectives

### Learning Objective 1

- Describe process control and identify basic components of the instrumentation control channel.
  a. Describe the basic characteristics of a process.
  b. Define and describe basic process control.
  c. Identify basic components of an instrumentation control channel.
  d. Identify and describe basic types of final control elements.

### Learning Objective 2

- Define and describe the basic types of process control loops.
  a. Define and describe open control loops.
  b. Define and describe closed control loops.
  c. Define and describe cascade control.
  d. Define and describe ratio control.

### Learning Objective 3

- Identify and describe various control modes.
  a. Identify and describe on-off control modes.
  b. Identify and describe various modulating control modes.

### Learning Objective 4

- Describe various control applications and explain their basic strategies.
  a. Describe the operation of typical temperature-control loops.
  b. Describe the operation of typical pressure-control loops.
  c. Describe the operation of typical level-control loops.
  d. Describe the operation of typical flow-control loops.

## Performance Tasks

**Performance Task 1 (Learning Objective 1)**

- Draw and accurately label a block diagram for a basic process control loop.

**Performance Task 2 (Learning Objective 2)**

- From a piping and instrumentation drawing (P&ID), identify the major components of each of these process control loop types:
  - Feedforward
  - Feedback
  - Cascade
  - Ratio

## Teaching Time: 25.0 hours

(Ten 2.5-Hour Sessions)

Session time may be adjusted to accommodate your class size, schedule, and teaching style.

## Prerequisites

*Core Curriculum*, *Instrumentation Level One*, and *Instrumentation Level Two*

## Before You Begin

As you prepare for each session, allow sufficient time to review the course objectives, content, visual aids, including the PowerPoint® presentation, and these lesson plans, and to gather the required equipment and materials. Consider the time required for demonstrations, laboratories, field trips, and testing.

Using your access code, download the module exams and Performance Profile Sheets from **www.nccerirc.com**. The passing score for submission into NCCER's Registry is 70% or above for the module exam; performance testing is graded pass or fail.

## Safety Considerations

This module requires that trainees work with tools and potentially energized equipment. Safety must be emphasized at all times. Trainees should be carefully observed to ensure that they wear the proper PPE, follow safe practices, and give due respect to unseen hazards. Any deficiencies must be corrected to ensure future trainee safety. All practice sessions and Performance Tasks must be completed under your direct supervision.

## Classroom Equipment and Materials

Whiteboard
Markers
Pencils and paper
*Instrumentation Level Three* PowerPoint® Presentation
DVD player or a computer with a DVD drive
LCD projector and screen
Computer with Internet access
Review Questions answer key
Copies of the module examination (for paper-based exams) and Performance Profile Sheets
Sensors
Transducers
Amplifier/signal conditioner
Transmitter
Controller
Simple bimetallic thermostat
PID-capable controller
Temperature transmitter (pneumatic or electronic)
Pressure transmitter (pneumatic or electronic)
Level transmitter (pneumatic or electronic)
Flow transmitter (pneumatic or electronic)

## Equipment and Materials for Laboratories and Performance Testing

Appropriate PPE to include the following if this laboratory is not conducted in a regular classroom:

- Safety glasses
- Work gloves
- Proper footwear as designated by the instructor or training facility provider
- Hearing protection as designated by the instructor or training facility provider
- Hard hat as designated by the instructor or training facility provider

P&ID drawings

## Additional Resources

This module presents thorough resources for task training. The following resource material is suggested for further study.

*Instrument Engineers' Handbook, Volume 1: Process Measurement and Analysis*, Béla G. Lipták (editor). Fourth Edition. 2003. Boca Raton, FL: CRC Press.

*Instrument Engineers Handbook, Volume 2: Process Control and Optimization*, Béla G. Lipták (editor). Fourth Edition. 2006. Boca Raton, FL: CRC Press.

*Measurement and Control Basics*, Thomas A. Hughes. Fifth Edition. 2014. Research Triangle Park, NC: International Society of Automation (ISA).

*The Condensed Handbook of Measurement and Control*, N.E. Battikha. Third Edition, 2006. Research Triangle Park, NC: The International Society of Automation, (ISA), **www.isa.org**

Instructors are also encouraged to locate additional audiovisual aids available on the Internet, make personal videos, and take still pictures related to the subject matter and add them to the PowerPoint® presentations throughout the program.

## Session Outline for 12204-16

# Process Control Theory

The Lesson Plan for this module is divided into ten 2.5-hour sessions.
This time includes 10 minutes for administrative tasks and a 10-minute break per session.

## Session One

Session One introduces the subject of process control and the various tools that make a process happen. Processes are defined and examined, as are the factors that influence how they behave. The concept of maintaining control over a process output relative to its inputs is examined. The different components in a process control channel are discussed. This session covers Sections 1.0.0 through 1.2.0.

1. Show the Session One PowerPoint® presentation.
2. Use the Kickoff Activity to get trainees engaged and give them an idea of what they will learn from this module.
3. Introduce and define the idea of a process.
4. Discuss disturbances and their effects on processes. Use this idea as the basis for control systems.
5. Present the idea that a process is essentially an energy or material balance equation with inputs and outputs.
6. Introduce the concept of process limits and the need to maintain an equilibrium condition.
7. Describe a process control system and its role in controlling process variables. Define the two key variables involved.
8. List the hardware involved in a process control system.

## Session Two

Session Two explores in greater detail the components of an instrument channel. Sensors, transducers, amplifiers, transmitters, and controllers are introduced. The way these components function together to create the instrument channel is addressed. The final control element is examined; since it is often a valve, different valve types are explored. Types of actuators are also introduced. Finally, the technology used to ensure accurate valve positioning is examined. This session covers Sections 1.3.0 through 1.4.5.

1. Show the Session Two PowerPoint® presentation.
2. Use the Kickoff Activity to introduce the trainees to different types of sensors used in process control.
3. Describe the key parts of an instrument channel.
4. Define and explain the role of detectors, transducers, amplifiers, transmitters, and controllers in the instrument chain. Note that there are many different ways for these components to be combined and packaged.
5. Introduce the idea of the final control element (often a valve).
6. Describe different valve types and the actuator technologies that control them.
7. Discuss the need for accurate control of the final element.

## SESSION THREE

Session Three presents information on types of control loops used to maintain equilibrium. Four different categories are examined and their relative advantages and disadvantages are considered. Feedback is studied in more detail, as it's one of the major control methods. Issues commonly encountered are examined. Cascade control is treated as an extension of feedback. Finally, ratio control is introduced as a specialized type of closed-loop control. This session covers Sections 2.0.0 through 2.4.0.

1. Show the Session Three PowerPoint® presentation.
2. Use the Kickoff Activity to provide a graphical overview of feedforward (open-loop) control.
3. Introduce the idea of a control loop as a means by which a process is manipulated and adjusted.
4. Define *feedforward control* and examine its basic qualities.
5. Define *feedback control* and look at it in some detail, particularly in the way that its quality is assessed.
6. Discuss cascade control as a variant of basic feedback control.
7. Define *ratio control* as a specialized type of closed-loop control used when two variables must be maintained in a particular ratio relationship to each other.

## SESSION FOUR

Session Four moves into some of the details of closed-loop control. On-off control is examined as the simplest version of this form of control. Its advantages and weaknesses are examined. Methods of reducing its weaknesses are considered. The consequences of these methods are considered as well. This session covers Sections 3.0.0 through 3.1.0.

1. Show the Session Four PowerPoint® presentation.
2. Use the Kickoff Activity to introduce on-off control through a familiar example.
3. Introduce on-off control as the simplest form of closed-loop control.
4. Explain the idea of a process setpoint, measurement, and error. Discuss how on-off control reacts to error.
5. Mention how adding a neutral zone corrects one weakness of on-off control (excessive cycling).
6. Explain how the neutral zone can make the process overshoot and undershoot the setpoint.

## SESSION FIVE

Session Five moves deeper into closed-loop control by looking at more sophisticated ways of controlling the process. Different kinds of modulated control are examined, each of which has certain positive and negative qualities. The concept of gain and proportionality is introduced and examined mathematically. Proportional, Integral, and Derivative control modes are examined both singly and in combination. This session covers Sections 3.2.0 through 3.2.6.

1. Show the Session Five PowerPoint® presentation.
2. Use the Kickoff Activity to point out the limitations of on-off control and lead into modulated control.
3. Introduce modulating control as an improvement over on-off control, particularly as a result of its ability to continuously adjust the process.
4. Discuss proportional control and define the terms *gain* and *proportional band*. Show their mathematical description and relationship.
5. Discuss integral control and explain what is gained by using it.
6. Discuss derivative control and explain what is gained by using it.
7. Discuss combinations of P, I, and D control and explain their specific advantages and disadvantages.

Session Outline for 12204-16

# Process Control Theory

## Session Six

Session Six examines process control from the perspective of specific variables. Temperature and pressure are addressed. Each is considered from both an electronic and a pneumatic context. This session covers Sections 4.0.0 through 4.2.2.

1. Show the Session Six PowerPoint® presentation.
2. Use the Kickoff Activity to expose trainees to pneumatic temperature control as an example of a typical control loop approach.
3. Introduce the four key variables monitored in typical processes.
4. Describe a pneumatic temperature-control loop and its components.
5. Describe an electronic temperature-control loop and its components.
6. Describe a pneumatic pressure-control loop and its components.
7. Describe an electronic pressure-control loop and its components.

## Session Seven

Session Seven examines process control from the perspective of specific variables. Level and flow are addressed. Each is considered from both an electronic and a pneumatic context. This session covers Sections 4.3.0 through 4.4.2.

1. Show the Session Seven PowerPoint® presentation.
2. Use the Kickoff Activity to give trainees a chance to ask questions and request clarification of difficult concepts.
3. Describe a pneumatic level-control loop and its components.
4. Describe an electronic level-control loop and its components.
5. Describe a pneumatic flow-control loop and its components.
6. Describe an electronic flow-control loop and its components.

## Sessions Eight and Nine

Sessions Eight and Nine are laboratory sessions devoted to the practice and completion of Performance Tasks 1 and 2.

1. Note that no PowerPoint® presentations are associated with these laboratory sessions.
2. Demonstrate how to draw and accurately label a block diagram for a basic process control loop.
3. Demonstrate how to use a piping and instrumentation drawing (P&ID) to identify the major components of each of these process control loop types: feedforward, feedback, cascade, and ratio.
4. Have trainees practice and/or complete the requirements of Performance Tasks 1 and 2.

## Session Ten

Session Ten is a review and testing session. Have the trainees complete the Module Review Questions. Alternatively, these may be assigned as homework at the end of Session Nine. Go over the answers to the Review Questions in class prior to the exam and answer any questions that the trainees may have.

1. Have trainees complete the module exam. Any outstanding performance testing must be completed during this session as well.
2. Record the testing results on the Registration of Training Modules form and submit the form to your Training Program Sponsor.

**Materials Checklist for Module 12204-16, Process Control Theory**

| Equipment and Materials | | | | | |
|---|---|---|---|---|---|
| **Personal protective equipment:** | | Sensors | | P&ID drawings | |
| Safety glasses | | Transducers | | | |
| Work gloves | | Amplifier/signal conditioner | | | |
| Proper footwear as designated by the instructor or training facility provider | | Transmitter | | | |
| Hearing protection as designated by the instructor or training facility provider | | Controller | | | |
| Hard hat as designated by the instructor or training facility provider | | Simple bimetallic thermostat | | | |
| Whiteboard | | PID-capable controller | | | |
| Markers | | Temperature transmitter (pneumatic or electronic) | | | |
| Pencils and paper | | Pressure transmitter (pneumatic or electronic) | | | |
| Instrumentation Level Three PowerPoint® Presentation | | Level transmitter (pneumatic or electronic) | | | |
| DVD player or a computer with a DVD drive | | Flow transmitter (pneumatic or electronic) | | | |
| LCD projector and screen | | | | | |
| Computer with Internet access | | | | | |
| Review Questions answer key | | | | | |
| Copies of the module examination (for paper-based exams) and Performance Profile Sheets | | | | | |

To the extent possible, and as required for performance testing, provide a selection of the tools listed for each session; alternatively, photos may be used to teach tool identification.

# Lesson Plans for Module 12206-16

# Controllers

**Module Nine (12206-16)** introduces the heart of any instrumentation system: the controller. This module introduces the trainees to the two major technology families used for control: pneumatic and electronic. Broad principles of control are addressed for both types of controllers. A number of specific controllers are also examined in order to provide a few examples of these principles in action.

## Objectives

**Learning Objective 1**

- Identify and describe the operation of various pneumatic and electronic controllers.
  a. Identify and describe controllers and their common operating modes.
  b. Identify and describe basic and specific pneumatic controller configurations.
  c. Identify and describe basic electronic controller configurations.

## Performance Tasks

**Performance Task 1 (Learning Objective 1)**

- Given a schematic for a pneumatic controller, explain the purpose and operation of all major components.

**Performance Task 2 (Learning Objective 1)**

- Given a block diagram of an electronic controller, explain the function of each block.

## Teaching Time: 10.0 hours

(Four 2.5-Hour Sessions)

Session time may be adjusted to accommodate your class size, schedule, and teaching style.

## Prerequisites

*Core Curriculum*, I*nstrumentation Level One*, and *Instrumentation Level Two*

## Before You Begin

As you prepare for each session, allow sufficient time to review the course objectives, content, visual aids, including the PowerPoint® presentation, and these lesson plans, and to gather the required equipment and materials. Consider the time required for demonstrations, laboratories, field trips, and testing.

Using your access code, download the module exams and Performance Profile Sheets from **www.nccerirc.com**. The passing score for submission into NCCER's Registry is 70% or above for the module exam; performance testing is graded pass or fail.

## Safety Considerations

Safety must be emphasized at all times. Trainees should be carefully observed to ensure that they wear the proper PPE, follow safe practices, and give due respect to unseen hazards. Any deficiencies must be corrected to ensure future trainee safety. All practice sessions and Performance Tasks must be completed under your direct supervision.

## Classroom Equipment and Materials

Whiteboard

Markers

Pencils and paper

*Instrumentation Level Three* PowerPoint® Presentation

DVD player or a computer with a DVD drive

LCD projector and screen

Computer with Internet access

Review Questions answer key

Copies of the module examination (for paper-based exams) and Performance Profile Sheets

Pneumatic controllers

Analog electronic controllers

Digital electronic controllers

## Equipment and Materials for Laboratories and Performance Testing

Appropriate PPE, to include the following if this laboratory is not conducted in a regular classroom:

- Safety glasses
- Work gloves
- Proper footwear as designated by the instructor or training facility provider
- Hearing protection as designated by the instructor or training facility provider
- Hard hat as designated by the instructor or training facility provider

Pneumatic controller schematics

Electronic controller block diagrams

## Additional Resources

This module presents thorough resources for task training. The following resource material is suggested for further study.

*Instrument Engineers Handbook, Volume 2: Process Control and Optimization*, Béla G. Lipták (editor). Fourth Edition. 2006. Boca Raton, FL: CRC Press.

*National Electrical Code® Handbook 2014*, Mark W. Earley, Christopher D. Coache, Mark Cloutier, and Gil Moniz. Thirteenth Edition. 2013. Quincy, MA: National Fire Protection Association.

*The Condensed Handbook of Measurement and Control*, N.E. Battikha. Third Edition, 2006. Research Triangle Park, NC: The International Society of Automation.

Dwyer Instruments, **www.dwyer-inst.com**

Emerson Electric Co., **www.emerson.com**

Micromod Automation and Controls, **www.micromod.com**

Omega Engineering, **www.omega.com**

Instructors are also encouraged to locate additional audiovisual aids available on the Internet, make personal videos, and take still pictures related to the subject matter and add them to the PowerPoint® presentations throughout the program.

# Session Outline for 12206-16

# CONTROLLERS

The Lesson Plan for this module is divided into four 2.5-hour sessions.
This time includes 10 minutes for administrative tasks and a 10-minute break per session.

## SESSION ONE

Session One introduces controllers and summarizes the different ways in which they operate. While this module focuses largely on automatic control, the other modes are briefly explored. Pneumatic controllers are summarized, as are the basic control configurations. Several specific pneumatic controllers are examined to connect the discussion to real systems. This session covers Sections 1.0.0 through 1.2.9.

1. Show the Session One PowerPoint® presentation.
2. Use the Kickoff Activity to get trainees engaged and to briefly review the big ideas of process control.
3. Summarize the purpose and operation of a controller.
4. Summarize the four control modes, stressing automatic control as the most commonly used.
5. Discuss the basic operation of a pneumatic controller and examine the different control configurations that they can use.
6. Examine several specific pneumatic controllers in order to connect theory to practice.

## SESSION TWO

Session Two addresses electronic controllers and compares them to pneumatic control. Advantages are stressed and the basic features of an electronic controller are examined. The same control configurations are examined from an electronic-control perspective. Finally, several specific electronic controllers are surveyed. This session covers Sections 1.3.0 through 1.3.4.

1. Show the Session Two PowerPoint® presentation.
2. Use the Kickoff Activity to help trainees see the advantages of electronic control over pneumatic control.
3. Summarize electronic controllers and list their key advantages over pneumatic controllers.
4. Discuss the basic operation of an electronic controller and examine the different control configurations that they can use.
5. Examine several specific electronic controllers to connect theory to practice.

## SESSION THREE

Session Three is a laboratory session devoted to the practice and completion of Performance Tasks 1 and 2.

1. Note that no PowerPoint® presentation is associated with this laboratory session.
2. Demonstrate how to explain the purpose and operation of all major components in a pneumatic controller.
3. Demonstrate how to explain the function of each block in an electronic controller.
4. Trainees practice and/or complete the requirements of Performance Tasks 1 and 2 in this hands-on session.

## SESSION FOUR

Session Four is a review and testing session. Have the trainees complete the Module Review Questions. Alternatively, these may be assigned as homework at the end of Session Three. Go over the answers to the Review Questions in class prior to the exam and answer any questions that the trainees may have.

1. Have trainees complete the module exam. Any outstanding performance testing must be completed during this session as well.
2. Record the testing results on the Registration of Training Modules form and submit the form to your Training Program Sponsor.

**Materials Checklist for Module 12206-16, Controllers**

| Equipment and Materials | | | | | |
|---|---|---|---|---|---|
| **Personal protective equipment:** | | Pneumatic controllers | | Pneumatic controller schematics | |
| Safety glasses | | Analog electronic controllers | | Electronic controller block diagrams | |
| Work gloves | | Digital electronic controllers | | | |
| Proper footwear as designated by the instructor or training facility provider | | | | | |
| Hearing protection as designated by the instructor or training facility provider | | | | | |
| Hard hat as designated by the instructor or training facility provider | | | | | |
| Whiteboard | | | | | |
| Markers | | | | | |
| Pencils and paper | | | | | |
| *Instrumentation Level Three* PowerPoint® Presentation | | | | | |
| DVD player or a computer with a DVD drive | | | | | |
| LCD projector and screen | | | | | |
| Computer with Internet access | | | | | |
| Review Questions answer key | | | | | |
| Copies of the module examination (for paper-based exams) and Performance Profile Sheets | | | | | |

To the extent possible, and as required for performance testing, provide a selection of the tools listed for each session; alternatively, photos may be used to teach tool identification.