AC BASICS – Electronics Module 2 (EM2)

COMPETENCY REQUIREMENTS

The five ETA Electronics Modules (EMs) are stand-alone certifications in five basic areas of electronics competency – DC, **AC**, Analog, Digital, and Comprehensive. These competencies are based upon the full Associate CET (CETa) certification program. Once a technician earns all five EM certifications, ETA will issue an official Associate CET certification.

Because there are basic fundamental competencies that apply to all the modules and a technician's job may require only one EM, the same competency may appear in more than one EM certification.

1.0 Basic Electrical Safety Precautions

- 1.1 Describe safe practices and standards for working with electrical and electronic devices including:
  - 1.1.1 precautions required in the area of electronics safety
  - 1.1.2 the "one hand" rule
  - 1.1.3 the use of personal protective equipment (PPE) including eye and ear protection
  - 1.1.4 what the NEC® (National Electrical Code) and NFPA® (National Fire Protection Association) are and various rules technicians must follow
- 1.2 Describe electrical shock, its causes and effects
  - 1.2.1. Describe the human physiological reactions to electrical shock
  - 1.2.2. List degrees of current the human body can tolerate, and their effects
  - 1.2.3. Explain how to help someone who is being shocked without unnecessarily endangering yourself
  - 1.2.4. List NEC® standards regarding safe AC, DC and wet-environment voltages
- 1.3 Define basic fire safety
  - 1.3.1. Describe the different classes of fire and types of extinguishers used to fight them
    - 1.3.1.1. Class A
    - 1.3.1.2. Class B
    - 1.3.1.3. Class C
    - 1.3.1.4. Class D
    - 1.3.1.5. Class K
  - 1.3.2. Describe ignition hazards associated with items such as soldering irons, heat guns and solvents, and proper precautions
- 1.4 Describe other basic emergency precautions, procedures and responses
  - 1.4.1. Explain First Aid concepts important in the electrical and electronic fields
  - 1.4.2. Describe first, second and third degree burns and list appropriate treatments
  - 1.4.3. Describe dangers associated with items such as soldering irons, heat guns, and solvents

2.0 Principles of Alternating Current (AC)

- 2.1 Define "alternating current" (AC) and compare it to "direct current" (DC)
  - 2.1.1. Describe polarity including:
    - 2.1.1.1. periodic voltage
    - 2.1.1.2. current reversal
- 2.2 Define wave, waveform, sinewave and frequency
- 2.3 Identify the following terms:
  - 2.3.1. Cycle
  - 2.3.2. Frequency units of measure:
    - 2.3.2.1. Hertz (Hz)
    - 2.3.2.2. Kilohertz (kHz)
    - 2.3.2.3. Megahertz (MHz)
  - 2.3.3. Phase and phase angle
- 2.4 Describe AC waveform characteristics including:
  - 2.4.1. effective voltage (Root-Mean-Square, RMS)
  - 2.4.2. Average voltage
  - 2.4.3. Peak voltage

- 2.4.4. Peak-to-peak voltage
- 2.4.5. Positive alternation
- 2.4.6. Negative alternation
- 2.4.7. Period
- 2.4.8. Amplitude
- 2.4.9. Harmonics

2.5 Describe how period and frequency are reciprocal
- 2.5.1. Explain voltage and period values for AC sine wave calculations

2.6 Describe the unique harmonic characteristic of the sine waveform and why that is often useful
- 2.6.1. Explain the relationship between a circle and a sine wave
- 2.6.2. Explain why points along a sine wave are associated with degrees
- 2.6.3. Define and discuss phasors/vectors

3.0 Basic AC Mathematics and Formulas

3.1 Quote voltage, current, resistance and power formulas (Ohm's and Watt's laws) solving for circuit values
- 3.1.1. Describe voltage and current relationships in:
  - 3.1.1.1. series circuits
  - 3.1.1.2. parallel circuits
  - 3.1.1.3. series-parallel circuits

3.2 List other common basic electronics formulas relative to AC electronics including:
- 3.2.1. basic trigonometric math and its application in AC electronics
- 3.2.2. two and four quadrant graphs
- 3.2.3. linear versus proportional versus logarithmic scales

3.3 Describe basic functions of a scientific calculator

3.4 Define standard prefixes used in electronics:
- 3.4.1. giga (G)
- 3.4.2. mega (M)
- 3.4.3. kilo (k)
- 3.4.4. milli (m)
- 3.4.5. micro (μ)
- 3.4.6. nano (n)
- 3.4.7. pico (p)
- 3.4.8. femto (f)

3.5 Describe how to make standard metric conversions from one prefix to another

4.0 Electronic Components and Terms

4.1 Identify common symbols used in AC schematic diagrams

4.2 Explain what a capacitor is and types
- 4.2.1. Describe a capacitor's construction in basic terms:
  - 4.2.1.1. Explain capacitor plates and their functions
  - 4.2.1.2. Explain capacitor dielectric and its function
  - 4.2.1.3. Explain connecting leads
- 4.2.2. Compare fixed and variable capacitors
  - 4.2.2.1. Describe electrolytic capacitors
- 4.2.3. Discuss polarized and non-polarized capacitors
- 4.2.4. List common uses of capacitors

4.3 Explain what an inductor is and types
- 4.3.1. Describe an inductor's construction in basic terms:
  - 4.3.1.1. an inductor coil and its function(s)
  - 4.3.1.2. an inductor core and its function(s)
  - 4.3.1.3. inductor turn(s) and its function
- 4.3.2. Compare air core, ferrite core and soft iron core inductors
  - 4.3.2.1. Identify an approximate frequency range where each is used
- 4.3.3. List common uses for inductors

4.4 Explain what a transformer is and what it does
- 4.4.1. Describe a transformer's construction in basic terms:
  - 4.4.1.1. Describe a transformer core and its function(s)
  - 4.4.1.2. Explain a transformer’s windings and its function including:

4.4.1.2.1. Primary
4.4.1.2.2. Secondary
4.4.1.3. Define transformer turn(s) and its function
4.4.2. List common types of transformers
4.4.3. List common uses of transformers
4.5 Identify and explain the following terms:
4.5.1. Reluctance (cursive R = $\mathcal{R}$)
4.5.2. Capacitance (C)
4.5.3. Inductance (L)
4.5.4. Reactance (X)
4.5.5. Impedance (Z)
4.5.6. Permeability

5.0 Principles of Capacitance

5.1 Describe Farad (F) as the unit of measure of capacitance including its prefixes used
5.2 Identify formulas for calculating series and parallel capacitances including:
5.2.1. a capacitor's charge/discharge rate versus current
5.3 Explain how a capacitor stores energy as an electrical charge in its dielectric between its plates
5.4 Explain how a capacitor opposes changes in voltage
5.4.1. Identify the current that would flow through an ideal capacitor (one without leakage) when voltage across it is constant (not changing)
5.4.2. Identify the current that would momentarily flow if a charged ideal capacitor were short-circuited
5.5 Describe capacitive reactance (X_C) and compare it to resistance
5.5.1. Explain how capacitive reactance varies with frequency
5.5.1.1. Identify the reactance formula for various capacitances and frequencies
5.6 Describe the phase relationship between AC voltage across a capacitor and current flowing through the capacitor
5.6.1. Summarize the mnemonic “ELI the ICE man” regarding capacitance
5.7 Describe a capacitor's voltage and current limits
5.8 Discuss how high temperature affects life expectancy in an electrolytic capacitor
5.9 Explain the dangers a high-voltage or high-capacitance capacitor may pose even in de-energized equipment

6.0 Principles of Inductance

6.1 Describe Henry (H) as the unit of measure of inductance including its prefixes used
6.2 Differentiate between self-inductance and mutual inductance
6.3 Identify formulas for calculating series and parallel inductances
6.4 Explain how an inductor stores energy in the magnetic field in and around it
6.5 Describe how an inductor opposes changes in current
6.5.1. Explain the formula describing an inductor’s current rate of change versus voltage across it
6.5.1.1. Explain what happens when a current-carrying inductor is suddenly open-circuited, and what it's called
6.5.1.2. Explain why this may cause problems and how to deal with them
6.5.1.3. Identify the voltage across an ideal inductor when current is constant (not changing)
6.6 Describe inductive reactance (X_L), comparing it to capacitive reactance and resistance
6.6.1. Describe how inductive reactance varies with frequency and give the formula
6.6.1.1. Identify the reactance of an ideal inductor at a frequency of zero (DC)
6.6.1.2. Calculate reactances for various inductors and frequencies
6.7 Describe the phase relationship between AC voltage across an inductor and current flowing through it
6.7.1. Summarize the mnemonic “ELI the ICE man” regarding inductance
6.8 Discuss an inductor's voltage and current limits
6.9 Discuss “eddy currents” and why low-frequency transformer cores are laminated

7.0 Principles of Transformers

- 7.1 Explain how a typical transformer is connected to the voltage source and load
- 7.2 Explain how a transformer gets power from primary to secondary with no electrical connection
  - 7.2.1. Explain why a transformer will not work with DC
- 7.3 List common frequency ranges for air-core, ferrite-core and iron-core transformers
- 7.4 Describe the relationship between input power and output power in an ideal transformer
  - 7.4.1. Describe how power losses in real-world transformers are rated for power transformers and for signal transformers
  - 7.4.2. Describe what happens to power lost in a transformer
- 7.5 Describe “step up” and “step down” ratios
  - 7.5.1. Describe how step up/down ratio relates to input versus output current
- 7.6 Describe a “tap” in a winding
- 7.7 Describe an autotransformer, giving purpose, advantages and disadvantages
- 7.8 Describe these types of transformers and their principal use:
  - 7.8.1. variable (“variac®”)
  - 7.8.2. isolation
  - 7.8.3. current
- 7.9 Explain how to deal with unused transformer leads

8.0 RC, RL and RCL Principles

- 8.1 Describe “time constant” and give formulas in RL and RC circuits
- 8.2 Describe “time to full charge” in an RC circuit and give the formula
- 8.3 Describe “time to full current” in an RL circuit and give the formula
- 8.4 Explain phase relationships of voltage and current for series and parallel RL, RC and RCL circuits
  - 8.4.1. Describe the phase relationship between voltage and current in a purely resistive circuit
- 8.5 Explain how impedance relates to resistance and reactance
  - 8.5.1. Describe the impedance of a purely resistive resistor
  - 8.5.2. List formulas to find voltage, current and impedance in circuits with both resistive and reactive components
- 8.6 Define “filter” and give the general frequency response shapes of the following:
  - 8.6.1. Low Pass
  - 8.6.2. High Pass
  - 8.6.3. Band Pass
  - 8.6.4. Band Reject
- 8.7 Define “resonance” and give the condition of X_L and X_C at the resonant frequency
  - 8.7.1. Describe the impedance of an ideal parallel LC circuit at resonance
  - 8.7.2. Describe the impedance of an ideal series LC circuit at resonance
  - 8.7.3. Describe the resonant-frequency formula and calculate the frequency for various combinations of L and C
- 8.8 Explain the following and give relevant formulas:
  - 8.8.1. “Q” (quality factor)
  - 8.8.2. Damping
  - 8.8.3. Bandwidth
  - 8.8.4. Selectivity
- 8.9 Describe the component configurations in Pi, L and T type high- and low-pass filters
- 8.10 Explain why it is important for signal source and load impedances connected to an RCL circuit to conform to the intended impedances

9.0 Copper Cabling

- 9.1 Describe the construction and uses of the following types of copper cabling:
  - 9.1.1. Untwisted, non-paired
  - 9.1.2. Twisted, paired
  - 9.1.3. Coaxial, shielded
- 9.2 Explain the American Wire Gauge (AWG) sizes of conductors
- 9.3 Identify NEC® wiring color code
  - 9.3.1. Describe the standard insulation color code for 25-pair cable

- 9.3.2. Describe the color code for cable with fewer than 25 pairs
- 9.3.3. Describe standard insulation colors for AC power wiring

9.4 Explain signal radiation and stray signal pickup by cables
- 9.4.1. Describe how electrostatic and magnetic coupling occurs
- 9.4.2. Define “crosstalk”
- 9.4.3. Explain balanced wiring protection against stray-signal interference
- 9.4.4. Explain how shielding protects against stray-signal interference
  - 9.4.4.1. Explain why and how to properly ground a cable shield
  - 9.4.4.2. Describe and discuss various types of cable shielding

9.5 Explain the purposes of grounding and common conventions used in electrical electronics work
- 9.5.1. Explain “ground potential” and “ground loops” and how to avoid or compensate for them

9.6 Define “cable impedance”
- 9.6.1. Name the standard impedance of cables used in video systems and give examples
- 9.6.2. Name the standard impedance of cables used in other RF systems and give examples
- 9.6.3. Give impedances of various types of cable used in data systems
- 9.6.4. Define “transmission line,” “impedance matching” and “termination”
  - 9.6.4.1. Explain the principal reason why RF and data systems are based on matched impedances
  - 9.6.4.2. Explain why audio systems typically are not matched
- 9.6.5. Explain how the speed of propagation in a cable compares to radiation in air or space

10.0 Test Equipment and Measurements

10.1 Explain how to use the DC volts, AC volts, current and resistance scales of a standard multimeter
- 10.1.1. Explain proper connections and conditions for measuring voltage, current and resistance
- 10.1.2. Explain how the 10-Amp scale is different
- 10.1.3. Explain how to compensate for the resistance of meter leads
- 10.1.4. Explain how the meter may load the circuit, especially with an analog meter
- 10.1.5. Explain an inexpensive meter's limitations when measuring AC voltages that are not sine waves or 60Hz

10.2 Explain the care of equipment and test leads

10.3 Explain the types and purposes of signal generators

10.4 Describe how various analog oscilloscope front panel controls are used
- 10.4.1. Explain how to use the 10X setting on probes, and why

10.5 Explain what LRC substitution equipment is and its purposes

10.6 Explain the reasons for using rheostats, series incandescent lamps, isolation transformers and variacs® when servicing equipment

End of AC BASICS Competencies Listing

Notes: The purpose in distributing the above Competencies list is to provide a detailed syllabus for electronics educational institutions and instructors. Also to go further and explain what the beginning electronics technician should be able to do with each of the items included in the Categories and Competencies listings.

Find An ETA Test Site: http://www.eta-i.org/test_sites.html

Suggested additional study materials and resources:

EM Study Guide series; Karl Eilers; download through ETA at 800-288-3824 or www.eta-i.org

The Associate CET Study Guide, 6E; ISBN 1-891749-07-2; ETA International; 2012; —Available through ETA at 800-288-3824, $60

Electronics; Principles and Applications,8E; Schuler; ISBN 978-0077567705; McGraw Hill; 2012

Teach Yourself Electricity and Electronics, 5E; ; Gibilisco ISBN 978-0071741354; McGraw-Hill / TAB Books; 2011

Mastering Technical Mathematics, 3E; ISBN 978-0071494489; Gibilisco, Crowhurst; McGraw-Hill / TAB Electronics; 2007

Electronics Principles, 8E; Malvino, Bates; ISBN 978-0073373881; McGraw-Hill Higher Ed; 2015

Introductory DC / AC Electronics, 6E; ISBN 978-0131139848; Cook; Prentice Hall; 2004

How to Diagnose and Fix Everything Electronic; Geier; ISBN 978- 0071744225; McGraw-Hill/TAB Elec. 2011

ARRL Handbook, 2016 edition; American Radio Relay League, ISBN 978-1-62595-042-0, available online from www.ARRL.org

Check online for **Radio-Electronics.com** website; electronics material**;** Ian Poole; author/editor

Check online for **NEETS** module content: www.tpub.com/neets/index.htm

Also see the list of electronics information websites: Available through ETA at 800-288-3824