

Electronics Technicians Association, International CATEGORIES LISTING



Commercial Audio Technician – CAT 2009

This CATEGORIES listing serves to identify the major areas of training-study-knowledge and skills which the sound system technician needs to design, install and troubleshoot speech and music sound systems in commercial and institutional environments.

The following is a listing of each topic considered necessary to be included in a course of study directed towards the education of workers who are expected to have knowledge and skills which make the technician competent to service and install commercial and institutional sound systems. There are eight (8) general categories of training. This COMPETENCY listing is the syllabus, or identification of each individual subject, in which the technician must be knowledgeable and skilled.

To be eligible for Commercial Audio Technician (CAT) certification, the student must first acquire the Associate CET. The CAT examination presupposes familiarity with the fundamental electronic knowledge covered by the Associate CET.

Once the CAT has acquired these skills, abilities and knowledge, they will be able to enter employment in many parts of the audio industry. With minimal training in areas unique to specific products, the CAT should become a profitable and efficient part of this industry workforce.

The following listings are comprised of the Major CATEGORIES and individual ITEMS, which have been verbalized into individual line item COMPETENCIES.

MAJOR CATEGORIES OF KNOWLEDGE – SKILLS REQUIRED:

- 1.0 Acoustics**
- 2.0 Microphones**
- 3.0 Speakers**
- 4.0 Sound & Measurements**
- 5.0 Wiring**
- 6.0 70-Volt Systems**
- 7.0 Troubleshooting**
- 8.0 Safety, Codes and Standards**

Electronics Technicians Association, International

Commercial Audio Technician Competencies - 2009

Requirements:

1.0 Acoustics

- 1.1 Define "acoustics."
- 1.2 Define "reverberation," "resonance" and "echo".
 - 1.2.1 Explain the relationships and differences among them.
 - 1.2.2 Explain the terms "live room" and "dead room." Describe situations in which it may be desirable to have a live room or a dead room.
 - 1.2.3 Explain how a room may be designed or modified to eliminate echoes without significantly reducing reverberation.
- 1.3 Define "reverberation time."
 - 1.3.1 State the standard abbreviation used to denote this quantity.
 - 1.3.2 Explain how reverberation time varies with frequency in a typical room.
 - 1.3.3 Discuss room construction details that might change reverberation time behavior.
- 1.4 Define "critical distance," "direct field" and "reverberant field."
 - 1.4.1 Describe the relationship between sound pressure level and distance between a sound source and a listener in the direct field.
 - 1.4.1.1 Describe how the relationship is different for a listener in the reverberant field.
- 1.5 Define "standing wave." Explain how standing waves are formed.
- 1.6 Define "room mode." Identify four modes that exist in a rectangular room.
- 1.7 Define "node" and "antinode."
 - 1.7.3 Explain how air pressure variations and air movement are different at node and antinode.
 - 1.7.4 Explain why the location of an antinode changes with frequency.
 - 1.7.5 Describe what a listener standing at a node or antinode would hear.
 - 1.7.6 Explain why accidentally placing a measurement device in a node or antinode will result in serious measurement errors. Explain how to avoid this problem.
- 1.8 Define "absorption coefficient"
 - 1.8.3 Explain the operation of absorbents, such as acoustic tile.
 - 1.8.4 Give examples of materials with low, medium and high absorption.
 - 1.8.5 Describe how a material's absorption coefficient may change with frequency and mounting.
- 1.9 Explain the techniques needed to keep sound from traveling from one room to another. Discuss whether acoustic tile will fulfill this function.
- 1.10 Discuss environmental factors that might cause sound from outdoor speakers to be degraded on its way to listeners.
- 1.11 Explain why the accidental placement of a measurement device in a node or antinode will result in serious measurement errors and how to avoid this problem.

2.0 Microphones

- 2.1 Describe the construction and operation of the following types of microphones:
 - 2.1.1 Dynamic
 - 2.1.2 Condenser
 - 2.1.3 Ribbon
 - 2.1.4 Carbon
 - 2.1.5 Moving magnet
 - 2.1.6 MEMS
- 2.2 Define "element"
- 2.3 Explain which microphones generate their output signal directly from the sound they receive, versus those needing a source of DC power to operate
- 2.4 List advantages, disadvantages and typical applications of each
- 2.5 List the characteristics each microphone requires of the rest of the system for best operation
- 2.6 Describe the voltage of a typical dynamic microphone's output resulting from a typical sound level

- 2.6.1 Compare the output of a dynamic microphone to line level
- 2.6.2 Compare the output of a dynamic microphone to that of a condenser microphone
- 2.6.3 Compare the typical output of a dynamic microphone to its peak output in the presence of a very loud sound, as when a microphone is placed inside a rock band's kick drum
 - 2.6.3.1 Explain why a microphone and the preamp it is connected to must have a greater dynamic range than any other part of the system. Discuss microphone and preamp overloading, and the steps you would take if you encountered the problem.
- 2.7 Identify the principal source of background hiss in a system where a dynamic or condenser microphone is connected to a well-designed preamp
- 2.8 Describe the purpose and application for each of the following pickup patterns:
 - 2.8.1 Omnidirectional
 - 2.8.1.1 Define the angle off-axis of maximum sound rejection
 - 2.8.2 Cardioid
 - 2.8.2.1 Define the angle off-axis of maximum sound rejection
 - 2.8.3 Super- or hyper-cardioid
 - 2.8.3.1 Define the angle off-axis of maximum sound rejection
 - 2.8.4 Bidirectional
 - 2.8.4.1 Define the angle off-axis of maximum sound rejection
 - 2.8.5 Figure-8
 - 2.8.5.1 Define the angle off-axis of maximum sound rejection
 - 2.8.6 Shotgun
 - 2.8.6.1 Define the angle off-axis of maximum sound rejection
- 2.9 Identify the probable pickup pattern of a microphone for the following conditions:
 - 2.9.1 Open only in front
 - 2.9.2 Open to the front, sides and rear of the element
- 2.10 Define "plosive" and "wind noise"
 - 2.10.1 Explain how a microphone can be constructed to reduce these effects
 - 2.10.2 Explain user techniques that will further reduce these effects
- 2.11 Define "proximity effect"
 - 2.11.3 Identify the types of microphones affected by the proximity effect
 - 2.11.3 Relate proximity effect to the fact that most vocal microphones have a pronounced low-frequency rolloff.
 - 2.11.3 Explain how an in-line high-pass filter may be used to reduce plosives and wind noise
- 2.12 Define "presence peak"
 - 2.12.1 Describe its function and which types of microphones to which it applies.
 - 2.12.2 Explain the circumstances when a microphone with presence peak should and should not be used
- 2.13 Define "phantom power" and explain its purpose
 - 2.13.1 Describe what may happen when a dynamic microphone is connected to a preamp with phantom power
 - 2.13.2 Explain what potential problems may occur when using an in-line attenuator or high pass filter when phantom power is present
- 2.14 Explain why a microphone on-off switch usually short-circuits the line instead of opening it.
 - 2.14.1 Explain why, when phantom power is present, the microphone on-off switch can cause an audible "pop"
 - 2.14.2 Explain how to remedy the audible "pop" associated with phantom power
- 2.15 Explain the principle of operation of a "boundary microphone."
 - 2.15.1 Describe the boundary microphone's advantages.
 - 2.15.2 Describe the potential problems that may be encountered in use.
- 2.16 Compare the various frequency bands commonly used for wireless microphones.
- 2.17 Define "diversity" as it applies to wireless microphones.

- 2.17.1 Explain “diversity” technology
- 2.17.2 Explain the problem “diversity” is designed to solve.
- 2.18 Explain when to use the line output for a wireless microphone receiver having both line and microphone outputs
- 2.19 Explain why two wireless microphones normally cannot be used on the same channel at the same time. Describe the various means, from simple to deluxe, which manufacturers have invented to solve this problem.
- 2.20 Compare wireless microphone systems using radio transmission to systems using infrared transmission.
 - 2.20.1 Explain the advantages and disadvantages of each (name a situation where a wireless system would be preferred, and a situation where an infrared system would be preferred).
- 2.21 Define “comb filtering”:
 - 2.21.1 Explain how comb filtering can occur when two microphones are picking up the same sound.
 - 2.21.2 Explain how comb filtering can occur with a single microphone and a nearby reflective surface, such as a pulpit or lectern:
 - 2.21.2.1 Explain how using a super- or hyper-cardioid microphone can reduce reflective comb filtering.
 - 2.21.2.2 Discuss whether covering the reflecting surface with carpet-like absorptive material can eliminate reflective comb filtering.
 - 2.21.3 Discuss whether a boundary microphone, in normal use, exhibits comb filtering.
 - 2.21.4 Explain why a graphic equalizer usually cannot correct for comb filtering.
- 2.22 Explain the “3-to-1” rule
- 2.23 Discuss the design of a city-council type system, with multiple participants and multiple microphones:
 - 2.23.1 Discuss the advantages of a one-microphone-per-two-people system.
 - 2.23.2 Discuss the disadvantages of a one-microphone-per-two-people system.
 - 2.23.3 Explain why means must be provided to insure that most microphones are “off” most of the time.
 - 2.23.4 Give the formula that describes the reduction in feedback margin as the number of active microphones is increased.
 - 2.23.5 Describe ways different manufacturers handle microphone switching and system gain reduction when several microphones are active.

3.0 Speakers

- 3.1 Define the following components:
 - 3.1.1 Cone speaker
 - 3.1.2 Cone
 - 3.1.3 Dome
 - 3.1.4 Direct radiator
 - 3.1.5 Driver
 - 3.1.6 Voice coil
 - 3.1.7 Suspension
 - 3.1.8 Spider
 - 3.1.9 Magnet
 - 3.1.10 Frame
 - 3.1.11 System
- 3.2 Explain how a speaker converts an electrical signal to sound.
- 3.3 Describe the following types of speakers and their approximate frequency ranges:
 - 3.3.1 Woofer
 - 3.3.2 Midrange
 - 3.3.3 Tweeter
- 3.4 Explain the difference between a “piezoelectric” tweeter is and a “voice-coil” tweeter.
 - 3.4.1 Explain why it is necessary to connect a resistor between an amplifier and a piezo tweeter.

- 3.5 Define “enclosure.”
 - 3.5.1 Explain why cone speakers are usually placed in enclosures
 - 3.5.2 Discuss the relationship among enclosure size, low frequency response and efficiency.
 - 3.5.3 Explain the interaction between a woofer and the air contained in an enclosure.
 - 3.5.3.1 Discuss whether a larger woofer always results in more extended low frequency response.
- 3.6 Describe how “3dB down point” and “cutoff frequency” relate to a speaker’s low frequency response.
- 3.7 Define the following types of enclosures:
 - 3.7.1 Sealed
 - 3.7.2 Vented
 - 3.7.3 Ported
 - 3.7.4 Acoustic suspension
- 3.8 Compare the advantages and disadvantages between sealed and vented enclosures
- 3.9 Describe “passive radiator” and its function
- 3.10 Define “horn speaker”
 - 3.10.1 Compare the advantages and disadvantages between a horn speaker and a direct radiator speaker.
 - 3.10.1.1 Discuss examples of applications to illustrate why one type would be the preferred choice over the other.
 - 3.10.2 Define “compression driver”
 - 3.10.2.1 Explain why compression drivers used with horns do not need to be enclosed.
 - 3.10.3 Define “cutoff frequency”:
 - 3.10.3.1 Explain why high-power signals lower in frequency than a horn’s cutoff frequency should be prevented from reaching the horn.
 - 3.10.3.2 Explain the steps that can be taken to protect a horn from low frequency energy.
- 3.11 Define “re-entrant horn”:
 - 3.11.1 List the advantages and disadvantages of a re-entrant horn
 - 3.11.2 List situations where a re-entrant horn would and would not be the proper choice.
- 3.12 Explain how a “constant directivity radiator” differs from a common horn.
 - 3.12.1 List its advantages and disadvantages.
- 3.13 Define “directionality,” “coverage pattern,” “coverage angle,” “beaming,” “dispersion,” “on axis,” “off axis.”
 - 3.13.1 Explain how a speaker’s coverage pattern is measured and how it is shown in a specification sheet.
 - 3.13.2 Explain how a speaker’s coverage pattern usually changes with frequency.
 - 3.13.3 Explain how a speaker’s physical size relates to coverage angle.
 - 3.13.3.1 In light of 3.13.3, explain why tweeters are physically small and why large cone speakers are not used to reproduce high frequencies, even if they could.
 - 3.13.3.2 In light of 3.13.3, explain why it is poor practice to place a ceiling speaker directly above a place where a people are likely to sit or stand.
 - 3.13.4 Explain why control of the coverage pattern is important in many applications. Explain what happens when the pattern is incorrect for the application.
 - 3.13.5 In light of 3.13.3 and 3.13.4, explain why some mid/high frequency horns are as large as four feet across.
- 3.14 Define “2-way” and “3-way” speaker systems.
- 3.15 Define “crossover” and explain why a speaker system would include one.
 - 3.15.1 Define “crossover frequency.”
 - 3.15.2 Explain “passband,” “attenuation band,” “rolloff.”

- 3.15.3 Explain what is meant by “first order,” “second order,” and “third order” crossovers. Give the approximate rolloff rates in the attenuation band of each type.
- 3.15.4 Explain the importance of rolloff rates.
 - 3.15.4.1 Explain the virtues of a fast rolloff.
 - 3.15.4.2 Explain the virtues of a slow rolloff.
- 3.16 Describe the construction of a small 2-way speaker system that might be used for background music in a restaurant.
 - 3.16.1 List the individual speakers likely to be used and why they would be chosen.
 - 3.16.2 Give a likely crossover frequency and explain why such a frequency would be chosen.
- 3.17 Describe the construction of a large, high-powered 3-way speaker system that might be used in an auditorium.
 - 3.17.1 List the individual speakers likely to be used and why they would be chosen.
 - 3.17.2 Give a likely crossover frequency and explain why such a frequency would be chosen.
- 3.18 Define “free space,” “half space,” “quarter space” and “eighth space.”
 - 3.18.1 Describe what usually happens to the frequency response of a speaker system when placed in each of these environments.
 - 3.18.2 Explain why, when looking at a speaker system’s published response curve, it is important to know which environment it was measured in.
- 3.19 Define “subwoofer” and describe its function.
- 3.20 Explain the advantage of placing a subwoofer against a wall, at the junction between two walls, or ideally in a corner. Explain dangers of doing so.
- 3.21 Describe the gain in maximum bass output capability to be expected when two, four or eight identical low frequency speakers are grouped together.
- 3.22 Define “line array,” “column speaker.”
 - 3.22.1 Explain the coverage pattern of a line array or column and why such a pattern is desirable in many applications.
- 3.23 Describe how, in an outdoor (non-reverberant) environment, the sound pressure level (SPL) heard by a listener is related to his/her distance from a loudspeaker. Assume that the listener is on-axis vis-à-vis the speaker and it is not a line array.
 - 3.23.1 Describe how this relationship will be different if the speaker is a line array. Explain why this would be an advantage in many applications.
 - 3.23.2 Describe how, in an indoor environment, the above relationships change for listeners in the reverberant field.
 - 3.23.2.1 Describe, in general terms, how the effective critical distance can be pushed back, reducing the size of the reverberant field, through careful control of a speaker’s coverage angle.
- 3.24 Explain speaker sensitivity and how it is typically specified.
 - 3.24.1 Calculate the amplifier power needed for various combinations of speaker sensitivity, desired SPL, and listener distance. Provide for 10dB headroom.
- 3.25 Explain why, when designing a central-cluster speaker array where several speakers are provided to cover different areas of the audience, the system should be designed so the coverage angles overlap as little as possible.
- 3.26 Define “distributed speaker array”:
 - 3.26.1 Give examples of venues where distributed speaker array systems are commonly found.
 - 3.26.2 List the advantages and disadvantages of a distributed system, and applications where a distributed system would and would not be appropriate.
 - 3.26.3 Describe applications where bright, forward-sounding speakers should be chosen for a distributed system. Describe applications where mild, self-effacing speakers should be chosen.
 - 3.26.4 Explain why you should choose speakers with wide dispersion when installing a system intended for environmental music. Explain why you

should choose speakers with a narrower dispersion for a system intended for distribution of speech.

- 3.26.4.1 Explain what kind of ceiling speakers should be used when the ceiling is unusually high, as in a hotel ballroom.
- 3.27 Explain what is meant by “continuous power,” “music power,” “peak power” as these expressions are commonly applied to speaker ratings.
- 3.28 Describe how to choose the right fuse to protect a speaker system.
 - 3.28.1 Explain why a small amplifier, driven into clipping, may be more likely to damage a speaker system than a large amplifier operated within its normal limits.
- 3.29 Describe how headphones differ from other types of speakers.
 - 3.29.1 Describe the average power level that would produce a “loud” sound in a pair of headphones.

4.0 Sound and Measurement

- 4.1 Define: tone, frequency, pitch, wave, period, wavelength, fundamental, harmonic, pure tone, complex tone, spectrum.
- 4.2 Define “fidelity” as it relates to audio.
- 4.3 Discuss the “audio frequency spectrum” as the expression commonly applies to audio equipment.
 - 4.3.1 Describe the frequency range that a young person with normal hearing can hear.
 - 4.3.2 Describe how this range changes as men age and as women age.
 - 4.3.3 Describe the range of frequencies produced by the adult male voice, the female voice, and various musical instruments.
 - 4.3.4 Describe the frequency range of FM broadcasting, AM broadcasting, CD players, and telephones.
 - 4.3.5 Define “infrasonic” and “ultrasonic.”
- 4.4 Explain the significance of a tone’s fundamental pitch, its harmonics, and why the specific composition of harmonic energy in a sound is important.
- 4.5 Discuss “frequency response linearity” – what it is, why it is important, and what happens to sound when the frequency response is nonlinear. Give specific examples.
- 4.6 Define “octave” in musical terms. Define “octave” in arithmetic terms. Explain why it is a useful measurement concept.
- 4.7 Discuss “linear” versus “logarithmic” or “log” scales. Explain, in broad terms, what a logarithmic scale is.
 - 4.7.1 Explain why, in frequency-versus-level charts, frequency is normally plotted on a log scale.
- 4.8 Define “sine wave.”
 - 4.8.1 Discuss the harmonic content of a sine wave and why this makes it useful for measurements.
- 4.9 Explain how the frequency of a tone relates to its period.
- 4.10 Define the approximate speed of sound in air. Explain how the frequency of a tone relates to its wavelength.
- 4.11 Define “distortion” in broad terms.
 - 4.11.1 Define “harmonic distortion.” Discuss what it does, subjectively, to sound. Explain how it is measured.
 - 4.11.2 Define “intermodulation distortion.” Discuss what it does, subjectively, to sound. Explain how it is measured.
 - 4.11.3 Define clipping. Discuss what it does to sound.
- 4.12 Define “transient” as the term is used in the audio industry.
 - 4.12.1 Discuss the basic concept of the frequency content of a transient.
 - 4.12.2 Give examples of desirable, deliberately generated transients, and of undesirable, accidental transients.
- 4.13 Define “noise” as the term is used in the audio industry.
 - 4.13.1 Discuss the basic concept of the frequency content of noise.

- 4.13.2 Define and discuss “white noise.”
- 4.13.3 Define and discuss “pink noise.”
 - 4.13.3.1 Explain how it relates to white noise.
 - 4.13.3.2 Explain why it is more useful than white noise for measurement purposes.
- 4.14 Discuss “average voltage,” “peak voltage,” and “RMS voltage.”
 - 4.14.1 Give the ratio of peak to RMS voltage of a sine wave.
 - 4.14.2 Give the ratio of peak to average power of a sine wave.
- 4.15 Explain what a decibel (dB) is, in subjective, sonic terms.
 - 4.15.1 Discuss how many dB’s have been found to represent a subjective doubling or halving of loudness, a modest change, and the smallest change a careful listener can hear. (Assume a person with normal hearing.)
- 4.16 Explain what a decibel is, in electrical terms.
 - 4.16.1 List approximate voltage increments and decrements that correspond to commonly encountered dB ratios.
 - 4.16.2 List approximate power increments and decrements that correspond to commonly encountered dB ratios.
 - 4.16.3 Explain the advantages of measuring sound levels (both sonic and electrical) in decibels.
- 4.17 Define “sound pressure level” (SPL).
 - 4.17.1 Define “0dB SPL” and explain what it represents.
 - 4.17.2 Discuss commonly encountered situations – conversational speech, various kinds of music, a library, traffic at rush hour, an air raid siren, etc – and give approximate SPL’s for each.
- 4.18 Discuss the “Fletcher-Munson” effect.
 - 4.18.1 Discuss how, in practical terms, “loudness” may mean something different from “level” with specific reference to the Fletcher-Munson effect.
- 4.19 With reference to an SPL meter, discuss “A” weighting and “C” weighting.
 - 4.19.1 Name the weighting that is most nearly “flat.”
 - 4.19.2 Name the weighting that corresponds most closely to the human ear’s response to loud sounds.
 - 4.19.3 Name the weighting that corresponds most closely to the human ear’s response to quiet sounds.
 - 4.19.4 Name the weighting that would be used to measure the noise of, say, an air hammer.
 - 4.19.5 Name the weighting that would be used to measure the noise of a ventilating system.
- 4.20 Define the standard electrical levels “0dBm,” “0dBu,” “0dBV,” “0dBW.”
 - 4.20.1 Discuss the relationships and ratios among these levels.
 - 4.20.2 Describe approximate voltages represented by 0dBu, -10dBu, +10dBu, +20dBu.
 - 4.20.3 Describe approximate voltages represented by 0dBV, -10dBV, +10dBV, +20dBV.
- 4.21 Define “average level” in general terms.
- 4.22 Define “peak level.”
 - 4.22.1 Discuss the ratio of peak to average voltage and power found in common audio program material.
 - 4.22.2 Define “clipping level.”
 - 4.22.3 Define and discuss “headroom.”
 - 4.22.3.1 Give the headroom, in decibels, usually regarded as adequate in noncritical work. Give the headroom required for critical, high fidelity work.
- 4.23 Define “noise floor.”
- 4.24 Define and discuss “dynamic range.”
 - 4.24.1 Discuss the dynamic range of a typical signal (speech or music) and how it relates to the dynamic range required of a piece of equipment.

- 4.25 Define “VU meter”:
 - 4.25.1 Describe how a true VU meter differs from another meter that gives the same reading with a continuous sine-wave input.
 - 4.25.2 Describe the special purpose of a VU meter, and the reason it was invented.
 - 4.25.3 Describe the proper way to connect a VU meter to an audio line.
 - 4.25.4 Name the voltage that will cause a properly connected VU meter to read “0.”
 - 4.25.4.1 Explain what this voltage represents relative to 0dBu.
 - 4.25.5 Discuss whether, when connected to an audio line, a VU meter causes a small amount of distortion. Explain how is this avoided in modern equipment.
 - 4.25.6 Discuss: most “VU” meters nowadays do/do not possess true VU meter characteristics.
- 4.26 Define “peak” or “Peak Program Meter “ (PPM) and describe its function.
 - 4.26.1 Compare the PPM to a VU meter and explain its advantages.

5.0 Wiring

- 5.1 Define “microphone level,” “line level,” “speaker level.”
 - 5.1.1 Explain where each would be found in a typical sound system and why.
- 5.2 Define “impedance” and explain the difference between high and low impedance in line and mic circuits.
 - 5.2.1 Discuss the advantages and drawbacks of each in microphone-level circuits.
 - 5.2.2 Discuss the advantages and drawbacks of each in line-level circuits.
 - 5.2.3 Define “impedance matching,” “terminating” and “bridging” (as the term applies to a load attached to a signal line).
- 5.3 Describe unbalanced and balanced circuits:
 - 5.3.1 Describe schematic diagrams of transformer-balanced inputs and outputs.
 - 5.3.2 Describe block diagrams of electronically-balanced inputs and outputs.
 - 5.3.2.1 Explain the comparative advantages and disadvantages of transformer and electronic balancing and where each would be preferred.
 - 5.3.2.2 Define “common mode,” “common mode rejection” and “common mode range.” Compare transformer and electronic balancing in this regard.
 - 5.3.3 In an unbalanced circuit, identify the reference which the signal on a wire is compared against.
 - 5.3.4 In a balanced circuit, identify the reference which the signal on a wire is compared against.
 - 5.3.5 Explain how a transformer is used to convert from balanced to unbalanced and vice versa.
- 5.4 Explain the differences between the two common “flavors” of microphone signal – high impedance unbalanced, and low impedance balanced.
 - 5.4.1 Discuss the problems with high impedance microphone lines and why they are almost never used in professional work.
- 5.5 Explain the differences between the two common “flavors” of line level signal – high impedance unbalanced, and low impedance balanced.
 - 5.5.1 Discuss the advantages, disadvantages and proper uses of each.
 - 5.5.2 Define the references by which signal levels are measured in each type of line. Give both the references, with their common abbreviations, and the actual signal levels compared to these references.
 - 5.5.3 Describe the range of acceptable load impedances for signal outputs of consumer-grade and professional-grade equipment.
 - 5.5.3.1 Discuss whether the historic 600-ohm standard is relevant to today’s audio systems.
 - 5.5.3.2 Discuss whether it is acceptable to connect the line-level output of one piece of equipment to the inputs of several others at once.
 - 5.5.3.3 Explain why combining signals using a Y-cord is a bad idea.
- 5.6 Explain the two kinds of radiated electrical interference that may be picked up by an audio cable.

- 5.6.1 Explain how a balanced line tends to guard against such interference.
- 5.6.2 Explain why twisted pair is preferred for balanced lines.
- 5.6.3 Explain why audio lines should be kept away from AC wiring.
 - 5.6.3.1 Explain how to minimize interference if an audio line must cross an AC line.
- 5.6.4 Explain why microphone and line-level lines should never be bundled with speaker cables.
- 5.7 Discuss the function of the shield in shielded cable:
 - 5.7.1 Explain how to properly connect the shield. Explain what will happen if the shield is left unconnected.
 - 5.7.2 Discuss whether a cable shield is effective against magnetically-induced interference.
 - 5.7.3 Discuss whether speaker cable should be shielded, and explain why or why not.
- 5.8 Discuss whether, in microphone and line level circuits, there is any benefit in using wire that is heavier than 22 or 24 gauge.
- 5.9 Define “ground loop” and “ground potential.”
 - 5.9.1 Describe how a ground loop or ground potential can induce hum or buzz into an audio signal. Describe steps that can be taken to eliminate this interference.
 - 5.9.2 Discuss whether a ground loop can exist between the shields of several audio cables. Explain how to minimize the potential for interference.
 - 5.9.3 Discuss the use of a ground-lift AC adapter to investigate the source of a ground loop.
 - 5.9.3.1 Explain whether a ground-lift adapter can be left in the circuit permanently.
 - 5.9.3.2 Describe the techniques used when installing equipment in a rack to protect against ground-induced interference.
- 5.10 Discuss the causes, identification methods and ways to combat radio-frequency interference (RFI).
 - 5.10.1 Explain whether provision of a separate earth ground is an effective way to combat RFI.
 - 5.10.2 Discuss whether pin 1 of an XLR connector, the shell of an RCA connector or the sleeve of a phone connector provide a dependably good chassis ground with respect to grounding out RF signals.
- 5.11 Compare the two common “flavors” of speaker circuit: 8-ohm (and 4 and 2 ohm) versus 70.7 volt (and 25V, 100V and 140V). Describe the advantages and disadvantages of each and what types of installations would be suited to each.
- 5.12 Describe the proper range of load impedance for an “8-ohm” power amplifier output.
 - 5.12.1 Explain why an 8-ohm output cannot drive a large number of 8-ohm speakers in parallel.
 - 5.12.2 Explain why connecting two power amplifier outputs in parallel is a potentially catastrophic mistake.
 - 5.12.3 Define “bridging” (in the context of power amplifiers) and explain how this permits the installer to sum the full power of two amplifier channels into one speaker.
- 5.13 Discuss how power is lost due to the resistance of the cable in speaker circuits.
 - 5.13.1 List approximate figures, in dB, percentage voltage drop and percentage power loss, generally considered acceptable.
 - 5.13.2 Define the approximate maximum length of 18-gauge cable that can be used with an 8-ohm speaker without exceeding the loss defined above. Give the maximum length with a 4-ohm or 2-ohm speaker load.
 - 5.13.2.1 Explain how the maximum length changes if 16, 14, 12 or 10-gauge cable is used in place of 18-gauge cable.
 - 5.13.3 Define the approximate maximum length of 18-gauge cable that can be used in a 70-volt circuit with a 100-watt amp and load.

6.0 70-Volt Systems

- 6.1 Explain what is meant by a “70-volt” system.
 - 6.1.1 Describe how a 70-volt system differs from the common “8-ohm” system. (We are using the expression “8-ohm” as a convenience; the concept, of course, includes 4- and 2-ohm systems.)
 - 6.1.2 List two principal advantages over the “8-ohm” system.
 - 6.1.3 Discuss situations where 70V systems are commonly used and why.
 - 6.1.4 Discuss situations where a 70V system would yield no benefit over an 8-ohm system.
- 6.2 Explain the expression “constant voltage.” Discuss the principal difference between constant-voltage systems and 8-ohm systems.
 - 6.2.1 Discuss whether an AC voltmeter attached to a 70V speaker line would be likely to show a reading of 70 volts, or explain what actual voltage should be expected and why.
 - 6.2.2 Discuss the similarities and differences between a 70V speaker system and a 120V AC power circuit.
- 6.3 Explain how to find the total power required in a system with many speakers.
 - 6.3.1 Discuss whether it is necessary or desirable for the speaker load’s total power draw at 70V to equal the amplifier’s maximum power output.
- 6.4 Given a measured load impedance, explain how to calculate the resulting power level; given a specified power level, explain how to calculate the load impedance.
 - 6.4.1 Discuss the “rule of 5,000” shortcut.
 - 6.4.2 Calculate the minimum acceptable total load impedance for various power amplifiers.
 - 6.4.3 Explain the likely cause when the measured load on a 70V speaker line is about 600 watts higher than it should be.
- 6.5 Discuss accepted 70V speaker system wiring techniques.
 - 6.5.1 Describe the most commonly used kinds of cable and explain why they are used.
 - 6.5.2 Explain whether either side of the speaker line should be grounded.
 - 6.5.4 Explain how to calculate the maximum line length that can be used without suffering excessive line loss.
 - 6.5.5 Explain the advantages of splitting a system with many speakers into groups, and running several “home runs” back to the amplifier.
- 6.6 Explain the precautions which should be observed when adding speakers to, or removing speakers from, an existing 70V system.
 - 6.6.1 Discuss whether a switch provided to turn a single speaker on and off must substitute a dummy load for the speaker when off.
- 6.7 Explain how a transformer permits an 8-ohm speaker to be connected to a 70V system.
 - 6.7.1 Define the terms “primary”, “secondary”, “core”, “step up”, “step down”, “tap”, “voltage ratio”, and “impedance ratio”.
 - 6.7.2 Describe how to properly connect a transformer between a 70V line and an 8-ohm speaker.
 - 6.7.3 Explain how the different power taps on a transformer work.
 - 6.7.3.1 Discuss the significance of the 2:1 power ratios of adjacent taps.
 - 6.7.3.2 Explain how unused transformer taps should be handled.
 - 6.7.3.3 Discuss whether an ideal transformer significantly loads the amplifier output, or only transmits the speaker load connected to it.
 - 6.7.3.3.1 Discuss the load impedance a transformer would present to the power amplifier if there were no speaker connected to it.
 - 6.7.3.3.2 Explain why the power taps are usually on the primary side.
 - 6.7.4 Explain why the transformer associated with a particular speaker is customarily placed near the speaker.

- 6.7.5 Explain why transformers only work with AC, not DC.
 - 6.7.5.1 Explain why you cannot measure a transformer's impedance with an ohmmeter.
- 6.7.6 Define "insertion loss" and explain why it is desirable to use transformers with minimal insertion loss.
- 6.7.7 Explain "saturation."
 - 6.7.7.1 Discuss the undesirable effects which result from saturation.
 - 6.7.7.2 Describe ways of avoiding transformer saturation.
 - 6.7.7.3 Explain why the shortcut of placing a transformer on the magnet of a speaker (instead of using its intended mounting) is likely to result in poor performance and an overheated amplifier.
- 6.7.8 Explain why, when a single speaker is provided with a switch, the switch is customarily installed in the line before the transformer.
- 6.8 Explain the operation of a 70V autotransformer-type level control.
 - 6.8.1 Describe how a system might be configured using a power amplifier, one or more autotransformer zone controls, and multiple speakers with individual transformers.
 - 6.8.2 Discuss the advantages of autotransformer controls compared to resistive controls such as L-pads.
 - 6.8.3 Explain why level controls in speaker lines are not desirable in systems that operate at high levels.
 - 6.8.4 Explain what can happen if an autotransformer control is connected with input and output wires reversed, and why great care must be taken to see that this does not happen.
- 6.9 Discuss safety issues in the electrical design of 70V systems, and in working on them.
 - 6.9.1 Explain why, in a situation where dependability is critical – a hospital, for example – it may be advisable to divide the speakers in each room or hallway between two amplifiers.
 - 6.9.1.1 Explain "leapfrog" speaker wiring.
 - 6.9.2 Discuss the need, in many systems, to provide relays to bypass switches and level controls.
 - 6.9.2.1 Discuss the benefits and drawbacks of providing a complete, separate system for use in emergencies.
 - 6.9.3 Discuss whether it is safe to work on a "live" 70V system.
 - 6.9.3.1 Discuss the actual maximum voltage that can appear on a 70V line if the amplifier is driven far into overload and whether this is close enough to the AC line voltage of 120V to pose a similar danger to the technician.
 - 6.9.3.2 Identify the power tap of a typical speaker transformer where the highest voltage appears.
 - 6.9.3.2.1 Explain the operation of an audio transformer, and the functionality of the various taps and their load limitations.
 - 6.9.4 Explain the advantages and disadvantages of 25V systems compared to 70V systems.
 - 6.9.4.1 Explain the primary limitation imposed by a 25V system.
 - 6.9.4.2 Explain the "rule of 625" shortcut.
 - 6.9.5 Explain the advantages and disadvantages of 100V systems compared to 70V systems.
 - 6.9.5.1 Discuss how wire gauge, power level and line loss can affect the amount of distance a line can be run
 - 6.9.6 Explain the advantages and disadvantages of 140V systems compared to 70V systems.
 - 6.9.7 Describe the extra precautions that may be required when running higher-voltage lines.
 - 6.9.7.1 Discuss the advantage of splitting the speaker load for a higher-voltage system.

7.0 Troubleshooting

- 7.1 Explain the concept of “isolating the problem.”
- 7.2 List the specific tests a technician would perform to locate the defective component in a non-functional sound system.
 - 7.2.1 List test equipment the technician would use in the course of these tests.
 - 7.2.2 List useful tests, if any, that can be performed with no test gear.
 - 7.2.3 List how to diagnose specific problems that might have occurred.
 - 7.2.3.1 Describe how to diagnose problems that could be caused by more than one kind of malfunction.
 - 7.2.3.1 List malfunctions that could be caused by other malfunctions.
 - 7.2.3.1.1 Explain how to insure that all malfunctions have been identified.
- 7.3 List questions you would ask a system owner before repairing an existing system that had previously been operating properly.
- 7.4 Discuss the procedure for finding and fixing a hum problem.
 - 7.4.1 Explain how to tell the difference between a 60Hz hum and a 120Hz hum.
 - 7.4.1.1 Explain (in general terms) the most likely causes of each.
 - 7.4.2 Explain how to fix the problem in the case of 120Hz hum.
 - 7.4.3 Explain how to fix the problem in the case of 60Hz hum.
 - 7.4.4 Explain how the sound made by a lamp dimmer differs from ordinary hum.
 - 7.4.4.1 Explain how this information would be useful in eliminating a hum problem.
 - 7.4.4.2 Explain whether it is possible to trace the problem to a specific dimmer.
- 7.5 Discuss the procedure for locating and correcting a radio-frequency interference (RFI) problem.
 - 7.5.1 Identify in general terms the mechanism whereby RFI is converted into audible noise. Name system components where this is most likely to happen.
 - 7.5.2 Identify the points where RFI may be getting into the system from most likely to least likely to be the source of the problem.
 - 7.5.3 Explain standard methods of correcting the problem for each RFI entry point. explain how correction methods for RFI source types differ depending on the type of RFI (AM radio vs. CB vs. FM radio vs. cell phone, etc.)
 - 7.5.4 Explain how to tell the difference between the buzz caused by the buzz caused by a video signal (RFI) and the buzz caused by a lamp dimmer (not RFI).
- 7.6 Discuss: you have been called to repair a system that works, but poorly – much worse than it once did.
 - 7.6.1 List questions you would ask the owner or user that might help identify the problem.
 - 7.6.2 List specific misadjustments, malfunctions or unauthorized modifications that might have occurred and resulting audible effects that might help you diagnose the problem.
- 7.7 Describe the process you would use to diagnose and repair speakers that keep burning out.
 - 7.7.1 Describe the testing procedure you would use to determine which speaker has failed.
 - 7.7.1.1 Describe how to determine which driver has failed when testing multiple-driver speakers.
 - 7.7.2 List common types of speaker failure.
 - 7.7.2.1 List possible causes of speaker failure.
 - 7.7.2.2 Discuss how the type of speaker (large, small, subwoofer, sealed, vented, horn) and specific damaged driver (woofer, tweeter) might influence your determination of the cause of failure.
 - 7.7.3 Describe the system modification you would make to prevent the problem from recurring for each type of failure,
- 7.8 Describe the process you would use to diagnose and repair a 2-way box-type speaker.

- 7.9 Describe the process you would use to diagnose and repair a system where the wireless microphones are making noise, experiencing signal dropouts, or other problems by listing possible problems and the malfunctions that would cause them.
 - 7.9.2 Describe the changes you would make to obtain better performance when no malfunction has occurred, but the system is not well designed.
 - 7.10 Describe the process you would use to diagnose and repair a system that has been assembled from good quality components, but has distorted sound at moderate loudness levels, or excessive hiss or noise.
 - 7.11 Describe the process you would use to diagnose and repair a system where the amplifier has either burned out or always runs very hot by listing possible causes and solutions for correction.
 - 7.11.2 Discuss whether an incorrectly installed microphone and speaker cable(s) can cause speaker and/or amplifier burnout.
- 8.0 Safety, Codes and Standards**
- 8.1 Explain the purpose and basic requirements of the following National Electrical Code standards:
 - 8.1.1 **NEC Article 604** (Manufactured Wiring Systems)
 - 8.1.2 **NEC Article 640** (Audio Signal Processing, Amplification, and Reproduction Equipment)
 - 8.1.3 **NEC Article 680** (Regarding safe installation of electrical equipment and wiring in or adjacent to swimming pools or similar locations)
 - 8.1.4 **NEC Article 725 Part III** (Class 1, Class 2, and Class 3 Remote-Control, signaling, and Power-Limited Circuits; Class 2 and Class 3 Circuits)
 - 8.1.5 **NEC Article 760 Part III** (Fire Alarm Systems; Power-Limited Fire Alarm Circuits)
 - 8.1.6 **NEC Article 770 Part V** (Optical Fiber Cables and Raceways; Installation Methods Within Buildings)
 - 8.1.7 **NEC Article 800 Part V** (Communications Circuits; Installation Methods Within Buildings)
 - 8.1.8 **NEC Article 820 Part V** (Community Antenna Television and Radio Distribution Systems; Installation Methods Within Buildings; Chapter 9 - Conduit Fill)
 - 8.2 Discuss the following sections of NEC code pertaining to removal of abandoned cable:
 - 8.2.1 **Article 604.6C**
 - 8.2.2 **Article 725.25**
 - 8.2.3 **Article 760.25**
 - 8.2.4 **Article 770.25**
 - 8.2.5 **Article 800.25**
 - 8.2.6 **Article 820.25**
 - 8.3 Explain the purpose and basic requirements of the following ANSI and IEC (International Electrotechnical Commission) standards:
 - 8.3.1 **ANSI S1.4** (Sound Level Meters)
 - 8.3.2 **ANSI S1.42-2001** (A-, B-, and C-Weighting Filters)
 - 8.3.3 **IEC 651** (Sound Level)
 - 8.3.4 **IEC 60942** (Sound Level Calibrators)
 - 8.3.5 **IEC 61672-1** (A-, B-, and C-Weighting Filters)
 - 8.3.6 **IEC 1260** (Electroacoustics – Octave- and Frequency-band Filters, Class 1)
 - 8.3 Discuss the standard to which a sound level meter must be calibrated to comply with OSHA requirements:
 - 8.4.1 NIST Type II
 - 8.5 Explain how industry standards, such as the NEC, may differ from local statutes and laws among municipalities and jurisdictions.

- 8.6 Discuss code-compliant wiring procedures for 8-ohm, 25-volt, 70-volt, 100-volt and 140-volt systems.
 - 8.6.1 Explain where to find the manufacturer's information regarding the correct wiring method for use with a particular amplifier.
 - 8.6.2 Identify special cases where usual wiring practices are not acceptable:
 - 8.6.2.1 Where local laws differ from the NEC
 - 8.6.2.2 In hazardous locations
 - 8.6.2.3 Where jurisdictions may require 25V instead of the 70V used in schools
 - 8.6.3 Discuss code requirements for installing, tagging and removing cables:
 - 8.6.3.1 Cable rated
 - 8.6.3.2 Dedicated wire suspension
 - 8.6.3.3 Tagging cables designated for future use
 - 8.6.3.4 Removal of cable not likely to be used
- 8.7 Discuss the code requirements relevant to ceiling speaker installation:
 - 8.7.1 Suspension by dedicated wires
 - 8.7.2 Fire-rated back box enclosures
- 8.8 Discuss code requirements of proper methods for the installation of hanging large speakers (i.e., speaker cluster at the front of a church).
- 8.9 Describe the proper hardware to be used:
 - 8.9.1 Describe the safety issues associated with the proper installation of lag bolts, bolts, and eye-hooks in wood.
 - 8.9.2 Discuss additional reinforcements that may be needed due to environmental factors (i.e., humidity)
- 8.10 Describe safe methods of locating and securing speaker supports when the manufacturer does not provide an attachment system.
- 8.11 Discuss the safe handling methods relevant to high-voltage shock hazards for the following:
 - 8.11.1 70V speaker line
 - 8.11.2 8 ohm system components
- 8.12 Describe proper safety grounding methods for systems of various sizes.
 - 8.12.1 Explain whether a unit that does not have a grounded plug requires an earth ground (i.e., CD player).
 - 8.12.2 Explain how to handle an installation in an older building where a good electrical ground is not easily available.
- 8.13 Discuss special precautions necessary for outdoor installation of an audio line:
 - 8.13.1 Explain the importance of selecting the correct surge protector AC voltage rating to avoid signal distortion
- 8.14 Discuss the safety issues relevant to Sound Pressure Levels (SPL's) that can cause the following types of hearing damage:
 - 8.14.1 Permanent hearing damage upon prolonged exposure
 - 8.14.2 Immediate permanent damage
 - 8.14.3 Hearing damage caused by high-level transient noises (i.e., gunshots)