Amateur Radio Technician Exam Preparation Course

ARRL
The National Association for Amateur Radio®

Amateur Radio Technician Exam Prep Course

Module 5

Amateur Radio Equipment

5.1 Modulation
5.2 Transmitters and Receivers
5.3 Digital Communications
5.4 Power Supplies and Batteries

Transmitters and Receivers

- Usually combined into one unit called a *transceiver*
- Give you control of *frequency* and *mode*
- Generalized categories
  - Mobile
  - Single band
  - Dual band
  - All band
  - Multi-mode
  - Handheld or HT

Single-Band Mobile

- Single-band, 2 meter … good starter radio
- Operates from 13.8 volts DC, requires external power supply or car battery
- Requires an external antenna
- Can be operated mobile or as a base station
- Limited to frequency modulation (FM) and usually either 2 meters or 70 cm bands
- Up to approximately 50 watts output
- Typical frequencies: VHF/UHF FM

Sample Single-Band Mobile

Alinco DR-135TMKIII

Icom IC-2300H

Icom IC-V3500

Yaesu FTM-3100R

Yaesu FT-2980R

Dual-Band Mobile

- Same as the single-band transceiver but includes additional band(s)
- Most common are 2 meter and 70 cm bands
- Often includes 6 meters, 222 MHz (1.25 meters) or 1.2 GHz bands
- Might have separate antenna connections for each band or a single connection for a dual-band antenna
- Up to approximately 50 watts output
- Typical frequencies: VHF/UHF FM

Sample Dual-Band Mobiles

Alinco DR-735T

Icom IC-2730A

Icom IC-4100A

Icom ID-5100A

Yaesu FTM-6000R

Yaesu FTM-300DR

Multimode Transceiver

- Nearly all HF rigs are multimode
- VHF multimode operates on FM plus AM/SSB/CW modes
- Required for *weak-signal* operation on VHF/UHF
- More features add complexity and cost
- More flexibility will allow you to explore new modes as you gain experience (and increased license privileges)

Multiband Transceiver

- Covers many bands – usually refers to coverage of HF + VHF/UHF
- Also covers all modes
- Frequently 100 watts on HF, some power limitations on high bands (25-50 watts)
- Larger units have internal power supplies, smaller units need external power supply
- Some have built-in “tuners”

Sample Multimode / Multiband Transceiver

Icom IC-7300

Yaesu FT-9100A

Kenwood TS-590SG

Handheld (HT) Transceiver

- Small handheld FM units
- Can be single band or dual band
- Limited power (usually 5 watts or less)
- Includes power (battery) and antenna in one package
- Often purchased as a starter rig but low power limits range
- Single, dual and multiband versions (with increasing cost and complexity)
- Some can receive outside the ham bands, such as aircraft, commercial FM broadcast, etc.

Handheld (HT) Transceiver (cont.)

- Very portable and self-contained
- Internal microphone and speaker
- Rubber duck antenna
- Battery powered
- Extra battery packs
  - AA cell pack useful in emergencies
- Drop-in, fast charger
- Extended antenna
- External microphone and speaker
- Headset

Handheld

Icom IC-V86

Icom ID51APlus2

Kenwood TH-K20A

Yaesu FT-70DR

Yaesu FT-5DR

Side-By-Side Comparison

	SINGLE BAND	DUAL BAND	MULTIMODE	MULTIBAND	HANDHELD
FREQUENCY AGILITY	LIMITED	MEDIUM	MEDIUM	FULL	LIMITED
FUNCTION-ALITY	LIMITED	LIMITED	FULL	FULL	LIMITED
EASE OF USE	EASY	MEDIUM	MEDIUM	DIFFICULT	EASY
PROGRAM-MING	EASY	EASY	MEDIUM	CHALLENGING	EASY/MEDIUM
POWER	LOW	LOW	MEDIUM	HIGH	LOW
COST	LOW	MODEST	HIGH	HIGH	LOW

Selecting Band, Frequency and Mode

- Two functions common to all radios …
  - Control of *frequency* and *mode*
  - Amateurs can use many different modes … most other radio services are restricted to a single mode
- For multiband radios, begin by selecting the *band*
- Then, select a *frequency* within the band (called *tuning*)
  - Uses the *variable frequency oscillator* (VFO) and/or keypad (directly enter frequencies)
  - Memories or *memory channels* are used to store frequencies and modes for later recall (quickly tune to frequently used frequencies)
- For multimode radios, select the *mode*
  - SSB, AM, FM, CW, Data

Transmitter Functions

- Transmitter output power
  - In HF rigs and radios using AM/SSB and CW, controlled by an RF power control knob
  - FM handheld and mobile radios have selectable fixed power levels
- Microphone *gain* controls the level of speech audio of SSB transmitters
  - FM transmitters usually have a fixed microphone gain
- Switching between receive and transmit on voice …
  - Manual: Use *push-to-talk* (PTT) button
  - Automatic: *Voice-operated transmitter* control circuit (VOX)
  - On CW (Morse Code), use a key (an *electronic keyer* is faster than manual)
- Use a *dummy load* to avoid interfering with other stations while you're adjusting transmitter (heavy duty resistor that can absorb and dissipate output power)

Spurious Signals

- Excessive modulation results in distortion of transmitted speech (*spurious* outputs on adjacent frequencies) … called *splatter*
- Overmodulated FM signal has excessive deviation (overdeviating)
  - Usually caused by speaking too loudly into the microphone
- Overmodulation of an AM or SSB signal is caused by speaking too loudly or by setting the microphone gain or speech compression too high

Receiver Functions

- AF Gain: *Volume control* (sets speaker or headphone listening level)
- RF Gain: Adjusts the sensitivity of the receiver to incoming signals
- Automatic Gain Control (AGC): Adjusts sensitivity to keep the output volume constant for both weak and strong signals
- Squelch: Mutes the receiver's audio output when no signal is present (eliminates continuous noise)
  - Many transceivers have a monitor switch that temporarily opens the squelch to hear weak signals

Selectivity and Sensitivity

- Receivers are compared on the basis of two primary characteristics: *sensitivity* and *selectivity*
- Sensitivity determines receiver's ability to detect signals
  - Specified as a minimum detectable signal level (in µV)
- A *preamplifier* (preamp) is used to boost sensitivity
- *Selectivity* is the ability of a receiver to discriminate between signals
- High selectivity means that a receiver can operate properly even in the presence of strong signals on nearby frequencies

Filtering and Tuning

- A receiver rejects unwanted signals through the use of *filters*
- Signals then pass through filters *narrow* enough (i.e., smaller bandwidth) to reject all but the desired signal
- Wide filters (around 2.4 kHz) are used for SSB reception
- Narrow filters (around 500 Hz) are used for CW and data mode
- Multiple filters allows you to reduce noise or interference by selecting a filter with just enough bandwidth to pass the desired signal
- *Receiver incremental tuning* (RIT … also called *clarifier*) is a fine-tuning control used for SSB or CW
  - Allows you to tune in a station that is slightly off frequency or to adjust the pitch of an operator's voice that seems too high or low

VHF/UHF RF Power Amplifiers

- *RF power amplifiers* can be used to increase the output power by a factor of five or more
- Many VHF/UHF power amplifiers can be used on all modes (including SSB and CW … switch between modes)
  - Caution 1: Be sure your antenna is capable of handling the higher power!
  - Caution 2: Be sure you learn about RF exposure!

Transverters

- By using *mixers*, it is possible to convert an entire transceiver to operate on a different band
  - Mixers are part of equipment called a *transverter*
- A *receiving converter mixer* shifts input signals to the desired band where they are received as regular signals by the transceiver
- Transverters allow one main transceiver to be used on one or more new bands

Digital Communications

- Why use digital modes?

- Special codes and characters embedded in the stream of data allow the receiving modem to detect [and correct] errors
- Amateurs have developed or adapted techniques for exchanging digital data by transforming the 1s and 0s of data into tones that are in the same frequency range as the human voice

Amateur Digital Modes

- Different combinations of protocols, codes, and modulation, such as SSB or FM, are used to create digital modes
- Popular *HF* digital modes
  - RTTY (radioteletype)
  - PSK31 (keyboard-to-keyboard)
  - FT8 and WSPR (weak signal modes)
  - PACTOR or WINMOR (for Winlink messaging)
- Popular *VHF/UHF* digital modes
  - Packet radio
  - B2F protocol (for Winlink)
  - JT65 for moon-bounce and MSK144 for scatter paths
  - IEEE 802.11 (Wi-Fi) adapted to amateur use on microwave bands
- Popular *Voice* digital modes
  - AOR and FreeDV (HF)
  - D-STAR, System Fusion (C4FM), DMR, and P25 (VHF/UHF)

Packet and Packet Networks

- On VHF and UHF, the most common digital mode is *packet radio*
- Data characters are transmitted in groups called *packets*
- *Frequency-shift keying* (FSK) is used to transmit individual characters
- Each packet consists of a *header*, *data*, and *checksum*
- If an error is detected, the receiver automatically requests the packet be retransmitted until the data is received properly (ARQ or *automatic repeat request*)

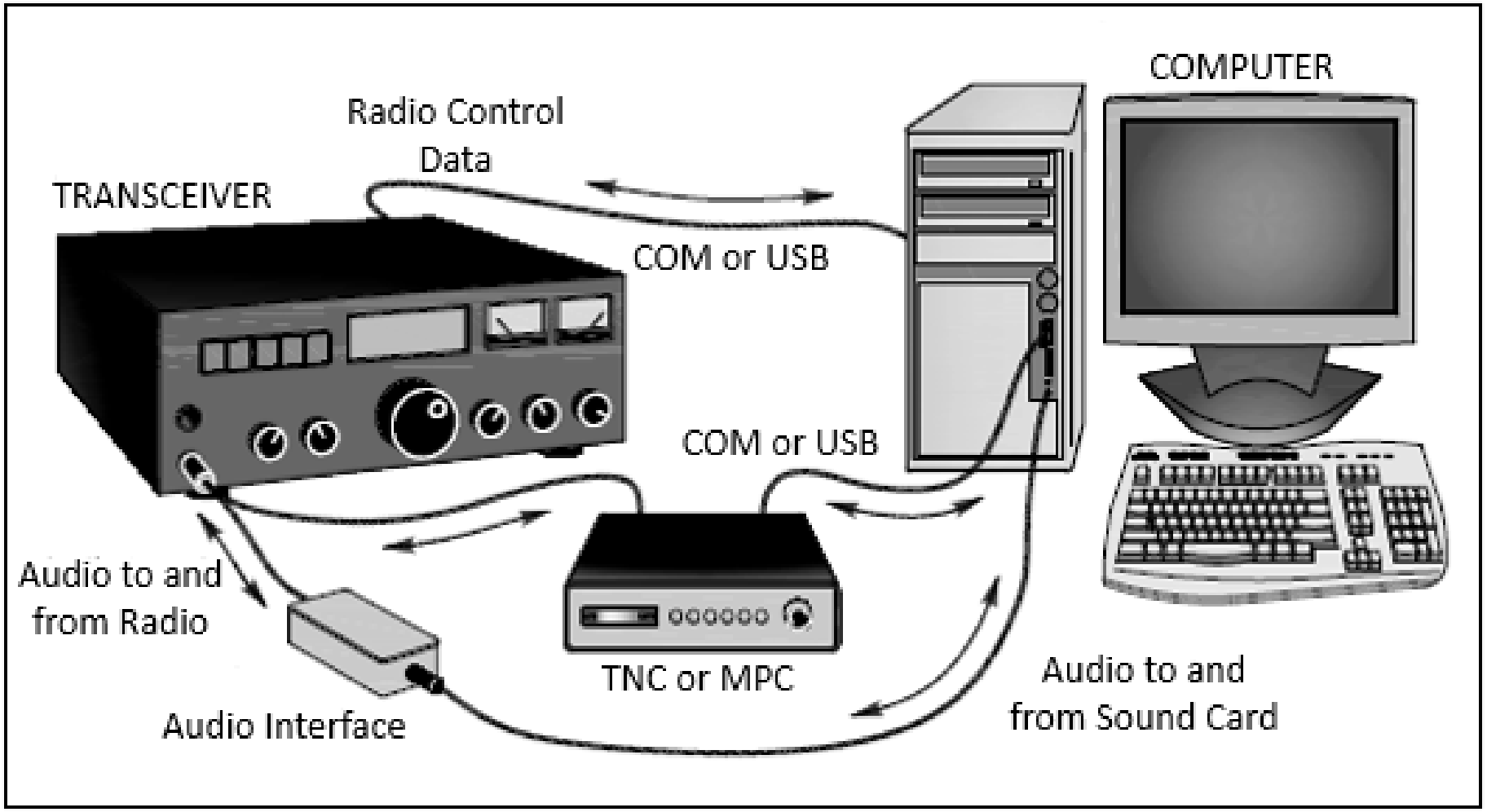
Keyboard-to-Keyboard Modes

- Digital modes that are designed for real-time person-to-person communication are called *keyboard-to-keyboard* modes
- Most popular on HF bands
- Most are generated by computer software using a *sound card* and an interface to a transceiver's audio input and output
- Radioteletype (RTTY) is the oldest
- Most popular is PSK31 (phase shift keying, 31 baud)
  - Works very well in noisy conditions

Automatic Packet Reporting System (APRS)

- Uses packet radio to transmit the position information from a moving or portable station
- Basically a packet radio station combined with a *Global Positioning System* (GPS) receiver … can transmit GPS position data
- Can also transmit weather information and short text messages
- A common public service application of APRS is to provide maps of station locations while they are providing real-time tactical communications

Setting Up For Digital Modes



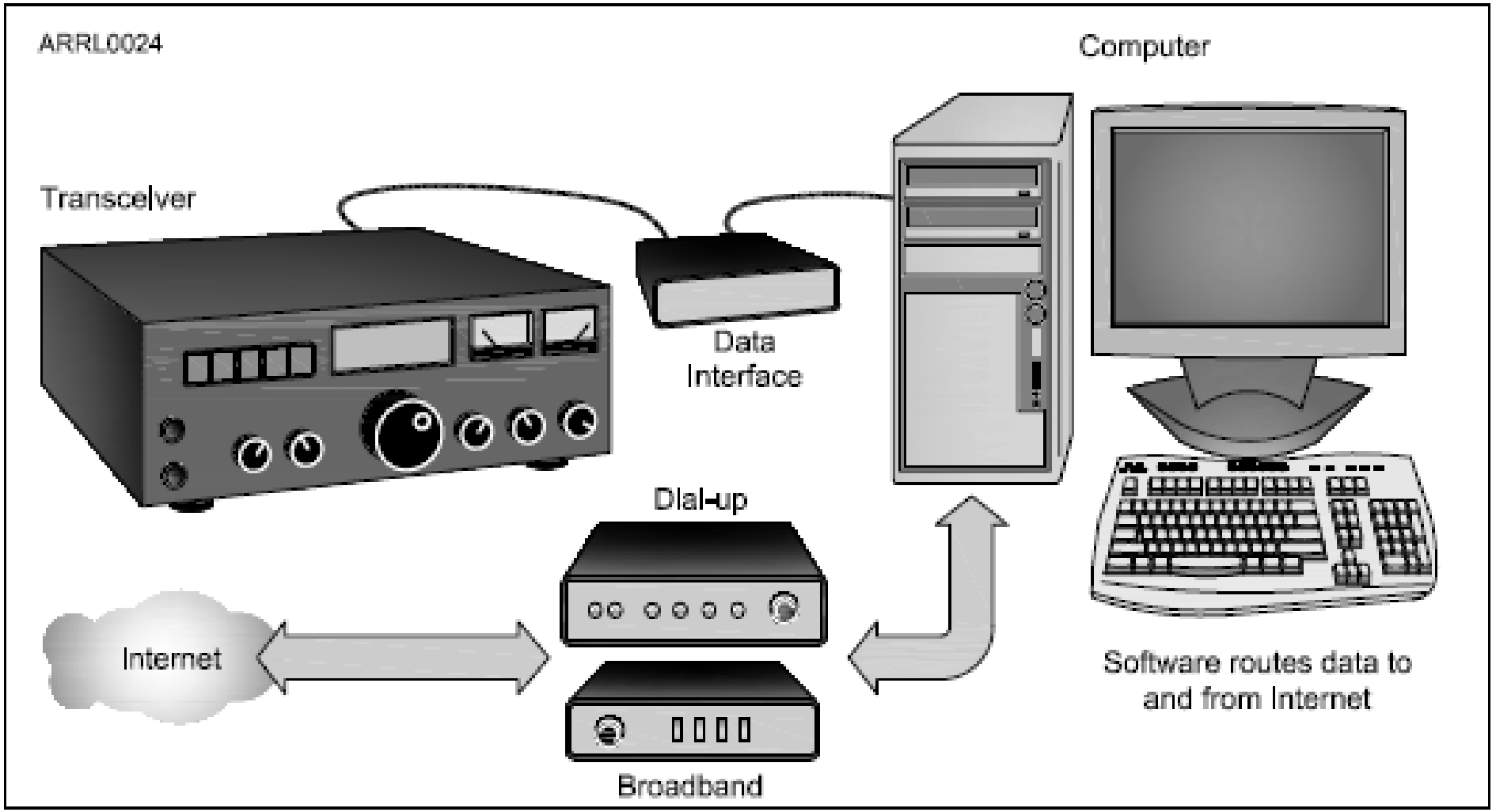
Data interfaces are connected between the transceiver's audio inputs and outputs and the computer's data connections (USB or COM ports) or sound card jacks. A TNC or MPC (multiprotocol controller) converts between data and audio. An audio interface isolates the computer sound card from the radio to prevent hum.

Figure 5.10 … Typical Digital Mode Set Up

Setting Up For Digital Modes (cont.)

- A very popular example of a “sound card mode” is FT8
- If you use a sound card, you may need a digital communications interface to supply the PTT (push-to-talk) signal for keying the transmitter

Gateways



An internet gateway station is a regular digital mode station and also runs software that relays data to and from the internet. The most common example of gateway stations are APRS gateways and Winlink RMS stations.

Figure 5.11 … Typical Gateway Set Up

Gateways (cont.)

- The gateway shown in Figure 5.11 is a special kind of digital station that provides a connection to the internet via Amateur Radio
- Most gateways are set up to *forward* messages
- All of the rules and regulations about commercial and business-related messages and communications apply to internet gateways (*follow the Amateur Radio rules*)

Power Supplies

- A solid power source is important for a clean, noise-free transmitted signal and better reception
- Converts the AC input power to DC current for the radio equipment
- Two main ratings:
  - Output voltage
  - Amount of current it can supply continuously
- Radios that operate from a “12 V” supply may actually work best at the slightly higher voltage of 13.8 V typical of vehicle power systems with the engine running
- If you don’t know the amount of current a radio can draw … divide output power by input voltage, then double the resulting current value and round up to the nearest amp (generally, anything above 8A will work for a 50-watt mobile rig)

Power Supplies (cont.)

- A supply's output voltage changes with the amount of output current
- A *regulated supply* uses a *regulator circuit* to minimize the amount of voltage change
- If more than just one piece of equipment is hooked up to the supply and turned on at the same time, add all of the equipment maximum current needs together

Mobile Power Wiring

- Radio equipment can draw large currents when transmitting
- If wire is too thin, its resistance (R) will create a voltage drop ($V = I \times R$)
- The resulting lower voltage at the radio can cause it to operate improperly (distorting output signal or creating interference)
- General guidelines for mobile wiring …
  - Fuse should be present in both the positive and negative leads of your radio
  - Connect the radio's negative lead to the negative battery terminal or where the battery ground lead is connected to the vehicle body
  - Use grommets or sleeves to protect wiring from chafing or rubbing on exposed metal
  - Don't assume all metal is connected to the battery's negative terminal

Batteries

- Batteries are made up of one or more *cells*
- How long will a fully-charged battery power your equipment? Check out Table 5.3 (next slide) …
  - Divide the *energy rating* in ampere-hours (Ah) by the total current needs of the equipment. Remember to use average current draw for transceivers since you won't be transmitting all the time.
- *Storage batteries* are often used as an emergency power source … cautions:
  - Contain strong acids that can be hazardous if spilled or allowed to leak
  - Can release or vent flammable hydrogen gas, that can cause an explosion
  - Accidentally short-circuiting a storage battery with a tool or faulty wiring can easily cause a fire and damage the battery

Table 5.3: Battery Types and Characteristics

(most common types used by hams)

Battery Style	Chemistry Type	Fully-Charged Voltage	Energy Rating (average)
AAA	Alkaline – Disposable	1.5 V	1100 mAh
AA	Alkaline – Disposable	1.5 V	2600 – 3200 mAh
AA	Carbon-Zinc – Disposable	1.5 V	600 mAh
AA	Nickel-Cadmium (NiCd) – Rechargeable	1.2 V	700 mAh
AA	Nickel-Metal Hydride (NiMH) – Rechargeable	1.2 V	1500 – 2200 mAh
C	Alkaline – Disposable	1.5 V	7500 mAh
D	Alkaline – Disposable	1.5 V	14000 mAh
9 V	Alkaline – Disposable	9 V	580 mAh
9 V	Nickel-Cadmium (NiCd) – Rechargeable	9 V	110 mAh
9 V	Nickel-Metal Hydride – Rechargeable	9 V	150 mAh
Coin Cells	Lithium — Disposable	3 – 3.3 V	25 – 1000 mAh
Packs	Lithium ion (Li-ion) – Rechargeable	3.3 – 3.6 V per cell	Varies
Storage	Lead-acid – Rechargeable	2 V per cell	Varies

Shack Battery Set-up

END OF MODULE 5

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