<u>LEAD-ACID BATTERY CONFIGURATIONS AND CONNECT/DISCONNECT SEQUENCES</u>

Disclaimer. This document is for generic educational purposes only. It is not intended to replace nor supersede Original Equipment Manufacturer (OEM) Technical Manuals (TM), Department of Defense (DoD) Manuals, Owner's Manuals, or other relevant authoritative guidance or directives.

Warnings.

1. Connecting and disconnecting lead-acid batteries from equipment and from each other requires careful steps to ensure safety for the operator/mechanic, the batteries, and the equipment.
2. Extreme caution must be taken to **prevent the short circuiting of batteries**. A short circuit is an electrical fault where an unintended, low-resistance path forms in a circuit, allowing current to bypass the intended load or components. This can cause excessive current flow, overheating, damage to components, or even fires. An example of a short circuit is when an uninsulated wrench simultaneously touches both the positive and negative terminals of the same battery.
3. Lead-acid batteries contain **sulfuric acid** as part of the electrolyte. Sulfuric acid (H_2SO_4) is a highly corrosive and hazardous substance that, if not handled properly, can cause severe harm to humans, animals, and the environment. Handling sulfuric acid requires strict safety measures, including personal protective equipment (PPE), proper ventilation, and neutralization protocols to mitigate its dangers. The risk of exposure is higher with flooded cell lead-acid batteries because their electrolyte is a free-flowing liquid, unlike the immobilized electrolytes found in absorbed glass mat (AGM) or gel batteries.

Assumptions. Information herein assumes that:

1. nominal 12V batteries are being connected or disconnected.
2. batteries are lead-acid: flooded (wet) cell, gel, or AGM.
3. batteries are connected to (or will be disconnected from) equipment that utilizes a **negative ground**. Though most modern battery-powered equipment (since the 1950's) uses a negative ground system (particularly in automotive, marine, and consumer electronics), **the operator/mechanic must ascertain whether their equipment uses a negative or positive ground**. The same holds true for military equipment. Note: In a negative ground system, the negative terminal of the battery is connected by cable to the chassis or ground bus of the equipment. The ground acts as the common return path for electrical circuits.
4. if more than one battery is in the system, the completed battery pack does not exceed 24VDC (nominal).
5. appropriate gauge wire (often referred to as "battery cable") is used for all connections.

Safety Precautions.

1. Safety Data Sheet (SDS): Obtain a copy from the battery manufacturer.
2. Personal Protective Equipment (PPE):
   a. For VRLA (valve-regulated lead-acid) batteries (e.g., AGM or gel), wear insulated gloves and safety glasses to protect against accidental shocks or sparks.
   b. For flooded cell lead-acid batteries, wear an acid-resistant rubber (butyl, neoprene, PVC, nitrile, etc.) apron that is ¾ length or longer, chemical splash goggles or a face shield, and insulated acid-resistant rubber gloves to protect against accidental shocks or sparks, as well as potential contact with electrolyte (i.e., **sulfuric acid** and water).
3. Work environment: Ensure the equipment is parked/stationed on a flat, dry, and stable surface with the ignition off, all electrical loads (lights, radios, etc.) turned off, and the key removed.
4. Tools: Use insulated tools (e.g., wrenches and/or screwdrivers) to prevent accidental short circuits.
5. Off-gassing: During the charging process, either via an onboard alternator/generator or an offboard battery charger, lead-acid batteries may off-gas (especially flooded cell lead-acid batteries).
6. Ventilation: Work in a well-ventilated area to avoid inhaling battery gases (especially when using flooded cell lead-acid batteries).
7. No sparks near batteries: Batteries can emit flammable gases (especially flooded cell lead-acid batteries). Avoid sparks or open flames.
8. No metal jewelry: Remove rings, watches, or other metal objects that could cause a short circuit.
9. Battery condition: Inspect batteries for damage, leaks, or swelling. If any are damaged, consult a professional before proceeding.
10. Heavy batteries: Typical automotive batteries weigh between 40-90 lbs (~18-41 kg) each (with some weighing even more). Use proper lifting techniques or assistance to avoid injury.
11. Professional help: If unsure about the equipment's battery wiring or encounter unexpected configurations (e.g., positive grounding), consult the equipment's Owner's Manual, TM, a senior mechanic, TACOM LAR (U.S. Army), or other knowledgeable professional.

Tools/Materials Needed.

1. Appropriate safety equipment mentioned above.
2. DC voltmeter or multimeter with DC voltage setting (to verify voltage).
3. Write-on tape and a marker (to label cables for reassembly).
4. Insulated wrench or socket set (to connect or disconnect battery terminal connector nuts and/or bolts).

5. Battery terminal puller (optional, for stuck terminal connectors).
6. Battery terminal cleaning brush (optional, for maintenance). A 4-in-1 brush is recommended for cleaning battery terminals and terminal connectors.
7. Soda ash (sodium carbonate) or crushed lime (limestone). If neither of those are available, household neutralizers, such as baking soda (sodium bicarbonate) or ammonia.
8. Electrical tape or battery terminal covers (to insulate exposed battery terminals).

Battery Terminals. Automotive batteries use a variety of terminal types, each with specific designs for compatibility, safety, and application. Below are the most common standard battery terminal types found in the automotive sector:

1. SAE (Society of Automotive Engineers) – top-mounted posts, where the negative post is 5/8ths inch wide and positive post is 11/16ths inch wide.
2. JIS (Japanese Industrial Standard) – like SAE posts, but narrower and shorter.
3. Side receptacles – typically, a threaded holes on the side of the battery.
4. Threaded studs – typically, top mounted.
5. Dual post (DP) – typically, top-mounted; negative SAE and threaded studs sit side-by-side, likewise for the positive terminals. Often referred to as a "marine" terminal.
6. Button – flat, threaded holes on the top of the battery; typically, M5 to M8.
7. L-shape – L-shaped posts with a bolt hole through the vertical portion of each.

Typical Battery Configurations (see graphics).

1. **Single.** A single 12V battery provides the battery's rated capacity (amp-hours, Ah) and cold cranking amps (CCAs).

   a. The positive cable (usually red) from the equipment is connected to the battery's positive terminal.
   b. The grounding cable (usually black) from the equipment is connected to the battery's negative terminal.

   For example, when a single nominal 12V battery (rated at 120Ah and 1225 CCAs) is connected, it results in:

   - Voltage = 12V (nominal)
   - Capacity = 120Ah
   - CCAs = 1225 CCAs

2. **Parallel.** A 12V battery parallel configuration involves connecting two or more 12V batteries together to <u>increase capacity (amp-hours, Ah) and cold cranking amps (CCAs)</u> while maintaining a nominal 12V circuit. In this configuration:

   a. The positive terminals of the batteries are **connected together** by cable.
   b. The negative terminals of the batteries are **connected together** by cable.
   c. The positive cable from the equipment is connected to the positive terminal of the first battery in parallel.

d. The grounding cable from the equipment is connected to the negative terminal of the last battery in parallel.

For example, when two nominal 12V batteries (each rated at 120Ah and 1225 CCAs) are connected in parallel (2P), it results in:

- Voltage = 12V (nominal)
- Capacity = 240Ah
- CCAs = 2450 CCAs

For example, when three nominal 12V batteries (each rated at 120Ah and 1225 CCAs) are connected in parallel (3P), it results in:

- Voltage = 12V (nominal)
- Capacity = 360Ah
- CCAs = 3675

3. **Series.** A 24V battery series configuration involves connecting two 12V batteries together to <u>double total circuit voltage</u> while maintaining the rated capacity (amp-hours, Ah) and cold cranking amps (CCAs) of the individual batteries. In this configuration:

a. The **positive terminal** of one battery is **connected by cable to the negative terminal** of the other battery.
b. The positive cable from the equipment is connected to the remaining positive terminal of the series.
c. The grounding cable from the equipment is connected to the remaining negative terminal of the series.

For example, when two nominal 12V batteries (each rated at 120Ah and 1225 CCAs) are connected in series (2S), it results in:

- Voltage = 24V (nominal)
- Capacity = 120Ah
- CCAs = 1225 CCAs

4. **Series with a 12V Tap.** A 24V battery series configuration with a 12V tap combines series with a 12V tap. This arrangement <u>permits both 24V and 12V circuits</u> from the battery pack.

a. The positive terminal of one battery is connected by cable to the negative terminal of the other battery. Next, the **12V tap cable from the equipment is connected to the same positive terminal**.
b. The main positive cable from the equipment is connected to the remaining positive battery terminal in the series.
c. The grounding cable from the equipment is connected to the remaining negative battery terminal in the series.

For example, when two nominal 12V batteries (each rated at 120Ah and 1225 CCAs) are connected in series (2S) with a 12V tap, it results in:

		24V Main	12V Tap
• Voltage	=	24V (nominal)	12V (nominal)
• Capacity	=	120Ah	120Ah
• CCAs	=	1225 CCAs	1225 CCAs

5. **Series-Parallel.** A 24V battery series-parallel configuration combines series and parallel configurations to <u>increase voltage, capacity (amp-hours, Ah), and cold cranking amps (CCAs)</u> by connecting multiple 12V batteries in a specific arrangement.

   For example, when four nominal 12V batteries (each rated at 120Ah and 1225 CCAs) are connected in series-parallel (2S2P), it results in:

   - Voltage = 24V (nominal)
   - Capacity = 240Ah
   - CCAs = 2450 CCAs

   For example, when six nominal 12V batteries (each rated at 120Ah and 1225 CCAs) are connected in series-parallel (2S3P), it results in:

   - Voltage = 24V (nominal)
   - Capacity = 360Ah
   - CCAs = 3675 CCAs

6. **Series-Parallel with a 12V Tap.** A 24V battery series-parallel configuration with a 12V tap combines series and parallel configurations to increase voltage, capacity (amp-hours, Ah), and cold cranking amps (CCAs) by connecting multiple 12V batteries in a specific arrangement while retaining a lower 12V tap for accessories that require it. This arrangement <u>permits both 24V and 12V circuits</u> from the battery pack.

   For example, when four nominal 12V batteries (each rated at 120Ah and 1225 CCAs) are connected in 24V series-parallel with a 12V tap (2S2P w/12V tap), it results in:

		24V Main	12V Tap
• Voltage	=	24V (nominal)	12V (nominal)
• Capacity	=	240Ah	240Ah
• CCAs	=	2450 CCAs	2450 CCAs

   For example, when six nominal 12V batteries (each rated at 120Ah and 1225 CCAs) are connected in 24V series-parallel with a 12V tap (2S3P w/12V tap), it results in:

		24V Main	12V Tap
• Voltage	=	24V (nominal)	12V (nominal)
• Capacity	=	360Ah	360Ah
• CCAs	=	3675 CCAs	3675 CCAs

Disconnection Instructions.

1. Turn "Off" all equipment power:

   a. Ensure the equipment's ignition is off, all accessories (lights, radio, etc.) are turned off, and the key (if applicable) is removed.

   b. If the equipment has a master disconnect switch, turn it to the "OFF" position.

   Why: This prevents any electrical load from drawing current, reducing the risk of sparks or damage to the equipment's electronics.

2. Locate and identify the battery configuration: Refer to the battery wiring diagram in the equipment's Owner's Manual or TM. If not available, then the graphics pages in this document may be able to assist.

3. Verify system voltage (optional, but recommended):

   a. Use a DC voltmeter or multimeter (set to DC voltage) to measure across the main positive and grounding cables connected to the equipment. If there is a 12V tap, also measure across the 12V tap cable and the grounding cable.

   b. For a nominal 12V system expect approximately 12V or slightly higher (e.g., 12.9V) if fully charged; if a 24V nominal system expect 24V or slightly higher (e.g., 25.8V) if fully charged. If voltage is present, ensure all loads are off.

   Why: Lower measured voltages may indicate that loads are still present. If so, reverify all loads are off. Note: Lower measured voltages could also indicate that one or more batteries need to be recharged.

4. Label the battery configuration:

   a. Using write-on tape and a marker, label each cable. For example, reference the 24V "(2S3P) w/12V Tap" graphic in this document. For this configuration, recommend labeling as follows:

      i. For the main ground, "GND neg to B6 neg" or "GND– to B6–"
      ii. For the main positive, "Main pos to B1 pos" or "Main+ to B1+"
      iii. For the 12V tap, recommend "12V tap pos to B2 pos" or "12VT+ to B2+"
      iv. For parallel connections, recommend "B1 pos to B3 pos" or "B1+ to B3+", respectively
      v. For series connections, recommend "B1 neg to B2 pos" or "B1– to B2+", respectively

   b. Other marking or labeling methods may be used instead.

Why: Clear labeling avoids confusion, ensures correct reassembly, and aids in preventing accidental reverse polarity connections, which could damage the equipment or batteries.

5. <u>Disconnect the main negative cable from the terminal on the battery or battery pack</u>:

   a. Verify that the equipment uses a negative ground. Locate the main negative cable (usually black) connecting the equipment's chassis or grounding bus to the battery or battery pack. However, **do not disconnect the grounding cable from the equipment's chassis or grounding bus**.

   b. Using an insulated wrench, loosen and remove the negative grounding cable from the terminal on the battery or battery pack.

   c. Secure removed cable(s) away from any metal surfaces.

   d. If there are no other cable connections to that battery terminal, place a terminal cover over it or wrap it with electrical tape.

   Why: Disconnecting the negative grounding cable first breaks the circuit to the equipment, minimizing the risk of short circuits or sparks when handling other terminals.

6. <u>Disconnect the main positive cable(s) from the battery or battery pack</u>:

   a. Deterine if the system is 12V, 24V, or 24V with a 12V tap.

   b. Locate the main 12V or 24V positive cable (usually red) connecting the battery or battery pack to the equipment's electrical system (e.g., starter or distribution block). **However, do not disconnect the main positive cable where it attaches to the to the equipment.**

   c. Using an insulated wrench, loosen and remove the main positive cable from the terminal on the battery or battery pack.

   d. Secure removed cable(s) away from any metal surfaces.

   e. If there are no other cable connections to that battery terminal, place a terminal cover over it or wrap it with electrical tape.

   f. If the system is 24V with a 12V tap, remove the 12V tap connection from the battery terminal of the battery pack, secure the loose cable away from any metal surfaces, and if there are no other cable connections to that battery terminal place a terminal cover over it or wrap it with electrical tape.

   Why: With the negative grounding cable already disconnected, removing the positive cable(s) is safer, as the circuit is fully isolated from the equipment.

7. <u>If batteries are connected in series or series-parallel, disconnect each series connection</u>:

   a. Identify the cables connecting batteries in series: positive-to-negative cable(s) between the batteries.

   b. For each series pair (two batteries connected to form 24V):

      i. Using an insulated wrench, loosen and remove the cable from the negative terminal of one battery (if the system is series-parallel, remove the cable from the negative battery terminal that is not connected to the parallel negative).
      ii. Do the same for the positive terminal of the other battery that it was connected to in series (if the system is series-parallel, remove the cable from the positive battery terminal that is not connected to the parallel positive).
      iii. Secure the series cable for that pair.
      iv. If there are no other cable connections to those battery terminals, place terminal covers over them or wrap them with electrical tape.

   c. Repeat until all series connections are removed.

   Why: Disconnecting each battery's terminals and each series in this order minimizes the risk of shorting, as each battery and series connection is isolated step-by-step. Furthermore, by first disconnecting the series connections before parallel connections, voltage is reduced.

8. <u>If batteries are connected in parallel, disconnect the parallel connections</u>:

   a. Identify the cables connecting batteries in parallel:

      i. Positive-to-positive cable(s) between the batteries.
      ii. Negative-to-negative cable(s) between the batteries.

   b. Using an insulated wrench, loosen and remove the negative cable(s) from the battery terminal(s) and secure the cable(s).

   c. Do the same for the positive cable(s).

   d. If there are no other cable connections to those battery terminals, place terminal covers over them or wrap them with electrical tape.

   Why: Disconnecting negative connections first reduces the likelihood of shorting and causing sparks.

9. <u>Remove batteries from the equipment (if necessary)</u>:

   a. If the batteries need to be physically removed, check for any mounting brackets or straps securing them.

b. Loosen and remove any hold-downs (straps, brackets, etc.) using appropriate tools.

c. Carefully lift each battery out of the battery box. If using flooded cell lead-acid batteries, keep them upright to avoid electrolyte (**sulfuric acid** and water) spills.

d. Place batteries on a stable surface.

10. Inspect and clean battery terminals and terminal connectors (if necessary):

a. Check battery terminals and terminal connectors for corrosion or damage.

b. If needed, clean battery terminals and terminal connectors with a battery terminal cleaning brush. Corrosive lead-sulfate can be neutralized using soda ash (sodium carbonate) or crushed lime (limestone). If neither of those are available, household neutralizers, such as baking soda (sodium bicarbonate) or ammonia, may be used. Then rinse with water and dry the battery terminals, connectors, and cables.

c. If battery terminals, terminal connectors, or battery connector cables are damaged, repair or replace as necessary.

d. Be sure to collect any corrosion and the “rinse” in a plastic container, as they may be hazardous materials (hazmat).

e. If the materials are hazardous, follow local hazmat directives when disposing of those materials.

Why: Ensures good connection upon reinstallation and extends battery life.

11. Disposition of removed batteries:

a. For healthy or recoverable batteries:

i. Ensure the batteries are fully charged before storing.
ii. Store batteries in a cool, dry, well-ventilated area away from flammable materials. Recommended storage temperature is between 41^{O}F (5^{O}C) to 77^{O}F (25^{O}C).
iii. When possible, recommend connecting a preventive maintenance charger to the battery/batteries to offset natural self-discharge. If not possible, recommend recharging flooded cell lead-acid batteries once every 3 months, recommend recharging gel or AGM batteries once yearly.
iv. Unless connected to a preventive maintenance charger, keep battery terminals insulated with battery terminal covers or electrical tape to prevent accidental contact during storage. Always insulate battery terminals during transport.

b. For unrecoverable batteries: recycle or dispose of in accordance with local regulations.

Why: Proper storage prevents electrical damage to batteries, ensuring they're ready for reuse. And lead-acid batteries are recyclable.

Reconnection Instructions.

Reconnection: To maintain the same safety priority, when reconnecting, reverse the process used during disconnection. Generally, reconnect in the following order (as applicable to the specific battery configuration):

1. Connect the positive terminals of the batteries to be wired in parallel.
2. Connect the negative terminals of the batteries to be wired in parallel.
3. Connect each series one at a time:
   a. Connect to the positive terminal of one battery, then
   b. Connect to the negative terminal of the other battery in that pair.
   c. Repeat until all series connections are complete.
4. Connect the 12V tap cable from the equipment to the appropriate positive battery terminal.
5. Connect the main positive equipment cable to the appropriate positive battery terminal.
6. Connect the main negative equipment cable to the appropriate negative battery terminal.
7. Ensure all connections are tightened to Owner's Manual or TM specifications (if applicable). Otherwise, ensure they are tight and will not loosen. Be careful not to overtighten, thereby causing damage to the battery terminal.
8. Verify system voltage (optional, but recommended).
9. Remove all labels from cables.

Additional Notes.

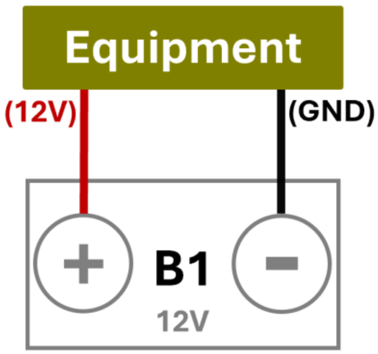
Battery Type: If the batteries are flooded cell lead-acid, handle with extra care due to free-flowing electrolyte (**sulfuric acid** and water), as well as hydrogen-sulfide gas hazards. If they are gel, AGM, lithium, or other types, follow specific manufacturer guidelines.

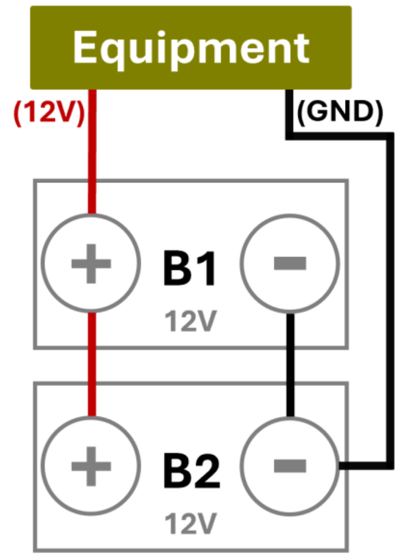
Equipment-Specific Considerations: Military tactical equipment may have additional safety interlocks or complex wiring. Consult the equipment's technical manual (TM) or seek guidance from a senior mechanic, TACOM LAR (U.S. Army), or other knowledgeable professional.

Battery Configurations & Connect/Disconnect Sequences

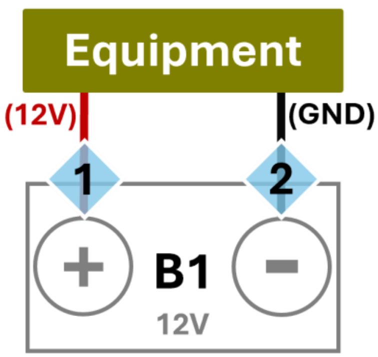
Single 12V	12V Parallel (2P)

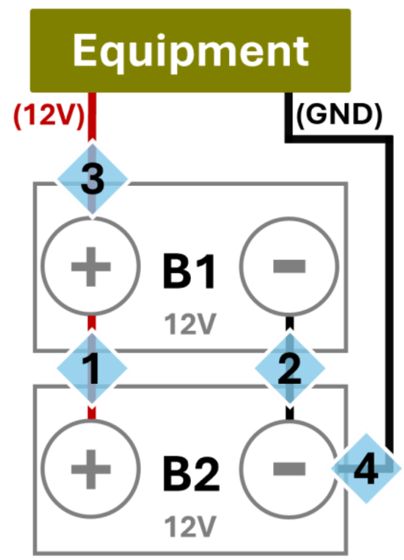
Configuration



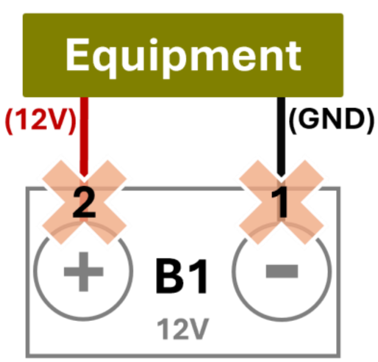


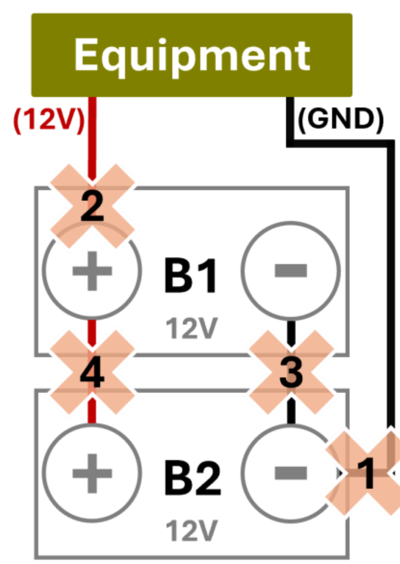
Connection Sequence





Disconnection Sequence

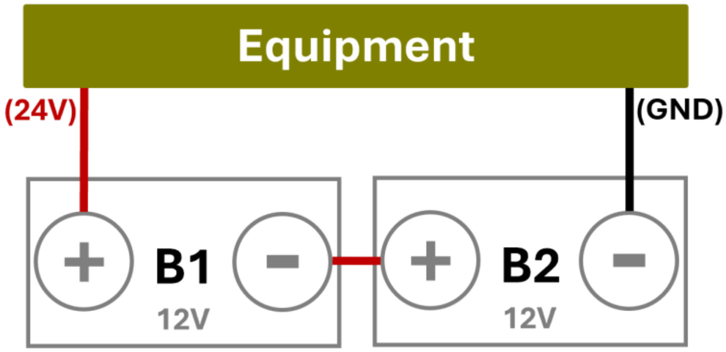


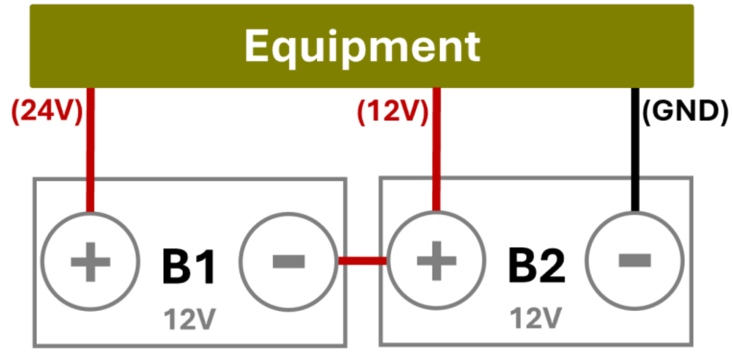


Battery Configurations & Connect/Disconnect Sequences

24V Series (2S)	24V Series (2S) w/12V Tap

Configuration





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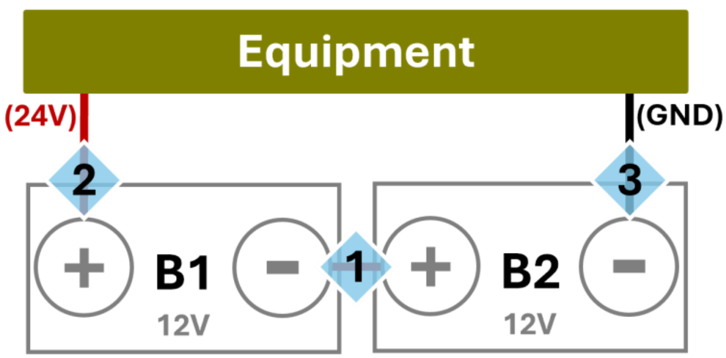

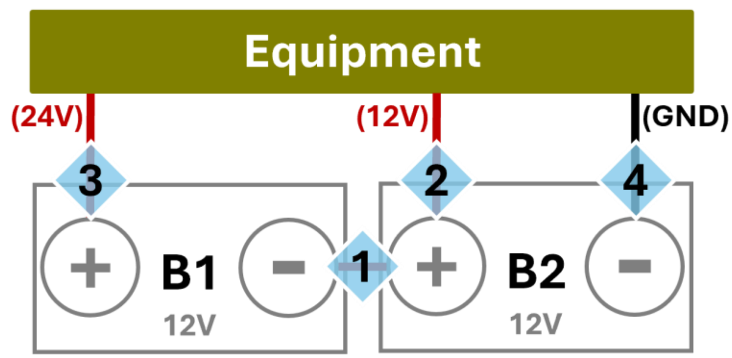

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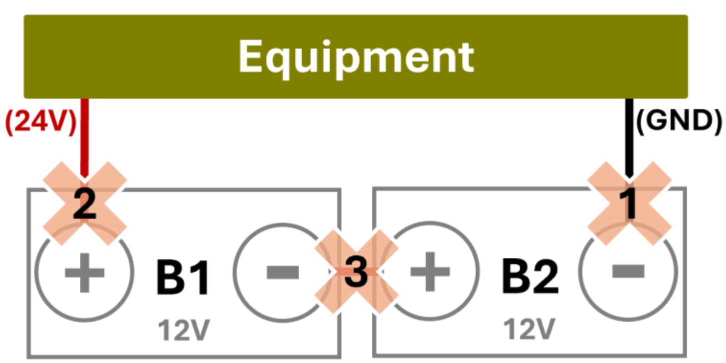
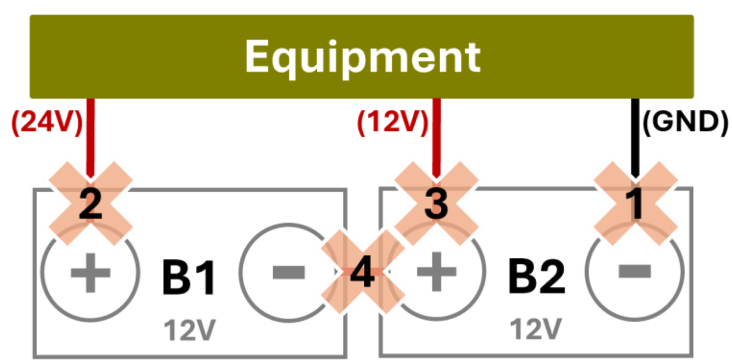
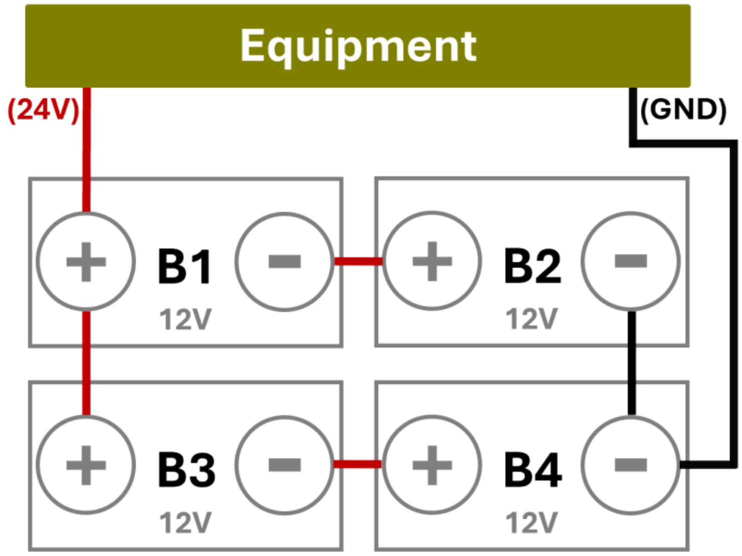


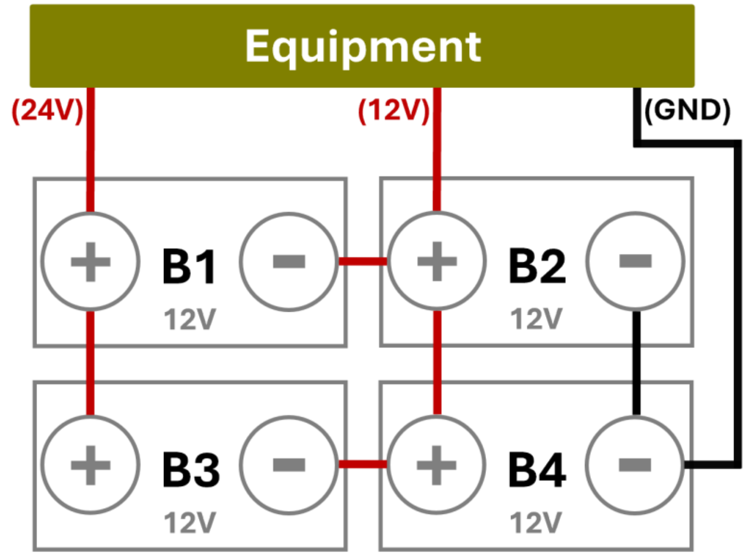


Battery Configurations & Connect/Disconnect Sequences

24V Series-Parallel (2S2P) | **24V Series–Parallel (2S2P) w/12V Tap**

Configuration





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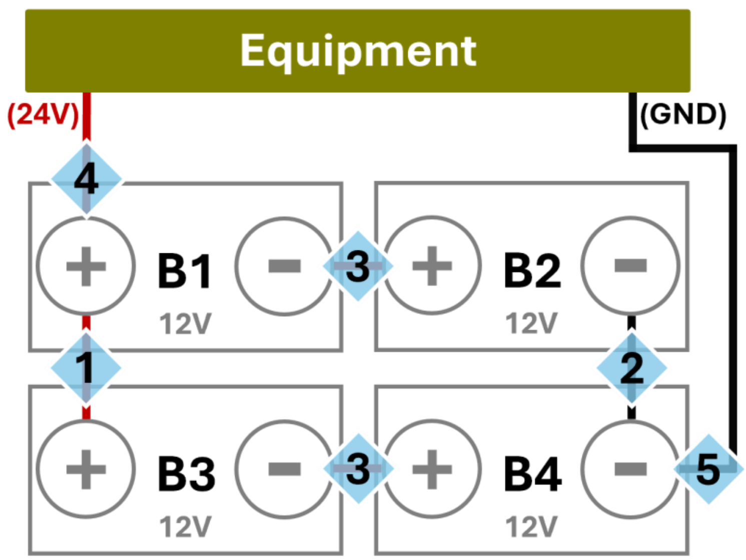
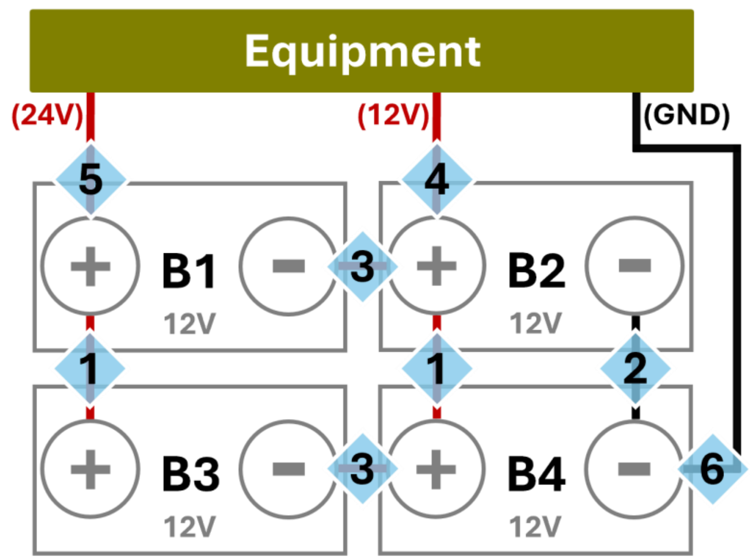
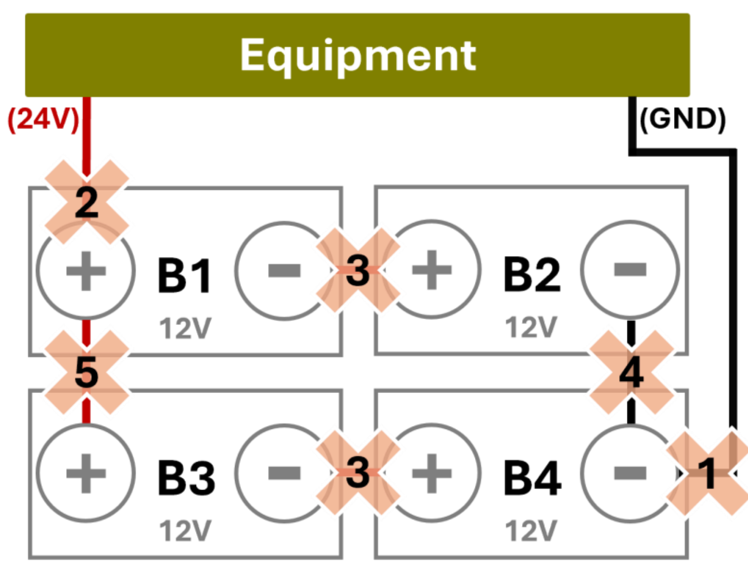
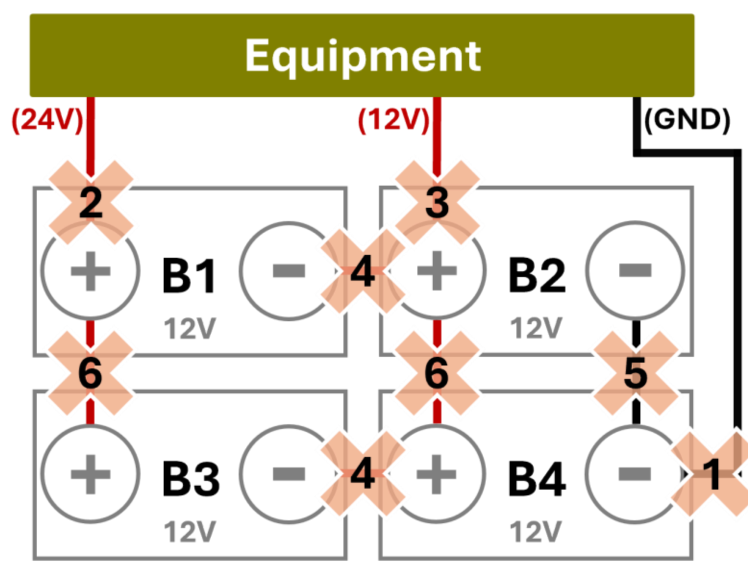




Disconnection Sequence

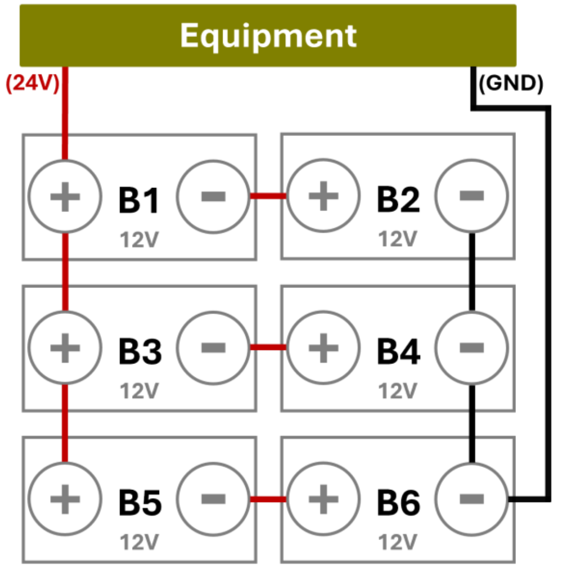


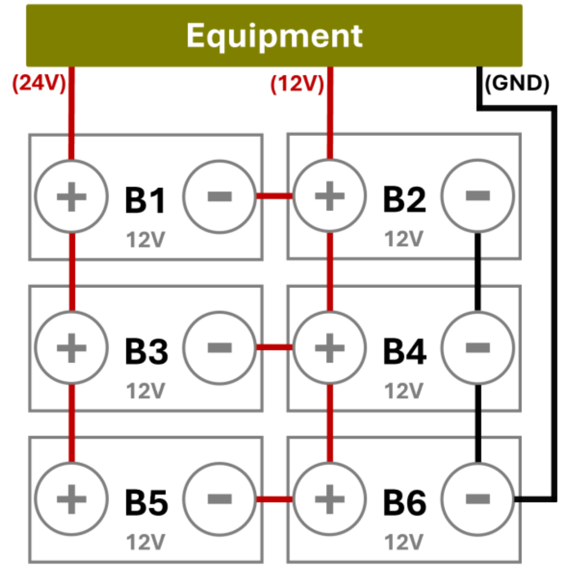


Battery Configurations & Connect/Disconnect Sequences

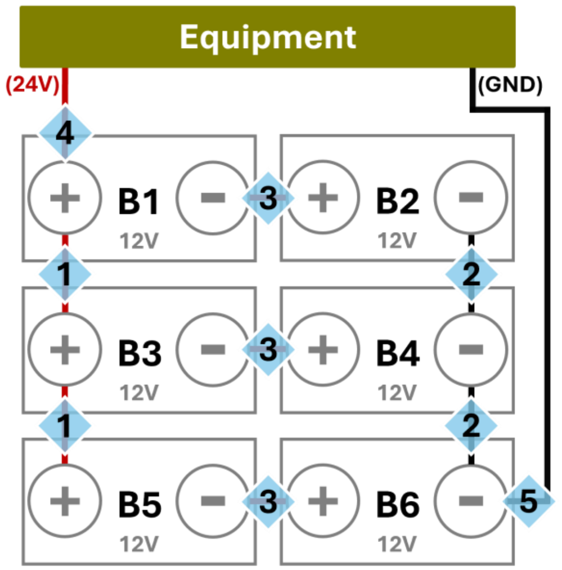
24V Series-Parallel (2S3P) | **24V Series–Parallel (2S3P) w/12 Tap**

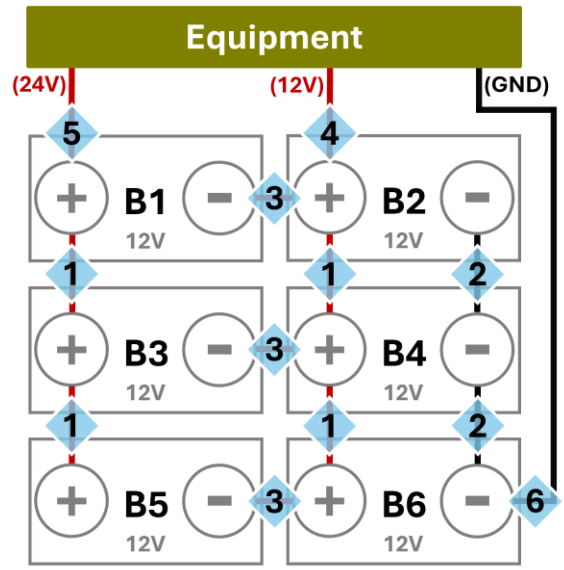
Configuration





Connection Sequence





Disconnection Sequence