

# Series and Parallel; What does it mean?

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## From the Masthead

I turned the key and absolutely nothing happened, no dash lights, not even a click from under the hood. My wife's new car, a 2018 GMC Terrain diesel's battery was stone-cold dead. The culprit...the back hatch was impeded from closing fully thanks to cargo that had come adrift, which left the dome light on as well as some portion of the dash lights and computer. Because we are in the midst of a move all of my shop tools, including my AGM-based start pack (which I've previously written about here) and heavy-duty battery charger/booster, and 16-foot long 4/0 (I made these myself) jumper cables, are in a different location than the Terrain. It was a scenario I've rarely experienced, all of my key tools were elsewhere; I've rarely felt so powerless.

As I stood in the garage contemplating my plight, briefly considering using my AAA membership, for the first time ever, and how ignominious that would be, I gazed around the mostly barren space for inspiration. My eyes came to rest on a black Pelican style-case, about the size of a small Igloo cooler, a KBi MiniHD ultracapacitor start pack; could this be my salvation?

Kold Ban International or KBi, Inc. has been making aids to engine starting for over three decades, including a cold weather diesel ether injection system, and more recently capacitor-based booster systems. I first encountered them back in the early 2000's when they sent me a sample of their ultracapacitor "battery" for evaluation. It was intriguing, made in Russia it was able to easily start a 6-cylinder diesel

engine multiple times with no difficulty, and yet unlike a lead acid battery it contained no electrolyte, would last for tens of thousands of cycles, recharged in seconds, and weighed a fraction of a traditional battery's heft. The only problem was its price, it was too expensive. Fast-forward to 2019, KBI is now making their own supercapacitor-based starting systems using domestically-made capacitors (which enables far more competitive pricing), offering a permanently installed unit, the KSM, and a portable start pack, called the KrankingKART Mini HD, both of which I've tested extensively, however, not under anything other than simulated no-start conditions, not until the above-described dead battery scenario.



Two of the attributes of the ultracapacitor-based MiniHD and KSM is their ability to be recharged very quickly, typically in under one minute, and the time they will hold this charge without requiring a re-charge, advertised as several months. The MiniHD sitting in my garage had been untouched since I

completed my testing of it in late 2017, it was then moved to an unheated offsite storage unit, then recently to my temporary residence; it hadn't received a charge in nearly 18-months. I picked it up, dusted it off, pressed the volt meter test button and was initially relieved to see that it illuminated. That elation was, however, quickly followed by disappointment, it read just 12.2 volts, otherwise dead for an ordinary lead acid battery. Yet another attribute of ultracapacitors, and unlike a traditional battery, is their ability to provide sufficient starting current even when their voltage is low; but would it work now? I opened the hood and hooked up the heavy-duty solid copper alligator clips to the vehicle's dead battery and pressed the MiniHD's relay button, which brought its ultracapacitors online, and then crossed my fingers and turned the ignition key. The Terrain's diesel engine roared to life; and the MiniHD recharged to 13.8 volts in less than a minute, leaving it ready for the next jump start.

Through my testing I knew what the KSM and MiniHD ultracapacitor start devices were capable of, however, this was a test I had not contemplated, allowing your last ditch emergency back up start device to lay dormant for a year and a half, and then call on it to start an engine whose battery isn't weak but totally dead, something it's not designed to do. Try that with a conventional AGM-based start pack and you'll almost certainly be disappointed. In short, I was already a believer in the KBI technology; this event, however, has only served to reinforce that opinion.

For more information on KBI ultracapacitor start devices visit KSM and MiniHD.

This month's Marine Systems Excellence eMagazine feature covers the subject of series vs. parallel electrical connections. I hope you find it both interesting and useful.

# Series and Parallel; What does it mean?



**Building larger battery banks often involves a combination of series and parallel connections.**

While I was the manager of a boat yard, and after contending with numerous job applicants who claimed to know a great deal more than they actually could demonstrate, I devised a prospective marine mechanic's and electrician's screening exam. It consisted of fifty multiple choice questions evenly segregated into mechanical and electrical categories; if a candidate came along and claimed to 'know it all', and then some, the exam quickly separated those who could from those who could not. The exam also included a practical, in the form of a box full of twenty-five numbered parts and tools that had to be matched up with their respective identifications, which were provided on a printed ledger; all

one had to do was match the number to the described part or tool. If you were genuinely knowledgeable and experienced, and you could differentiate a gram scale indicator from a glow plug, you would do well and would likely be hired.

I didn't consider the exam to be overly difficult; when testing the content on my most skilled employees, those who I knew had what I (and author Tom Wolff) referred to as "the right stuff", they obtained perfect or near-perfect scores. However, it was rigorous and many found it challenging indeed, a fact that was demonstrated every so often by the behavior of some exam-takers. On a few occasions I would check in on the candidate to see how he or she was doing only to find the chair empty, the exam partially completed; they were never seen or heard from again. Others asked if they could take it home.

Invariably, the electrical questions that ensnared even many seasoned professionals involved the subject of series and parallel connections. While the concept in and of itself is anything but complex, many folks, even professionals, have a hard time fully grasping just what it means and how it relates to real-world marine electrical systems and, as importantly, troubleshooting, installation instructions and digital multimeter use.

### Series, Parallel and Battery Banks

Perhaps the most common example, and just as commonly a frequent source of misunderstanding, involves batteries. Battery banks are often made up of individual batteries connected in parallel to provide increased amp-hour or reserve capacity as well as increased cranking amperage. In short, no pun intended, the definition of parallel electrical connections means like terminals are connected, positive to positive and negative to negative.

For instance, a single 12 volt battery of the 8D group size

will typically provide about 250 amp-hours of reserve capacity and 1300 cold cranking amps or CCA. If two of these batteries are connected in parallel, the figures essentially double with the notable exception of the voltage (demonstrating the electrical 'no free lunch' rule), the amp-hours go to 500 and the CCA capacity (this is a measure of the number of amps a battery provides for 30 seconds at 0°F, not to be confused with marine cranking amps or MCA, which is measured at 32°F) reaches an impressive 2,600 amps. Adding more batteries to this equation has the same effect; voltage remains the same, while amp-hours and cold cranking amps are added.





**Paralleling batteries, connecting like terminals, positive to positive and negative to negative, yields higher reserve or amp-hour capacity, as well as cranking amps, while maintaining the same voltage as each individual battery.**

What if, however, the vessel's electrical system is 24 volts, a scenario that requires a different battery arrangement to achieve that voltage? That changes the equation while continuing to observe the no free lunch rule, albeit in an inverse manner. Two 8D batteries connected in *series* will yield 24 volts; however the amp-hours and CCA will remain the same, 250 and 1300 respectively. Series connections are made by connecting *unlike* terminals of *different* batteries, positive to negative. While that may seem counter-intuitive, connecting positive and negative, it is completely natural to do so for disparate batteries, it's the same process used to create 12 volts within a single battery, by connecting the positive and negative terminals of multiple individual cells

within a single battery. These connections are usually, but not always, hidden under the battery's case.

### Batteries Other Than the 12-Volt Variety

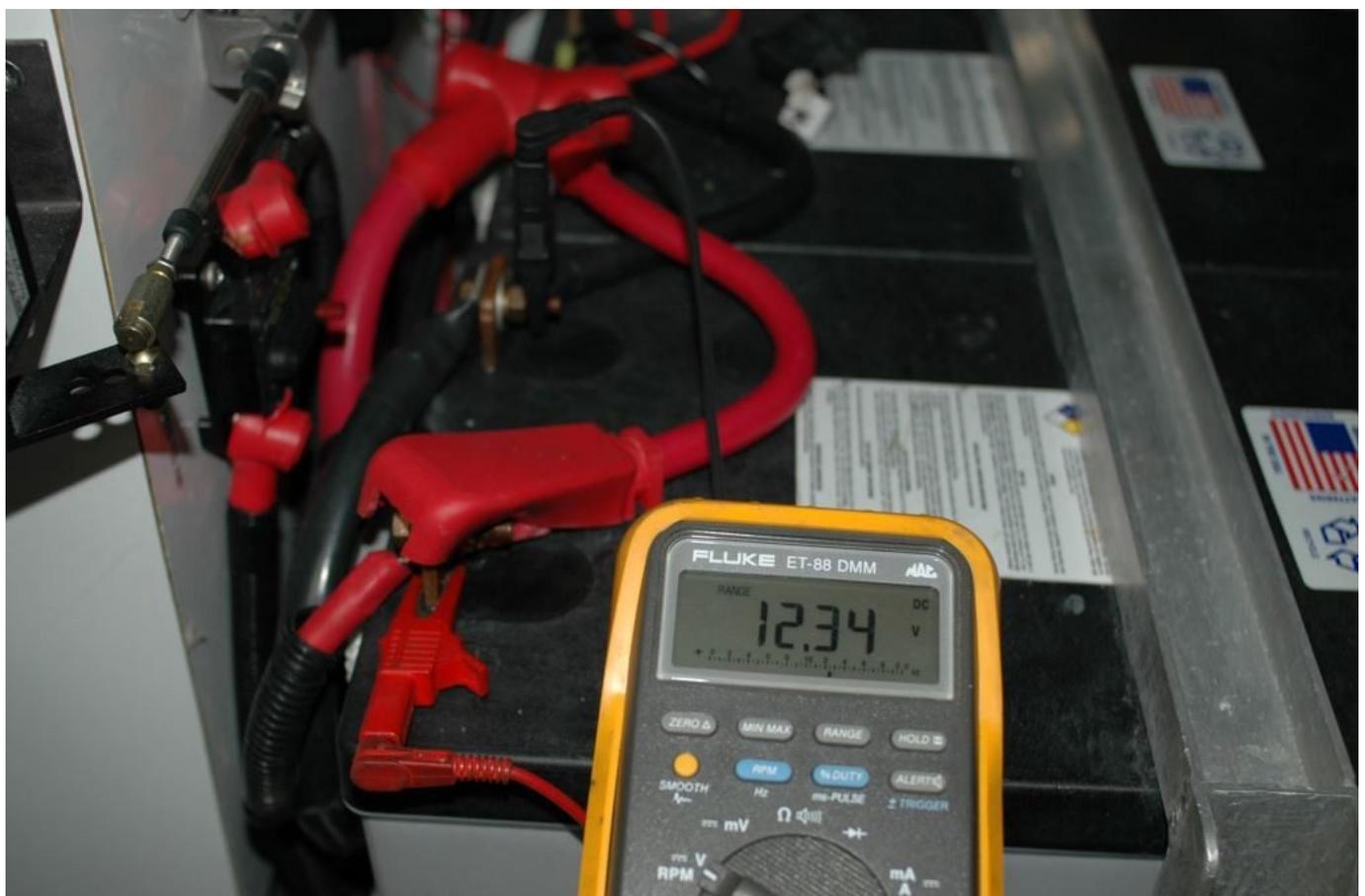
Using the same series logic, 6-volt batteries can be connected in series to make twelve or 24 volts, with the same caveats, voltage is added while amp-hours and CCA remain constant based on each individual battery's capacity. Connecting batteries in series has several advantages, chief among these being they resist charging and voltage imbalances that are common in large battery banks that consist of batteries connected in parallel. Very large battery banks may be made up of 2-volt batteries, twelve for a 24 volt system. Each of these may be rated at as much as 1200 amp-hours. Here's your test, if you create such a bank, for 24 volt applications, using these 2-volt batteries, what will the overall amp hour capacity of that bank be? While you are thinking about that consider this, WWII diesel-electric "Fleet Class" submarines used two volt cells, *250 of them*, (in two banks of 125 each), connected in series, providing 250 volts DC and 4000 amperes of current, which was used to operate electric propulsion motors and house loads while submerged. These batteries were behemoths; each was eighteen inches square and four and a half feet tall. The answer to the above question...1200 amp hours; remember, when connecting batteries in series voltage is added while amp-hours remain constant.

Large 24-volt battery banks are often created using an amalgamation of both series and parallel connections. Four 6-volt batteries may be connected in series to create 24-volts, essentially one 24-volt bank, groups of which are then connected in parallel to increase amp-hour capacity.

### Measuring Voltage and Amperage

A thorough understanding of series and parallel is also required when working with measurement tools such as digital

multimeters or DMMs. Voltage measurements are made in parallel, which means that after setting your DMM to volts DC (or AC if you are measuring shore power, generator or inverter voltage), the test leads are paralleled with whatever is being measured, the red test lead is placed on the positive battery terminal or source and the black test lead is placed on the negative terminal or source. Ampere measurements, on the other hand are made in series. For example, if you wanted to determine how many amps a light fixture used, you would separate the positive (or negative, it doesn't matter) lead from the power source, a switch perhaps and, after setting the DMM to AMPS DC, insert the meter's leads into the circuit, the red test lead on the power supply side of the circuit, the switch terminal, and the black test lead to the wire leading to the light, thereby completing the circuit. The DMM becomes part of the circuit, the lamp lights and the meter reads the current flow, to a point.





**Multimeter voltage measurements are always made in parallel, with the red and black leads connected to positive and negative terminals respectively.**

Most DMMs will measure current in this manner up to about 10 amps, after which an internal fuse will blow, hopefully, before its circuits are damaged. If you wish to measure

larger amperages, you'll have to use an inductive amp clamp, a feature found on many DMMs today, which senses amperage via an electromagnetic field, without ever making contact with the wire through which the current is passing. It's well worth the added expense to select a DMM that includes an inductive amp clamp, just make sure it measures AC as well as DC.





**Current or ampere measurements are made in series, with the multimeter becoming part of the circuit. For current measurements above about 10 amps an inductive amp clamp, like the one shown here, is often used.**

If you can come to grips with the parallel and series concepts, many other electrical scenarios will begin to make

more sense. Take the time to learn these precepts, as well as learning how to use your DMM, you won't regret it.