Lithium Battery Series_Parallel Operation

26.4V system using 13.2V batteries

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Basics

Battery packs are designed by connecting multiple cells in series; each cell adds its voltage to the battery's terminal voltage. Figure 1 below shows a typical EarthX 13.2V LiFePO4 starter battery cell configuration.

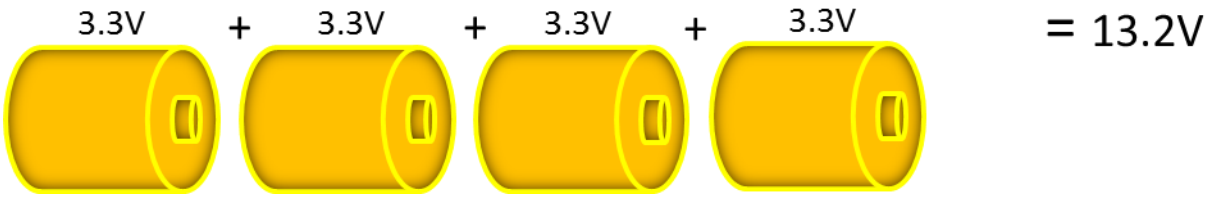

FIGURE 1

Batteries may consist of a combination of series and parallel connections. Cells in parallel increased current handling; each cell adds to the ampere-hour (Ah) total of the battery The EarthX ETX680 is an example of a series and parallel configuration. The ETX680 configuration, 13.2V / 12.4Ah, is shown in Figure 2.

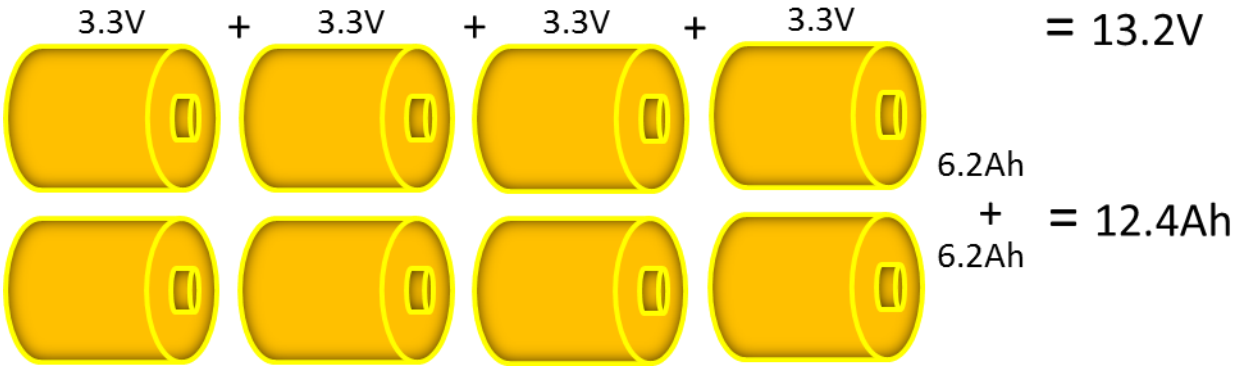

FIGURE 2

A weaker cell in series connected cells would cause an imbalance. This is especially critical in a series configuration because a battery is only as strong as the weakest cell (analogous to the weak link in the chain). A weak cell may not fail immediately but may be drained (voltage dropping below a safe level, 2.8V per cell) more quickly than the strong ones when discharging. On charge, the weak cell may fill up before the healthy ones and be over-charged (voltage exceeding 3.9V per cell). Unlike the weak link in a chain analogy, a weak cell causes stress on the other healthy cells in a battery. Cells in multi-packs must be matched, especially when exposed to high charge and discharge currents. Figure 3 below shows an example of a battery with a weak cell.

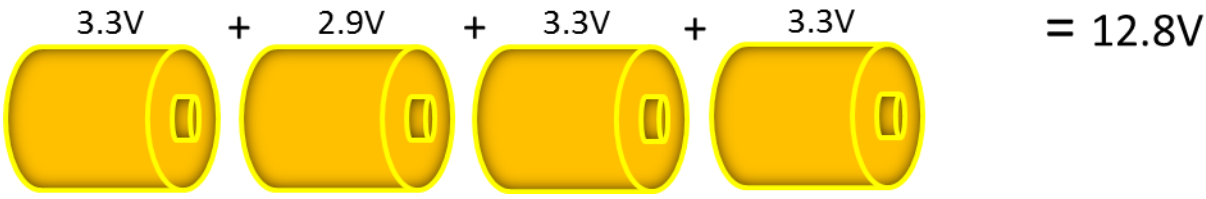

FIGURE 3

Battery Management System (BMS) Cell Protection

A BMS continuously monitors each cell's voltage. If the voltage of a cell exceeds the others, the BMS circuits will work to reduce that cell's charge level. This ensures that the charge level of all the cells remains equal, even with the high discharge (> 100Amps) and charge current (>10Amps).

A cell can be permanently damaged if over-charged (over-voltage) or over-discharged (drained) just one time. The BMS has circuitry to block charging if the voltage exceeds 15.5 volts (or if any cell's voltage exceeds 3.9V). The BMS also disconnects the battery from the load if it is drained to less than 5% remaining charge (an over-discharge condition). An over-discharged battery typically has a voltage less than 11.5V (< 2.8V per cell).

Multiple Batteries in Series and or Parallel (each battery with its own BMS)

EarthX's 13.2V batteries may be used in series and or parallel to achieve higher operating voltages and or capacities for your specific application. It is important to use the same battery model with equal voltage and capacity (Ah) and never to mix batteries of a different age.

Unless stated otherwise, EarthX batteries are approved for use in up to a two series and or two parallel operations, with no additional external electronics. This restriction is applied due to the fact that impedance, capacity, or self-discharge rates between cells may vary. The restriction allows for normal variations in one battery without adversely affecting the other battery. Additionally, the restriction and operating limits allows for abnormal conditions, such as weak or failing cell in one battery. Note, that the ratings for a specific battery are different when it is used in a series operation. See section below "Maximum Safe Operating Limits" for battery ratings.

The wire and connectors used to make the series/parallel array of batteries shall be sized for the currents expected.

Do not connect ETX series lithium batteries with other chemistry batteries.

Parallel Operation

Like individual cells, you can combine batteries together in parallel to achieve higher energy/power (amp-hours, amps). Up to two batteries can be put in parallel. To combine batteries in parallel, connect positive to positive and negative to negative as shown in Figure 4 below.

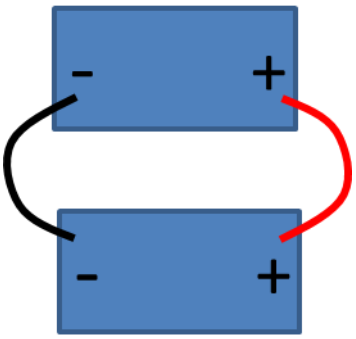

FIGURE 4

Series Operation

Our batteries can be connected in series to increase the operating voltages. Two batteries can be used in series with a nominal system voltage of 26.4V (a single battery's voltage is 13.2V). See the example below for series wiring (Figure 5).

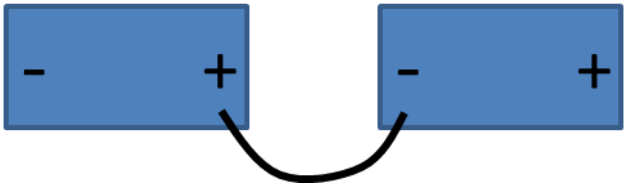

FIGURE 5

Series / Parallel Operation

Below is the approved series and parallel configuration (Figure 6). The batteries are wired as two separate series battery paths, meaning there is no cross ties between the centers of the two separate paths. Figure 7 shows an incorrect connection with a cross tie between the centers of the two separate paths.

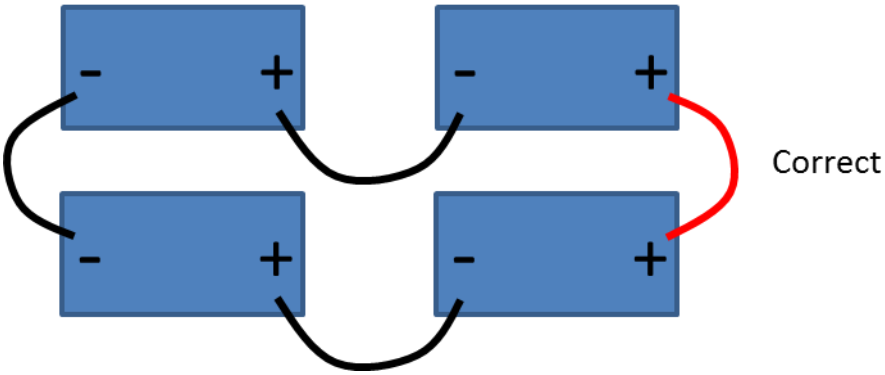

FIGURE 6

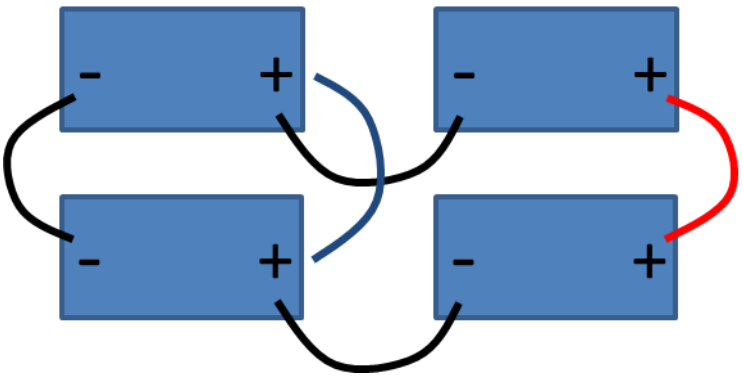

FIGURE 7

Maximum Safe Operating Limits

Based on extensive testing and knowledge of the cells and BMS design, our battery's nameplate ratings are de-rated when used in parallel and or series configurations. For example, the normal maximum charging voltage for a single battery is 14.6V, but when two batteries are put in series the combined normal maximum charging voltage is reduced to 28.8V. When two batteries are put in parallel the continuous discharge amp rating and charge amp rating is typically reduced to 90% of the two batteries' combined rating.

Our ETX series batteries have the capability of extremely high discharge rates and charge rates. However, when our batteries are connected in series and or parallel we recommend you don't exceed the values shown in Table 1 below. Please contact us for applications using battery models not shown in this document.

Model	# in Parallel	# in Series	Max Continuous Discharge Amps	Max Charge Amps	Max Charge Volts
ETX18	2	1	108A	54A	14.6V
ETX18	1	2	60A	27A	28.8V
ETX18	2	2	108A	54A	28.8V
ETX680(C) ETX36	2	1	180A	108A	14.6V
ETX680(C) ETX36	1	2	100A	54A	28.8V
ETX680(C) ETX36	2	2	180A	108A	28.8V
ETX900	2	1	270A	144A	14.6V
ETX900	1	2	150A	72A	28.8V
ETX900	2	2	270A	144A	28.8V
ETX1200 ETX48	2	1	270A	216A	14.6V
ETX1200 ETX48	1	2	150A	108A	28.8V
ETX1200 ETX48	2	2	270A	216A	28.8V

TABLE 1

Series / Parallel Operation and Fault Indication

Each ETX hundred series battery requires its own remote fault indication LED. The 12V LED is connected across the battery's positive terminal and the remote fault indicator wire (pigtail wire out the side of the battery), see Figure 8 below. Connecting the remote fault indicator to an EFIS is not an option in any series configuration (12V LED light is the only option).

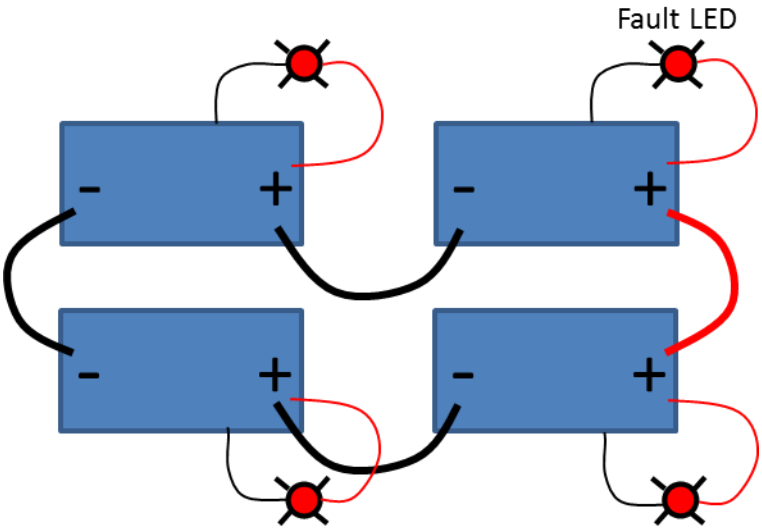

FIGURE 8

References

Source1

EarthX ETX Lithium Battery User's Manual 2016