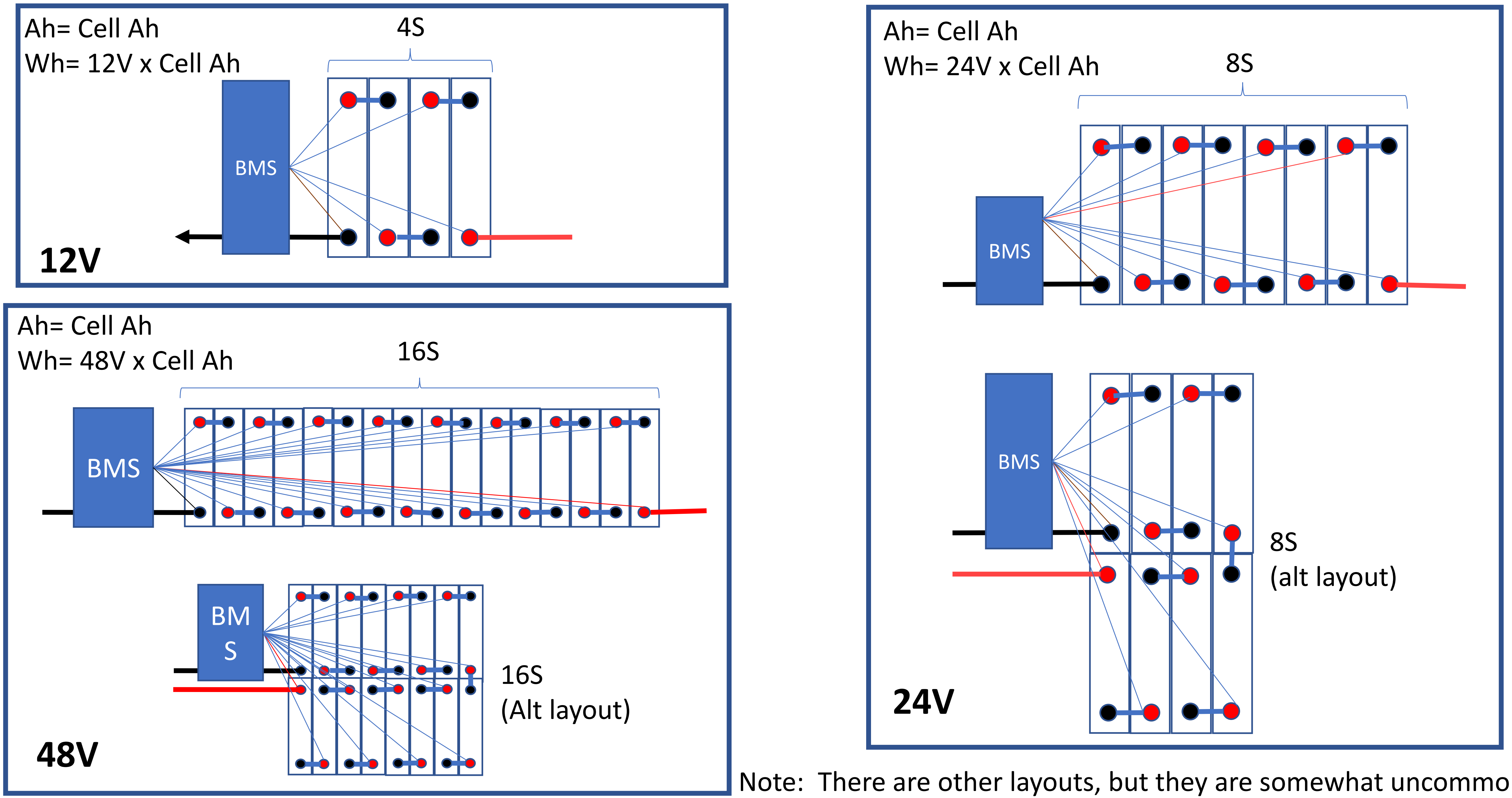
LiFePO4 Cell Configurations 12V, 24V & 48V

This deck shows several common configurations for using LiFePO4 Cells to build 12V, 24V and 48V batteries.

Series-Only (1P) Configurations 12V, 24V & 48V



Note: There are other layouts, but they are somewhat uncommon.

Using Parallel configurations for higher Amp Hours

When cells are in series, the voltage adds but the Amp-hour (Ah) rating remains constant.
The previous slide showed the simplest configurations for the 3 typical voltages (Serial Only). However, the Amp-hours of the resulting battery is equal to the amp-hours of the cells used.

Example: If 8 100Ah cells are in series to create a 24V battery, the AH of the battery is 100AH.

When cells are in parallel, the Ah rating adds but the voltage remains constant
If an Ah ratting for the battery bank needs to be larger than the Ah rating of the cells, then cells must be paralleled in order to increase the Ah Rating of the battery bank.

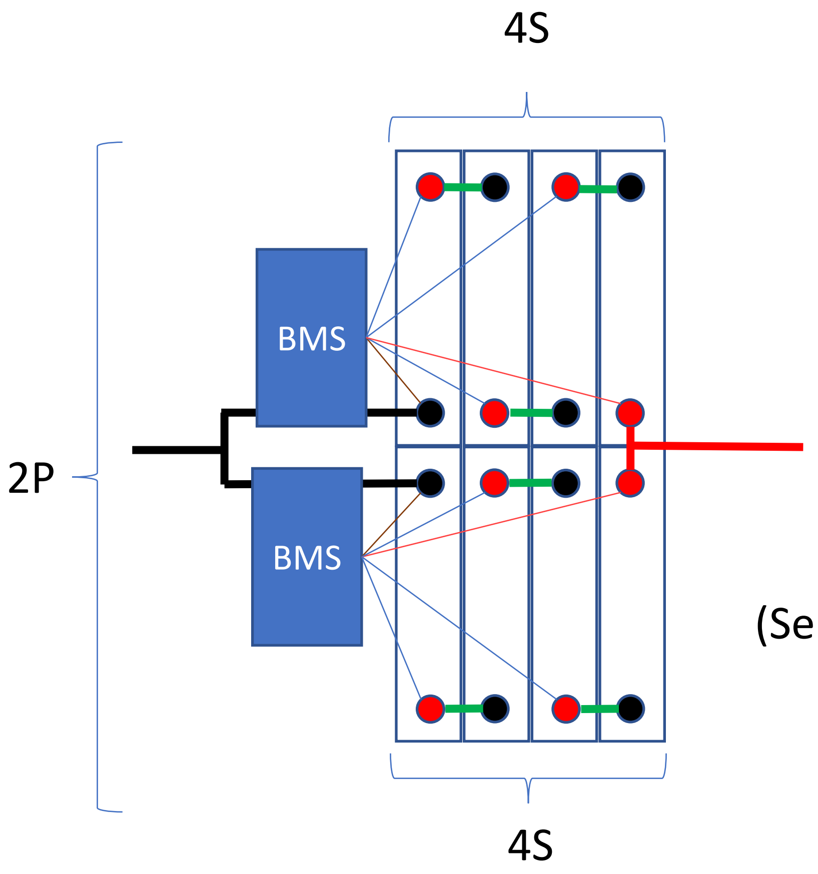
There are two ways to parallel the cells to get higher AH ratings:

1. Series First.
2. Parallel First.

The following slides show how to do both Series First and Parallel First configurations for the 3 common battery voltages.

4S2P Wiring for 12V batteries (Series First)

Voltage = 4 times cell voltage = Nominal 12V for LiFePO4
Ah= 2X Cell Ah (assuming balanced Cells)
Wh= Voltage X Battery Ah = 12V x (2 x Cell Ah) = 24 x Cell Ah

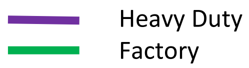


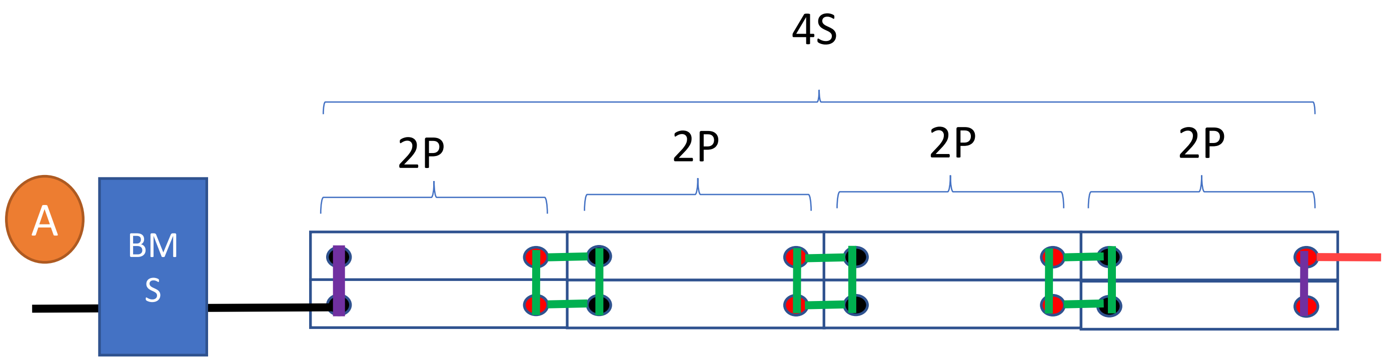
4S2P
(Series-First)

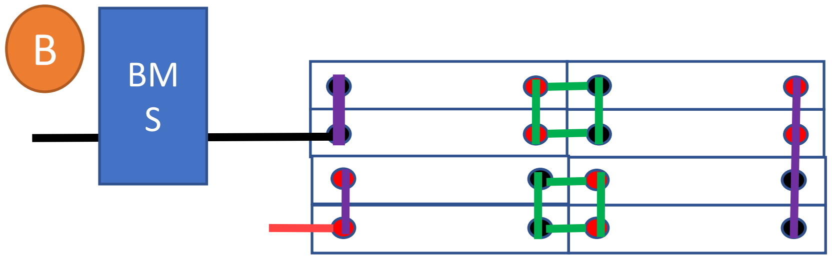
Note: There are other layouts, but they are somewhat uncommon.

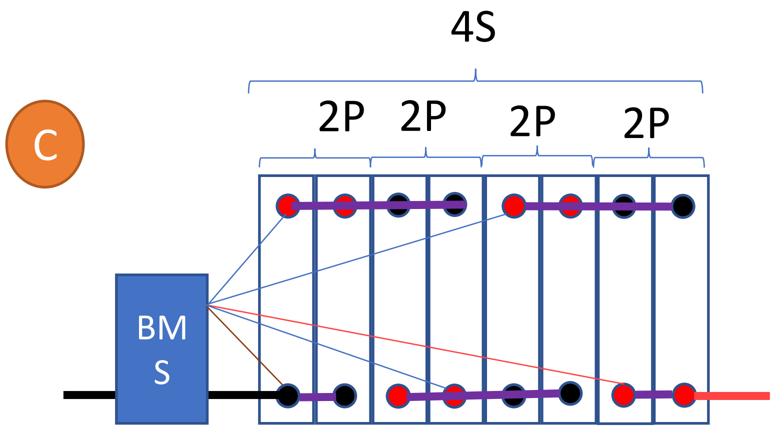
2P4s Wiring for 12V batteries (Parallel first)

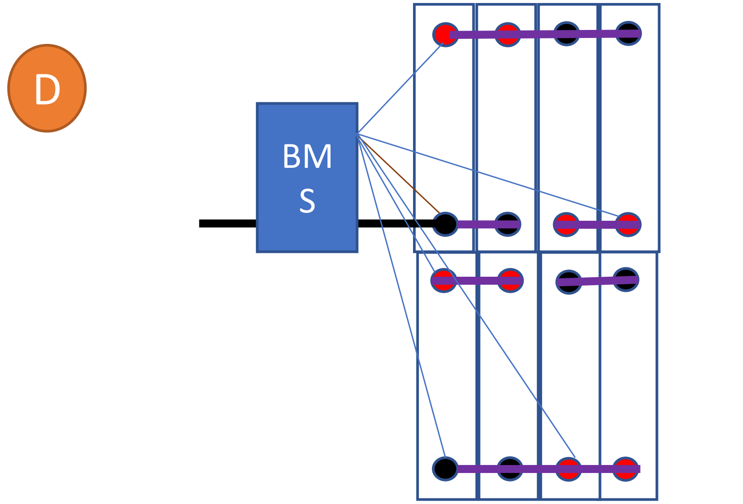
Voltage = 4 times cell voltage = Nominal 12V for LiFePO4
Ah= 2X Cell Ah (assuming balanced Cells)
Wh= Voltage X Battery Ah = 12V x (2 x Cell Ah) = 24 x Cell Ah





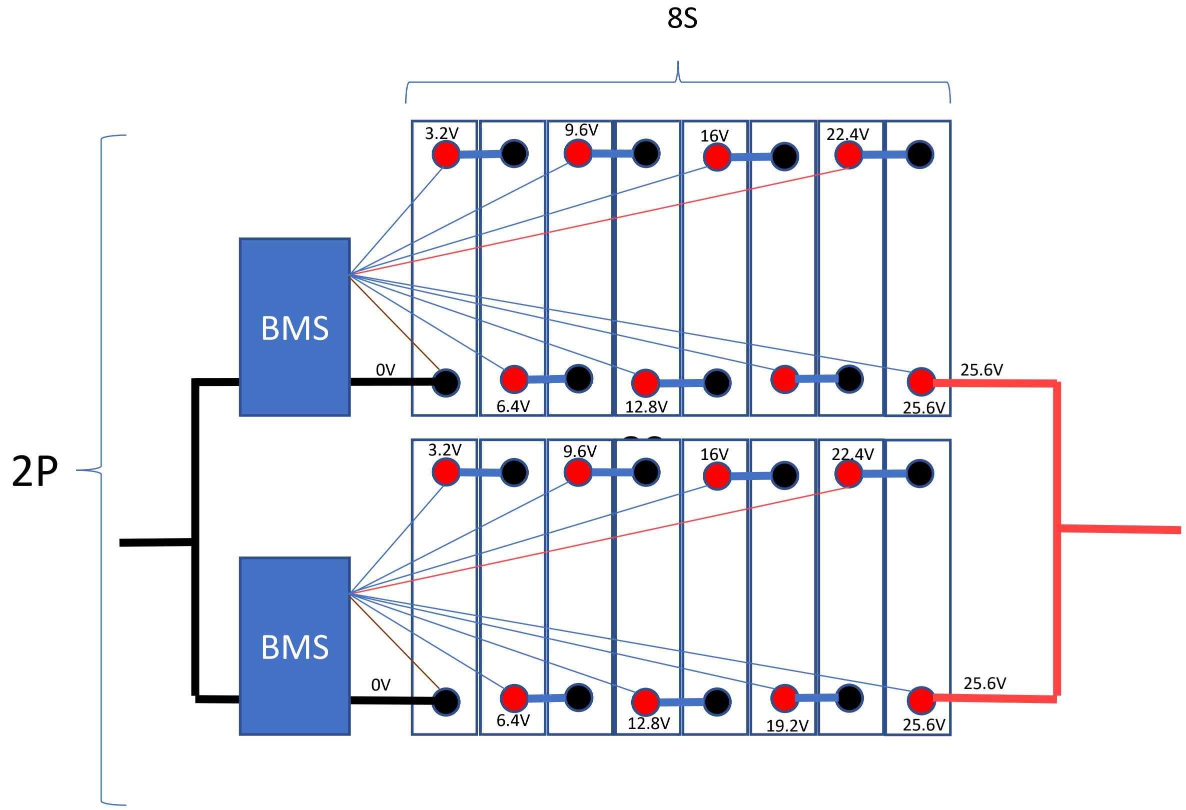






8S2P Wiring for 24V Batteries – Series First

Voltage = 8 times cell voltage = Nominal 24V for LiFePO4
Ah= 2X Cell Ah (assuming balanced Cells)
Wh= 24V x (2 x Cell Ah) = 48 x Cell Ah



8S2P
(Series-First)

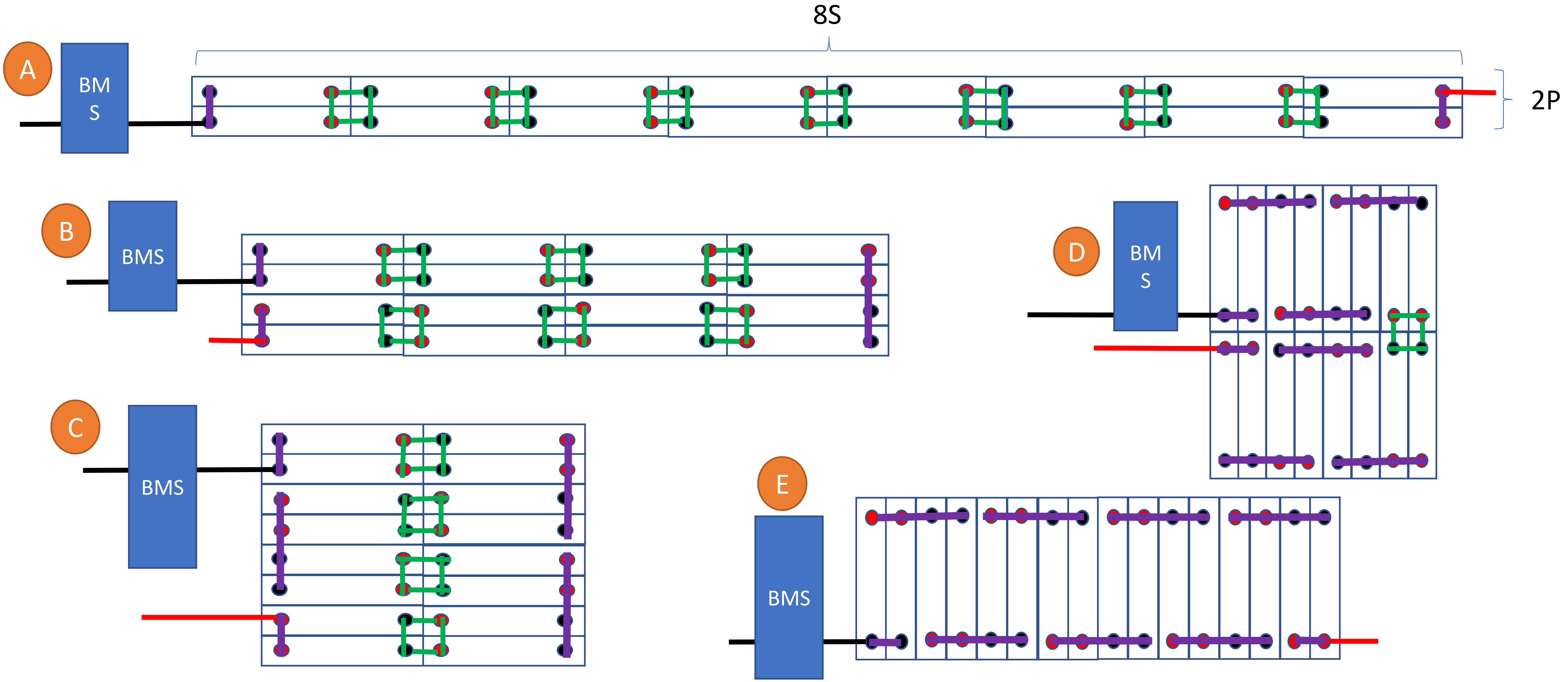
Note: There are other layouts, but they are somewhat uncommon.

Possible 24V 2P8S Fortune Cell Layouts

BMS Balance Harness not shown

Voltage = 8 times cell voltage = Nominal 24V for LiFePO4
Ah= 2X Cell Ah (assuming balanced Cells)
Wh= 24V x (2 x Cell Ah) = 48 x Cell Ah

Heavy Duty
Factory

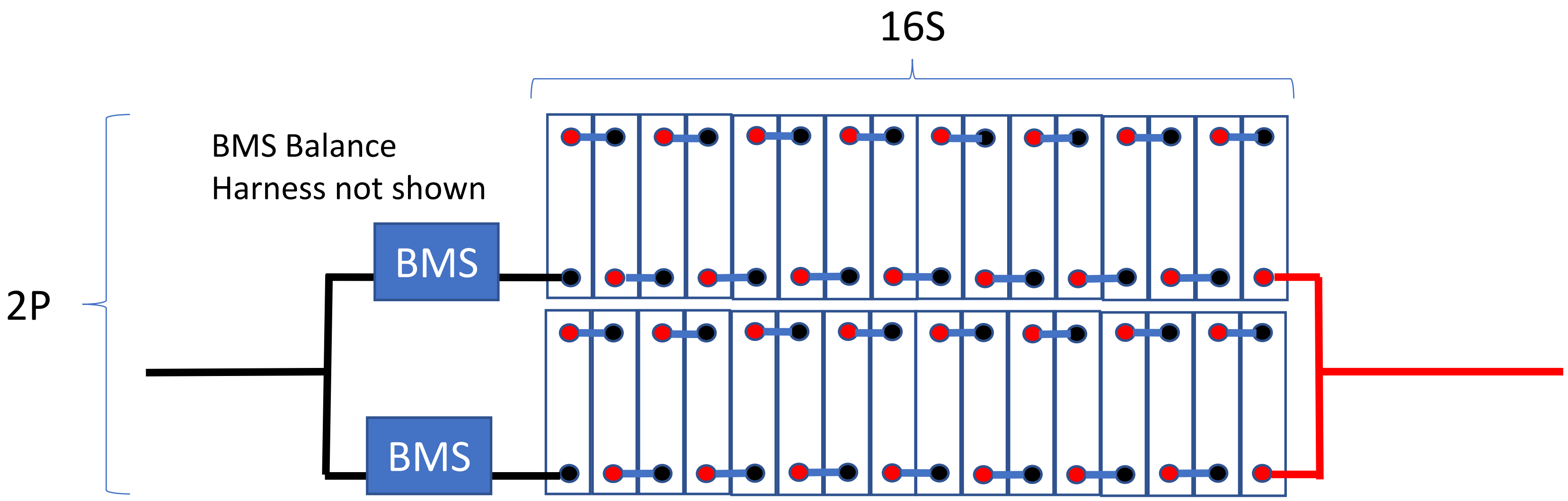


16S2P Wiring for 48V Batteries – Series First

Voltage = 16 times cell voltage = Nominal 48V for LiFePO4

Ah= 2X Cell Ah (assuming balanced Cells)

Wh = 48 X (2 x Cell Ah) = 96 x Cell Ah



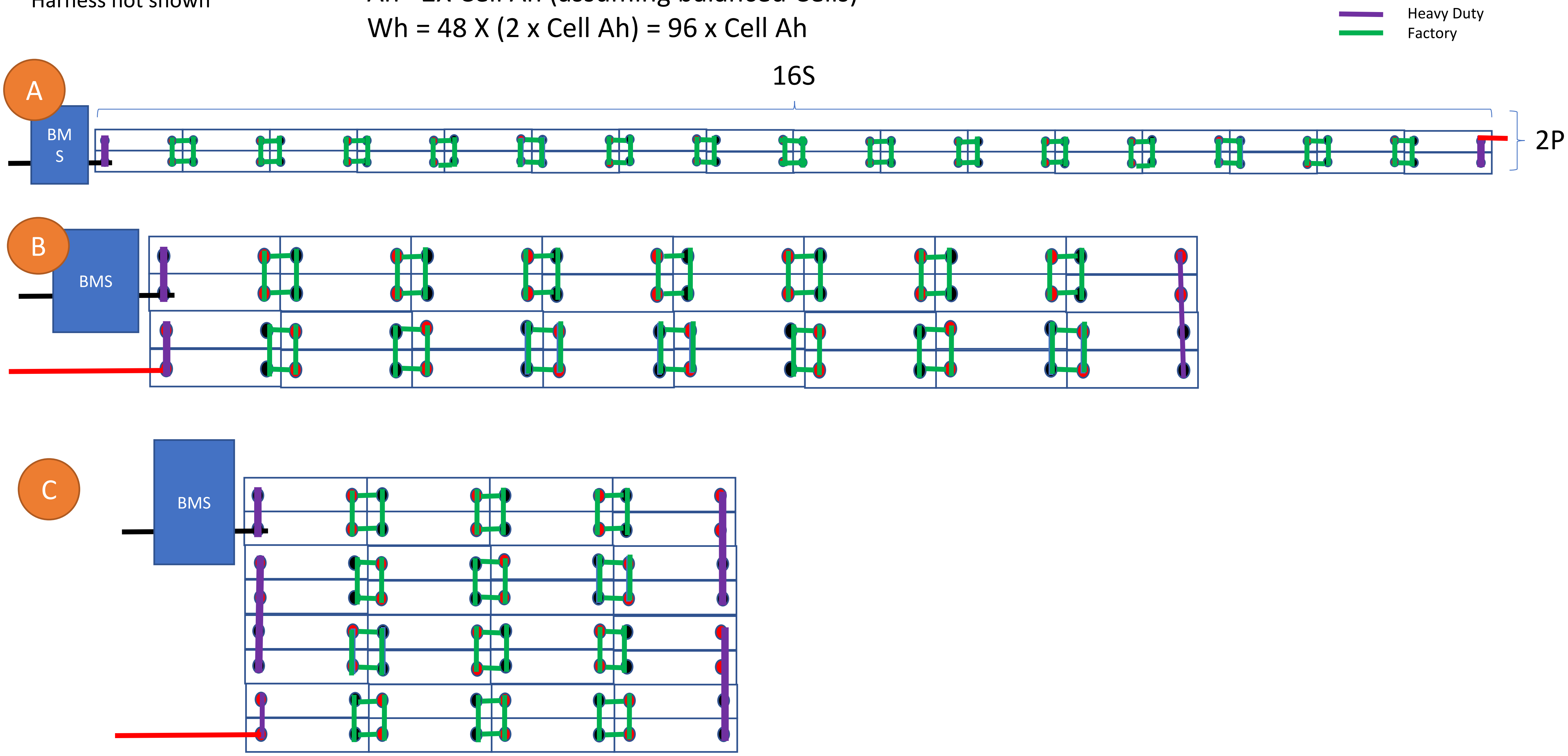
16S2P Series First

Note: There are other layouts, but they are somewhat uncommon.

2P16S Wiring for 48V Batteries – Parallel First

BMS Balance
Harness not shown

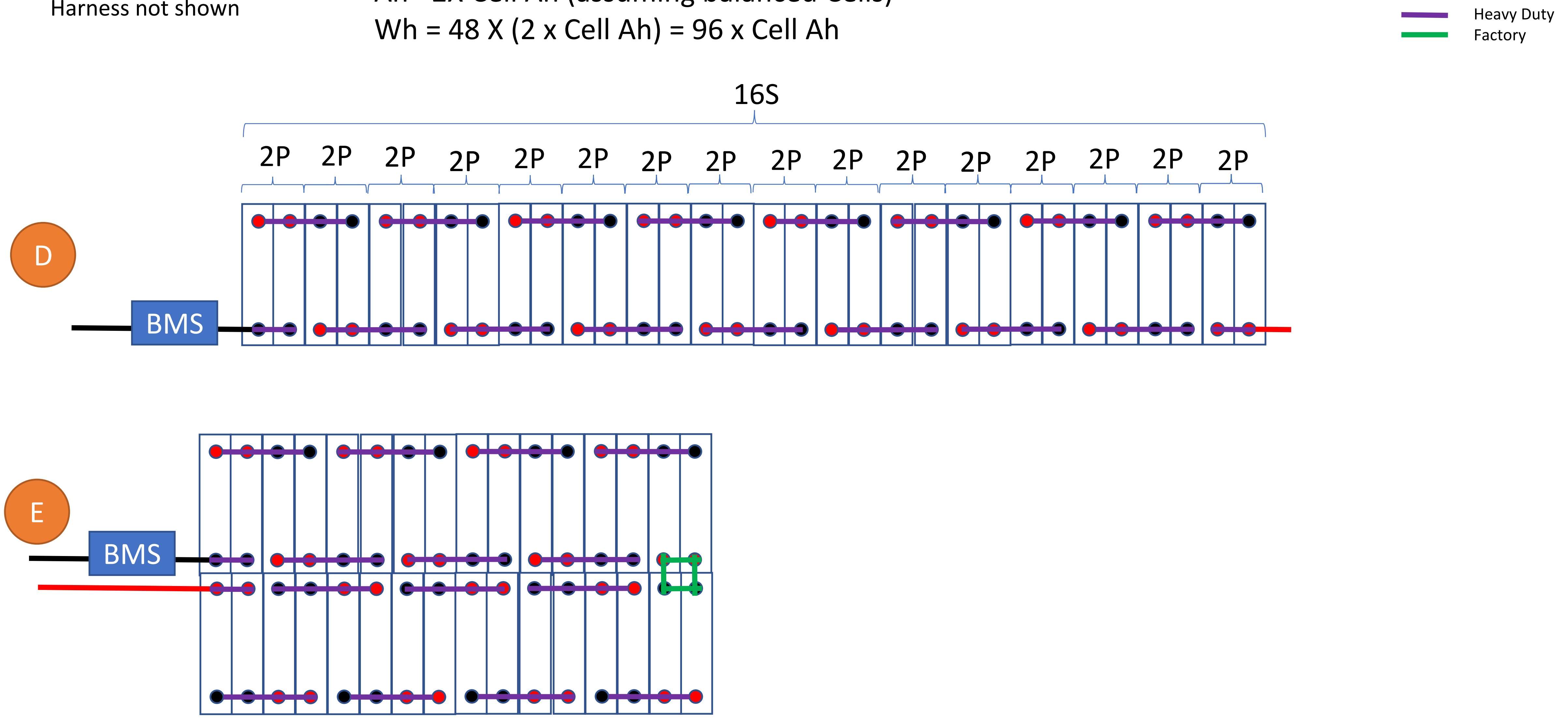
Voltage = 16 times cell voltage = Nominal 48V for LiFePO4
Ah= 2X Cell Ah (assuming balanced Cells)
Wh = 48 X (2 x Cell Ah) = 96 x Cell Ah



2P16S Wiring for 48V Batteries – Parallel first (Continued)

BMS Balance
Harness not shown

Voltage = 16 times cell voltage = Nominal 48V for LiFePO4
Ah= 2X Cell Ah (assuming balanced Cells)
Wh = 48 X (2 x Cell Ah) = 96 x Cell Ah

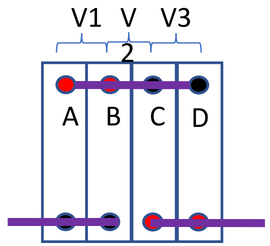


Note: There are other layouts, but they are somewhat uncommon.

A note about Bus-Bars

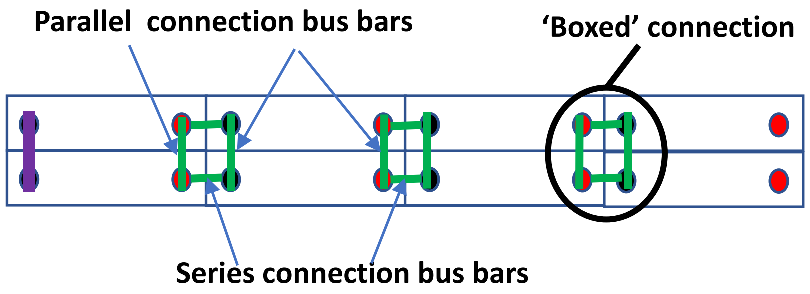
Factory bus bars are generally sized to work well in series hook-ups, but may be undersized for parallel cell hook-ups. In the Previous pages, when 'heavy duty' bus-bars are indicated, I make Bus-Bars out of stock that is twice as thick as the factory bus bars (or at least double up the factory bus-bars).

Figure 1



For parallel cell configurations it is important to balance voltage drop between cells so the cells wear evenly and long bus bars that span more than two cells pose a greater risk of uneven voltage drops. In the diagram to the right, posts A, B, C, and D are tied together so we think of them as all being the same voltage. However, due to the resistance in the bus bars, there will be a small voltage drop between A&B, another drop between B&C and a third drop between C&D.

Figure 2



Since the charge curve for $LiFePO_4$ is so flat the result of these small voltage drops is that the cells with the higher voltages will charge and discharge at a slightly faster rate. If you have good busbars, this effect will be very small but can add up over time. Consequently, I like to avoid the longer bus bars where I can. That is why I prefer arranging parallel cells with the 'boxed' connections as shown in Figure 2. In addition, the series bus bars will carry the bulk of the current and the parallel bars only carry enough to keep the voltage balanced. Consequently, I put the series bus bars down first to minimize the resistance between the cell terminal pad and the higher current bus bar.

When I do need to span more than two posts, I like to **make my own multi-hole bus bars** rather than use a series of 2-hole bus-bars. The connection between the 2-hole bus bars will typically be higher resistance than the bus bars themselves.

This may all be overkill, but it is the way I do it.

Series first vs parallel first

There is a lot of debate about whether series-first or parallel-first is best. The fact is, both of them are used successfully by many people. The 'correct' choice comes down to the particular situation and the designer's preference.

Parallel-First		Series-First	
Pro	**Con**	**Pro**	**Con**
• Simplicity of a single BMS (Fewer corner cases, less electronics that can go bad) • (possibly) Lower Price of the single BMS • The BMS balances everything	• Must use higher current BMS • Only 'groups' of cells are managed and monitored • With only one bank there is no fall back redundancy • More need to pay attention to voltage drop on bus-bars	• Each cell is monitored and managed separately. • If one bank goes out, you still have the other bank • You can use lower current BMSs to build up a High current solution.	• Complexity of two BMS and making sure the corner cases are covered. • Doubling the BMSs can increase cost • Doubling the BMSs doubles the circuitry that can go bad. • The multiple BMSs don't balance between the two banks

Complexities to consider on Series-First

Series first is a more complex set-up and therefore care must be taken in the design.

- **Does there need to be a balance function between the batteries?**
- **What is the indication if one of the BMSs fails and service is needed?**
- **If one BMS turns off discharge for any reason, what will happen to the other BMS(s) & battery(s)?**
  - **Can the remaining BMS(s) carry the full load?   If not, will the remaining BMS(s) be damaged, or will it fail gracefully so the user can shed load and restart? (What will it take to restart?)**
  - **If up-time is critical, does the condition need to be automatically detected and load automatically shed?**
  - **Can the remaining battery bank handle the full load, or will the remaining battery(s) be stressed?**
- **If one BMS turns off charge for any reason, what will happen to the other BMS & Battery(s)**
  - **Can the remaining BMS(s) carry the full charge current? If not will the remaining BMS(s) be damaged or will it fail gracefully.   Can the user throttle the charge system and bring the remaining BMSs back online?**
  - **Can the remaining battery bank handle the full charge current, or will they be stressed?**
  - **If up-time is critical, does the condition need to be automatically detected and charge sources automatically throttled or shed?**
- **If up-time is critical, should there be special disconnects or other provisions in order to work on one BMS/Battery without taking the full system off-line?**

All of these potential issues have reasonable solutions, but they need to be thought through before hand. Otherwise, the system may have cascading failure modes, or the redundancy imagined may not actually exist.

Series first vs parallel first – Personal Preference

Warning: The following is the authors personal preference. There is no right or wrong

Where possible I use 1PnS (no parallel at all)
Where there must be parallel, I do builds both ways but I prefer Parallel First.

- I believe that if you start out with good matched cells, the likelihood of one cell drifting way out from the others is very low so I don't feel a need for monitoring individual cells.
- I am a strong believer that simplicity leads to higher reliability.
- In most of my builds, having half capacity does not help much.

When I do series first it is usually because the BMS available will not handle the current for a parallel-first configuration.

Other folks on the forum *strongly* believe Serial-First is the only way to go.

Each designer must decide based on their situation and priorities

Note About Weight

LiFePO4 cells are considerably lighter than any form of Lead-Acid, but as the cell count goes up the battery can still get very heavy.

Example. the EVE 280AH cells weight in at 5.2 Kg (11.5 LBS) each cell

8 cells = 41.2Kg (93 Lbs)

16 cells = 82.4Kg (184 LBS)

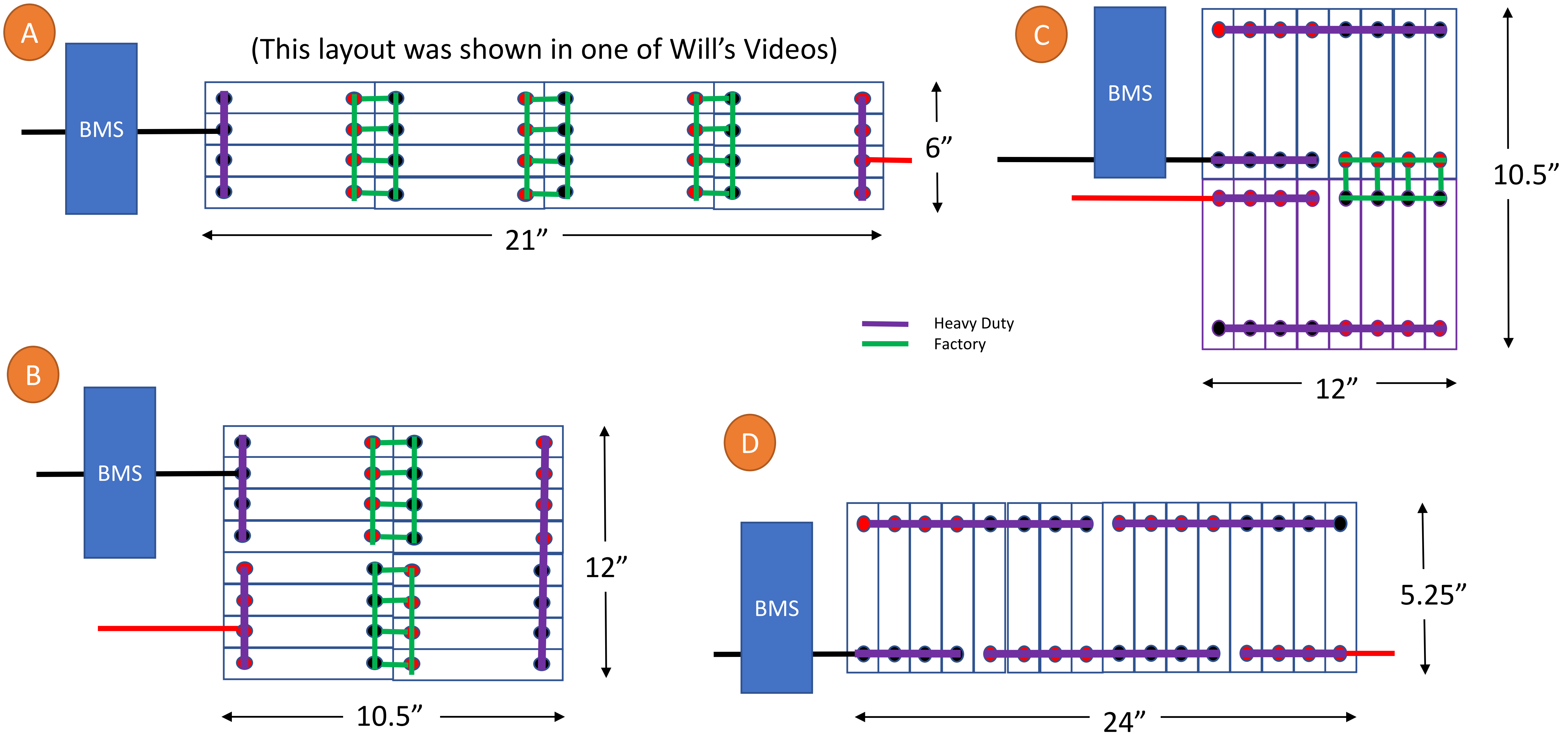
Add the weight of Box and bits it becomes unwieldy quickly.

Document Revision History

Revision 1 - Original
Revision 2 - Added comments about alternate physical layouts
Revision 3 - Added note about weight of large configurations.
Revision 4 - Added Wh (Watt Hour) Calculations.
Revision 5 – Added Parallel first layouts for each voltage and added a note about Bus-Bars

Heavy Duty Bus-bar
Factory Bus-bar

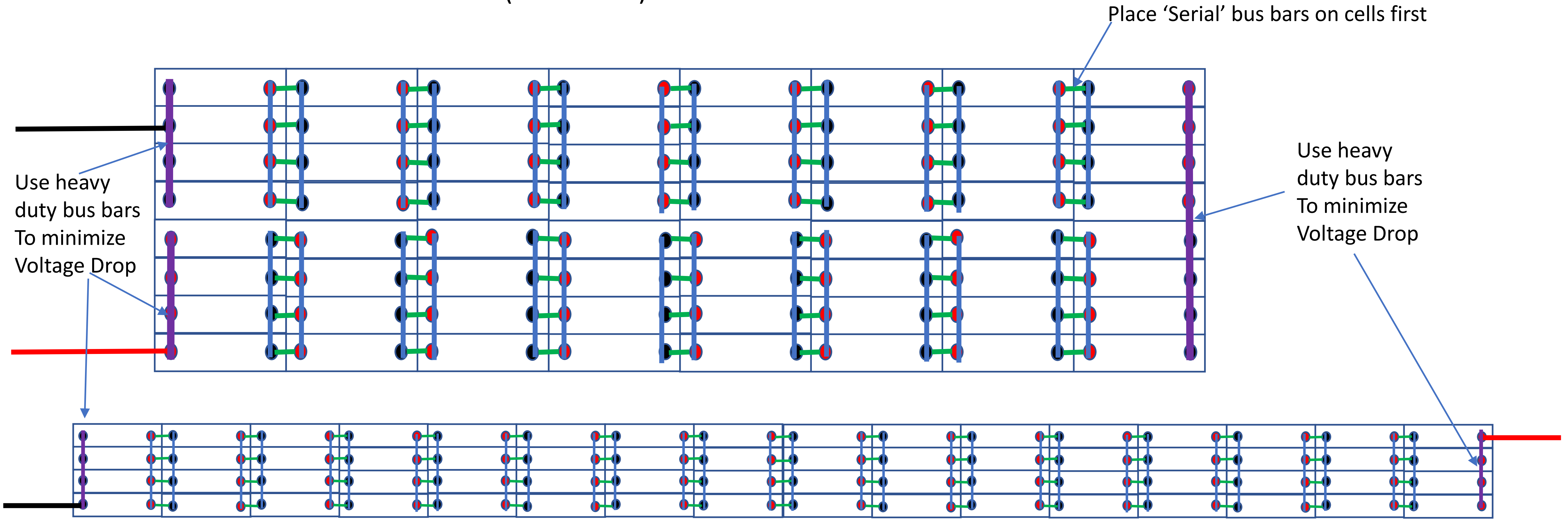
Bonus: A few Possible 12V 4P4S Fortune Cell Layouts



Bonus: 4P16S Wiring for 48V Batteries – Parallel First

BMS & Balance
Harness not shown

Voltage = 16 times cell voltage = Nominal 48V for LiFePO4
Ah= 4X Cell Ah (assuming balanced Cells)
Wh = 48 X (4 x Cell Ah) = 192 x Cell Ah



There are <u>many</u> other arrangements for 4P16S

Heavy Duty
Factory or long fabricated
Factory

Warning: If the application calls for high current, be careful of voltage drop across 'end' long bus bars.