Series vs. Parallel

Batteries in Series

Batteries connected end to end (positive terminal to negative terminal) are said to be connected in series.

System Voltage

The total voltage of the batteries connected in series will be a sum of the individual battery voltages in the series string.

System Capacity

The system capacity, measured in mAh, does not increase in a series string compared to an individual battery.

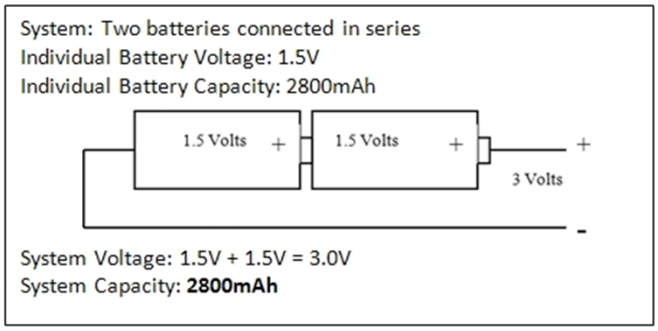

Figure 1 - Example of Batteries in Series

Potential Pitfalls

Incorrect Installation

Reversal protection is recommended to prevent the charging of an incorrectly installed battery in a string of three or more. For information on reversal protection see the design considerations page: http://data.energizer.com/design_hints/pages/dhints_revprotection.html

Deep Discharge

Batteries in a series configuration are susceptible to deep discharge. This will occur when a battery is discharged to less than 0.8V. There is an increased potential of internal gassing and subsequent leakage concerns when a battery is deep discharged. A device that uses a single battery that is closely monitored can be discharged down to 0.5V. If the batteries are deep discharged and cannot be disconnected from the load, a maximum drain of 50 µA is recommended to limit internal gassing over time.

Series vs. Parallel

Batteries in Parallel

Batteries connected by a common negative end and common positive end to the device circuit as illustrated in Figure 1 below are said to be connected in parallel.

System Voltage

With batteries in parallel, the system voltage remains the same as a single battery but the total capacity of the system will increase with the number of batteries in parallel.

System Capacity

The system capacity with batteries in a parallel configuration increases with the number of parallel strings. Figure 2 below shows a simple example of the capacity increase calculation.

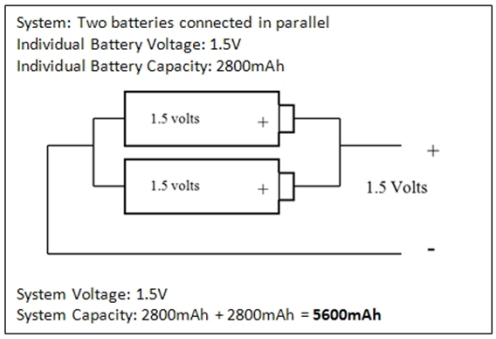

Figure 2 - Example of Batteries in Parallel

Potential Pitfalls

Incorrect Installation

Reversal protection is recommended to prevent a short circuit. For information on reversal protection see the design considerations page: http://data.energizer.com/design_hints/pages/dhints_revprotection.html

Installation of Dissimilarly Discharged Batteries

Batteries connected in parallel should be at the same state of discharge. If batteries at different states of discharge are installed into a device using a parallel battery configuration, the battery with the higher voltage will charge the battery with lower voltage until voltage equilibrium is reached in the system. This charging could lead to leakage, elevated temperature, or other damage to the lower voltage cell.

To reduce the chance of dissimilarly discharged batteries being used in the system, we recommend always installing fresh batteries into the device.

If there is a high likelihood of a device user installing dissimilarly discharged cells, we recommend incorporating blocking diodes into the device circuit to limit charging between parallel strings. Blocking diodes can be used to limit charging between parallel battery strings that are not similarly discharged but the voltage drop caused by the diode can be undesirable in circuit design. Schottky diodes are well suited for blocking current between parallel strings due to their low voltage drop.

Series vs. Parallel

Series/Parallel Combination

System Voltage

In a series/parallel configuration, two or more batteries are connected in series and then placed in parallel with additional series strings. The voltage of this system is additive in the series string.

System Capacity

The capacity of the battery system increases by the number of parallel strings.

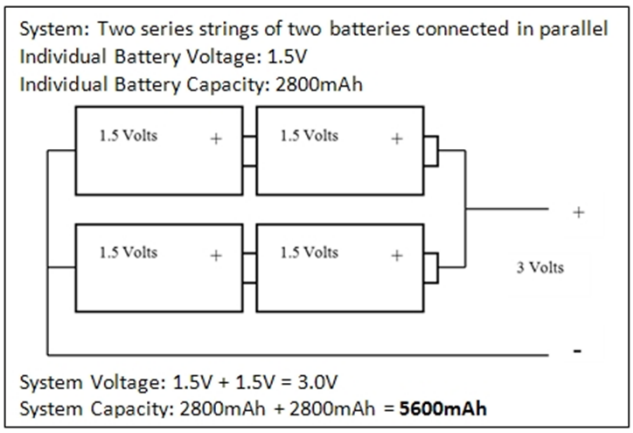

Figure 3 - Example of Batteries Connected in a Series/Parallel String

For example, with the series / parallel configuration shown in Figure 3 using 1.5V 2800 mAh batteries, the output would be 3.0V with a capacity of 5600 mAh.

Potential Pitfalls

Incorrect Installation

Reversal protection is recommended to prevent charging of one battery and shorting of other incorrectly installed batteries. For information on reversal protection see the design considerations page: http://data.energizer.com/design_hints/pages/dhints_revprotection.html

Installation of Dissimilarly Discharged Batteries

Batteries connected in parallel should be at the same state of discharge. If batteries at different states of discharge are installed into a device using a parallel battery configuration, the battery with the higher voltage will charge the battery with lower voltage until voltage equilibrium is reached in the system. This charging could lead to leakage, elevated temperature, or other damage to the lower voltage cell.

To reduce the chance of dissimilarly discharged batteries being used in the system, we recommend always installing fresh batteries into the device.

If there is a high likelihood of a device user installing dissimilarly discharged cells, we recommend incorporating blocking diodes into the device circuit to limit charging between parallel strings. Blocking diodes can be used to limit charging between parallel battery strings that are not similarly discharged but the voltage drop caused by the diode can be undesirable in circuit design. Schottky diodes are well suited for blocking current between parallel strings due to their low voltage drop.