Detailed Test Results

True Balancing – Gen 3 – Phase 1

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Overview of this Report

This report presents complete results of each test we performed in Phase 1 of the True Balancing Gen 3 system.

There is a separate (much shorter) report that summarizes test results and highlights the gains in battery performance provided by True Balancing.

We are conducting the tests in three phases:

Phase 1: One 12-cell module with 2.4Ah NMC cells

Phase 2: Two 12-cell modules connected in series, also with 2.4Ah NMC cells

Phase 3: Two or three 12-cell modules in series, with LFP cells

All test results in this report are from Phase 1. The first set of tests were performed on module #1 (also called pack #1). The second set of tests were performed on module #2 (also called pack #2).

Overview of Phase 1 Testing

The goal of phase 1 tests is to get an initial set of test results using a small battery with low capacity cells. With a small battery, tests can be set up and completed quickly.

In phase 1, all tests are performed on a single module with 12 cells. All cells are 18650 NMC cells with a nominal capacity of 2.4Ah. In these tests balancing current is capped at 1.7A, or approximately 0.7C.

Comment on the cells in this set-up

We have been using the NMC cells for testing for about four years. Some of the cells have been subject to abuse, such as repeated discharges to below cutoff voltage.

The cells have degraded and have significant variation in characteristics and capacities. The actual capacity of each individual cell is different, and the capacity of each cell is less than the nominal rating of 2.4Ah.

This creates test conditions that represent real-world situations in which a battery has been used for an extended period in an uncontrolled environment. We are not using "ideal cells" and "ideal conditions" in our tests. We are making the test conditions as close to real world as possible and as tough as possible.

Tests Performed in Phase 1

Tests on Pack #1

Test 1: Measure the capacity of the 12-cell NMC pack

Test 2: Measure discharge capacity of the pack with a worst-case scenario for cell imbalance

Test 3: Verify that capacity of the pack (when using True Balancing) is the sum of the capacities of the individual cells

Test 4: Measure the additional capacity that True Balancing adds to the pack

Test 5: Recoverable energy at end of a discharge cycle

Test 6: Measure capacity of each cell in pack #1

Tests Performed in Phase 1, cont'd.

<u>Tests on Pack #2</u>

Test 7: Measure capacities of the individual cells in pack #2

Test 8: Repeat test 4 on pack #2, with improved controls over the test parameters

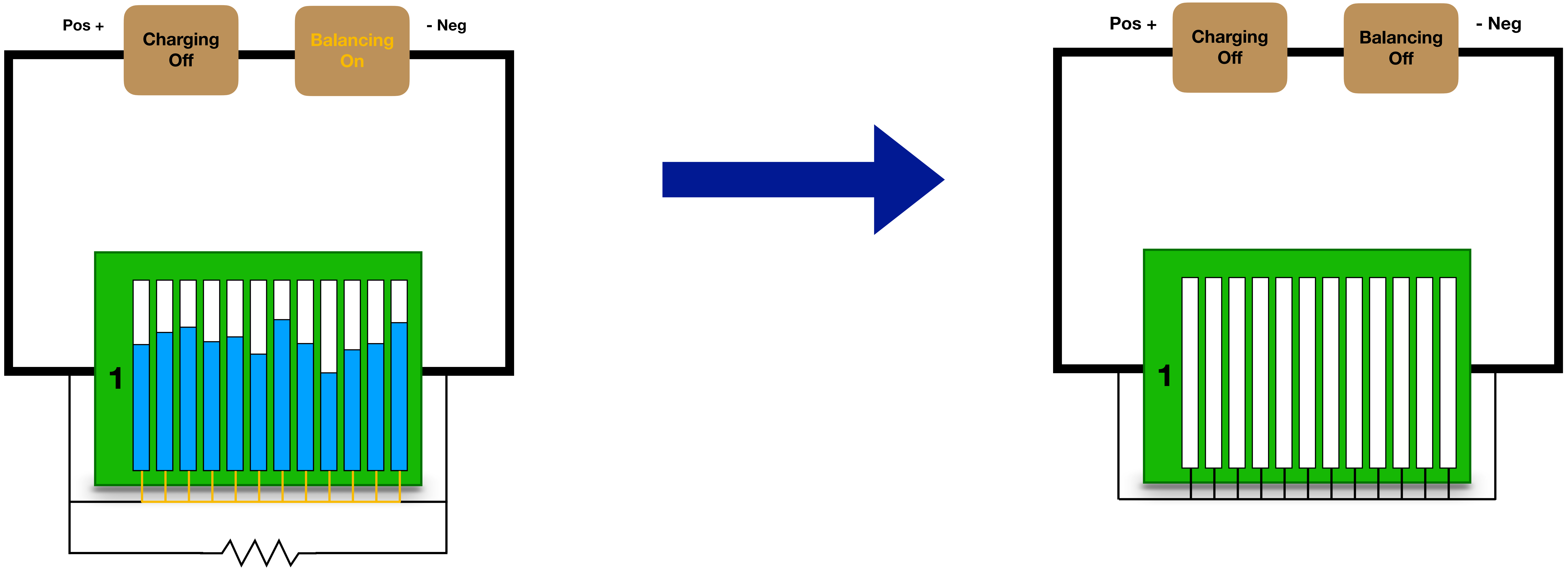
Test 9: Recoverable energy at end of a discharge cycle

Test 10: Additional direct comparisons of battery capacity with True Balancing off then on

Test 1: Measure Pack Capacity

Step 1: Test Set-up – Create Initial Condition

- All cells discharged to COV (with True Balancing running)
- The SOC of the entire pack was brought down to 0% to prepare for step 2 of the test



Load resistor to discharge battery

True Balancing is on to assure that all cells get to COV

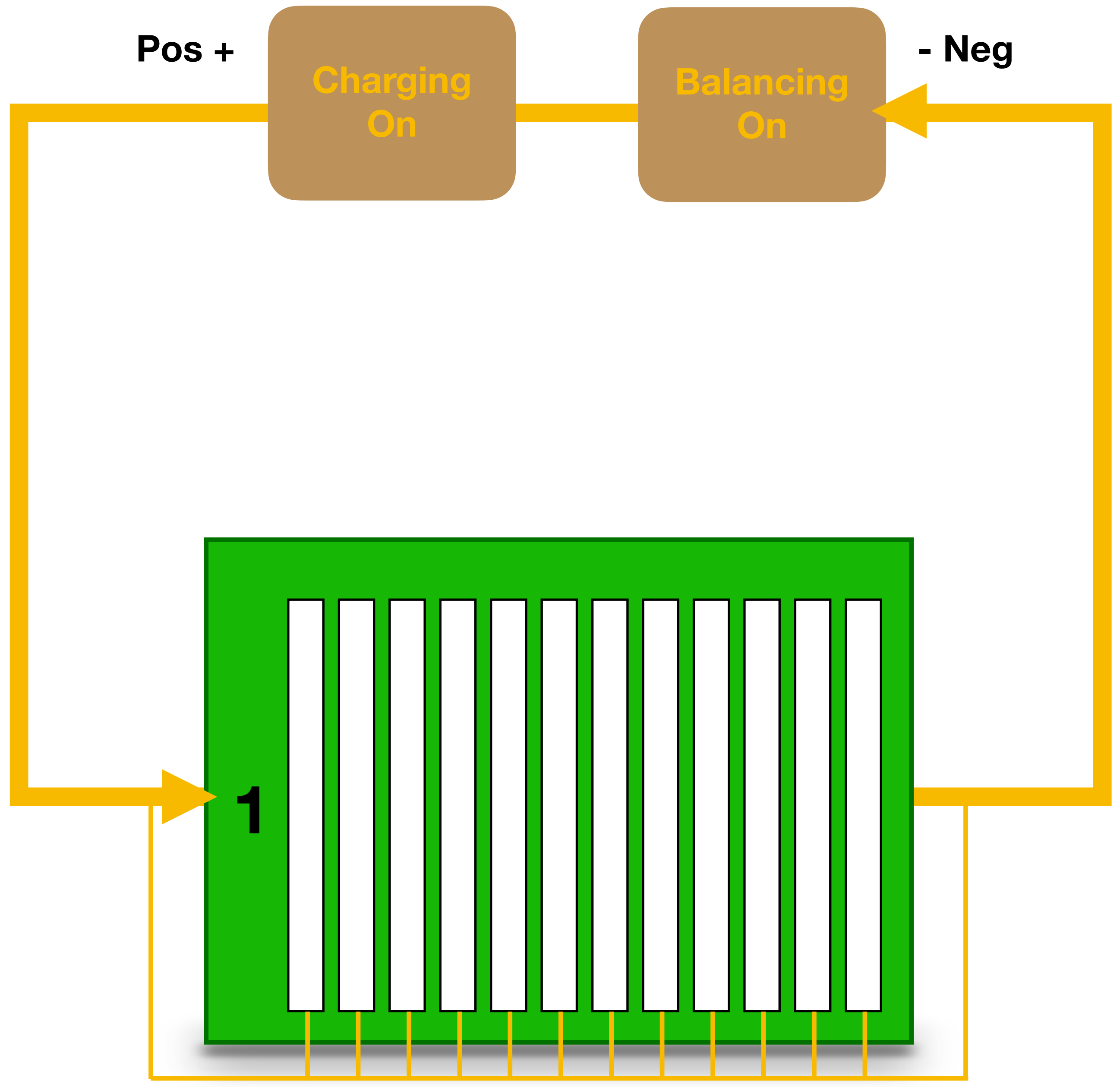
End of Step 1: All cells discharged to COV. SOC of battery is 0%. Ready for step 2 (charging).

Test 1: Measure Pack Capacity

Step 2: Charge the pack

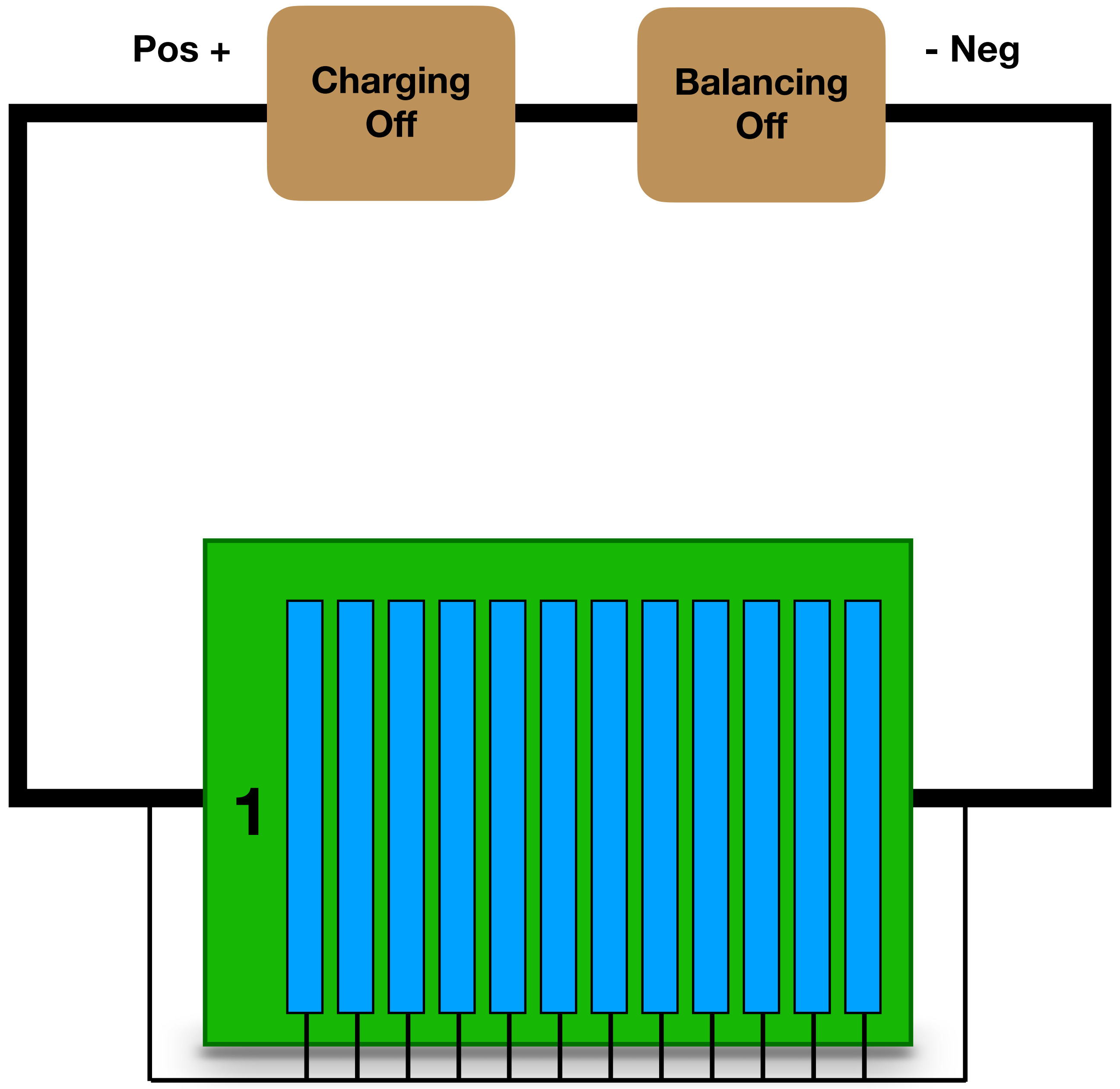
- Charge the pack until all cells reach 100% SOC[1]
- Count coulombs during charging to measure capacity of the pack

(1) True Balancing provides a lot of flexibility in defining the endpoint of the charge cycle for each cell. If you are interested in the details, we can disclose the parameters we used to define the charging endpoint in this test.



Start charging the battery with True Balancing turned on.

Count coulombs while charging



Terminate charging when all cells reach 100% SOC.

Test 1: Results

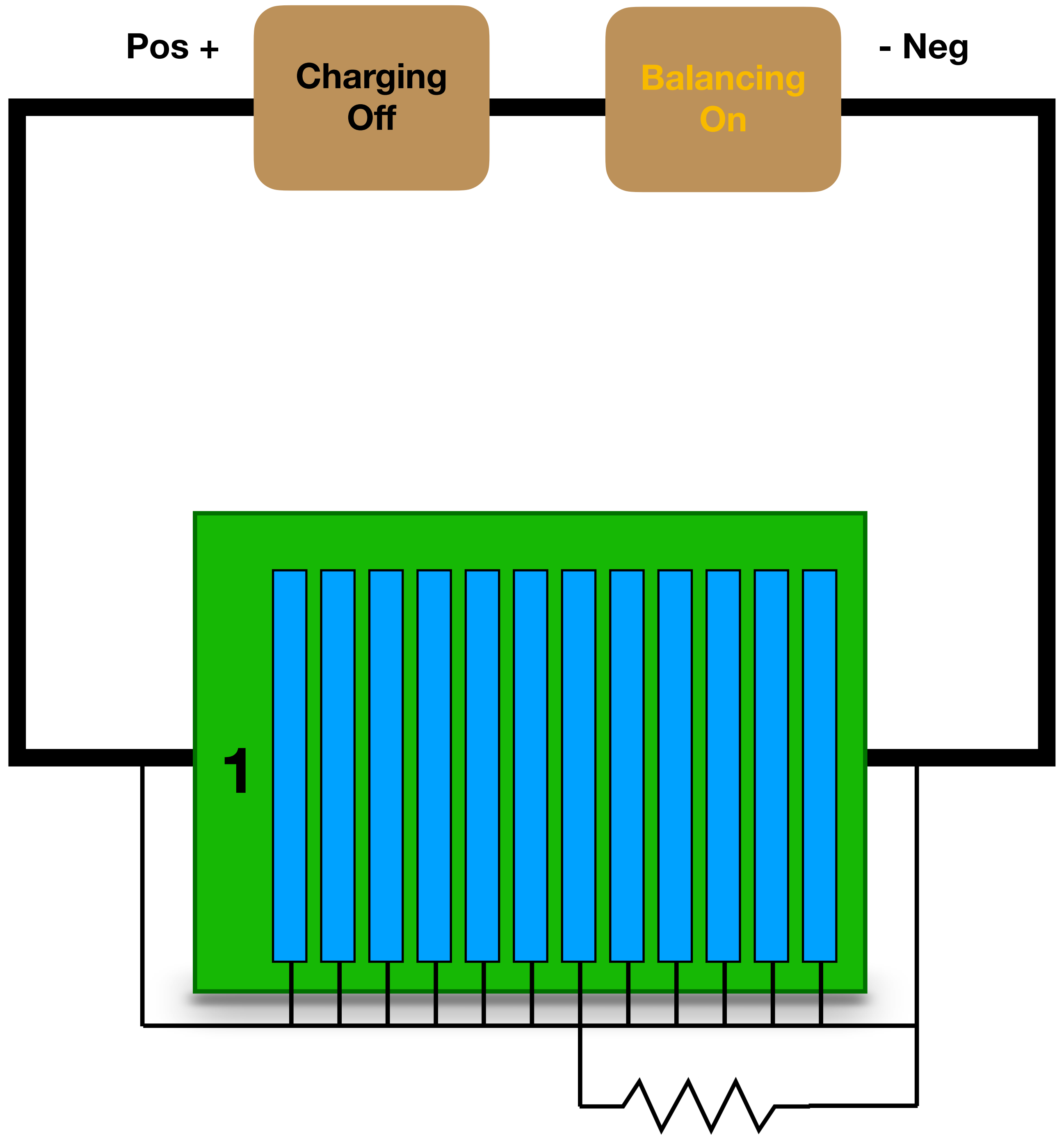
- We measured 2.06Ah of charge stored in the pack
- This result is used in evaluating the outcome of test 2

Test 2: Measure Discharge Capacity with Very Unbalanced Cells

Step 1: Create a worst-case condition for True Balancing

- Start with the fully charged pack from the end of test 1
- Discharge cells 1-6 to very low SOC

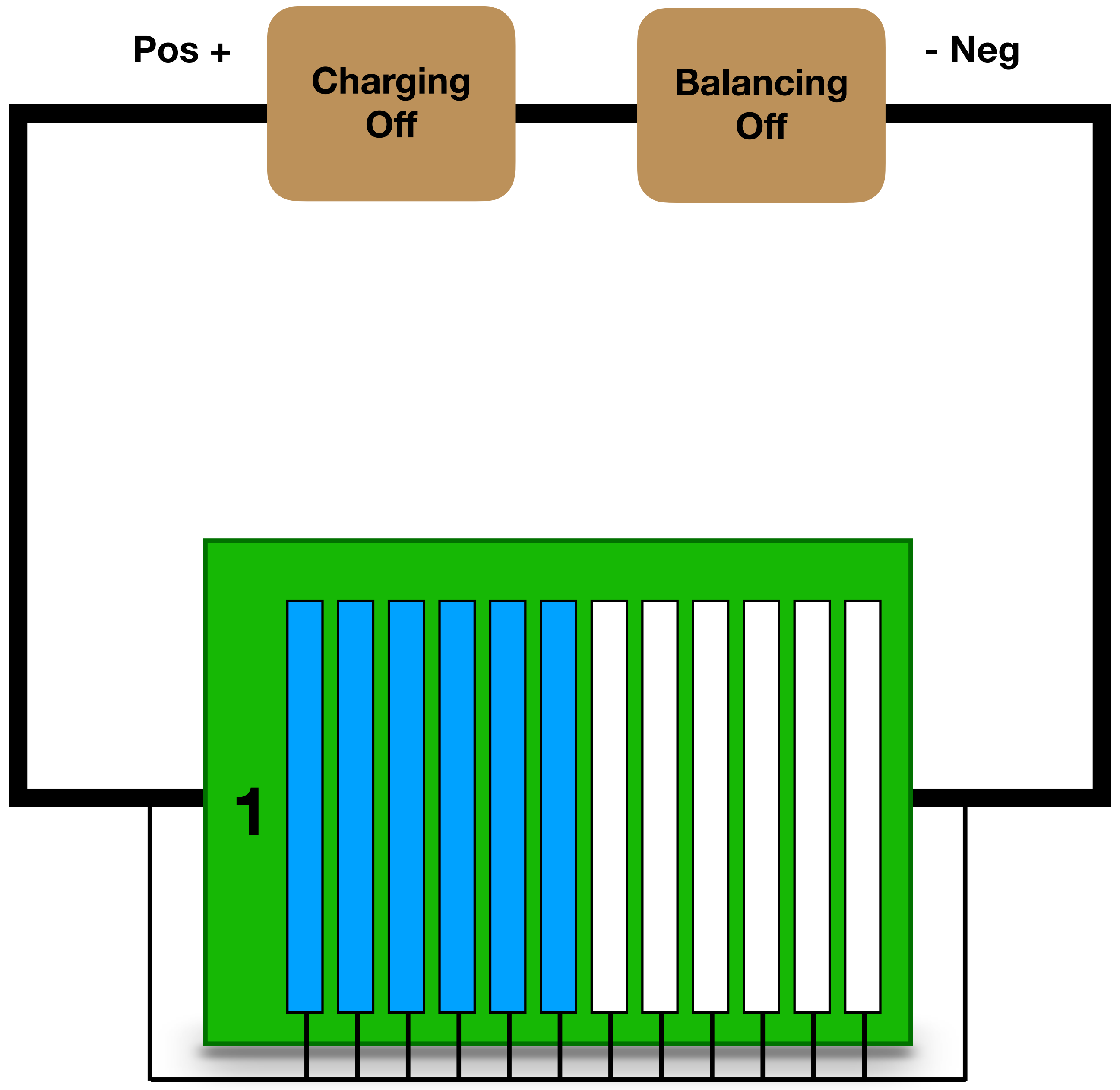
Worst case condition for True Balancing is when half the cells are at 100% SOC, half the cells are at 0% SOC, and the 0% SOC cells are grouped together.



Start with the fully charged battery from test 1
Connect a load resistor to discharge cells 1-6

Discharge cells 1-6 using a 1A load

Count coulombs while discharging

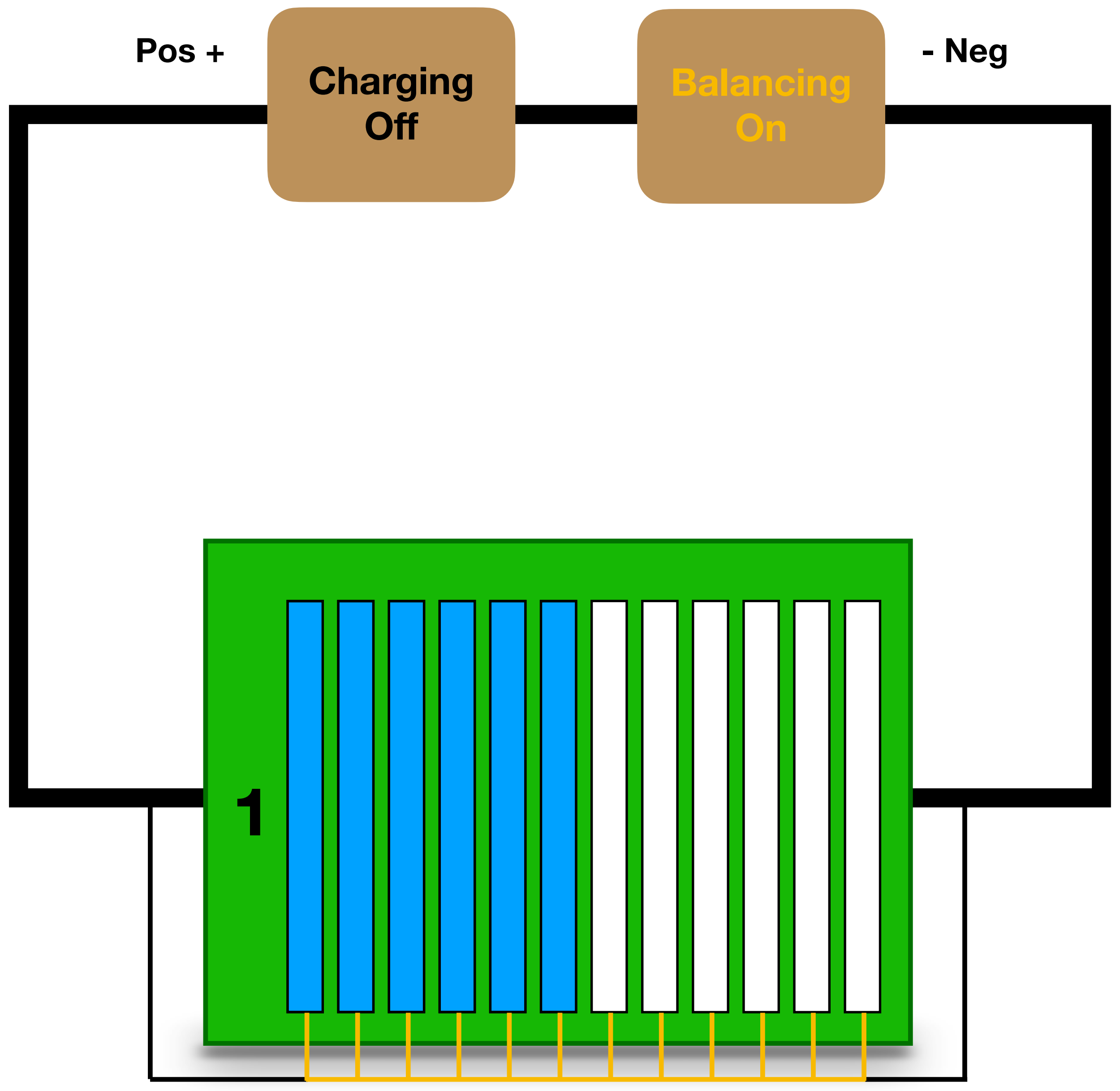


All 6 cells reached 0% SOC at about the same time because we used True Balancing to balancing during the discharge cycle.

Test 2: Measure Discharge Capacity with Very Unbalanced Cells

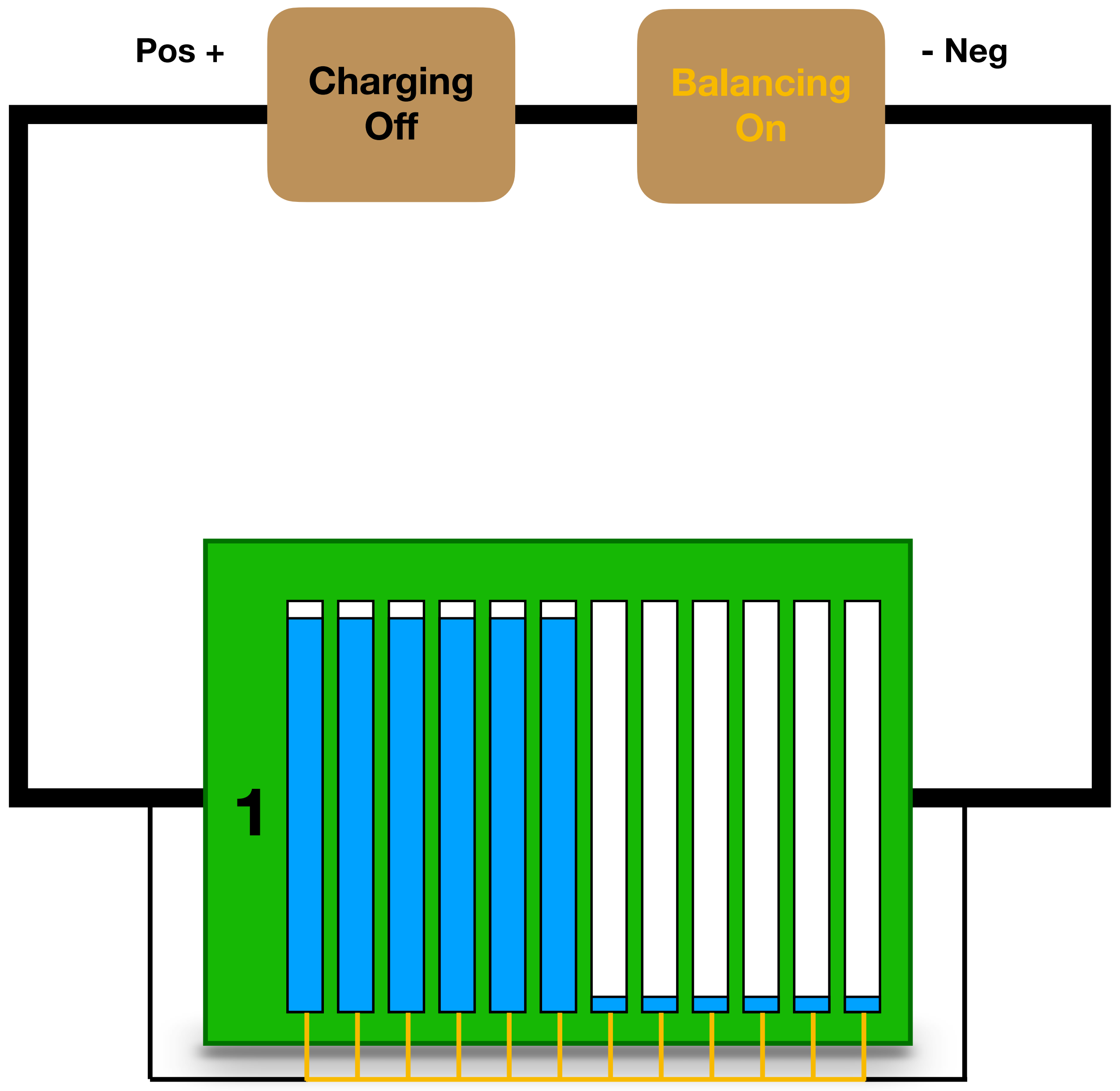
Step 2: Turn on True Balancing with no load for a short period

- We needed to move a little bit of energy to cells 1-6 so that we could apply a load across the entire pack.
- It took just 4 minutes of balancing to get to a point where we could apply a 1A (0.5C) load to the entire battery.



Four minutes of balancing to put a bit of energy into cells 1-6

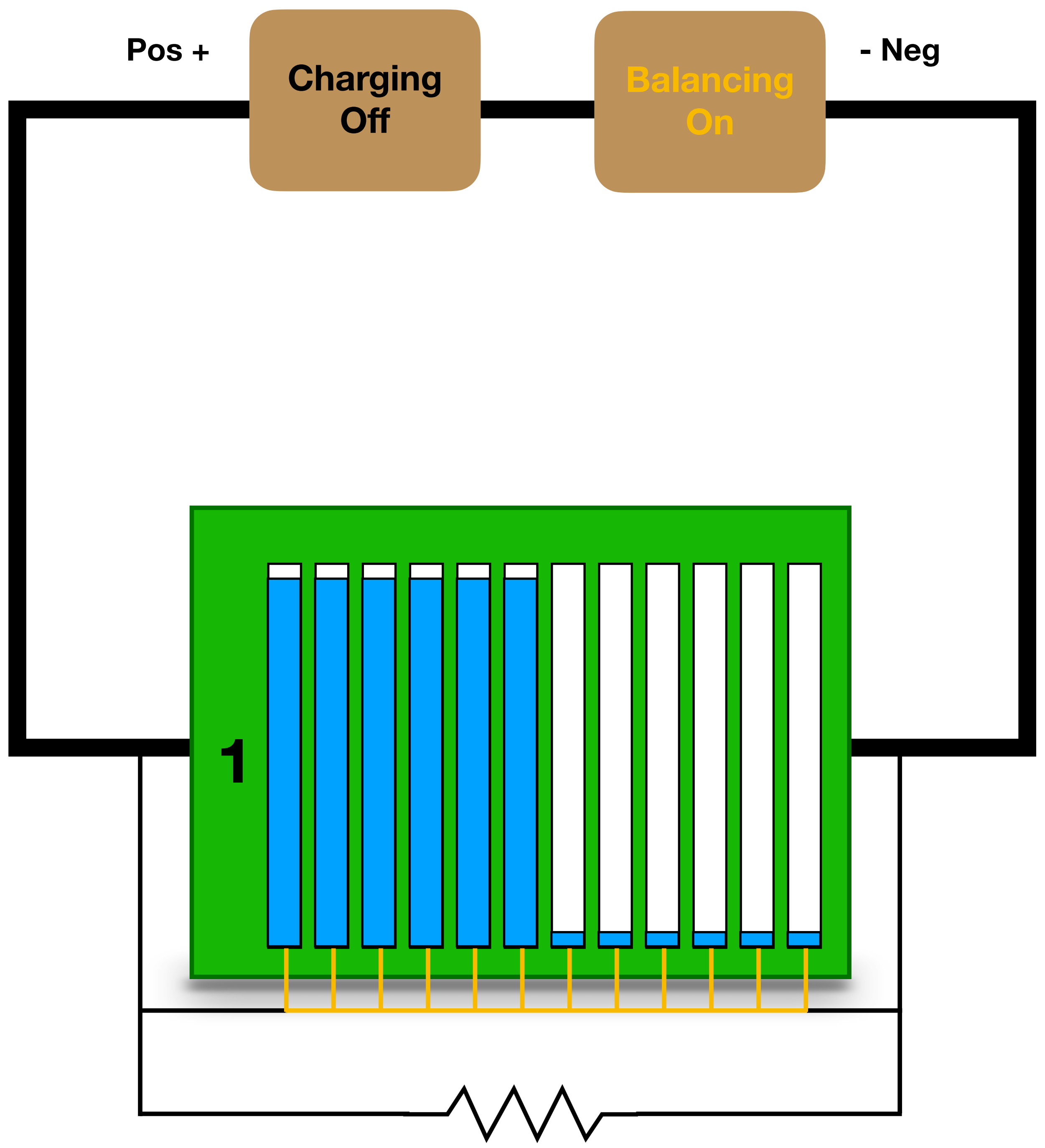
Count coulombs while discharging



Test 2: Measure Discharge Capacity with Very Unbalanced Cells

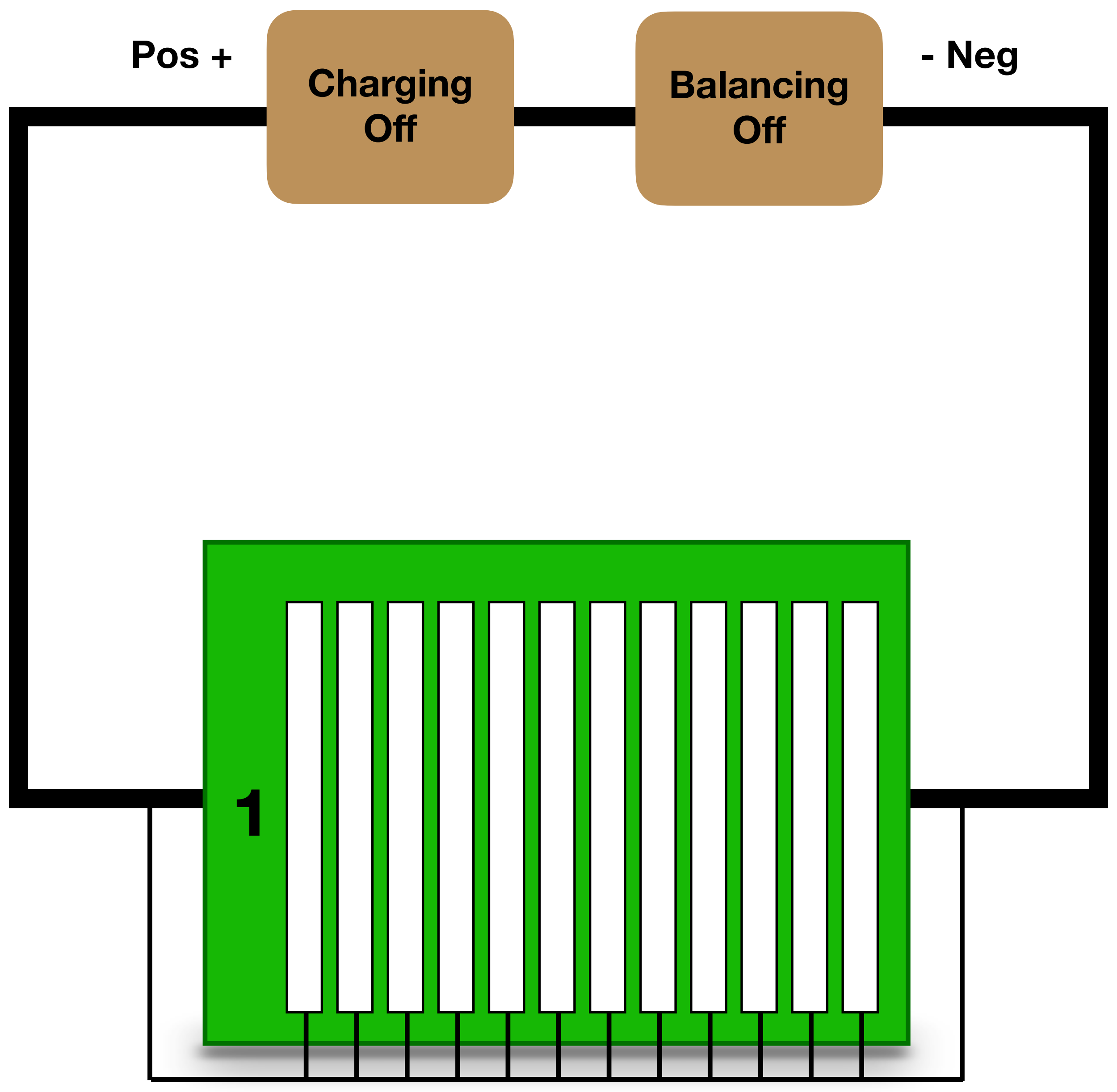
Step 3: Discharge the entire pack with True Balancing turned on

- Use a 1A 0.5C load to discharge the entire pack with True Balancing turned on
- Count coulombs while discharging
- Stop the test when at least one cell reaches COV



1A load on the entire pack

Discharge the pack at 1A
Balance while discharging
Stop discharging when one cell reaches COV



We used True Balancing to balance during discharge, so all of the cells were very close to 0% SOC when the first cell reached COV.

Test 2: Results

- The pack started with 2.06Ah of charge (the result of test 1)
- We measured 1.7Ah of total charge withdrawn from the battery during test 2 (calculated as the sum of coulombs counted during phases 1 and 2 of the test)
- **True Balancing recovered 82.5% of the energy available in the pack (1.7/2.06)**

<u>Comments</u>

This test represents a worst case scenario for True Balancing. In the initial state, half of the cells were depleted to COV and they were grouped together at the bottom half of the series.

If a battery with passive balancing were in this condition (half the cells at COV and half the cells at 100% SOC and the battery is trying to power a load) the battery would be unusable, even though the battery is at 50% SOC on average. If this battery had a passive balancing system, the high SOC cells would have to be drained and then the battery would require prolonged charging and balancing before it could be used.

With True Balancing, we balanced for only 4 minutes and then could apply a 1A 0.5C load to the battery. There was a loss of 17.5% of stored battery energy in this “worst case scenario” test. Not all of the lost energy was due to the operation of True Balancing. There are inherent losses in other parts of the system, including in the cells (which are in pretty bad condition). We don’t have data on how much of the lost charge was due to the operation of True Balancing and how much was due to other areas of loss.

Test 3: Confirm the Ability of True Balancing to Utilize Full Capacity of the Pack

Overview of Test 3

One of the advantages of True Balancing is its ability utilize the capacity of a battery more fully than other balancing systems. Test 3 is one approach to confirming and quantifying this ability.

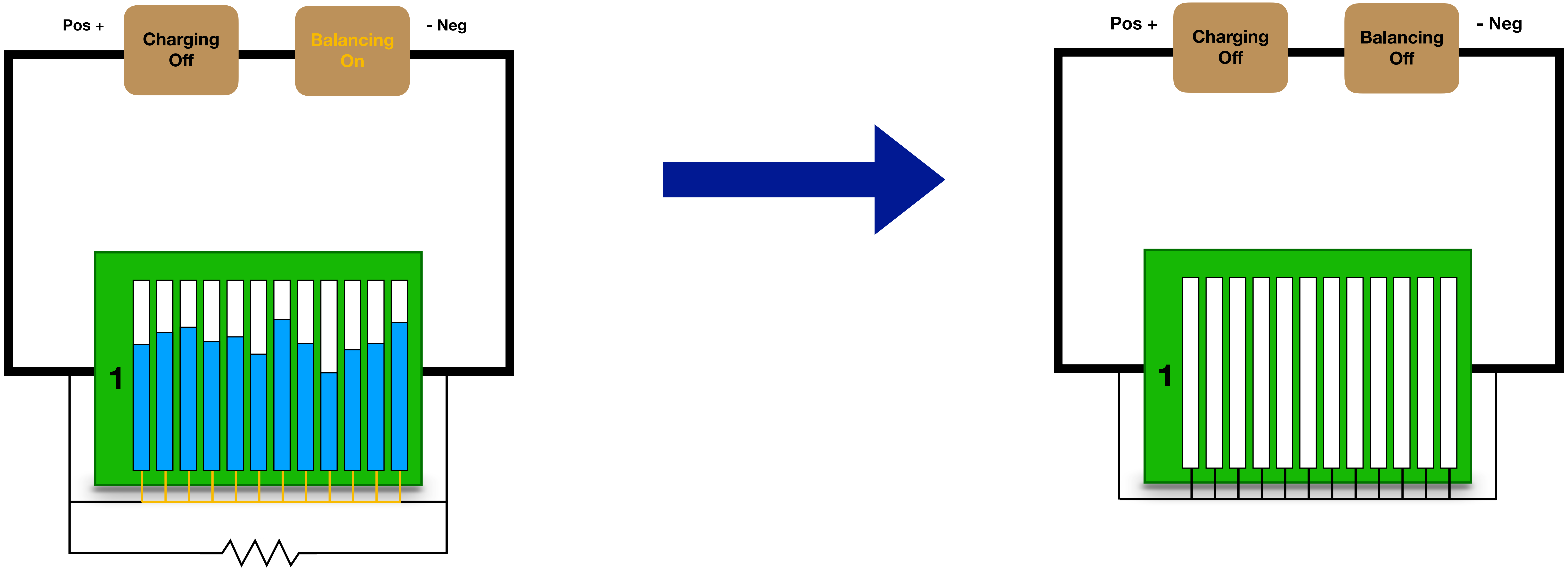
Test 3 consists of the following steps, which are shown graphically on the following pages:

1. Discharge the pack with True Balancing on to bring all cells to 0% SOC
2. Charge the pack with True Balancing off. This makes the test challenging, because we aren't charging the pack as fully as possible if True Balancing were on.
3. Discharge selected individual cells to 0% SOC to create a very unbalanced back.
4. Use True Balancing to get as much energy as possible out of this unbalanced pack.

Test 3: Confirm the Ability of True Balancing to Utilize Full Capacity of the Pack

Step 1: Discharge pack to nearly 0% SOC

- Discharge with True Balancing on until all cells are at COV
- At the end of step 1, the entire pack is at 0% SOC



Load resistor to discharge battery

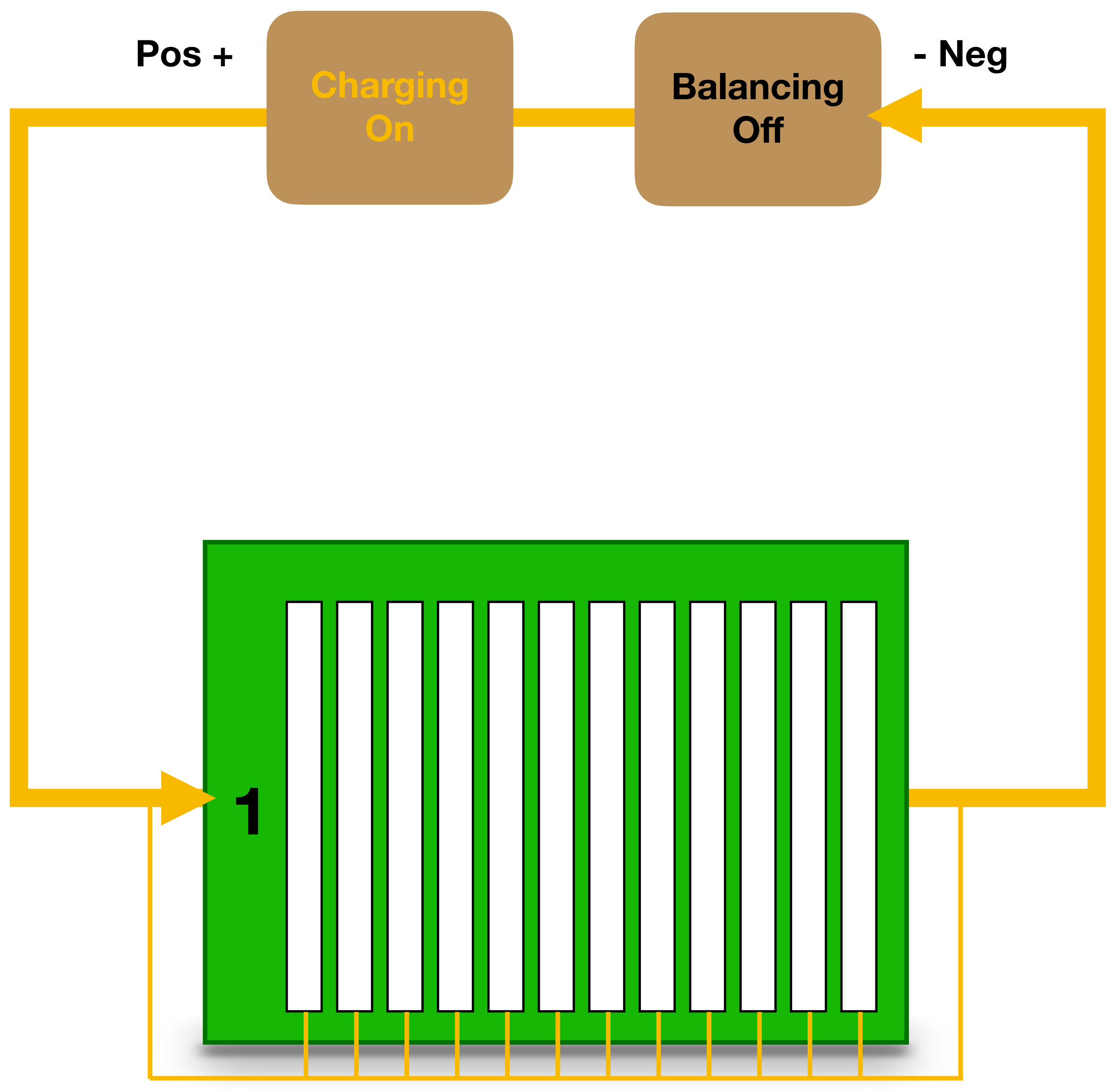
True Balancing is on to assure that all cells get to COV

End of Step 1: All cells discharged to COV. SOC of battery is 0%. Ready for step 2 (charging).

Test 3: Confirm the Ability of True Balancing to Utilize Full Capacity of the Pack

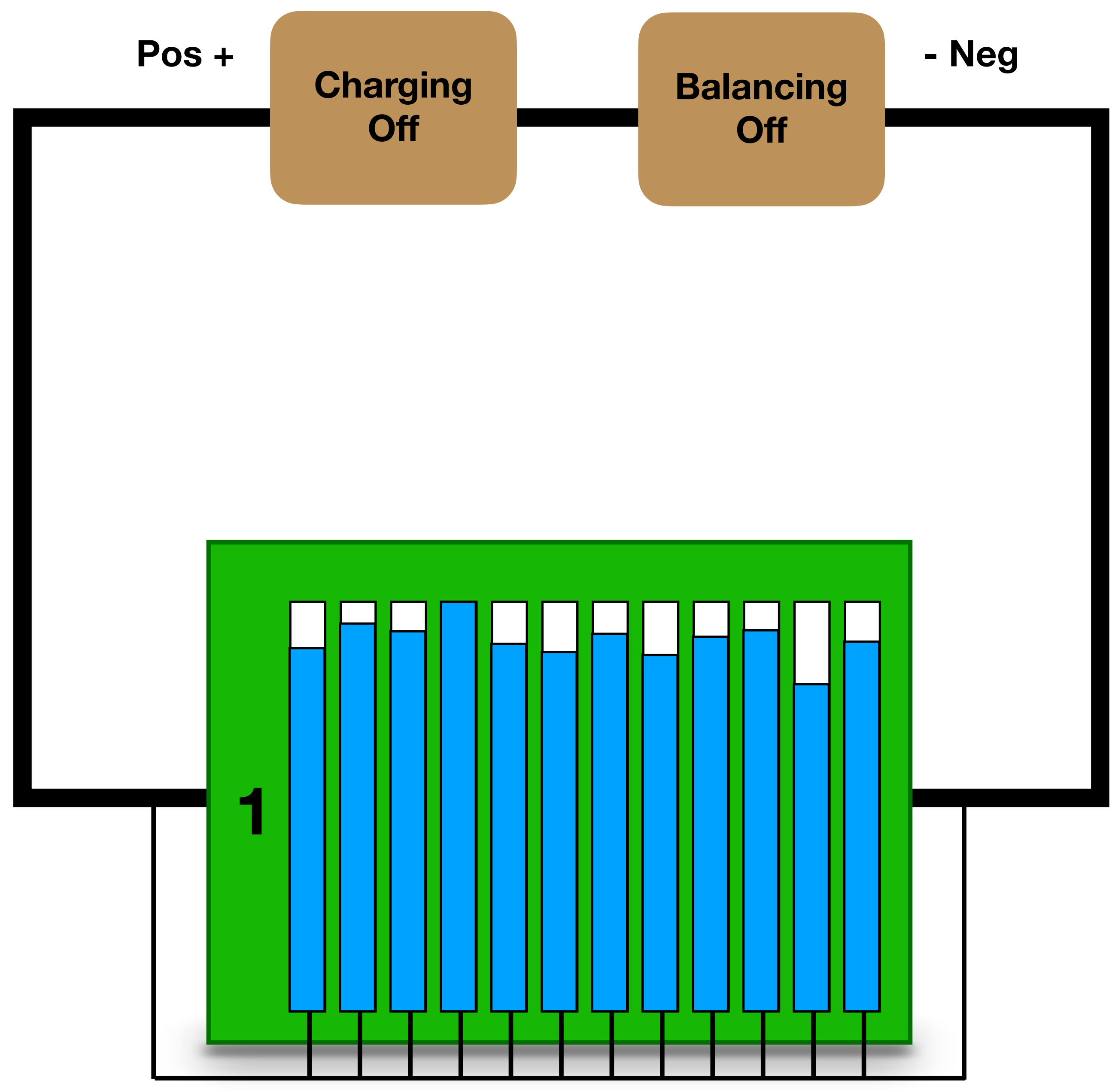
Step 2: Charge the pack with True Balancing off

- Charge the pack until one cell reaches FCV and charging must be stopped
- Count coulombs during charging to measure capacity of the pack without True Balancing



Start charging the battery with True Balancing turned off.

Count coulombs while charging
Pack capacity with True Balancing off was measured at 2.04Ah

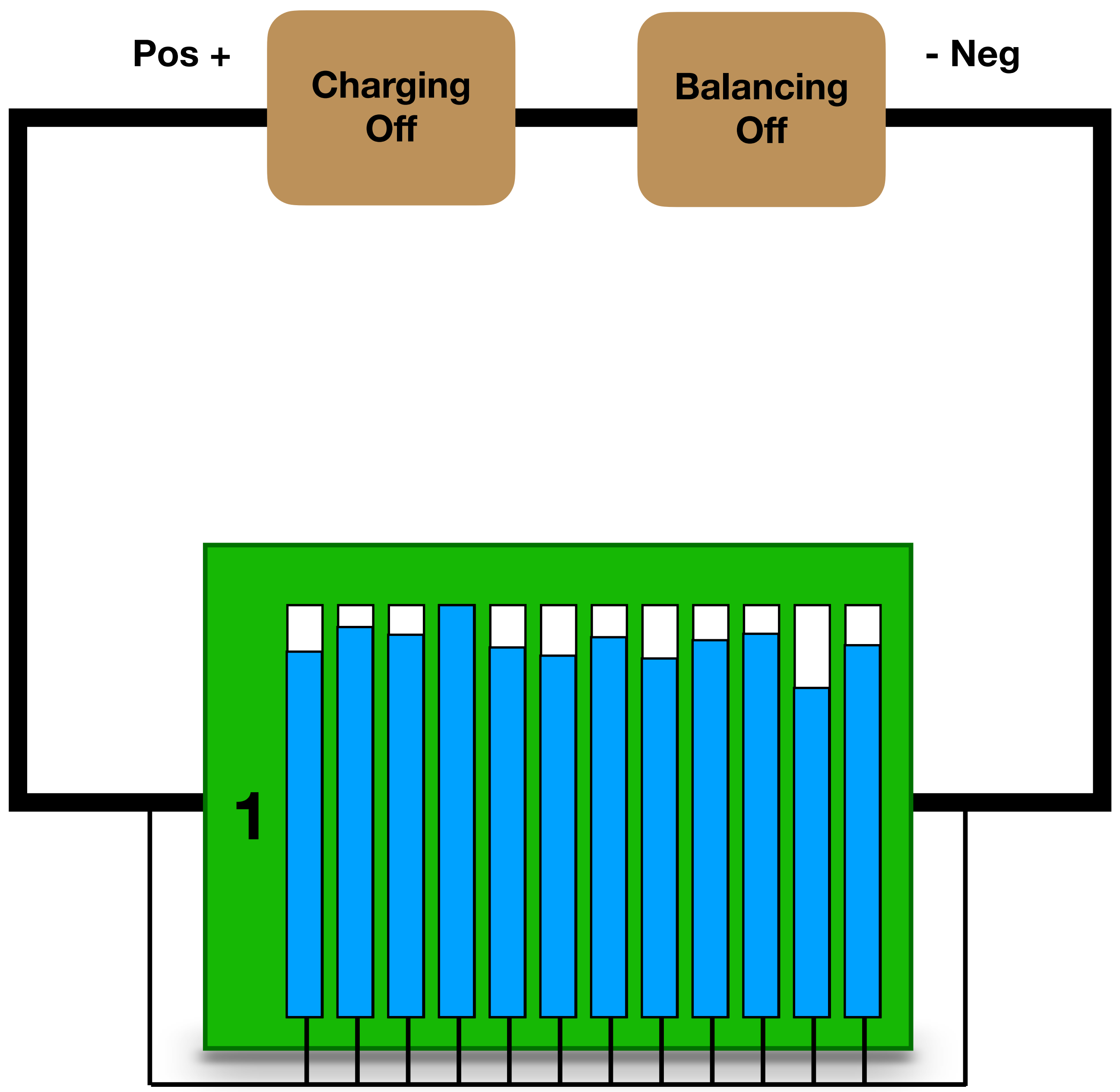


Terminate charging when one cell reaches 100% SOC.

Test 3: Confirm the Ability of True Balancing to Utilize Full Capacity of the Pack

Step 3: Discharge cells 3, 4, 7, 8 and 11 to create an unbalanced battery

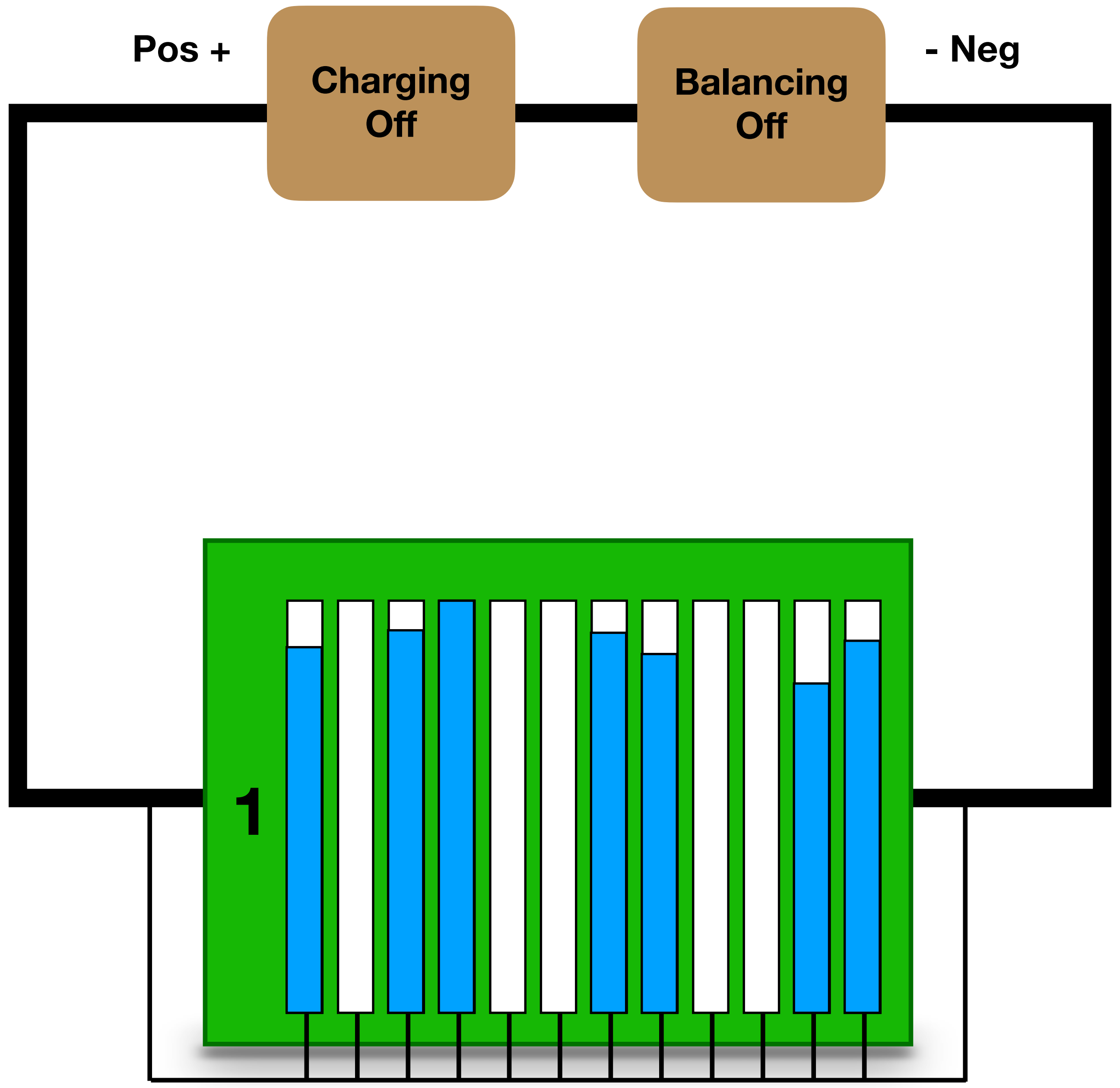
- Count coulombs to measure capacity of the cells that are discharged



Terminate charging when one cell reaches 100% SOC.

Count coulombs while discharging

Data on next page



Cells 3, 4, 7, 8 and 11 discharged to 0% SOC

Test 3: Confirm the Ability of True Balancing to Utilize Full Capacity of the Pack

Data on discharge of cells 3, 4, 7, 8 and 11

- Cells 3 and 4 were discharged as a pair
  - 5.9Ω load @ 1.27A
  - Discharge for 94 minutes = 1.82Ah
  - Cell 4 reached COV before cell 3

- Cells 7 and 8 were discharged as a pair
  - 5.9Ω load @ 1.27A
  - Discharge for 100 minutes = 1.91Ah
  - Cell 7 reached COV before cell 8

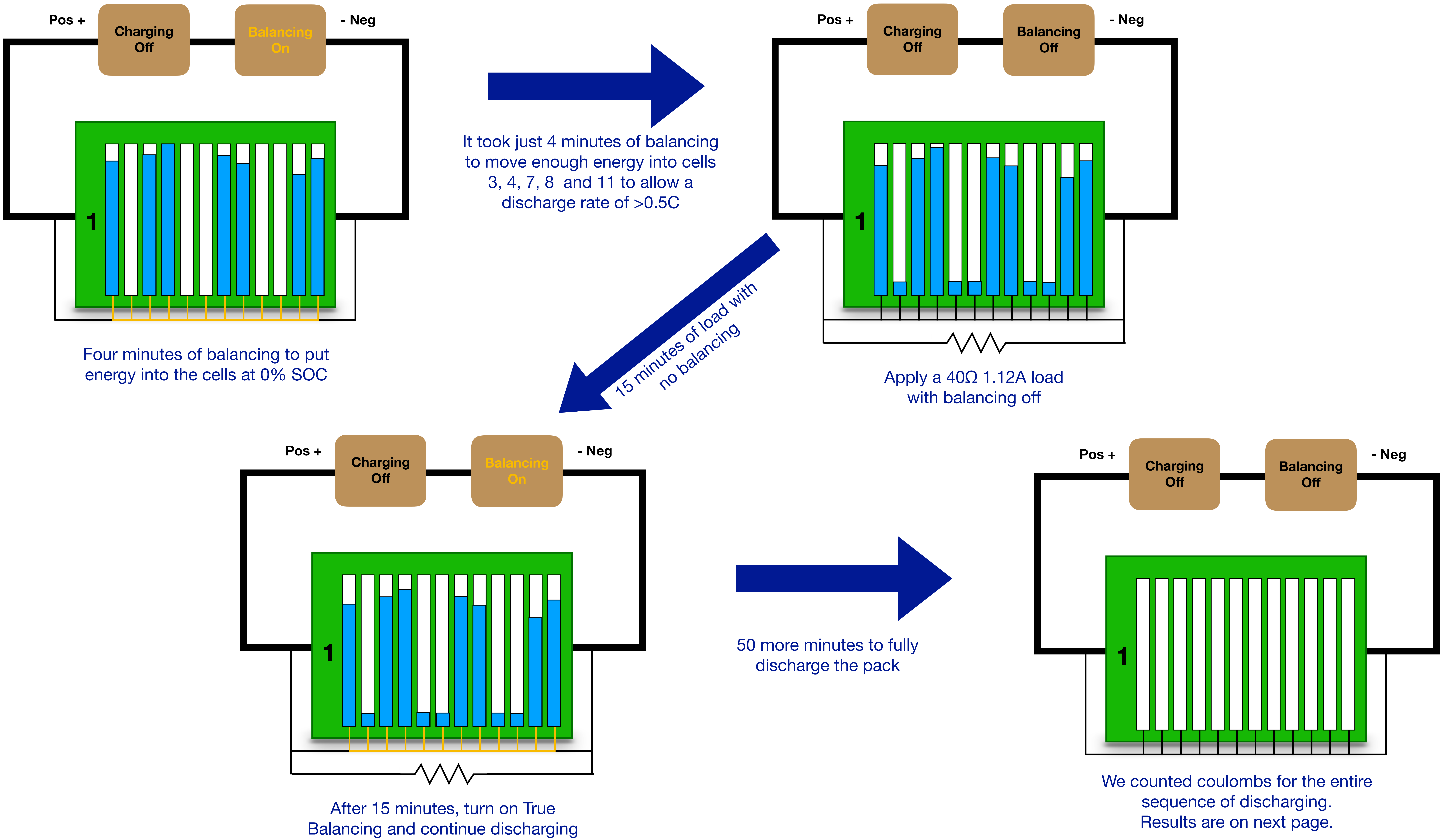
- Cell 11 discharged alone
  - 3.15Ω load @ 1.19A
  - Discharge for 126 minutes = 2.23Ah (strong cell)

Test 3: Confirm the Ability of True Balancing to Utilize Full Capacity of the Pack

Step 4: Discharge the unbalanced pack and measure total energy delivered to load

- The discharge cycle consisted of the following steps
  - Turn on True Balancing with no load for 4 minutes to move some energy into the cells that were at 0% SOC
  - Turn off True Balancing and apply a 40Ω load to the pack for 15 minutes
  - Turn True Balancing back on and continue discharging with the 40Ω load until at least one cell reaches 0% SOC. This took 50 minutes.

These steps are shown graphically on the following page.


Pos +
Charging Off
Balancing On
- Neg
1
Four minutes of balancing to put energy into the cells at 0% SOC
It took just 4 minutes of balancing to move enough energy into cells 3, 4, 7, 8 and 11 to allow a discharge rate of >0.5C
Pos +
Charging Off
Balancing Off
- Neg
1
Apply a 40Ω 1.12A load with balancing off
15 minutes of load with no balancing
Pos +
Charging Off
Balancing On
- Neg
1
After 15 minutes, turn on True Balancing and continue discharging
50 more minutes to fully discharge the pack
Pos +
Charging Off
Balancing Off
- Neg
1
We counted coulombs for the entire sequence of discharging. Results are on next page.

Test 3: Confirm the Ability of True Balancing to Utilize Full Capacity of the Pack

Results

- After discharging five cells to 0% SOC, the available capacity of the pack was:
  - 2.04Ah x (7/12) = 1.19Ah
  - So if there is zero loss of charge during discharge, the pack could deliver 1.19Ah to the load
- The actual amount of energy delivered was 1.13Ah
- This is 95% efficient (1.13/1.19)

Conclusion

With an extremely unbalanced back in a “nearly worst case” scenario, True Balancing delivered 95% of the available energy to the load.

We know of no other balancing technology that can achieve this level of efficiency.

If this battery had passive balancing and if five of the cells were at 0% SOC, the pack would need to go through extensive charging and balancing before it could deliver energy to a load.

Test 4: Direct Comparison of TB ON vs. TB OFF

Overview of Test 4

- Perform three consecutive charge/discharge cycles of the pack with True Balancing ON
- Perform three consecutive charge/discharge cycles of the pack with True Balancing OFF
- Compare how much energy can be stored and then discharged from the pack
- The initial condition of the battery in test 4 was the fully discharged pack from the end of test 3

This is a simple, direct comparison of how True Balancing affects the capacity of the pack.

Test 4: Direct Comparison of TB ON vs. TB OFF

True Balancing ON

Test #	Charge Ah	Discharge Ah
1	2.23	2.09
2	2.31	2.19
3	2.30	2.19
Mean	2.28	2.16

True Balancing OFF

Test #	Charge Ah	Discharge Ah
1	1.96	1.94
2	2.01	1.98
3*	1.91	1.96
Mean	1.99	1.96

Results

With True Balancing on we were able to store 13.6% more energy in the battery during charging and withdraw 9.7% more energy from the battery during discharging.

** There was a problem with the coulomb counter during the tests with True Balancing off, so we re-ran this portion of test #4 after we recalibrated the coulomb counter. See results of the re-run on the next slide. We included these results because this document contains a complete record of all of our tests, including tests where we found errors in our test procedure.*

Test 4: Re-Run After Recalibrating Coulomb Counter

True Balancing ON

Test #	Charge Ah	Discharge Ah
1	2.23	2.09
2	2.31	2.19
3	2.30	2.19
Mean	2.28	2.16

We didn’t re-run the tests with True Balancing ON

True Balancing OFF

Test #	Charge Ah	Discharge Ah
1	n/a	1.91
2	n/a	1.91
3	n/a	n/a
Mean	n/a	1.91

After recalibrating the coulomb counter, we measured pack capacity during two discharge cycles as shown here

Results

Mean discharge capacity with True Balancing ON is 2.16Ah.

Mean discharge capacity with True Balancing OFF is 1.91Ah.

True Balancing added 13.1% to the discharge capacity of the pack: (2.16-1.91)/1.91 = 13.1%

Test 5: Recoverable Energy at End of Discharge

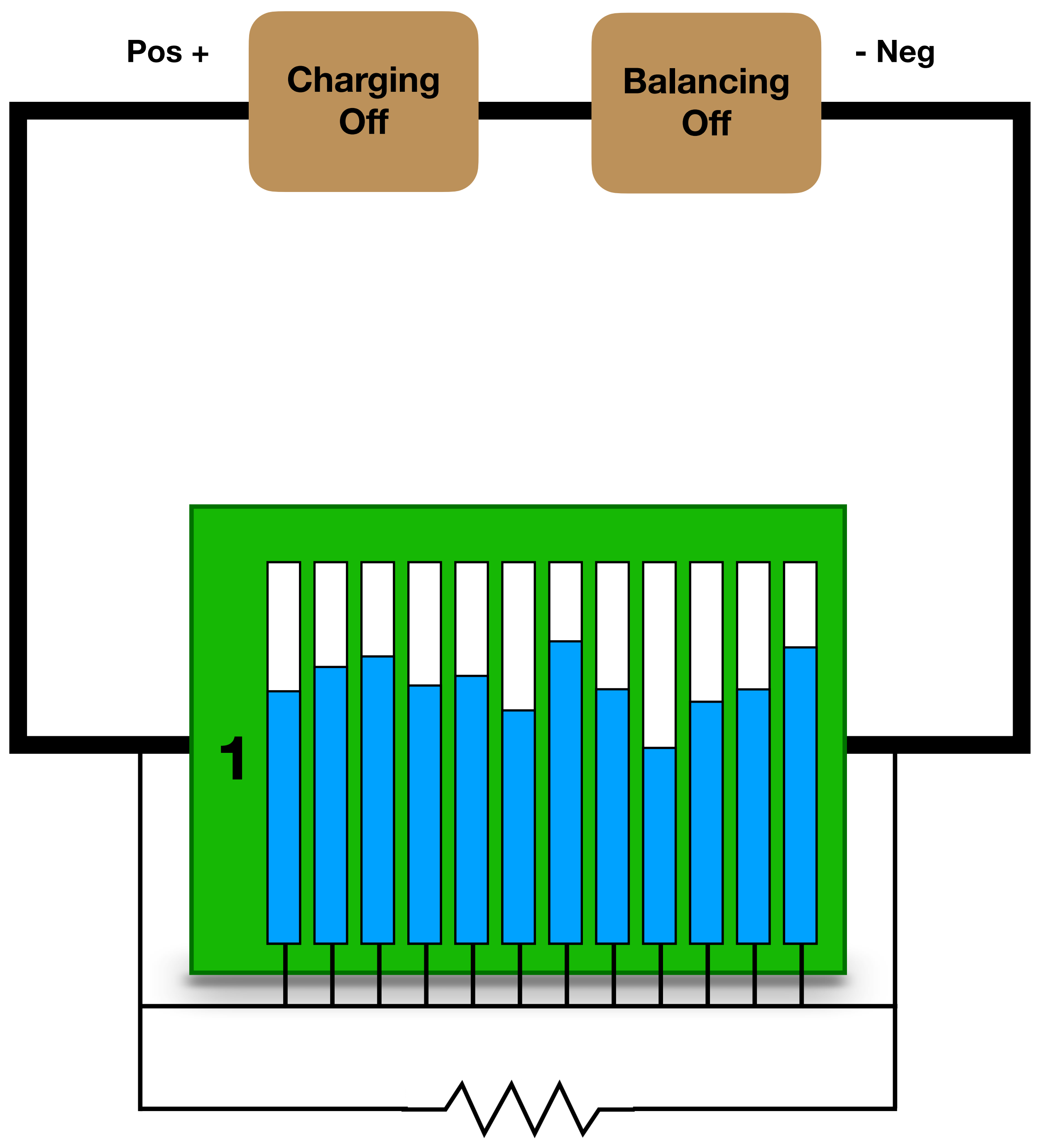
Overview of Test 5

- Discharge the pack to COV with True Balancing **off**
- Remove the load and turn True Balancing on for 7 minutes
- Re-apply the load and measure how much additional energy can be recovered from the pack

This test is illustrated on the following pages.

Test 5: Recoverable Energy at End of Discharge

Step 1: Discharge pack with True Balancing OFF

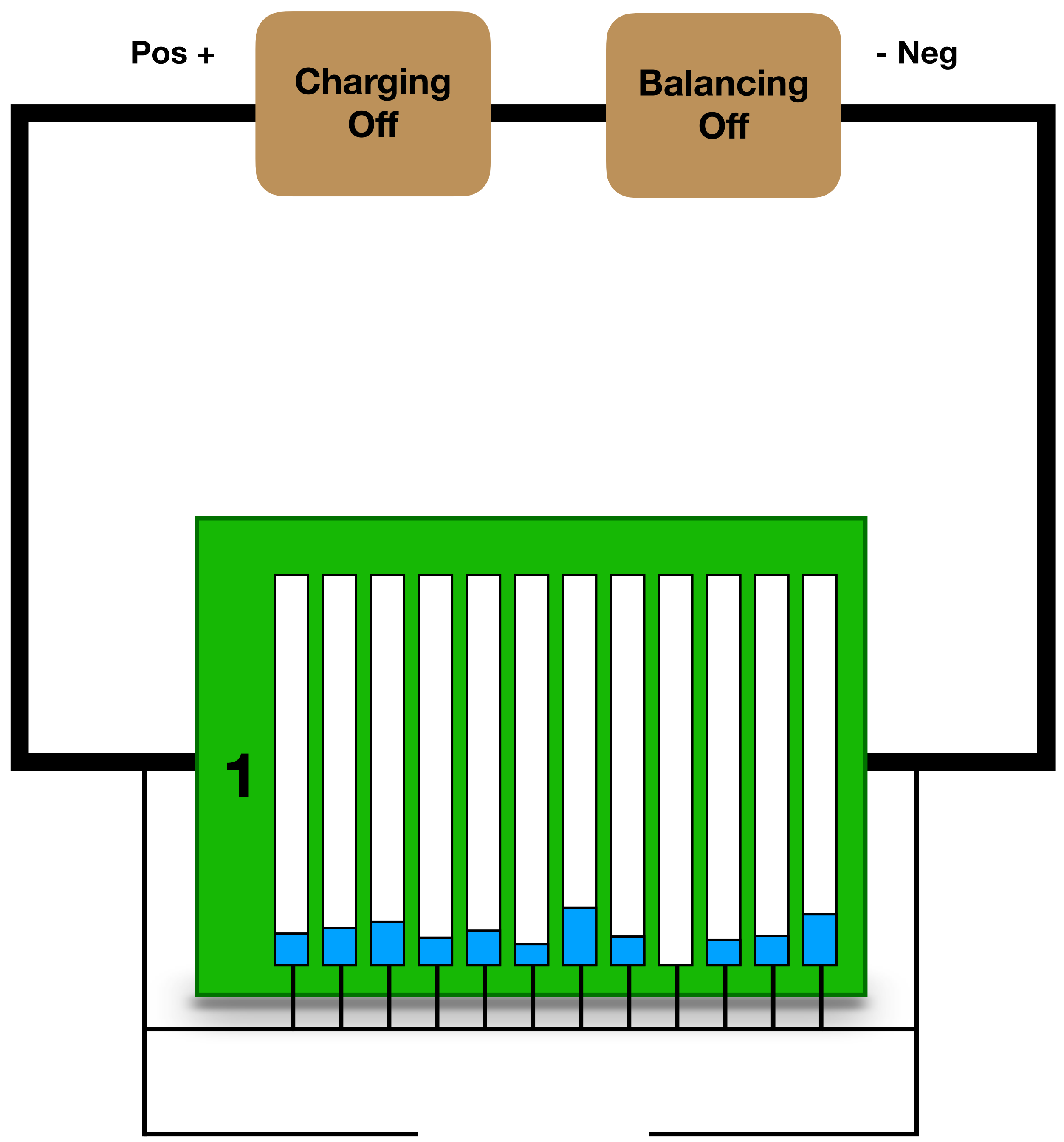


Initial state of battery is not relevant in this test.

Load resistor to discharge battery

40Ω, 1A, ~0.5C

Discharge until at least one cell reaches COV (which forces removal of the load)

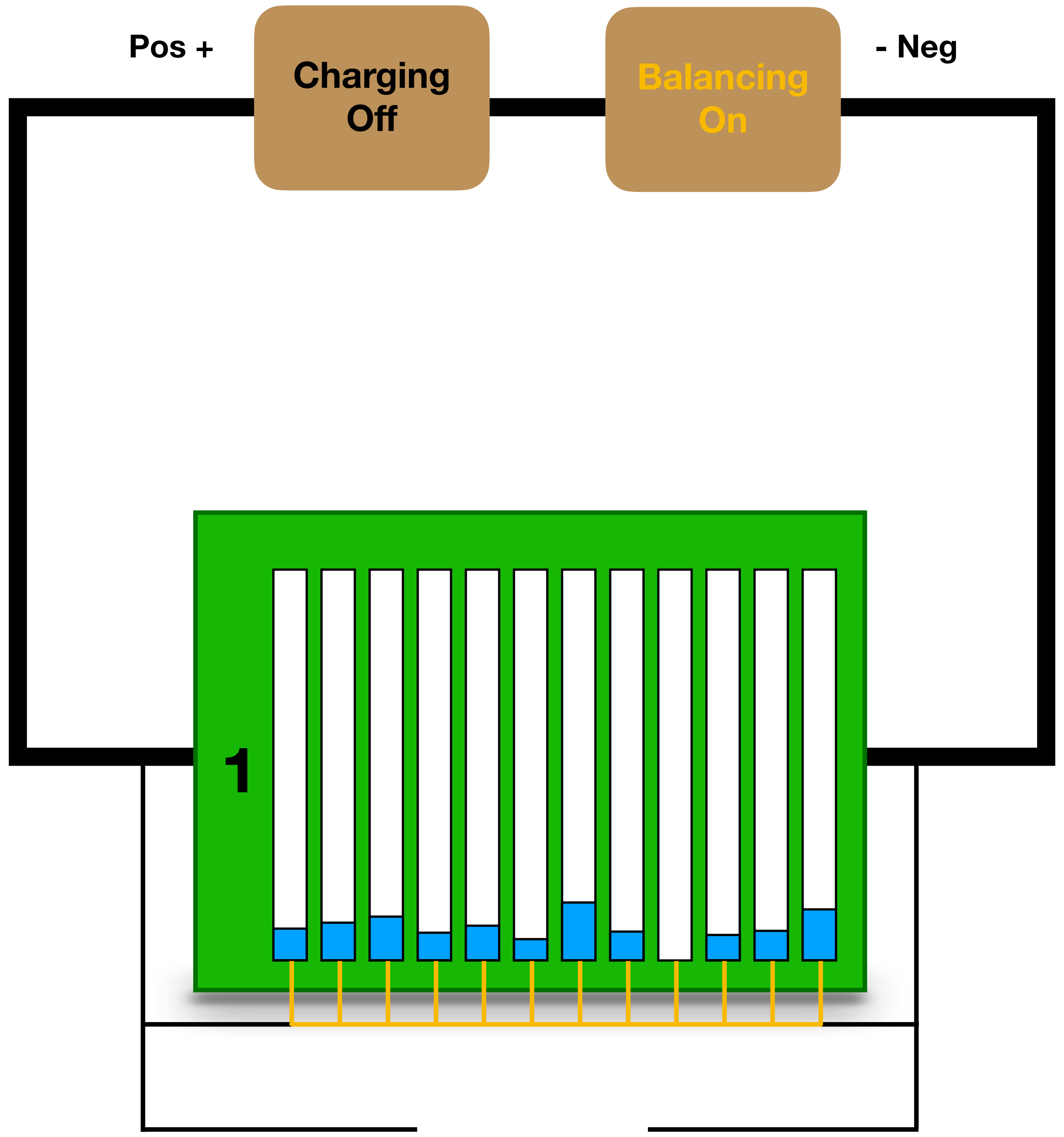


Load resistor is removed.

There is energy left in the pack but it couldn’t be accessed because cell 4 reached COV.

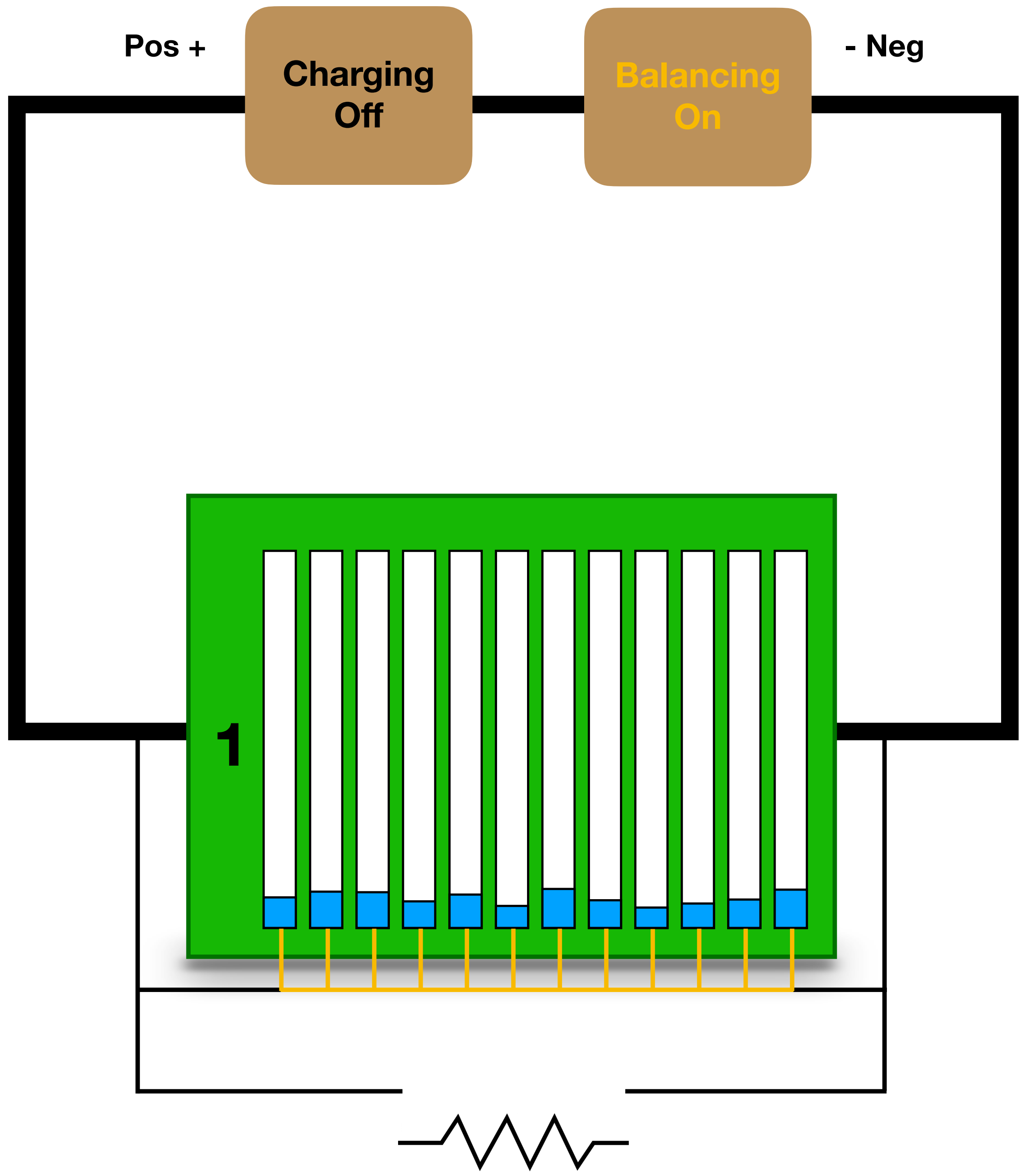
Test 5: Recoverable Energy at End of Discharge

Step 2: Turn on True Balancing with no load - start to balance the cells



Turn on True Balancing to move energy into cell 4

Balance for 7 minutes with no load

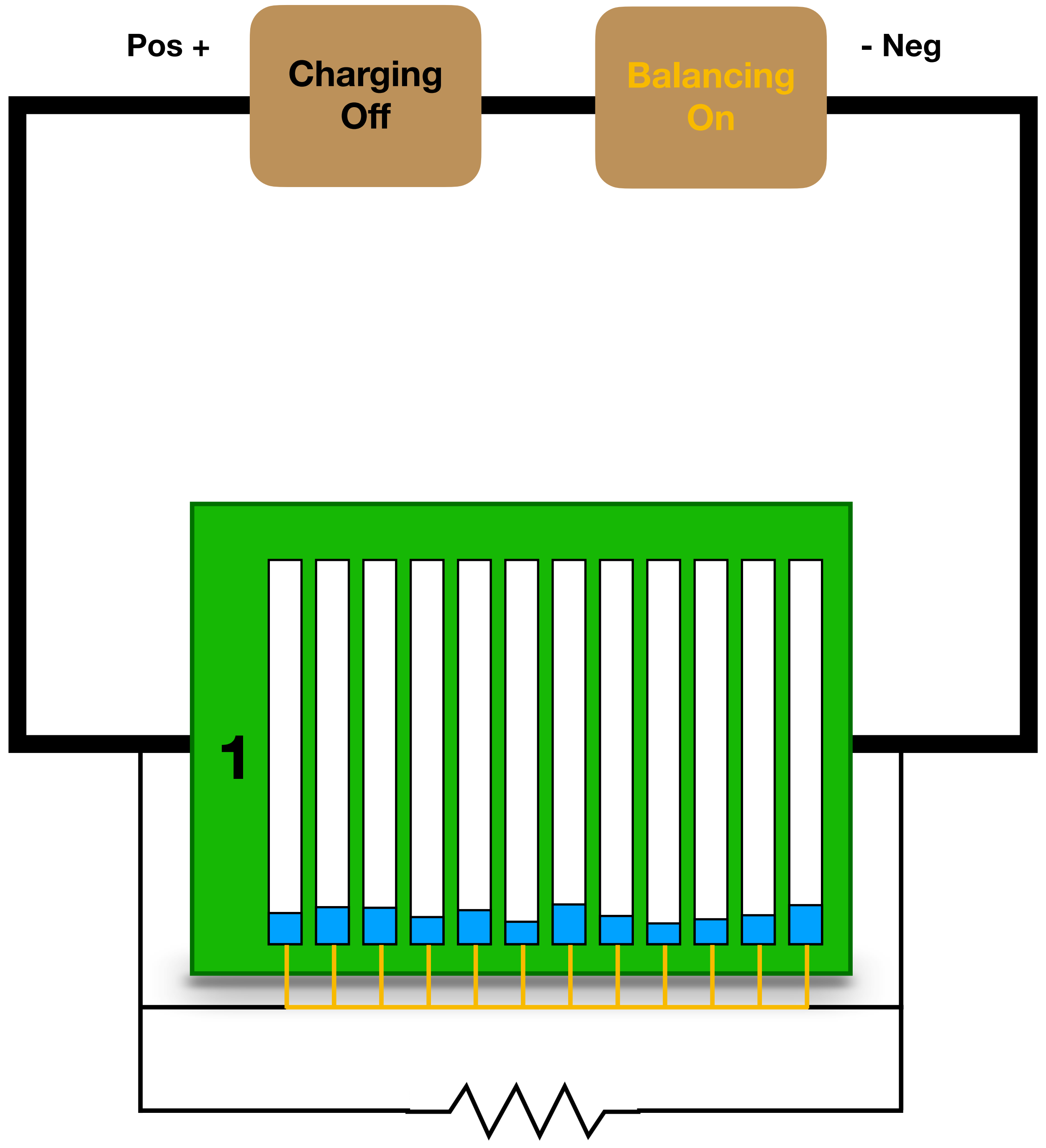


There is enough energy in cell 4 to reapply the load and discharge the battery further.

(The resistor will be reconnected on the next slide.)

Test 5: Recoverable Energy at End of Discharge

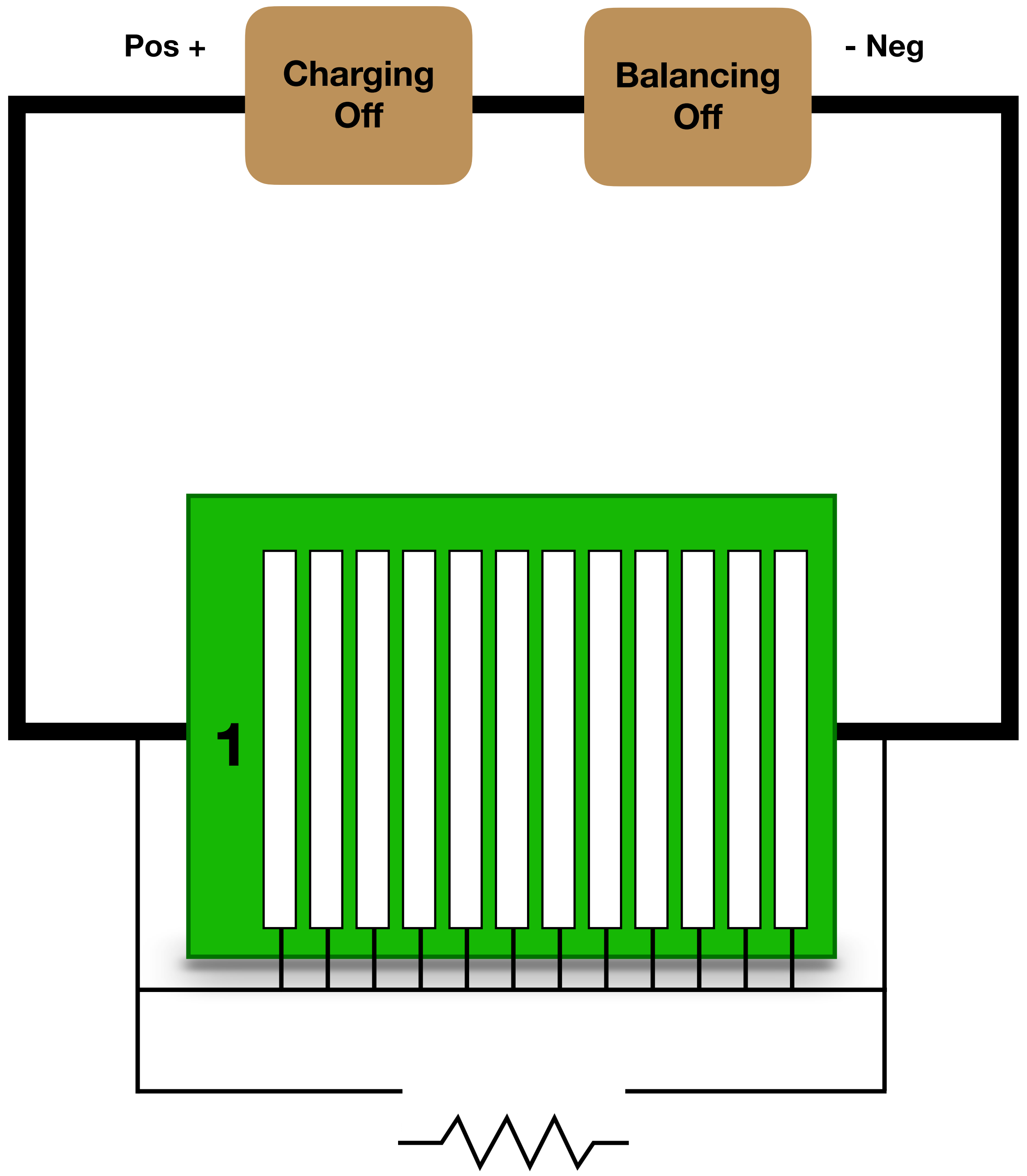
Step 3: Resume discharging with True Balancing on and count coulombs



Reapply the 0.5C load

Balance the cells while discharging

Count coulombs while discharging



When at least one cell reaches COV, remove the load and turn off balancing. (All cells were at or near COV at the end of the test.)

Test 5: Recoverable Energy at End of Discharge

Results

- True Balancing recovered 0.23Ah from the pack

Comments

At the end of step 1, the battery was essentially dead. If this battery were in an EV with a passive balancing system, the vehicle could not be driven until the battery had completed a charge cycle.

Simply by turning on True Balancing, the pack gained about 10% additional capacity. If this were an EV with a nominal range of 300 miles, True Balancing would add about 30 miles to the vehicle's range.

Test 6: Measure Capacity of Each Cell in Pack #1

Cell #	Capacity Ah
1	2.23
2	2.23
3	2.20
4	1.92
5	2.13
6	2.30
7	2.05
8	2.20
9	2.26
10	2.21
11	2.20
12	2.19

Mean cell capacity = 2.177Ah
Weakest cell = 1.92Ah

Comments

With passive balancing, the capacity of a battery is limited by the weakest cell in the pack. If this pack had passive balancing, its available capacity would be 1.92Ah (capacity of cell 4).

With True Balancing, the capacity of the pack is equal to the total capacity of the cells in the pack, minus the losses that occur when True Balancing is running.

This is why True Balancing adds capacity to any battery pack. The total capacity of the cells is always greater than the capacity of the weakest cell (unless all cells have exactly equal capacity – which is never the case).

In theory, True Balancing would add 13.4% capacity to this pack:
(2.177-1.92)/1.92 = 13.4%

In test #4, True Balancing added 13.1% to the capacity of this pack, compared to a theoretical maximum of 13.4% additional capacity that could be added. This indicates a loss of 2.24%, or True Balancing efficiency of 97.76%.[1] I.e., the amount of capacity that True Balancing could discharge from this pack was more than 97% of the theoretical maximum capacity of the pack.

(1) This correlates very closely to our previous calculations of the efficiency of True Balancing.

Error Analysis

After we finished test 6, we shifted our testing to pack #2. Before we started performing tests on pack #2, we analyzed the results of tests 1-6 to determine sources of error in our test set-up.

We didn't perform a rigorous mathematical error analysis, but we noted sources of error in our test system. Prior to starting tests on pack #2, we modified our test system to reduce the sources of error.

Here are the sources of error we identified in the test set-up that we used for tests 1-6:

- The coulomb meter was drifting
- Cell temperatures were not recorded or controlled
- True Balancing was turned on and off manually during the tests
- FCV and COV were manually controlled by an engineer who had to monitor these voltages during the tests
- The end point currents at FCV and COV (which we call cut-off current or COC) were not controlled
- Charge and discharge currents were unregulated and not precisely normalized
- The discharge load was purely resistive

Changes in Test Set-up

Prior to starting the tests on pack #2, we made the following changes to our test set-up:

- We calibrated the coulomb meter prior to each phase of each test
- Added computer control of FCV and COV
- Added computer control of when True Balancing is turned on and off
- Added computer control of cut-off current (COC) at the end charge and discharge cycles

The above changes improve the accuracy and repeatability of the tests we performed on pack #2.

We made no changes to compensate for the following sources of error:

- Charge and discharge currents are unregulated and not precisely normalized
- The discharge load is purely resistive
- Cell temperatures are not recorded or controlled

Test 7: More Direct Comparisons of TB ON vs. TB OFF

Overview of Test 7

- This is similar to test 4, with the following changes:
  - Testing was done on pack #2
  - Changes to the test set-up (as described previously) to improve test repeatability and to reduce error

Test 7: Measure the additional capacity True Balancing can add with changes in the cut-off current (COC)*

Note: In all of these tests, COV = 2800mV and FCV = 4150mV

Cycle #1: Charge

TB	COC (mA)	Capacity Ah
OFF	370	1.92
OFF	200	2.01
ON	200	2.13
Capacity Gain		6%

Cycle #2: Discharge

TB	COC (mA)	Capacity Ah
OFF	900	1.94
ON	900	2.11
Capacity Gain		9%

Cycle #3: Recharge

TB	COC (mA)	Capacity Ah
ON	200	2.12
N/A		
Capacity Gain		N/A

Cycle #4: Discharge

TB	COC (mA)	Capacity Ah
OFF	900	1.93
ON	900	2.12
Capacity Gain		9%

Cycle #5: Recharge

TB	COC (mA)	Capacity Ah
OFF	200	2.02
ON	50	2.31
Capacity Gain		14%

Result: True Balancing added between 6% and 14% to the capacity of the pack

COC is a parameter that can be set in firmware. True Balancing has a number of parameters that can be set to optimize operating conditions for any kind of battery in any kind of use environment. As of test 7, we have not yet optimized all of True Balancing's operating parameters. (We're working our way towards parameter optimization with each round of tests.)

*COC (cut-off current) is the current on the primary charge path at which charging or discharging is terminated (or cut off). At the end of charge and discharge cycles, cell impedance begins to rise so primary charge current begins to drop. With True Balancing you can specify how low you want primary charge current to drop before you terminate the charge or discharge cycle.

Two other parameters that can be set are full charge voltage (FCV) and cut-off voltage (COV). These are the upper and lower limits, respectively, of cell voltages that are allowed to occur during charging and discharging.

Test 7 — More comments

Cycle #1: Charge

TB	COC (mA)	Capacity Ah
OFF	370	1.92
OFF	200	2.01
ON	200	2.13
Capacity Gain		6%

Cycle #2: Discharge

TB	COC (mA)	Capacity Ah
OFF	900	1.94
ON	900	2.11
Capacity Gain		9%

99%

Cycle #3: Recharge

TB	COC (mA)	Capacity Ah
ON	200	2.12
N/A		
Capacity Gain		N/A

100%

Cycle #4: Discharge

TB	COC (mA)	Capacity Ah
OFF	900	1.93
ON	900	2.12
Capacity Gain		9%

Cycle #5: Recharge

TB	COC (mA)	Capacity Ah
OFF	200	2.02
ON	50	2.31
Capacity Gain		14%

Result: Full utilization of battery capacity

Note that in cycle 2, True Balancing delivered 99% of the battery's energy to the load. In cycle 4, True Balancing delivered 100% of the battery's energy to the load.

Actually, it's impossible to deliver 99% or 100% of the battery's energy to the load, especially when balancing is occurring. This is an indication of the noise that remains in our test set-up, even after the improvements we made to the system. So these results can't be taken literally, but they are an indication of the efficiency and effectiveness of True Balancing.

Test 8: Measure Capacity of Each Cell in Pack #2

Cell #	Capacity Ah
1	1.95 → 2.04
2	2.14
3	2.14
4	2.28
5	2.13
6	2.09
7	2.01
8	2.14
9	2.11
10	1.91 → 2.03
11	2.13
12	2.34

Mean cell capacity = 2.13Ah
Weakest cell = 2.01Ah

Comments

When we first measured the capacities of the cells, cell numbers 1 and 10 were outliers - very low. Some of these cells had been unused for several years, which could have affected the capacities of cells 1 and 10.

We applied additional charge/discharge cycles to cells 1 and 10 to recondition them. Their capacities of these cells rebounded significantly as shown in the table.[1] In all subsequent tests, we used the larger capacities of these cells (after reconditioning) as baseline data.[2]

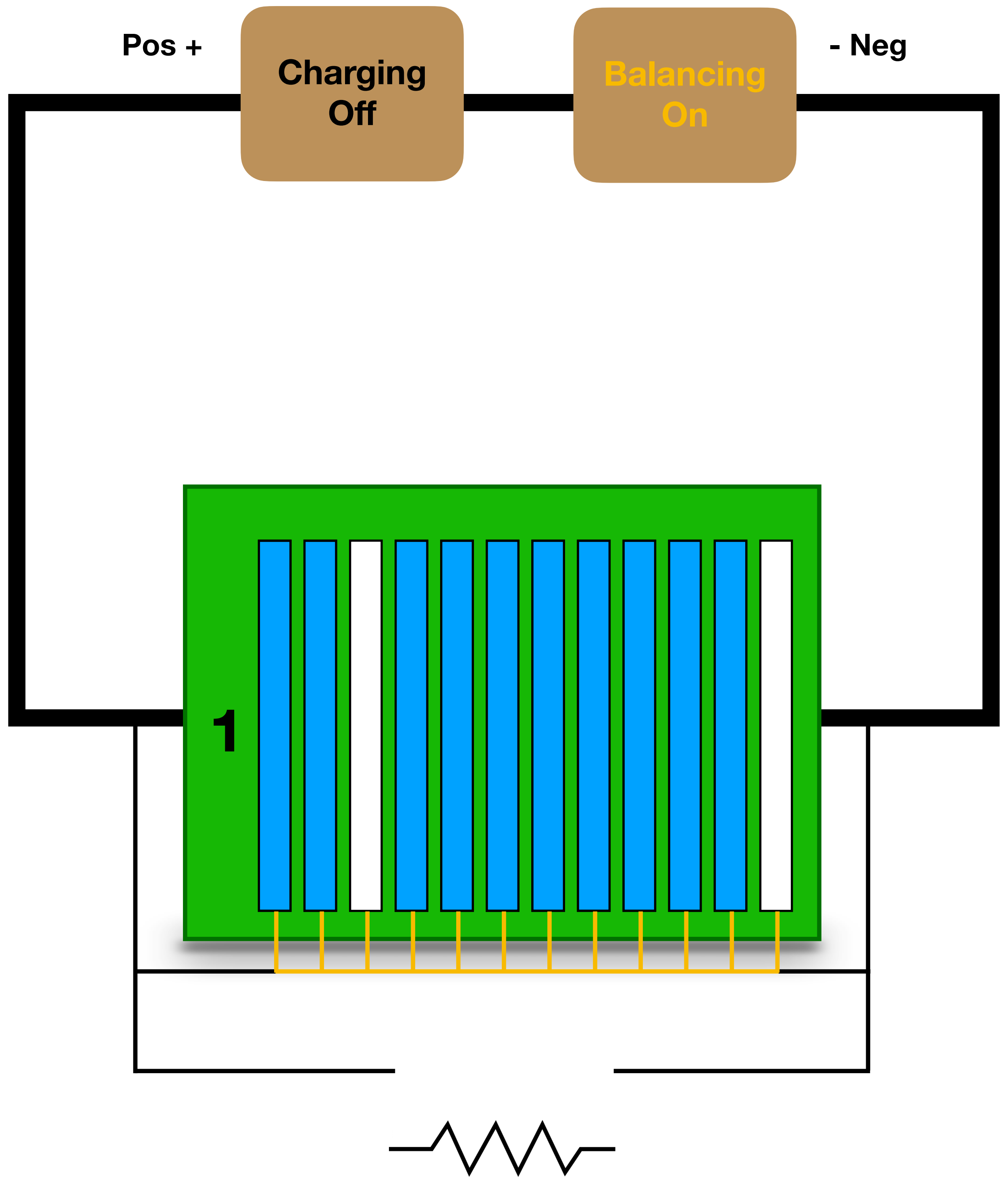
After reconditioning the cells, the theoretical maximum increase in capacity that True Balancing can provide to this pack is 6%. (2.13 - 2.01)/2.01

(1) This is an example of memory effect in NMC cells.

(2) We used 300mA COC during this test

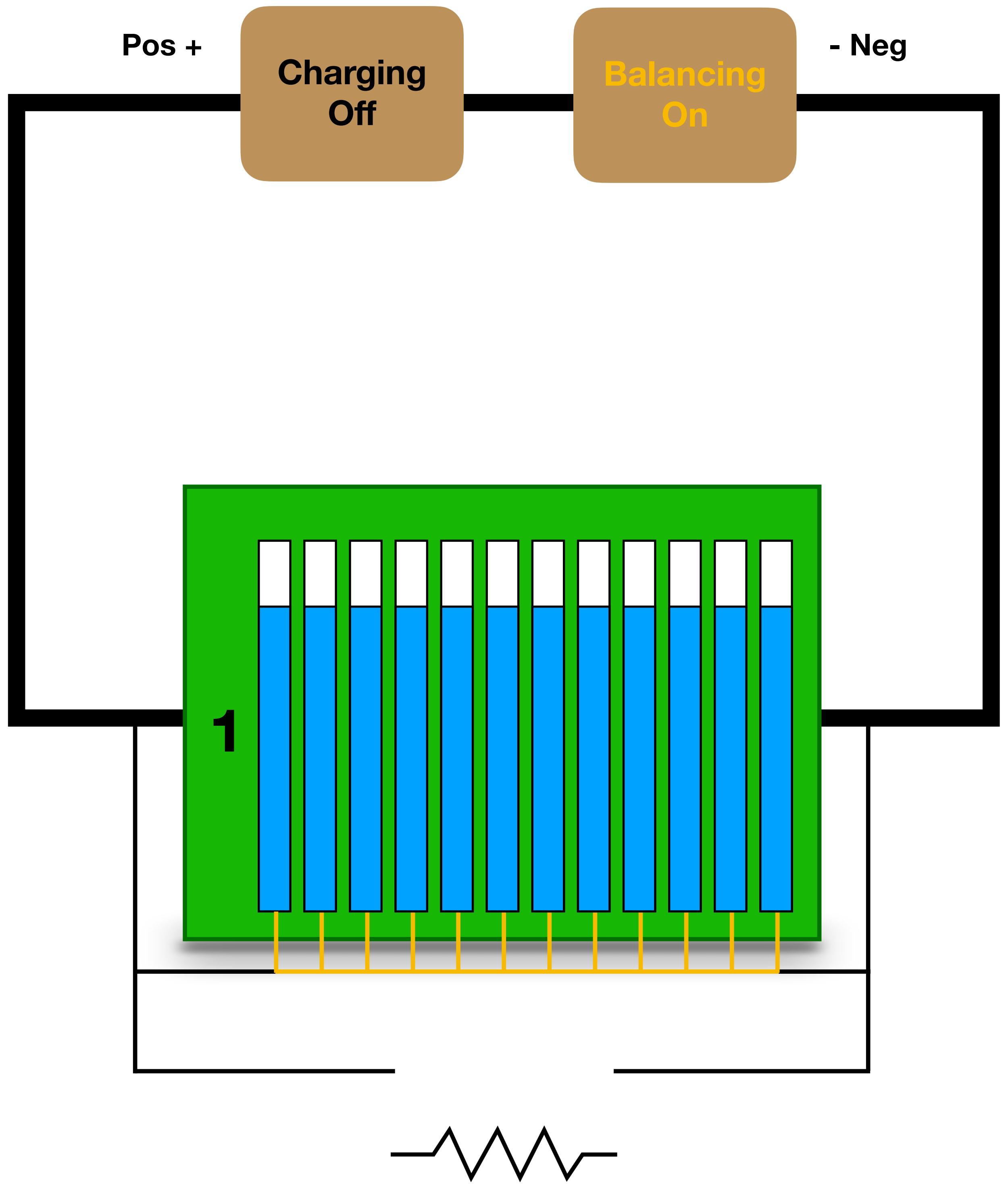
Test 9: Total Energy from an Out-of-Balance Pack

Step 1: Start with an unbalanced pack and balance with True Balancing



After reconditioning (test 8) cells 1 and 10 were discharged to 0% SOC; all other cells were at 100% SOC.

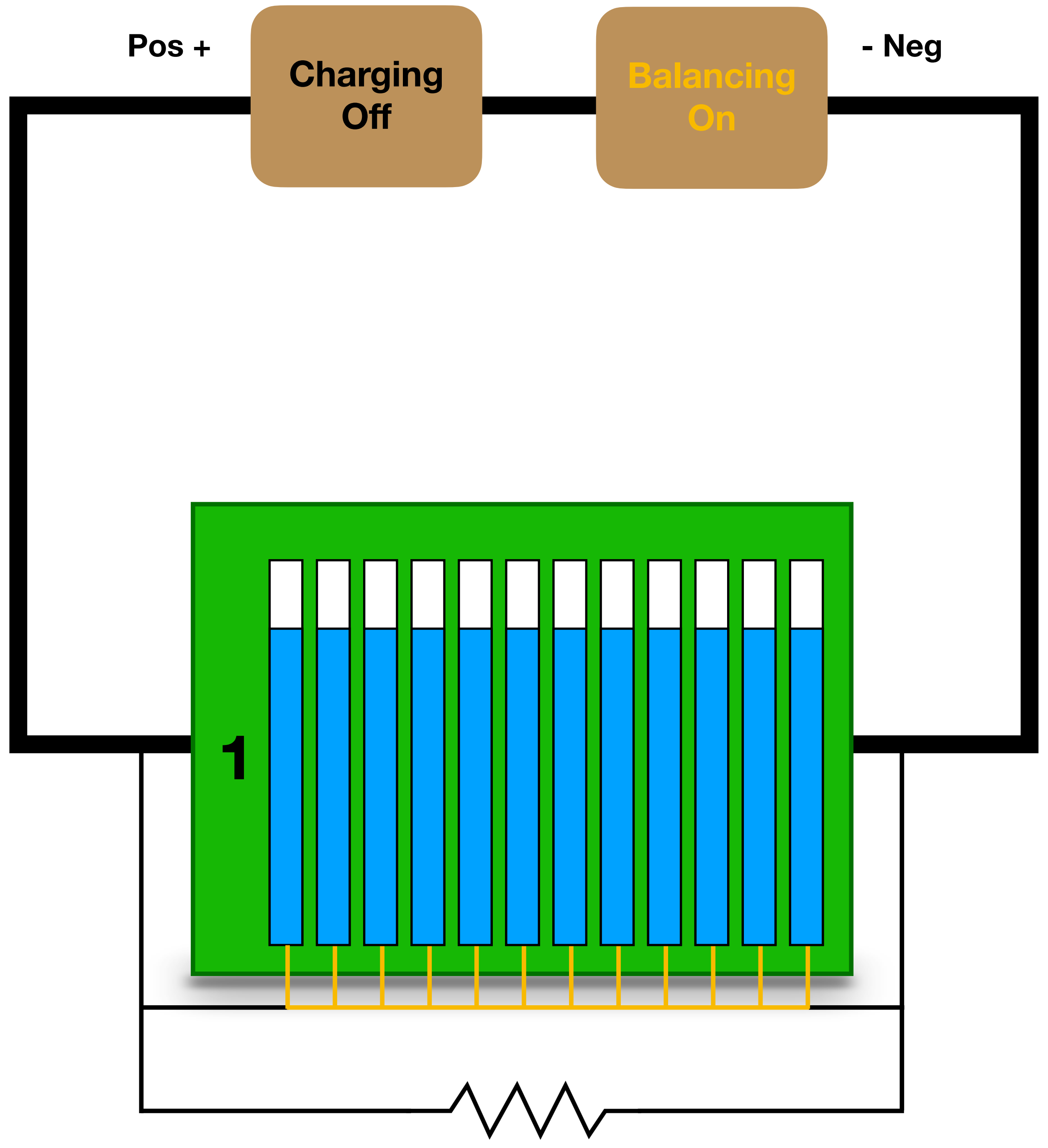
True Balancing on with no load for 96 minutes to balance the pack



After 96 minutes of True Balancing with no load the cells were balanced.

Test 9: Total Energy from an Out-of-Balance Pack

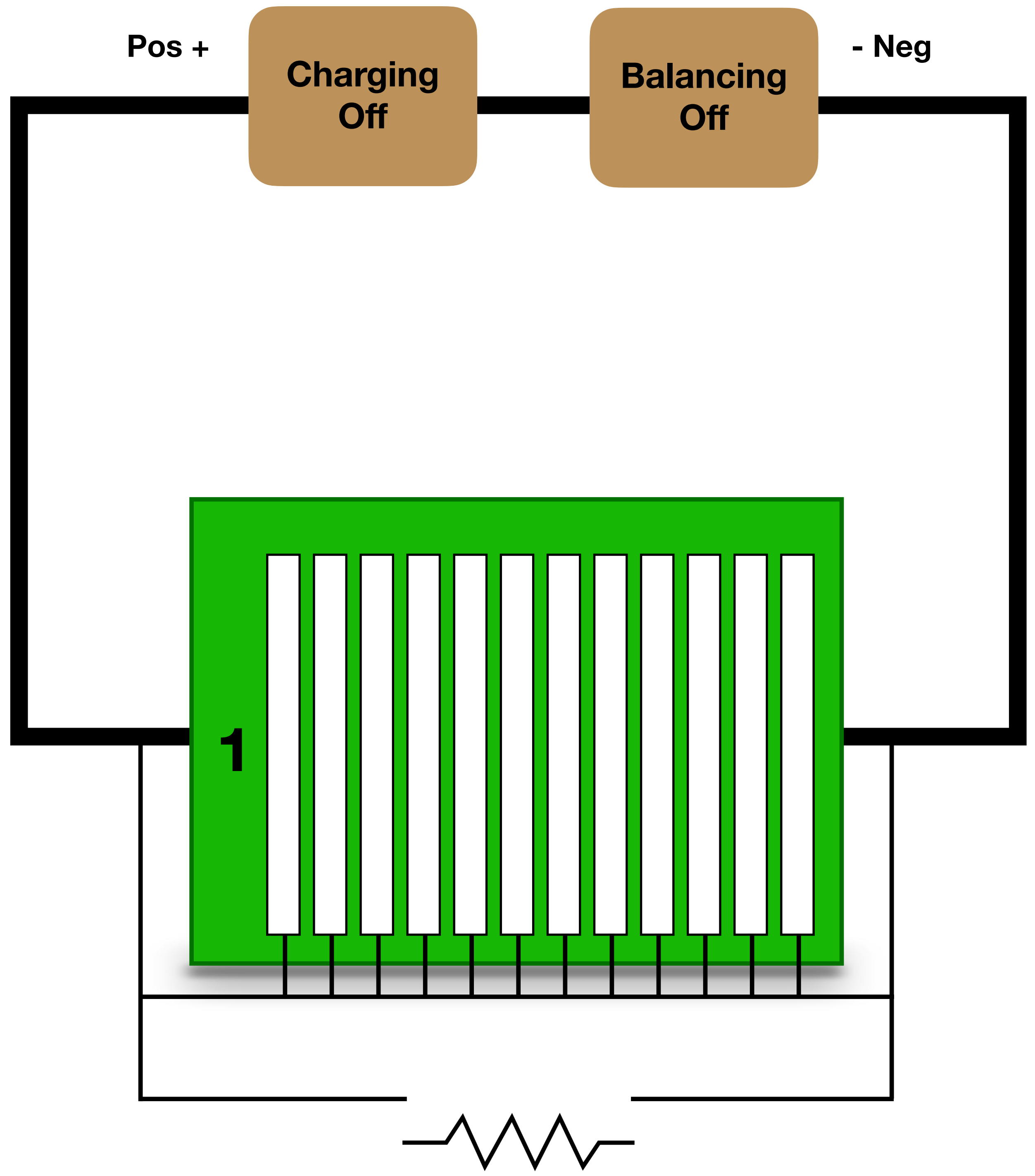
Step 2: Discharge the pack with True Balancing ON and count coulombs



After balancing the cells, apply a load resistor to discharge battery:

40Ω, 1A, ~0.5C

Load was applied for 104 minutes at which point all cells were at 0% SOC and the battery was completely discharged



Pack is fully discharged

Turn off True Balancing

Load resistor is disconnected

Test 9: Total Energy from an Out-of-Balance Pack

Results

The theoretical maximum capacity of the pack (with cells 1 and 10 at 0% SOC) is 1.79Ah.

The measured discharge capacity with True Balancing on was 1.66Ah.

True Balancing extracted 92.7% of the energy from the pack.

Comments

The test conditions were designed to be unfavorable to True Balancing. Ten cells were at 100% SOC and two cells were at 0% SOC – an extreme out-of-balance condition that would never occur in the real world, and we ran True Balancing for a long time. In 200 minutes of balancing, only 0.13Ah of energy was lost from a 1.79Ah pack. This is another example of the efficiency of True Balancing.

Test 10: Additional Direct Comparisons of TB ON vs. TB OFF

Overview of Test 10

This is similar to tests 4 and 8. We performed complete charge and discharge cycles with True Balancing off, then we turned True Balancing on and measured how much additional energy True Balancing can put into or get out of the pack.

Test 10: Measure the additional capacity True Balancing can add with changes in the cut-off current (COC)*

Note: In all of these tests, COV = 2800mV and FCV = 4150mV

Cycle #1: Charge

TB	COC (mA)	Capacity Ah
OFF	300	2.08
ON	300	2.27
Capacity Gain		9.1%

Cycle #3: Recharge

TB	COC (mA)	Capacity Ah
OFF	300	2.05
ON	300	2.22
Capacity Gain		8.3%

Note: During charge cycles, the charging power supply supplies energy to the True Balancing circuit. So losses in the True Balancing circuit will be included in the energy counted by the coulomb meter. This adds slightly to the amount of additional energy that is measured during the True Balancing portion of the charge cycle.

Cycle #2: Discharge

TB	COC (mA)	Capacity Ah
OFF	500	2.08
ON	500	2.24
Capacity Gain		7.7%

Cycle #4: Discharge

TB	COC (mA)	Capacity Ah
OFF	500	2.02
ON	500	2.18
Capacity Gain		7.9%

During discharge cycles, the losses in the True Balancing circuit are dissipated and are not counted by the coulomb meter. This subtracts slightly from the energy that is measured during the discharge cycles.

Result:

These tests were performed with the improvements to the test set-up listed previously. This eliminates some of the error and makes the tests more repeatable. The additional capacity provided by True Balancing during discharge cycles is of the most interest, because this reflects how much usable energy the battery can deliver (for example, it reflects additional range that True Balancing can provide to an EV).

In this test, True Balancing added an average of 7.8% to battery capacity during discharge.