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Multimode Balancing of LiFePo4 Battery Using Inductor for Electric Vehicles

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ABSTRACT: Cell-balancing device is required when employing high-voltage battery systems to maintain correct safety conditions in the battery system.. recently novel energy applications have been actively conducted to solve CO2 emissions. There are numerous topologies of active balancing of cell based on active device , on the basis of controller and also based on cell to cell , cell to pack , pack to cell , cell to module , module to module.

KEYWORDS: Cell balancing, Inductor based equaliser , Voltage balancing circuit, Multi-inductor cell balancer.

I.INTRODUCTION

Electric vehicles have become the need of the hour for reducing carbon footprint to make renewable energy accessible forms a crucial part of electric vehicles and their monitoring is important. Active cell balancing proves efficient and improved transfer of voltage from cell to cell due to its design and control. The inductor based balancing transfers the energy stored in inductor from highest potential to lowest potential [14]. The paper proposes active inductive balancing of LIFEPo4 battery as it has advantage over other Li-Ion cells. The equalization of voltage of each cell is achieved by transferring the switching the mosfet switches. The paper also proposes way to overcome drawback of high current flow from the inductor during the balancing. The balancing topologies [12] are classified on the basis of cell to cell , cell to pack , pack to cell , pack to pack respectively. The proposed paper highlights the circuit design capable to deliver voltage from cell to cell and also cell to pack [7] in case of array of cells used in packs for electric vehicles. The challenge of balancing cell in short time during the charging of car can be overcome when there is an embedded controller which provide improvement in energy efficiency and capable of performing multiple cell balancing at same time. There are numerous topologies of active balancing of cell based on active device , on the basis of controller and also based on cell to cell , cell to pack , pack to cell , cell to module , module to module.

II. PROPOSED CIRCUIT OF INDUCTIVE BALANCING.

In the proposed circuit there are 2 modes for delivering excess voltage across each cell.

1. Mode 1 between each cell and another one
2. Mode 2 between one and many cells.

The mode is selected by writing a algorithm in microcontroller. There are 8 cells in one module and it is modelled on the lines of battery of an vehicle. The inductors are connected across cell and Mosfet and their count is designed on the basis of cells present in the battery pack. As a thumb rule for 8 cells there are n-1 inductors and 2(n) -2 MOSFET’s for n cells . They are pulse triggered with duty cycle of 50 percent.In the proposed circuit there are 2 modes for delivering excess voltage across each cell.

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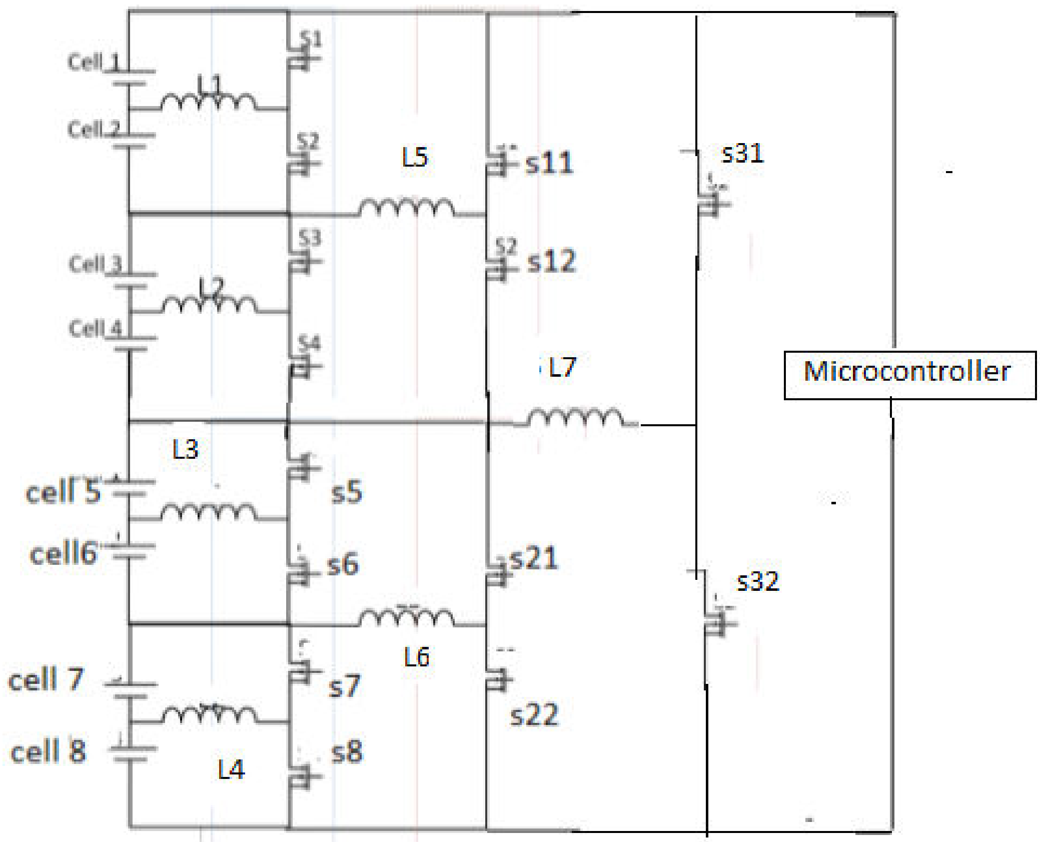

III. WORKING OF THE CIRCUIT

In stage one, the switches S1-S7 are turned on to store energy to the inductors while the switches S8-S14 are kept turned off. When the switches S1-S7 are turned on the energy of the cell 1, cell 3, cell 5 and cell 7 will be transferred to the inductors L1-L7. The inductor voltage of L1 can be driven as Vl1 = L1di1/dt1 Similarly inductor voltages of L2-L4 can be expressed as VL2 = L2 (diL2/dt) = Vcell 2. In general we can formulate

VLn = Ln(din /dt)

where k = 2, 3, 4, and n = 3, 5, 7

The inductor current of L5 and L6 are transferred to battery 5 and 6 In next mode, the switch S1 will be turned off, while the body diode of switch S2 turns on. Therefore the energy stored in L1 bill be transferred to the cell 2. As it is known, in steady state the inductor current changes.

Stage Two In stage two, the switches S1-S7 are turned off while the switches S8-S18 will be turned on to transfer energy stored in the inductors to the adjacent cells. As explained in previous mode the principle is similar expect that in this mode cells 2, 4, 6 and 8 act as an input and the energy will be transferred in opposite direction.

The cell potential ranges from 3.0 to 3.7V with Li ion cell chemistry. During discharging it is essential to maintain the minimum cell voltage of 3.0 V to prevent deep discharge which can create a catastrophic effect on the cell recovery and also may lead to short circuit. During charging it is required to maintain a maximum cell voltage of 3.8 V to prevent overheating and damage of the cell.

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Mode 2 cell to pack

The circuit shown above is second mode of operation of cell balancer . Here the cell having the highest voltage is chosen using logic program in microcontroller and voltage difference is transferred to adjacent cell packs in series. Suppose cell 2 is having highest voltage when compared with 3,4, 5 then excess voltage is transferred from L1 - S1-S2 -S3 -S4 cell 4 , cell3 -L5 cell1 path ensuring the voltage difference is reduced . The switching of S1 , S2 , S3 , S4 at the same time ensures the voltage is transferred . The voltage difference is transferred to all the cells in pack or group of 4 by turning on the mosfet respectively. The switching sequence is again implemented for next cell number and corresponding inductor and switches . The advantage of this mode is less time taken to balance the entire battery pack. The control signal to MOSFET is given in such a way that cell having highest voltage should not form a loop. Voltage algorithm is selected for cell equalization.

Sr no	Lowest voltage	Switch ON
1	Cell1 – Cell 2,3,4	S2, S11, S12
2	Cell 6- Cell 5, 7, 8	S6, S21, S22

Switching action during Cell to pack balancing

The flowchart describes the modes and how the cell voltages are compared for faster balancing to reduce time.

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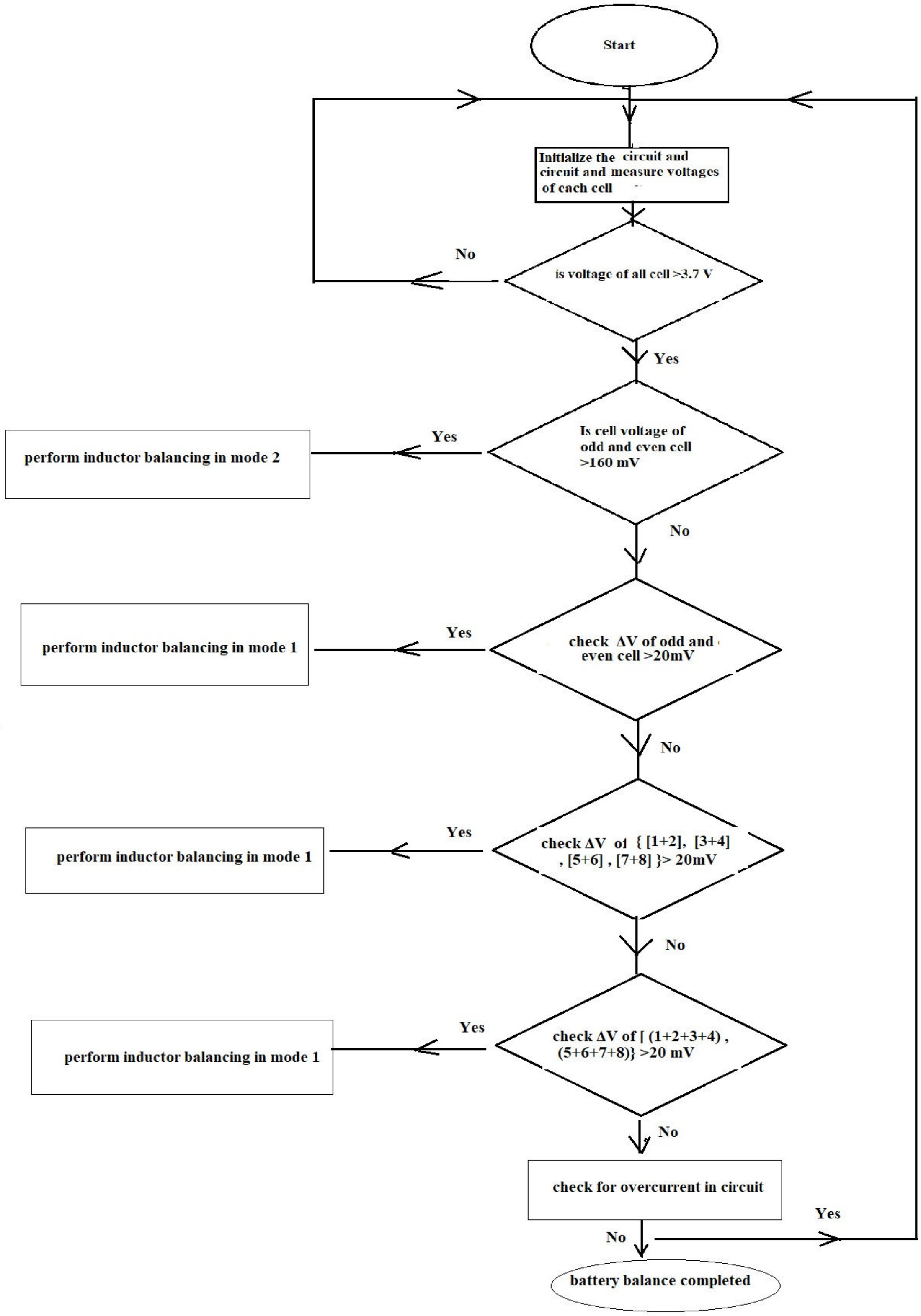

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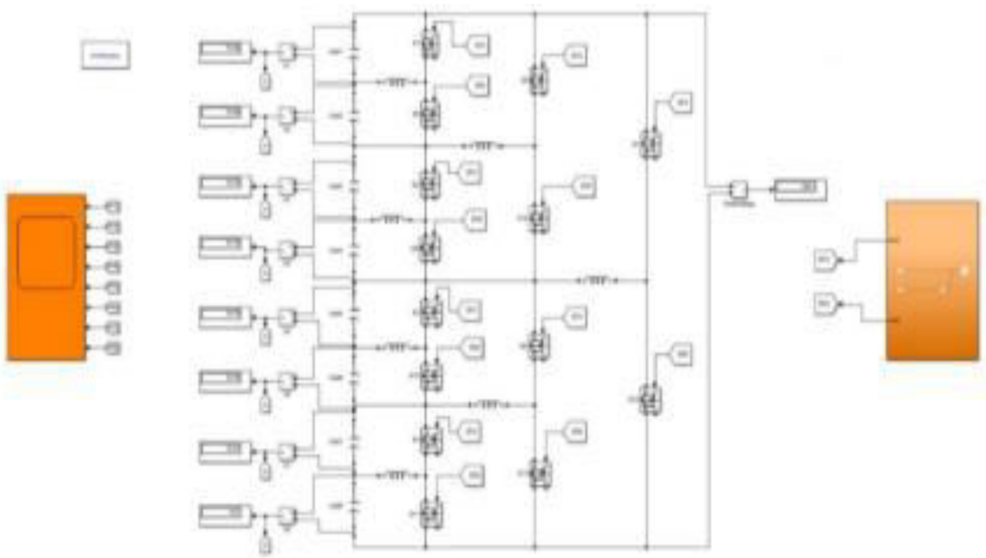
V. SIMULATION MODEL AND RESULTS

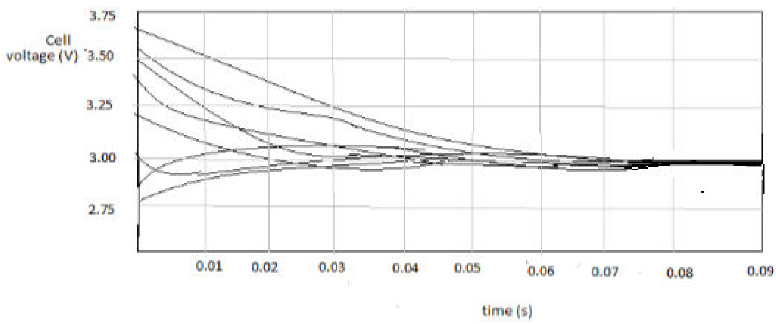


The proposed circuit is implemented in Matlab 2017 and the simulation model is shown below. Mosfet switches are used for switching the inductor current and capacitor is used to represent a cell. The charging and discharging of the cell is similar to that of the capacitor and suitable design values are taken.

V. RESULT AND DISCUSSION

The voltage variation is seen from the simulation and it has lowered from 0.3 V to 10 mV during a balancing period of time in ms under the initial conditions indicated in Table 1, as shown in Fig. 9. Higher-voltage cells isw1 and isw2 have negative switch currents, as illustrated in Fig. 10, indicating that Cell1 and Cell2 are charged for cell balancing by higher-voltage cells (i.e., Cell3 and Cell4). Furthermore, the lower-potential pairs and ' MOSFET currents (i.e., isw3 and isw4)

eight cells are shown in a battery pack that are connected like coupling . The SOC levels of cells L1, L2, L3, and L4 were 23 percent, 44 percent, 77 percent, and 91 percent, respectively, before balancing.



CELL VS INDUCTOR CURRENT

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Cell No	**INDUCTOR CURRENT AT TIME 2 0.01s**
1	**-0.4**
2	**-0.2**
3	**-0.18**
4	**-0.14**
5	**-0.37**
6	**-0.32**
7	**-0.39**
8	**-0.29**

CONVENTIONAL CIRCUIT	**PROPOSED CIRCUIT**
TIME TO BALANCE : 0.07S	TIME TO BALANCE: 0.02S
INDUCTOR CURRENT : 0.4mA	INDUCTOR CURRENT: 0.2mA
NO OF GATE SIGNAL : 4	NO OF GATE SIGNAL : 8
CELL TO PACK : NOT POSSIBLE	CELL TO PACK : POSSIBLE

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VI.CONCLUSION

In this study, a circuit for the LifePo4 battery is developed that can conduct different charge patterns with a decreased control signal, lowering the balance time and making it suitable for battery packs used in electric cars. The balancing results have proved the circuit has improved the efficiency time and simultaneous balancing paths are achieved by cell to pack method. .The simulation of an battery pack as a miniature model revealed that this is a viable way for charging the battery pack, including safety features such as overcurrent and short-circuit protection. The results also showed that it may be used to simulate the charging and draining of a Lifepo4 battery.

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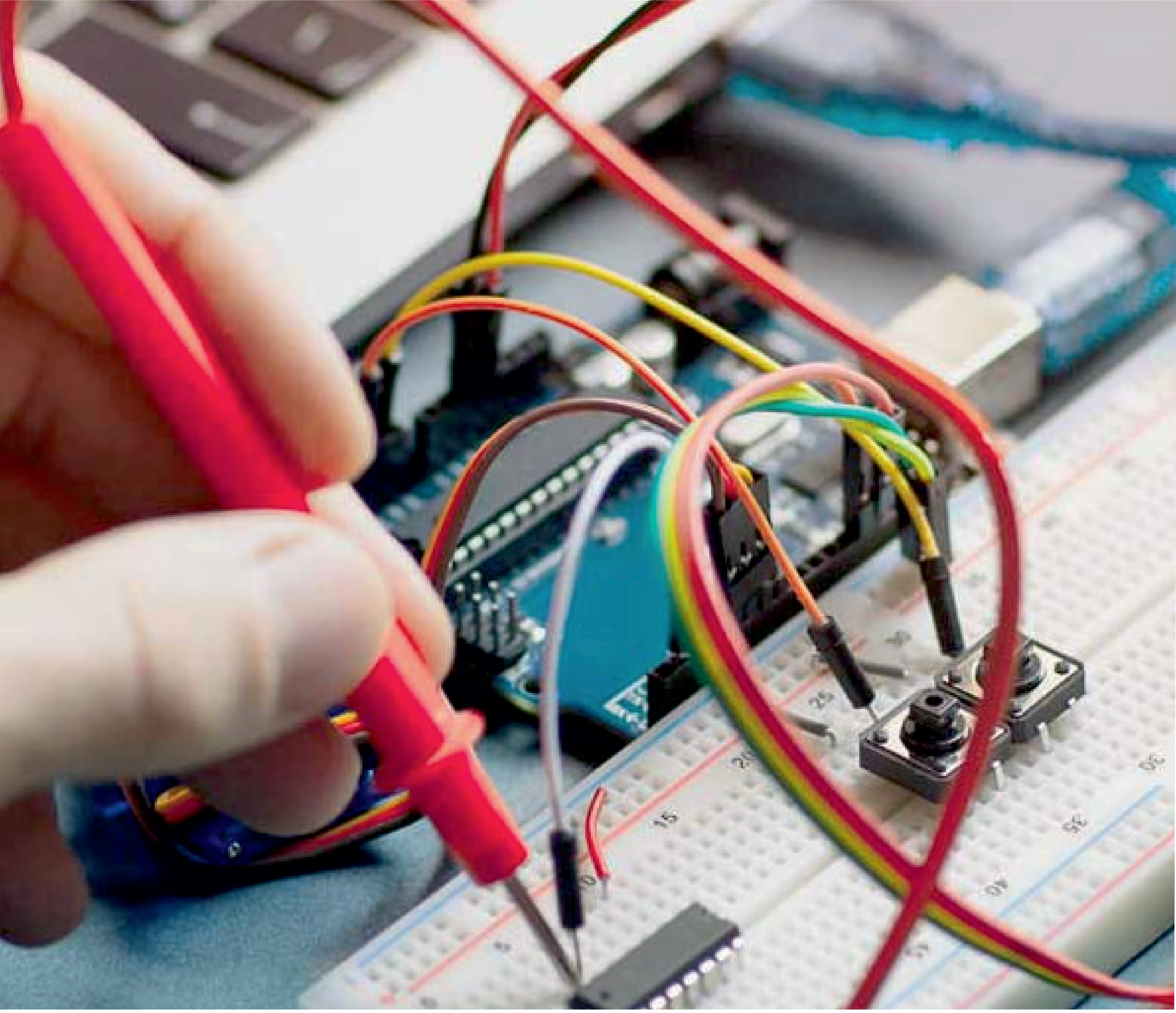

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