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Single Switch Positive Output Boost Converter With Switched InductorCell

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ABSTRACT:A single switch positive output boost converter withswitched inductor cell is introduced. In order to improve the gaina switched inductor concept is used. A non-isolated type positiveoutput fifth-order dc-dc boost converter having a capacitor diodecell. This topology is developed from the existing fourth-orderboost converter (FOBC) by appropriately inserting a chargepumpcell. Analysis and controller design for positive outputboost converter is done. The dc-dc converter exhibits continuousoutput-port current and it results in the reduction of peak to peakripple current in the output capacitor. This topology is essentiallyderived from a fourth-order boost converter. Compared to fourthorder boost converter, the topology offers enhanced voltagegain with reduced switch voltage stress. The converter hasan advantage of continuous output-port current over existingboost topologies, which reduces the output capacitor currentstress. The simulation is done by using MATLAB/ SIMULINKsoftware. The converter is controlled using PIC16F877A. Theexperimental results obtained from a converter prototype confirm
the theoretical considerations and the simulation results.

KEYWORDS:switched inductor cell, charge pump cell.

I.INTRODUCTION

Power electronics-based converters have been extensivelyused in many applications. For example, renewable energy generation systems, sources such as fuel cells and solar panels,and other dc-sources. Converters for fuel cell or solar powersystems typically need a boost-type converter to convert alow-level dc voltage obtained from fuel cells or solar cellsinto a high-level dc voltage. Renewable energy has moreattention on the recent years for increasing the cost of thefossil fuel. The energy sources are solar panel fuel cells andout voltage of these energy sources are low and variable. A
number of high step-up converter topologies have been used toget the high voltage gain with suitable duty cycle.Nowadaysthe necessity of high-frequency dc-dc power conversion isgradually increasing in many applications such as automobileheadlamps, X-ray systems, electric vehicles, photovoltaic systems,and uninterruptible power supplies, etc. Designers in thedevelopment of dc-dc converters for point-of-load applicationswith the following goals are higher voltage gain, higher powerdensity, and better conversion efficiency. Conventional boostdc-dc converter is a well-established topology for the applicationsdemanding higher load voltages. However, achievinghigher voltage boostingat full-load imposes a constraint onthe efficiency. Priyabrata Shaw [1] introduces Analysis andController Design for Positive Output Boost Converter withLow Current Stress on Output Capacitornon-isolated typepositive output fifth-order dc-dc boost converter is proposed inthis paper.This topology is developed from the existing fourthorderboost converter (FOBC) by appropriately inserting acharge-pump cell. Compared to FOBC, the proposed topologyoffers enhanced voltage gain with reduced switch voltagestress. P. Shaw [2] introduces Positive output boost converterwith low current stress on output capacitor. A non-isolated typepositive output fifth-order dcdc boost converter is proposed.Compared with basic boost converter, the proposed topologyis capable of offering higher voltage gain with lower voltagestress on switch. Anmol Ratna Saxena [3] introduces a designof robust digital stabilizing controller for fourth-order boostDC DC converter a quantitative feedback theory approach. Inthis paper, we have proposed a quantitative feedback theorybased robust digital voltage mode controller for a fourthorderboost dc dc converter operating in continuous conductionmode. The fifth-order boost [4] topologies exhibiting gainfind limited utility in point-of-load applications due to lackof common ground, inverted load voltage polarity, highlypulsating source current, and moreswitching devices, etc. Thisfifth-order boost converter which successfully overcomes thelimitations. The basis for evolution of this topology is additionof a charge pump capacitor with a diode to the converter. Alimitation in some of these circuits is that the load groundis isolated from the source ground. So, this

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converter is notsuitable in applications needing voltage gain of FOBC, butwith common ground. P. Shaw [5] introduces analysis anddesign of CD-cell-based fifth-order boost converter with robuststability considerations illustrates fifth-order boost topologiesexhibiting gain to find limited utility in point-of-load applicationsdue to lack of common ground, inverted load voltagepolarity, highly pulsating source current, and more switchingdevices, etc. The fifth-order boost converter which successfullyovercomes the enlisted limitations.Several voltage lift techniques[6] has used to improve the gain and efficiency like interleavedconcepts. The voltage lift techniques used to convert theconverter into high power application by lifting the voltage.Omar Abdel-Rahim [7] introduces a boost converter withhigh dc gain as a solution for partial shading of photovoltaic(PV) module. Switched inductor boost converter (SIBC) isintroduced by replacing the inductor of the boost converterwith a switched inductor branch. As a result, the conversiongain ratio can be increased. The proposed converter is used asan interface between the PV system and the load. A MaximumPower Point Tracking (MPPT) control is applied to extractthe maximum power of the PV module. This paper introducesswitched inductor boost type with PV module. With referenceto the above-mentioned papers to overcome the drawbacksa Positive output boost converter with low current stress onoutput capacitor is introduced. Analysis and design of positiveoutput boostconverter [1] is taken as the base paper. In orderto improve the efficiency and gain a switched inductor conceptis implemented compared with the basic converter.

II.METHODOLOGY

In the fig. 1 shows the single switch positive output boost converterwith switched inductor cell operated in two modes. Thepositive output boost converter has only a single switch. Theswitch operated in frequency of 50kHz. The output voltageis higher than the input voltage. The boost converter boosts theinput voltage.

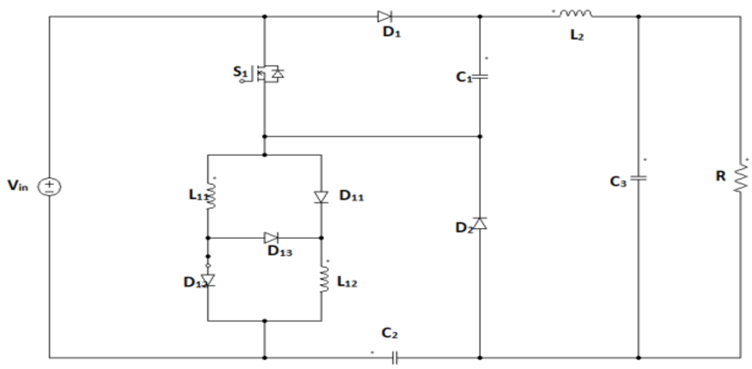

Fig. 1Switched inductor based positive output boost converter

III.MODES OF OPERATION

In the fig. 2 shows the mode 1 operation. In this mode, switchesS1 turned on. The diode D_1, D_2 and D_{13} are in reversebiased and all other diodes are forward biased. The inputvoltage source charges three inductors L_{11}, L_{12} and L_2 andare utilized to drive the load-R. The capacitor C_2 feeds theload and supplies current to the loads and also C_1 discharges.Meanwhile C_2 being discharged to load.

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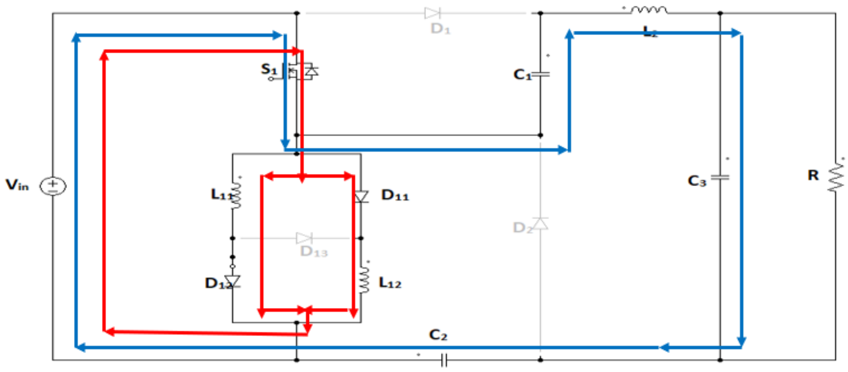

Fig. 2Operating circuit of mode 1

In the fig.3 shows the mode 2 operation.In this mode S_1 in offcondition. The diode D_1, D_2 and D_{13} are simultaneouslyforward biased condition and all other diodes are reversebiased. The stored energy in the inductors L_{11}, L_{12} and $L_2$are discharges and are utilized to drive the load-R and chargethe intermediate capacitors C_1 and C_2.

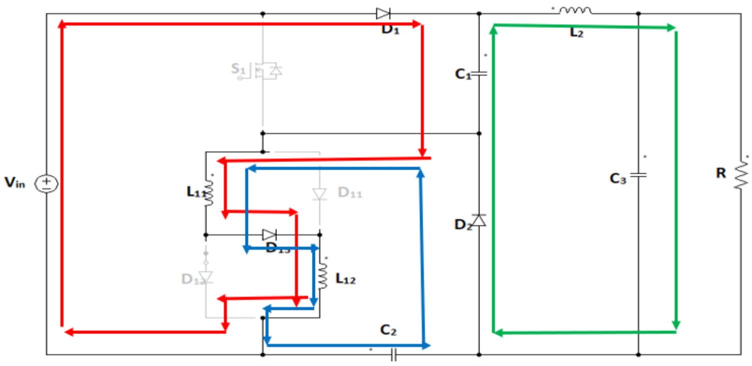

Fig. 3Operating circuit of mode 2

In the fig. 4 shows thetheoretical waveforms of a single switch positive output boostconverter with switched inductor cell.

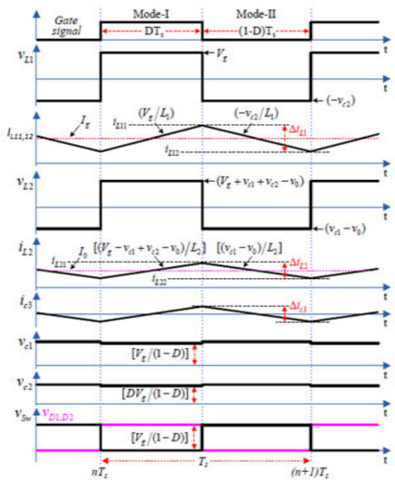

Fig. 4 Theoretical wave form of POBC

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IV.DESIGN OF COMPONENTS

In order to operate the converter, its components should bedesigned properly. It consists of inductors and capacitors. Thedesign of positive output boost converter with input voltage istaken as 36V. The switching pulses are at the rate of 50kHzand the duty ratio of 47% is fixed. The output voltage of theconverter is V_0 is equal to 142V with a output power of 200W.The output current of the converter is I_0 is 0.42A. D is theduty ratio of the switch which is fixed. The current rippleis taken as less than 40% of inductor current. Resistance is100Ω.

$$Gain = \frac{V_0}{V_{in}} = \frac{142}{36} = 3.78 \quad (1)$$

Consider the positive output boost converter with the dutycycle D which is equal to 0.47. The current ripple of inductorsis taken as 40% of inductor current.Current through inductorL_{11} is

$$I_0 = \frac{V}{R} \quad (2)$$

$$I_{L11} = I_0 * \frac{1+D}{1-D} \quad (3)$$

$$L_{11} \geq \frac{V_{in} * D}{f * \Delta I_{L11}} \quad (4)$$

Current through inductor $L_2$is

$$I_{L2} = I_0 = \frac{V}{R} \quad (5)$$

$$L_2 \geq \frac{V_{in} * D}{f * \Delta I_{L2}} \quad (6)$$

The value of inductor is set as L_{11} and L_{12}=205µH. The valueof inductor is set as L_2 =1100µH.Consider the three capacitors C_1 and C_2,C_3 with same dutyratio. The capacitor values are given below. The voltage rippleof capacitor is taken as 1% of capacitor voltage. Voltage acrossthe capacitor C_1 is

$$V_{C1} = \frac{V_{in}}{1-D} \quad (7)$$

$$C_1 \geq \frac{V_0 * D}{f * R * \Delta V_{C1}} \quad (8)$$

Voltage across the capacitor C_2 is

$$V_{C2} = \frac{V_{in}}{1-D} \quad (9)$$

$$C_2 \geq \frac{V_0 * D}{f * R * \Delta V_{C2}} \quad (10)$$

Voltage across the capacitor C_3 is

$$V_{C3} = V_0 \quad (11)$$

$$C_3 \geq \frac{V_0 * D * (1-D)}{8 * (1+D) * f^2 * L_2 * \Delta V_{C3}} \quad (12)$$

The capacitor C_1 and C_2 taken as 100µF and C_3 is taken as220µF.

V.SIMULATION RESULTS AND ANALYSIS

Simulation parameters for a positive output boost converteris chosen based on the design of components.The switches are MOSFET with constantswitchingfrequency of 50kHz.Simulation parameters of POBC are input voltage V_{in} is 36V, Rated power P_0 is 200W Inductor L_{11}, L_{12} is 205µH, Inductor L_2 is 1100µH and Capacitor C_1, C_2 100µF, 220µF. Fig. 5(a). shows the simulation result of input current and inputvoltage of the converter and $I_{in}$is 5.41A. The input currentripple of the converter is 0.02A.

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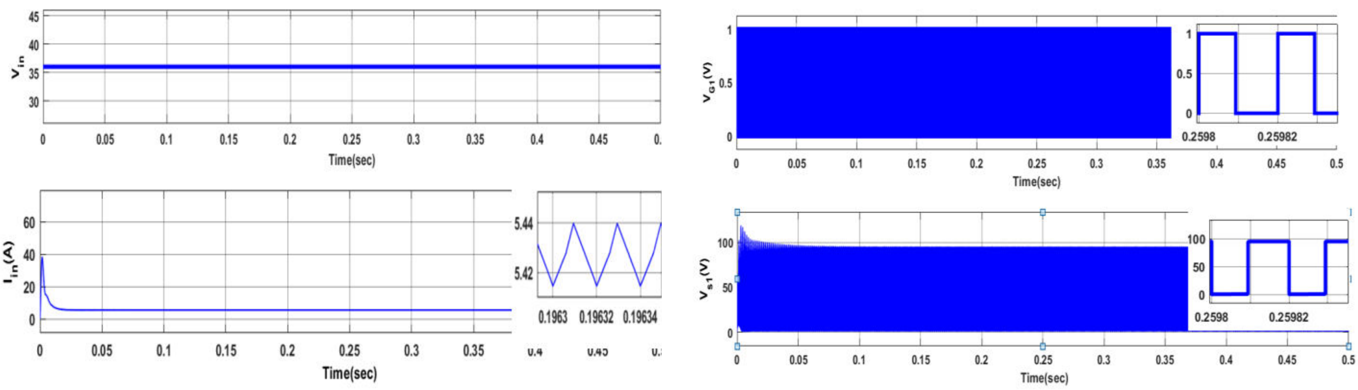

Fig. 5(a)Simulation time vs Input Voltage and Input Current(b)Simulation time vs Switching pulse and Voltage stress

Fig. 5 (b). shows gate pulse and voltage stress across the switchS1. The duty ratio of switch S1 is equal to 0.47. The switchingfrequency is chosen as 50kHz. Voltage stress across switch is95V. Fig. 7. shows the output voltage V_0 and output current I_0.The output voltage is measured as 137V and it has outputvoltage ripple of 0.005V. The output current is measured as1.37A and current ripple of 40µA.

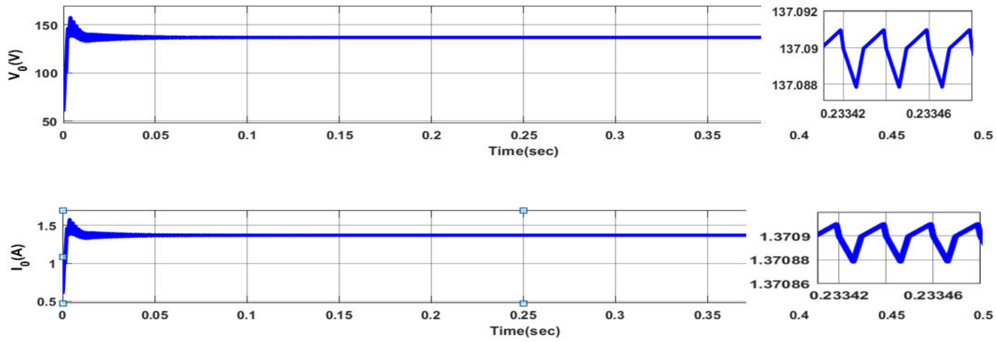

Fig. 7Output voltage and Output current

ANALYSIS:Analysis of positive output boost converter is carried out byconsidering parameters like efficiency, voltage gain.

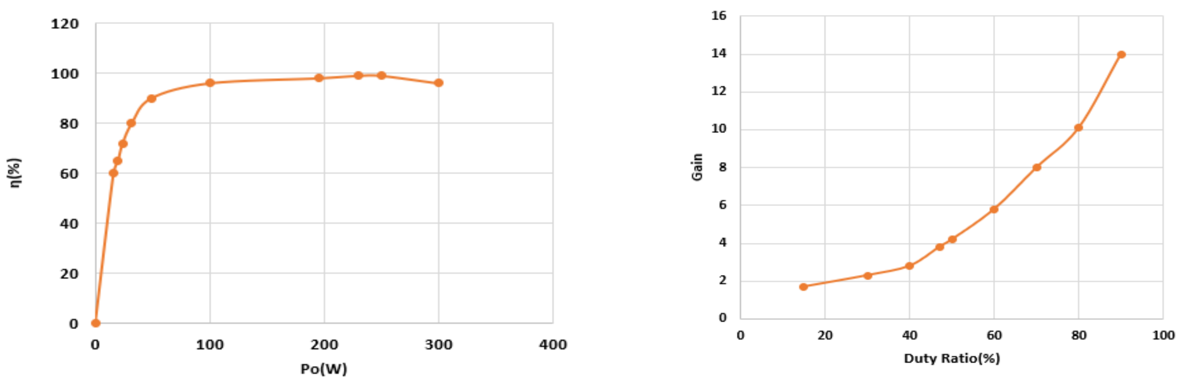

Fig .8(a)Efficiency Vs Output power with R load(b)Voltage Gain Vs Duty ratio

Efficiency of a power equipment is defined at any load asthe ratio of the power output to the power input.Fig. 8(a). Showsthe efficiency Vs output power with R load. Here the resistiveload is varied. switched inductor based positive output boostconverter has efficiency of 95%˙Voltage Gain is defined at any load as the ratio of outputvoltage to input

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voltage.Here the voltage gain increases for anincrease in the duty ratio.Fig. 8(b). shows the analysis of dutyratiowith gain. Here the duty ratio increases gain of the converterhas also increases. The switched inductor based positive outputboost converter has improved gain.

VI.HARDWARE IMPLEMENTATION

A prototype of POBC converter with input voltage of 5Vis implemented. It consists of control circuit, driver circuitand power circuit. Control circuit is composed of PIC microcontrollerand its power supply. The control pulses forMOSFET switches are generated using PIC microcontroller.The pulses from microcontroller are amplified by driver circuitwhich is composed of TLP250H. It also provides isolationbetween control and power circuit. The experimental setup ofpositive output boost converter is done through two stages.First the program is written in microC for generating gatepulses for switching devices. The program is verified andfrequency is checked by simulating it in the Proteus software.The program is burned to the microcontroller(PIC16F877A)using the software micro programming suit for PIC. Theswitches used are MOSFET IRF640 along with its driverTLP250H. In power circuit an input of 5V isgiven to theconverter. The switches used are IRF640. The pulses obtainedfrom the microcontroller is fed to theinterfacing circuit and theamplified pulse is given to the gate terminal of the MOSFET.The diodes used are 10A10NSL. The output voltage obtainedis given to the digital storage oscilloscope (DSO).Fig. 9(a). shows the interfacing with controller circuit andexperimental setup for the converter circuit. The controllercircuit consist of PIC16F877A micro controller and crystaloscillator. It used to select clock frequency for controller. A5V supply is given to the controller and output of controlleris given to interfacing circuit. The experimental setup forconverter circuit is shown in fig. 9. It consist of power circuitand driver circuit. The output of the converter is shown in thedigital storage oscilloscope.Fig. 9(b). shows the experimental result of the converter. Theprototype is designed for 5V input with output of 19V. Herethe output is obtained as 18.8V

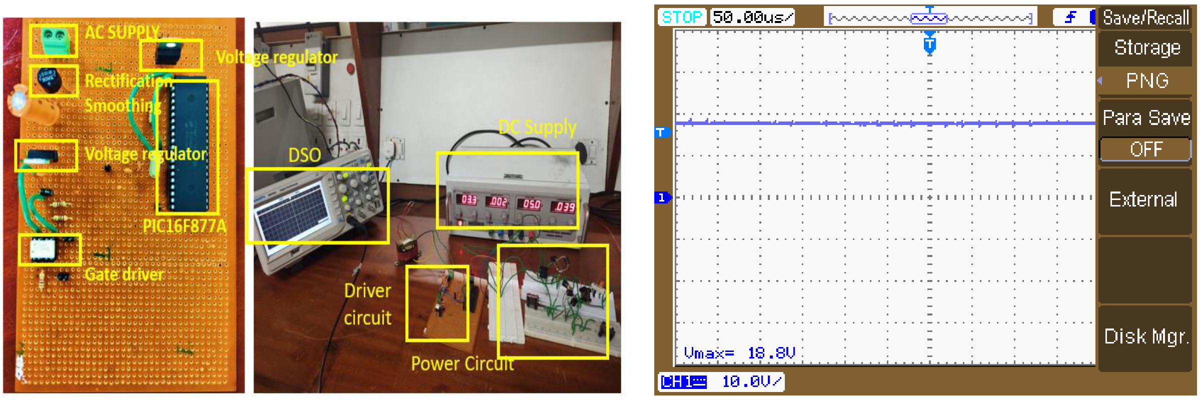

Fig. 9(a) Hardware implementation (b) Output voltage

VII.CONCLUSION

A single switch positive output boost converters withswitched inductor cell are widely used for the renewableenergy applications.The charge pump cell concept is used to improvethe gain of the converter.It has low voltage ripple.The converter has low output capacitor currentstress. The efficiency of the converter is low comparatively. Ithas acontinuous input current. The voltage stress across theswitch one is low. From the simulation results the voltage gainof the proposed converter is increased to 3.78 and efficiency of95% for this converter for an input of 36V. The converter offerslow voltage ripple of 0.005V. The design and simulationare done.Design and operation isflexible.The control of theproposed converter is implemented using PIC16F877A microcontroller.Converter prototype of 3.6W provides the expectedperformance with an output voltage of nearly 19V, consideringthe drop across thecomponents. The overall analysis confirmsthat the proposed converter can be used in applications suchas photovoltaics, electric vehicles, solar panel fuel cell etc.

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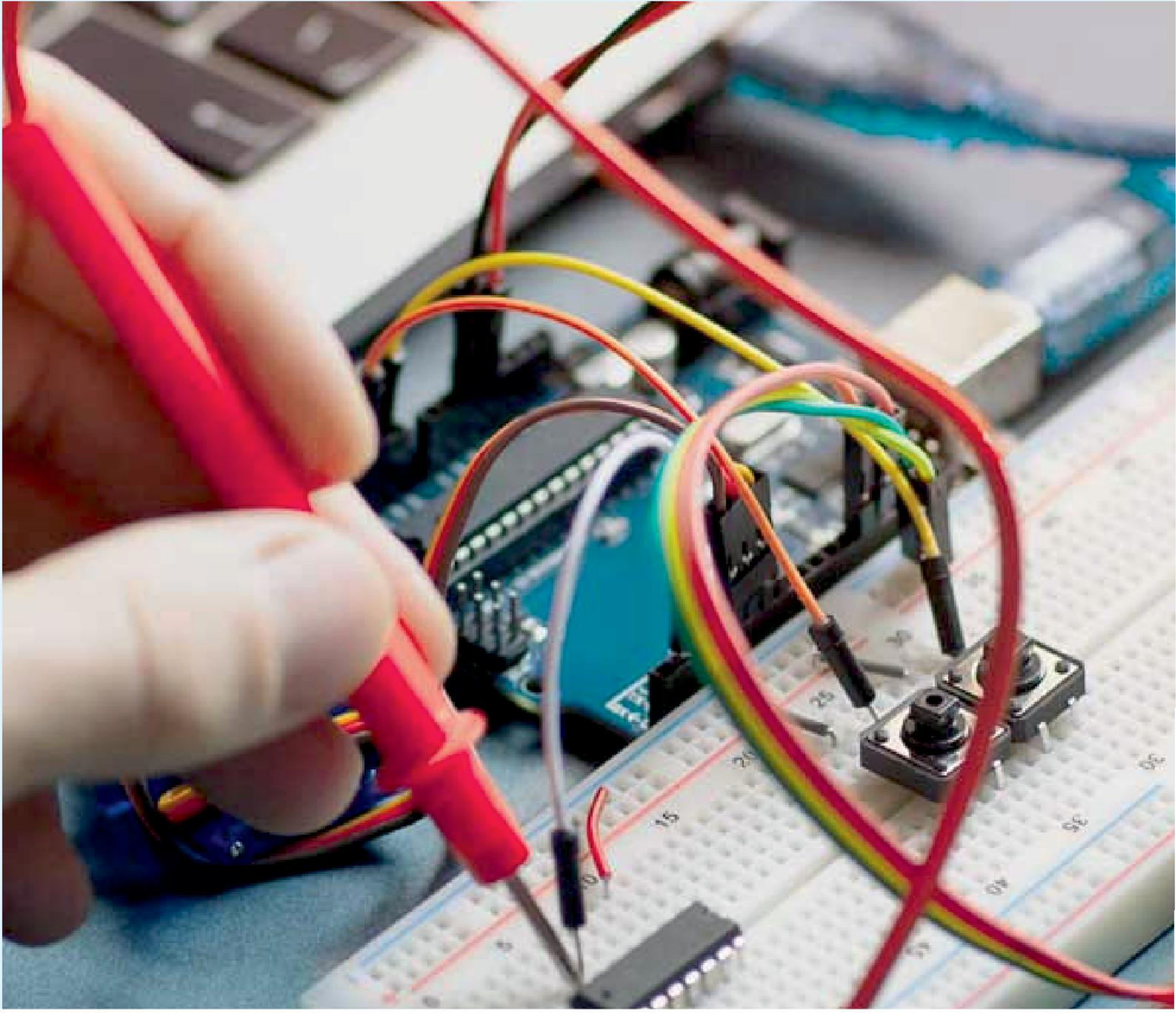

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