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Design and Performance Evaluation of Modified SEPIC Converter with VM Network

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ABSTRACT: In recent years, DC-DC converter plays a vital role in many applications such as EV, micro grid etc. Hence, the designed converter should exhibits high voltage gain ratio and higher efficiency. Thus, this work proposed a new topology of DC-DC converter with soft switching. This proposed converter is a modified SEPIC converter. It integrates switched inductor at the input side and voltage lift configuration topology to enhance the voltage gain of the proposed converter. This converter comprises only one switch which results in lower switching losses. Thus, the performance of the proposed converter is validated using MATLAB simulation. From the observed results, it can be concluded that this proposed converter can be a viable solution to PV system.

KEYWORDS: DC-DC converter, SEPIC converter, SI (Switched Inductor Network).

I. INTRODUCTION

The current scenario of depletion of nonrenewable energy source makes the world to graze towards alternate energy sources. RESs are a viable alternative to fossil fuel and nuclear energy for generating electrical power. The use of renewable energy sources in power generating has increased dramatically in recent years. Solar cells, fuel cells and wind turbines are used in distributed generation (DG) technologies [1, 2]. Sustainable energy production can be done using RES [3,4] to overcome the problem of environmental pollution and global warming caused by fossil fuels. In the future, RES plays a vital role in low-carbon energy emission systems [5]

Photovoltaic (PV) power generation is widely utilized among all RES because of its distinct advantages, including a longer lifespan, environmental friendliness and mobility [6]. However, the irregular availability of sun irradiances is the key factor which affects the efficiency of PV systems. Various power electronic DC–DC converters are utilized to solve this problem and provide a steady output voltage. The DC–DC converter has been used with solar PV systems since 1920s. The primary goal of these converters was to eliminate the need for traditional circuits like rheostats and potential dividers. The disadvantage of this method is that the output voltage obtained is lower than the input voltage, resulting in a reduction in efficiency.

In order to regulate the input voltage, many DC–DC converter topologies are used nowadays. The isolated DC–DC converter and the non-isolated DC–DC converter are the two types of DC–DC converters that are commonly used. A high-frequency transformer is used to build an electrical barrier between the converter's input and output in case of isolated DC–DC converters. This phenomenon is employed to safeguard sensitive loads, and the converter's output can be adjusted with positive or negative polarity. But it exhibits a high noise interference capability [7].

Traditional boost converters used in micro grids would have to operate at high duty ratios,. At higher duty ratios, the voltage drop across the parasitic resistance of capacitors and inductors increases significantly, reducing the voltage gain and efficiency of the conventional boost converter. [8]

Several DC-DC converter topologies have been developed to address these issues. A summary of several boosting strategies is given in [9], including the use of voltage multipliers to multiply the boost factor, as well as switched inductor, switched capacitor, magnetic coupling, and multistage methods. Most of the high-gain DC-DC converters utilized these topologies. To boost the voltage gain, the converter in [10] uses a voltage doubler circuit.

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Several converters use isolated high-frequency transformers to increase the turns ratio of the transformer to obtain voltage gain. However, such circuits are larger, more expensive, and more complicated. Furthermore, the transformer's leakage inductance would affect switch operation of a converter [9,10].

Coupled inductor and non-coupled converters are the two forms of non-isolated converters [11]. The output of coupled-inductor-based converters can be increased by selecting a suitable inductor coil turn ratio. The inductor's leakage inductance may cause a surge in switch current results in clamping [12]. In some circumstances, an isolated converter is not required; in these cases, non-isolated DC-DC converters are preferable to achieve significant voltage gains [13–15].

A modified quadratic boost converter created by replacing the inductor with a switched inductor module to obtain a voltage gain twice that of the conventional Boost converter [16, 17]. In addition, combining different converters can result in the creation of new converters. By combining the regular SEPIC with the boosting module, a modified SEPIC converter is formulated to achieve larger voltage gain [18]. Ref. [19] describes hybrid switched-capacitor quadratic boost converters with high DC gain and low voltage stress on power devices. A hybrid switched-capacitor approach [20] also yields high gain.

The voltage lift (VL) approach is a well-known electrical circuit design methodology which can be effectively used in DC-DC converter applications in recent years. It leads to the development of high voltage gain converters. Luo converters utilized effectively the VL approach to obtain high gain [21]. It boosts the voltage gain of the circuit by using extra energy storage devices like inductors and capacitors. A positive output Luo converter, including a self-lift, re-lift, triple-lift, and quadruple-lift boost converter are introduced using this approach. These methods overcome the effect of parasitic elements and enhance the voltage at the output. A high-gain converter that uses the VL approach to generate gain double that of a standard boost converter with two inductors is formulated [22]. But in this, the voltage stress over the switch is equal to the output voltage. The output voltage can also be increased by using a voltage doubler circuit like the Cockroft–Walton circuit [23], which reduces the voltage stress across the switch. The VL approach is also utilized with a voltage doubler in [24,25]. To obtain a negative voltage with respect to ground, a non-isolated DC-DC converter based on the VL approach was utilized [26]. In ref. [27], an independent type of converter based on interleaving technology is proposed.

Thus, to address the all the complications of various converters discussed above, this work proposed novel boost converter. The proposed converter is a combination of modified SEPIC converter with VL technique. The following are some of the benefits of the proposed topology.

1. Exhibits higher voltage gain when compared to traditional boost converter.
2. The voltage stress across the power switch is lower than the output voltage.
4. The implantation of a single power switch allows easy control.
5. Low voltage stress on power devices decreases power losses, resulting in high efficiency.

II.MODELING OF PROPOSED CONVERTER

The proposed converter depicted in figure 1, is the modified SEPIC converter. In order to increase the output voltage of the proposed converter, an additional VL topology is added to the output side of the proposed converter. Apart from an increased voltage output, it also lowers the di/dt stress on diodes.

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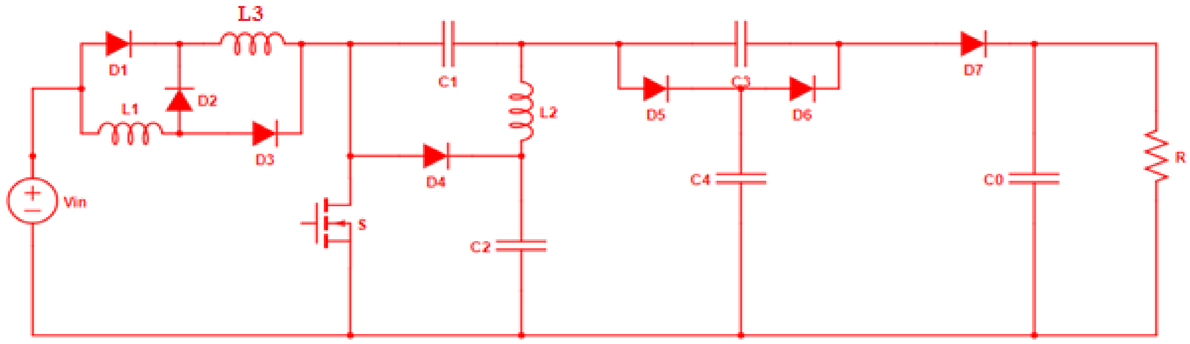


Figure 1. Schematic diagram of the proposed DC-DC converter

Mode of Operation

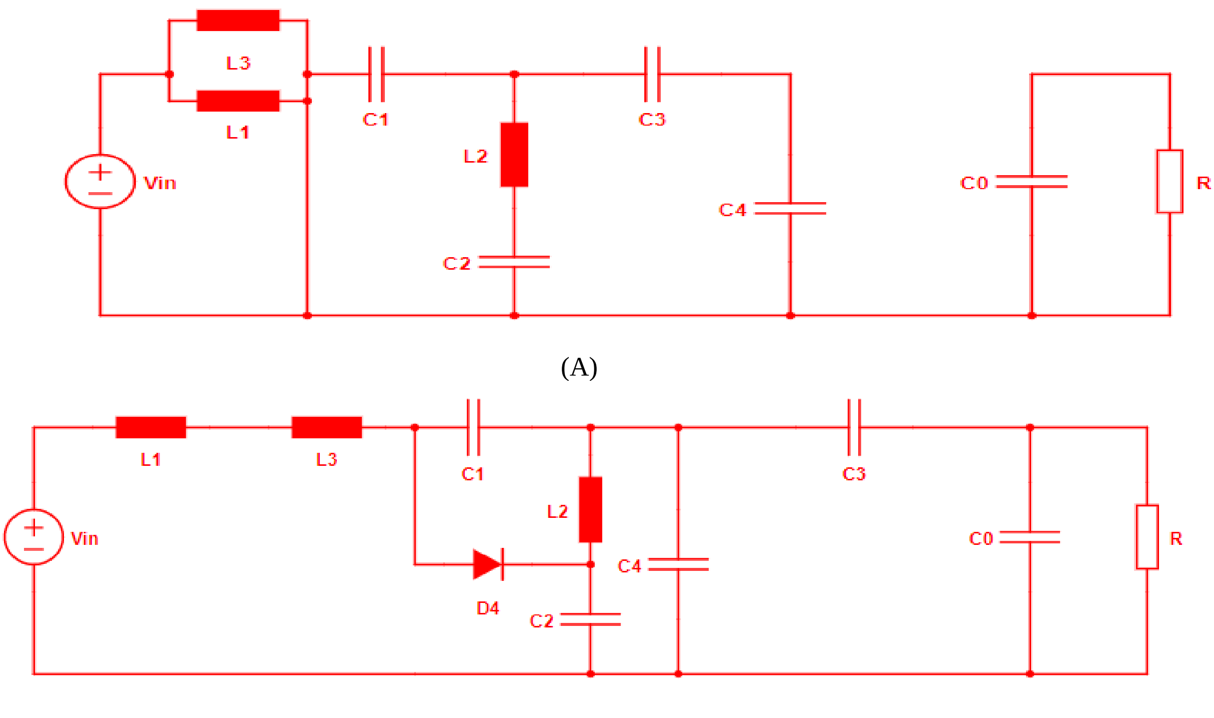
The modified SEPIC DC-DC converter topology features two modes of operation:

(i) Switch in ON condition

(ii) Switch in OFF condition

The behavior of each component under steady-state conditions can be used to examine the converter operation mode. All components are assumed to be in perfect working order. During one period of switching, the voltage in the capacitor is also assumed to remain constant, and the converter runs in continuous conduction mode (CCM), or the inductor currents IL1 and IL2 are always constant.

Figures 2(a) and 2(b) show the equivalent circuit of the improved SEPIC converter based on the ON or OFF state of the static switch S.



(B)

Figure 2. Equivalent circuit of proposed SEPIC (A) when switch *S* is turned ON and (B) when switch *S* is turned OFF.

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When the switch S is closed, the input voltage will pass via the inductor and switch before returning to the voltage source Vin. The inductor L_1 is charging in this condition, therefore the magnitude of the input voltage is equal to the voltage across the inductor L_1.

$$V_{L1} = V_1 \quad (1)$$

In addition to the inductor L_1 being charged by the input voltage, the voltage across the inductor L_2 is depicted below

$$V_{L2} = V_{c2} - V_{c1}$$

$$V_{L2} = V_{c2} + V_{c3} - V_{c4}$$

$$V_{c1} + V_{c3} = V_{c4}$$

When the switch, S is opened, then *D0, D1, D2* turns ON and *D3* turns OFF.

Thus, voltage across L_1

$$V_{L1} = V_1 - V_{c2} \quad (3)$$

Thus,

$$V_{c2} = \frac{1+D}{1-D} V_{in} \quad (4)$$

Similarly, voltage across L_2 can be depicted as

$$V_{L2} = -V_{c1}$$

$$V_{L2} = V_{c2} - V_{c4} \quad (5)$$

Using (2) and (5) the following values can be obtained

$$V_{c2} = \frac{1+D}{1-D} V_{in}$$

Thus, output voltage is about $V_0 = V_{c3} + V_{c4}$ (6)

$$V_0 = \frac{(1+D)(2+D)}{1-D} V_{in}$$

Selection of Inductor

While designing a Inductor, the inductor ripple current I_L has to be taken into consideration. Thus, it can be calculated using a formula

$$\Delta(I_L) = 30\% \times \left(\frac{I_{in}}{\eta}\right) \quad (7)$$

$$L_1 = L_2 = 1/2 \times \left(\frac{V_{in} \times (D)}{\Delta(I_L) \times (F_{sw})}\right) \quad (8)$$

Selection of Capacitor

Similarly, the output capacitor can be calculated using the formula

$$C_1 = \frac{I_{out} \times (D_{max})}{\Delta(V_{cp} \times (F_{sw})} \quad (9)$$

III. RESULTS AND DISCUSSION

To demonstrate the effectiveness of the proposed converter, it is simulated in MATLAB. As a result, its efficacy has been demonstrated in open loop operations. Table 1 lists the design limits of the components used during simulation.

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Table 1. Design parameters

Parameter	Values
V_1	20 V
V_o	240 V
Inductance	100 µH
fs	100 kHz
D	0.69
Capacitance	36µF

Thus, the converter is tested under open loop mode and the output obtained is depicted in fig.3.

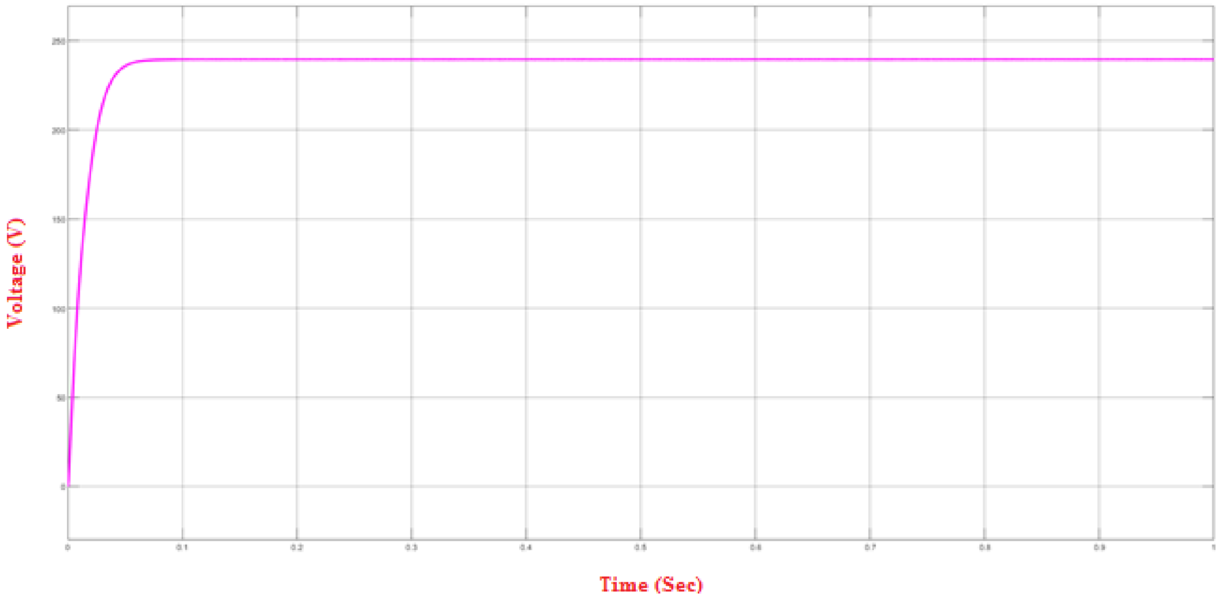

Figure 3.Output voltage of the converter under open loop control

The converter outer performs as shown in the diagram, and its gain value is around 12. As a result, given an input voltage of roughly 20V and a duty cycle of 0.69, the output voltage is around 240 V.

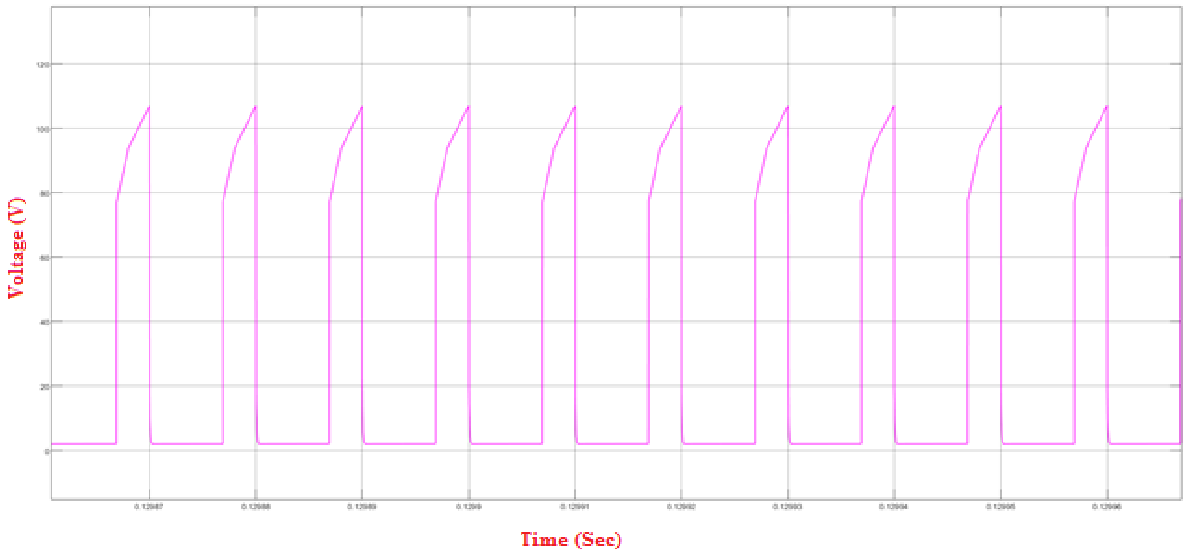

Figure 4. Voltage across switch S

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Figure 4 shows the current and voltage across the switch S. Low voltage across S, no additional clamping circuit is necessary. As a result, a low voltage rating MOSFET with low on resistances can be applied in a realistic application. The loss of conduction across the switch is decreased. Hence, it is concluded that the suggested converter will have a minimal conduction loss. Similarly, the voltage stress in the preceding figure is just about 100 V, which is quite low when compared to the output voltage.

COMPARATIVE ANALYSIS

Table 2. Performance Comparison with traditional converter

Topology	**Boost converter**	**Proposed converter**
Voltage gain	$\frac{1}{1-D}$	$\frac{(1+D)(2+D)}{1-D}$
No. of Switches	1	1
No.of Diodes	1	5
Voltage stress across the switch	V_o	Less thanV_0

From the above table, it is concluded that the propsoed converter improves the voltage gain of the converter more than 10 times as that of conventional boost converter. Hence, this converter can be utilized for PV applications. Thus, the voltage across the Switch of the proposed converter is very low as compared to Boost converter. Hence, the proposed converter exhibits lower conduction loss.

IV.CONCLUSION

A DC-DC converter with high gain is modeled and designed in this work. This proposed converter is the modified Sepic converter. It comprises SI network and voltage lift topology to enhance the voltage gain of the converter. Thus, the proposed converter exhibits a voltage gain about 12 at a duty cycle about 0.69. As single switch is implemented in this topology and ZVS condition is acquired, the switching loss is very less very compared to other boost converters, Similarly, the voltage stress of the switch also less and hence, results in reduced conduction loss. As a result, low rating device can be utilized for this converter which in turn increases the efficiency of the converter. Thus the performance of the formulated converter is examined using simulation. From the Simulation results, it is evident that this proposed converter exhibits higher efficiency and can be adopted for PV application.

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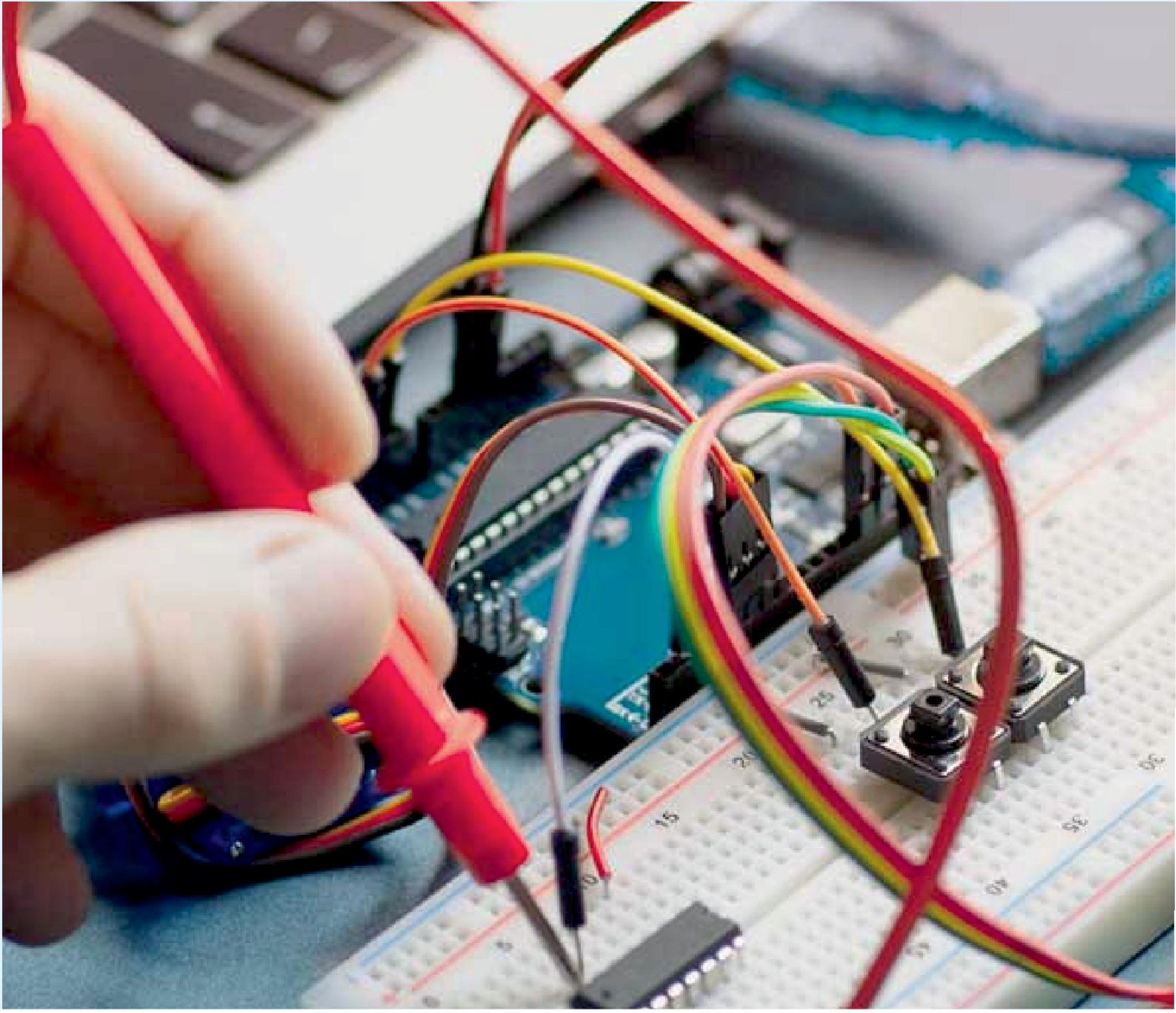

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