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Ultra High Gain DC-DC Converter for Renewable Energy Applications

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ABSTRACT: In this paper, a new buck-boost dc-dc converter, which is applicable to renewable energy sources, is proposed. The proposed converter is capable of delivering the desired output voltage over a wide range of input voltage variations. Depending on the load requirements, by changing the duty cycle of the switches, the proposed converter can operate as a buck-boost converter. In this converter, the output voltage polarity is the same with the input voltage polarity, and the input has a common ground with the output. The voltage gain of the proposed converter is high compared to similar structures. The simulation result is analyzed using the MATLAB/SIMULINK

KEYWORDS: High gain Converter, High Efficiency.

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I.INTRODUCTION

Today, the application of renewable energy sources is increasing with regard to the existing conditions for fossil fuels, the expiry of these resources and environmental issues. Due to the instantaneous nature of the power taken from renewable sources and the power volatility of these sources, the interface devices between the load and the source should be used to provide the necessary conditions for feeding the load. Power electronic converters play the role of these interface devices .All converters presented in the references are derived from basic converters. One of the most important of these converters is the buck-boost converter, which is utilized inmany applications. The buck and boost converters have a limited voltage gain and are suitable only for applications designed to increase or decrease the voltage individually [1-4]. In applications which do not require galvanic isolation, non-isolated converters can be used to increase or decrease the voltage. The low cost and the simplicity of the control are the advantages of non-isolated converters [5]. Interleaved converters can produce high voltaic gain, however, these converters have man components, which will increase the cost of the converter and make it more difficult to control [6],[7].In [8], to improve the voltage gain, the boost converter has been integrated with the SUG converter, but this increases the number of components and subsequently increases the cost of the converter,and the voltage gain is not significantly improved.In [9],a bidirectional converter is proposed which operates as a boost converter in one direction and in the other direction acts as a buck converter. Although this converter has high voltage gain, however, by changing the duty cycle this converter cannot be used as a buck-boost converter. In [10], a structure is proposed to increase the voltage gain using voltage multiplier cells and coupled inductors. To reduce the output current ripple of the converters, the filter is used. Using the filter and coupled inductors the volume and cost of the converter increases. In [11], the cascaded buck-boost converter is used to feed the load by PV source. This converter is bidirectional, and thepower can flow in two directions. Compared to the number of components used in this converter, the voltage gain of this converter is low.

In this paper, a new dc-dc converter with buck-boost capability is proposed which is suitable for application in renewable energy sources. Delivering the desired output voltage over a wide range of input voltage variations is one of the most important capabilities of the proposed converter. By changing the duty cycle of the switches, the converter can act as a buck boost converter depending on the load variations

II.METHODOLOGY

The very high gain DC-DC converter has two MOSFET switches (S1, S2), bidirectional switches (D_1, D_2, $D_3$and D_4) four capacitor (C_1, C_2 , C_3, C_4) and two inductor (L_1, L_2). Figure 1 shows the circuit diagram of very high gain DC-DCconverter for renewable energy application.

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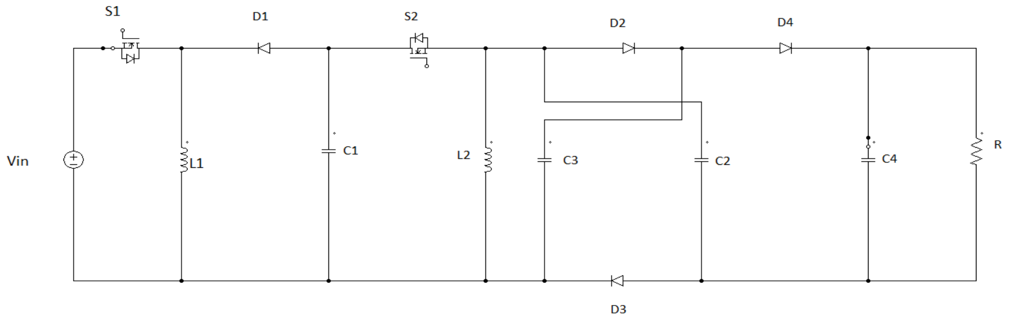

Fig. 1High gain DC-DC converter

III.MODES OF OPERATION

The proposed converter works on the continuous conduction mode. There are two modes of operations in the converter in one switching cycle. The key waveforms of this scenario are shown in Fig.3.

In mode I operation both the switches S1 and S2 will turned on and one diode D_4 will be forward biased the diodes D_1, D_2, D_3 will be reverse biased. The input voltage (V_{in}) charges the inductor L_1 , the capacitor C_1 charges the inductor L_2 and the output is given by the capacitor C_2, C_3. Mode I operation is shown in Fig.2(a)

In mode II operation both the switches S1 and S2 will turned off and one diode D_4 will be reverse biased the diodes D_1, D_2, D_3 will be forward biased. The inductor L_1 charges the capacitorC_1 , the inductor L_2 charges the capacitor C_2&C_3 and the output is given by the capacitor C_4. The mode II operation is shown in Fig.2(b).

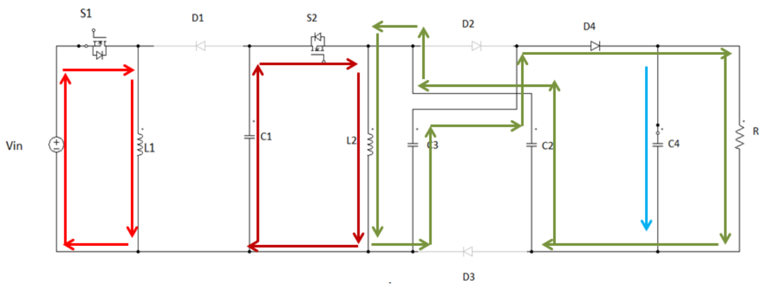

Figure 2(a): Mode I Operation

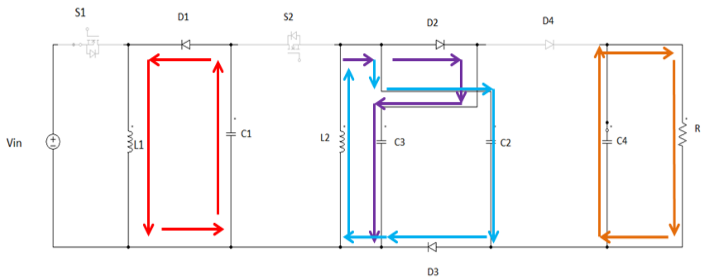

Figure 2(b): Mode II Operation

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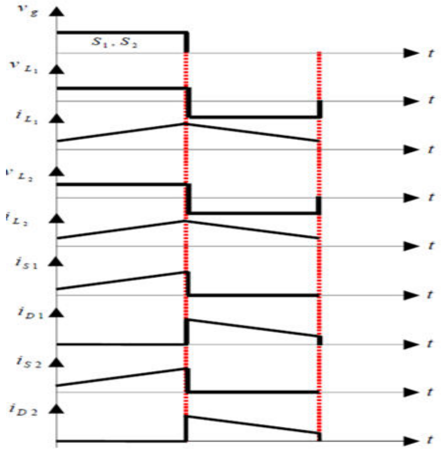

Fig. 3: Theoretical waveforms of high gain DC-DC converter

IV. DESIGN OF COMPONENTS

In order to operate the converter properly, its components should be designed properly. It consist of design of load resistor, inductors L_1, L_2 and the capacitor $C_1, C_2, C_3 \& C_4$. Here in switched capacitor concept the pair of capacitor values (i.e. $C_2 \& C_3$) are taken the same. The input voltage, V_{in} is taken as 18V, the output voltageV_{out} is taken as 47V, the output resistance R value is taken as 10Ω and the switching frequency f_s is taken as 10kHz.

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

By solving the equation 1 the value of duty ratio D is 0.57 and the output power can be found by (2) which is approximated to 100W.

$$P_o = \frac{Vo^2}{R} \qquad (2)$$

Inductors L_1 and L_2 are obtained by from (3) and (4) are approximated as 50μH and 450μH. The value inductor is taken as current through the converter is minimum.

$$L_1 \geq \frac{R(1-D)^4}{2(D)^2 f} \qquad (3)$$

$$L_2 = \frac{R(1-D)^2}{2f} \qquad (4)$$

The value of capacitors $C_1, C_2, C_3, and\ C_4$ are calculated by the assumption that the rate of change of voltage is minimum. That is output voltage ripple is minimum. From (5), (6), and (7) the values of capacitors $C_1, C_2, C_3, and\ C_4$ are approximated as $C_1 = 1800$μF, $C_2, C_3 = 100$μF and $C_4 = 200$μF.

$$C_1 = \frac{(D)^2}{0.01(1-D)Rf} \qquad (5)$$

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$$C_4 \geq \frac{0.57}{0.02Rf} \quad (6)$$

$$C_2, C_3 \geq \frac{D}{0.02Rf2} \quad (7)$$

V.SIMULATION AND RESULTS

The new very high gain non-isolated buck-boost converter is simulated in MATLAB/SIMULINK by choosing the parameters listed in Table 1. The switches are MOSFET/Diodes with constant switching frequency of 10kHz.

Table 1. Simulation parameters.

Parametrs	Value
Input Voltage V_{in}	18V
Output Voltage V_{out}	47V
Frequency f_s	10kHzz
Inductor L_1	50µH
Inductor L_2	450µH
Capacitor C_1	1800µF
Capacitor C_2	100µF
Capacitor C_3	100µF
Capacitor C_4	200µF
Load R	10Ω

Fig 4 shows the input voltage and input current, the input voltage V_{in} is 18V and input current is 25A with a a ripple of ΔI_{in} is 20A. Fig 5 shows the voltage stress across the switches S_1 and S_2 , the voltage stress across switch S_1 is 41V and switch S_2 is 52V. Fig 6 shows the current through the inductors L_1 and L_2 , the current through inductor L_1 is 10.1A with a ripple of ΔI_{L1} is 4.1A and the current through inductor L_2 is 8A with a ripple of ΔI_{L2} is 1.4A. Fig 7 shows the voltage across capacitors C_1, C_2, C_3 and C_4, the voltage across capacitor C_1 is V_{C1} is 40V with a ripple of 0.6V,the voltage across capacitor C_2 and C_3 are $V_{C2} = V_{C3}$ is 17V with a ripple of 2V and the voltage across the capacitor C_4 is V_{C4} is 47V with a ripple of 1.2V. Fig 8 shows the output voltage and output current through the converter V_{out} is 47V and I_{out} is 4.65A with ripple of 0.1A.

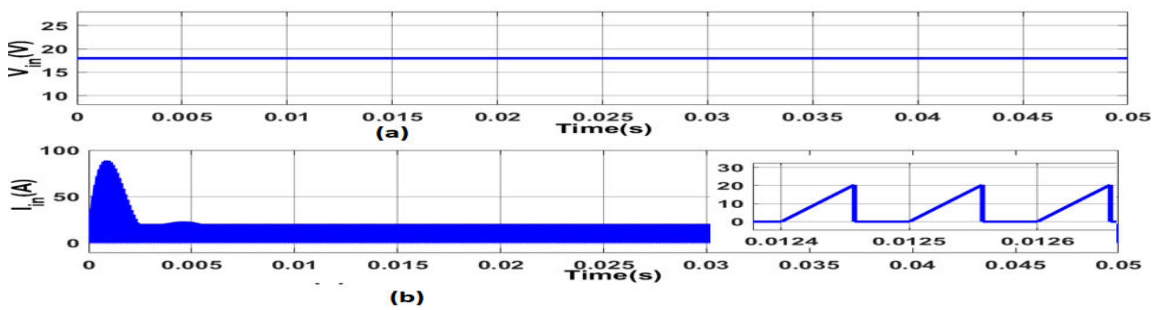

Figure 4: (a) Input Voltage (b) Input Current

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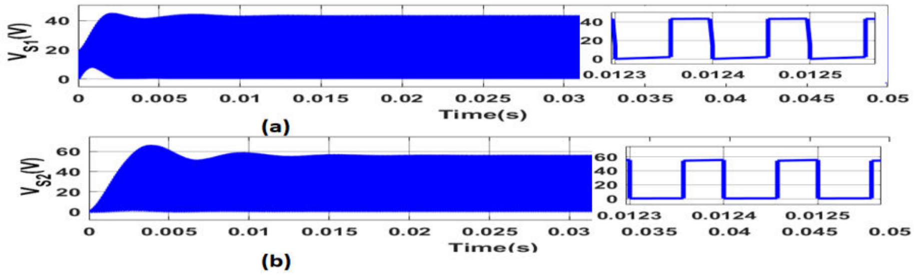

Figure 5: Voltage Stress Across Switches (a)S_1 (b) S_2

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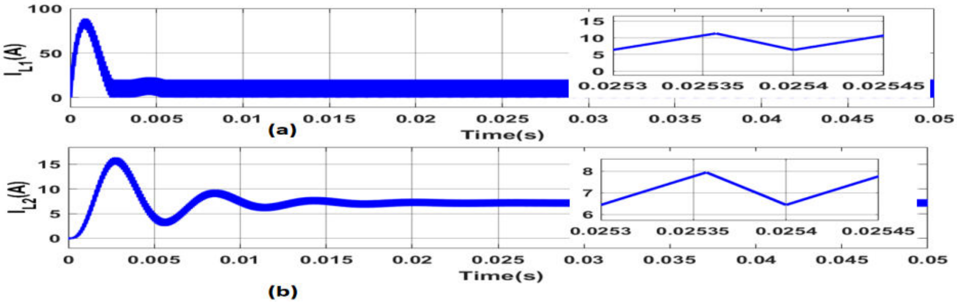

Figure 6: Current Through Inductors (a)I_{L1} (b) I_{L2}

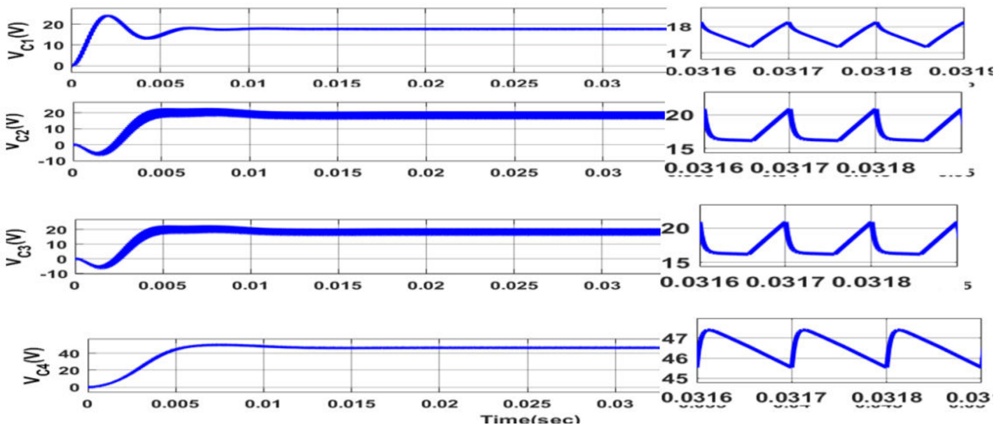

Figure 7: Voltage Across Capacitors (a)V_{C1} (b) V_{C2} (c) V_{C3} (d) V_{C4}

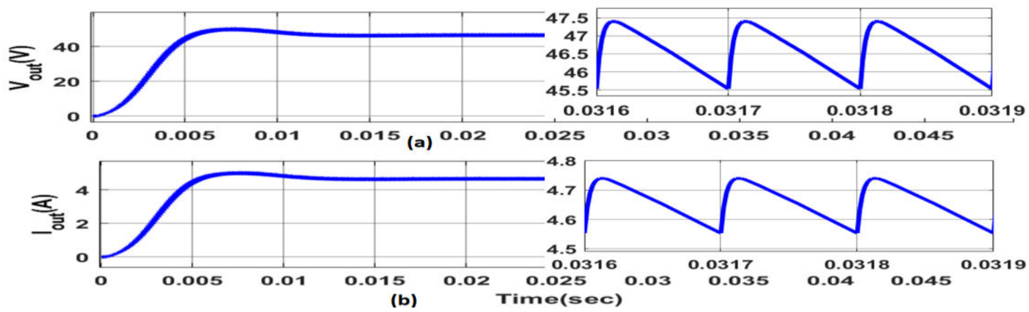

Figure 8: (a)$Output\ Voltag\ \ V_{out}$ (b) Output Current I_{out}

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VI.PERFORMANCE ANALYSIS

The efficiency of power equipment is defined as the ratio of output power to input power. The efficiency tells the fraction of input power delivered to the load. Fig. 9(a) shows the efficiency versus Output power graph with R load and RL load. The converter has an efficiency of 95% at 72W power. It can achieve maximum efficiency of 98% in case of R load. In case of RL load it has a maximum efficiency of 98%. The efficiency is gradually increased within output power.

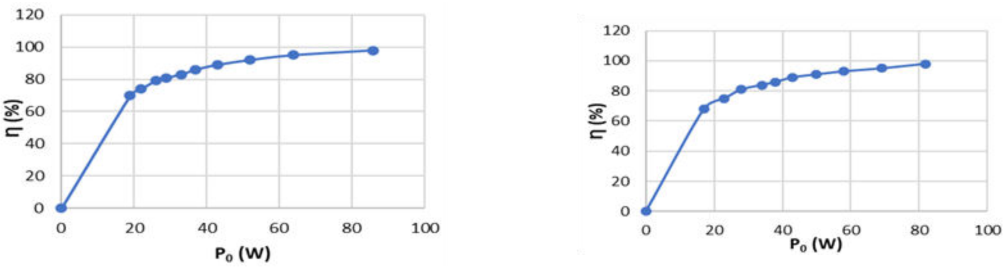

Fig .9efficiency analysisR and RL load vs Output power

Fig. 10 shows the ripple vs duty ratio. It seems that as the duty ratio increases, the ripple also gradually increases. The percentage ripple voltage varies from 0.01% to 0.1% when the duty cycle increases from 15 to 80%. The gain vs duty ratio shows that the gain increases with the duty ratio. The converter has a gain of 6 at a duty ratio of 46.55%.

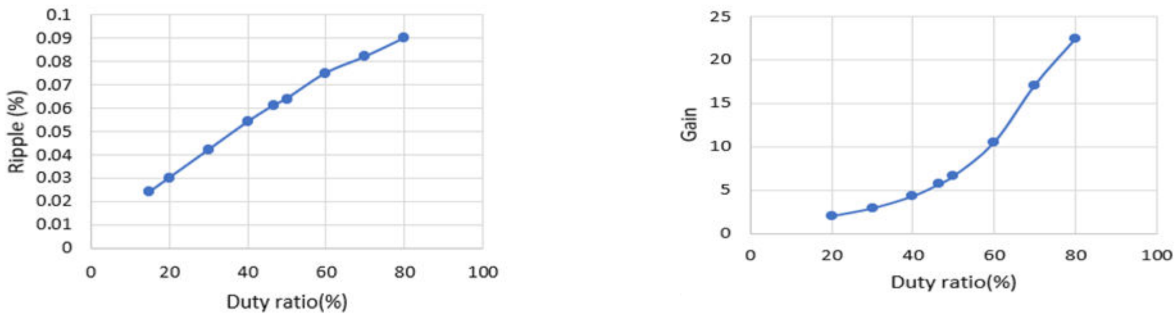

Fig.10Analysis of ripple vs Duty ratio and Gain Vs Duty ratio

Fig.11 shows the percentage ripple Vs switching frequency as the ripple decreases with an increase in switching frequency. Here the lowest ripple at 0.070% at a switching frequency of 50kHz.

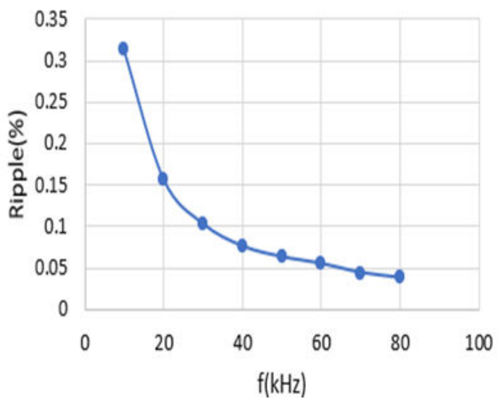

Fig .11Ripple vs Switching frequency;

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VII.CONCLUSION

In this paper a dc-dc converter was proposed to improve the voltage gain. This converter has a positive polarity and the output and the input has common ground. The converter switches turn on and turn off simultaneously which will simplify the control system of the proposed converter. The converter has a high gain which best suitable for renewable energy applications.

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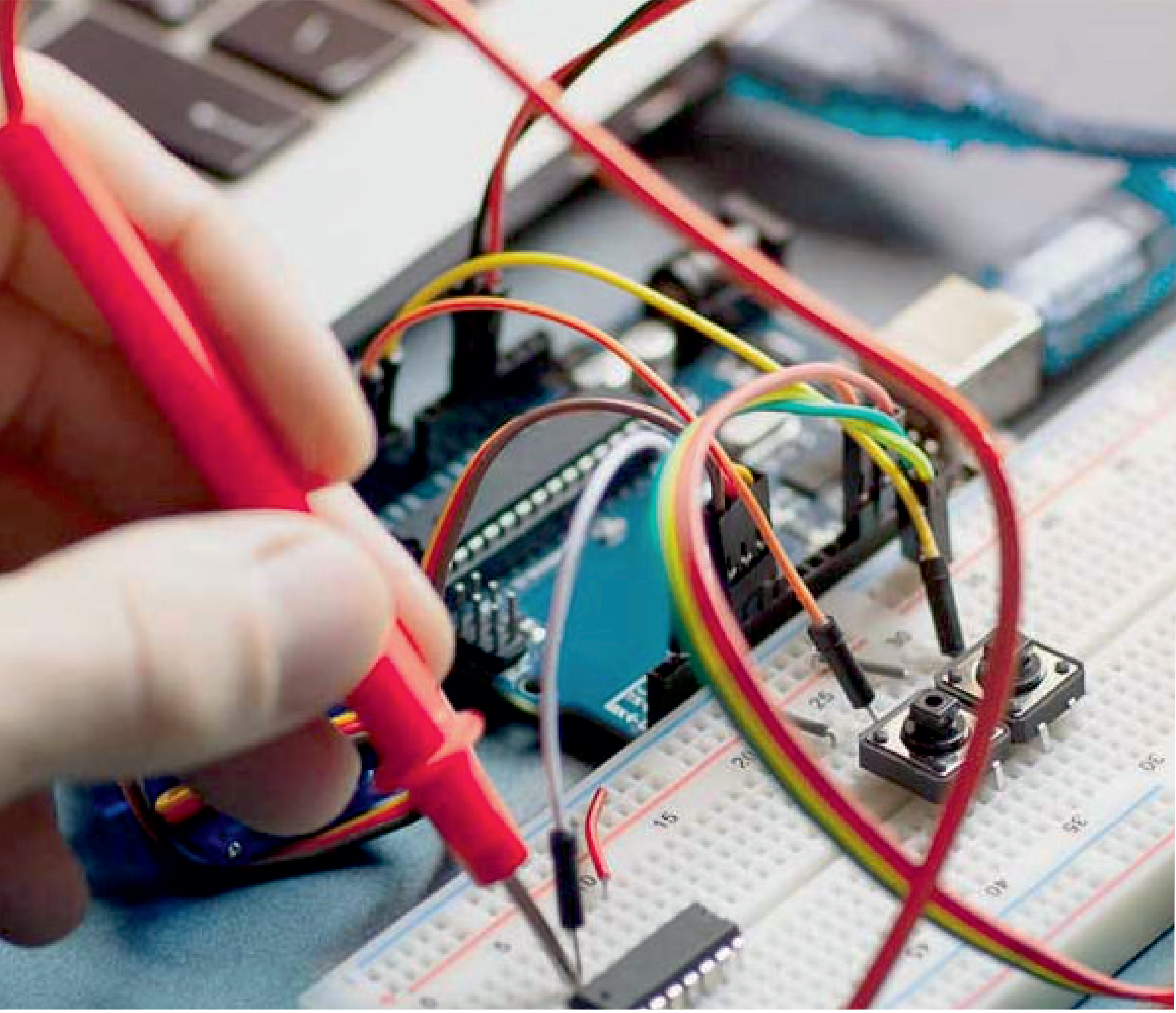

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