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DC -AC –DC Converter for Renewable Energy Application

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ABSTRACT*:* Because of its small size and weight, single stage LLC resonant converters with intrinsic power factor correction are gaining appeal in AC-DC converters. Single stage topologies, on the other hand, are less effective in regulating the dc bus capacitor voltage during line and load transients. This to overcome the problem, the research offers a single stage AC-DC LLC topology based on flying capacitors of dc-bus capacitor voltage balancing and lowering the voltage stress on switching devices The suggested three-level inverter structure ensures zero voltage switching, lower circulating currents, and lower power consumption. Stress and losses are switched. For increased efficiency, the converter employs a bridgeless rectification technique. The source-side inductor is operated in discontinuous current conduction to bring the power factor close to unity. This paper proposes an LLC converter for 300V DC and convertsit to 24V DC. The proposed system has been done in MATLAB/Simulink.Also a hardware prototype for the same system has been designed and implemented.

KEYWORDS*:* LLC resonant converter, single stage AC-DC, Bridgeless rectification.

I. INTRODUCTION

LLC resonant converters provide several advantages, including switching of switching devices, inherent short circuit and open circuit protection, and high efficiency [2]– [4]. They may operate at a very high switching frequency, which decreases the converter's size and weight and makes them ideal for applications such as electric car battery charging. However, to enhance the power factor in AC-DC applications, a front end boost power factor correction (PFC) stage is frequently required [3]. The current tendency is to employ a single power converter to manage both the power factor stage and the LLC stage, where the input inductor's operation in the discontinuous conduction mode helps shape the average input current without any closed loop control, thus enhancing pf.

To get around this problem and attain energy balance, The controller normally shifts when the DC bus voltage is reasonable. the converter's switching frequency and at low loads, the converter's switching frequency may be extremely high. High switching losses and control challenges result from these levels. A burst mode control approach is employed in [7]–[9], where the For a set period of time, the controller pauses the switching action. intervals depends on the voltage of the bus capacitor and the output DC When the switching frequency reaches its maximum, the voltage rises dramatically. a lot of it This results in voltage and current transients. The controller's usual operation and waveforms are affected. interrupted. In addition, the burst mode of operation introduces low frequency components in the voltage, necessitating the use of a low frequency filter.

Pulse-width-modulation (PWM) converters and resonant converters are the two types of DC-DC converters. Because most applications require a regulated voltage output, a feedback loop is included in the control system to keep the output voltage stable. Small-signal equivalent circuit models are essential for optimal design [1]-[2]. The input stage, resonant tank, and output stage are the three stages of the resonant LLC topology. Input signals, control signals, and output signals are all present in each stage. Each stage's relationship between three sections is thoroughly explored and modelled. A FPGA-based HIL simulation experiment is performed, as well as a standard PSIM simulation, to evaluate the FPGA-based model [3]. The size of the resonant components will eventually shrink as the switching frequency rises.

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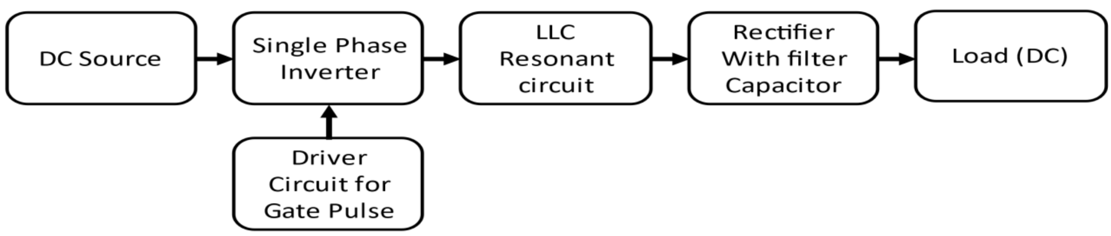
In LLC resonant converters, pulse frequency modulation (PFM) is extensively utilised. Adjusting the operating switching frequency modifies the impedances of the resonant tank elements, which eventually influences the voltage distribution within the resonant tank. Wide voltage range applications, on the other hand, necessitate a wide working switching frequency range, making the design and optimization of magnetic components and gate driver circuits more difficult. Furthermore, a lower magnetising inductance value is preferred for PFMLLC to fulfil the wide output voltage range, resulting in significant circulating current and conduction losses. Meanwhile, the electromagnetic interference (EMI) filter's performance has deteriorated, posing further design issues. Furthermore, because the specified switching frequency influences each output channel, the standard PFM LLC cannot accomplish independent control of each output channel in multiple-output applications.
The many aspects of the LLC resonant converter were discussed by many authors. The leakage inductance of the transformer can be used as a resonant inductor in an LLC resonant converter. This will generate a resonant tank when combined with the capacitor. The magnetic integration minimises the number of components and achieves flux ripple cancellation, which reduces core loss [5]. Most notably, the output voltage may be regulated throughout a wide range of line and load fluctuations [10].
Resonant frequency modulation (RFM), in addition to PWM, is another method for achieving both a constant duty cycle and switching frequency functioning. The PFM's main purpose is to alter the normalised switching frequency, which is the difference between the series resonant frequency and the switching frequency. The switching frequency is constant in RFM, but the series resonant frequency is controlled by changing the value of the resonant capacitor or resonant inductor. The RFM can be achieved in a variety of ways, including I switch-controlled capacitor (SCC) [11–16] and (ii) variable resonant inductor control (VRIC) [17–25]. The equivalent resonant capacitance is changed for SCC. There is a need for an extra switch, capacitor, and resonant current sensing and synchronisation circuit. The resonant inductor value in VRIC is changeable. Despite the fact that no new component is required, the controlled voltage gain range is limited, and there is additional control winding loss.

II. BLOCK DIAGRAM

The block diagram shown first supplies 300V of DC voltage to the inverter circuit. The inverter circuit is reduced inverter module with only two switches. This converts the DC power to the AC power. This is given to the LC resonant circuit or converter which converts 300V DC to 300V AC and steps down to the 48V AC. This is given to the rectifier circuit which converts AC to DC power and fed to the charging capacitor which is in parallel to the resistive load.



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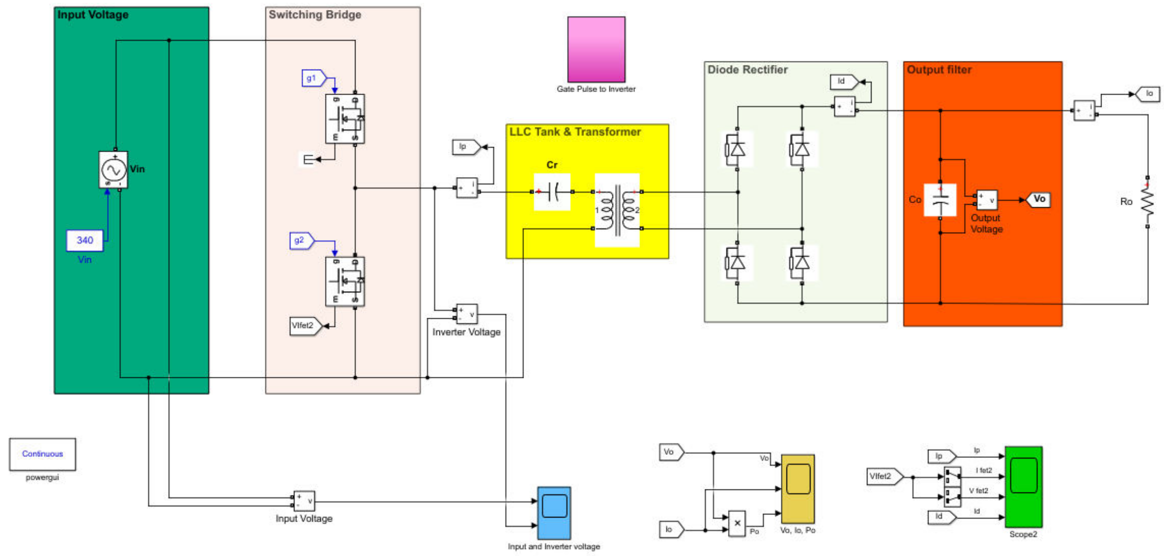
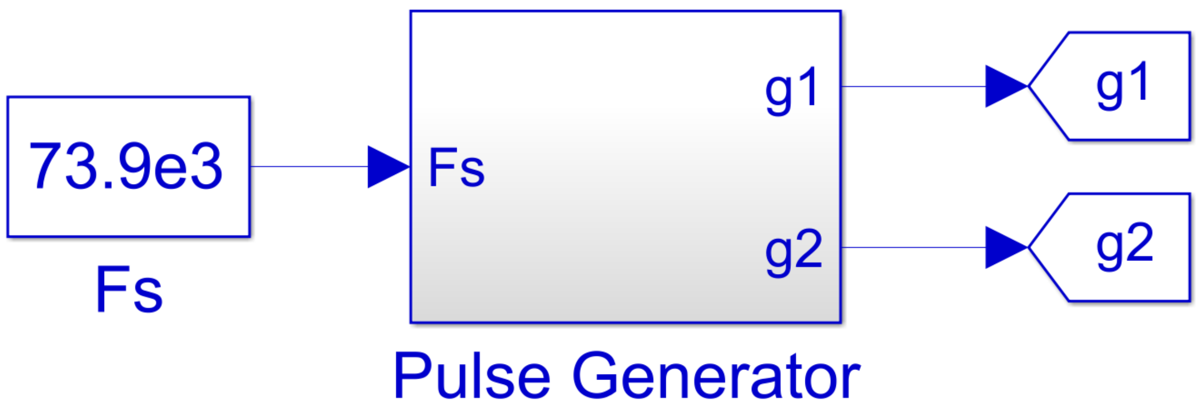
III. SIMULATION SYSTEM

The simulation system has been done in MATLAB/Simulink for the same. The figure is shown below using the single phase single stage DC to AC to DC converter with LC resonant converter.



The input to the circuit is of 300V given by DC source. This is given to the inverter which converts DC to AC power. The inverter uses only two switches for the conversion. This becomes a reduced circuit. The pulses are 180^{o} phase shifted. There two gate pulses given to it from the pulse generator of frequency 75 kHz as shown below.



This converted AC is passed through the LC resonant converter where voltage is reduced to 24V DC. This is passed through single phase rectifier consisting of four switches which converts AC to DC power. This is passed through a filter capacitor to remove all the noises produced in circuit. The load used is an resistive load of 3 ohm. The voltages and the current for the circuit are shown in scope.

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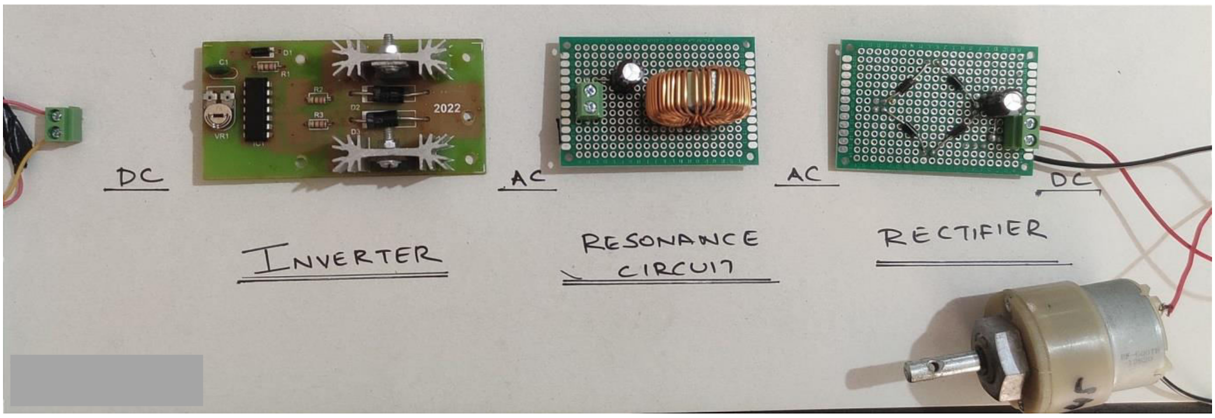
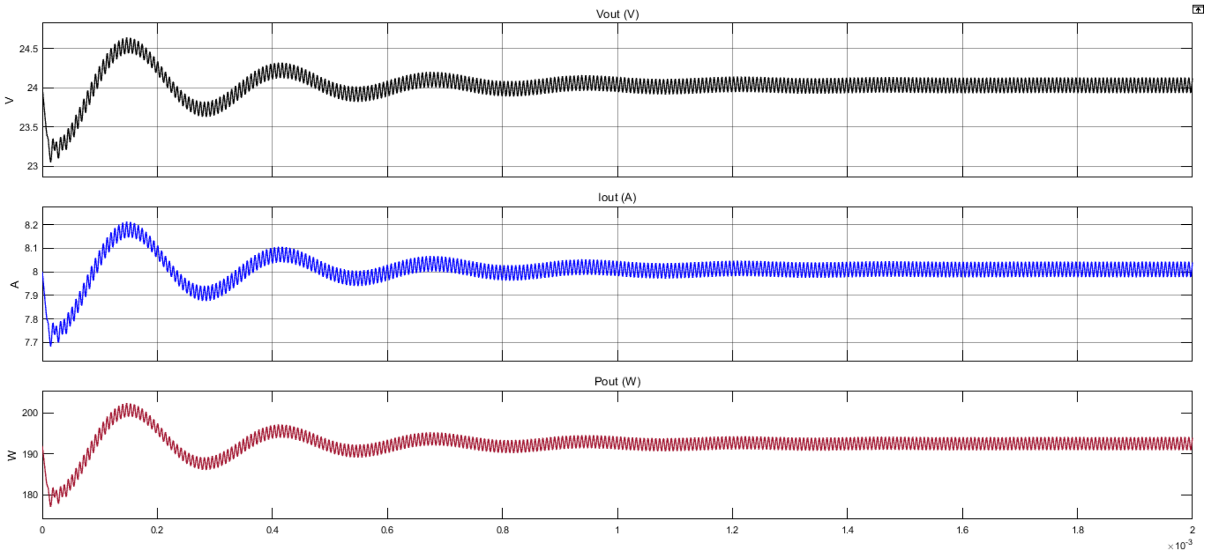


The above diagram is the hardware prototype for the circuit where the motor is used as an application for the system. The system uses Inverter, resonant converter and a rectifier where it changes DC-AC-DC.
Natural power factor adjustment, single-stage operation, and zero voltage switching are all advantages of the proposed architecture over standard topologies [5–9]. The following are some of the additional benefits of the suggested topology above traditional topologies. The topology that has been proposed6 switching devices (2 diodes and 4 IGBT) are used to generate a voltage two control parameters and a three-level voltage to the LLC stage (duty ratio and switching frequency). The commonplaceThe number of switching devices used in both topologies is the same (4).To generate two-level voltage for the LLC, two diodes and two IGBTs were used.a single control variable stage (switching frequency).Only four switching devices are used in the bridgeless topologies [6].However, they lack the following advantages:The proposed topology has two control variables, which is a significant advantage. By adjusting the duty ratio and switching frequency, the controller may regulate the DC bus voltage and the output DC voltage separately. To retain the voltage symmetry of the LLC stage in typical two-level single-stage converters, the duty ratio must be set to 50%. The decay slope of the inductor current must be larger than the rising slope to ensure discontinuous functioning.

IV. RESULTS

The results for the proposed system are shown below in the figure. The results include output voltage, current and the Power of the circuit.



The first graph represented is an Output voltage of 24V, output current of 8A and the total output power of 192W.
The below figure shows the input DC voltage and the inverter AC voltage after the conversion from DC to AC.

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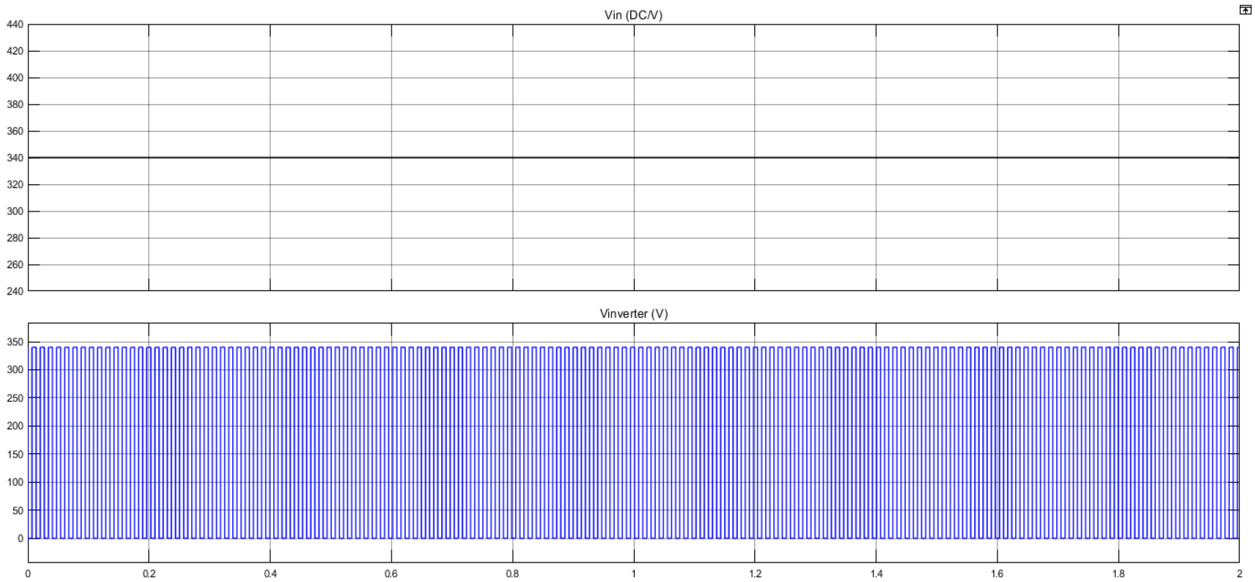

V. CONCLUSION

For AC/DC LLC resonant converters, this research proposes a three-level flying capacitor based structure. The converter's topology is bridgeless, reducing the number of conducting components. To manage the DC bus and output DC voltages, the controller employs a dual control method that varies duty ratio and frequency. Without any active current control measures, the converter is designed to run in discontinuous conduction mode to achieve a near unity power factor. Furthermore, the design decreases losses and provides low voltage stress, ZVS for all four switches.A 190W, 230V to 24V AC-DC converter prototype was created and implemented for testing.

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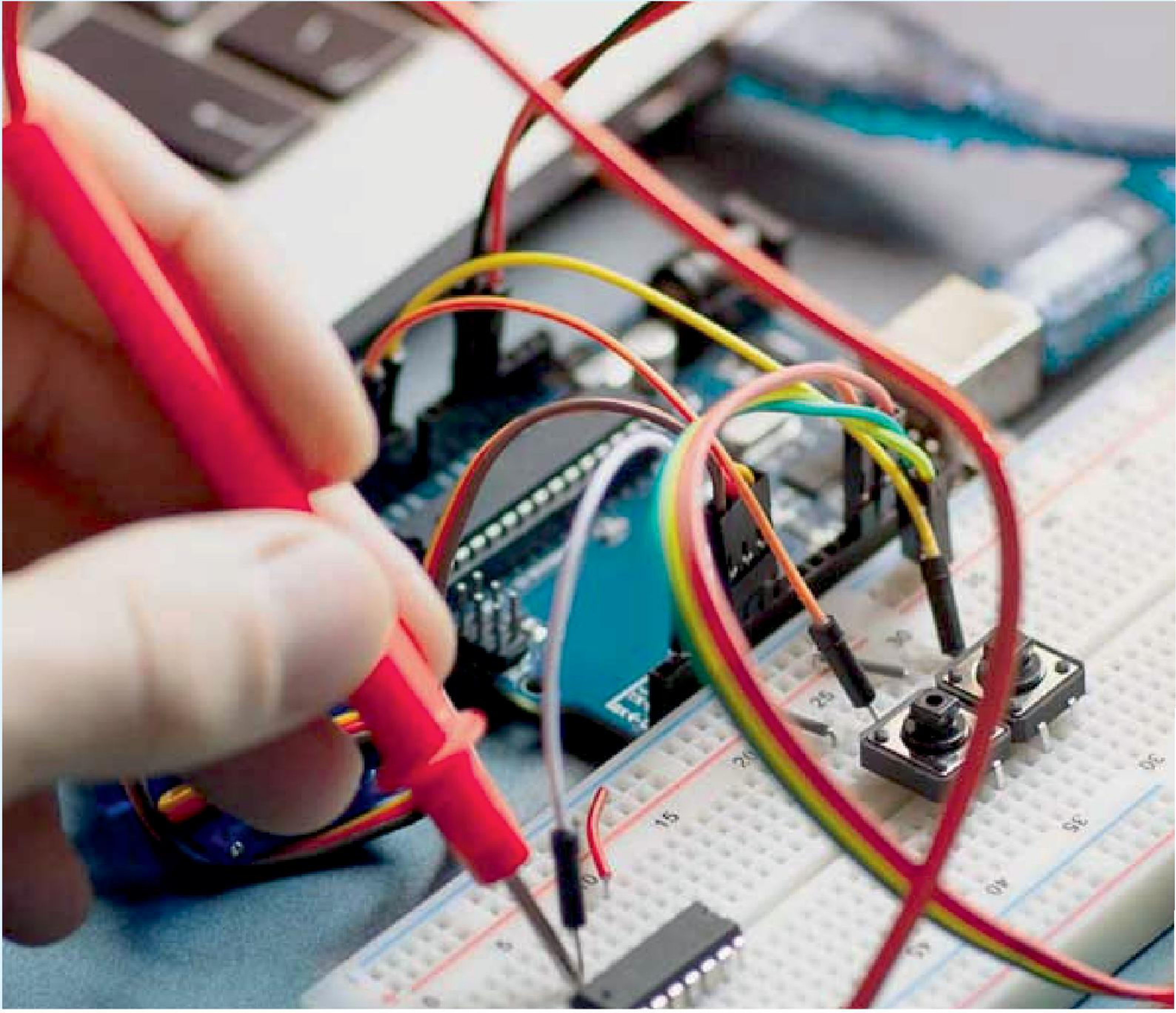

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