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Design of Average Current Mode Controlled Boost Converter

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ABSTRACT: The boost converter increases the output voltage when the input voltage is not sufficient to load. In simulation, solar panel act as input source and resistive load act as output. By using average current mode technique with boost converter constant voltage is obtained at resistive load. In hardware, Regulated Power Supply act as input source and DC bulb act as output which obtain sufficient voltage from boost converter. Constant current and constant voltage are obtained in simulation whereas increased voltage at output is obtained in hardware.

KEYWORDS: PV system, Average current mode controller, boost converter

I. INTRODUCTION

Average current mode control (ACMC) is a popular method for regulating boost converters due to its simplicity and robust performance. Unlike voltage mode control, which directly regulates the output voltage, ACMC regulates the average inductor current. This approach offers inherent benefits such as improved transient response, better stability over a wide range of operating conditions, and ease of implementation with fewer external components. Solar panels generate direct current (DC) electricity from sunlight, but the output varies based on factors like sunlight intensity and angle. To efficiently utilize this energy, a control mechanism like ACMC can be implemented to maintain a stable output current.

Block diagram

The proposed system's block diagram is shown in Fig. -1. Solar panel, converter, ACMC controller, PWM generator, and load make up this system.

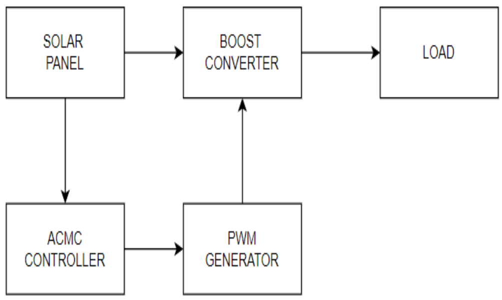

Fig .1 Block Diagram

Objectives of the work

Average current mode control uses both a voltage loop and a current loop to regulate the output. The voltage loop sets a reference for the current loop by comparing the output voltage to a reference voltage. The current loop senses and averages the inductor current, comparing it to the reference current from the voltage loop.

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This current error modulates the PWM duty cycle to maintain the desired output voltage, improving regulation and transient response. The average current mode- controlled boost converter maintains the desired output voltage by regulating the average inductor current.

Inductor, capacitor, diode, MOSFET, TL20 gate drive circuit and LED are used in hardware implementation of the proposed system. In a boost converter, the gate drive circuit controls the switching of a MOSFET transistor. It ensures that the MOSFET alternates between fully on and off states efficiently. The gate drive voltage must be sufficient to fully turn on the MOSFET to minimize switching losses.

II. DC -DC BOOST CONVERTER

In electronics, boost converters are used to increase the supply voltage by producing a DC output voltage that is higher than the DC input. Boost converters are frequently found in many different applications, such as power supplies for white LEDs and battery packs for electric cars.

One kind of DC-DC switching converter that effectively raises (steps up) the input voltage to a higher output voltage is called a boost converter. By storing energy in an inductor during the switch-on phase and releasing it to the load during the switch-off phase, this voltage conversion is made possible.

Topology

The circuit diagram of the boost converter shown in Fig -2 consists of supply voltage, semiconductor switch, diode, inductor, capacitor, and load.

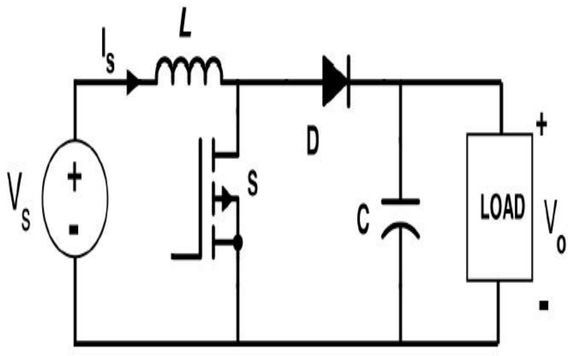

Fig.2 Boost Converter

A boost converter is a type of DC-DC converter that steps up the input voltage to a higher output voltage. It begins with a DC voltage source that provides a lower input voltage. An inductor is connected in series with the input voltage source and the switch, storing energy when the switch is closed. The switch, typically a transistor, alternates between open and closed states, controlled by a pulse-width modulation (PWM) signal. In order for the inductor to store energy in its magnetic field, current must flow through it while the switch is closed. A diode is placed in series with the output and prevents the backflow of current from the capacitor to the inductor when the switch is open.

Mode 1

The switch is closed, causing the inductor to store energy as the current through it increases linearly. The diode is reverse biased, preventing current from flowing to the output, and the input voltage is directly applied across the inductor.

Mode 2

The switch is open, causing the inductor to release its stored energy. The inductor voltage reverse, forward biasing the diode, and allowing current to flow to the output. The inductor current decreases, transferring energy to the output capacitor and load. To obtain the input–output voltage relationship, apply the volt-second balance rule to the inductor. This suggests that, in steady state circumstances, the area under the inductor voltage curve in a single period should equal zero.

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Design of boost converter

The output equation of the converter is given by

$$V_o=\frac{V_i}{1-D} \quad \text{(V)} \qquad \text{-> (1)}$$

where V_o is Output voltage,
V_i=Input voltage,
D=duty cycle
The duty cycle formula given by

$$D=\frac{1-V_i}{V_O} \qquad \text{->(2)}$$

The inductance and capacitance values are given by

$$\mathrm{L}=\frac{V_i D}{\Delta i_L f_s} \quad \text{(H)} \qquad \text{->(3)}$$

Where L is inductance
V_i=Input voltage
D=Duty cycle
ΔI_L=Peak-to-peak inductor current ripple
F_s=Switching frequency
Δi_L=10% of (I_{in}+I_0)

$$\mathrm{C}=\frac{I_o D}{\Delta V_0 f_s} \quad \text{(F)} \qquad \text{->(4)}$$

Where C is capacitance
I_o=Input current
D=Duty cycle
ΔV_O=Peak-to-peak output voltage ripple
F_s= Switching frequency
ΔV_0=2% of V_0

III. SIMULATION OF AVERAGE CURRENT MODE CONTROLLER

Simulating an average current mode controller involves several crucial steps. First, define system parameters such as input voltage, output voltage, inductor, capacitor, switching frequency, and load resistance. Create a power stage model for the DC-DC converter, incorporating MOSFETs, diodes, inductors, and capacitors. Implement current sensing to accurately measure inductor current, and design an error amplifier to compare this current with a reference develop a compensation network, typically a PID- controller, to ensure system stability. Construct a PWM generator using a comparator and sawtooth waveform to control the switching element.

The proposed boost converter is simulated using MATLAB/SIMULINK tool. Conduct transient analysis to observe system response to input or load changes, and steady-state analysis to verify performance under stable conditions. Perform frequency response analysis to evaluate the system's behaviour to perturbations. Optimize compensator parameters for desired performance. Integrate advanced features like soft start and over-current protection. Run the simulation, gather data on key metrics, and analyze results for stability and accuracy. Finally, iterate the design based on the analysis to enhance overall system performance.

The goal is to simulate a boost converter with an average current mode controller that takes an input voltage of 12V and boosts it to an output voltage of 23.68V. This setup is common in applications requiring efficient voltage step-up and precise control.

The main components of the boost converter include an inductor, a switching device (MOSFET), a diode, an output capacitor, and a load. These components work together to increase the input voltage to the desired output level. When the switch is on, the inductor accumulates energy, and when it is off, it releases it. Its value is critical for determining the ripple current and ensuring efficient energy transfer. For simulation, an appropriate inductor value is selected based on desired performance criteria. Simulink model is shown in fig 3.

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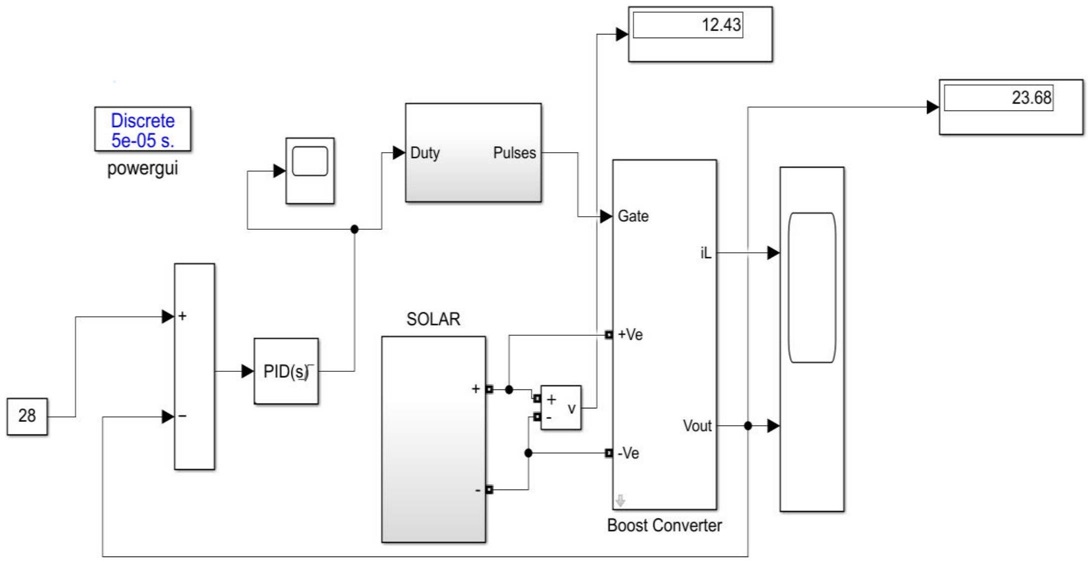

Fig.3 Simulink Model

Simulation results and observations

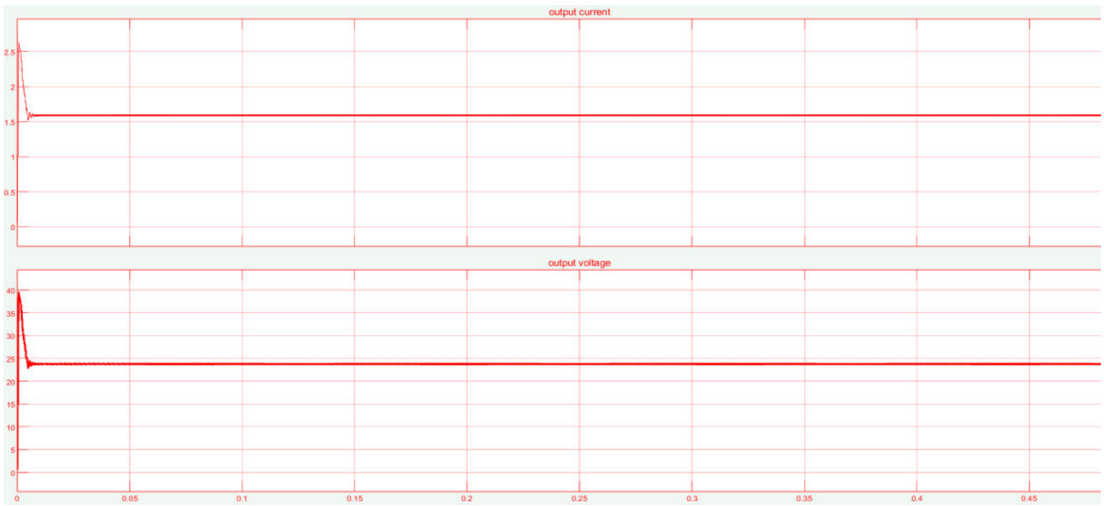

Fig.4 Simulation Output Waveform

The boost converter takes an input voltage of 12V and steps it up to an output voltage of 23.68V. Key components include an inductor, MOSFET, diode, output capacitor, and load. The inductor stores energy during the MOSFET's on-time and releases it during off-time, enabling voltage boost. The MOSFET's duty cycle, controlled by PWM, is crucial for regulating output voltage. Accurate current sensing is achieved using a sense resistor, feeding into an error amplifier that compares sensed current with a reference value. This generates an error signal for PWM adjustment.

The PWM controller adjusts the duty cycle based on the error signal, while the compensation network ensures stable control loop response, preventing oscillations and maintaining performance using tools like MATLAB/Simulink, the simulation models the boost converter and Average current mode-controlled algorithm. Parameters such as switching frequency and component values are defined to match desired performance. Fig 4 shows simulation output waveform.

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Observation

Successfully steps up the input voltage from 12V to a stable output of 23.68V, demonstrating the effectiveness of average current mode control in maintaining the desired voltage. The steady-state performance shows a low output voltage ripple, indicating that average current mode controller provides a smooth and stable DC output, which is crucial for sensitive electronic applications.

The simulation reveals that the converter responds quickly to changes in load and input voltage, with minimal overshoot or undershoot. This quick transient response is a significant advantage of average current mode controller. The current sensing mechanism accurately measures the inductor current, and the error amplifier effectively maintains the average current at the desired level. This precise regulation ensures consistent performance. The PWM controller adjusts the duty cycle accurately based on the error signal, which is crucial for regulating the energy transfer from the input to the output, ensuring stable voltage boosting. The simulation identifies areas of power loss and helps optimize component selection and control strategies to maximize efficiency. High efficiency is observed, which is beneficial for energy-saving applications.

IV. HARDWARE OF BOOST CONVERTER

A boost converter, or step-up converter, is a DC power converter that elevates the input voltage to a higher output voltage, making it essential in applications such as power supplies for electronic devices, renewable energy systems, and automotive electronics. The primary components include an inductor, switching device (typically a MOSFET), diode, output capacitor, and load. The inductor stores energy when the switch is on and releases it when the switch is off, while the switching device, controlled by a PWM signal, regulates the energy transfer to achieve the desired output voltage. The diode ensures unidirectional current flow, preventing backflow, and the output capacitor smooths the pulsating DC from the inductor, providing a stable output. Accurate current sensing, often achieved using a sense resistor or current transformer, is vital for effective control and protection. The control circuitry, comprising a PWM controller and error amplifier, adjusts the duty cycle of the switching device based on feedback from the output voltage and current. Additionally, protection circuits such as overcurrent and overvoltage protection safeguard the converter from damage, while thermal management components like heat sinks dissipate excess heat to ensure reliable operation. Proper PCB layout, with careful attention to component placement, grounding, and trace routing, minimizes noise and enhances efficiency. Finally, thorough testing and validation under various conditions confirm that the boost converter meets design specifications and performs reliably in real-world applications. Fig 5 shows hardware implementation of boost converter. Fig 6 shows output waveform in hardware implementation.

Implementation of boost converter

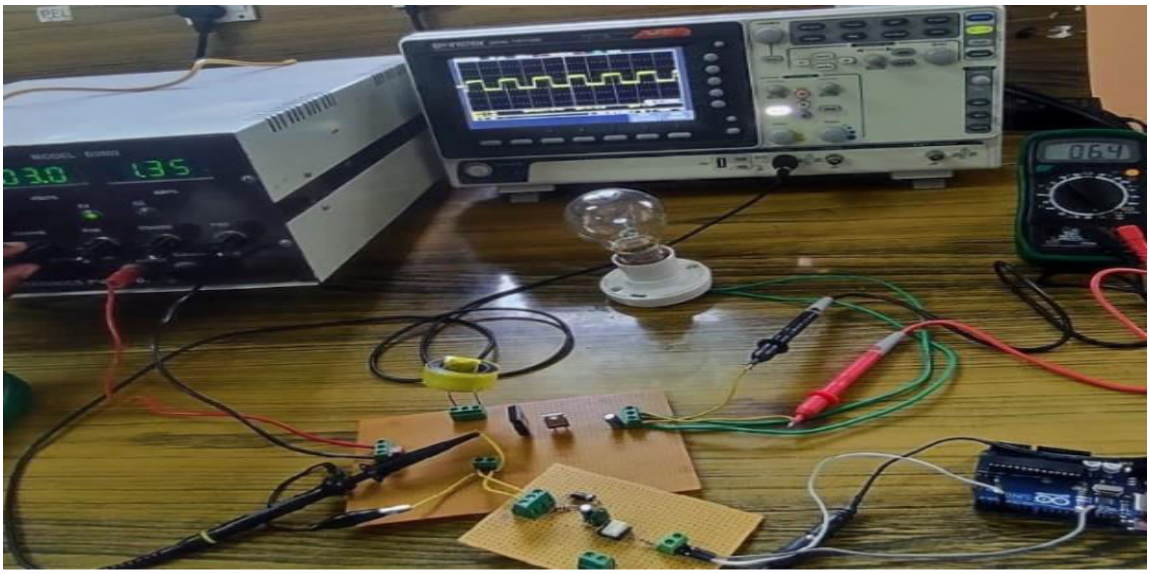

Fig .5 Boost Converter

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Output waveform

Fig .6 Output Waveform

V. CONCULSION

RPS is used as input supply in hardware implementation and boosted voltage is obtained at DC bulb (load) by using boost converter. Average current mode controller with boost converter gives constant current and voltage at load is simulated by using MATLAB/SIMULINK 2021 software. In simulation, 23.68V is obtained at output. Constant current and constant voltage are obtained in simulation whereas increased voltage at output is obtained in hardware. The proposed design is suitable for practical application LED drivers, battery chargers, electric vehicles and Uninterruptible Power Supplies (UPS).

REFERENCES

[1] Agrawal N, Samanta S, Ghosh S, ‘Modified LQR Technique for Fuel –Cell-Integrated Boost Converter’, IEEE transactions on industrial electronics 2020.
[2] Chen HC, Lu C, Lien WH, Chen TH, ‘Active Capacitor Voltage Balancing Control for Three –Level Flying Capacitor Boost- Converter Based on Average –Behavior Circuit Model’. IEEE Trans Ind Appl 2019.
[3] J.P.M Figueiredo, F.L. Tofoli and Silva A. Bruno Leonardo Silva, ‘A Review of Single-Phase PFC Topologies Based on The Boost Converter’, IEEE/IAS International Conference on Industry Applications - INDUSCON 2010 .
[4] Kim SK, Ahn CK, ‘Nonlinear Tracking Controller for DC/DC Boost Converter Voltage Control Application via Energy –Shaping and Invariant Dynamic Surface Approach’, IEEE Trans Circuits System Express Briefs 2019.
[5] Martinez, P.N. Enjeti, ‘A high-performance single-phase rectifier with input power factor correction’, IEEE Trans. PE 11, Vol. 2, 1996.
[6] Thomas Tatietse Tamo, ‘Photovoltaic Systems Based on Average Current Mode: Dynamical Analysis and Chaos Suppression by Using a Non-Adaptive Feedback Outer Loop Controller’, MDPI ,2023.
[7] Y. Qiu, H. Liu, and X. Chen, ‘Digital average current-mode control of PWM dc–dc converters without current sensors’, IEEE transactions on industrial electronics, vol. 57, no. 5, may 2010.
[8] Habib, Aftab Alam, Shahbaz Khan, Rooh ul Amin, and Syed M Ali, “Average current mode control boost converter for the tuning of total harmonic distortion and power factor correction using PSIM,” Journal of Electrical Engineering, Vol.15, pp. 287-293, March 2015.

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[9] C. K. Tse, “Circuit theory of power factor correction in switching converters,” Int. J. Circuit Theory Appl., vol. 31, no. 2, pp. 157–198, 2003.

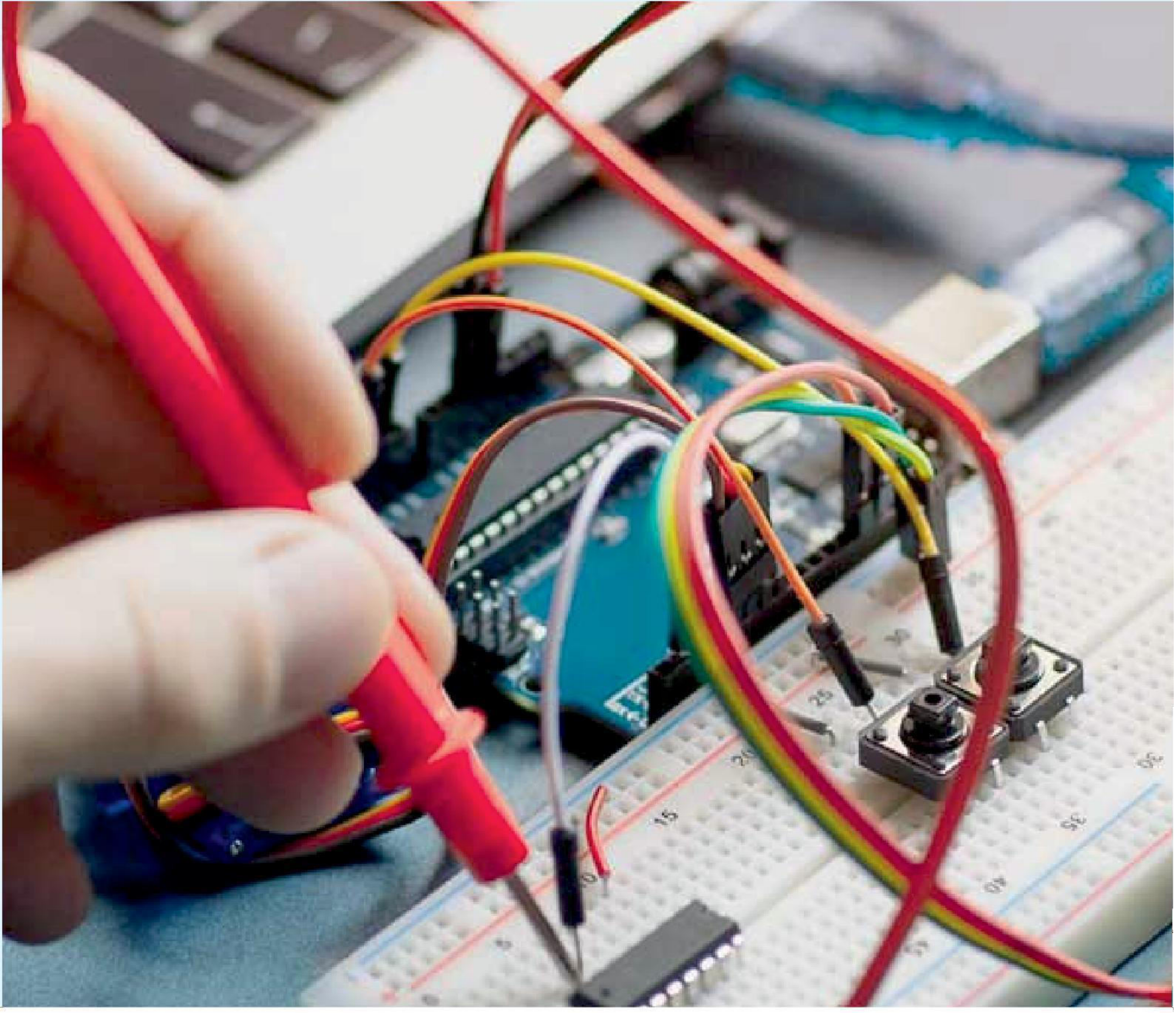
[10] G. Chu, C. K. Tse, and S. C. Wong, “Line-frequency instability of PFC power supplies,” IEEE Trans. Power Electron., vol. 24, no. 2, Feb. 2009 , pp. 469–482.

[11] M. Orabi and T. Ninomiya, “Nonlinear dynamics of power factor-correction converter,” IEEE Trans. Ind. Electron., vol. 50, no. 6, Dec. 2003. pp.1116–1125.

[12] C.Morel, P. Yang, Y. Liu and J. Deng, “Application of Slide Mode Control to a Current-Mode-Controlled Boost Converter,” IECON 28th Annual Conference of the Industrial Electronics Society, Vol no. 50407017, 2012, pp. 2199–2204.

[13] S. Kolluri, “Analysis, Modeming, Design and Implementation of Average current mode control for interleaved boost converter,” Power Electronics and Drive Systems (PEDS), IEEE 10th International Conference, no. 4, 2013, pp. 280 285.

[14] W. Method, W. Ma, M. Wang, S. Liu, S. Li and P. Yu, Stabilizing the Average current mode-controlled boost PFC Converter,” IEEE transactions on circuits and systems, vol. 58, no. 9, september 2011, pp. 595-599.



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