# Design and simulation of Arduino Nano controlled DC-DC converters for low and medium power applications

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**ABSTRACT**

This paper mainly focuses on the controller of portable direct current to direct current (DC-DC) converter which may be simple, low cost and efficient. Nowadays, proportional integral (PI) controller and opto-isolator based circuits are used for switching control. The switching control through the controller makes the DC-DC converter into larger circuit and less efficient. This problem will be rectified using the Arduino Nano controller which is small and low cost-effective controller. It is useful for low and medium power applications like residential solar power system, electronic gadgets, and academic laboratories. Arduino Nano-based DC chopper has been developed, and the Proteus software used for simulation. The different topologies of DC choppers like buck, boost, and buck-boost converter have been designed with mathematical calculations and simulated.



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## 1. INTRODUCTION

A direct current (DC) chopper is a section of power electronics which carries a constant DC voltage that delivers a variable DC voltage. The load voltage of a DC chopper could be higher or lower than the source voltage. The converters load voltages are being utilized to meet the power requirements sought by the loads. The regulation of voltage in conventional DC chopper circuit can be obtained between source and load [1]. Transistor or diode switches, inductors and capacitors are utilized in these circuits. Typical applications for these converters include linear voltage regulators and switched-mode voltage regulators [2]–[5]. In low power domestic appliances and computer accessories, power conversion takes place easily between alternating current (AC) source and batteries with the help of switched regulators. It ensures constant load voltage even in the variation of input voltage. Furthermore, the battery's voltage declines when its stored energy is depleted [6]. Performance of switched converters reduces the number of batteries and space by increasing the voltage.

Except high performance light-emitting diode (LED) loads, load voltage is normally varied in regulated DC converters [7]–[11]. Power optimizers are DC-to-DC converters intended to increase energy harvesting in solar and wind turbines [12]. Switching mechanisms are used in practical electronic converters [13]. The duty cycle variation gives the variation in load voltage. The circuit at which metal–oxide–semiconductor field-effect transistor (MOSFET) acts as chopper requires additional gate driver circuit to change duty cycle [14]–[16]. This method of voltage conversion can both raise and decrease voltage. Power dissipation occurs as a heat in linear voltage regulation, whereas switching conversion saves energy.

Improved efficiency of switched converters reduces the temperature of battery used in electronic gadgets. Power field-effect transistors (FETs) are more efficient than power bipolar transistors because they minimize switching losses during the operation of high frequencies and require less sophisticated driving circuitry [17]. Another significant advancement in DC-DC converters is the use of synchronous rectification with a power FET, which has a reduced 'on resistance' and so reduces switching losses. In general inductor L acts as storage device that stores or releases energy, often at frequencies ranging from 300 kHz to 10 MHz [18]. It is easier to control the quantity of electricity given to a load regulated by modifying the duty cycle of the charging voltage. Similarly current magnitude also can be controlled as the voltage controlled.

Nowadays, duty cycle variation of DC-DC converters is achieved through pulse-width modulation (PWM) control. Driver circuits are helping to vary the duty cycle [19]–[21]. These drives circuit are designed using simple circuit elements to generate pulses, but cost and design of the circuit is not so easy and affordable. PI controller and microcontroller have been introduced at later stage, but power consumption of those circuits is not convincing [22]. Arduino Uno controller rectifies all those disadvantages but some features, like flash memory and number of analog I/O, are not satisfied [23], [24].

Arduino Nano controller overcomes the said disadvantages and pulses are generated easily to control the switches used in DC-DC converter. Programming section is not so difficult. Design of the controller part looking easy and cost also not so high [25]–[27]. After the verification of the circuit using simulation software the controller could be used for applications of residential solar, academic laboratories and simple electronic gadgets.

## 2. BLOCK DIAGRAM

### 2.1. Existing system

The gating pulses required to turn on the semiconductor switches in the DC-DC converter can be generated in a variety of ways in existing systems Figure 1. A programmable intelligent computer (PIC) microcontroller can be used, but the pulses must be generated via an external interface [21]. Another method employs an op-amp based microcontroller, which is cumbersome to handle and thus ineffective.

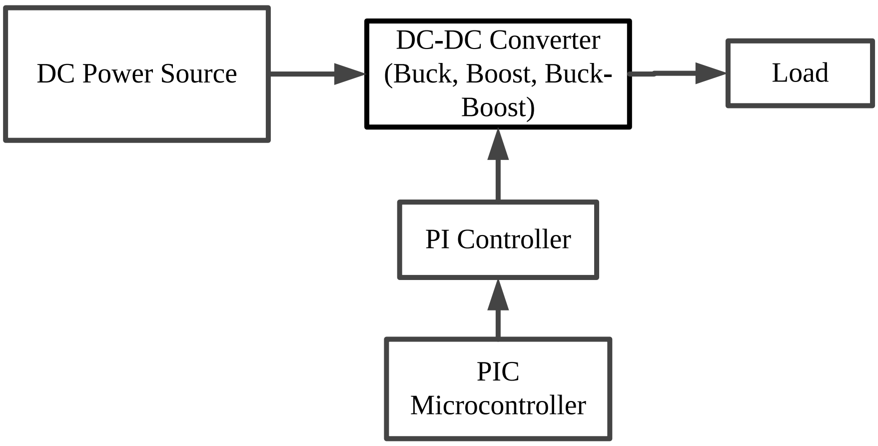



Figure 1. Block diagram of existing system

### 2.2. Proposed system

Arduino microcontroller is a single-board microcontroller with a simple open-source hardware board Figure 2. A standard programming language compiler and a boot loader are included in the software, which runs on the microcontroller. The programming is done in the C programming language. This package simplifies the process of producing PWM triggering signals. The output voltage can also be monitored using this Arduino board based on the development of an effective control mechanism. The Arduino Nano is used to generate the pulse needed to turn on the semiconductor switch in the DC-DC converter. We implement the next version of Arduino Uno i.e., Arduino Nano. It is an ATmega based small size bread board. It is simple, low-cost, and smaller in size than any other Arduino board.

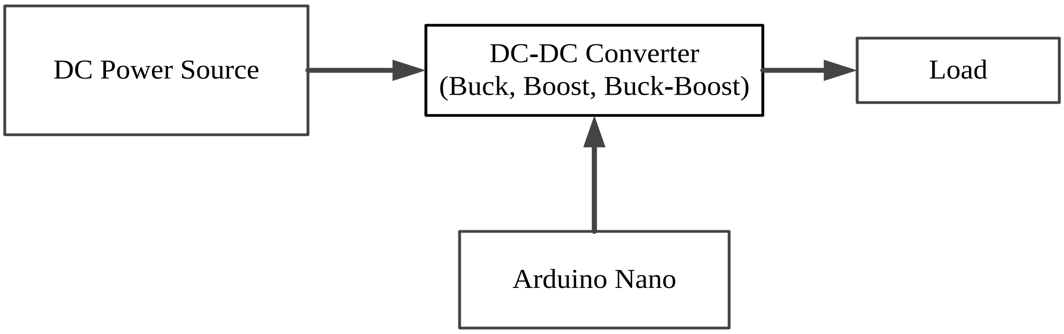



Figure 2. Block diagram of proposed system

## 3. CONTROLLER CIRCUIT

The control circuit consists of Arduino Nano, transistor, and resistor. This control circuit provides the necessary duty cycle for switching device to ON and OFF condition. The Arduino Nano as shown in Figure 3 is coded using Arduino integrated development environment (IDE) software to give the square wave signal to the switching device in frequency f=1 kHz and thereby providing the duty cycle d=0.6 by the Arduino. This control circuit provides the easy switching and efficient in low cost.

Program to be feed in Arduino, to provide signal for proper switching

```
void setup()
{
pinMode(5,OUTPUT);
}
void loop()
{
digitalWrite(5,HIGH);
delayMicroseconds(400);
digitalWrite(5,LOW);
delayMicroseconds(1000-400);
}
```

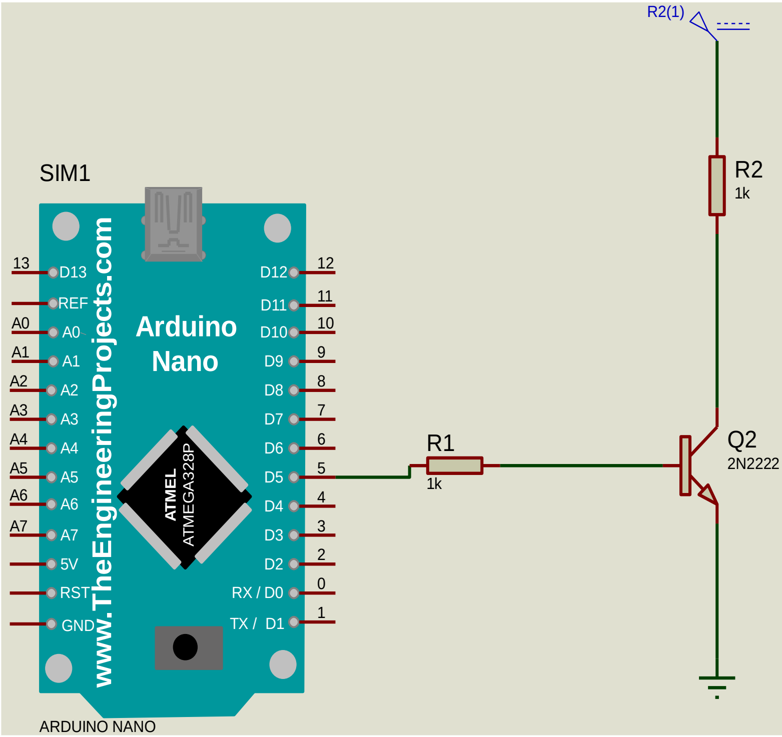



Figure 3. Control circuit using Arduino Nano

## 4. OPERATING PRINCIPLE WITH DESIGN CALCULATIONS

This section discusses the design calculations and operating principle of DC-DC converters. They are basic topologies used in our electronic appliances. Pulse variation decides the output voltage. There are three types of converters: buck converter, boost converter, and buck-boost converter.

### 4.1. Buck converter

The DC-to-DC buck converters must have a lower output DC voltage than the input DC voltage in these circuits. A step-down converter is another name for a buck converter Figure 4. Any DC source or rectified AC can be used for the DC input. The inductor in the input circuit resists the sudden variations in input current, which is how the buck converter works. The inductor stores magnetic energy during the ON state of the switch and discharges it when the switch is turned off. Buck converters have high efficiency; they're useful for tasks like changing a system's primary source voltage, which is typically 12 V, to the minimum voltage required by universal serial bus (USB), dynamic random-access memory (DRAM), and the central processing unit (CPU), nearly 5, 3.3, or 1.8 V.

$V_s$=15 V, $V_o$=7 V, R=50 Ω, f=1 kHz

$$K = \frac{V_O}{V_S} = \frac{7}{15} = 0.466 = 46.66\%$$

$$L_c = \frac{(1-K)R}{2f} = \frac{(1-0.466)50}{2(1*10^3)} = 13.35\ mH$$

$$Cc = \frac{(1-K)}{16Lf} = \frac{(1-0.466)}{16*13.35(10^{-3})*(1*10^3)} = 2.5\ \mu F$$

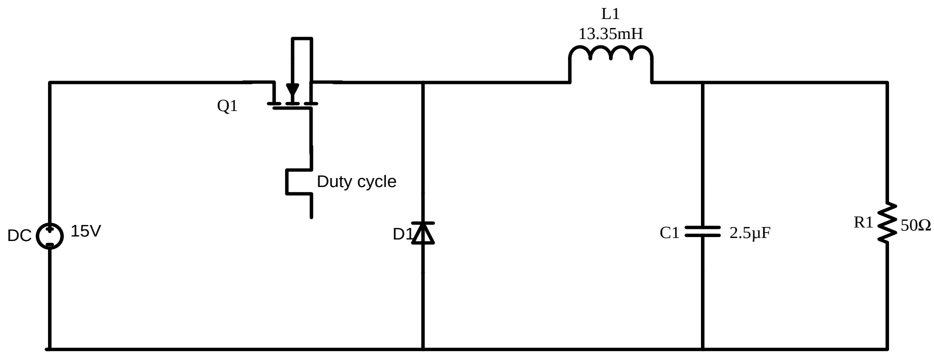



Figure 4. Circuit diagram of buck converter

### 4.2. Boost converter

It is a step-up converter gives the output voltage higher than the source voltage Figure 5. An inductor is connected in series with the DC source. MOSFET acts as a switch that is connected across the source. When switch is in off state, both the source and inductor voltage adding each other. So, the load voltage is becoming higher than the source. Inductor stores energy when switch Q closes and releases the energy when it opens. Variation of duty cycle achieved with the help of pulse width modulation (PWM) technique. As a result, the two sources will be connected in series, resulting in a larger voltage, which will cause the diode to charge the capacitor.

$V_s$=15 V, $V_o$=40 V, R=50 Ω, f=1 kHz

$$K = 1 - \frac{V_O}{V_S} = 1 - \frac{15}{40} = 0.625 = 62.5\%$$

$$L_c = \frac{(1-K)KR}{2f} = \frac{(1-0.625)0.625*50}{2(1*10^3)} = 5.85\ mH$$

$$Cc = \frac{K}{2fR} = \frac{0.625}{2*(1*10^3)*50} = 6.25\mu F$$

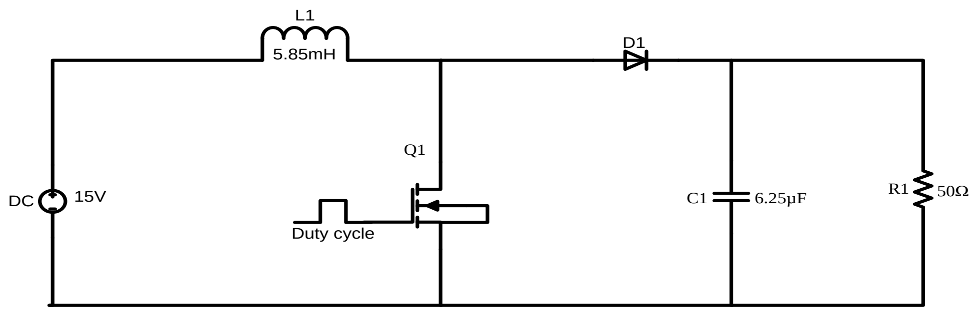



Figure 5. Circuit diagram of boost converter

### 4.3. Buck-boost converter

It is also called as inverting regulator. It gives similar work of a transformer in AC circuits. Both step up and step-down voltage can be obtained in this topology. Fly back converter requires transformer consisting of both primary and secondary windings. In buck boost converter switch $Q_1$ is connected in series and single inductor connected in parallel with DC source. Apart from switch Q1, diode acts as another switch Figure 6. When duty cycle is greater than 0.5, converter gives output voltage higher than source voltage and when lesser than 0.5, that gives voltage lesser than source voltage. Pulse width modulation (PWM) is used to turn on and off the controlled switch. The buck-boost converter operates on the concept that the inductor in the input circuit will counteract any unexpected fluctuations in the input current. During the ON state of the switch, energy from the input is stored in the form of magnetic energy in the inductor, and it is discharged during the OFF state of the switch. Because the output circuit's capacitance is expected to be large enough, the time constant of the resistor-capacitor (RC) circuit at the output stage is high. In the steady state, a constant output voltage across the load terminals is produced by comparing the switching period with a large time constant. The components of the circuits have been chosen as shown in Table 1.

$V_s$=15 V, $V_o$=-20 V, R=50 Ω, f=1 kHz

$$K = 1 - \frac{V_S}{V_O - V_S} = 1 - \frac{15}{(-20-15)} = 0.571 = 57.1\%$$

$$L_c = \frac{(1-K)KR}{2f} = \frac{(1-0.571)0.571}{2(1*10\text{^}3)} = 10.71\ mH$$

$$Cc = \frac{K}{2fR} = \frac{0.571}{2*(1*10\text{^}3)*50} = 5.71\ \mu F$$

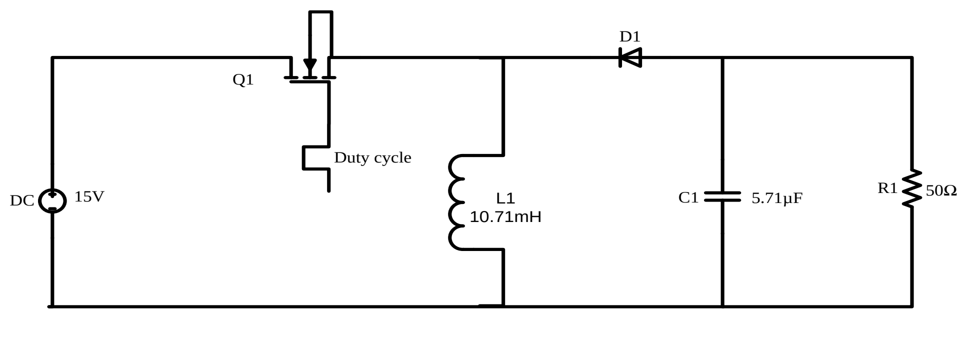



Figure 6. Circuit diagram of buck-boost converter

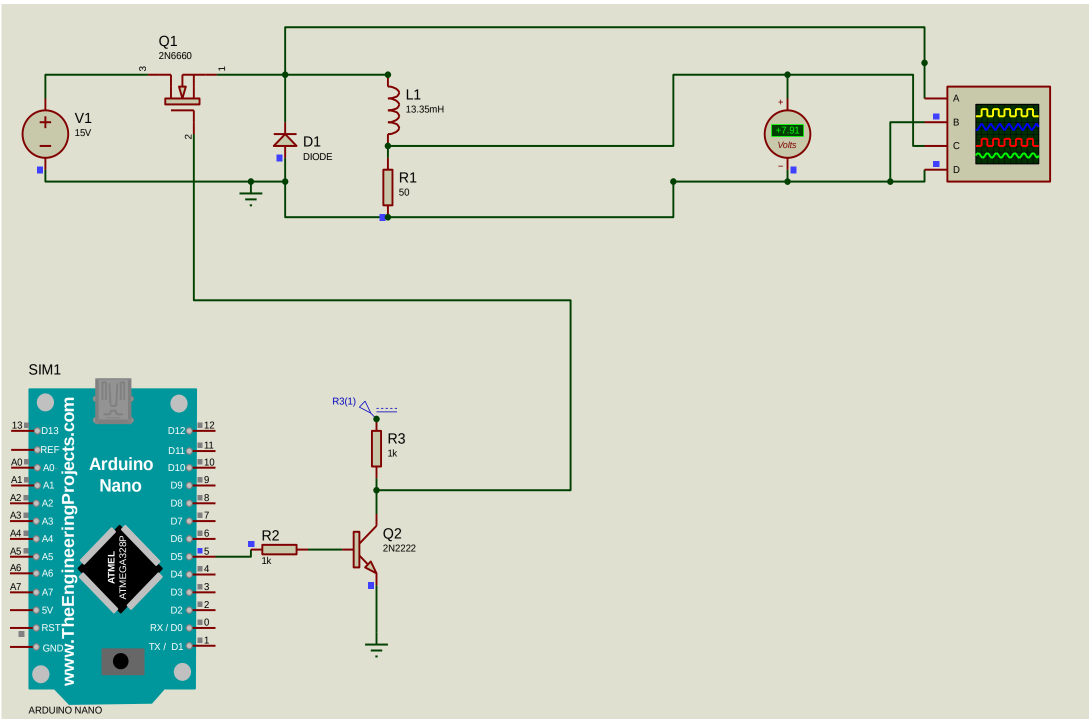
Table 1. Components of DC-DC converter

| S. No. | Components | Specifications |
|---|---|---|
| 1 | DC Source | 15 V |
| 2 | MOSFET | 2N6660 |
| 3 | Inductor | 300 mH |
| 4 | Capacitor | 20 uF |
| 5 | Diode | BYY56 |
| 6 | Resistor | 50 Ω |

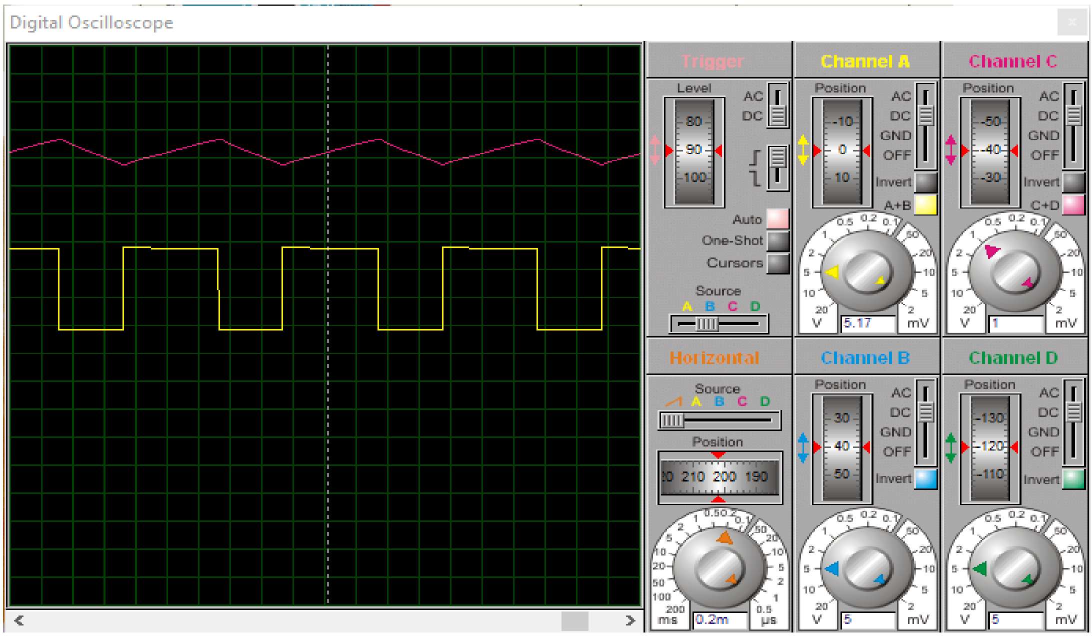
## 5. SIMULATION

### 5.1. Buck converter with controller

Simulation of proposed buck converter has been carried out in Proteus software using the practical values and the corresponding output voltage is displayed in the DC voltmeter. The waveform of the buck converter also displayed in the oscilloscope of the simulation diagram. Simulation circuit diagram shown in Figure 7 (a) and the result shown in Figure 7(b). Time (milli seconds) in X axis and output voltage (volts) in Y axis considered in output waveform shown in Figure 7(b).




(a)

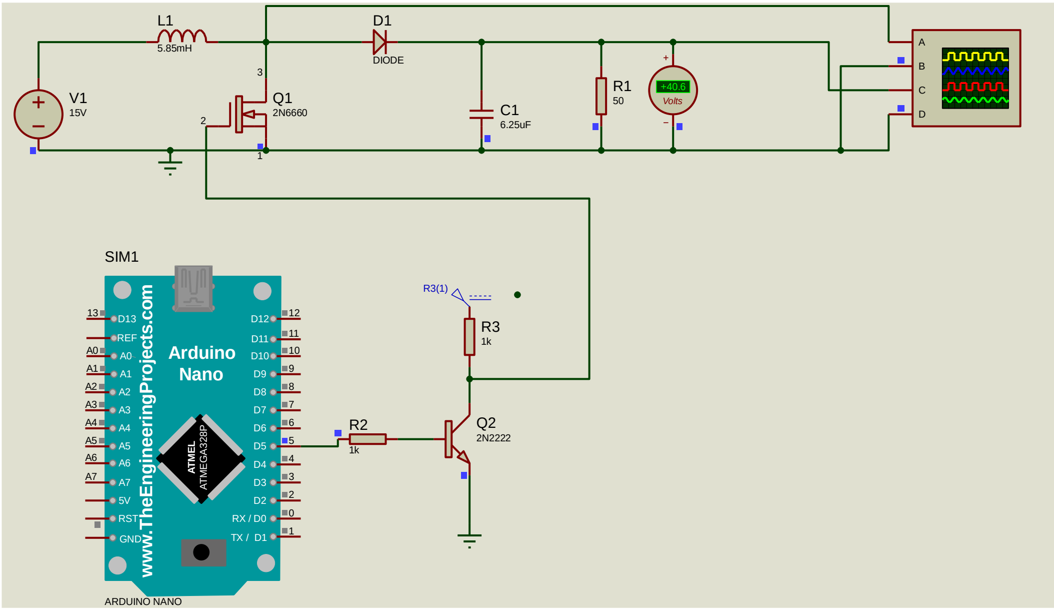



(b)

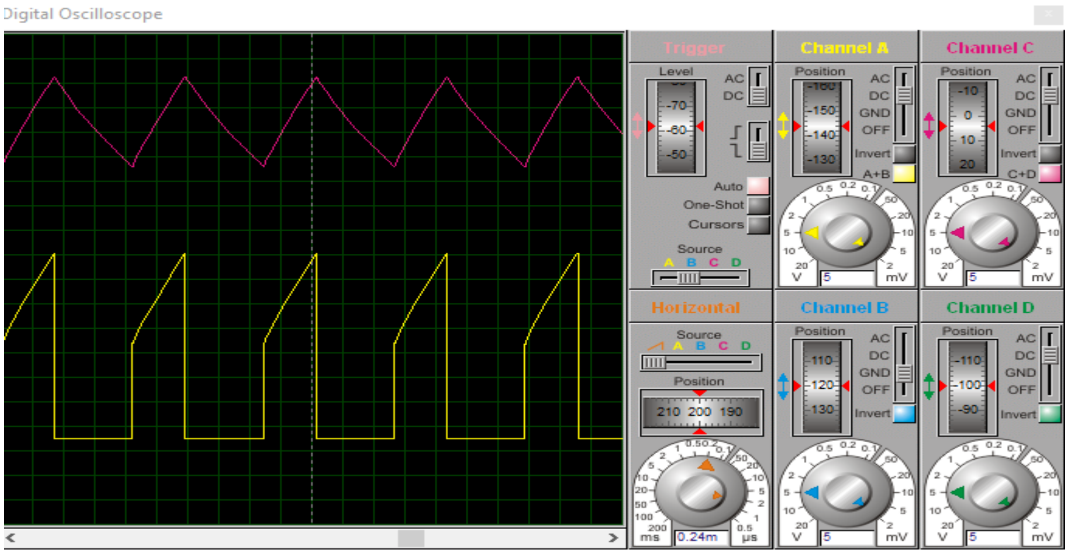
Figure 7. Simulation work for buck converter (a) simulation circuit diagram and (b) simulation result for output voltage

### 5.2. Boost converter with controller

The proposed boost converter has been simulated in the Proteus software using the corresponding values. The boosted output voltage is displayed in the DC voltmeter and the corresponding waveform of switch voltage and load voltage also displayed in the oscilloscope. Simulation circuit diagram shown in Figure 8(a) and the result shown in Figure 8(b). Time (milli seconds) in X axis and output voltage (volts) in Y axis considered in output waveform shown in Figure 8(b).




(a)



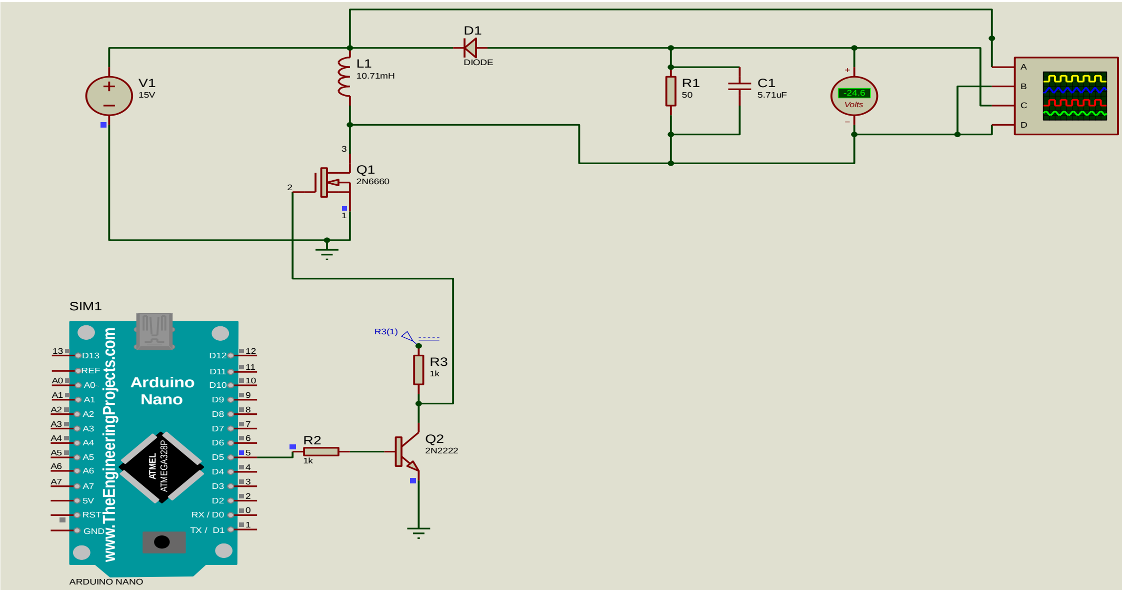

(b)

Figure 8. Simulation work for boost converter (a) simulation circuit diagram and (b) simulation result for output voltage

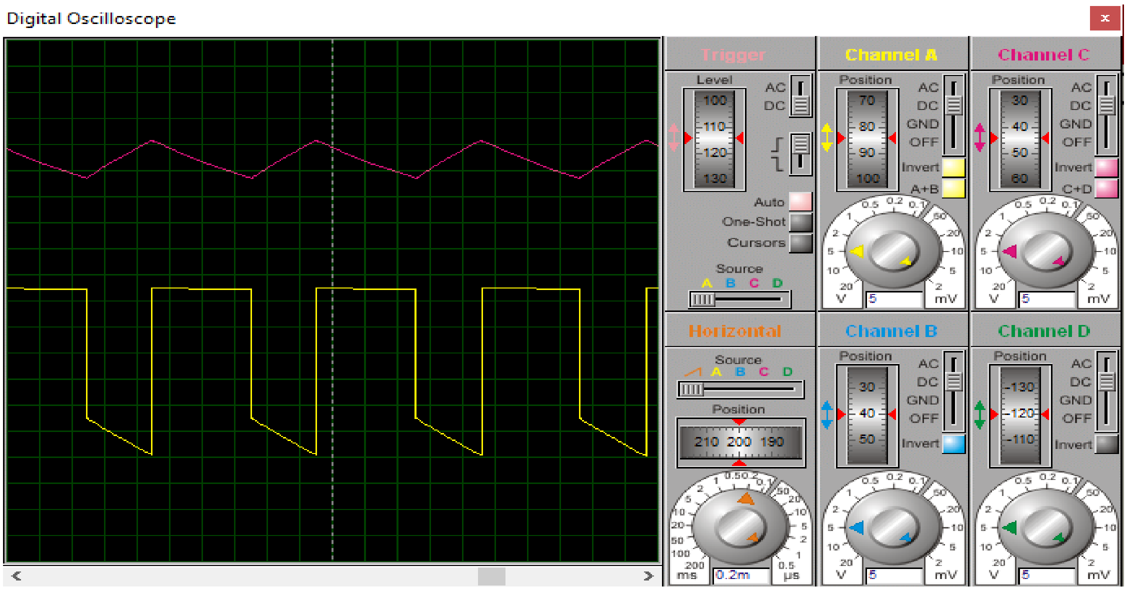
### 5.3. Buck-boost converter with controller

Simulation of proposed buck-boost converter has been carried out in Proteus software using the practical values. Output voltage is displayed in the DC voltmeter and waveform of inductor voltage and load voltage of converter also displayed in the oscilloscope. Simulation circuit diagram shown in Figure 9(a) and the result shown in Figure 9(b). Time (milli seconds) in X axis and output voltage (Volts) in Y axis considered in output waveform shown in Figure 9(b).

Thus, the different topologies of DC-DC converter have been simulated using Proteus software and the output voltage Table 2 for buck, boost, buck-boost converters are displayed using the dc voltmeter. The waveform for load voltage, load current, switch voltage, inductor voltage is obtained in the oscilloscope. For buck converter the voltage is step down and gives the output as lower voltage than the input voltage. In boost converter the input voltage is boosted, and the higher voltage has taken in output. In buck-boost converter the voltage is either step up or step down according to the load. Table 3 shows that the proposed controller consumes less memory and low cost. Figure 10 ensures the visual representation of controllers.




(a)




(b)

Figure 9. Simulation work for buck-boost converter (a) simulation circuit diagram and (b) simulation result for output voltage

Table 2. Input and output for different topologies of DC-DC converter

| Different Topologies | Input | Output |
|---|---|---|
| Buck Converter | 15 V | 7 V |
| Boost Converter | 15 V | 40 V |
| Buck-Boost converter | 15 V | 20 V |

Table 3. Comparison between existing and proposed controller for DC-DC converter

| Description | Existing Controller | Proposed controller |
|---|---|---|
| Type of controller | Arduino Uno, PIC & PI controller | Arduino Nano |
| Microcontroller | ATmega328 | ATmega168/328 |
| Flash Memory | 32 KB | 16 KB/32 KB |
| SRAM | 2 KB | 1 KB/2 KB |
| EEPROM | 1 KB | 512 bytes/1 KB |
| Analog I/O | 6 | 8 |
| Cost of controller | $20-$23 (uno) | Around 7$ |

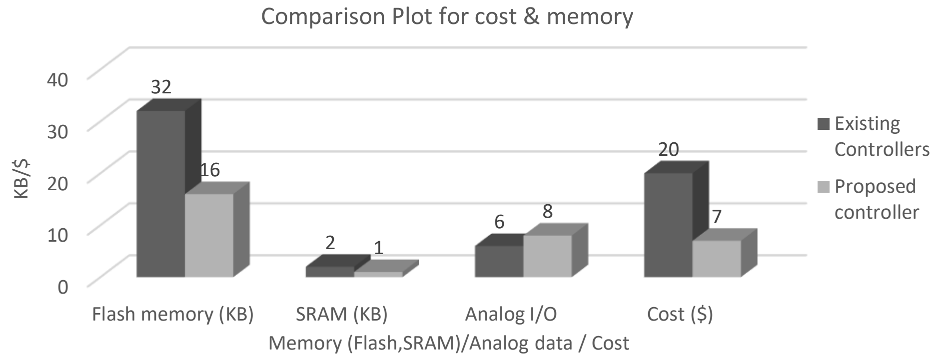



Figure 10. Cost and memory comparison

## 6. CONCLUSION

Arduino-nano controller for pulse generation in DC chopper circuit is a new idea implemented in this paper. Basics of DC-DC converters and its applications are explained in section 1. Block diagram of existing and proposed system described in section 2. Controller circuit and operating principles of DC-DC converters with design calculations have been illustrated in sections 3 and 4. Section 5 shows simulation diagram of converter with controller and its result using proteus software. The multi-topology of DC-DC converter has been designed and simulation of proposed design carried out. This proposed design can be used for recent trends of photovoltaics (PV) application and Electrical vehicle application. This system has Arduino Nano for switching control that provides easy control, occupies less space, and comparatively low cost. In future this proposed system can be employed for the multiport converter which comprise of all the three converters in one device for a better DC-DC conversion according to the load demand.

## REFERENCES


[1] C. Buccella, C. Cecati, and H. Latafat, "Digital control of power converters—A survey," *IEEE Transactions on Industrial Informatics*, vol. 8, no. 3, pp. 437–447, Aug. 2012, doi: 10.1109/TII.2012.2192280.

[2] T. Bouguettaya and N. Obeidi, "Controlling a chopper-powered DC motor with the Arduino board," (in French) El-Oued University, 2016.

[3] F. Legrand, "Computer science applied to physical sciences (in French)," https://www.f-legrand.fr/scidoc/ (accessed May 20, 2022).

[4] M. H. Rashid, *Power electronics handbook: devices, circuits and applications*, 2nd ed. Ne. Elsevier Academic, 2006.

[5] H. Gholizadeh, N. Totonchi, R. S. Shahrivar, S. Mahdizadeh, E. Afjei, and A. Abbasi, "Design and implementation of A transformerless high step-up DC-DC converter based on conventional boost converter and voltage multiplier cells," in *2021 12th Power Electronics, Drive Systems, and Technologies Conference (PEDSTC)*, Feb. 2021, pp. 1–5, doi: 10.1109/PEDSTC52094.2021.9405855.

[6] T. D. Sudhakar, M. M. Krishnan, K. N. Srinivas, and R. R. Prabu, "Design of a grid connected system using proteus software," in *2016 3rd International Conference on Electrical Energy Systems (ICEES)*, Mar. 2016, pp. 192–194, doi: 10.1109/ICEES.2016.7510639.

[7] F. M. Shahir and E. Babaei, "New transformer-less single switch structure for boost DC-DC converter with low input current ripple," in *2020 28th Iranian Conference on Electrical Engineering (ICEE)*, Aug. 2020, pp. 1–5, doi: 10.1109/ICEE50131.2020.9260968.

[8] S. N. Soheli, G. Sarowar, M. A. Hoque, and M. S. Hasan, "Design and analysis of a DC -DC buck boost converter to achieve high efficiency and low voltage gain by using buck boost topology into buck topology," in *2018 International Conference on Advancement in Electrical and Electronic Engineering (ICAEEE)*, Nov. 2018, pp. 1–4, doi: 10.1109/ICAEEE.2018.8643001.

[9] F. M. Shahir, M. Aberoumandazar, and E. Babaei, "High gain DC-DC boost converter applied in hybrid system of photovoltaic and battery," in *2021 International Symposium on Devices, Circuits and Systems (ISDCS)*, Mar. 2021, pp. 1–4, doi: 10.1109/ISDCS52006.2021.9397922.

[10] G. I. Vacheva and N. L. Hinov, "Current and voltage mode control of DC-DC converter in PSIM environment," in *2020 XXIX International Scientific Conference Electronics (ET)*, Sep. 2020, pp. 1–4, doi: 10.1109/ET50336.2020.9238335.

[11] A. F. Algamluoli, H. Mohammed Abdulhadi, and A. F. Algamluoli, "DC-DC X-converter comparison with buck boost converter with proposed controller," in *2020 2nd Global Power, Energy and Communication Conference (GPECOM)*, Oct. 2020, pp. 41–46, doi: 10.1109/GPECOM49333.2020.9248713.

[12] M. Y. Bote-Vazquez, E. S. Estevez-Encarnacion, J. Ramirez-Hernandez, L. Hernandez-Gonzalez, and O. U. Juarez-Sandoval, "Predictive current control design methodology for DC-DC basic topologies: Buck, boost and buck-boost converters," in *2021 IEEE International Autumn Meeting on Power, Electronics and Computing (ROPEC)*, Nov. 2021, pp. 1–6, doi: 10.1109/ROPEC53248.2021.9668051.

[13] A. Agarwal, K. Agarwal, and G. Misra, "Is internet becoming a major contributor for global warming – the online carbon footprint!!," *Journal of Information Technology and Digital World*, vol. 02, no. 04, pp. 217–220, Dec. 2020, doi: 10.36548/jitdw.2020.4.005.

[14] H. Wang, "Fault diagnosis in hybrid renewable energy sources with machine learning approach," *Journal of Trends in Computer Science and Smart Technology*, vol. 3, no. 3, pp. 222–237, Oct. 2021, doi: 10.36548/jtcsst.2021.3.005.

[15] V. B, "Ideal time-based voltage control using evolutionary algorithm in distributed generator centered networks," *Journal of Electronics and Informatics*, vol. 2, no. 4, pp. 233–238, Feb. 2021, doi: 10.36548/jei.2020.4.006.

[16] N. Gothwal, T. Manglani, and D. Kumar, "Importance of off-grid power generation using renewable energy resources - A review," *International Journal of Computer Applications*, vol. 179, no. 28, pp. 38–41, Mar. 2018, doi: 10.5120/ijca2018916634.

[17] A. Lavanya, J. D. Navamani, and K. Vijayakumar, "Performance analysis of triple port DC-DC converter for energy harvesting systems," 2019, doi: 10.1063/1.5112197.

[18] R Saravanamoorthi, P Rathinavel, E Sandhya, and K M Manu, "Arduino based PWM voltage control of boost converter," *International Journal of Engineering and Technical Research*, vol. V6, no. 03, Mar. 2017, doi: 10.17577/IJERTV6IS030350.

[19] C. Pineda, J. Pereda, F. Rojas, C. Cerda, X. Zhang, and A. J. Watson, "Asymmetrical triangular current mode (ATCM) for bidirectional high step ratio modular multilevel Dc–Dc converter," *IEEE Transactions on Power Electronics*, vol. 35, no. 7, pp. 6906–6915, Jul. 2020, doi: 10.1109/TPEL.2019.2957951.

[20] B. N. Ch.V. Chakravarthi, P. Naveen, S. Pragaspathy, and V. S. N. N. Raju, "Performance of induction motor with hybrid multi level inverter for electric vehicles," in *2021 International Conference on Artificial Intelligence and Smart Systems (ICAIS)*, Mar. 2021, pp. 1474–1478, doi: 10.1109/ICAIS50930.2021.9395885.

[21] R. Bhukya, K. S. Kadali, A. Siva, Y. T. R. Palleswari, Pragaspathy, and S. Saravanan, "Experimental validation with FPGA controller to A switched-capacitor interleaved bidirectional DC-DC converter for A renewable energy storage systems," *Journal of Physics: Conference Series*, vol. 1916, 2021.

[22] R. Kannan, S. Karthikkumar, P. Suseendhar, S. Pragaspathy, B. N. C. V. Chakravarthi, and B. Swamy, "Hybrid renewable energy fed battery electric vehicle charging station," in *2021 Second International Conference on Electronics and Sustainable Communication Systems (ICESC)*, Aug. 2021, pp. 151–156, doi: 10.1109/ICESC51422.2021.9532995.

[23] C. G. Zogogianni, E. C. Tatakis, and M. S. Vekic, "Non-isolated reduced redundant power processing DC/DC converters: A systematic study of topologies with wide voltage ratio for high-power applications," *IEEE Transactions on Power Electronics*, vol. 34, no. 9, pp. 8491–8502, Sep. 2019, doi: 10.1109/TPEL.2018.2889294.

[24] R. Ramaprabha, B. L. Mathur, and M. Sharanya, "Solar array modeling and simulation of MPPT using neural network," in *2009 International Conference on Control, Automation, Communication and Energy Conservation*, 2009, pp. 1–5.

[25] S. Saravanan, M. Kalaiyarasi, K. Karunanithi, S. Karthi, S. Pragaspathy, and K. S. Kadali, "IoT based healthcare system for patient monitoring," in *IoT and Analytics for Sensor Networks*, 2022, pp. 445–453.

[26] T. Yuvaraj, K. Ravi, and K. R. Devabalaji, "DSTATCOM allocation in distribution networks considering load variations using bat algorithm," *Ain Shams Engineering Journal*, vol. 8, no. 3, pp. 391–403, Sep. 2017, doi: 10.1016/j.asej.2015.08.006.

[27] K. S. Sankaran, N. Vasudevan, K. R. Devabalaji, T. S. Babu, H. H. Alhelou, and T. Yuvaraj, "A recurrent reward based learning technique for secure neighbor selection in mobile AD-HOC networks," *IEEE Access*, vol. 9, pp. 21735–21745, 2021, doi: 10.1109/ACCESS.2021.3055422.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