

# Comparative Assessment of Multi modular DC-DC Boost converter's Calculated and Circuitry output

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**Abstract** - This paper represents comparison between multi modular DC-DC boost converter's calculated and circuitry output using MATLAB. For calculated output state-space method is used here. We used two modules here as an example, but it can also applied to more. Outputs of both are in represented in tabular mode to check the difference between calculated and circuitry output.

**Key Words:** Boost converter, DC-DC model, Multi modular, switched power supply, State – space modelling

## 1. INTRODUCTION

A DC-to-DC converter is an electronic circuit or electromechanical device that converts a source of direct current (DC) from one voltage level to another. It is a type of electric power converter. Power levels range from very low (small batteries) to very high (high-voltage power transmission). There are various types of DC-DC converters.

Before the development of power semiconductors and allied technologies, one way to convert the voltage of a DC supply to a higher voltage, for low-power applications, was to convert it to AC by using a vibrator, followed by a step-up transformer and rectifier. For higher power an electric motor was used to drive a generator of the desired voltage (sometimes combined into a single "dynamotor" unit, a motor and generator combined into one unit, with one winding driving the motor and the other generating the output voltage). These were relatively inefficient and expensive procedures used only when there was no alternative, as to power a car radio (which then used thermionic valves/tubes requiring much higher voltages than available from a 6 or 12 V car battery).<sup>[1]</sup> The introduction of power semiconductors and integrated circuits made it economically viable to use techniques as described below. For example, to convert the DC power supply to high-frequency AC, use a transformer — small, light, and cheap due to the high frequency — to change the voltage, and rectify back to DC. Although by 1976 transistor car radio receivers did not require high voltages, some amateur radio operators continued to use vibrator supplies and dynamotors for mobile transceivers requiring high voltages although transistorized power supplies were available.

While it was possible to derive a lower voltage from a higher with a linear electronic circuit or even a resistor, these methods dissipated the excess as heat; energy-efficient conversion only became possible with solid-state switch-mode circuits.

Here we have used dual module boost type DC-DC converter. Circuit simulation and mathematical model is done by using MATLAB. For mathematical model state space method is used and final output variation at different duty cycle is measured.

## 2. CIRCUITRY MODEL

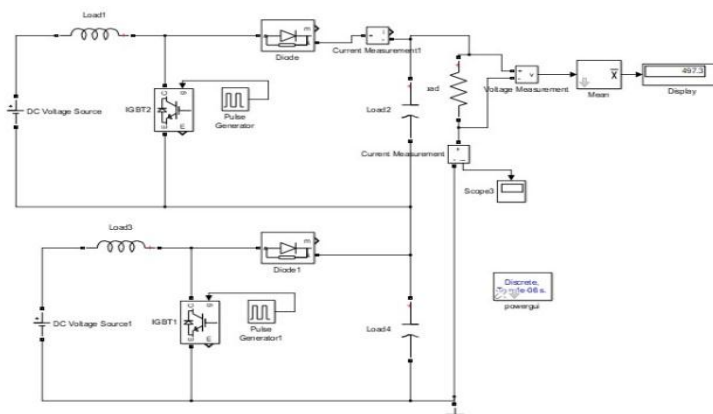


Fig -1: MATLAB model of dual boost converter

Two identical boost converters are connected in series to supply purely resistive load.

Values of elements,

Input voltage = 100 volts

Inductor = 300 micro-henry

Capacitor = 200 micro-farads

Load resistance = 10 ohm

In the pulse generator,

Amplitude = 1

Frequency = 10 kilo-hertz

And there is 20 micro-second delay between two pulse generators to prevent short-circuit.

Output of this circuit at 60% duty cycle is shown in graph.

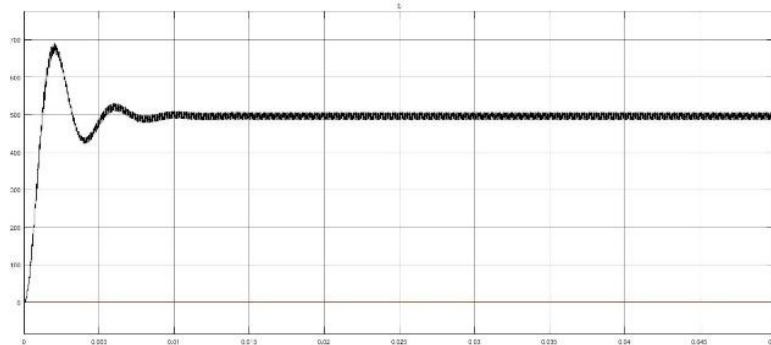


Fig -2: Output of dual boost converter

### 3. STATE – SPACE MODEL

In control engineering, a state-space representation is a mathematical model of a physical system as a set of input, output and state variables related by first-order differential equations or difference equations. State variables are variables whose values evolve through time in a way that depends on the values they have at any given time and also depends on the externally imposed values of input variables. Output variables' values depend on the values of the state variables.

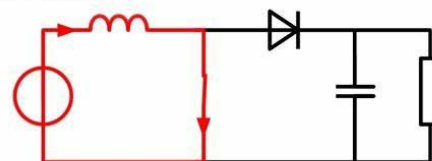
Standard representation of state space,

$$\dot{x} = Ax + Bu$$

$$y = Cx + Du$$

For boost converter on and off state are as shown.

On-State



Off-State

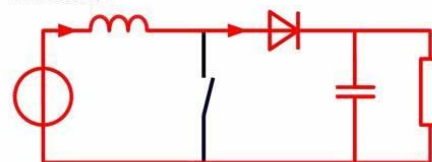


Fig -3: ON-OFF stages of boost converter

Here,

V = Input voltage

$V_c = V_o$  = Capacitor / Output voltage

$i_L$  = Inductor current

L = Inductance

C = Capacitance

R = Resistance

At ON stage inductor is charged through input voltage switch is in closed position. So no current flows through capacitor and load as shown in Fig.3. Circuit of ON state can be represented by equation 1 and equation 2.

$$V = L \frac{di_L}{dt} \quad - (1)$$

$$0 = C \frac{dV_C}{dt} + \frac{V_C}{R} \quad - (2)$$

Writing equation 1 and equation 2 in standard form. ON state equations are:

$$\dot{i}_L = 0 \times i_L + 0 \times V_C + \frac{V}{L} \quad - (3)$$

$$\dot{V}_C = 0 \times i_L - \frac{1}{RC} \times V_C + 0 \times V \quad - (4)$$

Writing equation 3 and equation 4 in matrix form:

$$\begin{bmatrix} \dot{i}_L \\ \dot{V}_C \end{bmatrix} = \begin{bmatrix} 0 & 0 \\ 0 & -\frac{1}{RC} \end{bmatrix} \begin{bmatrix} i_L \\ V_C \end{bmatrix} + \begin{bmatrix} \frac{1}{L} \\ 0 \end{bmatrix} [V] \quad - (5)$$

At the OFF state switch is in open condition and current flows through capacitor and load. Due to already charged inductor that flow is with greater potential.

$$V_C = V - L \frac{di_L}{dt} \quad - (6)$$

$$i_L = C \frac{dV_C}{dt} + \frac{V_C}{R} \quad - (7)$$

Writing equation 6 and equation 7 in standard form. OFF state equation are:

$$\dot{i}_L = 0 \times i_L - \frac{V_C}{L} + \frac{V}{L} \quad - (8)$$

$$\dot{V}_C = \frac{1}{C} \times i_L - \frac{1}{RC} \times V_C + 0 \times V \quad - (9)$$

Writing equation 8 and equation 9 in matrix form:

$$\begin{bmatrix} \dot{i}_L \\ \dot{V}_C \end{bmatrix} = \begin{bmatrix} 0 & -\frac{1}{L} \\ \frac{1}{C} & -\frac{1}{RC} \end{bmatrix} \begin{bmatrix} i_L \\ V_C \end{bmatrix} + \begin{bmatrix} \frac{1}{L} \\ 0 \end{bmatrix} [V] \quad - (10)$$

Signals have a noise which could directly affect the output and to assure that doesn't happen a technique called averaging is applied, this technique is applied in the time domain intended to increase the strength of signal relative to noise that is obscuring it. By averaging set of replicate measurements (here from the equations of time DT and (1-D)T) the signal-to-noise ratio (SNR) will be increased, ideally in proportion to the number of measurements.

Equatorial representation:

$$A_{AVG} = dA_{ON} + (1-d)A_{OFF} \quad - (11)$$

$$A_{AVG} = d \begin{bmatrix} 0 & 0 \\ 0 & -\frac{1}{RC} \end{bmatrix} + (1-d) \begin{bmatrix} 0 & -\frac{1}{L} \\ \frac{1}{C} & -\frac{1}{RC} \end{bmatrix} = \begin{bmatrix} 0 & -\frac{1-d}{L} \\ \frac{1-d}{C} & -\frac{1}{RC} \end{bmatrix} \quad - (12)$$

$$B_{AVG} = dB_{ON} + (1-d)B_{OFF} \quad - (13)$$

$$B_{AVG} = d \begin{bmatrix} \frac{1}{L} \\ 0 \end{bmatrix} + (1-d) \begin{bmatrix} \frac{1}{L} \\ 0 \end{bmatrix} = \begin{bmatrix} \frac{1}{L} \\ 0 \end{bmatrix} \quad - (14)$$

Substituting  $A_{AVG}$  and  $B_{AVG}$  to finalize the state space model of single boost converter:

$$\begin{bmatrix} \dot{i}_L \\ \dot{V}_C \end{bmatrix} = \begin{bmatrix} 0 & -\frac{1-d}{L} \\ \frac{1-d}{C} & -\frac{1}{RC} \end{bmatrix} \begin{bmatrix} i_L \\ V_C \end{bmatrix} + \begin{bmatrix} \frac{1}{L} \\ 0 \end{bmatrix} [V] \quad - (15)$$

Here in the case of identical boost converter in series we can write the equation 15 as follow:

$$\begin{bmatrix} \dot{i}_L \\ \dot{V}_C \end{bmatrix} = \begin{bmatrix} 0 & -\frac{1-d}{L} \\ \frac{1-d}{C} & -\frac{1}{RC} \end{bmatrix} \begin{bmatrix} i_L \\ V_C \end{bmatrix} + \begin{bmatrix} N \\ \frac{L}{0} \end{bmatrix} [V] \quad - (16)$$

Where,

N = No. Of identical boost converter modules.

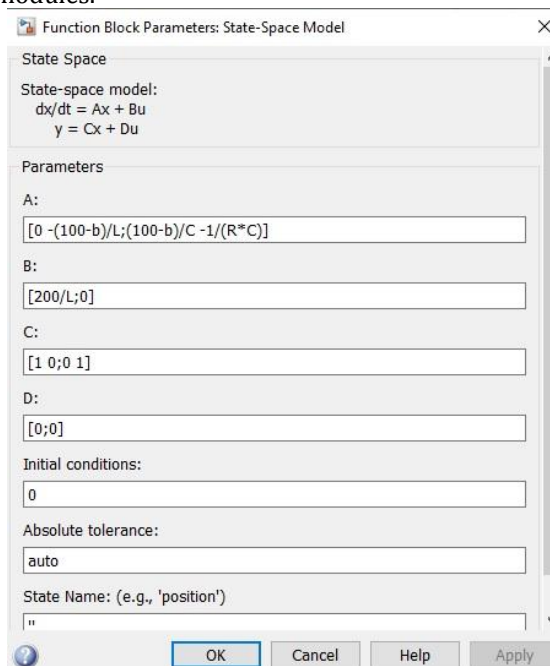


Fig -4: Values of State-space coefficients in MATLAB block

#### 4. COMPARATIVE ASSESSMENT BETWEEN CIRCUITRY AND CALCULATED MODEL OF DUAL BOOST CONVERTER CIRCUIT

Now for different duty cycles we compared outputs of circuitry and calculated model shown in tabular form below. Values of elements in both are:

Input voltage = 100 volts

Inductor = 300 micro-henry

Capacitor = 200 micro-farads

Load resistance = 10 ohm

In the pulse generator,

Amplitude = 1

Frequency = 10 kilo-hertz

$$\%V = \frac{V_{CAL} - V_{CIR}}{V_{CAL}} \times 100 \quad - (17)$$

**Table -1:** Comparison between circuitry and calculated output of dual module boost DC-DC converter

Duty (%)	Circuitry output( $V_{CIR}$ )	Calculated output( $V_{CAL}$ )	Variation(%V)
10	220.7	222.2	0.67
20	248.4	250	0.64
30	284	285.7	0.59
40	331.4	333.3	0.57
50	397.8	400	0.55
60	497.3	500	0.54
70	662.8	666.7	0.58
80	991.6	1000	0.84
90	1946	2000	2.7

## 5. CONCLUSION

As we can see from the data of Table.1 percentage variation between circuitry and calculated output is  $0.67 < \%V < 2.7$  for duty range 10%-90% of time period (here  $10 \times 10^{-6}$  seconds or 10 micro-seconds). For value above 90 that difference is very vast. So we can use this method to compare the output of the system and to define the operating point. Because of that obstruction of safety remain intact. Also we can use this to find the loss components except elements and measures to prevent that loss can be taken. Which leads to decrease in both operational and maintenance cost.

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