Boost converter theory pdf

Boost converter control theory. Buck boost converter theory pdf. Buck boost converter theory. Boost converter theory of operation. Boost converter theory pdf.

Key topics: Electric modeling systems, time-response analysis, system identification, modulation content width of the Arduino card (eg one, Mega 2560, etc.) Breadboard battery (for example) Electronic components (Inductor, resistor, condenser) Diodo transistor (MOSFET) Jumper cables The system that we will use in this activity is a type of DC / DC converter called a boost converter (step-up). The purpose of a boost converter is to take the voltage provided by a constant voltage source (for example a battery) and at the output a higher output voltage constant (approximately). We will implement a couple of very simple (not optimized) versions of a boost converter in order to illustrate its operating principle. The Arduino card will be used to measure the circuit output via one of the analogue inputs of the card and to check the output voltage level via one of the digital outputs of the card. The Arduino card will also communicate the registered data to Simulink for viewing and analysis. Purpose The purpose of this activity is to build the intuition concerning the operation of a boost converter circuit. The activity also demonstrates two techniques for modeling and analyzing a simple electrical system. The first approach modeling the circuit based on its basic physics and will compare the expected response time of the data circuit derived from a physical realization of the circuit. The second approach will model the circuit based on frequency response data exemptually and can be found in part (b) of the activity. Boost Principle Working converter The following is a simplified version of a Boost converter composed of a DC voltage source, a inductor, a switch, a diode, and a load. Here the load is simply a resistor, but it must not be. In practical applications the load would be a motor, or lighting system, etc. in the thrust circuit, when the switch is closed (see below) the current from the battery flows mainly through the closed switch as this path is very resistance Inferior to the parallel path included the load. In practice, the switch will be implemented using a transistor (MOSFET) and will be controlled by the Arduino card. In this state ON, the inductor in the circuit accumulates an energy reserve (enables the voltage to the loads of the load from "upgraded" to a higher level than the battery voltage). In this status of the indicated circuit, the negligible current is supplied to the load. In practice, however, a condenser is included in parallel with the load. This condenser provides the current load when the circuit is in this state state. When the switch is opened (see below), the diode is polarized directly and all the current flows from the battery to the load. Some of the energy that had been stored in the inductor are transferred to the load and the voltage through the load lapses. Because the circuit is turned on and off, the output voltage through the load clung up and down. The output, however, can approximate a constant voltage (DC) using a high switching frequency and adding the aforementioned condenser to "filter" ripple. Modeling from early principles at this point will examine the behavior of the thrust circuit described in the previous paragraph with more mathematical rigor. Specifically, we will use our understanding of the underlying physics of the Boost circuit to derive the structure of the system model. We will end this process "shaping by the first principles". In this example we use the variables shown below. In particular, we added to our model of a "resistance" more than The equivalent series resistance (ESR) contributions from the inductor. In this analysis we will treat the transistor as an ideal. That is, when the transistor is activated "ON", it will be treated as a short circuit (negligible resistance), and when the transistor is activated "OFF", it will be considered as an open circuit (infinite resistance). infinity). The diode is treated as ideal as in the direction of destination it is considered a negligible resistance and in the reverse direction it is considered an infinite resistance. (Rload) Resistance of the load resistance (REQ) equivalent resistance of the equivalent (ESR) series of the inductor (L) inductance of the input voltage of the inductor (EI) (from the battery) (EO) output voltage will start with the circuit In its on the state and assume that it is not initially the current in the circuit (). Therefore, all current flows through the switch and since the current scrolls from a higher potential to a lower potential, the direction of the current will be clockwise as shown below. Application of the tension law of Kirchhoff, the sum of the voltages around the closed cycle must be equal to zero. Therefore, the law of the cycle produces the following differential equation that shapes this thrust circuit in its state status. (1) In order to predict the response of the current time in this circuit, we will resolve the differential equation above using the transformation of the laplace. Taking the transformation of the sink above provides the following, it is assumed that it is a constant equal to. (2) Then resolve (assuming), we obtain the following. (3) We can recognize it as a standard first order phase response or can reorganize the expression by performing a partial expansion of the fraction. (4) Apply the reverse laplace transformation operation to the above, we get the response of the desired current time. (5) This answer can be identified as a first order step response with constant time and the DC gain equal to, which corresponds to the form found above. After some time, the switch will be opened and all the power will flow through the load as shown below. We can again apply the Kirchhoff voltage law to shape the Boost circuit in this State OFF to obtain the following. For now, we will closed that the switch is currently (even if it actually occurs at some time). (6) The above differential equation has the same form as the state on the state, but with total resistance. We can still resolve this differential equation that we use the transformation of the laplace, except now we cannot assume that the initial current is zero (). (7) Solving for. (8) The above exam shows that the first term is the response due to the "INPUT" input (battery voltage) and the second term is the response due to the initial condition. The first mandate is identical to the circuit in the state state, except for the total resistance it is different. By applying the transformation of reverse laplace, we arrive at the following. (9) Whereas the switch actually occurs at the moment, the shifted version above is the following. (10) If we assume that the time of the switch is sufficiently large for the current through the inductor to be overcome, then the current through the inductor will have the following behavior. By continuing to change the Boost circuit between its own and off states, the current through the inductor has the following behavior. In practice, the total period (over time beyond leisure time) will be constant and the level of the output voltage will be controlled by varying the switching work cycle (the percentage of the circuit time is turned on). When this circuit is in the OFF state, the current through the load is approximately equal to the current through the inductor. However, when this circuit is in the state state, almost no current flows through the load because its resistance is much larger than the resistance through the branch with the switch (the transistor). Therefore, applying Ohm's law We can determine that the output voltage through the load has the following time response. As mentioned above, in practice the Boost circuit will include a parallel condenser with the load to provide the load when the circuit is in the state state. We will consider the addition of such a short condenser. Time response experiment in this experiment we will demonstrate that a physical instance of a simple boost circuit will show expected expected behavior The analysis of the previous section. Specifically, we will use Arduino card to switch the circuit between its on and off states and read the output voltage to the load leaders. Hardware configuration Our simple thrust circuit can be implemented on a base and connected to the Arduino card to generate the switching signal and for the recording of the output voltage. A scheme of our circuit is shown below. The voltage source () for the circuit is a battery. We will use an alkaline AA battery, but other sizes are acceptable as well. The nominal voltage of a typical domestic alkaline battery is 1.5 volts. This voltage level allows us to "boost" the output without exceeding the 5 volt limit of one of the analogue inputs of the card. We will look for our resistor inductor and load so that the circuit response is slow enough that we can reconstruct the shape of the circuit output waveform shape with the Arduino board communication with the host computer running simulink. Referring to our theoretical note analysis, the time constant of the response of our increase circuit is the same in the ON state and in the OFF state. Therefore, in order to maintain the response of the "slow" circuit we want to use a great inductor while maintaining relatively small resistances. In this experiment we will use a 1 h inducer with an approximate equivalent series resistance of 40 which is relatively inexpensive for the purchase. The load resistance is chosen to be about 60. Because our circuit is low power with relatively slow switching, we don't need to be too particular about our choice of transistors or diodes. A possible choice of power mosfet is the IRF1520 whose technical sheet can be found here. The orientation of the gate, source and drain are pins identified in the following figure. For our diode, we will use the 1N4007 general finalità, whose technical sheet can be found here. The increase of the increase circuit and its connection to the Arduino card is shown below. The colored band on the diode indicates its cathode. The gate, source, and Mosfet drain pins can be deduced from its orientation in the figure given. Setting the software In this experiment, Simulink will be used to check the transistor switching, to read the voltage data output from the card, and to trace data in real time. In particular, we will use the MathWorks IO package. For details on how to use the IO package, refer to the following link. The Simulink model we will use it below and can be downloaded here, where it may be necessary to change the port to which the Arduino card is connected (the door is COM3 in this case). The Pulse Generator Switches Blocks between 0 and 1 and is connected to the digital Write block to switch the transistor between its off status and its ON state, respectively. Referring to the previous analysis with the components indicated above (H ,,), the time constant of our circuit is approximately seconds in its state on and seconds in its status OFF. How it takes about 4 time constants for a step-like response to reach 98 percent of its regime value, we set the pulse generator block to have a period of 0.2 seconds with a duty cycle of 50 percent. In other words, the circuit is ON for 0.1 seconds and off for 0.1 seconds. This time is sufficiently long for the interval exit between near its minimum and close to its maximum. As the gate of the MOSFET is activated by the digital output 9, the digital writing block must be set to the corresponding pin. In particular, double-clicking on the block allows us to set the button to 9 from the drop-down menu. There will also set the time of In order to grasp clearly the transient response of the circuit , we will choose our sampling time to be 0.01 seconds (2.5 times faster than the time constant OFF). This sampling period is about the limit of what the IO package can achieve running the Windows operating system . If you need to increase the sampling time of 0.02 0.02 You should still get reasonably clear results. The downloadable model included above defines all sampling times like TS (or left as "-1"). Therefore, before performing this model it is necessary to define the TS variable in the matlab work area by typing TS = 0.01; At the command line. Because the output voltage is read on the analogue input AO, the analog reading block must be set to that channel. This is obtained again by double-clicking on the block and set the PIN to 0 from the drop-down menu. This block is also set to have a TS sampling time. The gain block is included to convert data into a volt unit (multiplying data within 5/1023). This conversion can be understood by recognizing that the Arduino card uses a 10-bit analogue converter, which means (for the default value) that an analog input channel reads a voltage between 0 and 5 V and slices in pieces. Therefore, 0 corresponds to 0 V and 1023 corresponds to 5 V. The SIMULINK model has therefore sets the output voltage recorded on a scope and also writes the output data in the MATLAB work area for further analysis. The Arduino digital writing block, the Arduino analogue reading block, the installation block of Arduino me and the Pacer block in real time is part of the IO package. The remaining blocks are part of the standard Simulink library, in particular, can be found under mathematics, sources and libraries sinks. The execution of the model above for 2 seconds generates the figure shown below of the output voltage compared to the time. The character of the displayed response corresponds to what we have foreseen, the voltage through the load is exponented exponentially when the circuit is in the OFF status and the voltage (current) decreases for almost zero when the circuit is in the state state. Let's take a look at how the output voltage range is compared to our expectations. Using the Ohm law and our previous analysis, the maximum voltage through the load is expected to be volt (where Volt in this case). Considering that the output signal is sampled only once every 0.01 seconds, it is likely that the data recorded are missing the peak voltage (if occurs between samples). Furthermore, our analysis made several simplified hypotheses. Therefore, the data shown above correspond to our expectations reasonably well. Againing the Ohm law and our previous analysis, the minimum voltage through the load when the circuit is in an off status is expected to be volt. The actual data demonstrate a limiting output voltage more in the proximity of 0.54 volts, which is not exactly the same, not bad considering all the simplifications we have achieved in our analysis. Specifically, we treated the transistor, the diode and the input and output channels of the card as ideal, which obviously are not. The constant time of the circuit in the OFF state indicated by the data indicated above also seems to be quite similar to the forecast of 0.01 seconds (although a little bigger). Time response with the condenser as mentioned above, in order to maintain the output voltage from dropping up to zero when the Boost circuit is in the state state, a generally adds a parallel condenser with the load as shown in the following. When this circuit configuration is in the OFF state, the current that previously went to the load is divided between the load and the condenser. The current sent to the condenser accumulates loads on the condenser. When the circuit then switches to the status on the state and all the power from the battery flows through the branch with the transistor, the charge accumulated on the condenser comes To the load. Using the same Simulink model from above and a 22000 condenser in parallel with the load, the voltage generated through the load is shown below. A relatively large condenser is chosen so that the dynamics are quite slow from the fact that the condenser is not completely discharged when the circuit is in the state state. When the condenser is not completely discharged, it is said that the converter is in a continuous "continuous" Model. "The relatively large dimensions of the condenser means that it takes a bit for the circuit to reach the stationary state (for the condenser to load) as you can see in the following figure. We can analyze this boost circuit from the first principles to again better Understanding the dynamics of the circuit. First we would consider the circuit in its state out without current (). The fact that the initial conditions are zero means that we can analyze the circuit in the domain of the laplace, ie using complex impedances. considering each of the elements of the circuit in terms of their complex impedances, the circuit in the discount state can be considered as follows. Examining the above, we can combine the impedances of the inductor and its resistance to the equivalent series using the fact that the impedance of components in series ADD ,. We can also combine the impedances of the capacitor and the resistance of the load in the S mode Eguent from when these two components are in parallel. (11) With this reduction s, we can think of the boost converter in this state as something of a voltage divisor. Therefore, we are able to generate the following transfer function for the circuit in this state for an input of and an output of use of the fact that it is the voltage in both and that they are in series and is the tension through. (12) Execution of some algebra, we generate the following model of second order. (13) Considering the values of the various components in our Boost circuit, we can determine the poles of this transfer function using the following MATLAB commands. Rload = 60; Req = 40; L = 1; C = 22000 * 10 ^ -6; s = tf ('s'); P = rload / (l * rload * c * s ^ 2 + (req * rload * c + l) * s + req + rload) pole (p) p = 60 ------------ ------------ 1.32 s ^ 2 + 53.8 s + 100 continuous timeline transfer function. ANS = -38.8053 -1.9522 Based on the above, we can see that the circuit in this mode is oversized as it has two real poles. Moreover, since the polo is about 20 times smaller than the other pole, will dominate the character of the response and the circuit will behave approximately as a first order system with a constant time. Considering the input voltage from the battery as a step input when the battery is initially connected to the circuit, we can imagine which is the response of the output voltage. When the boost converter is turned on, the load accumulated on the condenser is released to the load and we can evaluate the response of the output voltage based on the next circuit. Note, in this state the energy from the battery still increases the energy stored in the inductor. By examining the circuit containing the condenser and the load, we can apply the Kirchhoff voltage law to shape the circuit as shown below. (14) We can solve this integrate-differential equation by applying the transformation of the laplace to reach the expression shown below. Note that the integral has an initial value because the condenser is initially loaded. For comfort, we will take over the state on the state. (15) Using the fact that the value of the integer at the time of the switch is negative of the initial charge on the condenser (current is the date derived time), we can solve as follows. (16) Remembering the definition of the ability, we have it. Therefore, we have the following. (17) Application of the Ohm () law and reverse laplazia transformation, so we have the response of the time of the exit voltage time when the switch is turned on. (18) In other words, when the switch is activated on the output voltage exponentially fades from its initial value with the constant time, which is 1.32 seconds in this case (slower, but similar to constant in the off state). This analysis of the response of the boost converter with the condenser in the ON and OFF states is consistent with the data recorded and depicted at the beginning of this section. In practice, you want the Boost converter's response to be faster and more fluid than the sample circuit we presented here. This is Mainly choosing several circuit components (for example a smaller capacitor) and using a PWM input with a significantly higher frequency. The use of a higher frequency PWM input makes the more fluid response by virtue of the fact that there is less time in the ON and OFF states for the release of the decay circuit and increase, respectively. We will examine the response of a converter in these conditions partly (B) of this activity. Extensions Some extensions to this activity would be to experiment with different circuit components to see what kind of performance can be reached. It might also be interesting to examine other types of DC / DC converters, such as the Buck converter and the Boost Buck converter. Converter.