AN EXPERIMENTAL INVESTIGATION COMPARING THE TYPES OF SWITCHING AND LINEAR VOLTAGE REGULATOR CIRCUIT TOPOLOGIES: THEIR EFFICIENCY PROBLEM AND ECONOMIC SIGNIFICANSE

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Key words: vreg, boost converter, buck converter

Economic significance. The Voltage Regulator circuits offer operational advantages like improved ease of use besides being cheap. They are minute in size, thus lowering the overall supplied size of power into the required magnitudes. They are also versatile and considerably simplify the power supply design and occur in built-in features such as programmable output, protection systems, voltage and current boosting systems, current limitation systems, and internal short-circuiting, among other characterristics. The size and cost of the discrete circuits elevate with the number of parts used in the entire circuit. Most importantly, electrical engineering is associated with fundamental challenges in operating and managing electrical and electronic devices, equipment, and machines. For instance, the efficient conversion of the available supply voltage into the needed supply voltage has prevalently proved to be a principal constraint, a fact that calls for the continued establishment and development of voltage regulators. The aspect of voltage regulation pegs to the design of power supply, which entails the conversion of the supply voltage that the system provides into one that will permit a circuit to satisfy its functional needs with consistency. In effect, the diverse functionalities of voltage regulators have necessitated the existence of different categorizations of the regulators.

Introduction. The continued establishment and development of vast electronic devices with associated capabilities and sophistication has helped improve the reliability channeled towards analog and mixed-signal integrated circuits in contemporary power systems. The advancements in the analog and mixed-signal integrated circuits have necessitated the edging out of power-supply-related constraints in line with boosting performance, reducing the area, and even lowering the power consumption of various integrated circuit designs, a fact that helps in improving their overall reliability and performance quality. Most importantly, the analog and mixed-signal integrated circuits are specially designed to boost, reduce and even regulate the flow of electric energy when required, without jeopardizing their intended functionality. An example such analog and mixed-signal integrated circuits are the voltage regulators. The article, therefore, compares a couple of parameters associated with functionalities and operations of equivalent circuits by narrowing down on and discussing the Voltage Regulator circuit topologies.

The Problem. The article presents an experimental analysis that compares the reliability and efficiency of voltage regulator topologies. It presents a uniform strategy of analyzing voltage regulators, particularly the AC, based on the step-up (boost converter) and step down (buck converter) switching voltage regulator topologies. This is attained through the analysis of the influence of essentials of the load voltage regulation range on topology pertinent to AC regulator, examining the modes of operation of the AC voltage regulator circuit topologies for different approaches of generating voltage, and power evaluation for the AC voltage regulators through the provision of a regulated boost voltage.

Switching Voltage Regulator. Switching Voltage Regulators occur and function in the form of integrated circuit topologies. Topology refers to various switching forms and combinations of energy storage elements vital in the control, regulation, and transmission of an input voltage or current to an output voltage source. Two types of switching voltage regulators were discussed below.

Step-Down or Buck Converter. The buck or step-down converters yields a low output voltage and take in a large input voltage. It can be regarded as a form of a forward regulator, therefore easily recognizable by its presence in an LC filter's output. In an instance where the transistor Q_1 is on (while run by a signal of PWM with a particular duty cycle and frequency), the inductor flowing current powers the load. The said current stores the energy in the output capacitor and inductor. On the other hand, diode (reverse-biased) gets blocked. When Q_1 is off, the diode (forward-biased) closes circuit. The load then gets powered by the energy stored in the capacitor and inductor until the following cycle of the "on" state occurs. V_{out} (output voltage) is therefore provided from the product of the duty cycle (D) (of PWM signal) and the input voltage (V_{in}).

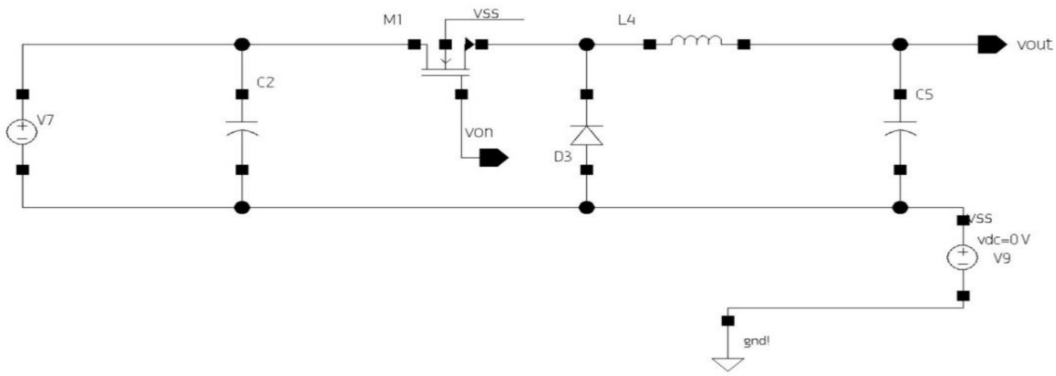

Figure 1: ***Buck converter circuit diagram***

Step-Up or Boost Converter. The boost or step-up converters yields a large output voltage and take in a low input voltage. Boost converter steps down current while stepping up voltage. Its inductor stores energy and has it released at an output voltage exceeding the input voltage. The latter feature proves its applicability in the boosting of electronic devices. In an instance where switching transistor Q_1 becomes on, the input voltage supplies energy. The inductor stores (reverse-biased diode) the said energy, and at the same time, the energy stored in the capacitor powers the load. On the other hand, when Q_1 goes off (forward-biased diode), the inductor stores the energy, which recharges, powers the output capacitor, and powers the load.

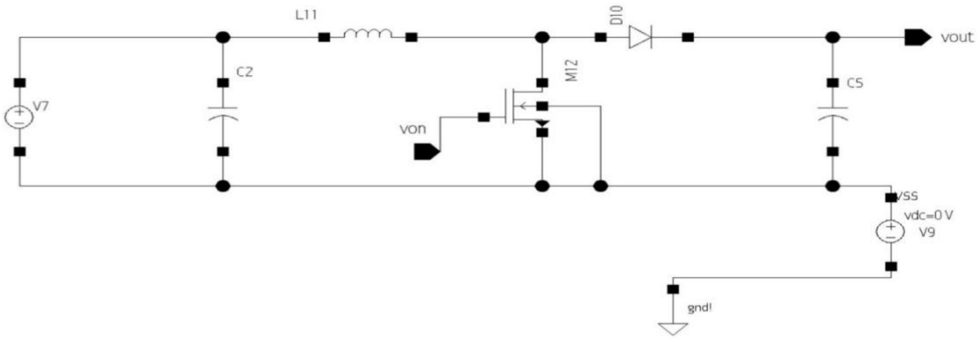

Figure 2: ***Boost converter circuit diagram***

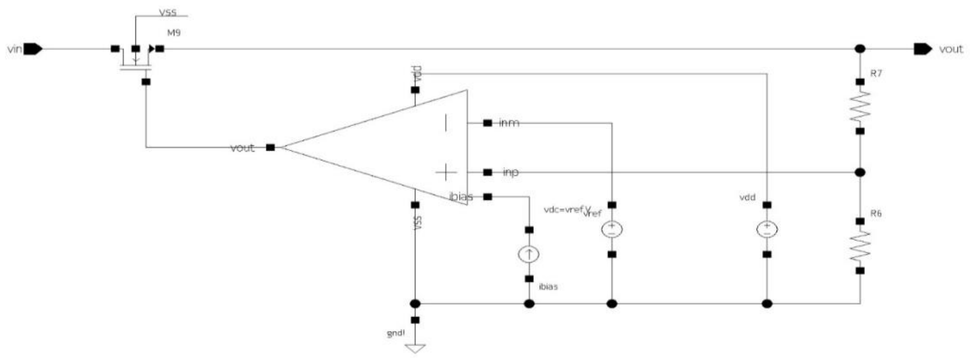

Figure 3: ***Linear voltage regulator circuit diagram***

Linear Voltage Regulator. The linear voltage regulators possess an error amplifier whose role is to compare the regulator's output voltage with the internal voltage of reference. The error amplifier propels an output transistor between the output node and the input node. The presented configuration of the negative feedback permits the linear voltage regulator to maintain an output voltage constantly regardless of the changes in the load current and the input voltage.

The linear voltage regulators function is like variable resistors. The resistive element's power dissipation matches the magnitude of current multiplied by the voltage drop. Therefore, if the difference between the output and the input voltages is large, the linear voltage regulator will thus put a lot of power into wastage concerning the necessary load current. The latter implies that; the linear voltage regulators have a worrying degree of inefficiency. It therefore means, a lot of energy deserved for powering the circuit dissipates as the heat just due to the need of converting an elevated supply voltage into its reduced size. However, linear voltage regulator ICs have increased in popularity due to their improved ease of use and small size. In analog applications with high sensitivity, linear voltage regulators may be vital in avoiding the switch-mode-generated noise through regulation. Though in instances where efficiency matters the most, circuit designers typically apply the switching voltage regulators.

Results and Discussion. Figure 4 and 5 shows the dependencies of the efficiency and power loss from the output load for all three circuits. As expected, the switching regulators performances are much better. To discuss the results for small output loads it is better to look at the figure 5, as it is not so obvious in figure 4 due to the large percentage difference. Thus, in the case of an input voltage of 25 volts and an output current of 10 mA, the power consumption of the switching voltage regulators are 2.59mW and 2.46 mW, respectively, and for linear voltage regulator is 398 mW also for the maximum output current we have the following: 0.89W (boost-converter), 0.24W (buck-converter), 2.08W (linear). All the results are summarized in Table 1.

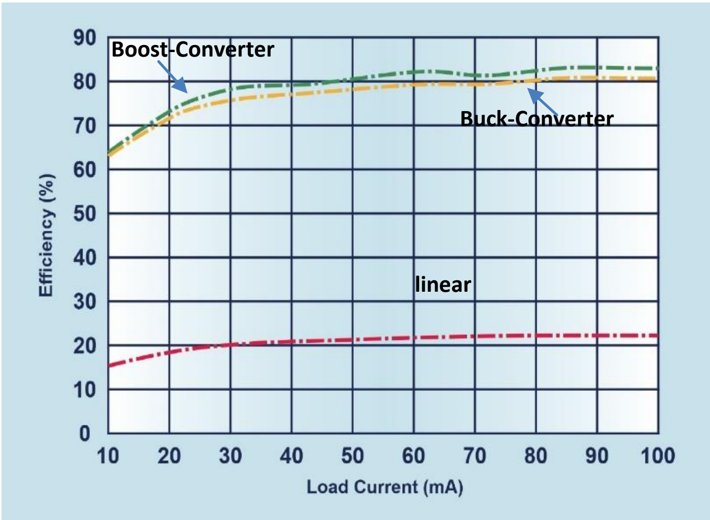

Figure 4: ***Efficiency vs load current***

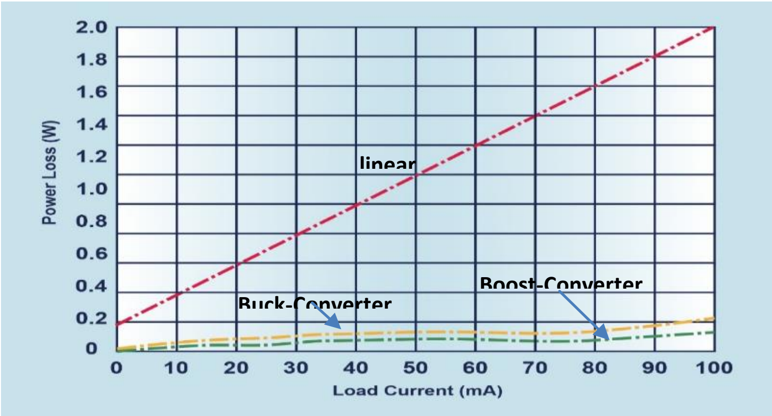

Figure 5: ***Power loss vs load current***

TOPOLOGY TYPE	MAXIMUM LOAD		NO LOAD
	EFFICIENCY (%)	POWER LOSS (W)	QUIESCENT CURRENT (mA)
BOOST-CONVERTER	84,5	0.89	0.48
BUCK-CONVERTER	80,1	0.24	0.39
LINEAR	22	2.08	5.59

Table 1: ***Summary of efficiency and power loss***

Conclusion. In general, electronic systems usually require many variant magnitudes of voltages for powering different internal circuits. The above investigation compared voltage regulators by majoring on switching voltage regulator integrated circuits (Buck Converter and Boost Converter). Switching voltage regulation remains an easy and common approach to converting a given magnitude or form of voltage to another. Based on the voltage regulation categories of linear and switching topologies, linear regulators stand to be the oldest forms of voltage regulation. They are therefore easy to use, besides being cheap. However, the simplicity and advantages of linear voltage regulation present the issues of low efficiency. On the other hand, switching voltage regulators tend to be quite internally complex and expensive but offer a better and improved efficiency. This fact makes them possess the ability to conduct enormous magnitudes of current except thermal concerns, as in the case of linear regulators.

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Արման ՄԱՆՈՒԿՅԱՆ, Արմեն ԴԱՆԻԵԼՅԱՆ, Արման ԳԱԼՍՏՅԱՆ, Դավիթ ԳԱԲՐԻԵԼՅԱՆ, Վլադիմիր ՄԿՐՏՉՅԱՆ

Փոխանջատվող և գծային լարման կայունարարների սխեմաների համեմատություն հիմնված փորձարարական հետազոտությունների վրա. դրանց արդյունավետության խնդիրները և տնտեսական նշանակությունը

Բանալի բառեր. լարման կայունարար, խթանող փոխարկիչ, եփնային փոխարկիչ

Այս աշխատանքում կատարվել է հետազոտություն համեմատության մեջ դնելով՝ փոխանջատվող և գծային լարման կայունարարների աշխատանքների արդյունավետությունը, ծախսած հզորությունները: Արդյունքներից պարզ է, որ արդյունավետության և էներգասպառման տեսանկյունից փոխանջատվող լարման կայունարարները շատ ավելի լավ են իրենց դրսևորում: Բայց գծային լարման կայունարարներ նախագծելը ավելի մատչելի է: Ուստի, կախված, թե ինչ խնդիր է կա՝ ունենալ ավելի թանկ, բայց ավելի հուսալի սարք, թե՞ ավելի էժան և քիչ հուսալի սարք, կարող ենք օգտագործել և՛ մեկը, և՛ մյուսը:

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An experimental investigation comparing the types of switching and linear voltage regulator circuit topologies, their efficiency problem and economic significance

Key words: vreg, boost converter, buck converter

In this article a research has been done comparing the work efficiency of both switch and linear voltage regulators and their power loss. In result, its clear that in terms of efficiency, as well as in terms of energy consumption, switching voltage regulators are much better. However, designing linear voltage regulators is cheaper. Therefore, depending on what challenge we face: having more expensive but more reliable device, or cheaper and less reliable one, we can use both the first and the second one. Design and simulations were done using 14nm FinFET technology developed by Synopsys Armenia Educational Department.

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Сравнение схем импульсных и линейных стабилизаторов напряжения на основе экспериментальных исследований. проблемы и экономическое значение их эффективности

Ключевые слова: врег, повышающий конвертер, понижающий конвертер

Эта работа была исследована путем сравнения эффективности и потраченной мощности импульсных и линейных стабилизаторов напряжения. Из результатов ясно, что импульсные стабилизаторы напряжения в работе намного эффективнее, а также намного экономичнее с точки зрения энергопотребления. Однако проектирование линейных стабилизаторов напряжения более доступно. Поэтому в зависимости от поставленной задачи, могут быть использованы как один, так и другой вариант.