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DESIGN OF ANALOGUE PULSE GENERATOR FOR NOVEL CONCEPT OF MULTI-LEG BOOST CONVERTER

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This article deals with design control for novel concept of multi-leg boost converter. This new concept allows effective utilization of energy from input source. The effective utilization of input energy is ensured by adding five parallel legs to the conventional single-leg boost converter. Appropriate algorithm of switches control allows converter to take the input source energy one of these six parallel legs in every moment. This algorithm allows multi-leg boost converter to work with high efficiency of energy conversion in compare with single-leg boost converter. The multi-leg boost converter continually delivers the energy of input source to the load. In this case, the time interval when the output energy is equal to zero is removed. The simulation and experimental models were built and measured to verify the theoretical properties of design control and correct function of multi-leg boost converter.

Key words: single-leg boost converter, multi-leg boost converter, analogue pulse generator, efficiency of energy conversion.

ПРОЕКТУВАННЯ АНАЛОГОВОГО ІМПУЛЬСНОГО ГЕНЕРАТОРА ДЛЯ НОВІТНЬОГО КОНЦЕПТУ БАГАТОВИВІДНОГО ПІДВИЩУЮЧОГО ПЕРЕТВОРЮВАЧА

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Розглянуто питання проектування новітнього концепту багатовивідного підвищуючого перетворювача. Даний концепт дозволяє ефективно використовувати енергію вхідного джерела, що забезпечується додаванням п'яти паралельних виводів до загальновідомого одновивідного підвищуючого перетворювача. Відповідний алгоритм керування перемиканнями дозволяє перетворювачу отримувати енергію джерела на одному із шести паралельних виводів у будь-який момент часу. Даний алгоритм дозволяє багатовивідному підвищуючому перетворювачу працювати з високою ефективністю перетворення енергії порівняно з одновивідним підвищуючим перетворювачем. Багатовивідний підвищуючий перетворювач безперервно постачає енергію вхідного джерела навантаженню. У такому випадку часовий проміжок, коли вихідна енергія дорівнює нулю, зникає. Синтезовано та побудовано комп'ютерну та експериментальну моделі для перевірки теоретичних властивостей зпроектованого пристрою керування та багатовивідного підвищуючого перетворювача.

Ключові слова: одновивідний підвищуючий перетворювач, багатовивідний підвищуючий перетворювач, аналоговий імпульсний генератор, ефективність перетворення енергії.

PROBLEM STATEMENT. This paper presents the novel concept of control of multi-leg boost converter (MLBC) with high efficiency of energy conversion [1]. The high efficiency of energy conversion is ensured by adding five more parallel legs to the single-leg boost converter (SLBC). The suitable algorithm of switches control in particular legs ensures that the almost whole energy enters to the converter is effective utilized.

The principle of function of conventional SLBC is very simple. The SLBC has two operating cycles within each period. When the switch S is turned on then the input source energy starts to accumulate in inductor L in form of magnetic field. The inductor energy included with source energy are delivered to the load Z after the switch S is turned off. The topology, operating modes and theoretical waveforms of conventional SLBC are shown in Fig. 1.

We can notice that there exists a time interval within the period T when the energy delivered to the load (in point A) is zero. This is the main problem of SLBC – effective utilization of energy of input source. We have to ensure that the energy will be delivered to the load Z over the whole period T. We have to remove the time interval within the period T where the energy delivered to the load Z is zero.

This is done by using of proposed MLBC. The abovementioned process of delivering energy to the load Z can be repeated 6-times because 6-parallel legs are presented in MLBC. The proposed MLBC allows elimination the time intervals when the energy delivered to the load in point A is zero and thus effective utilization of energy from input source. The proposed topology and theoretical waveforms of MLBC are shown in Fig. 2.

EXPERIMENTAL PART AND RESULTS OBTAINED. *Design control.* The correct function of MLBC is ensured by suitable algorithm of design control [2–5]. The main idea of design control is to create the six time-shifted pulses to cover the whole period T of delivering the converter input energy to the load Z. The proposed control structure is shown in Fig. 3 [6, 7].

The pulse generator signal is connected to the input of counter. The counting of counter is limited to six because six legs of MLBC. The operating frequency of MLBC is set to f_S = 50 kHz so the frequency of pulse generator signal has to be set at f_{PG} = 300 kHz.

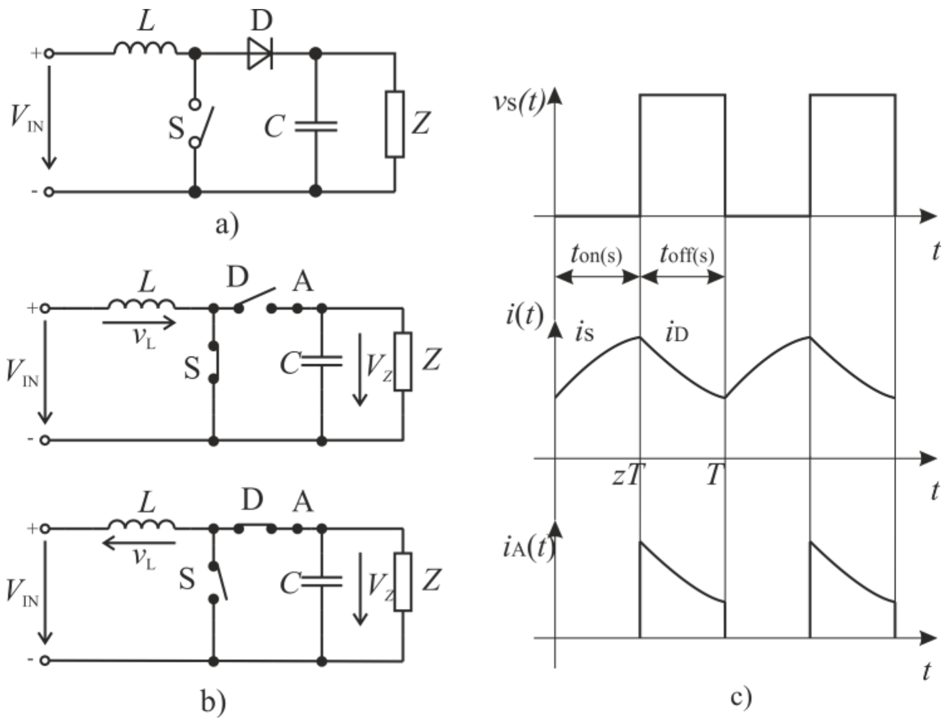


Figure 1 – Single-leg boost converter: a) topology; b) operating modes; c) typical theoretical waveforms

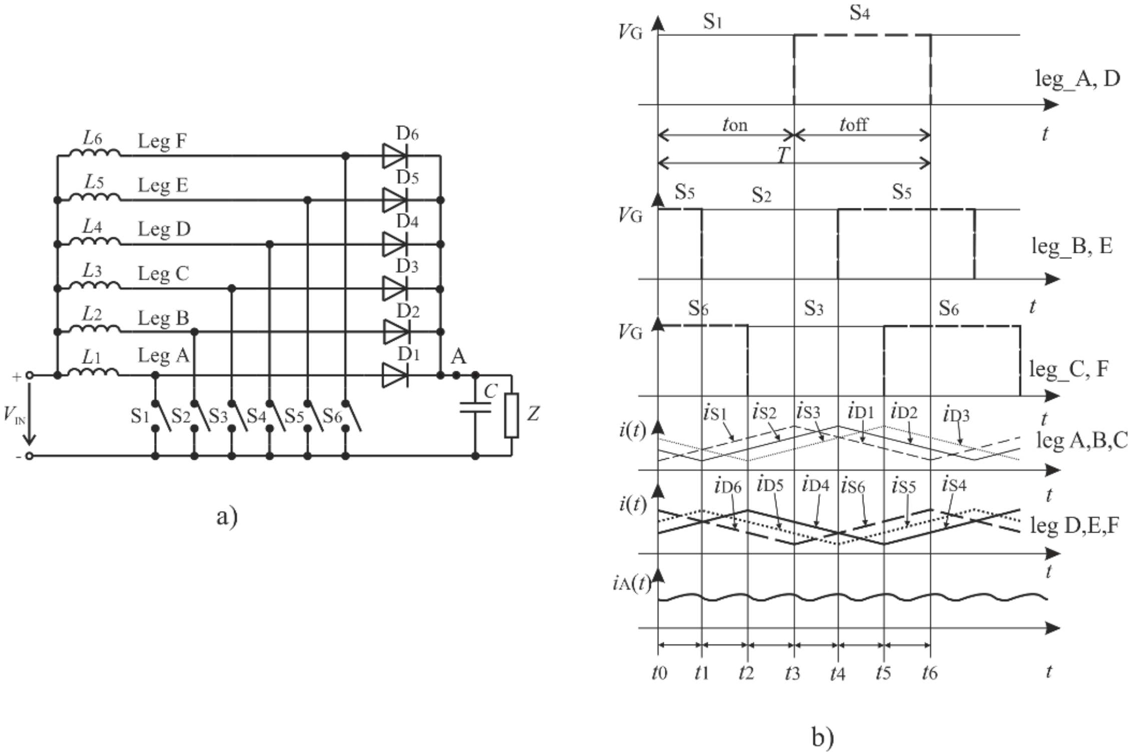


Figure 2 – Multi-leg boost converter: a) topology; b) typical theoretical waveforms

The counter output signal enters to the BCD (Binary Coded Decimal) to decimal decoder. The decoder ensures six output signals to control six legs of MLBC. The correct time-shift of control signals is ensured by means of basic logical operation executing by basic logic elements in block Time-shift. The time-shifted signal enters to the 555 timer which works in monostable mode. Triangle signal is taken from discharge pin of 555 timer and enters to the operational amplifier which works as comparator.

Operational amplifier (OA) compares the triangle signal with voltage Vcompare. The voltage level Vcompare is sets by means of potentiometer P and thus the different values of duty cycle z can be set. At the end of this process the OA outputs are set to desired level to control the main switches in particular legs of MPBC.

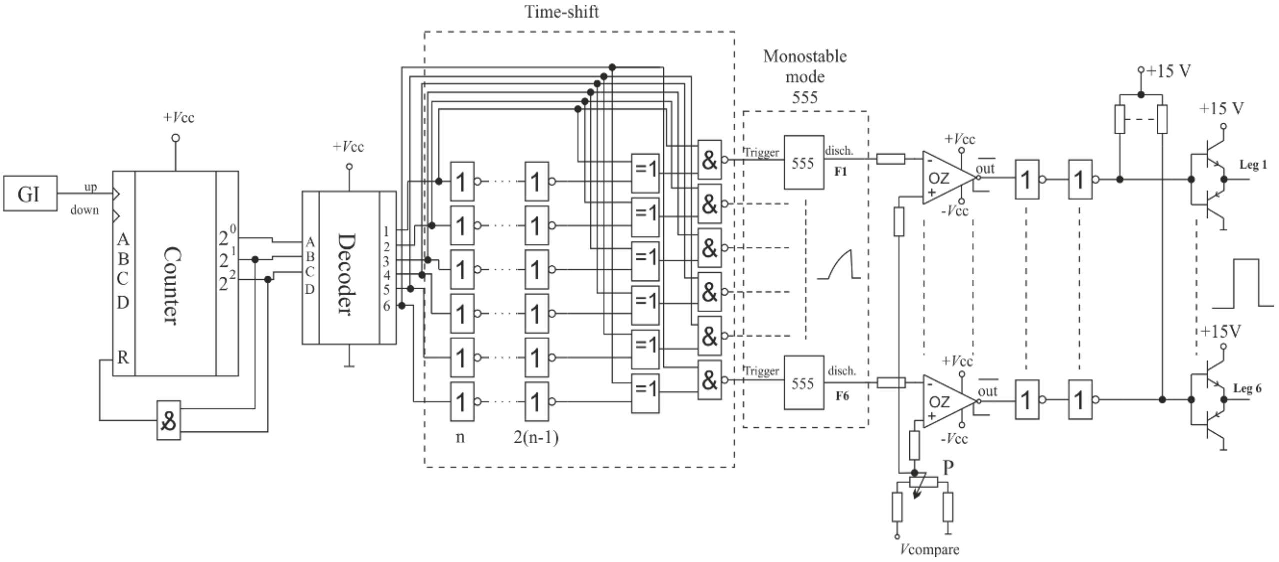


Figure 3 – Proposed control structure of MLBC

Simulation results. The simulation model of proposed control structure of MLBC shown in Fig. 4 was created in simulation environment OrCAD Capture CSI to verify its theoretical properties [8].

The pulse generator output enters to the simulation model (input UP) of counter IO 74 193. Outputs (QA–QC) of IO 74 193 enter to the inputs of simulation model of DCB to decimal decoder IO 7442 as it is shown in Fig. 4. Fig. 5 shows the pulse generator signal (PG), output signals from counter IO 74 193 (QA–QC) and output signals from decoder IO 7442 (Y0–Y5).

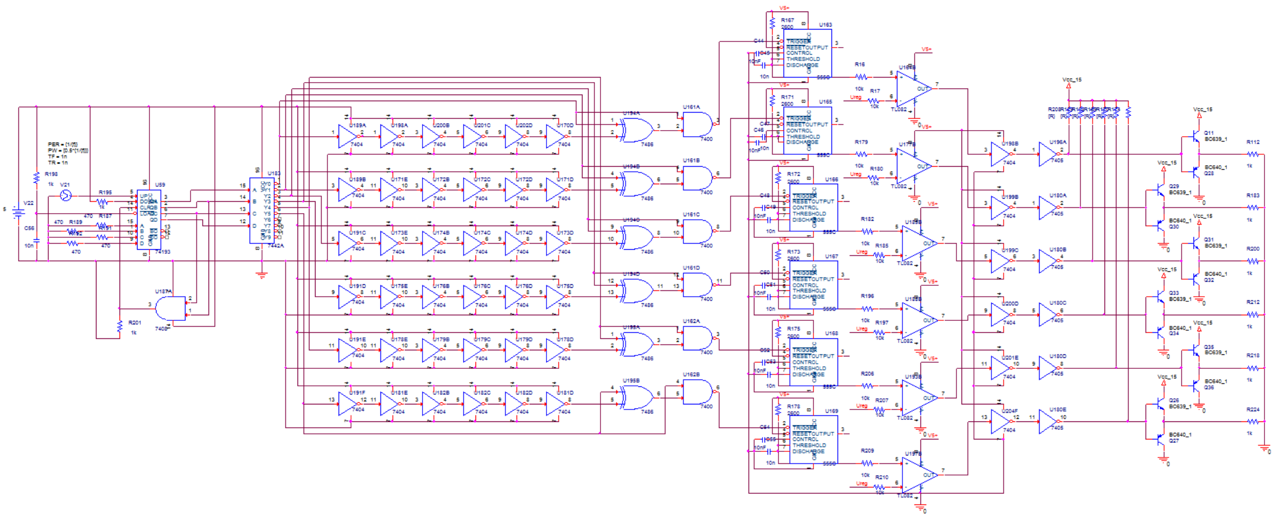


Figure 4 – Simulation model of proposed control structure

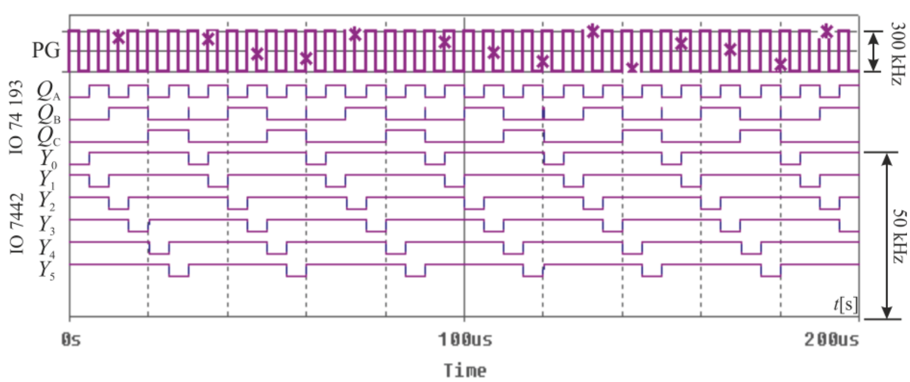


Figure 5 – Output signals from pulse generator, IO 741932 *(Q_A–Q_C)* and IO 7442 (Y_0–Y_5)

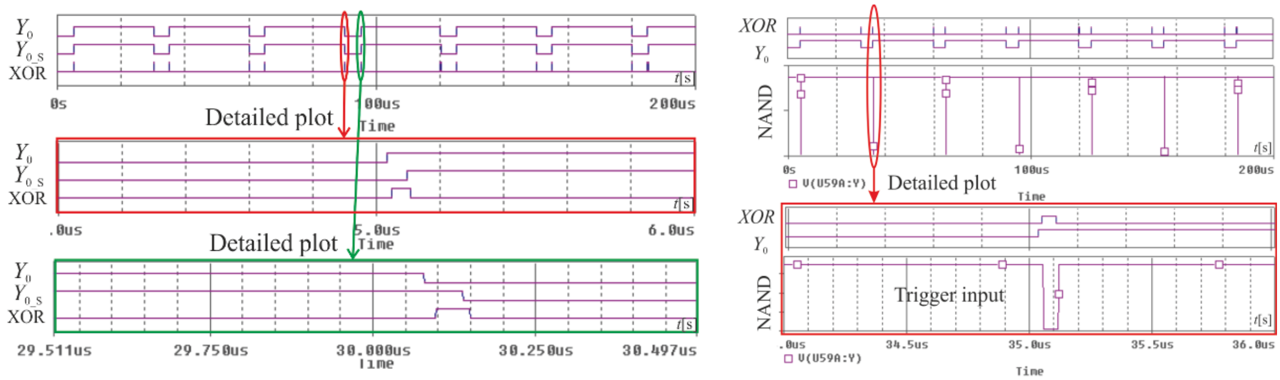
The correct time-shift of control signals is ensured by means of basic logical operation exclusive OR (XOR). Fig. 6,a shows the logical operation XOR of output signal Y0 with shifted output signal Y0_S. The shifted signal Y0_S is ensured by means 2(n-1) logic gates NOT which ensure the shift of signal Y0 which enters to the first logic gate NOT. The result of logical operation XOR are two short pulse signals depicted in red and green square (Fig. 6,a).

Fig. 6,b shows the logical operation NAND of output signal Y0 with two short pulse signals as a result of previous logical operation XOR. The result of logical operation NAND is inverted signal which serves as an input trigger signal to 555 timer that works in monostable mode.

Triangle signal taken from discharge pin of 555 timer enters to the OA which works as comparator. OA compares the triangle signal with voltage Vcompare and the output of operation amplifier is set to desired level to control the switch in particular legs of MLBC as it is shown in Fig. 7,a. Fig. 7,b shows all six control signal for switches of MLBC.

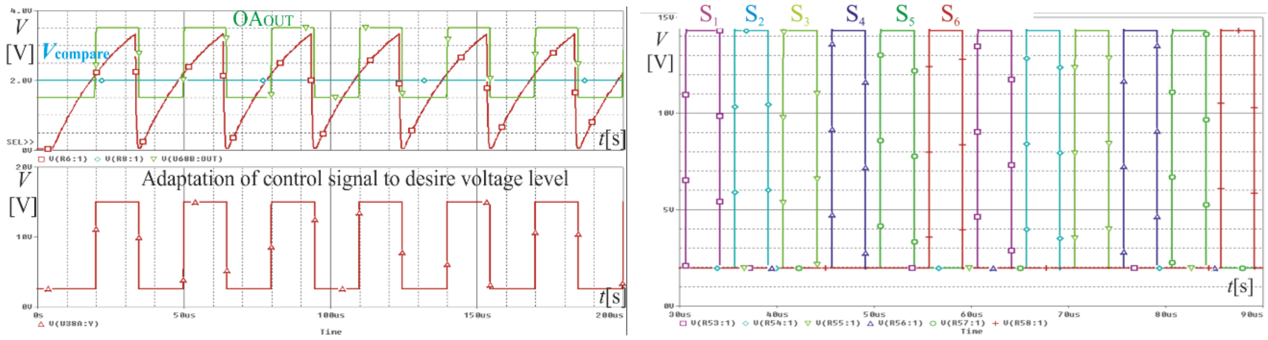
EXPERIMENTAL RESULTS. The laboratory model of MLBC with control structure were built and tasted to verify the principle of the operation (Fig. 8). The following oscillograms fully confirm the theoretical assumes and simulation results and thus only the particular oscillograms are placed here (Fig. 9–11).

The oscillograms shown in fig. 11 describe the comparison of properties of laboratory models of MLBC and SLBC. It can be seen, that for entire range of input voltage VDC the MLBC works in the discontinuous current mode in comparison with SLBC, as can be seen for boundary conditions at the VDC = 12 V and VDC = 4 V. The values of energy usability of the input DC source and the efficiency of the energy conversion of input converter energy are very high for the entire range of input voltages VDC in the case of MLBC.



a) b)

Figure 6 – Logical operations: a) XOR; b) NAND



a) b)

Figure 7 – Simulation results: a) comparative process adaptation of control signal to desire voltage level; b) six control signal for switches of MLBC

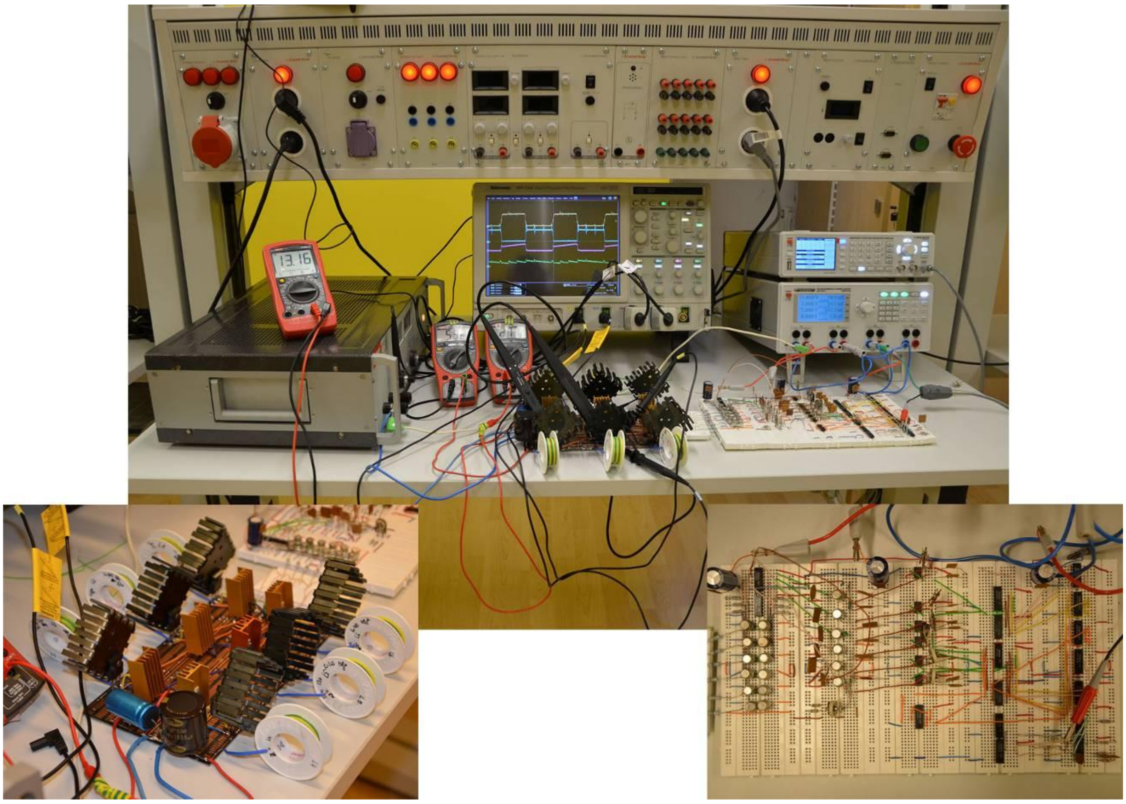
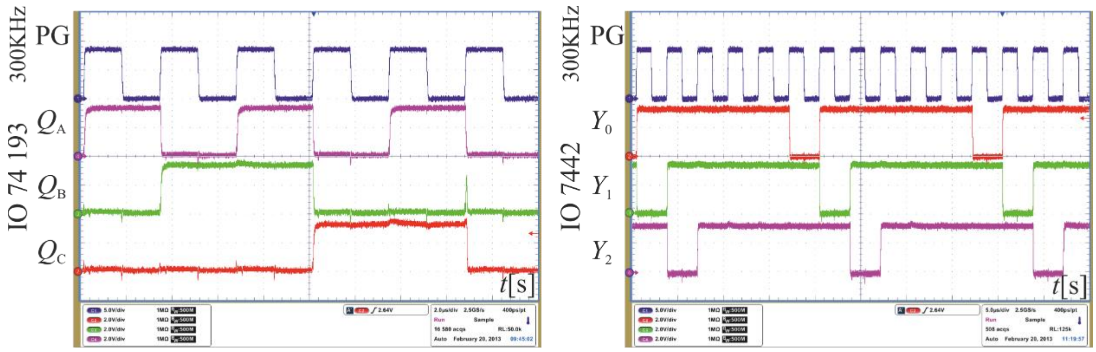
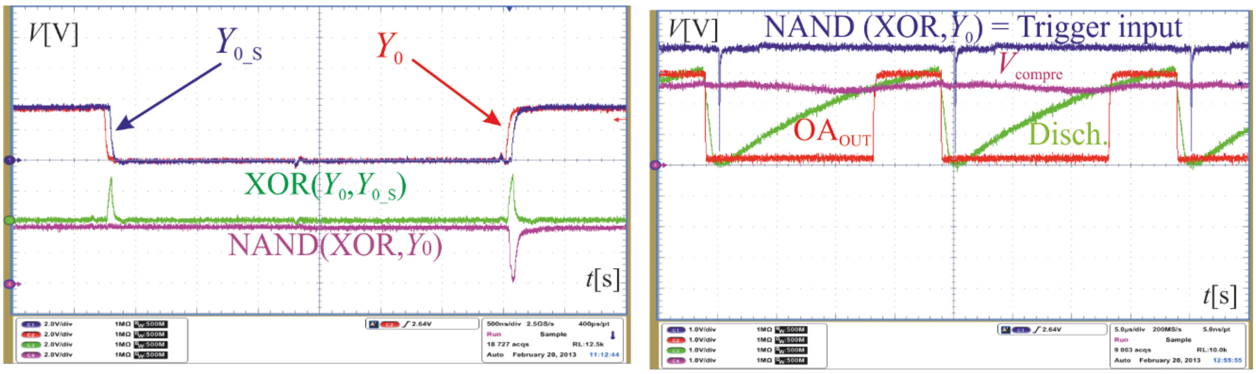


Figure 8 – Laboratory model of proposed MLBC with proposed control structure



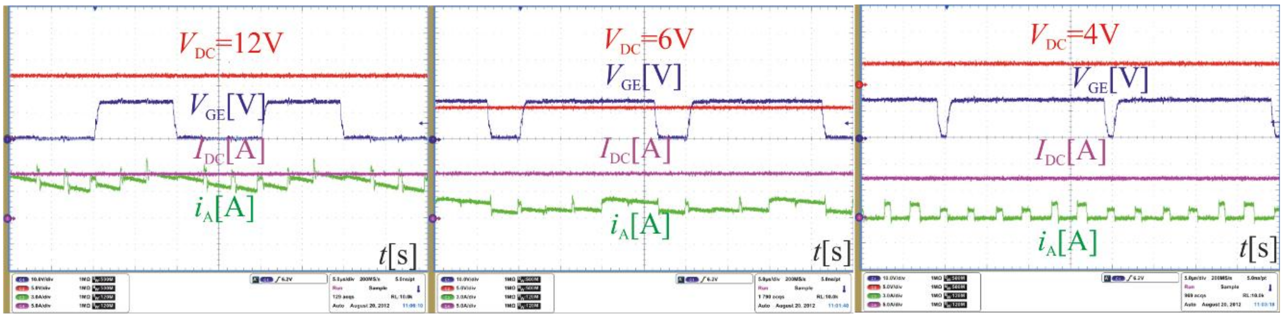
a) b)

Figure 9 – Experimental results: a) output signals from PG and counter IO 74 193 (Q_1–Q_3);
b) output signal from PG and decoder IO 7442 (Y_0–Y_2)

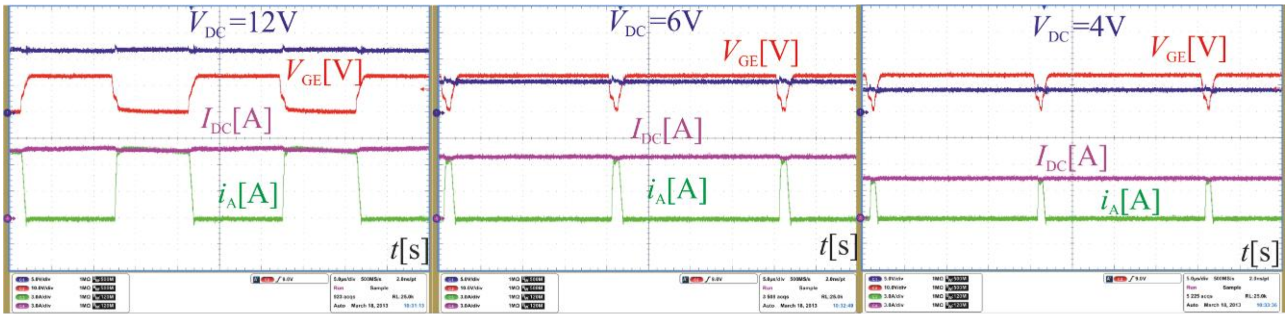


a) b)

Figure 10 – Experimental results: a) logical operations XOR and NAND;
b) trigger input to 555 timer and discharge output



a)



b)

Figure 11 – Comparison of usability of input DC source:
a) MLBC; b) SLBC

CONCLUSION. The MLBC works with high efficiency of energy conversion in compare with SLBC. The MLBC continually delivers the energy of input source to the load Z. In this case, the time interval when the output energy is equal to zero is removed. This is because the appropriate algorithm of control of MLBC was designed and applied.

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ПРОЕКТИРОВАНИЕ АНАЛОГОВОГО ИМПУЛЬСНОГО ГЕНЕРАТОРА ДЛЯ НОВАТОРСКОГО КОНЦЕПТА МНОГОВЫВОДНОГО ПОВЫШАЮЩЕГО ПРЕОБРАЗОВАТЕЛЯ

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Рассмотрены вопросы проектирования новаторского концепта многовыводного повышающего преобразователя. Данный концепт позволяет эффективно использовать энергию входного источника, что обеспечивается добавлением пяти параллельных выводов к общеизвестному одновыводному повышающему преобразователю. Соответствующий алгоритм управления переключениями позволяет преобразователю получать энергию источника на одном из шести параллельных выводов в любой момент времени. Данный алгоритм позволяет многовыводному повышающему преобразователю работать с высокой эффективностью преобразования энергии по сравнению с одновыводным повышающим преобразователем. Многовыводной повышающий преобразователь непрерывно поставляет энергию входного источника нагрузке, при этом временной промежуток, когда выходная энергия равна нулю, исчезает. Синтезированы и построены компьютерная и экспериментальная модели для проверки теоретических свойств спроектированного устройства управления и многовыводного повышающего преобразователя.

Ключевые слова: одновыводной повышающий преобразователь, многовыводной повышающий преобразователь, аналоговый импульсный генератор, эффективность преобразования энергии.

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