

Generation of Exponentially Decaying Voltage of Desired Time Constant

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Abstract—

This paper presents circuit methodology in which a constant DC voltage source or power supply has been given from which an exponentially decaying voltage can be generated by the application of buck converter circuit. The circuit methodology presented shows the generation of switching pulse of exponentially decaying duty ratio decaying from 1 to zero which will be used to operate the controlled switch of the buck converter. This in turn will result in the generation of output voltage which will follow the decay curve of the duty ratio. Also it must be kept in mind that the amplitude of the switching pulse must be high enough to trigger the controlled switch of the buck converter. This decaying voltage can be used in charging devices in which voltage decreases over time as the device charges or could be used to resemble the characteristic of discharging supercapacitor. The components used in the circuit have been specified. The current at the beginning of the exponentially decaying voltage shall be decided by the load connected at the output of the buck converter or the load running on the exponentially decaying voltage and operating frequency of converter ranges from 1 to 2 KHz.

Keywords— loop ,control, duty ratio, buck, switching pulse.

I. INTRODUCTION

Any exponential parameter in the field of science bears huge significance. In the field of electrical and electrical engineering an exponentially increasing current-voltage curve would represent a diode forward biased characteristics or could resemble the characteristic of the base emitter junction of npn transistor. Also in the field of electrical and electronics exponential voltages relate most with capacitor. It is because the exponentially decaying voltage will also resemble the decaying voltage of a discharging capacitor. Also the charging characteristic of capacitor will also be somewhat exponential in nature. An exponentially decaying voltage can also represent the discharge characteristic of supercapacitor [1] when supercapacitor is powering a load at a regulated voltage [2] via a custom built buck converter circuit [3] designed to suit the application needs. An exponential voltage could be used in circuit [4] to designate fault voltage in circuits. Exponential decaying voltage can also be used in many circuits as test signal to check circuit performance under the influence of a decaying voltage. Exponentially decaying voltage is preferred over steeply decaying voltage because for the former the circuit gets a bit of time to adapt to the signal but a steeply decaying circuit might destroy a device while testing due to fast rate of change. For example for capacitors and the junction capacitances in devices a high rate of change of voltage of low magnitude would give rise to current high enough to destroy the capacitor or the device as the case may be.

Exponential parameters and voltage has various other applications. Exponential functions can be used in CMOS for automatic gain control. Studies have been carried out regarding low-power exponential voltage-mode circuit with tunable output range. Exponential voltages are also used in testing ADCs. New CMOS based exponential current to voltage circuits have also been designed. CMOS based exponential function circuits for VGAs have also been developed by researchers. Research has been carried out on the context of designing exponential voltage to voltage converter. Product failure voltages for different products are also calculated using

exponential voltage signals. Power Management in micro-grids also employs control strategy based on exponential signal. Studies have also been done regarding the exponential voltage factor for large-area field emitter studies. Exponential functions are also used in the field of low power technology. Exponential voltages are also used in switched reluctance motors for reducing vibration. Exponential recovery voltage is used in battery to determine its open circuit voltage. Researchers have also designed exponential voltage to voltage converter to get the desired voltage of exponential nature.

In this paper a circuit design has been shown that uses buck converter to decay the voltage of a power supply exponentially over a desired period of time. This circuit design doesn't use any load regulation [5] and hence there is no extra power loss at the output.

For designing the duty ratio control methodology some of the control methods were studied [6,7] but these methods concentrate on generation of fixed output rather than controlled decay of output. Again for the generation of switching pulse triangular wave or saw tooth wave had to be generated for comparing with a dc voltage. Some waveform generator ICs can be used to generate the saw-tooth and or triangular waveform. An input based saw tooth wave generation was studied but its application in our design remains uncertain. Also a delay gets introduced between the waves if frequency lies in the range of few KHz. The generation of duty ratio based on comparing inductor current of the converter to a reference current has also been studied. Although inductor current assumes triangular wave shape in CCM but this method cannot be used to generate an exponentially decaying duty ratio. Hence this method cannot be used. Also due to internal fault the converter sometimes would start working in discontinuous conduction mode (DCM) which would cause circuit failure. A few digital control methods were also studied for buck converter but these methods only aim to regulate output voltage and cannot generate an exponentially decaying voltage.

Thus this is the only work which shows the generation of decaying exponential voltage.

II. PROPOSED METHODOLOGY

A decaying exponential voltage generator is shown in fig.1. As we can see the circuit shown in fig 1 is a buck converter circuit in which ' V_i ' is the input to the converter, 'S1' is a MOSFET, 'S2' is a schottky diode, 'L' denotes the value of inductance used, 'C' denotes the capacitance used. 'ZA' in the figure denotes any application that would be tested by the exponential voltage and ' V_{exp} ' is the exponential output voltage of the converter. A1 is an op-am which is used as comparator in the circuit for generating the desired duty ratio. 'Fn' is the function generator used to generate triangular wave of a desired frequency and ' V_{tr} ' denotes peak voltage. ' V_{C2} ' is the voltage to which capacitor 'C2' will be charged. And this ' V_{C2} ' will decay over a time depending on the value of resistance 'R2'. This decaying voltage will be the reference voltage ' V_{ref} ' of the circuit. 'S3' in the circuit is also a schottky diode while the 'C3' is also a schottky diode and together they form the clamper circuit that will make the output of the op-amp unipolar thus generating a unipolar switching pulse at 'B'.

First the capacitor 'C2' is charged to ' V_{C2} ' such that ' $V_{C2}=V_{tr}$ '. During charging it must be kept in mind that the capacitor 'C2' should not be in connection with the resistance 'R2'. Once the 'C2' gets charged to the desired voltage, then it will be disconnected from the source and connected with 'R2'. Thereafter ' V_{C2} ' will start decaying exponentially giving rise to a switching pulse of duty ratio exponentially decaying from 1 to zero. This duty ratio will operate the S1 of the converter. Thus the output voltage of exponentially decaying nature will be generated at the output i.e. at point 'A'.

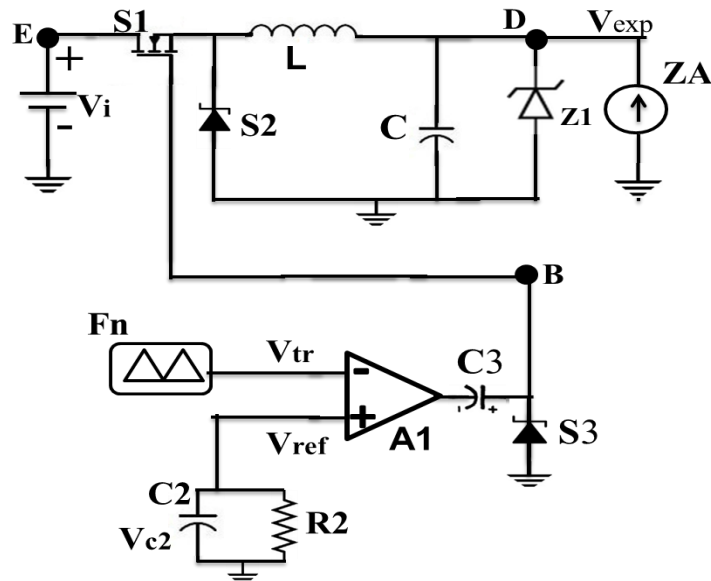


Fig. 1. Decaying exponential voltage generator circuit

$$V_{\text{exp}} = \frac{V_{tr} e^{-\frac{t}{R2.C2}}}{V_{tr}} V_i \quad (1)$$

III. SIMULATION RESULTS

The simulation has been done with $V_i=8V$, $C2=1000\mu F$, $R2=1M\Omega$, $V_{tr}=5V$, $V_{c2}(\text{initial})=5V$.

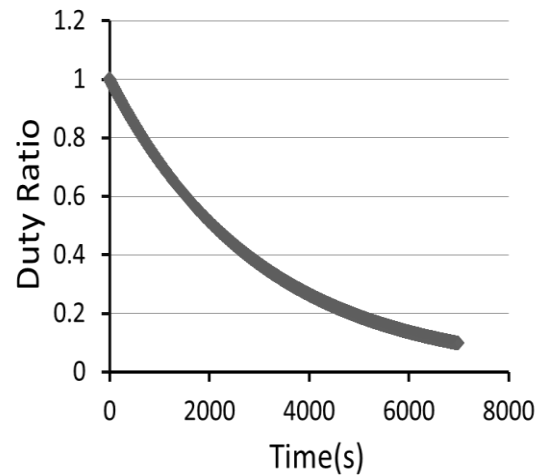
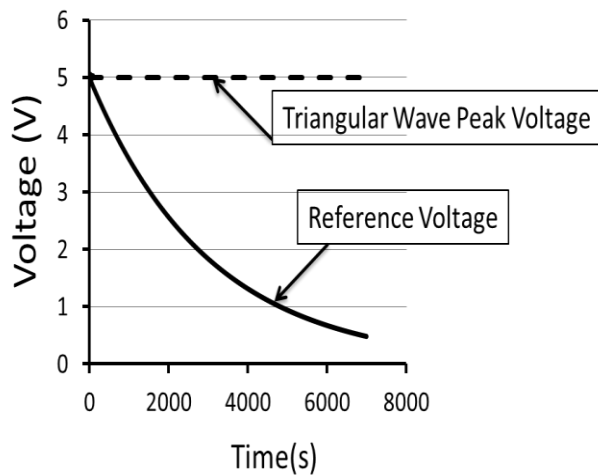


Fig. 2. Decaying reference voltage and constant peak voltage of triangular wave

Fig. 3. Exponentially decaying duty ratio

All the graphs have been shown with respect to time. In fig.2 the dashed line is the triangular wave peak voltage with respect to time and is represented on the voltage scale of the graph. And it can be observed that the peak voltage of triangular wave. The solid black curve of fig.2 represents the reference voltage given to the op-amp. It is also represented on the voltage scale. Fig. 3 represents the exponentially decaying duty ratio decaying from 1 to zero.

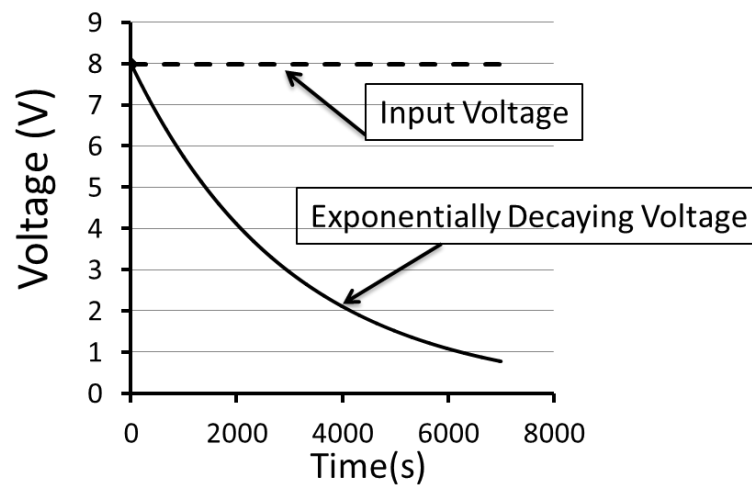


Fig. 3. Input and exponential decaying output voltage

In fig.3 the dashed line is the input voltage with respect to time while the solid black curve of fig.3 represents the output voltage that is decaying exponentially as can be seen from the graph.. It is also represented on the voltage scale.

CONCLUSION

In this paper we intended to create a circuit that would generate a voltage of exponentially decaying nature having a time constant as per user need and from fig. 3 it can be concluded that we have successfully designed the circuit capable of generating exponentially decaying voltage and its time constant can be set by selecting value of 'C2' and 'R2' as per our requirement. This method will generate a duty ratio decaying exponentially from 1 to zero having the desired time constant as shown in fig.2. This duty ratio will in turn lead to the generation of the desired exponential output voltage having the desired time constant.

REFERENCES

- [1] A. S. Sengupta, A. K. Chakraborty, B. K. Bhattacharyya, "Modeling of Super-Capacitor Discharge Characteristic Using Power," IEEE Trans. Electron. Devices, vol.9 ED-18, pp. 8853-8857, Nov. 2016.

- [2] A. S. Sengupta, S. P. Mohanty, B. K. Bhattacharyya, "Modeling DC–DC buck converter solely powered by supercapacitors for efficiently powering the hand-held devices Power," IET Power Electron., vol.11 ED-12, pp. 1946 - 1954, Oct. 2018.
- [3] A. S. Sengupta, S. Satpathy, S. P. Mohanty, D. Baral, and B. K. Bhattacharyya, "Modeling DC–DC buck converter solely powered by supercapacitors for efficiently powering the hand-held devices Power," IEEE Consumer Electron. Mag., vol.11 ED-12, pp. 50-53, Sep. 2018.
- [4] A. S. Sengupta, A. K. Chakraborty, B. K. Bhattacharyya, "Modeling Supercapacitor Module Solely Powering DC–DC Buck Converter for Hand-Held Applications," IETE J. Res., <https://doi.org/10.1080/03772063.2018.1466733>.
- [5] J. J.Chen, J. H. Hsu, Y. S. Hwang, C. C. Yu, "A DC–DC Buck Converter With Load-Regulation Improvement Using Dual-Path-Feedback Techniques", Analog Integr Circ Sig Process, vol.79 D-1 pp. 149-159, April 2014.
- [6] Yanqi Zheng, Hua Chen, and Ka Nang Leung, "A Fast-Response Pseudo-PWM Buck Converter With PLL-Based Hysteresis Control", IEEE Trans. On VLSI Systems, vol.20, ED-7, July 2012.
- [7] Chien-Hung Tsai, Bo-Ming Chen, Hsin-Lun Li, "Switching Frequency Stabilization Techniques for Adaptive On-Time Controlled Buck Converter with Adaptive Voltage Positioning Mechanism", IEEE Trans. on Power Electron. vol.31, ED-1, pp. 443-451, January 2016.