SUPPLY HEADROOM ISSUE IN MULTI-LEVEL REFERENCE VOLTAGE GENERATORS AND PROPOSED SOLUTIONS

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Introduction. Integrated circuits often use multi-level reference generators for a number of reasons. One of the reasons is that the results obtained during the modeling phase may have small discrepancies with the silicon produced in the production. The multi-level generator controlled by digital signals allows to bring the circuit to the most optimal working condition through digital settings. Defects are also possible in the technical specification requirements of the generator-powered circuit, in which case it is possible to find the one that best meets the actual requirements of the powered circuit from the many available voltages. In addition to post-production settings, multistage reference voltage generators are widely used in systems where different voltage levels are required to perform different functions. Such systems are, for example, energy-independent memories, which, with the exception of NVMe memories connected to the PCIe bus (Christian Watto, 2015), can perform only one function at a time: either write/delete, or read. Each of these operations requires voltage levels (Saed Abed, 2020) to be generated by a multistage reference voltage generator. Compared to the function of reading stored information, much higher voltage levels and high power are required to change the state of the memory element.

Economic significance. Modern integrated circuits such as non-volatile memories use multilevel supply voltages. In order to increase the efficiency of energy consumption different parts of the circuit can be supplied different voltages according to their requirement, which makes it possible to minimize the power consumption in each operating mode. The proposed solution allows using one wide range of supply voltage to provide multiple accurate reference voltages. Decreasing energy dissipation lowers the costs associated with providing charge, as well as for mobile applications battery life and aging of the circuit itself.

Literature overview. The supply headroom is the minimum supply voltage level required to ensure the correct operation of the circuit. Both short-term and long-term voltage level drops are possible in the supply rails that feed the integrated circuits. The failures may be due to overload of the supply battery, abrupt shifts in the load of the feeding rails, transition to a state of low energy consumption as a result of discharge, etc. Figure 1 shows a simple multi-level reference voltage generator.

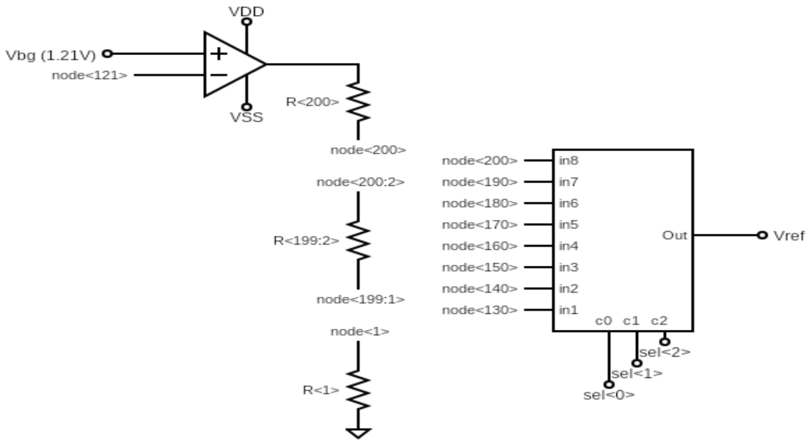

Figure 1. Simple multilevel reference generator

The diagram shown contains a differential amplifier, a series of resistors and three-order multiplexer. A series of two hundred resistors is connected at one end to the output of the operational amplifier and at the other to ground. A positive input voltage of 1 . 21 volts is given to the positive input of the operating amplifier, which is received from a voltage source based on the semiconductor band gap [Feng, Wang, et al., 2013].

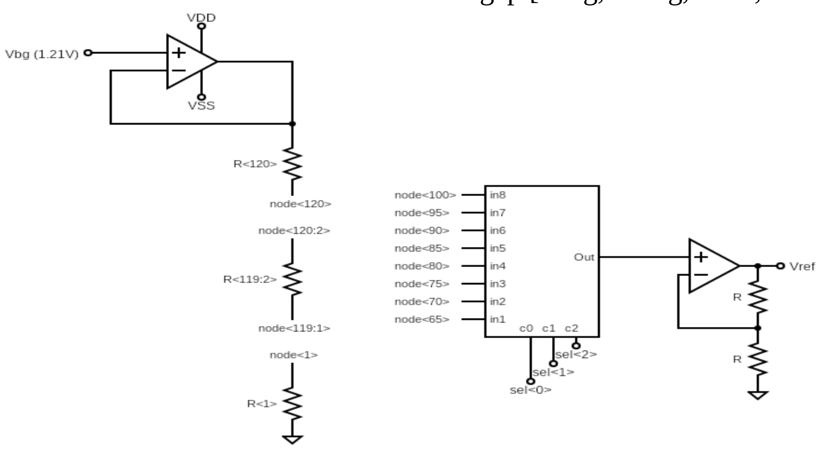

Figure 2. Multilevel reference generator with an output buffer

The point connecting the 120 and 121 resistors is connected to negative input of amplifier, which will be regulated at the value equal to the positive input due to the negative feedback, therefore the voltage drop across each resistor will be 1 . 21 Volt ÷ 121 = 10 millivolts. The inputs of the multiplexer are connected to different points in the series of resistors, and the output is selected by the input selected by the digital control code. The circuit is designed with 90 nm technological process input/output elements used in nodes with a nominal supply voltage of 2.5 volts [Melikyan, 2009]. In this multi-level voltage generator architecture, two problems with power supply headroom are obvious.

- A drop in supply voltage level below 2 volts will deviate all reference levels
- Installing a current load at the output will increase the voltage drop from the series of resistors from the selected wire to the output, creating a potential problem with the supply voltage headroom.

To avoid the possibility of these problems, the solution shown in Figure 2 was given. This solution uses a simple multi-level voltage generator, from which it receives half of the required levels, ie a maximum of 1 Volt, and the multiplier added to the output multiplies these levels by two. In this structure, the problem with the power load is completely eliminated, and the reference levels do not deviate as the power drops. Only the output multiplier is limited by supply drops. Figure 3 shows the operation of the two circuits in the event of a normal operation and supply voltage brown-out.

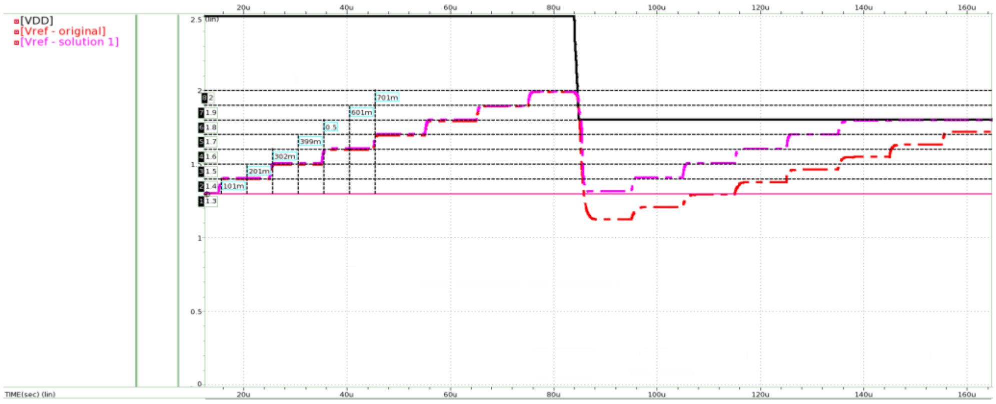

Figure 3. Output levels of two circuits during normal supply level and power brown-out

As expected, all levels of the first circuit deviate when the supply voltage level is less than the generator maximum level. In the case of the second circuit, all the levels below the supply have asserted the intended values.

***Proposed solution*.** Although the above method closes the gaps in the problem of the power supply headroom, it creates a new problem of increasing the area, as the number of differential operational amplifiers used in the design doubles. To avoid this problem, the design shown in Figure 4 is suggested. The proposed design differs from a simple multi-level generator only in that the output level selected by the multiplexer is connected to the output of a differential opera-tional amplifier. This virtually disconnects the resistors above the selected level from the circuit of the resistor divider, which allows to obtain a reference level below any supply voltage. Figure 5 shows a simplified version of the operation of the two circuits. As can be seen in Figure 5, in the proposed circuit, the output level selected at that point is short-circuited to the output of the operating amplifier; it becomes the highest point of the voltage divider; Figure 6 shows the operation of the proposed scheme under unstable supply conditions. As can be seen, the proposed design provides a solution to the problem of the power supply headroom without the use of an output multiplier.

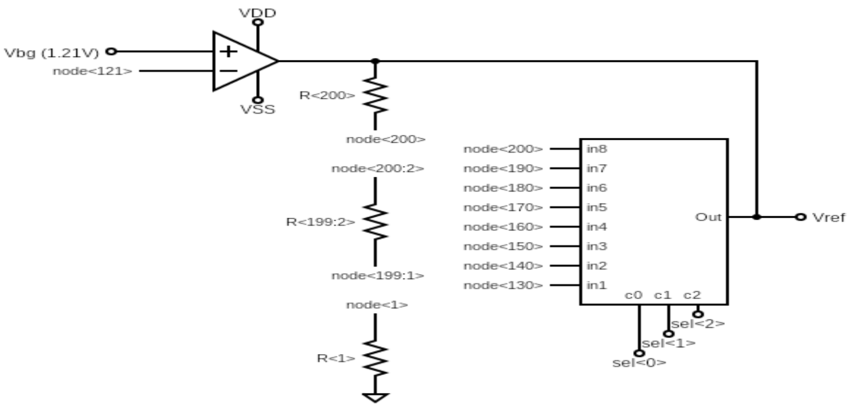

Figure 4. Proposed multilevel reference generator

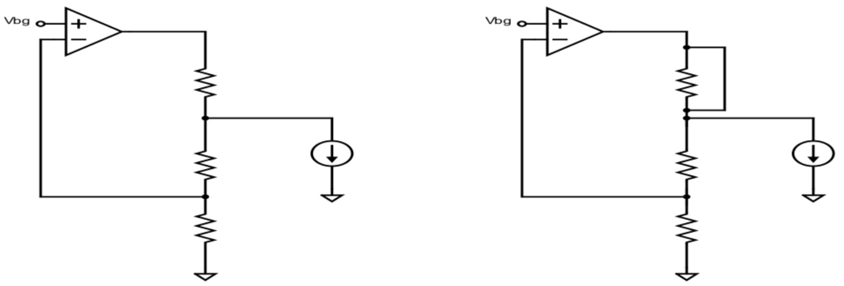

Figure 5. Simplified circuits of existing(right) and proposed(left) circuits

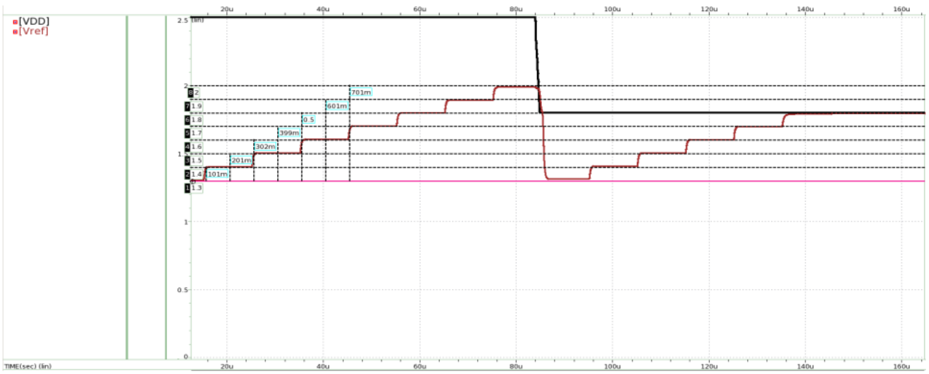

Figure 6. Operation of the proposed design under unstable supply conditions

Conclusion. The main disadvantage of the proposed design is the complication of the design and testing stages. Depending on the control digital input signals, the operating amplifier feedback multiplier also changes, so it becomes necessary to check the amplitude-frequency and phase-frequency characteristics for all output levels (Everett Rogers, 2005).

Designed for the SAED 90 nanometer technological process, multi-level support voltage generators with three different structures were studied. The problem of the power supply headroom in multi-level generators has been studied, its consequences and the solution of these problems in the structure of the output multiplier. A new solution to the problem of the power supply headroom has been proposed, which is not inferior to the simple structure in terms of both size and energy consumption, at the same time repeating the functionality of the structure with output multiplier.

References.

1. Kristian Vättö, 2015 Mixed Read/Write performance - Intel SSD 750 PCIe SSD Review: NVMe for the Client,
Abed, Sa'Ed. (2020). Reducing Write Latency by Integrating Advanced PreSET Technique and Two-Stage-Write with Inversion Schemes. Journal of Computers. 15. 22-36. 10.17706/jcp.15.1.
2. Chao Feng, Jinhui Wang, Wei Wu, Ligang Hou and Jianbo Kang, "CMOS 1.2V bandgap voltage reference design," 2013 IEEE 10th International Conference on ASIC, 2013, pp. 1-4, doi: 10.1109/ASICON.2013.6812039.
3. Goldman, Ronald & Bartleson, K. & Wood, T. & Kranen, Kevin & Cao, C. & Melikyan, Vazgen & Markosyan, Gayane. (2009). Synopsys' Open Educational Design Kit: Capabilities, Deployment and Future. 20 - 24. 10.1109/MSE.2009.5270840.
4. Everett Rogers, "Stability analysis of low-dropout linear regulators with a PMOS pass element", 2005, Texas Instruments

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Supply headroom issue in multi-level reference voltage generators and proposed solutions

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In this research paper, SAED 90 nanometer technological process was used to design and simulate three different multi-level reference voltage generator architectures. The study examines supply headroom issue in multi-level voltage generators, it's consequences and solution through an output multiplier architecture. A new method is proposed, that eliminates supply headroom related issues just as well as output multiplier design, whilst maintaining the layout area and energy consumption of the simple architecture.