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The impact of undervolting on the parameters of selected graphics cards

Stanisław Szabłowski[1*], Adrian Pękalski[2]

[1] Dr. Eng., Professor, Institute of Technical Sciences, State University of Applied Sciences, Przemyśl Poland

[2] M.Sc. Eng. Institute of Technical Sciences, State University of Applied Sciences, Przemyśl Poland

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***Corresponding author:** Stanisław Szabłowski

Dr. Eng., Professor, Institute of Technical Sciences, State University of Applied Sciences, Przemyśl Poland

Abstract

The study presents the results of research on the impact of undervolting on the operating parameters of selected graphics cards, focusing on the PNY GeForce RTX 4070 Ti and Gigabyte models. GeForce RTX 2070 Super. Analysis shows that undervolting can effectively improve the energy efficiency of graphics cards with minimal impact on their performance.

It has been found that there is an optimal level of undervolting that maximizes the benefits of energy efficiency while maintaining satisfactory performance. In addition, undervolting helps to reduce the operating temperature of components, which can translate into quieter operation and potentially longer device life. These results indicate the significant potential of undervolting as a method for optimizing power consumption and managing the performance of computer hardware.

Keywords: *undervolting, graphics card, computer games*

Introduction

The growing interest in computer games, computer graphics, and data processing using GPU hardware acceleration contributes to the rapid development of the graphics card market. At the same time, increased application requirements lead to an increase in the demand for computing power and higher energy consumption. Increasing the energy efficiency of electronic devices and searching for methods to optimize the operation of computer equipment is currently gaining priority. Undervolting, as a process of reducing voltage, is an attractive method of optimizing the operation of the GPU.

The aim of the research conducted by the authors of the study was to understand and evaluate the impact of undervolting on the parameters of selected graphics card models, with particular emphasis on their performance, energy efficiency and work. This

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study focuses on undervolting as a potential method of reducing energy demand while maintaining or even improving the performance of computer components.

In the available scientific and technical literature, the topic of power supply voltage modification, especially in the context of undervolting , is more often described in relation to processors, while information about its impact on graphics cards often comes from computer enthusiasts and enthusiasts. There is a significant lack of academic research on the latest series of graphics cards, despite the fact that this market is developing dynamically and presents new models and technologies every year. This prompted the authors to undertake new research on the impact of undervolting on the work of the GPU (Pękalski, 2024).

Literature Review

When analyzing undervolting, an important aspect is the relationship between power consumption and signal latency. In the publication (Prajapati, 2016) an analysis of different types of delay lines was carried out, showing that modifying the supply voltage can affect the power consumption of digital delay lines. The paper also investigates how changes in supply voltage affect the power consumption in different delay line configurations, including a line with series-connected inverters, NAND and NOR gates, presenting the trade-offs between power consumption and performance. Undervolting leads to a reduction in the current flow rate through the transistors, which can increase the response time (delay), but at the same time reduces the power consumption.

In this paper (Zamani, 2019), a GPU power saving technique is presented by reducing the supply voltage below the minimum operating voltage (Vmin), which allows for maximum power savings while maintaining a constant operating frequency. Since such voltage reduction can lead to errors, an algorithm-based fault tolerance (ABFT) algorithm is designed to detect and correct these errors. Various errors are empirically studied and a model of errors is developed as a function of voltage reduction levels and array sizes. Then, using this model, the proposed FT -cuBLAS -MM algorithm is configured. It is shown that the power consumption can be reduced up to 19.8%. GreenMM also improves the GFLOPS/Watt performance by 9% with a negligible performance penalty.

The article (Muc, 2020) presents research on undervolting processors as a method to reduce the consumption of electricity and heat generated by computers without negatively affecting their performance. The authors indicate that undervolting allows for a reduction in processor voltage, which translates into a reduction in energy consumption by up to 30%, especially in situations of intensive use. Experiments conducted in computer laboratories have shown that this method allows for significant energy savings and extension of the equipment's life. Undervolting is presented as a safe and easy-to-use technique, beneficial for both individual users and organizations, contributing to a more ecological use of resources.

The publication (Shuaib, 2022) focuses on the optimization of the cryptocurrency mining process using graphics cards (GPU). The main goal is to reduce energy consumption and increase the efficiency of cryptocurrency mining through overclocking and undervolting. Researchers compare these methods with existing approaches and illustrate the benefits of their use, especially in the context of Monero mining using the RandomX algorithm. Hardware optimization, including managing power consumption and GPU computational efficiency, allows for a more profitable and environmentally sustainable mining process.

The work (Leng, 2015) focuses on the study of the effectiveness of voltage reduction in graphics processing units (GPU). The aim of the research is to determine safe limits for voltage reduction in GPU to maximize energy savings while maintaining stable system operation. This work introduces a direct measurement method, enabling a more detailed understanding of the impact of voltage reduction on GPU performance and power consumption, which is crucial for designing more energy-efficient computing systems.

Methodology

The basic research questions were formulated as follows:

1) Q1: How does undervolting affect power consumption and computing performance in typical usage scenarios?
1) Q2: How does undervolting affect the energy efficiency of graphics cards?
2) Q3: Does undervolting effectively reduce the temperature and fan speed of graphics cards?

In response to the research problems posed, the following hypotheses were adopted:

1) H1: Undervolting leads to improved graphics card energy efficiency at the cost of decreased performance.
2) H2: There is an optimal level of undervolting that maximizes energy efficiency without compromising performance.
3) H3: Undervolting GPU reduces the temperature and speed of graphics card fans.

The research was conducted on a series of experiments conducted using specialized software for monitoring and modifying the operating parameters of graphics cards. The tests included various usage scenarios, from intensive gaming sessions to advanced calculations using the GPU. The GPU voltage was set to three levels: 0, 1 and 2, where undervolting is levels 1 and 2. The following card parameters were measured:

- power consumption (Watts [W])
- operating temperature (degrees Celsius [°C])
- average FPS (frames per second [fps**]**)
- 1% Low FPS ((frames per second [fps])
- 0.1% Low FPS ((frames per second [fps])
- FPS/10W (frames per second/10 Watt [fps/W **s**]))

To verify the hypotheses, a natural experiment was used in two groups.

Experimental group:

This group consisted of two graphics cards that were undervolted. The voltage settings were reduced in a controlled manner using specialized software.

The goal was to observe the impact of undervolting on the performance, operating temperature, power consumption, and stability of the graphics card. The graphics cards were used in typical scenarios, such as gaming and graphics rendering.

Control group:

It consisted of identical graphics cards that did not have undervolting. The graphics cards in this group were also used in identical scenarios as in the experimental group.

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The test subjects are PNY GeForce RTX 4070 Ti and Gigabyte GeForce RTX 2070 Super, based on the Turing architecture (table 1).

Table 1
Graphics card parameters

Parameter	RTX 4070 Ti	RTX 2070 Super
Architecture	Ada Lovelace	Turing
Technological process	5nm	12nm
CUDA Cores	7680	2560
Amount of RAM	12GB	8GB
Memory Clock Speed	21000MHz	14000MHz
Memory Bandwidth	504.2 GB/s	448.0 GB/s
Release date	January 3, 2023	July 2, 2019

Source: https://www.nvidia.com/pl-pl/geforce/graphics-cards/compare/?section=compare-20

Research tools used were carefully selected for their unique properties and ability to precisely measure and analyze the effects of undervolting.

One of the tools was MSI Afterburner, used to change graphics card settings, including voltage changes. MSI Afterburner is widely regarded as one of the most intuitive and comprehensive graphics card tuning programs. Its ability to precisely adjust voltages and monitor the health of the graphics card makes it an ideal choice for controlling undervolting .

Graphics performance was assessed using 3DMark, a widely respected and widely used benchmarking software. 3DMark provides comprehensive graphics card performance tests, simulating various load scenarios, allowing for a thorough analysis of the impact of undervolting on performance.

The next tool was CapFrameX , used for recording measurements and data analysis. CapFrameX is an advanced tool for recording and analyzing performance data in games and applications, offering detailed tracking of parameters such as frames per second (FPS) and frame rendering times. This is crucial for assessing the impact of undervolting on fluidity and stability in real-world conditions of use.

The final test tool chosen for the study was Cyberpunk 2077 Phantom Liberty. Using this game as a benchmark allowed us to test the graphics card in a realistic and graphically demanding scenario. It is one of the most graphically demanding games on the market. Using this game in the study provided a realistic test of GPU performance under graphically intensive load conditions, which is important for assessing the effectiveness of undervolting in everyday use.

RTX 4070 Ti Test Results Discussion

The graphics card parameters at different undervolting levels are presented below (tables 2 and 3).

Table 2

RTX 4070 Super card measurement results in 3DMark benchmark

Sensor	Unit	Level 0	Level 1	Level 2
GPU Core	MHz	2872	2854	2580
GPU Memory	MHz	10502	10502	10502
GPU Fan	%	69	59	50
GPU Fan	RPM	2311	2002	1708
GPU Core	%	100	100	100
GPU Memory	%	55	55	55
GPU Power	W	273,4	226,4	174,7
GPU Core	°C	65	58	50
GPU Voltage	V	1,093	0,995	0,895
GPU Memory Exee	GB	5,40	5,41	5,40
GPU Memory Used	GB	6,60	6,59	6,60
GPU Memory Total	GB	11,99	11,99	11.99

Table 3

RTX 4070 Super Card measurement results in Cyberpunk 2077

Sensor	Unit	Level 0	Level 1	Level 2
GPU Core	MHz	2880	2865	2580
GPU Memory	MHz	10502	10502	10502
GPU Fan	%	64	56	49
GPU Fan	RPM	2240	1964	1713
GPU Core	%	96	96	96
GPU Memory	%	81	98	93
GPU Power	W	220,9	179,8	133,4
GPU Core	°C	61	55	49
GPU Voltage	V	1,095	0,995	0,895
GPU Memory Free	GB	2,24	0,22	0,85
GPU Memory Used	GB	9,49	11,78	11,14
GPU Memory Total	GB	11,99	11,99	11,99

Figures 1 and 2 show the graphics card performance results for three different undervolting levels.

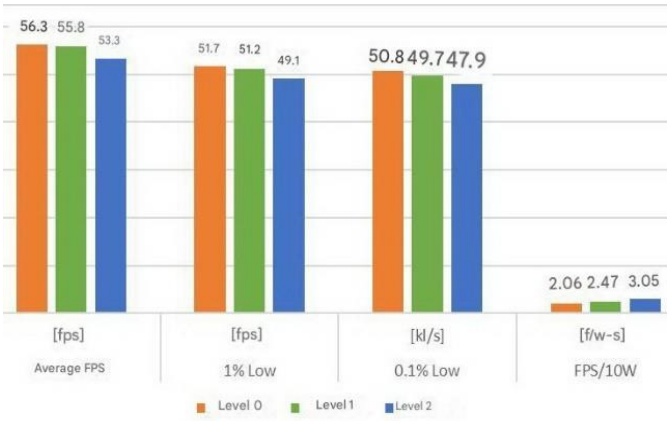

Figure 1. FPS measurement results in 3Dmark

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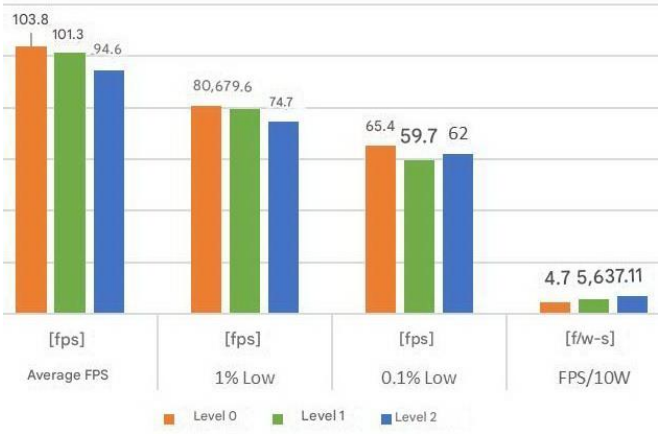

Figure 2. FPS measurement results in the Cyberpunk 2077 game

Undervolting effectively lowered power consumption, GPU core temperature, and fan speeds, resulting in quieter and cooler operation. The power consumption reduction at level 2 reached a whopping 56.50% in 3DMark tests and 65.59% in Cyberpunk 2077, which is a significant indication of increased energy efficiency.

While there is little impact on overall performance at undervolting level 1, lowering the voltage more can lead to noticeable drops in frame rates. In Cyberpunk 2077, the average FPS drop at level 2 was 9.73%, showing that there is a limit beyond which further undervolting negatively impacts performance.

The voltage reduction also affected the card's stability in high-load scenarios, as seen in the 1% Low and 0.1% Low FPS results. In Cyberpunk 2077, at undervolting level 2, 1% Low FPS dropped by 7.9%, and 0.1% Low FPS improved compared to level 1, which could indicate better stability with further voltage reduction.

Despite some loss in peak performance, undervolting significantly increased FPS for every 10W of power. At level 2 in Cyberpunk 2077, power efficiency increased by 33.9%.

Analysis shows that undervolting does not affect the amount of available and used GPU memory, suggesting that the process does not negatively impact graphics card memory management.

RTX 2070 Super Test Results Discussion

The graphics card parameters at different undervolting levels are presented below (tables 4 and 5).

Table 4

The results of the RTX 2070 Super card parameters measurement in the 3DMark benchmark

Sensor	Unit	Level 0	Level 1	Level 2
GPU Core	MHz	2017	2029	1925
GPU Memory	MHz	7001	7001	7001
GPU Fan	%	51	50	48
GPU Fan	RPM	1567	1534	1474
GPU Core	%	100	100	100
GPU Memory	%	84	83	83
GPU Power	W	205,6	191,5	162,9
GPU Core	°C	50	50	46
GPU Voltage	V	1,025	0,981	0,902
GPU Memory Free	GB	1,31	1,35	1,35
GPU Memory Used	GB	6,69	6,65	6,65
GPU Memory Total	GB	8,00	8,00	8,00

Table 5

RTX 2070 Super card parameter measurement results in Cyberpunk 2077

Sensor	Unit	Level 0	Level 1	Level 2
GPU Core	MHz	2025	2025	1892
GPU Memory	MHz	7001	7001	7001
GPU Fan	%	53	55	51
GPU Fan	RPM	1634	1713	1566
GPU Core	%	94	95	95
GPU Memory	%	95	95	95
GPU Power	W	196,9	184,3	141,0
GPU Core	°C	52	54	51
GPU Voltage	V	1,040	0,981	0,870
GPU Memory Free	GB	0,40	0,43	0,39
GPU Memory Used	GB	7,60	7,38	7,61
GPU Memory Total	GB	8,00	8,00	8,00

Figure 3 shows the graphics card performance results for three different undervolting levels.

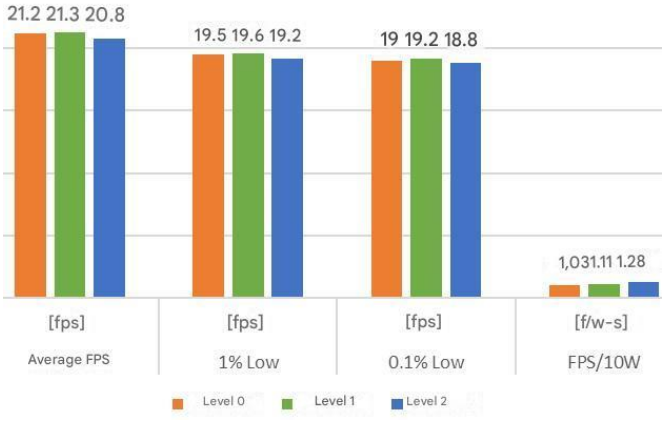

Figure 3. FPS measurement results in 3DMark.

For the RTX 2070 Super, the reduction in power consumption was noticeable at undervolting levels 1 and 2, 191.5[W] and 162[W] for 3DMark and 184.3[W] 141[W] in Cyberpunk. Fan speeds also

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showed a downward trend, suggesting a positive impact on energy efficiency.

Undervolting at level 1 resulted in a slight performance increase of 0.47% and 1.13%**,** while level 2 reduced FPS by 0.4 [fps] and 2.4 [fps],

The 1% Low and 0.1% Low FPS results for Level 1 undervolting showed stability improvements of 0.51% and 1.04% during the benchmark test and 3.14% and 5.71% during gaming. Level 2, on the other hand, presented a decrease of 1.56% and 1.06% and 1.74% and 1.38%. For the RTX 2070 Super, the changes in performance were minor, indicating that undervolting can contribute to more stable operation of the card without a significant loss in performance.

Energy Efficiency Improvement: The biggest differences are in FPS/10W. The first level showed an increase of 7.21% and a whopping 19.53% for 3DMark and 7.55% and a whopping 25.73% for Cyberpunk, which shows that undervolting can be an effective way to improve the card's energy efficiency.

No impact on memory amount and management: In this case also the GPU memory amount and frequency were not affected by undervolting .

Conclusions

The research hypotheses were tested separately for both tested models:

1. PNY GeForce RTX 4070 Ti

Reducing voltage at both levels results in more frames per second per 10[W] and less average FPS. Hypothesis H1 was confirmed for both levels.

Undervolting at level 2 significantly improves energy efficiency at the cost of a large decrease in performance. Hypothesis H2 is confirmed.

Undervolting reduces fan speed and graphics card operating temperature. Hypothesis H3 was confirmed for levels 1 and 2.

2. Gigabyte GeForce RTX 2070 Super

The use of undervolting resulted in an increase in the number of frames generated for every 10 watts of power consumed. A marginal improvement in performance was observed at the first level, which confirms hypothesis H1 for the first stage of voltage reduction. Hypothesis H1 was not confirmed for level 2.

Undervolting leads to better energy efficiency, but at the cost of lowering overall graphics performance. Thus, hypothesis H2 is confirmed by the research results.

Undervolting caused a decrease in the operating temperature and a decrease in the fan speed, which indicates a positive effect on the device's operating culture. Such observations confirm the compliance with hypothesis H3 at two levels of undervolting.

The analyses show that the use of undervolting can significantly affect the performance of graphics cards, with these effects varying depending on the GPU model. For the PNY GeForce RTX 4070 Ti, both an improvement in energy efficiency and a reduction in the average number of frames per second (FPS) were observed, which confirmed hypothesis H1 at both undervolting levels. A deeper reduction in the supply voltage showed significant benefits in terms of energy efficiency, at the cost of a significant drop in performance, thus confirming hypothesis H2. Additionally, reducing the voltage had a positive effect on GPU performance, confirming hypothesis H3.

For Gigabyte GeForce RTX 2070 Super, undervolting also contributed to the improvement of energy efficiency, which was especially visible at the second, undervoltage level. The first undervoltage level showed a slight, performance improvement, which partially confirmed hypothesis H1. The analysis also confirmed that greater undervoltage increases energy efficiency at the cost of reduced performance, consistent with hypothesis H2. Furthermore, voltage reduction resulted in lower operating temperatures and fan speeds, confirming hypothesis H3.

In summary, the research has shown that undervolting is an effective method to increase the energy efficiency of graphics cards while having a minimal impact on their performance. In addition, this process has a positive effect on the operation of the devices, making them quieter and cooler. The results of the research can be valuable information for users and manufacturers of graphics cards.

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