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Performance analysis of amd ryzen 5 4600h mobile processor undervolting using AMD APU tuning utility on cinebench R23

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ABSTRACT

In an effort to optimize laptop performance for gaming and high-demand applications without costly hardware upgrades, this research investigates the impact of CPU undervoltage using the AMD Ryzen Mobile 4600H processor. Undervolting, the process of reducing the CPU's voltage supply, is proposed as a strategy to enhance performance by lowering operational temperatures, potentially allowing for more efficient processing. This study uses the AMD APU Tuning Utility to adjust voltage settings and assesses performance changes using a series of benchmarks. Initial findings indicate that undervoltage can indeed have beneficial effects. The most significant data point from the research is the comparison of Cinebench R23 scores before and after applying undervolting settings. From a baseline score of 6835 points, system performance increased to 7880 points in the optimal undervolting scenario, an improvement of 1045 points. This shows a noticeable enhancement in processing efficiency. However, the study also reveals some complexities in undervolting, such as an initial drop in performance in the first configuration before gains are realized in subsequent adjustments. Efficiency values varied across different settings, starting with a decrease (-0.41) and culminating in a substantial gain (+1.54) by the fourth configuration. These results suggest that while undervolting can improve performance, the outcomes depend significantly on finding the right voltage balance, highlighting the nuanced nature of CPU voltage manipulation for performance optimization.

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1. INTRODUCTION

In recent years, advances in laptop technology have considerably improved the user experience by integrating sophisticated hardware and more capable software solutions [1]. In particular, gaming on laptops has become increasingly demanding due to the rapid evolution of game design, reflecting complexities comparable to real-world scenarios such as sports and warfare simulations [2]. Despite these advances, many users still face performance problems due to hardware specifications that barely meet or quickly become outdated with ever-evolving software requirements [3]. This often leads to increased costs as users are forced to upgrade components like RAM, storage, or even transition from HDDs to faster SSDs to maintain a satisfactory gaming experience [4]. A prevalent method to improve desktop CPU performance is overclocking, where hardware capabilities extend beyond manufacturer specifications, provided the existing components support modifications [5]. However, laptops present unique challenges due to their compact design and limited thermal management capabilities, making traditional overclocking methods less feasible. Instead, undervoltage emerges as a viable alternative [6]. Undervolting involves operating the CPU at subnominal voltage levels without reducing frequency, exploiting the conservative voltage margins set by manufacturers. This technique not only reduces heat generation and power consumption, but can also enhance performance by maintaining lower operating temperatures, aiming to improve power and energy efficiency in various computer systems without compromising functionality [7].

Previous research has demonstrated various techniques to optimize laptop performance through hardware and software adjustments. Studies such as those by Neil [8] and Thapa [9] have explored the effects of component updates on gaming laptops, showing temporary improvements in performance. In contrast, research by Muc et al. [10] on undervolting desktop CPUs highlighted significant gains in efficiency and thermal performance, suggesting potential applicability to laptops. Furthermore, a comparative analysis on overclocking [11] [12] [13] versus undervoltage [10] [14] revealed that while both methods enhance performance, undervolting is typically safer and more sustainable in thermally limited environments like laptops [15]. However, these studies focus primarily on short-term performance enhancements without considering long-term stability and cost-effectiveness, which are crucial for average users. Furthermore, comprehensive studies specifically addressing the AMD Ryzen 5 Mobile 4600H processor, its compatibility with undervolting, and its holistic impact on laptop performance across various applications remain scarce. This research aims to bridge this gap by systematically exploring the impact on the AMD Ryzen 5 Mobile 4600H processor using the AMD APU Tuning Utility [16]. It seeks to validate whether undervolting can consistently improve performance without the adverse effects associated with traditional overclocking methods.

The AMD APU Tuning Utility (AATU) is an open source tool designed to fine-tune AMD Ryzen processors, particularly focusing on the mobile editions found in laptops. This utility, developed by contributors to the Ryzen Controller project, allows users to control power limits and optimize the performance of their AMD APUs. It is compatible with Ryzen Mobile APUs from the 2000 series up to experimental support for the 6000 series, and it can also be used on desktop APUs. The tool includes presets for easy application of optimized settings, making it accessible even to users without extensive technical knowledge. AATU enables users to unlock additional performance from their Ryzen processors. Depending on configuration and usage, users can achieve performance gains ranging from 5% to more than 35%, which can significantly extend the useful life of their hardware without the need to purchase new equipment [17] [18]. The utility includes various performance modes:

1) Adaptive Eco Mode: Reduces the power limit of the APU over time to extend battery life while maintaining as much performance as possible [17].
2) Adaptive thermal design power (TDP) refers to the maximum amount of heat that a computer processor is designed to dissipate under a typical workload. It is a critical parameter in processor design because it determines the cooling requirements and influences the performance and energy efficiency [19]: Adjust power limits to find the optimal balance of performance based on the APU's temperature and load of the APU [17].
3) Turbo Boost Overdrive (TBO): Modifies power management algorithms to dynamically adjust clock speeds according to load, power limits, and temperatures, particularly by improving integrated GPU performance [17].

Although primarily aimed at mobile APUs, AATU can also be used on desktop APUs. It supports various series including the 2000, 3000, 4000, 5000, and experimental support for the 6000 series. The tool includes presets for easy application of optimized settings.

The main research question centers on the efficacy and safety of undervolting as a sustainable performance optimization technique in gaming laptops, particularly focusing on the balance between performance enhancement and system stability. This study intends to quantify performance improvements in gaming and high-demand applications through systematic undervolting of the AMD Ryzen 5 Mobile 4600H processor, evaluate the thermal and energy consumption changes resulting from undervolting to determine its effectiveness in enhancing the longevity and stability of laptop performance, and compare these results with traditional component upgrades to assess cost-effectiveness and practicality for average users. This research focuses on a specific processor within the context of gaming laptops, employing a methodologically rigorous approach to assess both the immediate and long-term implications of undervolting, thus filling a critical gap in existing literature on sustainable computing practices.

2. METHOD

The AMD Ryzen 5 Mobile 4600H CPU is the subject of investigation integrated into the ASUS TUF Gaming A15 laptop and will undergo undervolting due to its exceptional balance of performance and efficiency, crucial for computational research and demanding applications. Featuring a robust 6-core, 12-thread configuration with a base clock of 3.0 GHz and a boost clock of up to 4.0 GHz, it excels in handling intensive tasks such as simulations, data analysis, and machine learning algorithms. Its significant potential for undervoltage further enhances its attractiveness by reducing power consumption and thermal output without compromising performance, which is vital for laptops where thermal management is paramount. This capability allows the processor to maintain or even improve its performance under reduced voltage conditions, making it ideal for optimizing computational efficiency and sustainability in energy-constrained environments [20] [21]. The AMD APU Tuning Utility is a software application designed by JamesJC, sbski, and ProjectSBC to optimize the performance of processors in laptops [17]. An application was released to optimize AMD processors by enabling undervoltage and unlocking more functions. This research requires several stages, including the preparation of software materials and media for undervoltage, the configuration of the AMD APU Tuning Utility, and the execution of undervolt testing after the configuration. If the system is in a stable state, proceed with benchmark testing on the synthetic benchmark program. If the system is unstable, repeat the configuration process of the AMD APU tuning utility. Following benchmark testing, an examination of the undervolt data is conducted.

Configure AM AMD APU Tuning Utility

All software utilized in this research must be prepared and capable of operating. If the software is not compatible, the remedy is to utilize a substitute that has identical functions and features. Furthermore, the default settings for each software have not been modified to meet the undervoltage requirements. As a result, there is a noticeable contrast between the performance before and after the undervoltage is implemented. This function involves adjusting the setup and voltage identification digital (VID) of the AMD APU Tuning Utility to meet the specific requirements for undervoltage. The adjustments will be made gradually, reducing the voltage at each step. If a scenario fails or the system is unstable, the configuration settings will be repeated to achieve the stability target. Default system testing: All system configurations will default to see the difference in the benchmark results before and after undervoltage. This initial score will be an important reference for the scenario to compare the two configurations. The aim is to increase the score in each scenario that will be executed; the CPU VID value at default is 1200, which means 1.2 V.

Undervolt Testing

Undervolt testing will occur after the default set-up has been benchmarked and an initial score has been received. Four benchmarking test scenarios will be carried out using the undervoltage method. The criterion is that the system must be stable when testing. In the 4 test scenarios, every time a benchmark test is carried out, there will be a 15-minute delay so that overheating does not occur and the data look even or balanced. This synthetic benchmark test is the score after undervolting. In these four scenarios, the findings will be given for each voltage differential, which is gradually lowered and used to calculate the final outcomes analysis. Analysis of these results compares two settings, namely the default and undervolting systems. They are explained as monitoring logs or statistics in the form of temperature, time, voltage, and scores from benchmarking. This is the final difference between the two setups considering their influence on the benchmarking score. The following is the flow of the research carried out, as illustrated in Figure 1.

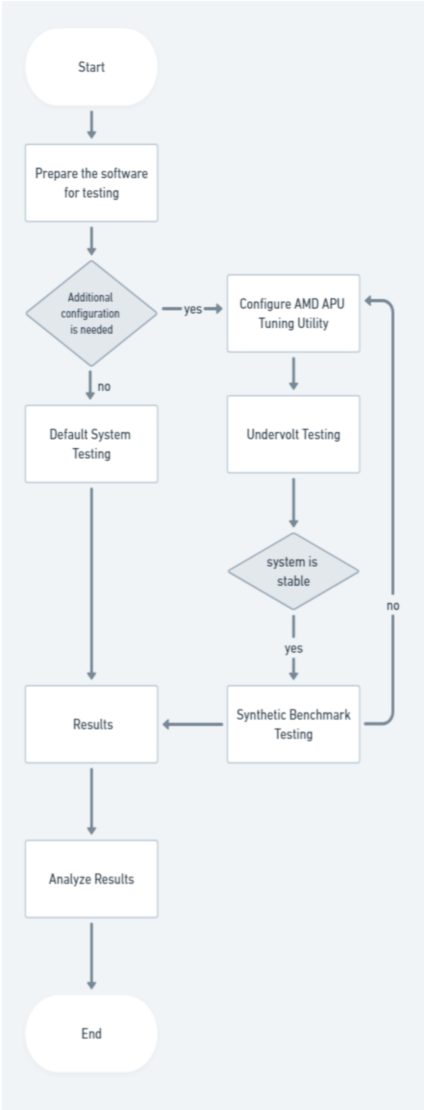

Figure 1. Research flow

Analysis System Defaults

At this step, researchers need parameters that will be used to study the effect of undervolting on the processor, consisting of the processor temperature, the core voltage used, and the core TDP package required by the processor when running the Cinebench R23 benchmark 10 times. These parameters will run on the hardware listed in Table 1 and the software used in Table 2.

Table 1. Hardware components

Component	Component name
Processor	AMD Ryzen 5 Mobile 4600H
GPU Slot 1	AMD Radeon™ Graphic
GPU Slot 2	NVIDIA GeForce GTX 1650 Ti
RAM Slot 1	V-Gen 8GB DDR4-3200
RAM Slot 2	Micron Technology DDR4-3200
SSD	M.2 512 GB PCIe® NVMe™

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Cooler	Arc Flow Fan™ (self-cleaning)
Mouse	Rexus Xierra X15

Table 2. Software applications

Application	Type
Cinebench R23	Synthetic Benchmark Application
AMD APU Tuning Utility	Undervolting Application
CPU-Z	Monitoring Application
HWiNFO	Monitoring Application
Generic Log Viewer	Sensor Log Recording Application

Experimental Design

To achieve undervoltage on laptop devices that employ AMD Ryzen processors, the parameter altered in the AMD APU Tuning Utility application is Core Voltage Identification Digital (VID). The default core voltage value averages 1.167 Volts from the preceding stage settings. The researchers carried out four testing of the undervolting system in phases considering stability and compatibility to avoid a loss in processor performance when performing the Cinebench R23 benchmarking test and will drop the voltage by -0.050 Volts in 4 experiments to exhibit the system design in Table 3.

Table 3. Experimental design

Digital core voltage identification digital	Operating mode	Cooling mode
-0,050 Volt	Turbo	Turbo
-0,100 Volt	Turbo	Turbo
-0,150 Volt	Turbo	Turbo
-0,200 Volt	Turbo	Turbo

3. RESULTS AND DISCUSSIONS

To establish the initial default settings and access the information, use the Armory Crate application, which is the pre-installed application provided by ASUS TUF. This program may alter the mode diagram the user requires and adjust the type of cooling system rotation speed. This research will exclusively utilize Turbo mode during the entire duration to optimize performance and distinguish it from other modes that impose severe restrictions on all offered capabilities. Turbo mode will make the processor perform at a frequency of 3.3 to 4.0 GHz. The cooling system or fan will move in Turbo mode, which means the fan will move at high rates, 80% to 100%, 5700 RPM CPU fan and 5500 RPM GPU Fan, as illustrated in Figure 2.

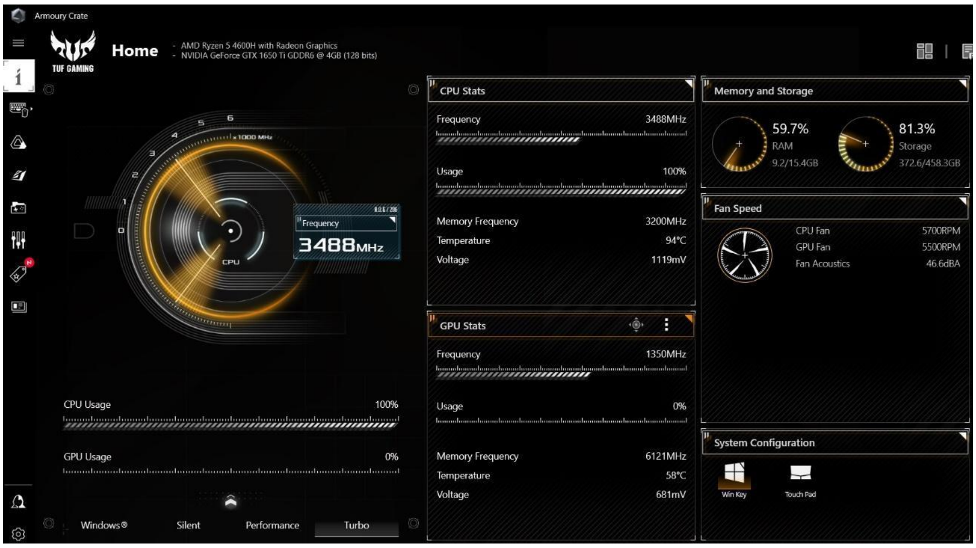

Figure 2. Armory crate profile

Figure 3. Sample run 1 test Cinebench R23 benchmark score

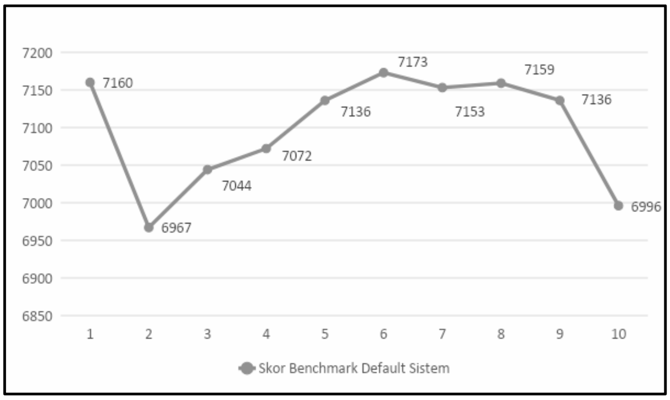

Figure 4. Overall results of 10 runs cinebench R23 benchmark score

In 10 repeats of the testing, the highest number attained was 7098 points and the lowest was 6573 points. The results of the study indicate that undervolting the AMD Ryzen 5 Mobile 4600H CPU can significantly enhance its performance while improving thermal efficiency. The initial default settings using Turbo mode yielded Cinebench R23 benchmark scores ranging from 6573 to 7098 points over ten runs. After the system's performance of the system was markedly improved, with the most significant score reaching 7880 points. This improvement demonstrates that undervolting can effectively increase the CPU's processing efficiency by lowering the operating voltage, which in turn reduces power consumption and thermal output. The acquired parameter values will be utilized as a comparison for the system that will be initiated, which is given in Figure 3, Figure 4, and Table 4.

Table 4. System default parameters

Parameters	Lowest	Highest	Average
Cinebench R23 score	6573 pts	7098 pts	6835 pts
Voltage	1,1 V	1,167 V	1,288 V
Watts power	3,535 W	29,86 W	54,11 W
Temperature	40,4°C	77,23 °C	95,5 °C

Cinebench R23 testing was carried out on an SSD storage system on the default system or after undervolting, recording score results, and recording sensors using HWiNFO64 as shown in Figure 5 and monitoring using GenericLogViewer, the results of which are presented in Table 4 above.

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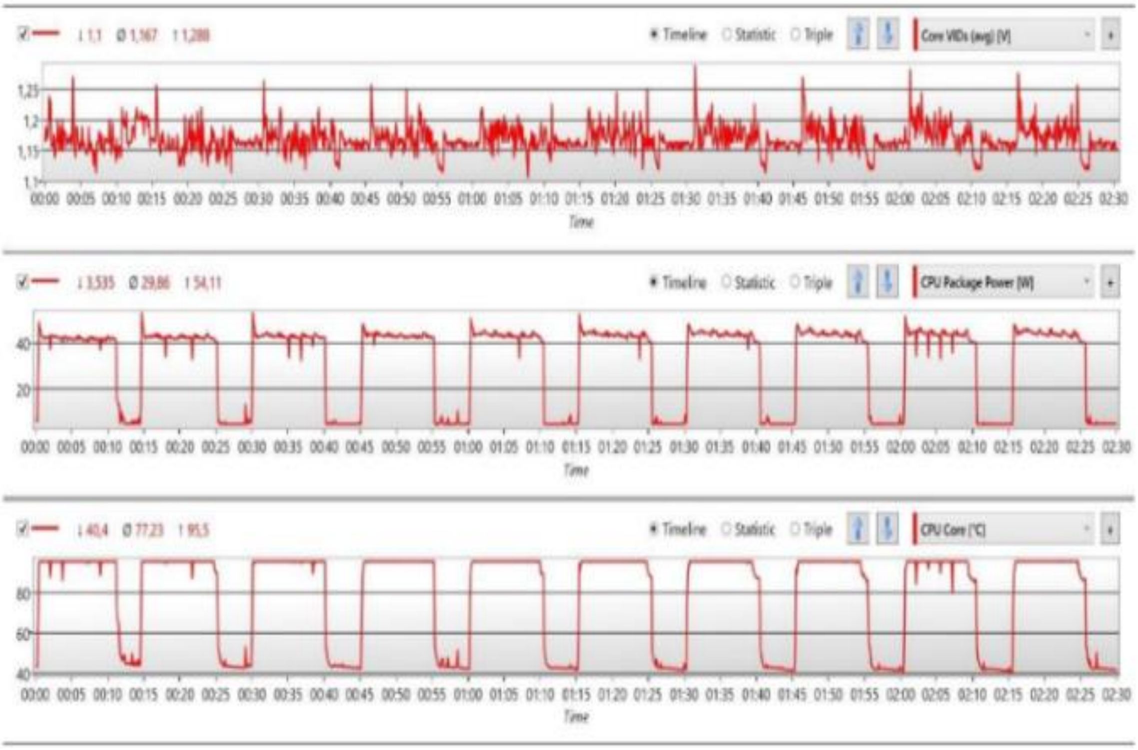

Figure 5. Default system sensor recording

Undervolting Experiment Scenario

According to the system design plan, there are 4 test scenarios for the system where undervolting will be carried out as shown in Table 5.

Table 5. Undervolting experiment scenario

Scenario	Voltage identification definiton	Operating mode	Cooling mode
1st	-0,050 V	Turbo	Peformance-Turbo
2nd	-0,100 V	Turbo	Peformance-Turbo
3rd	-0,150 V	Turbo	Peformance-Turbo
4th	-0,200 V	Turbo	Peformance-Turbo

Table 5 illustrates how the system will be set up for digital voltage identification, where the first undervolting will be -0.050 Volts, the second undervolting will be -0.100 Volts, the third undervolting will be -0.150 Volts, and the fourth undervolting will be -0.200 Volts. This can be seen in the AMD APU Tuning Utility, which is shown in Figure 6.

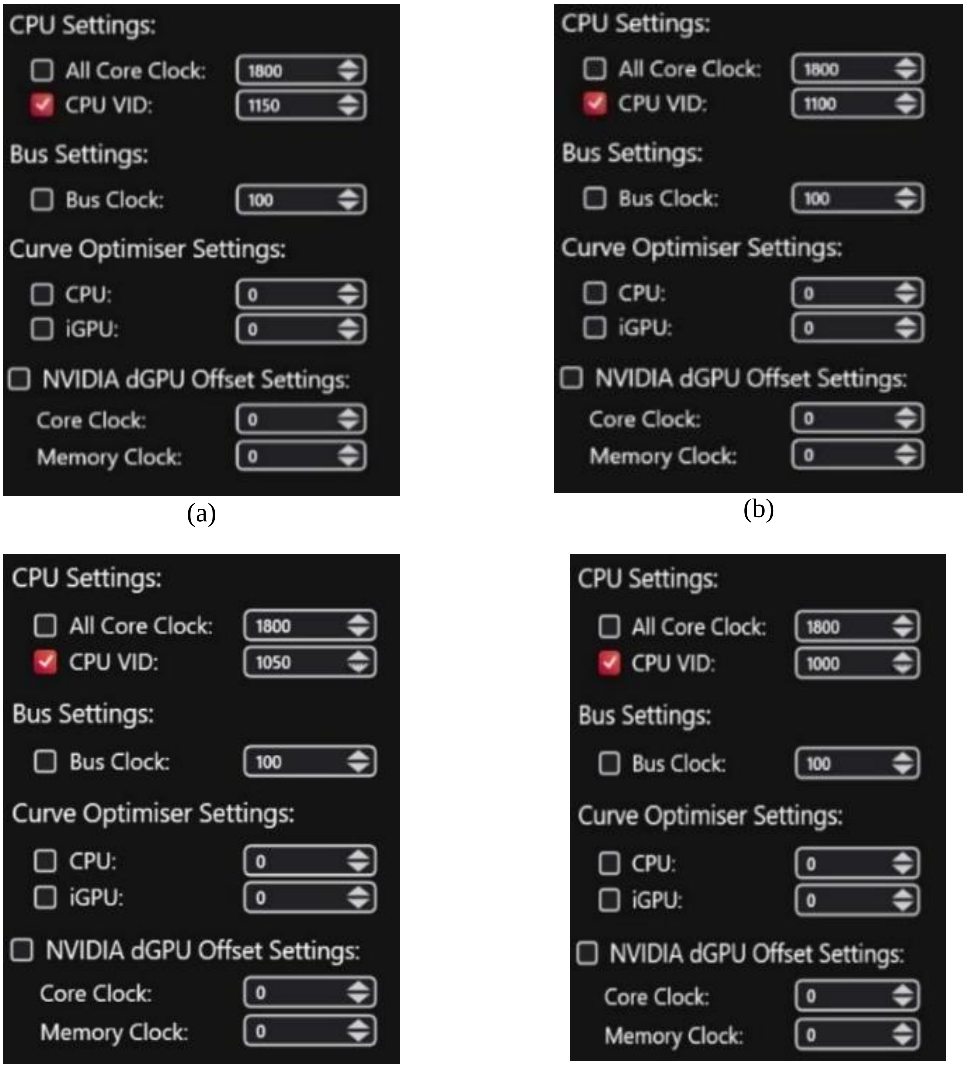

Figure 6. All AMD APU tuning utility undervolting experiments

Initially, the default CPU voltage identification (VID) value is set at 1200, equal to 1.2 Volts.

1) First Undervolting: The voltage is dropped by 0.050, altering the CPU VID value to 1150, which amounts to 1.15 Volts. After performing this adjustment, the voltage is reduced to 1.15 Volts.
2) Second Undervolting: The voltage is further dropped by 0.100, setting the CPU VID value to 1100, or 1.1 Volts. After implementing this change, the voltage is lowered to 1.1 Volts.
3) Third Undervolting: The voltage is dropped again by 0.150, changing the CPU VID value to 1050, or 1.05 Volts. After implementing this adjustment, the voltage is lowered to 1.05 Volts.
4) Fourth Undervolting: The voltage is further dropped by 0.200, resulting in a CPU VID value of 1000, equal to 1 Volt. After performing this adjustment, the voltage is reduced to 1 Volt.

Adjusting the CPU VID parameters as stated progressively reduces the voltage according to the undervoltage plan. Each step corresponds to a specific reduction in voltage, as mentioned above.

Undervoltage Configuration Stability Test

After configuring the first to fourth undervolting of the stability of the system, the setup will be checked using a stress test in the AIDA64 Extreme application for 10 minutes. The system has completed a

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stress test for 10 minutes without incurring system failure or system restart, as shown in Figure 7. Therefore, the first to fourth configurations can be used as test configurations against simulated benchmarks.

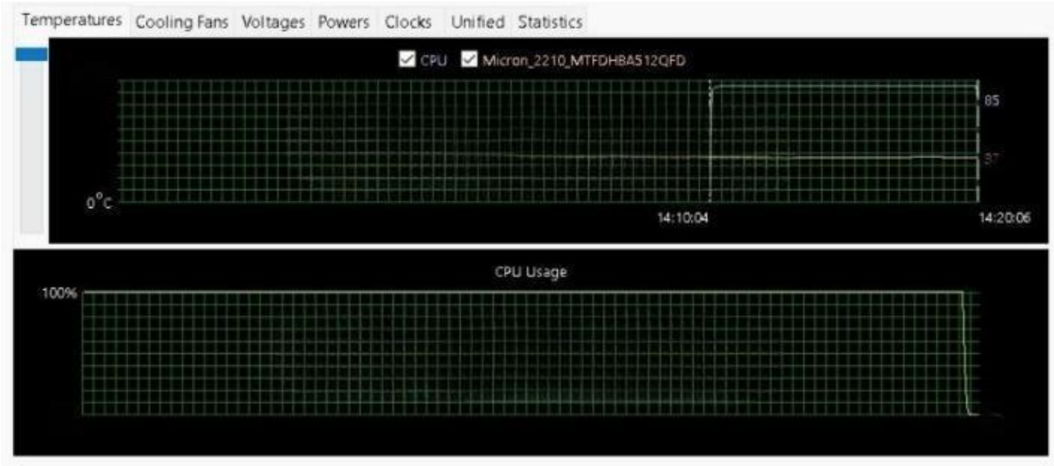

Figure 7. Fourth results of the stability test results

Testing Phase

After implementing the configuration and verifying the system stability, the next stage is the benchmarking testing stage for each configuration. That is, the machine will execute the Cinebench R23 synthetic benchmark ten times. The temperature, voltage, and wattage on the processor will be recorded during the test using the HWiNFO64 application. Data will be processed using the Generic Log Viewer tool and the Cinebench R23 score. Table 6 summarizes the results of the testing phase for each undervoltage configuration, showing the average, maximum, and minimum values for temperature, power consumption, and voltage. The data from Table 6 indicate that undervoltage can significantly reduce average and maximum temperatures, power consumption, and voltage, enhancing CPU efficiency and thermal performance. The -0.200 V configuration provides the best results, with the lowest average temperature (73.89°C) and power consumption (27.23 W), suggesting that it is the most effective undervolt setting among those tested. This reduction in temperature and power consumption demonstrates the potential for undervoltage to improve thermal management and energy efficiency in the CPU, which is critical for maintaining optimal performance in a thermally constrained environment like a laptop.

Table 6. Results of the testing phase

Undervolting configuration	Avg. temperature (°C)	Max temperature (°C)	Min temperature (°C)	Avg. power (W)	Max power (W)	Min power (W)	Avg. voltage (V)	Max voltage (V)	Min voltage (V)
-0,050 V	80.26	95.1	45.8	28.92	51.29	3.479	1.144	1.281	0.706
-0,100 V	76.53	96.1	40.5	29.61	54.05	3.541	1.1	1.267	0.662
-0,150 V	80.42	95.9	47.1	28.59	51.7	3.591	1.074	1.26	0.668
-0,200 V	73.89	97	41.5	27.23	52.03	3.585	1.068	1.267	0.662

Comparison Phase

The following stage is the stage of comparing the findings of the system test. The default for each undervolting setting is related to the efficiency of processor performance relative to the resulting temperature by dividing the average Cinebench R23 score by the average processor voltage, watts of power and processor temperature as a comparison. The results of the comparison stages are in Table 7.

Table 7. Results of the comparison phase

Undervolting configuration	Voltage difference (V)	Power difference (W)	Temperature difference (°C)	Cinebench R23 score difference (pts)	Efficiency value (undervolted)	Efficiency value (default)	Efficiency difference
-0,050 V	0.23	-0.94	6.37	239	8.84	9.25	-0.41
-0,100 V	0.67	-0.25	2.64	437	9.56	9.25	0.31
-0,150 V	0.93	-1.27	6.53	761	9.51	9.25	0.26
-0,200 V	0.99	-2.63	0	1045	10.79	9.25	1.54

Table 7 helps to understand how each undervoltage level impacts the overall system performance, power efficiency and thermal behavior—for instance, reducing the voltage by -0.200 V results in the highest efficiency gain (+1.54) and the most significant performance improvement (+1045 pt) without increasing the temperature. On the contrary, a reduction in -0.050 V marginally affects efficiency (-0.41), but still delivers a considerable performance improvement (+239 points). This analysis is critical for optimizing the balance between processor performance and power efficiency.

After carrying out all the comparison stages of each undervolt configuration with the default system, the parameter values are obtained as in Table 8, which is the average value of each configuration test result, and there is a maximum temperature parameter value for the processor.

Table 8. Comparison of average parameters for all system configurations

Information	System default	Undervolting configuration			
		1	2	3	4
Undervolting configuration	-0,000 V	-0,050 V	-0,100 V	-0,150 V	-0,200 V
Cinebench R23 score (pts)	6835	7074	7074	7614	7880
Temperature (°C)	73.89	80.26	76.53	80.42	73.89
Max temperature (°C)	95.5	95.1	96.1	95.9	97
Voltage (V)	1.167	1.144	1.100	1.074	1.068
Power (W)	29.86.	28.92	29.61	28.59	27.23
Efficiency value	9.25	8.84	9.56	9.51	10.79

A comparison of efficiency values and growth for all system configurations can be given in Table 9. The growth in the efficiency value is the growth value from the difference in the prior configuration value.

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Table 9. Comparison of efficiency values for all system configurations

Information	System default	Undervolting configuration			
		1	2	3	4
Undervolting configuration	-0,000 V	-0,050 V	-0,100 V	-0,150 V	-0,200 V
Efficiency values	9.25	8.84	9.56	9.51	10.79
Growth in efficiency value	0	-0.41	+0.31	+0.26	+1.54

The fourth configuration has the highest growth value of all the previous setups, namely +1.54. This configuration shows the most significant improvement, with the highest positive growth value (+1.54). It indicates a substantial increase in performance and efficiency, making it the best configuration among the tested ones. The second highest position is in the second undervoltage setup, namely +0.31. This configuration has the second-highest improvement, with a positive growth value of +0.31. It represents a notable but smaller improvement in performance and efficiency compared to the fourth configuration. Next, the highest place is the third, in the third undervolt configuration of +0.26. This configuration shows a moderate improvement, with a positive growth value of +0.26. Although it enhances performance, it does so to a lesser extent than the second and fourth configurations. The lowest or fourth position is in the initial undervolting configuration with a drop in efficiency value of -0.41. This configuration results in a decrease in efficiency with a negative growth value (-0.41). It indicates that this configuration did not improve performance and may have even hindered it, making it the least effective configuration tested. Thus, the fourth option is the configuration with superior CPU performance, as evidenced by the Cinebench R23 score obtained, with the average temperature being the same or the same as the default system configuration. The third undervolting setup has the highest average temperature among all configurations, with CPU performance exceeding the default system, as evidenced in the Cinebench R23 score results.

4. CONCLUSION

Based on the configuration outcomes of all test scenarios that have been carried out, the performance of the AMD Ryzen 5 Mobile 4600H CPU after undervolting increased marginally, as shown from the results of the default system and the fourth undervolting configuration, with an improvement in the efficiency value reached, namely +1.54 Efficient. The effect on Cinebench R23 from the default system to undervolting is fairly good, with the average difference between the default system being 6835 pts and the fourth undervolting configuration at 7880 pts, with an average increase of 1045 pts demonstrating quite a good shift. The difference between the default system and the full undervolting setup is comparable; the comparison of efficiency numbers from the first to the fourth configuration is: (-0.41):(+0.31):(+0.26):(+1.54). The initial undervoltage configuration even reduces processor performance. Undervolting the AMD Ryzen 5 Mobile 4600H CPU is not suggested for undervolting because the difference is not significant from the normal setup. This is different from the Intel vendor processor, which has a large difference after undervolting because Intel also provides a particular application for configuring the processor.

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