



AMD Ryzen Processor and AMD Ryzen Master Over-clocking User's Guide



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Revision History

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March 2, 2017	1.0	Public release

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This information describes methods to change factory settings and operate the processor outside of AMD's published operating specifications. Recipient understands that operation of the product outside of AMD's published specifications will void any AMD warranty and that overclocking of the processor may impact its functionality and longevity.

Chapter 2 Supported Products and Operating Systems

This document and the AMD Ryzen Master application currently support the following AMD products:

- AMD “Ryzen” Processor family in the AM4 socket infrastructure

Future AMD products will be added when supported.

AMD product overclocking support provided by AMD OverDrive™ and the AMD Ryzen Master application are mutually exclusive.

The AMD OverDrive™ application remains the sole AMD-provided overclocking tool for the following AMD products:

- Processor products in the AMD AM3 and AM3+ socket infrastructures
- Processor products in the AMD FM2 and FM2+ socket infrastructures

The AMD Ryzen Master application is supported on the following operating systems:

- Microsoft Windows 10 64-bit version

Chapter 3 Introduction to AMD Ryzen Processor Overclocking

Systems based on the AMD Ryzen processor may be tuned to deliver added system performance. The AMD Ryzen family of processors offer an exciting amount of performance tuning options, including potential overclocking headroom. Note that each processor and motherboard is different, and may result in lower or no overclocking margin. *Examples of processor configurations, cores and frequencies described herein are examples only and do not necessarily reflect commercially available products or overclocking range.*

AMD Ryzen Master gives users advanced, real-time control of system performance. More details on how to use the AMD Ryzen Master application are included in the “AMD Ryzen Master Application” section of this guide.

The purpose of this document is to provide detailed information on the various performance tuning knobs that are present in systems using the AMD Ryzen processor based on AMD's Zen processor core.



Figure 1: AMD Ryzen Processor

Chapter 4 AMD Ryzen Processor Overclocking Summary

AMD AM4-based Ryzen processors are unlocked when paired with the enabling AMD chipsets and necessary BIOS software and therefore allow the user to adjust the CPU clock above or below the stock value. When run on boards enabled for overclocking, AMD Ryzen Master will automatically enable the Overclocking Mode at the user's initiation of a change to a stock parameter. The CPU will be returned to stock operation through a system power cycle.

The process for finding a stable overclocking configuration with the AMD Ryzen processor is not fundamentally different from the previous generation AMD processors (such as the AMD FX processors). The final operating voltages and frequencies will depend highly on the specific system's processor, motherboard, cooling solution, operating environment, and the user's decisions on what elements to overclock and to what degree.

4.1.1 AMD Ryzen Processor Normal Operation

To describe how the AMD processor operates in Overclocking Mode it is best to understand how the AMD Ryzen processor operates normally. When operating normally, the AMD Ryzen processor has the following characteristics:

1. The frequency of processor core clock is determined by a combination of the software-requested p-state and then adjusted by a combination of numerous power and performance optimizing features to attain any of number of fine grain p-states around that software-requested p-state.
2. Internal control mechanisms measure internal temperatures, power and current consumption, and manage the operating voltage and frequency of various internal cores to maintain specified levels. For example, when the number of active cores is below a pre-determined threshold, the active core temperatures are below maximum, and the consumed total current is below infrastructure limits, then those active cores will be boosted in voltage and frequency to the c-state "boost" frequency until any of those conditions are no longer true.
3. The voltages for some of the various cores are internally generated from external supplies. For example, each of the processor cores uses a supply independently generated from the external supply. As the operating frequency for each processor core is adjusted to attain various fine grain p-states, the operating voltage of the core is adjusted to support that new frequency at optimal power consumption. The voltage adjustments are done using the internal voltage regulator and the SVI2 controlled external supply voltage, if needed.
4. Software requested p-state or halt states adjust the level of power to which those internal control mechanisms manage. For example, when software executes a HALT instruction on a processor core, that core will enter the C1 reduced-power state. If that core does not receive an interrupt to resume execution, it will progress to increasingly-lower power states until finally saving the state of the core and being powered off.

5. The internal memory controller and various other data paths will be initialized to the highest common operating frequency of any of the memory DIMMS present in the system and with memory timing parameters obtained from the DIMM resident SPD ROMs.

A fundamental assumption of the normal operation of the AMD Ryzen processor is that the surrounding system current delivery and cooling capabilities are designed to the specified levels. The complicated operation described above manages the overall AMD Ryzen processor operation to maintain those specified capabilities. But what can be done if the system provides more current and cooling than those required for normal operation?

4.1.2 AMD Ryzen Processor Overclocking Mode

The AMD Ryzen processor supports an operating mode allowing enthusiast users to directly control the operating condition of the processor to precisely tune the performance and power consumption to the extent of their specific and unique system capabilities (current and cooling) and environmental conditions (ambient temperature). This is done by allowing the user to program or run utilities to directly set the precise voltage and frequency at which the CPU operates so that the maximum performance can be achieved. This is called the Overclocking Mode. This mode still uses the processor's control methods for the external power supplies (SVI2) and internal clock generators and divisors thereby simplifying the implementation and eliminating any needs for voltage regulator overrides or external clock generators. This mode allows overclocking-capable motherboards to use the same voltage regulator controllers and the same BIOS to support normal operation and overclocking.

4.1.3 CPU Overclocking Enablement

When used on an overclocking-enabled motherboard, an AMD Ryzen processor is ready for Overclocking Mode. The processor will run normally with all internal power, voltage, and thermal management features enabled until a point in time when user-directed system software reprograms the specific voltage and frequency values to levels other than stock operating values. The following changes take effect when the values are re-programmed and the processor enters Overclocking Mode:

- 1) All enabled CPU cores operate at the newly user-programmed voltage and P0 frequency value. Adjustment of the CPU clock is in 25MHz steps.
- 2) Internal features of the processor which control the CPU operating voltage and frequency to manage the CPU temperature, current consumption, and power consumption to specified maximums are disabled so that no additional stress to system voltage regulators and thermals are induced. This includes c-state boost.
- 3) CPU low power c-states (CC1, CC6, and PC6) and software visible p-states (P1 and P2) remain operational and may be requested by software so that power savings can be achieved.
 - a. The P1 and P2 p-state tables may also be modified to adjust the voltage and frequency of the CPU when running in software-requested, reduced-performance states. These may also be left at stock values.
 - b. If the OS-level software power policy is also changed so that the CPU's power-saving p-states are not used, then these power-saving states will never be requested.
 - c. If AMD Cool'n'Quiet is disabled, then low power c-states will also be disabled.
- 4) Various internal voltage regulators supplying CPU core power are placed into bypass mode, allowing the external VDDCR_CPU to directly supply the CPU cores.

Chapter 5 AMD Ryzen Master Application

The new AMD Ryzen Master application supports AMD's new generation of Socket AM4 processors. This new application no longer includes GPU overclocking as was provided in the former AMD OverDrive™ utility. For overclocking AMD's discrete graphics cards, see the Radeon WattMan GPU Overclocking utility within the Radeon Software provided with AMD discrete graphics cards. AMD Ryzen Master is compatible with GPU overclocking tools provided by other discrete graphics card manufacturers.

AMD Ryzen Master allows the user to control various clock and voltage settings in real time directly from supported Windows Operating System. In addition to real-time control there are certain adjustable parameters – normally found only inside the BIOS menu – that require a system restart for applying the new values.

The use of the AMD Ryzen Master application requires that the user accepts the End User License Agreement and inherent risks of configuring the AMD processor to performance levels that exceed specifications and stock settings

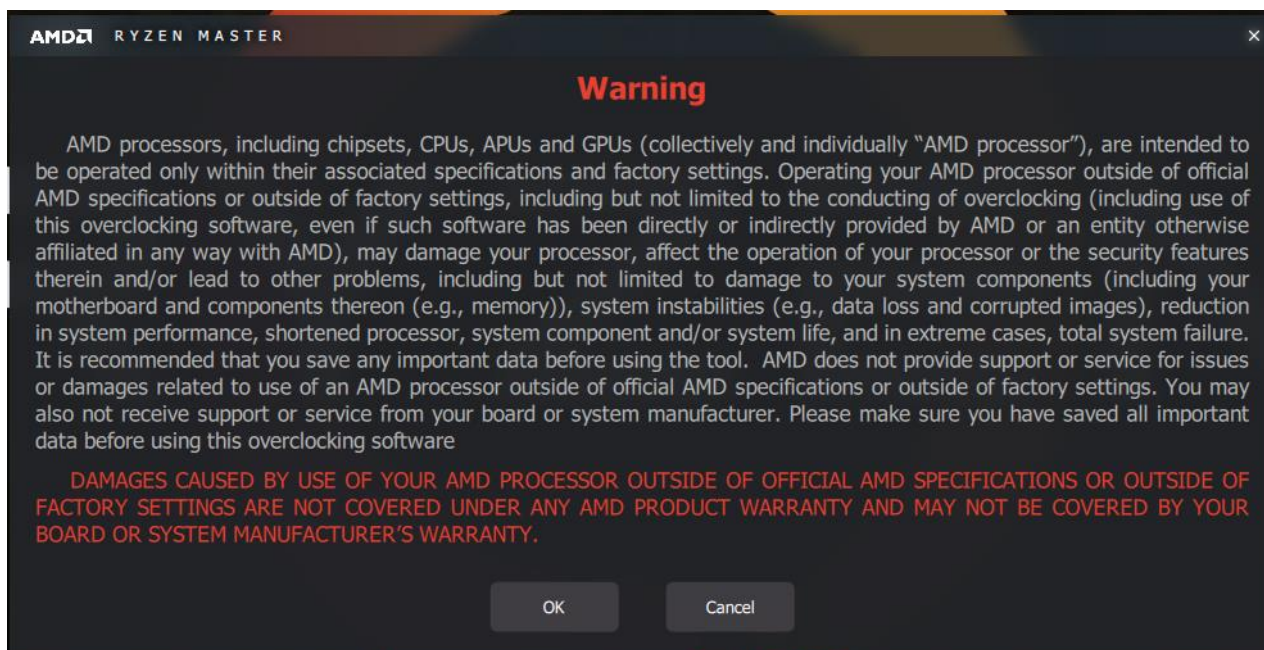


Figure 2: AMD Ryzen Master Warning and Warranty Disclaimer Message

5.1.1 Main features

AMD Ryzen Master supports the following key capabilities for AMD Ryzen processor performance-tuning and monitoring:

- CPU core clock adjustment
 - CPU clock speed slider (mouse) or via CPU clock speed text box (type in value, use mouse scroll, use up/down keyboard keys or click the up/down button)
- CPU core voltage adjustment
 - CPU VID value (type in value, use mouse scroll, use up/down keyboard keys or click the up/down button)
- CPU SOC voltage adjustment
 - VDDCR_SOC value (type in value, use mouse scroll, use up/down keyboard keys or click the up/down button)
- CPU Core Disable
 - Select 0, 2, 4 or 6 cores to disable
- Memory voltage adjustment
 - MEM VDDIO (type in value, use mouse scroll, use up/down keyboard keys or click the up/down button) and MEM VTT (type in value, use mouse scroll, use up/down keyboard keys or click the up/down button, recommended to set for one half of MEM VDDIO)
 - Note: Motherboards that do not make MEM VDDIO available to AMD Ryzen Master through BIOS will cause AMD Ryzen Master to display 0.000V for MEM VDDIO and MEM VTT. Memory clock and timing adjustment may still function within the scope of the fixed memory voltage. For detailed memory over-clocking, use the motherboard's BIOS utility.
- Memory clock adjustment
 - Memory clock horizontal speed slider (move with mouse or use mouse scroll)
 - Keyboard left/right arrow keys can also be used to adjust the memory clock
- Memory timing adjustment
 - Tc1, Trcdrd, Trcdwr, Tras and Trp clock cycle values from drop down menus
- Profiles support
 - Up to four different profiles can be created, tested and saved for use.
 - A given profile can be created to optimize core configuration and performance for a class of applications, typically based on how many cores and threads the applications tend to use.
 - With four profiles, a system with an AMD Ryzen 7 8-core processor could configure and optimize frequencies for 8-core, 6-core, 4-core and 2-core application classes, respectively. Note that a system reset will be required when switching between profiles that change enabled cores.
- Clock monitoring
 - Per-core CPU clock monitoring via Histogram (including current, average and peak clock readings)
 - Current average clock speed across all enabled cores
- CPU Temperature monitoring
 - CPU temperature monitoring via Histogram

NOTE:

- AMD Ryzen Master requires that HPET (High Precision Event Timer) is enabled within Windows 10. Please refer to Chapter 8.1 for additional information on HPET.
- AMD Ryzen Master requires that the Windows 10 Power Options be configured such that the Power Button mode is set with Fast Boot disabled. This is necessary to allow the processor cores to all be enabled after a system power cycle.

5.1.2 CPU overclocking example

Examples of CPU configurations, cores and frequencies described herein are examples only and do not necessarily reflect commercially available products or overclocking range.

The CPU core clock is by far the most important performance tuning knob available on the AMD Ryzen processor. The following example shows the necessary steps for CPU overclocking using AMD Ryzen Master.

In the below example AMD Ryzen Master has been launched while the CPU is running at the given core clock speed and CPU voltage. AMD Ryzen Master opens the Current profile (“C” profile tab in the lower left corner of the UI). The Current profile reflects the current CPU settings from boot or as applied from an AMD Ryzen Master profile; it is read-only and does not directly allow user adjustments.

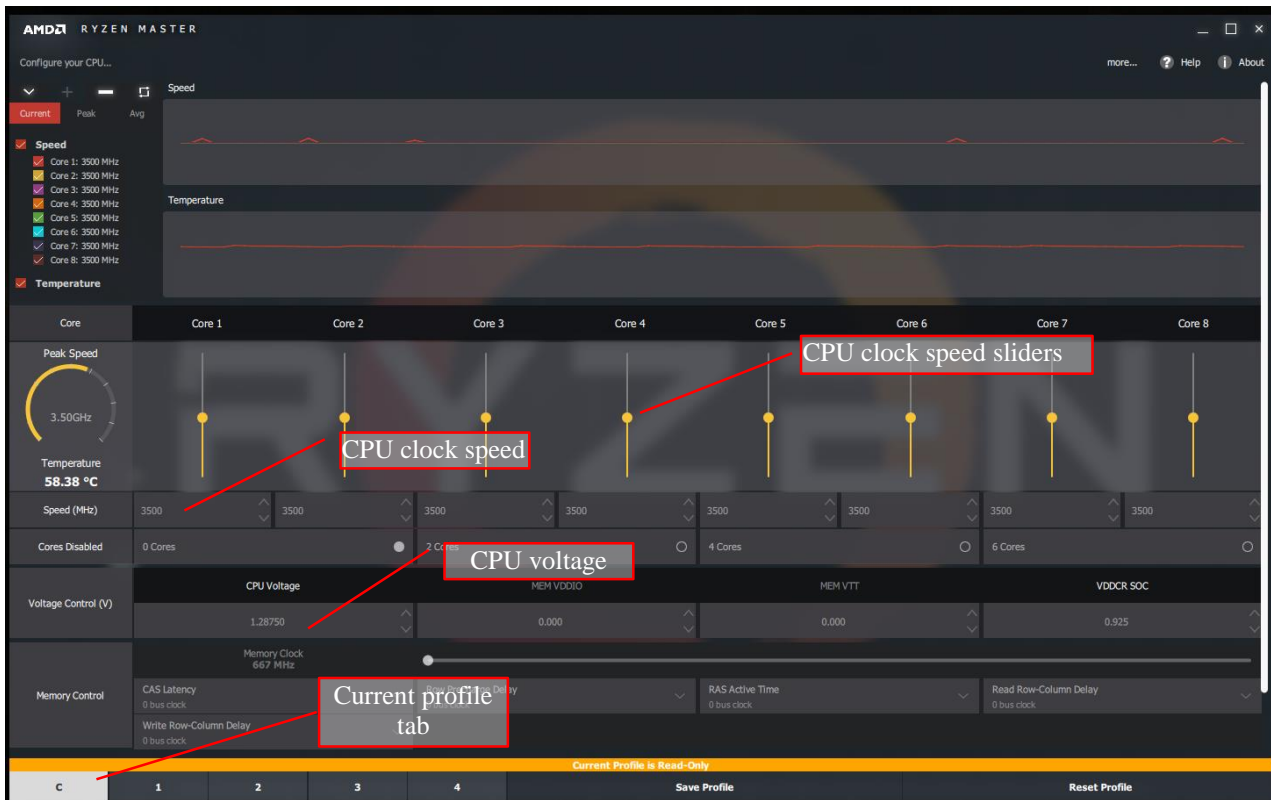


Figure 3: Current settings for AMD Ryzen Master application

The values can be adjusted by selecting one of the four user editable profiles (1 to 4). In the below example Profile 1 has been selected.

To Overclock the CPU the user needs to adjust the CPU clock. There are five ways to do this with AMD Ryzen Master:

1) dragging the yellow dot in the clock slider

2) by typing in the desired CPU clock in the text box.

3) by clicking the up and down buttons with mouse



4) by clicking the Speed text box (left mouse button) and then dialing in the desired value using keyboard up/down button

5) by activating the text box and adjusting the value with mouse scroll wheel

The CPU clock can be adjusted in 25MHz steps.

CPU Voltage can be adjusted by typing in a new value in the CPU VID text box. The example below uses a value of 1.40V. The CPU voltage can be adjusted in 0.00625V steps.

Note: Some motherboards may apply a voltage offset from the BIOS. In this case the actual CPU voltage may be higher (or lower) than what the CPU VID value suggests. It's always a good idea to monitor the actual voltage level (from the BIOS or with the motherboard vendors monitoring application).

Caution: Raising the CPU Voltage above the stock setting is the single-most contributing factor to reduced life of the processor and/or damage due to transistor over-stress and temperature. Each individual CPU unit may respond to changes in CPU Voltage differently.

The settings are not applied until the user clicks the “Apply” button in the upper right corner of the UI. Clicking “Apply” will also automatically save the settings to the active profile.

Note: Under overclocking mode all CPU Cores will operate at the same frequency and voltage.

It's a good idea to verify the performance increase and stability by running CPU performance benchmark(s) and stability tests (example: Maxon's CINEBENCH R15). Please close all background apps to ensure stable and consistent performance results run-to-run, but expect some variation.

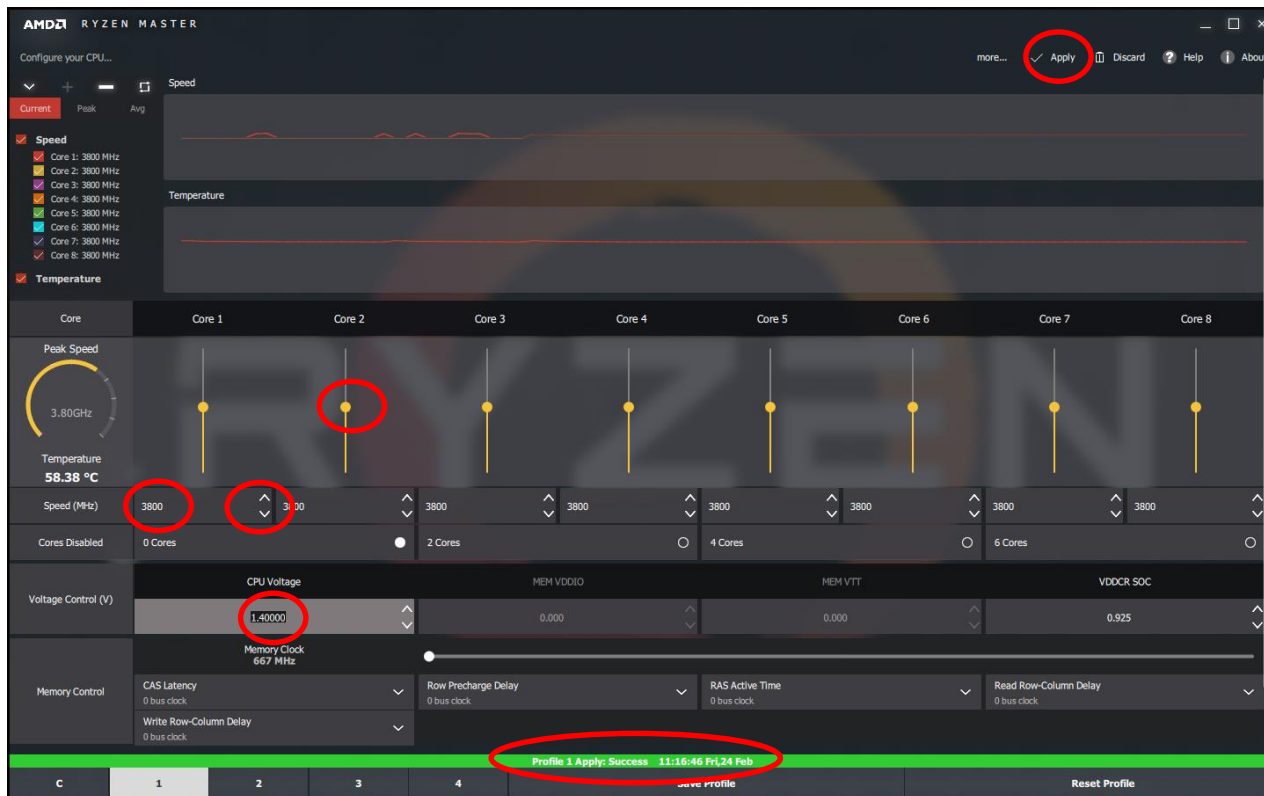


Figure 4: AMD Ryzen Master example

The recommendation is to increase the CPU clock in small steps while monitoring CPU performance, stability and CPU, motherboard, system and GPU temperatures.

Once an unstable CPU clock has been reached and the CPU temperature is not too high it's possible to increase the CPU voltage in small steps to see if the increased CPU voltage allows stable operation at higher frequencies.

The optimal settings for this profile can be saved by clicking the “Save Profile” button. To apply a saved profile, launch AMD Ryzen Master, browse to the desired profile and click “Apply”.

5.1.3 CPU Performance & Temperature Histogram

AMD Ryzen Master features a Histogram for monitoring the CPU core clock speeds and the CPU temperature. The Histogram can be expanded and minimized by clicking the \vee and \gt buttons. The Speed and Temperature histograms may be individually displayed via their respective check boxes.

The Speed Histogram graph displays the sampled current (instantaneous) clock speeds of enabled cores. The Current, Peak or Avg core clock speeds are available per core left of the Histogram. The User may select which parameter is displayed. Each Core can be individually displayed (checked) or hidden (unchecked) from the listing and the histogram. Note that the histogram only displays the Current core clock speed. A core's check box color corresponds to that core's line color in the histogram.

The Temperature Histogram displays approximate CPU die temperature averaged across a range of sensors across the die, down to 0C.

To the left of the core speed sliders is displayed the instantaneous peak speed of the fastest core and the instantaneous die temperature.

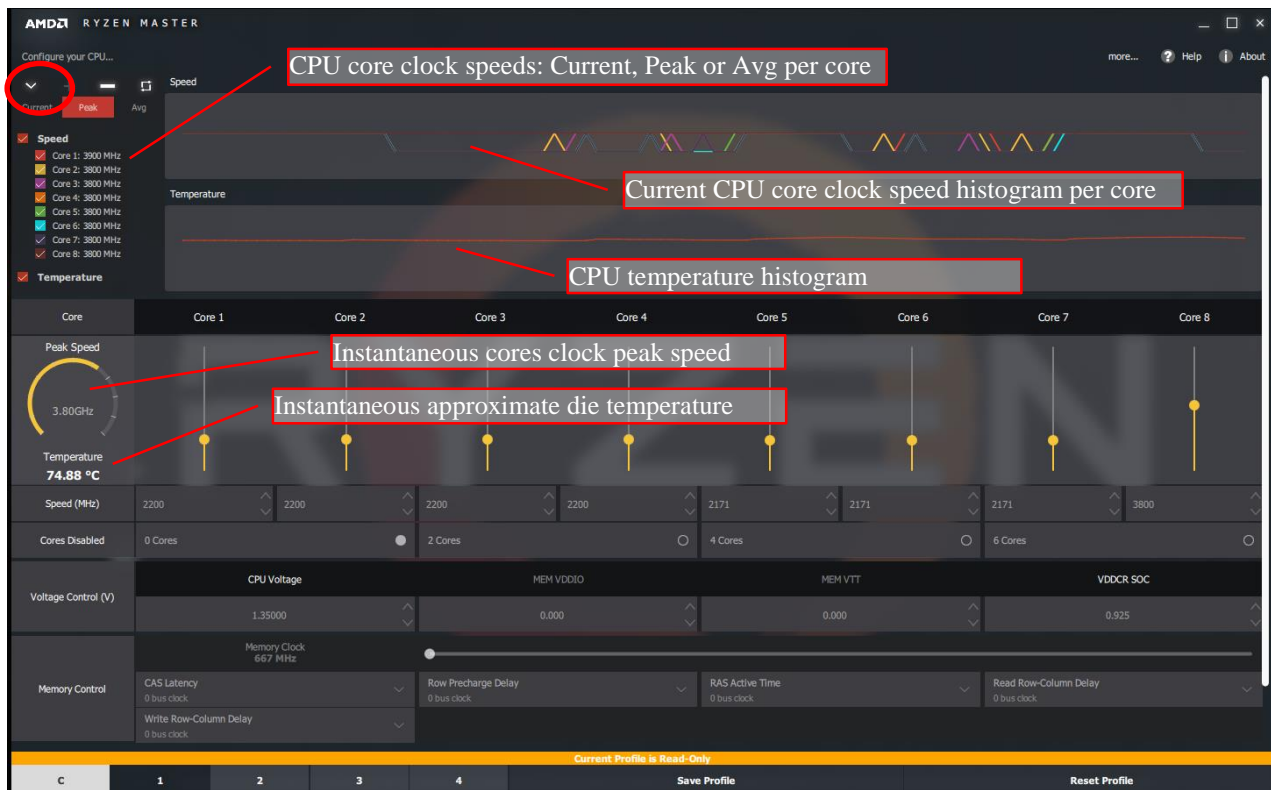


Figure 5: AMD Ryzen Master application histogram

5.1.4 Disabling Cores

The AMD Ryzen Master application allows the user to disable a select number of CPU cores. This may improve overclocking headroom for the remaining CPU cores or can be used to reduce the overall CPU power consumption. Please refer to Chapter 7 for further information on AMD Ryzen processor core configuration.

By default, the CPU runs with all cores enabled. AMD Ryzen Master supports disabling cores in pairs. For example, an 8-core AMD Ryzen processor model can be configured to disable two, four or six cores. Disabling all cores is not supported since the product would cease to function with no enabled cores.

The below example outlines the necessary steps for disabling two CPU cores which results in six enabled cores.

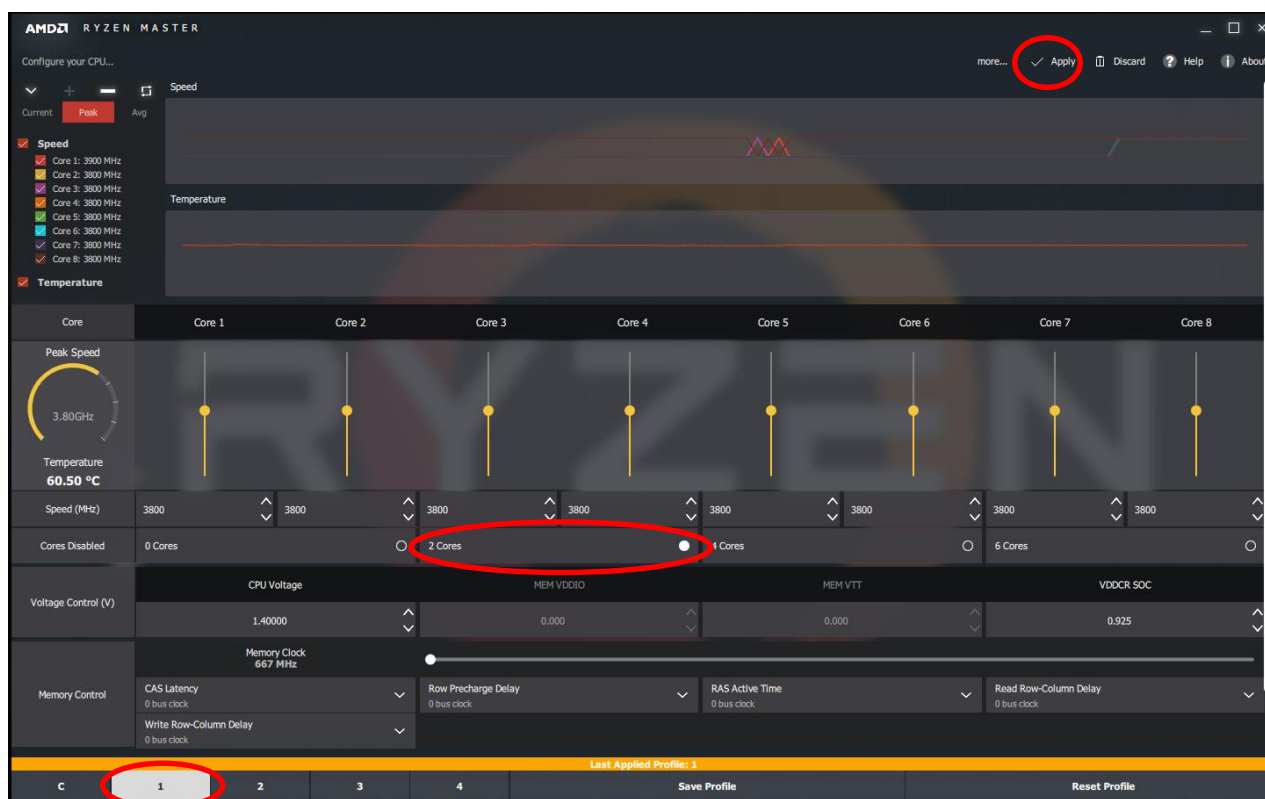


Figure 6: CPU Core Configuration – disabling two cores

The first step includes activating the user-editable Profile 1 by clicking “1” from the lower left corner. In this example two cores are disabled and the settings are applied by hitting “Apply” from the upper right corner.

Since Core Disable requires a system reboot the following pop up message will appear. Click “OK” to reboot the system or “Cancel” if you do not wish to park the cores now.

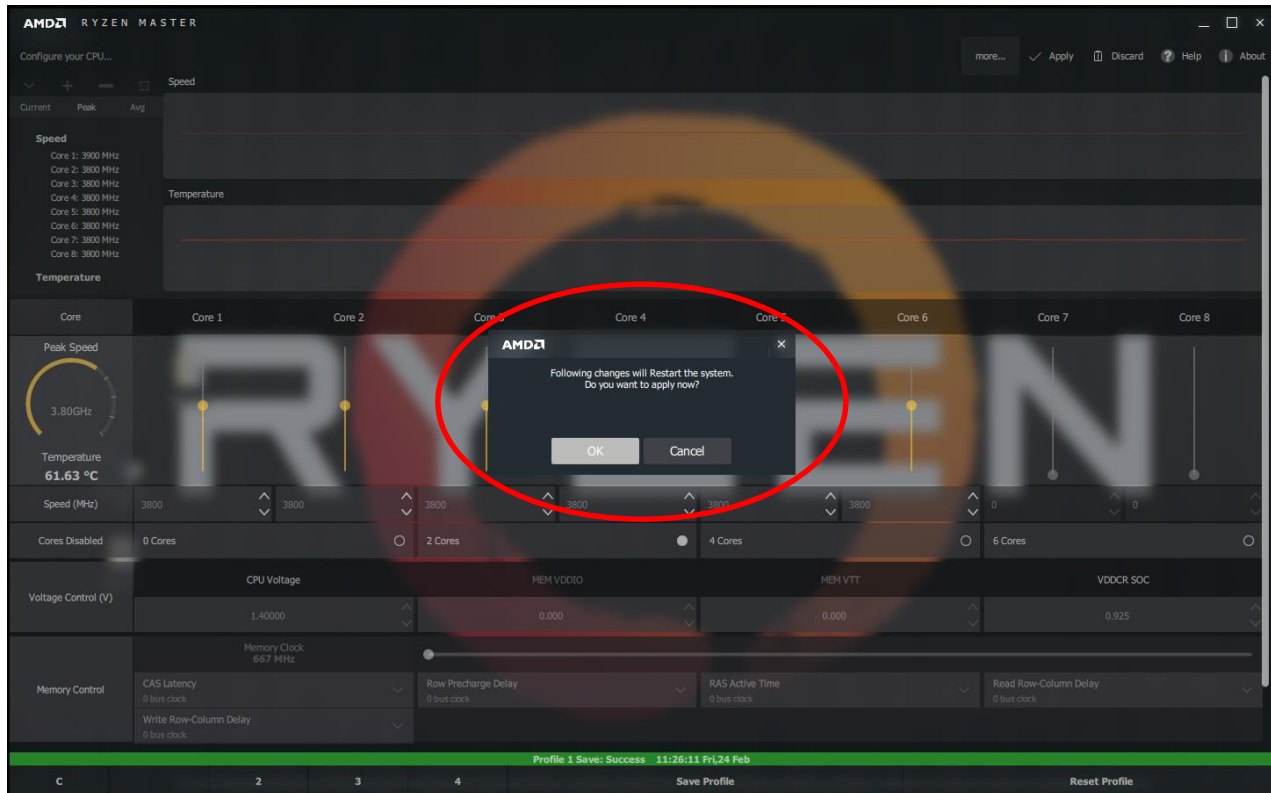


Figure 7: CPU Core Configuration – system restart pop-up

Once the system has rebooted back to the Operating System, AMD Ryzen Master is automatically launched. It is important to give the OS and AMD Ryzen Master a few moments to initialize after this step. Do not re-start AMD Ryzen Master manually or you will get the message that another instance of AMD Ryzen Master is already running, either the automatic one or the one you opened, and the second instance cannot start.

The following screenshot shows the new default profile with six enabled cores and two disabled cores.

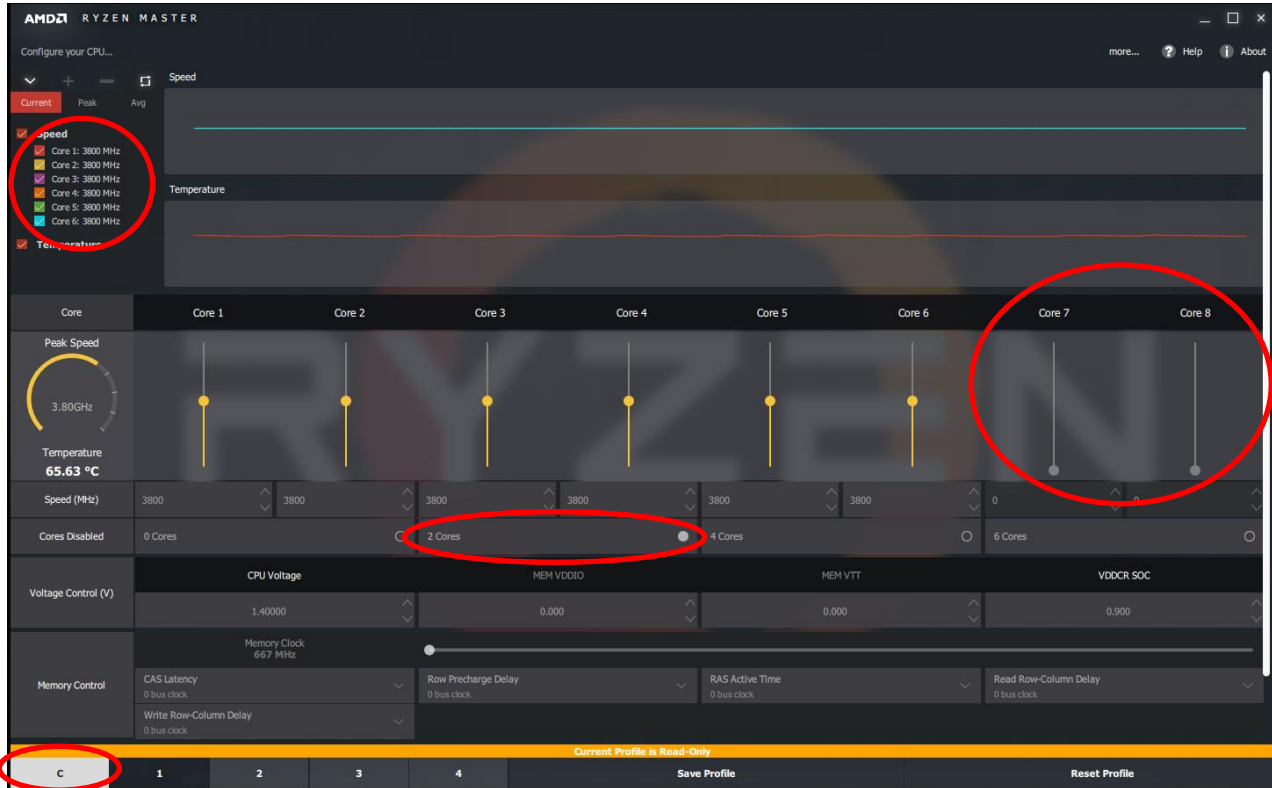


Figure 8: CPU Core Configuration - two cores disabled

The number of enabled cores can be verified by opening the Windows 10 Task Manager and the Performance tab (change the CPU graph to display Logical processors):

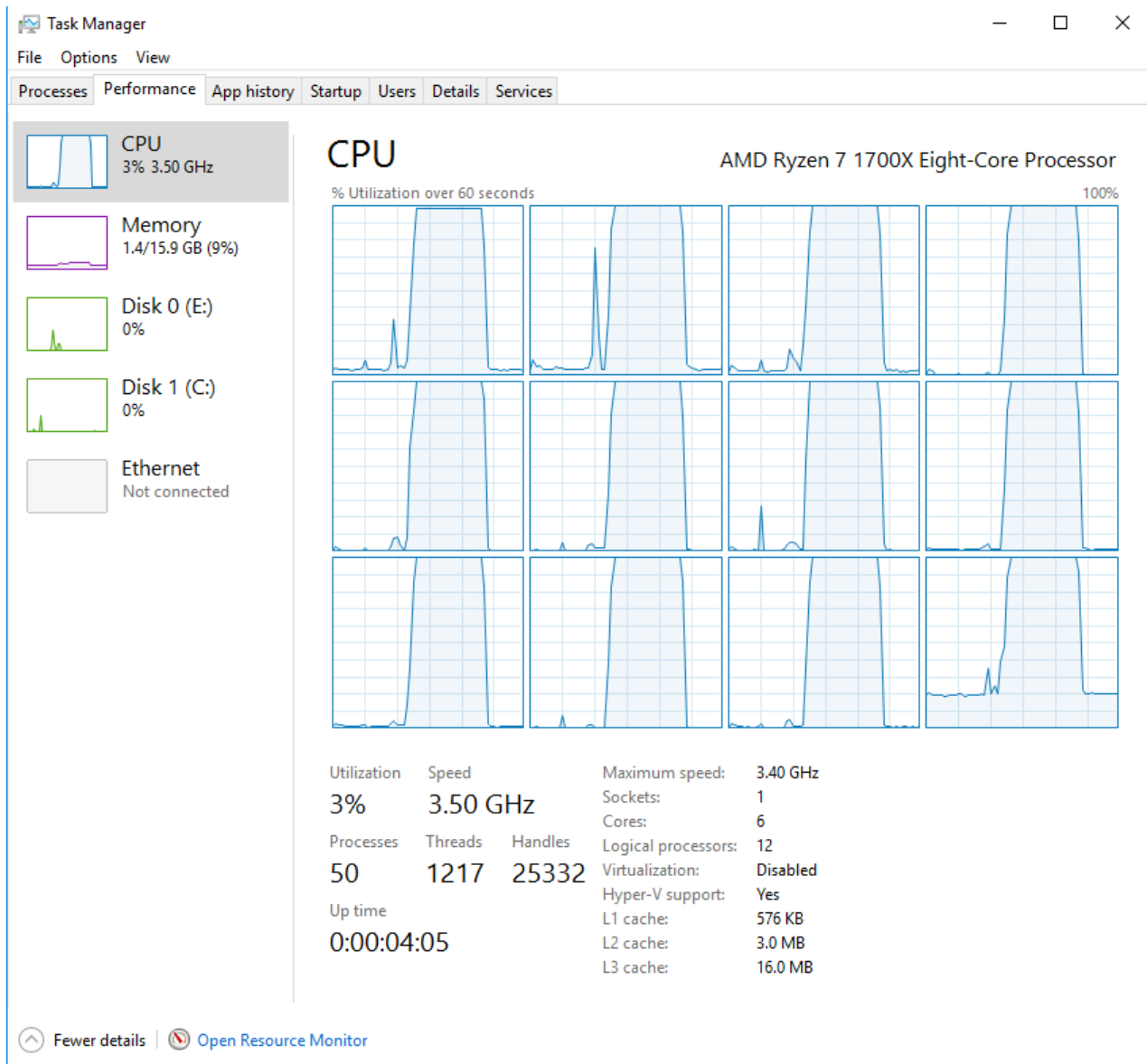


Figure 9: Windows 10 Task Manager with six enabled CPU cores

Note that since the disabled cores have been hidden from the OS, they will not appear as idle or parked in any Windows resource-monitoring application until enabled.

Note also that most applications that report the number of cores or threads, such as benchmarks, sample the CPU resources only when first started and will not register changes to CPU core count or frequency that you change via AMD Ryzen Master. Always re-open such monitoring applications after AMD Ryzen Master changes are applied.

Certain CPU monitoring tools are able to track dynamic changes initiated by AMD Ryzen Master.

In order to re-enable the disabled cores, the system must be powered off completely (alternatively the motherboard may initiate a cold reset) and restarted.

Note that Windows 10 must be configured in the Power Options to disable fast startup when the chassis power button is pressed to turn the system on. Make sure the box is unchecked for “Turn on fast startup”

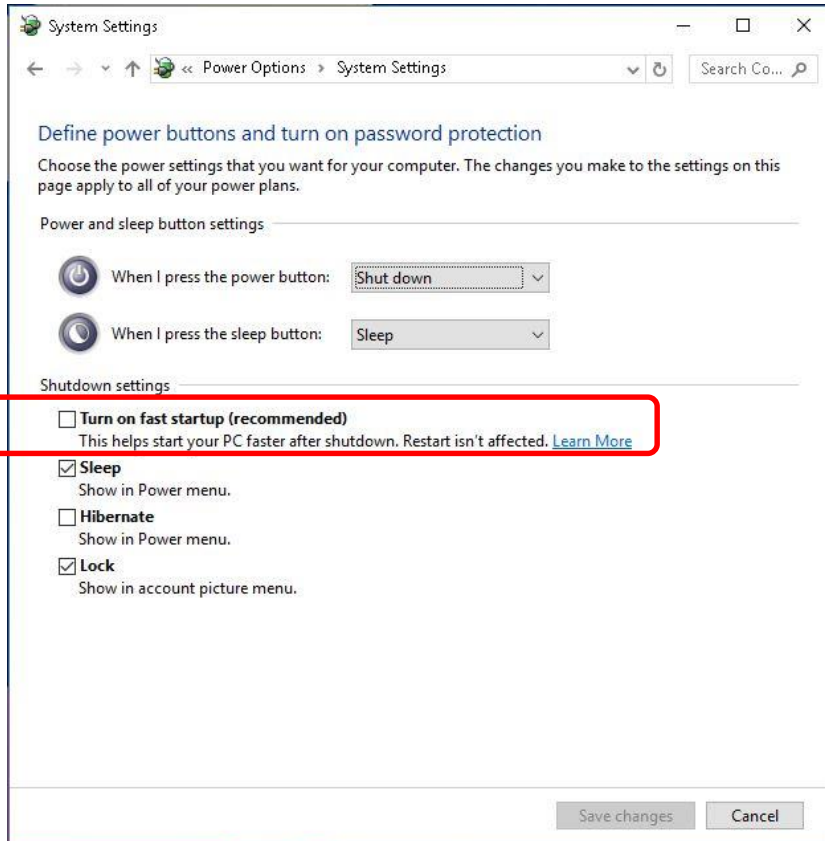


Figure 10: Windows Power Options configuration

It is possible to disable additional cores without cold resetting the system (i.e. a normal OS system restart will work here). Therefore the user can switch within a profile or across profiles from 8 to 6 to 4 to 2 cores without shutting down the system.

5.1.5 Memory Overclocking

AMD Ryzen Master offers an easy-to-use graphical user interface for adjusting the most important memory parameters.

Memory performance can be tuned by increasing the memory clock or by reducing the memory timings and latency. Typically, the higher memory clocks require higher memory timing values but in some cases, it may be possible to maintain the timings or even lower them. Results will vary depending on the exact configuration.

If the memory modules support a higher memory clock it's recommended to apply the timings as per the memory specification (SPD settings).

The following example uses a dual channel DDR4-2400 memory kit (CL17-17-17-17-39 timings, 1.2V voltage, 2x8GB).

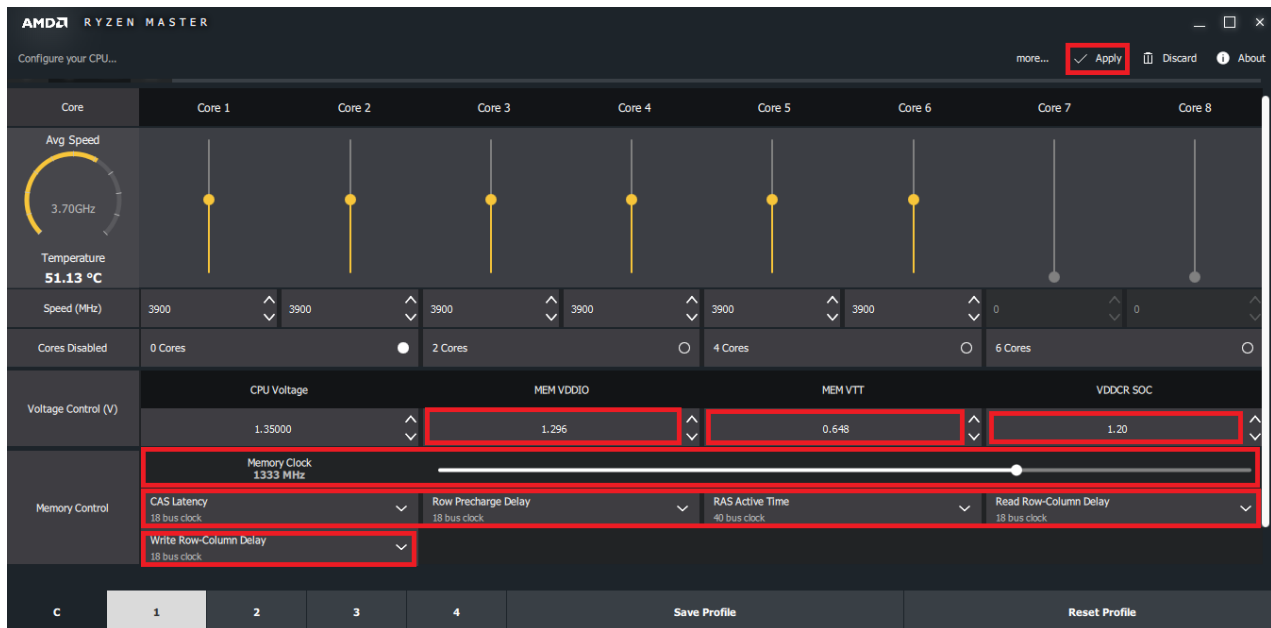


Figure 11: AMD Ryzen Master application - Memory Overclocking Example

In the above example the memory clock is adjusted from default 1200MHz (DDR4-2400) to 1333MHz (DDR4-2666) while timings have been increased from 17-17-17-17-39 to 18-18-18-18-40. Memory voltage was also adjusted from default 1.20V up to 1.296V and SOC Voltage was set to 1.20V. Note that Memory VTT voltage will automatically be set to half of Memory voltage (MEM VDDIO).

System restart is required for applying the settings as memory needs to be retrained for the new values.

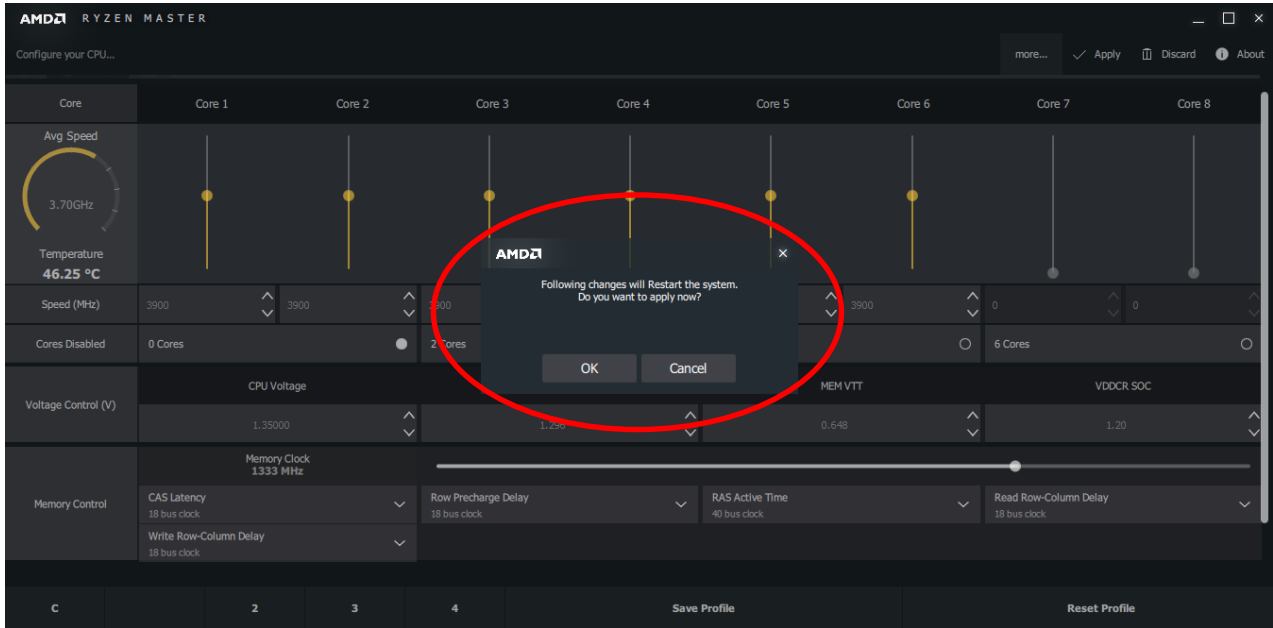


Figure 12: System reboot pop-up message following Memory adjustments

Click “OK” to reboot the system and apply the new memory settings.

NOTE: Memory settings should be adjusted with great care as incorrect or unstable settings may prevent the system from booting up or may fail to load the OS (including corrupting the OS installation). Running a stand-alone memory stability test (such as MemTest86™) is recommended for checking the memory stability in advance of loading the OS.

Chapter 6 CPU Core Configuration

As core counts increase for enthusiast processors, it becomes valuable for the user to have control over how many cores are accessible to software. A performance-tuned system running low thread-count software and four enabled cores might be optimal for one user. Alternatively, a performance-tuned system with all cores enabled might be better for another user.

- 1) The number of enabled CPU cores may be reduced from the maximum to tune the available number of threads of execution and the associated CPU power requirements and related cooling requirements to achieve maximum performance for given applications.
- 2) Reduction of the number of enabled CPU cores from the maximum will reduce the current and power consumed by the processor. This power consumption reduction can allow the user to avoid current delivery limitations of the system, avoid processor cooling limitations of the system, and/or allow the enabled CPU cores to operate at lower temperatures and therefore potentially higher frequencies.
- 3) Through core configuration the number of cores to be enabled is selected by the user and after a system restart, only that number of cores is initialized and reported to the operating system for task scheduling. This is a static assignment of enabled cores per system boot.
- 4) The AMD Ryzen processor operates all cores at the same operating frequency. This provides uniform performance for each enabled core to the operating system task scheduler. In overclocking mode, each core is supplied power directly from the external VDDCR_CPU supply and therefore at the same voltage.
- 5) Core configuration allows for cores to be disabled in logical pairs. Cores may be disabled in increments of two up to two less than the total cores provided by the given processor model. For example, a four-core model will allow only two cores to be disabled, leaving two cores active. An eight-core model will allow two, four or six cores to be disabled, leaving no less than two cores active.
- 6) To re-activate disabled cores, the system must be cold reset and restarted. Upon restart, the processor will be returned to stock configuration and all originally available cores will be enabled

Chapter 7 Important Information

7.1.1 Enabling HPET

Most of the AMD Ryzen Master application functionality is available only when the system timer is set to High Precision Event Timer (HPET). It is highly recommended that HPET is enabled before using the application.

To enable HPET:

- Start a command prompt as an administrator
- Execute the "HPET.bat" available from the installation path of the AMD Ryzen Master application
- If HPET is already enabled, then no action is performed else the HPET.bat file will enable HPET
- Restart the system

Note: If system is not restarted after HPET is enabled, the Application will not behave as expected

Please also note that updates of Windows may reset and disable HPET. If you find that AMD Ryzen Master has been running fine but unexpectedly begins warning you that HPET is not enabled, your OS has probably been updated. In that case, please run the above instructions for enabling HPET; it is not necessary to re-install AMD Ryzen Master.

7.1.2 Memory voltages - VDDIO and VTT

When MEM VDDIO is set using AMD Ryzen Master, the VTT value is automatically set to VDDIO/2. However, if the motherboard and its BIOS supports VTT control, the user can adjust VTT to other than VDDIO/2 values after the automatic setting of VDDIO/2.

7.1.3 Windows Power Options

For workloads that can use the full thread capacity of the CPU, the OS power policy should be set to "High performance" by the user for maximum performance. For workloads that don't stress the thread capacity, the OS power policy can be left in "Balanced" mode for lower idle power and temperature.

7.1.4 AMD Ryzen Master processor resource consumption

Since AMD Ryzen Master is an application and samples many processor parameters to display real-time performance information, it consumes processor resources but presents a light load at idle. You may notice AMD Ryzen Master taking slightly more resources as a percentage when a heavy workload is running, such as a highly-threaded benchmark. The multi-thread workload of Maxon's CINEBENCH benchmark is a good example of this behavior. This is due to the operating system's higher overhead of thread-context switching between AMD Ryzen Master and the other workload.

If a highly-threaded application can consume all available thread capacity and maximum performance is important, shut AMD Ryzen Master down while running that workload.

Example: When running CINEBENCH for maximum score while over-clocked

- set the Windows power policy to "High Performance"
- shut down AMD Ryzen Master and any other processor monitoring utilities

Chapter 8 Glossary of Terms

The following table provides further information on the commonly used terms.

Term	Description
AM4	AM4 is an AMD single-socket client infrastructure supporting DDR4 memory
CCLK	CPU Core Clock
CCX	Core Complex where more than one core shares L3 resources.
Core	The instruction execution unit of the processor when the term Core is used in an x86 core context.
CPU	The total resources of the specific processor model consisting of Cores and cache memory
CoreCOF	Core current operating frequency in MHz
FCLK	Data Fabric clock – equal to Memory clock
L1 cache	The level 1 caches (instruction cache and the data cache).
L2 cache	The level 2 caches.
L3 cache	Level 3 Cache.
MEMCLK	Internal and external memory clock
Memory interface	<ul style="list-style-type: none"> • 2 Unified Memory Controllers (UMC), each supporting one DRAM channel • 2 DDR4 PHYs. Each PHY supports: <ul style="list-style-type: none"> • 64-bit data • One DRAM channel per PHY, two DIMMs per channel • DDR4 transfer rates from 1333 MT/s to 2667 MT/s • UDIMM, RDIMM, LRDIMM, SODIMM, NVDIMM, Flash DIMM and 3DS support
Processor	The complete product that encompasses the CPU, memory interface and other computing resources.
P-state	Processor Performance State. P-states are valid combinations of CPU voltage and CPU COF
SMT	Simultaneous Multi Threading.
Thread	One architectural context for instruction execution.
UCLK	Internal Memory Controller clock – equal to Memory clock
VDDCR_CPU	The VDDCR_CPU voltage is the VID-requested VDDCR_CPU supply level.
VDDCR_SOC	The VDDCR_SOC voltage is the VID-requested VDDCR_SOC supply level.

Table 1: Glossary of Terms