LDAT

Latency Display Analysis Tool

USER GUIDE

LDAT — LATENCY DISPLAY ANALYSIS TOOL

The industry has long used Frames Per Second as the primary method of gaming performance. But when talking about esports and competitive gaming, performance is not just about raw throughput measured in frames per second (FPS), but also about the time it takes for a frame to travel through the system from mouse click to display update (system latency). In fact, latency has a strong correlation to aim and shot accuracy in games.

Measuring end-to-end system latency traditionally requires recording the input and display using a high-speed camera and then counting the individual frames. This is both expensive and very tedious.

To simplify the process of measuring system latency, NVIDIA has created an intuitive and powerful hardware latency tool called LDAT, which stands for Latency Display Analysis Tool. LDAT is a discrete hardware analyzer that uses a luminance sensor to quickly and accurately measure the click-to-photon latency in a game or application. LDAT works with GPUs from all vendors.

Gamers are interested in the experience/latency a system can deliver in a given game and display resolution. In the past, average FPS of game benchmarks or manually tested gaming scenarios was usually the only information provided in articles and reviews. Thanks to more advanced software tools such as FrameView™, additional information such as frame time data, 1% percentile numbers, and other advanced metrics could easily be charted to describe the gaming experience.

LDAT adds a totally new dimension to measuring and tuning gaming performance, and can answer questions like: “How does resolution or certain in-game settings and graphics impact overall end-to-end latency?” or “How can I tune my settings to reduce latency while still maintaining great image quality?” or “How does latency compare among different games that I play?”, and “Which ones need more latency tuning than others?” Capturing such data was complex and very time consuming in the past—if possible at all. LDAT makes this data available easily and quickly.

> New with the latest LDAT unit and software, is the ability to measure pixel response time (also known as Gray-to-Gray), display latency, and gamma. Measuring the key gaming properties of your monitor has never been easier!

> Optionally, you can also measure end-to-end system latency with NVIDIA Reflex Analyzer built into NVIDIA® 360Hz G-SYNC® displays. Simply plug in your mouse into the monitor and fire away, then capture the log with GeForce Experience. Refer to the **NVIDIA Reflex Analyzer Automatic Configuration Reviewer's Guide** for more information.

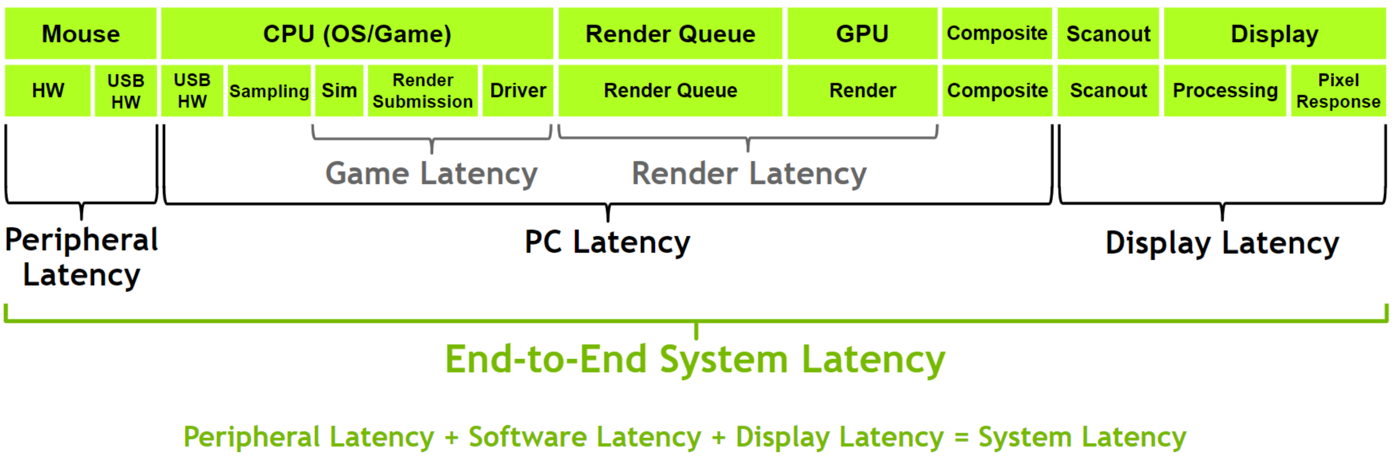
Using LDAT is easy: slide the sensor onto your monitor, and position it over an area that will change luminance when you press the mouse button (like weapon muzzle flash). LDAT comes with an instrumented mouse that plugs into the sensor, which allows the system to measure the entire end-to-end latency. Open the LDAT software, click the mouse button, and watch LDAT measure your system latency in real time.

You can also place the LDAT sensor on the Latency Flash Indicator that comes with NVIDIA Reflex games. This helps to make testing easier and more accurate as there is no need to find an instantaneous luminance change.

That's pretty much it. We'll walk you through the setup process step by step in Setting Up LDAT. And if you're already savvy with setup and are ready to start measuring latency now, skip to Best Known Methods For Measuring Latency for all our tips and tricks, with great game locations to start testing. For those of you who want to know more about latency, read on.

End-to-end System Latency

There are many components to overall system latency, not only physical components such as the peripheral (mouse), the PC (system), and the display, but also software components such as the game running on the OS, and the rendering operations of the GPU. Once a user presses the mouse in a game, that event data is then sent to the PC, where it is processed by many components and subsystems inside the PC including the CPU, the operating system (Windows), the game application, the render queue, the GPU, and then the OS compositor. Next, it goes through scan out, which technically happens on the GPU, but is initiated by the display, before it's finally processed and displayed on the screen. The time it takes for this to happen is called the **pixel response time**. LDAT measures the complete "click-to-photon" timing, which includes processing by all of the above hardware and software systems.

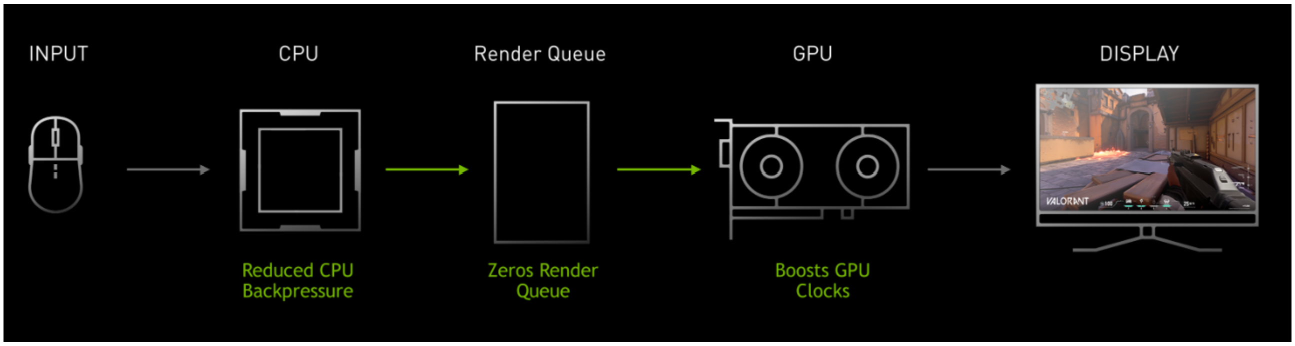


**Blocks not to scale*

The preceding diagram shows a high-level and medium-level view of all of the various components that contribute to latency in a system. PC gaming includes processing by a complex system of serial and parallel pipes, but we will do our best to break down the basic concepts.

If a game feels laggy, it's likely because you are experiencing high system latency—due to any of the smaller latency areas shown above. A few of the areas where latency is incurred are more important than others. The render queue and the GPU form one of these areas that is called the render latency.

While reducing display resolution and/or game graphics settings can lower render latency (not necessarily preferred), a great method to reduce render latency is to get a faster GPU and/or you could enable NVIDIA Reflex. The Reflex SDK allows game developers to dramatically reduce latency in their games by up to 50% by aligning game engine work to complete just-in time for rendering, eliminating the GPU render queue and reducing CPU back pressure in GPU-bound scenarios, resulting in lower latency and improving responsiveness and aiming.



▲ The Reflex SDK allows game developers to dramatically reduce latency in their games by up to 50%

For the CPU, there is game simulation processing, render submit, and the graphics driver that runs on the CPU—these are controlled by the speed of the CPU. If you have latency in your game, you may also need a faster CPU in order to reduce game latency.

To help break down some of the measurements above, here is a helpful list that describes each latency section in more detail.

- **Mouse HW** - This is defined as the first electrical contact when the mouse is ready to send the event down the wire. In the mouse, there are a few routines (such as debounce) that add latency to your mouse button press.
- **Mouse USB HW** - The mouse has to wait on the next poll to send the packets down the wire. This time is reflected in USB HW.
- **Mouse USB SW** - Mouse USB SW is the time the OS and mouse driver handle the USB packet.
- **Sampling** - This section can grow or shrink based on your CPU framerate. Clicks can come into the OS based on a polling rate of 1000Hz (typically). This means that the click may have to wait for the next opportunity to be sampled by the game. That waiting time is called sampling latency.
- **Simulation** - Games constantly have to update the state of the world. This update is called Simulation. Simulation includes things like animations, the game state, and changes due to player input. Simulation is where your mouse inputs are applied to the game state.
- **Render Submission** - As the simulation figures out where to place things in the next frame, it will start to send rendering work to the graphics API runtime. The runtime in-turn hands off rendering commands to the graphics driver.
- **Graphics Driver** - The driver is responsible for communicating with the GPU and sending it groupings of commands. Depending on the graphics API, the driver does this grouping for the developer or the developer is responsible for grouping rendering work.
- **Render Queue** - Once the driver submits the work, it enters the Render Queue. The render queue is designed to keep the GPU constantly fed by always having work for the GPU to do. However, this comes at the cost of latency.
- **Render** - The time it takes for the GPU to render all the work associated with a single frame.
- **Composition** - Depending on your display mode (Fullscreen, borderless, windowed), Desktop Windows Manager (DWM) has to submit some additional rendering work to composite the rest

of the desktop for a particular frame. This can add latency. It’s recommended to always be in fullscreen!

- **Scanout** - Finally, the flip occurs (the currently displayed frame buffer is swapped to the newly completed frame buffer) and scanout is scheduled. Scanout feeds the display line by line based on the Hz of the display. Which is why we have included it into display latency.
- **Display Processing** - Display Processing is the time the display takes to process the incoming scanlines and initiate the pixel response.
- **Pixel Response** - This is the time it takes from when the pixel received the new color value to the first detectable change by LDAT.

How LDAT Works

The LDAT system includes an external light sensor device that safely secures to the front of the monitor with a convenient elastic strap. The top of the LDAT sensor has two pins for connecting any modified mouse through which the click event is captured, and a status indicator light that changes color to indicate the current mode of operation. The backside of the LDAT sensor device includes a luminance sensor that measures the change in brightness on the screen.

LDAT measures system latency beginning with the mouse switch electrically closing the contact and ending when the screen luminance increases by at least 6% compared to its initial value. This value was chosen as it's the first detectable change that does not trigger on common luminance noise.

Typically, response times are measured from 10%-90% Gray-to-Gray (GtG), however, humans can start detecting the change earlier than 90% of the full pixel value. For this reason, we have chosen the first detectable change by the LDAT sensor in order to isolate the system latency and not account for any human latency.

Placing the LDAT device on the screen is simple: position the luminance sensor over an area of the display that shows a luminance change (such as muzzle flash) once the left mouse button has been pressed. LDAT compares the time difference between the exact moment of the mouse click and the moment the light changes on the display. The LDAT software shows your latency measurements in real time, and can average multiple measurements, showing you a histogram and a Gaussian distribution. We've added additional functionality to speed up measurements even more dramatically: the ability to have LDAT auto-fire so you don't have to press the mouse button repeatedly.

LDAT Interface & Hotkeys

F1	— Reconnect LDAT
F5	— Measure Mouse Latency one time
F6	— Measure Mouse Latency According to GUI
F7	— Reflex Mouse Latency Validation
T	— Measure Video Latency
A	— Measure Aux Latency
M	— Measure Mic Latency
F11	— Start a New Latency Log File
F12	— Specify the Log File
L	— Toggle Active Latency Capture
F	— Toggle Autofire
S	— Save Screenshot
P	— Take Snapshot of the Luminance Plot
H	— Show Help Box

LDAT Features

We're always looking for ways to improve latency measurement, and will periodically update and upgrade LDAT to incorporate new features to make testing easier and more convenient. You may have an LDAT unit with new capabilities. LDAT v2 does not require a specially wired mouse to be connected directly to the LDAT sensor. It comes with a button in the sensor that emulates the mouse click.

LDAT software interfaces with the LDAT device and delivers the following benefits:

- The LDAT system is used by top esports game developers for their game design and QA.
- End-to-end system latency (or click-to-photon latency):
    - Can work with an instrumented mouse/controller.
    - Can emulate a mouse.
    - Shows latency distribution and Gaussian curve in real time.
- Calculates latency measurement stats, including average, standard deviation, minimum, maximum, and sample size.
- Logs data to a CSV for further analysis.
- LDAT works with GPUs from all vendors.
- Features Autofire with a programmable delay to reduce manual input and increase ease of use.
- Includes Active Luminance Measurement mode, measuring display brightness in nits.
- Test for A/V (audiovisual) sync latency.
- Optionally, you could also connect a microphone to detect the mouse click to trigger LDAT's measurement.
- Display gray-to-gray response: response time in ms and overshoot percentage.
- Display latency: the signal processing delay of a display from when a frame starts scanning out on the GPU to when the screen responds.

SETTING UP LDAT

Follow these instructions to set up your LDAT hardware and software. Note that if you haven't installed a recent video game, you might need the Microsoft 2015 or 2017 x86 redistributable in order to use the LDAT software. You can download it directly here: https://go.microsoft.com/fwlink/?LinkId=746571.

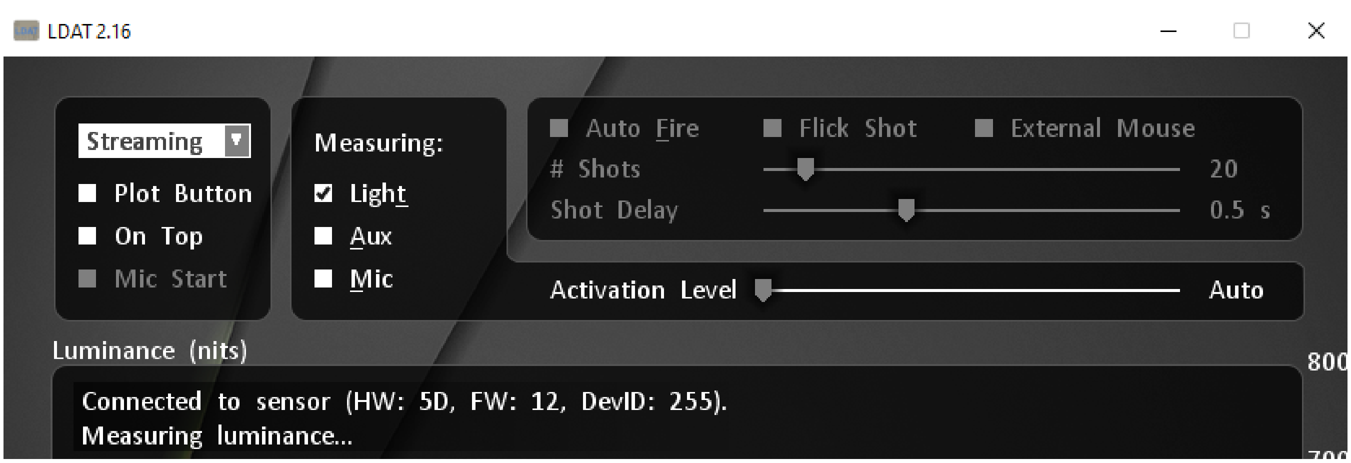
1. Wrap the LDAT module around the monitor using the elastic strap. Make sure the light sensor is facing the monitor and the status indicator is facing you (as shown below).
2. Connect the included wired mouse to the LDAT device.
3. Connect the mouse cord to your gaming system (PC Under Test).
4. Connect LDAT to your Host system with the Micro-USB cable.

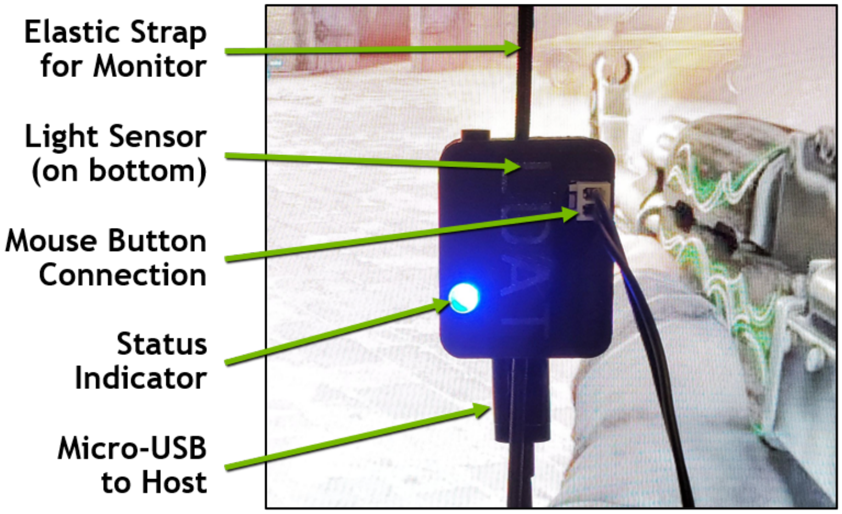
> If necessary, the Host PC and PC Under Test can be the same PC.

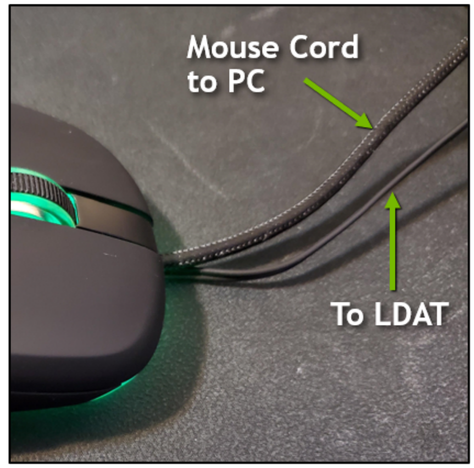
5. Confirm that the blue status indicator light on LDAT is being displayed.
6. Launch **LDAT.exe** on your host system.
7. Confirm that the green status indicator light on LDAT is being displayed.
8. Check to see if the LDAT application is properly connected to the sensor.

Establishing a connection to the LDAT sensor

With everything properly connected, the message **Connected to sensor** appears after launching LDAT software (for about 5 seconds). If you don't see this message, ensure the LDAT mouse is connected to the gaming PC and the LDAT unit is connected to both the mouse and the system with the LDAT software (preferably a secondary host system).







Status Indicator Light Color Codes

The LED indicates the current mode of LDAT operation:

- **Cycling Colors** Standby
- **Blue** Latency mode, waiting for click
- **Pulsing color** A click was detected, waiting for the response (in latency mode)
- **Green** Luminance streaming
- **Orange** Microphone streaming
- **Red** Aux streaming

Recommended Testing Setup

You can test LDAT using a single system, but for the highest efficiency for end-to-end system latency testing, we recommend that all testing be performed with two systems. System #1 (Host) will connect to the LDAT device via the Micro-USB to host cable and will run the LDAT software. System #2 (PC Under Test) will have the LDAT sensor attached to its screen, LDAT modified mouse connected to the sensor, and will run games. For pixel response time testing (also known as Gray-to-Gray) and display latency testing, you'll run LDAT_Display_Test.exe on the same PC that has the LDAT unit connected.

Troubleshooting

- **The LDAT sensor is not detected when running LDAT from the Host.**
  - Double check that the provided Micro-USB cable from the LDAT is connected to the Host PC, the mouse cord is connected to the PC Under Test, and the other mouse cable is connected to the LDAT unit as well. Exit and open LDAT again. If that didn't fix your issue, there is likely some type of USB conflict on the Host PC that needs to be troubleshooted. If you still can't get it working, try using a single PC.
- **The LDAT application does not flash when the button or mouse is clicked.**
  - The LDAT app flashes only when left-clicked in the graph area. If using the internal LDAT mouse, note that the LDAT button sends clicks only when the sensor is in latency mode.
- **LDAT advanced options do not display in the interface.**
  - This can occur if the user uses an older LDAT sensor (v1) or it doesn't detect an LDAT sensor at all. Plug in an LDAT v2 and press F1 to connect to it.
- **You may need to update the firmware if using an older LDAT sensor.**
  - The most recent LDAT v2 firmware version is 16.

Your First Latency Measurement

Using LDAT is really easy. An easy way to illustrate how LDAT works is by performing your first measurements in the LDAT app itself without any game. These directions are designed to familiarize you with the software interface and demonstrate the concept of LDAT before testing latency in a game.

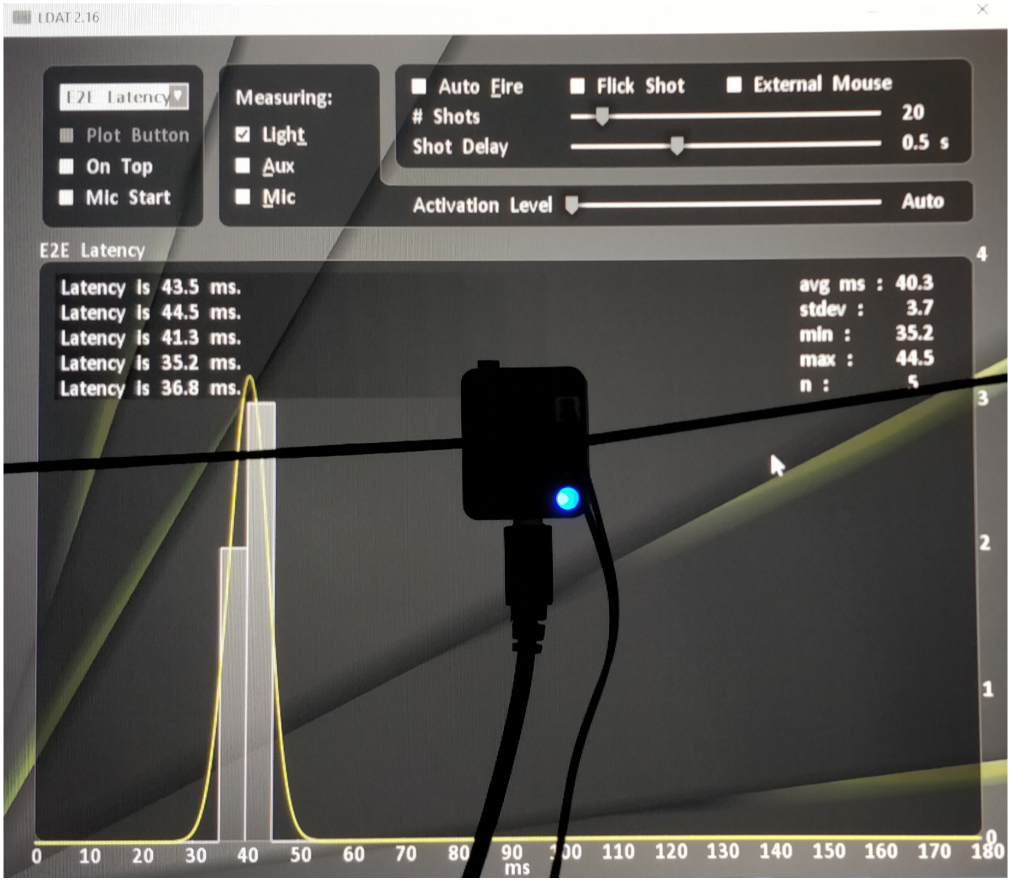
1. Follow these initial steps.
2. Open **LDAT.exe** on the PC Under Test. (Not the Host. All set up on the same PC.)
3. Ensure the LDAT sensor is detected.
4. Move the LDAT application window to the center of the screen, with the LDAT sensor directly in the middle.
5. LDAT starts in **Streaming Mode**, indicating that LDAT measures the instantaneous luminance levels (nits) on your display screen in real time. Try this now by moving the windows on the screen that are under your LDAT sensor. The LDAT app visualizes the brightness level measured in nits.
6. Now let's measure latency. Using the drop-down menu, change from Streaming to **E2E Latency**.

> Note that testing latency on the Windows desktop *will* show increased latency. This test is for demonstration purposes only to show you how LDAT works. To properly test click to photon latency, load up a game or test using LDAT Display Test.

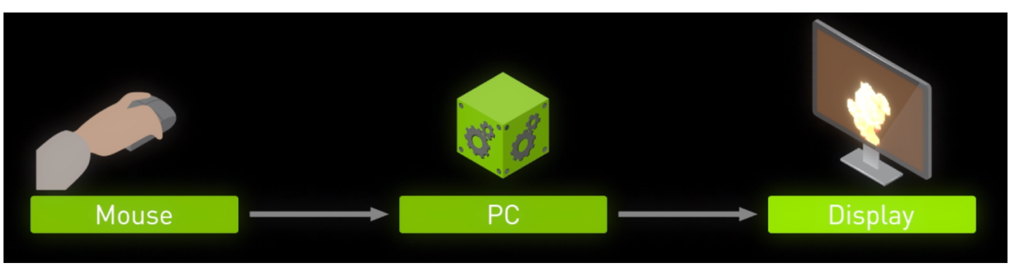
7. Move the **mouse cursor** so that it's **inside** the LDAT application window.

If you are sensitive to bright flashes, consider brightening the room or reading on for an explanation instead of testing.

8. With the mouse cursor **inside** the LDAT application window, click the left mouse button using the mouse that is connected to both LDAT and the PC Under Test. Do not begin the test if the LDAT help menu is on the screen. Remove it by pressing **H**.



9. The LDAT background flashes from light gray to white and LDAT measures the end-to-end latency, from your mouse click to the pixels changing on the screen.

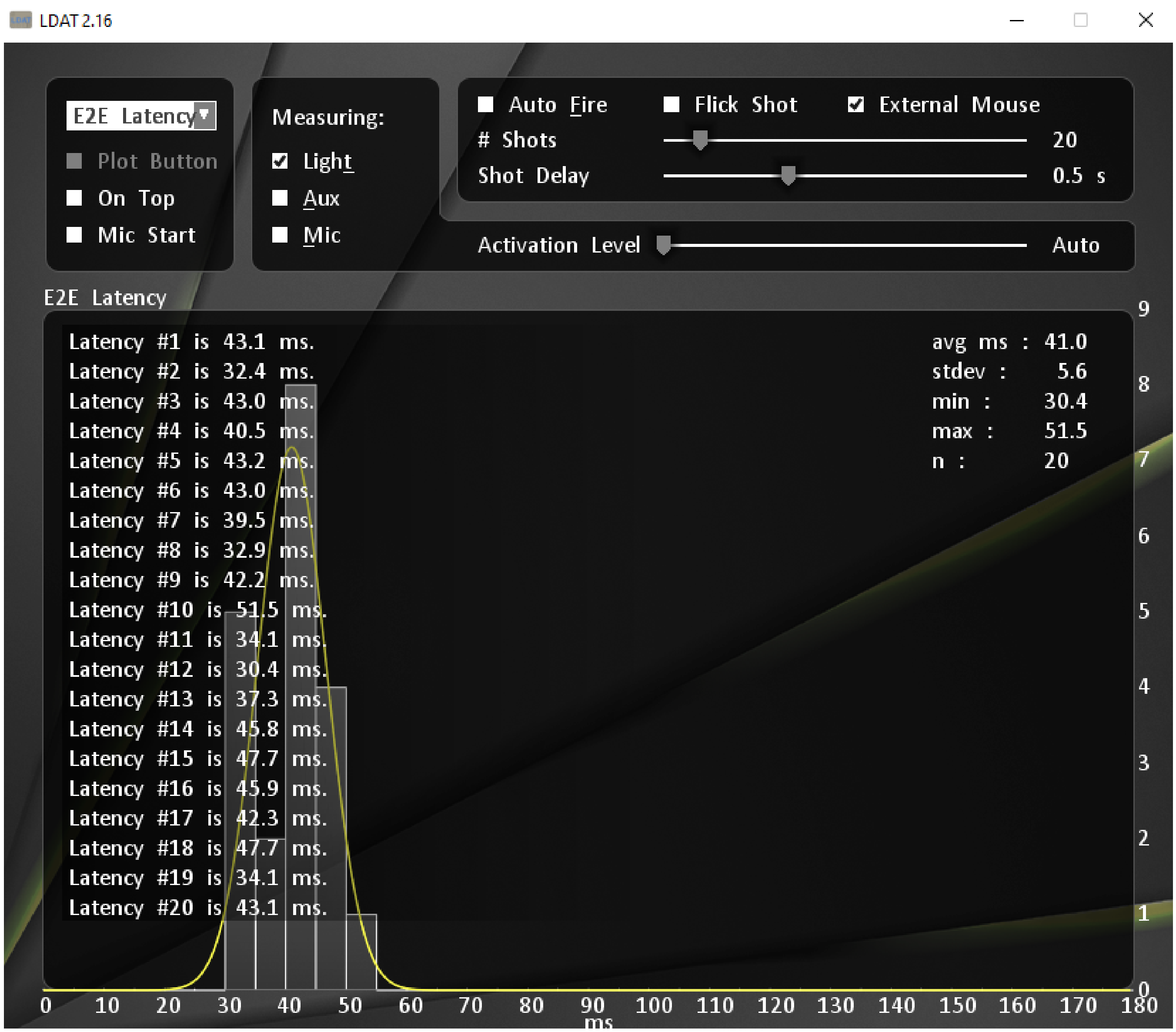


10. Press the mouse button a few more times, and notice how LDAT reports each click's latency in milliseconds and provides a graph with averaged latency. On the right side, it also reports the average latency in milliseconds, the standard deviation in milliseconds, the minimum and maximum latency measurements, and the sample size so far.

11. Let's take a number of samples very quickly by using the Auto Fire feature.

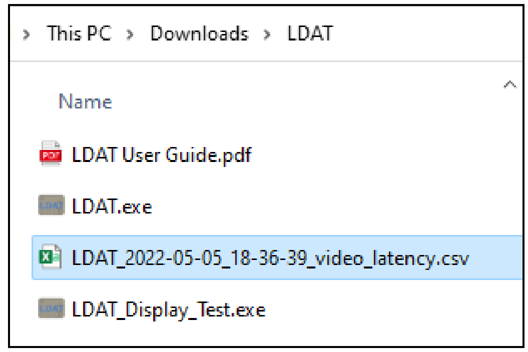
a. Click the **External Mouse** checkbox. Make sure **E2E Latency** is selected.
b. Set the **# Shots** slider to a larger number, like 20.
c. To begin auto fire, click the Auto Fire check box or click the **F** hotkey, or alternatively - check the **Auto Fire box.**

The screen will flash rapidly and LDAT measures the latency of each flash automatically while still capturing the end-to-end latency. It does this by sending a signal from the LDAT sensor to the connected testing mouse as if the mouse button were clicked. The signal still travels from the mouse and we incur the mouse latency as if we had pressed the button.



LDAT also captures logs for all your testing as session-based .csv files in the folder where LDAT.exe is located.

- To start a new log, **press F11**. LDAT then closes and saves your previous log, and begins a new one.
- To name and choose a save location for your log, **press F12** instead.



Start a new log file for each test case—this helps keep you organized!

Testing Games

The same principles described above apply to testing games. Start the game you want to test, position the LDAT sensor over the muzzle of a weapon—or other object with near instantaneous luminance change keyed to your mouse input—and begin capturing. See the following chapter for advice on the best practices.

BEST KNOWN METHODS FOR MEASURING LATENCY

We recommend finding areas of the map that have the highest luminance variance for the best results. To help, we've included another section that describes some ideal placements for LDAT and the best areas to test in top games. Be sure that your monitor is set to the highest refresh rate possible.

Measuring System Latency

Here are some of our preferred methods for placing LDAT on the display and the areas of top tested games that are best for measuring latency. To highlight the most important benchmarking points:

> You need to position the sensor where there is a near immediate change in luminance. The faster, the better. This is most often the muzzle flash, but can be a scope change or other instantaneous movement. This will vary by game.
>
> You **will** see latency variability. Because latency in each stage in the system can vary, these small amounts can compound when combined, and you will get occasional outliers. This is normal. LDAT is simply recording the accurate latency that exists.

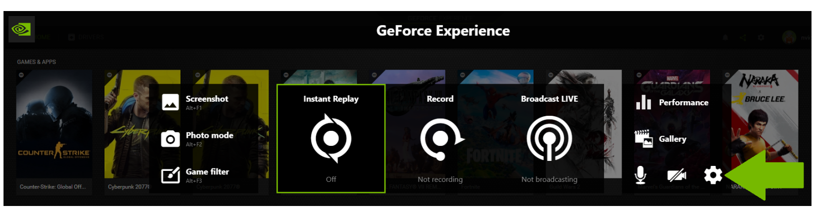
This means that gamers aren't always experiencing the same latency with each shot they take. Once in a while, a shot will take either much longer or shorter. So, because of this:

> You need to capture enough runs to minimize variability—100 per benchmark set is a good amount. Auto Fire mode makes this fast and easy.

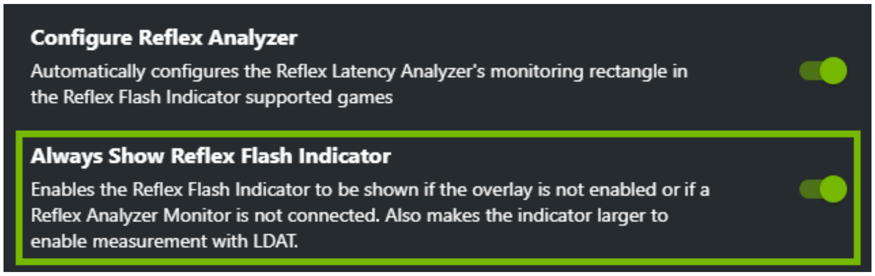
Latency Flash Indicator

You can also place the LDAT sensor on the Latency Flash Indicator that comes with NVIDIA Reflex games. This helps to make testing easier and more accurate as there is no need to find an instantaneous luminance change such as a muzzle flash. Place the LDAT sensor on this white box.

- To enable the Latency Flash Indicator for LDAT usage (with or without a Reflex Analyzer monitor):
    a. Press **ALT + Z** to open the GeForce Experience™ in-game overlay or click in the app.



    b. Click the **Large Gear** next to the microphone and camera.
    c. Click **Performance Monitoring**.
    d. Turn on **Always Show Reflex Flash Indicator.**



e. Be sure to enable the Latency Flash Indicator in the game menu as well, if available.
    i. For some games, you need to also enable Latency Markers.

f. Play the game. Get weapons and ammo. Press the left mouse button to make the Latency Flash Indicator change from dark gray to white.

General Testing Tips

Where does the sensor go? How do you find the right spot? We've performed hundreds of hours of testing—here are the starting points you should know.

- **Make testing easier and more accurate.**
  Most Reflex-enabled games support the latency flash Indicator which displays a white box on the left side of your screen when the left mouse button is clicked. Place the Reflex Latency Analyzer monitoring rectangle or LDAT in this location. Keep in mind that this feature only works on NVIDIA.

Latency Flash Indicator

- **Muzzle flashes are usually the best area to measure.**
  In most game worlds, nothing is faster than a bullet. The next fastest element after the bullet is the escape of gases that result in muzzle flash. This is your go-to for the quickest luminance change. This method or something similar should be used for all competitive testing as the Latency Flash Indicator is only available on NVIDIA.

- **But beware of muzzle bloom.**
  Some weapon muzzle flashes can take longer than others to fully bloom, so be sure to place the sensor directly in the center of the muzzle flash to avoid capturing the end of the animation.

- **Keep the sensor in the same exact spot.**
  Ensure the sensor is placed in the exact same spot for each test. If the sensor is placed only a bit higher than your previous sensor location, the muzzle flash animation could be captured at an earlier interval, effectively lowering latency, potentially by 3 ms — 16 ms (depending on the refresh rate of the display). Keep in mind that the sensor is at the top of the underside of the LDAT unit, not in the middle.

- **Ensure the sensor maintains direct and flat contact with the panel.**
  Click-to-photon measurements may not be reliable if the sensor is exposed to other light.

- **Use the instantaneous luminance mode to find the exact edge between light and dark pixels.**
  Uncheck the LDAT software boxes or **press L** to enter Luminance Measurement Mode in order to surgically find the area of fastest luminance change. If the fastest mouse-response is tied to, say, a snap scope zoom out, or on the edge of a weapon that moves almost instantaneously, the LDAT sensor will get you as close to the line between light and dark pixels as possible, so that when benchmarking the sensor experiences the quickest luminance change.

- **You can reprogram the key command.**
  Most of the time, the left mouse button is keyed to an attack, but in case it isn't, or a better option is available, you can always key another movement to the left mouse button. LDAT only works with the left mouse button as input, but you usually have the flexibility of assigning different game functions to that button in the game settings.

- **Don't measure menu animations.**
  Only measure game world animations, not on-screen menu movements. Menu items can sometimes go through different paths engine-side and may not reflect the actual game latency feel.

- **Many tests are needed. Autofire is your friend.**
  You'll see latency variability from test to test, including some outliers that are much longer or shorter than the rest. While the LDAT software accounts for standard deviation, you'll want to perform many benchmark tests to minimize the inherent variability. We perform 100 tests per benchmark, which ensures reliable data. This may sound like a lot, but the Autofire function makes for very fast testing. Compared to the traditional method of counting high speed video frames, we found that testing with LDAT is about 25x faster.

- **Check the data for large outliers or errors.**
  Open the results with Excel and plot as a scatter or a straight line. Results should be consistent across with no large outliers. If too much variability is present, run the test again or omit the few remaining outliers. Typically, these outliers are caused by inconsistencies in the game animation or muzzle flash, or that the system under test is faulty.

- **Keep the frame rate consistent.**
  Game frame rate directly affects GPU latency, so keep an eye on the FPS counter to make sure recoil, character animations, or unintentional mouse bumps don't change the performance.

- **Each game is unique.**
  While LDAT is the easiest and most accurate way to measure latency, you will have to tailor the sensor placement for each game and scenario. This is because each game animates differently and features different weapon behaviors. You will want to experiment to see what works best for each game. The next section explains more in detail. But if you aren't getting good results, move the sensor to a different area on the weapon or arm, or face the game camera against a different background.

- **Focus on dark pixels that go bright on a shot.**
  A bigger brightness change will reduce the likelihood of high variance in your measurement.

- **You can measure on objects or backgrounds.**
  Try placing the sensor on a weapon that recoils or attacks away, leaving the sensor exposed to the background behind the object. You can also try the opposite: placing the sensor on the area right above a weapon barrel, which then measures the muzzle flash as it jumps into range.

- **Watch out for sway.**
  Some games feature heavy camera or character sway. Make sure this excessive movement doesn't interfere with measurements. In these circumstances, experiment with the sensor placement and take individual LDAT measurements while you shift it slowly around to find the sweet spot. We've found that there's almost always a solution.

- **Learn the animation reset timing.**
  Character animation takes a moment to reset to its original position, and each game and weapon movement is different. If you're testing by hand with individual mouse clicks, learn the

reset timing after some practice movements. If you're instead using the Autofire option, customize the Shot Delay setting to account for the weapon reset.

- **Tape up your LDAT mouse.**
  It can be frustrating when bumping your mouse out of position after finding the perfect test location, or accidentally moving the mouse when carefully clicking the mouse button. If you know you have the desired location, try putting tape or a sticky note on the underside of your mouse over the sensor, or flipping the mouse upside down.

- **Use a secondary mouse to freely navigate the PC.**
  It's helpful to connect a secondary mouse while testing, in order to reposition the camera for repeatability and make minor adjustments without touching the LDAT mouse and starting a measurement every time the mouse is clicked.

- **Try save games and sticky notes.**
  When testing latency across GPUs and configurations, use a save game point to load the same scene for each benchmark. But what about the location of LDAT on the monitor? Not one to overcomplicate things, we've used a couple of sticky notes to indicate one of the LDAT corners for precise placement in case we have to shift or remove LDAT in between benchmarks. You can even write pertinent game and level details on the sticky and label multiple locations when testing more than one game.

- **Use a secondary PC and monitor to view results in real time.**
  The best way to ensure everything is functioning properly is to keep an eye on the LDAT real-time latency numbers. Using a secondary "host" PC is the best way to observe the real-time data. Strive for a low standard deviation number, and try finding a better sensor location if exceeding 8 ms. For exceptionally fast GPUs paired with high refresh rate displays, standard deviation can be as low as 2 ms.

- **Remember good benchmarking practices.**
  Be mindful of variables that affect latency, such as in-game frame rate, frame rate limiters, graphics settings, resolution sliders, improper camera position, refresh rate, VSync, and display modes such as full screen, borderless, and windowed modes, etc. Always be mindful of your frame rate and display refresh rate, as it has a profound influence on latency. It's recommended to restart the game when changing graphics settings even if the app doesn't require a restart to update settings. Check your monitor refresh rate in the NVIDIA Control Panel. It's also recommended to set the Refresh Rate to Highest Available in Manage 3D Settings.

- **Make the LDAT window larger.**
  LDAT automatically adjusts it's window size based on DPI settings. This can be overridden by the "**-dpiZoom N**" command-line parameter, where N is 1, 2 or 3.

Testing Games & Reflex Titles

Have fun exploring different testing locations all you want, but to jump in right away with less of a learning curve, you might try some of our favorite locations in these specific games that are proven to return good results with minimal sensor repositioning.

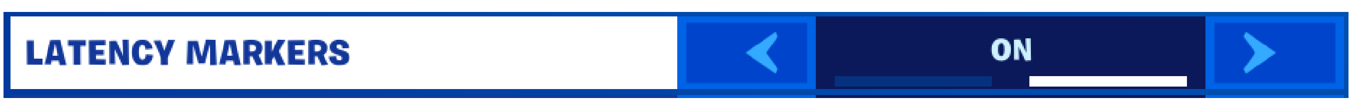
Fortnite

NVIDIA and Epic Games have teamed up to bring ray tracing and Reflex to the world's most popular Battle Royale, *Fortnite*. Gamers are enjoying new heights of immersion with ray-traced shadows, reflections, global illumination, and ambient occlusion—along with DLSS to provide state-of-the-art anti-aliasing and upscaling. **With numerous ray tracing techniques working in tandem, this results in a heavy GPU workload, making Fortnite the perfect game for testing Reflex, allowing for incredible latency savings across all GPUs and resolutions while ray tracing itself provides an incredible visual experience.**

Enabling the Latency Flash Indicator in Fortnite

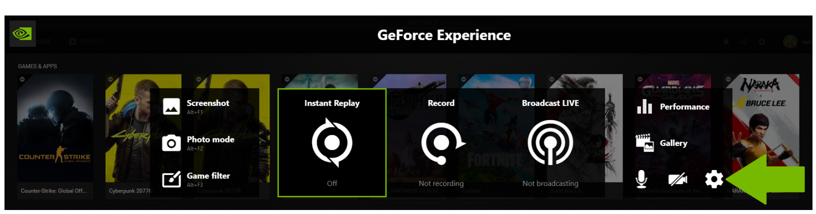
Fornite also supports the Latency Flash Indicator (white box) when the left-mouse button is clicked which makes testing latency with LDAT that much easier.

To use this feature, set **Latency Markers** to **On** in the **Video** options. Click the mouse button to make the flash indicator appear (white box) and move the LDAT to that location.

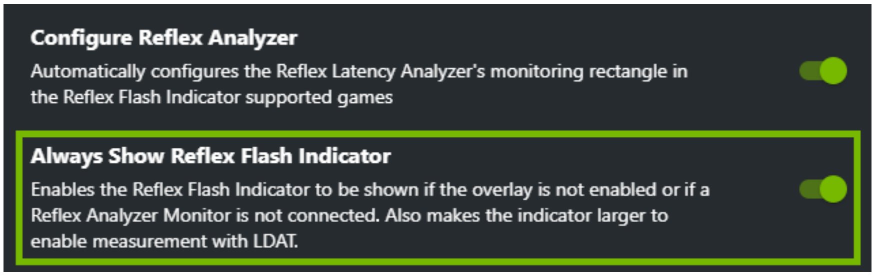


Next, turn on the Flash Indicator in GeForce Experience:

- To enable the Latency Flash Indicator for LDAT usage (with or without a Reflex Analyzer monitor):
    a. Press **ALT + Z** to open the GeForce Experience in-game overlay or click  in the app.



    b. Click the **Large Gear** next to the microphone and camera.
    c. Click **Performance Monitoring**.
    d. Turn on **Always Show Reflex Flash Indicator.**



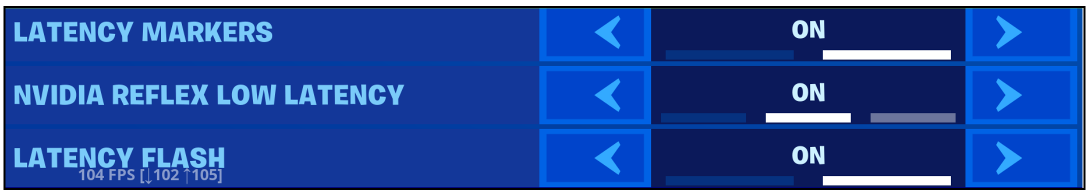
e. Be sure to enable the Latency Markers in the game menu as well.
f. Play the game. Get weapons and ammo. Press the left mouse button to make the Latency Flash Indicator change from dark gray to white.

The Latency Flash Indicator only works on NVIDIA and cannot be utilized for head-to-head competitive testing. We have provided both methods to test where applicable. If you are testing NVIDIA only, it's recommended to use the flash indicator white box, but if you plan to test latency on AMD or a game that does not support the flash indicator, please use the LDAT placement detailed in each game section for all testing.

Place the LDAT sensor on the white box (left center of screen) or on the muzzle flash.

Enabling NVIDIA Reflex in Fortnite

1) Install the latest NVIDIA driver.
2) Download *Fortnite* through the Epic Games launcher.
3) Launch the game.
4) Open the **Video** settings page and make the following changes to **Advanced Graphics**:
    a) **Latency Markers:** Enable to turn on latency markers. This displays the latency metrics on the HUD when **Latency Debug Stats** is turned on in HUD Settings. It also enables the Latency Flash Indicator to work in this specific game.
    b) **NVIDIA Reflex Low Latency**: Turn on Reflex + Boost.



Configure the Game for Testing

1. In Display settings, set Framerate Limit to **Unlimited**.
2. Enable DX12, Epic Preset, DLSS, and all ray tracing effects, then restart the game.

3. Change to **Creative** gameplay mode and click **Play.**
4. Move forward towards the **yellow rift** and use the **console.**

5. Select a creative island and click confirm.
    a. River Island is a good choice.
    b. The more structures and geometry, the better.
6. Enter the rift when the map is finished loading.
7. Press **I** on your keyboard to access settings, choose **My Island**, and **enable infinite ammo** and **infinite resources**.

8. Press **I** on your keyboard to access settings, choose **Creative**, and click and hold the **orange Assault Rifle** and drag it into the equipment slot.
9. Find a scene for testing and **stand in the same location for consistency**. Place your aiming reticle in the **exact same spot for each test**.
10. If you are testing NVIDIA only, it's recommended to use the flash indicator white box, but if you plan to test latency on AMD as well, please use the recommended LDAT placement for all testing.

11. Enable **Toggle Targeting** to remain zoomed in without having to hold right-mouse click. This will also make the muzzle flash larger. Enable the **Latency Flash Indicator** to make testing easier. Ensure data is captured **using the same methods**; don't mix zoomed with unzoomed data.

12. Optionally, you can also fill your creative world with various buildings, vegetation, and other objects to put more pressure on the system. This scenario will better simulate conditions from a real multiplayer match. Object placement is saved in your custom world, so you don't need to worry about placing them again, as long as you don't destroy them.
13. Test with Reflex + Boost and compare it to off. Check latency on another GPU vendor. Reflex provides the best way to play a game—improving aiming and responsiveness for all.

Overwatch

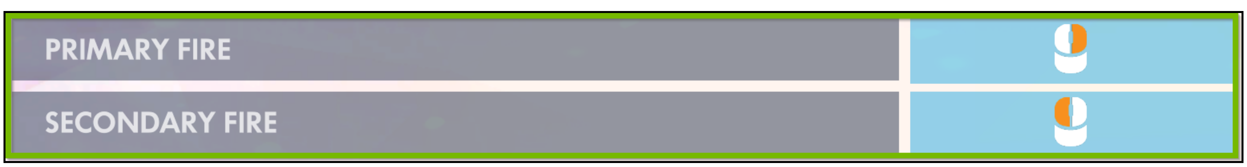
Enabling NVIDIA Reflex in Overwatch

1. Install the latest NVIDIA driver.
2. Open **Battle.net** and install **Overwatch**.
3. Launch the game.
4. Select **Options** in the main menu, then select **Video**.
5. Scroll down and set **NVIDIA Reflex** to **Enabled + Boost**. It's also recommended to use the Latency Flash Indicator.

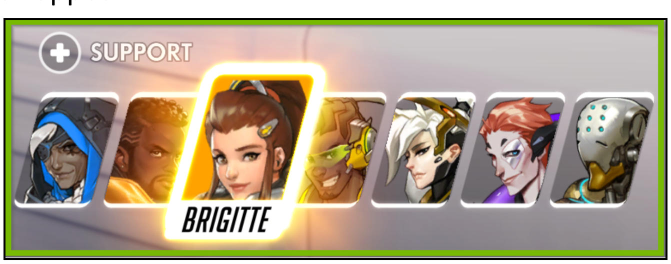
Configure the Game for Testing

1. Select **Options** in the main menu, then select **Video**.
    a. Set Limit FPS to **Custom** and Frame Rate Cap to **400**.
    b. Test at the highest resolution and graphics settings.
2. For latency testing, we recommend using **Brigitte's Barrier Shield** ability for the easiest and most efficient data collection. Testing with **Bridgette's Barrier Shield** requires the swapping of the left and right mouse buttons.

3. Head to the **Options menu** and select **Controls.** Scroll down to **Weapons & Abilities** and set **Primary Fire** to the Right Mouse Button and **Secondary Fire** to the Left Mouse Button.



4. Select **Training** in the main menu and head to the **Practice Range**.
5. Select **Brigitte** as your Hero. She is located in the Support category. Ensure that the control settings mentioned above for the Left Mouse Button and the Right Mouse Button have been swapped.



6. Place the LDAT sensor over Brigitte's flail or over the Latency Flash Indicator to the left.

VALORANT

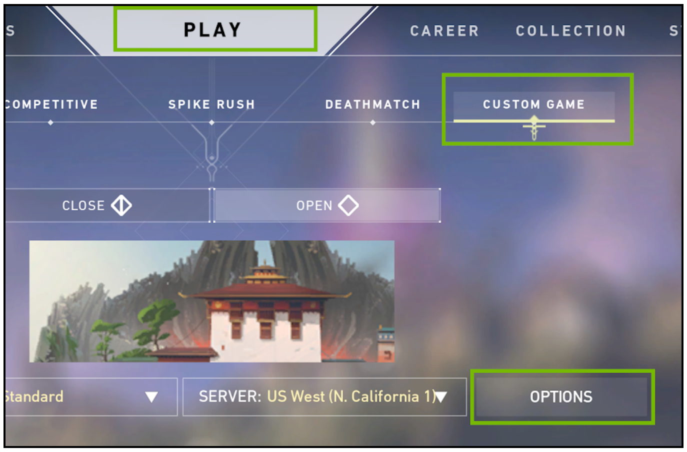
Enabling NVIDIA Reflex in Valorant

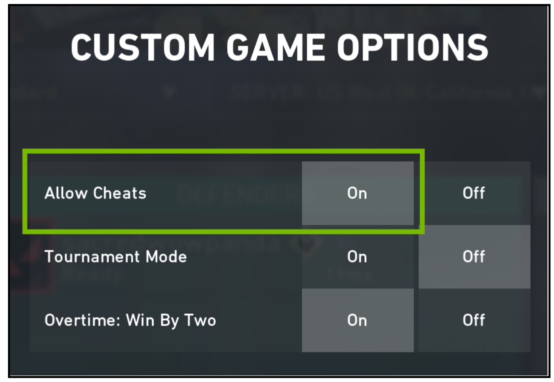
1. Install the latest NVIDIA driver.
2. Download *Valorant* through the Riot Games launcher.
3. Launch the game.
4. Open the **Video** settings page by clicking the **gear**, and under General Settings turn on Reflex + Boost.
    a. General settings: **Turn on Reflex + Boost**.

Configure the Game for Testing

1. Disable the fps limiter.

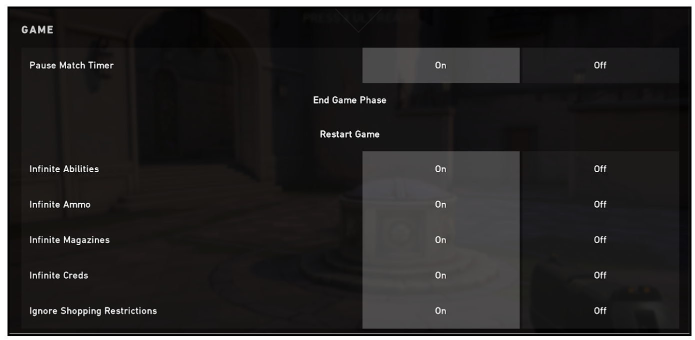
2. Under General & Graphics Quality settings, choose the highest resolution and graphics.
3. Choose **Custom Game** and click **Options** to enable **Cheats**. Change map to **Haven**.





4. Click **Start** to launch the private server.

5. Once the map loads, press **ESC** and navigate to **Cheats** and enable all **Game** cheats.



6. Find a scene for testing and **stand in the same location for consistency**. Place your aiming reticle in the **exact same spot for each test**. Use the starter pistol for instantaneous muzzle flashes. Beware—some weapons have a slower muzzle animation. Optionally, to make testing even easier, you can place the LDAT sensor over the Latency Flash Indicator to the left.

CounterStrike: Global Offensive

1. Set **Shot Delay** to **2 seconds** in **LDAT**.
2. From the main game menu click the **gear** and set **Enable Developer Console (~)** to **Yes**.
3. Press **~** to open the command console and input **net_graph 1** to show in-game fps and other useful networking metrics. Next, input **fps_max 999** to remove the fps cap.
4. Click **Video** to modify **resolution** and **graphics** settings. Test at the highest resolution and graphics settings.
5. Click the **Play CSGO** button. From the drop down menu click **Practice with Bots**. Underneath the drop down choose **Competitive** and select the **No Bots** option to the right, then pick **Inferno** as the test map and click **Go**.
6. Input these other commands when the map loads:
    - sv_cheats 1
    - mp_roundtime_defuse 60
    - mp_buy_anywhere 1
    - mp_restartgame 1 – Choose the **Terrorist** side (or Press M)
    - sv_infinite_ammo 1
    - give weapon_awp
7. Once again, type **“fps_max”** to confirm **max frame rate** has been set to **999**. Check with **net_graph 1**. If not, make it so.
8. Position yourself at mid so that your back is directly touching the wall with the tan window flower box visible. This is to ensure frame rate remains consistent for each test as slight changes in camera positioning can significantly alter fps and latency.

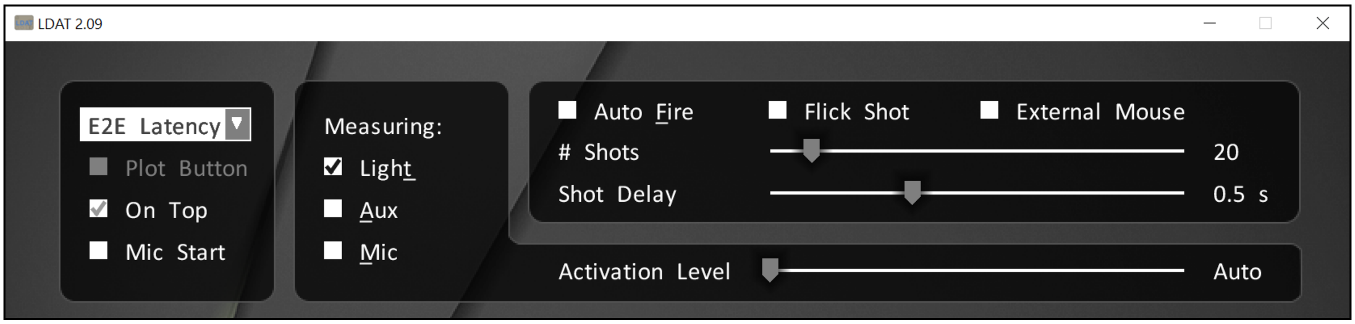
9. With the AWP equipped, **zoom in once with right click** and place the crosshairs on the tan window flower box. Set **# Shots** in LDAT to **100**. Ensure **Shot Delay** has been set to **2 seconds** in **LDAT**. Click **Autofire**.


Middle
47:20
0 0
A
B
$800
Place LDAT Sensor Here!
AWP
100
0
10 / 30

OTHER LDAT FEATURES

Internal / External Mouse

Unchecking the External Mouse option enables the LDAT v2 sensor to emulate a mouse click by acting as a USB mouse itself. When in Latency mode, **press the button on the LDAT v2** to emulate the mouse click.

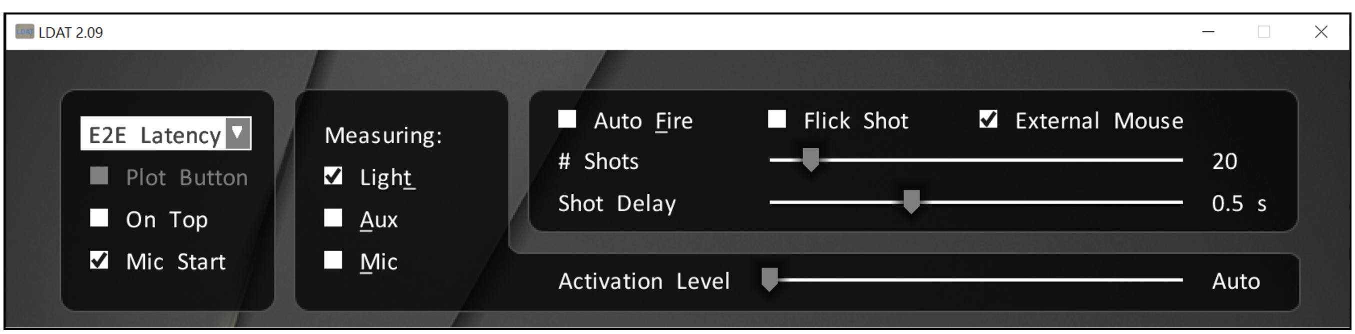


> This mode requires LDAT to be connected to the target system so that it can send a mouse click.

Mic Start

The Mic option enables the LDAT v2 sensor to listen for mouse clicks through a microphone, so you can use any mouse on hand, and not an officially wired mouse.

To enable this feature, select the **Mic Start** option and plug-in a **4 pole 3.5mm connector** into the headphone jack located on the top of the LDAT v2. Position the microphone close to the mouse that will be used for measuring latency. Click on the LDAT 2.0 software **within the latency measurement window** (click inside the application). Upon left mouse click or spacebar keyboard press, the software window will flash, and the microphone will send a signal to LDAT, indicating the mouse or keyboard has been clicked. The latency will then be calculated.



This method of calculating latency is a bit less accurate, but can serve as a great convenience feature when a wired LDAT mouse is not available.

Pause Key

By pressing the P hotkey, you can take a screenshot of the luminance measurement. This is a helpful way of pausing the pulse measurement for further analysis, such as adjusting the activation level.

Audio Measurement

LDAT includes a bonus feature for measuring audio latency, in order to confirm a good A/V (audiovisual) synchronization on your system. Using an aux cable, connect the LDAT sensor to the line-out jack on your PC. In the LDAT app, click the **Aux** check box in the measurement options, or press **A**. While not a core feature of LDAT, we thought its inclusion would be beneficial for some.

Measuring Pixel Response Time

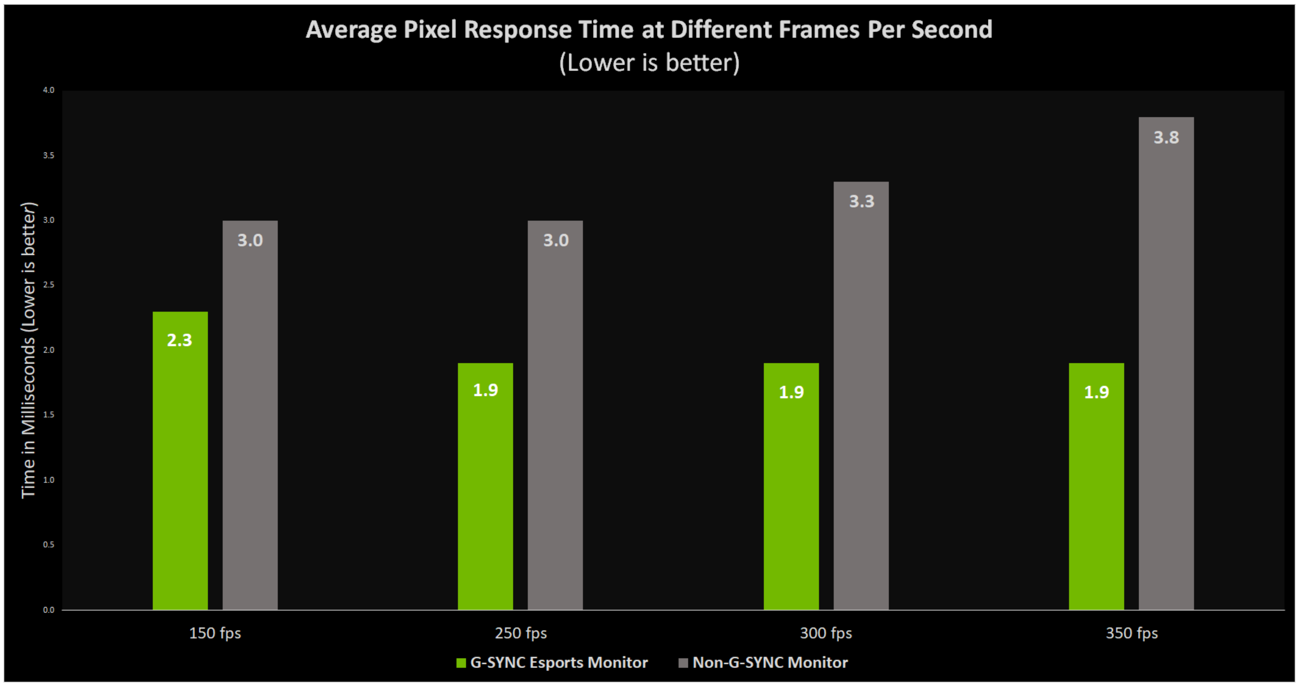
LDAT also has the ability to measure monitor pixel response time, the speed at which pixels on-screen change from one color to another, also known as Gray-to-Gray (GtG). Fast pixel response times are necessary to prevent motion blur in games. A common technique to improve response time is LCD overdrive, but excessive overdrive results in ghosting and other visual artifacts.

While higher refresh rates help improve motion clarity, a fast panel response time is critical for great motion clarity. With G-SYNC Variable Overdrive (explained below), G-SYNC displays can tune the panel's response time for the best motion clarity, regardless of frame rate.

NVIDIA G-SYNC Advantage

G-SYNC uses a patented technique called Variable Overdrive, which allows the display to choose the best overdrive tuning at any rendering rate (FPS), allowing for the fastest pixel response times possible in Variable Refresh Rate mode (VRR) without introducing unpleasant ghosting. Non-G-SYNC monitors don’t have this feature and suffer from reduced motion clarity. G-SYNC Variable Overdrive is a must-have motion clarity feature for high variable refresh rate displays. For competitive gamers, better motion clarity translates to faster decisions on the go, more precise clicking, and improved battlefield perception.

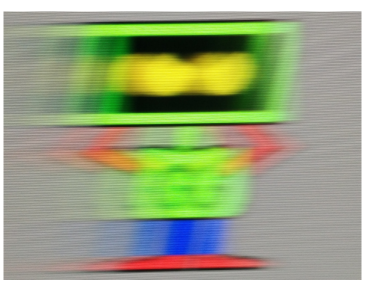
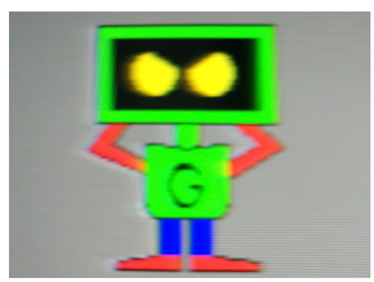
NVIDIA G-SYNC’s variable refresh rate (VRR) display technology eliminates screen tearing and reduces display stutter completely to deliver the smoothest and clearest gaming experience possible. It employs techniques to ensure frames are fully synchronized across the full range of FPS supported—with no minimum, and up to the panel’s maximum refresh rate, and with no artifacts. Thanks to careful quality control and attentive tuning and refinement, G-SYNC greatly reduces ghosting across the entire refresh range, providing crisp and detailed motion.



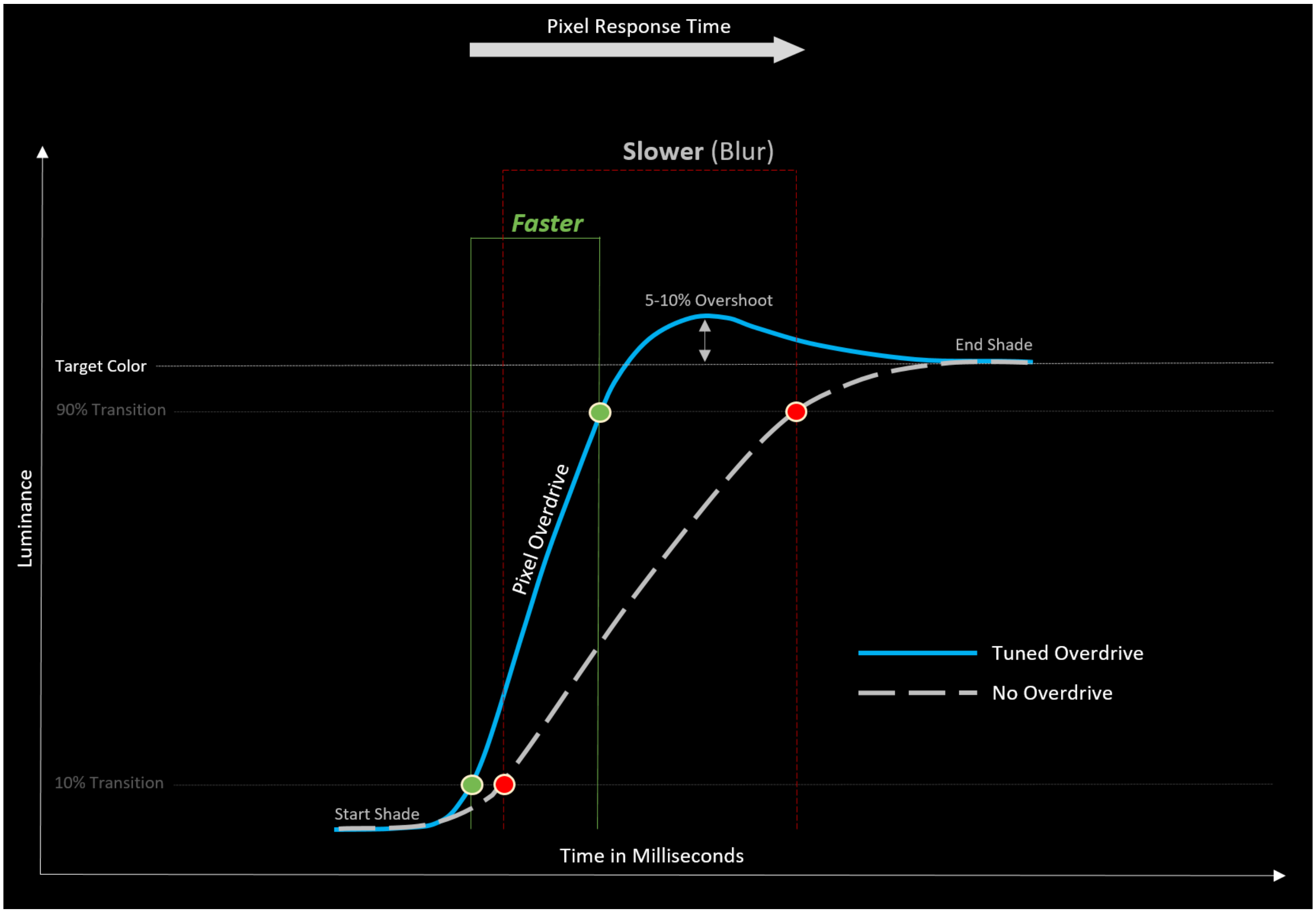
▲ G-SYNC Variable Overdrive maintains fast pixel transitions providing the best motion clarity at any frame rate.

How Variable Overdrive Works

To achieve the best motion clarity, display manufacturers increase the responsiveness of the panel with a technique called overdrive, allowing the changing pixels to “overshoot” the desired color values before settling back to the intended color. This helps the display transition to the intended color quicker, allowing you to react faster. But, if the overdrive is too high it will leave “negative ghosts” in the wake of movement.

		
No Overdrive **Blurry trailing image** **“Ghosting”**	**Excessive Overdrive** **Trailing artifacts** **“Negative Ghosting”**	**Well Tuned Overdrive** **Clear Image**

These ghosts and negative ghosts are created when the pixels from the prior frame have not finished transitioning by the time the next frame is ready to be displayed. With ghosting, color trails are left behind the image, making it look smeary. With negative ghosting, color trails are also left behind the image, but the colors are inverted because the pixel exceeded the target color with too much overdrive.



In the above diagram, the top line is the target color to transition to. The point from 10% of the transition to 90% of the transition is the pixel response time. Overdrive allows the transition of pixels to go from 10% to 90% of the transition quicker. A well tuned overdrive won't overshoot the target color too much while providing significant response time benefits.

This tuning process is complex and is typically done for a single refresh rate - except for G-SYNC displays. G-SYNC uses a patented technique called Variable Overdrive, which allows the display to choose the best overdrive tuning at any framerate. Since pixel overshoot typically increases as the refresh rate is lowered, non-G-SYNC displays generally use a single overdrive setting tuned for lowest Hz of the VRR range.

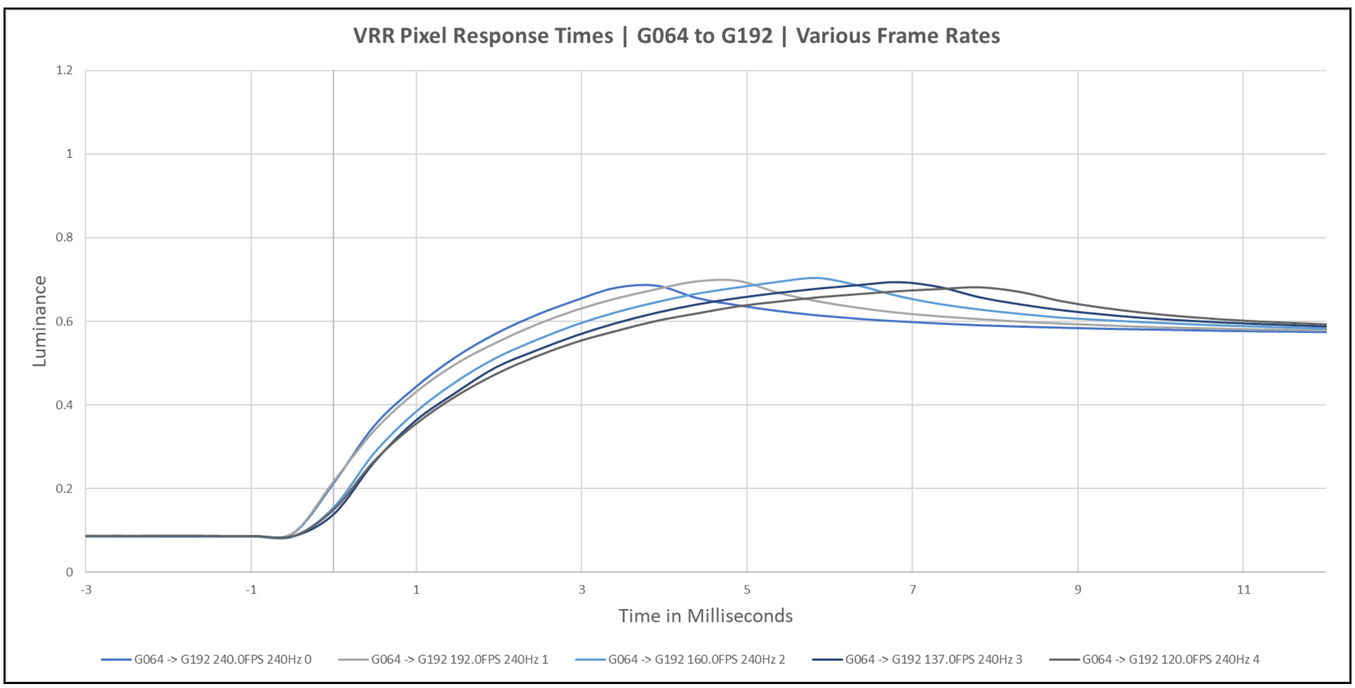
At higher frame rates, G-SYNC Esports displays have faster pixel response times because the amount of overshoot can be carefully managed as the frame rate increases and decreases. Non-G-SYNC displays nerf overdrive to avoid aggressive overshoot artifacts at lower frame rates, resulting in a blurrier image at higher frame rates. To put the numbers above into a real world context, below is an example at 350 FPS in *Counter Strike: Global Offensive* using G-SYNC Esports mode with hand tuned overdrive values for competitive play.

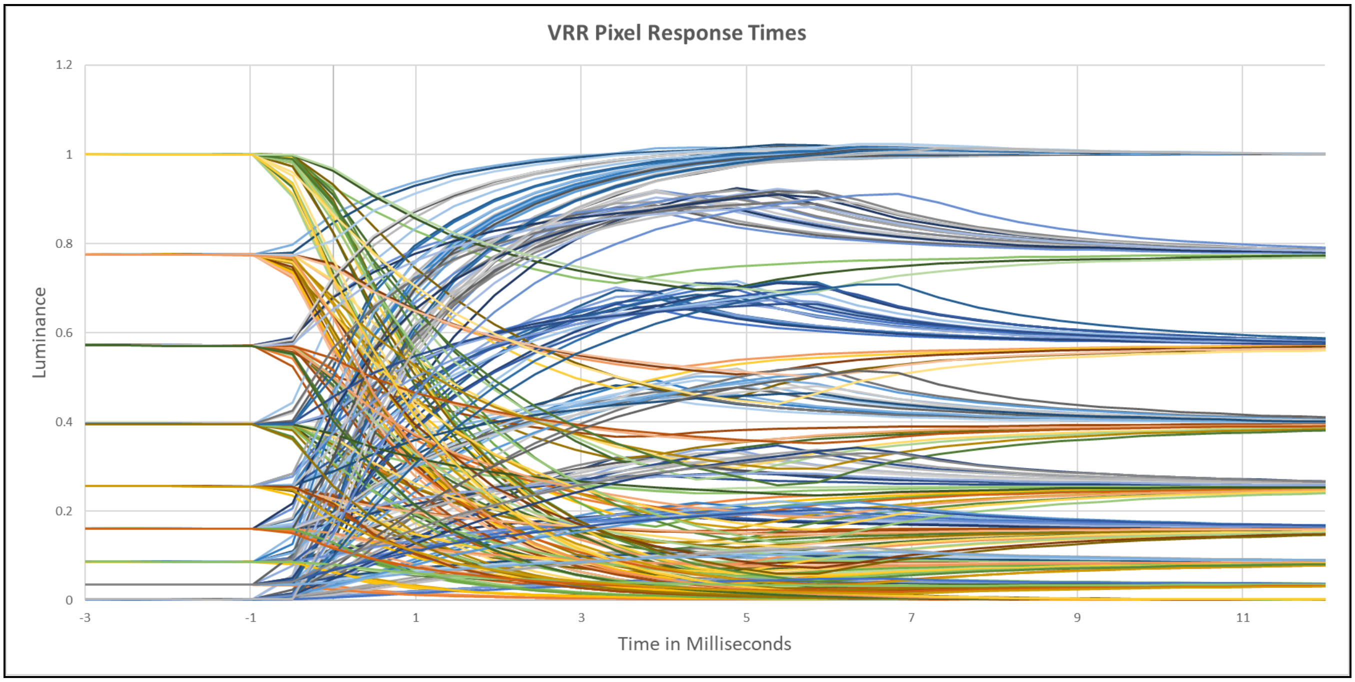
	
G-SYNC Esports Display **Variable Overdrive provides a clearer image**	Non-G-SYNC Display **Blurry trailing image**

Test G-SYNC Variable Overdrive

How does the test work?

The LDAT Display Test software runs the monitor through a series of gray level changes ranging from G000 (black) to G255 (white), such as G064 → G192 and G192→ G064, and at various frame rates in VRR. The LDAT sensor measures the time in milliseconds it takes for the pixels to transition from 10% to 90% of their final luminance.





▲ LDAT is an extremely robust and simple to use tool, capturing each pixel transition across various frame rates with minimal effort.

LDAT Setup

1. Ensure that you have an LDAT 5D (or newer) hardware sensor. It is required for testing pixel response time and display latency.
2. Follow the initial setup instructions.

Monitor Setup

3. **IMPORTANT:** The monitor should be pre-warmed by staying on for 1 hour with a bright and colorful background (no solid black background). The liquid crystals get faster as temperatures go up, allowing the individual pixels to change from one color to another color much faster. Lightly touch the monitor with your hand. It should feel *very* warm to the touch. To ensure the monitor warms up in a timely manner, adjust the Windows power plan settings as follows.
    a. Adjust the Windows **power** plan settings:
        i. Turn off the display: **Never**
        ii. Put the computer to sleep: **Never**

4. Due to the importance of measuring the display at warmer temperatures, it's recommended to run the various tests numerous times until the results have stabilized and no longer decrease, even if you think the monitor has already warmed enough. If pixel response times continue to go down after each test with the same overdrive setting, the monitor has not been warmed up sufficiently.

Failure to warm up the display will result in bad data		
FPS/Hz	**Display on for 10 minutes**	**Display on for 60 minutes**
	Slower Pixel Response Time	*Faster* Pixel Response Time
240	**5.676**	**5.215**
192	**5.412**	**4.896**
160	**5.188**	**4.781**
137	**5.039**	**4.679**
120	**5.012**	**4.645**

5. Access the monitor OSD by clicking the menu button or by pushing in the joystick. Navigate to the system menu and **reset the monitor to factory settings**. If you cannot reset the monitor, look for **(i)** in the OSD, and click the corresponding button next to **(i)** on the monitor itself in order to reset the monitor to factory defaults.
6. For G-SYNC monitors, navigate to **G-SYNC Processor** in the monitor OSD and turn on **G-SYNC Esports** mode. Make sure to enable G-SYNC Esports mode again after you're done experimenting with other overdrive settings.
7. For non G-SYNC monitors, you may have to enable AMD FreeSync in the monitor OSD to activate VRR.
8. Next, go to **Picture** and ensure **Max Brightness** is set to **On**. To increase/override the brightness on other monitors you may need to find a similarly named setting in the monitor power settings. Turn off any display adaptive brightness features, if any.
    a. Some monitors have an **Auto Brightness Control** (ABC) setting located in either the **Picture** or **Power** menu; make sure to turn it off to prevent the monitor from changing brightness based on local environment light.
9. Now set the **monitor brightness** or **peak white (nits)** to **maximum**.
10. Typically found in the **Picture** OSD menu, ensure that SDR/HDR **Variable Backlight** is **off**.
    a. Note whether HDR is on or off. You cannot disable the Full Array Local Dimming (FALD) backlight if HDR is on.
11. Typically found in the **Game** OSD menu, note the current **Overdrive** setting. **Do not change it**, for now. This is the factory default pixel overdrive setting. For the latest G-SYNC monitors, overdrive will be set to Esports mode. Be sure to set G-SYNC Esports mode to enable Esports

pixel overdrive. For other monitors it could be labeled Medium, High, Fast, or Extreme. Feel free to test the various overdrive settings once you've learned the ropes.

12. Note that pixel overdrive settings cannot be adjusted in VRR mode on certain Adaptive Sync monitors.
13. When comparing to non G-SYNC monitors, ensure the pixel overdrive settings for both monitors are similar in performance. For example, if Monitor A is set to Extreme (very fast response times but with extreme overshoot) and Monitor B is set to Normal (fast response times but with well controlled overshoot)—be careful—very fast response times are only beneficial if overshoot is well controlled. To ensure that you cover all the bases, it's best to test all overdrive settings available on the monitor. For some G-SYNC monitors, you cannot manually change to Esports overdrive in the standard overdrive menu; you must first enable G-SYNC Esports Mode in the monitor OSD to use Esports overdrive.

Response Times & Resulting Image Quality		
Aggressive Pixel Response Times	**Extreme** Overshoot *40% average or higher*	**Visual Experience: Poor** Negative Ghosting / Corona
Very Fast Pixel Response Times	**Well-controlled** Overshoot *5-15% average*	**Visual Experience: Great** Clear Image
Slow Pixel Response Times	**Limited** / **no** Overshoot *0-1% average*	**Visual Experience: Poor** Blurry Trailing Image

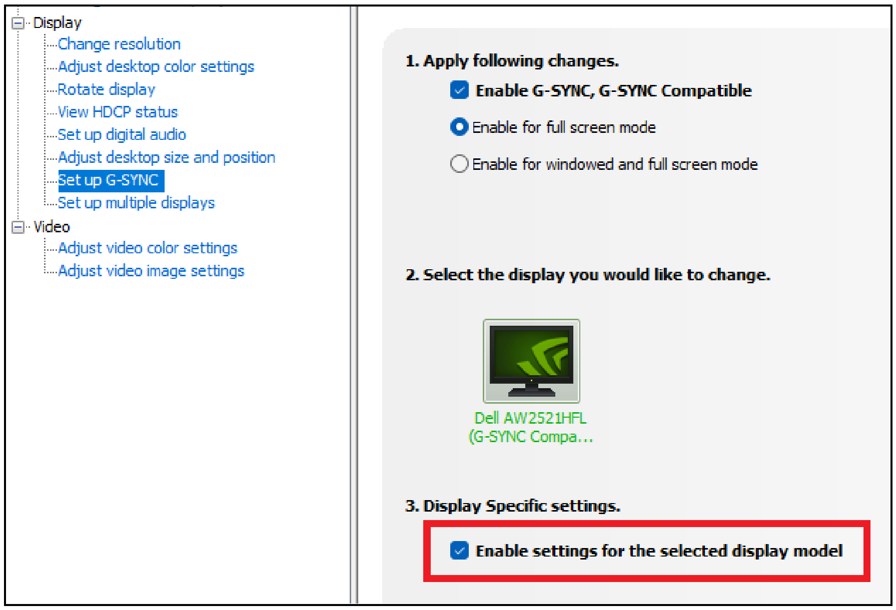
NVIDIA Control Panel Setup

- Install the latest GeForce Game Ready Driver.
- Open the **NVIDIA Control Panel**
    a. Click **Set up G-SYNC** and check the box to **enable G-SYNC**. Click Apply.
    b. Click **Change Resolution** and set the **monitor refresh rate** to the **highest.** Click Apply.
        i. Also set the monitor to its native resolution. Click Apply.
    c. Click **Manage 3D settings** and ensure
        i. **Vertical Sync** is set to **Use the 3D application setting**
        ii. **Preferred refresh rate** is set to **Highest Available**
        iii. **Monitor Technology** is set to **G-SYNC**.
        iv. Click Apply.
- **IMPORTANT:** If you're using a non-G-SYNC monitor, configuration will be slightly different.
    a. Click **Set up G-SYNC** and check the box to **enable G-SYNC Compatible**. Click Apply.
        i. You may have to enable AMD FreeSync in the monitor OSD to activate VRR.

b. If your Adaptive Sync monitor isn't listed as a G-SYNC Compatible monitor, you can still force enable Variable Refresh Rate. It may work, it may work partly, or it may not work at all. On the same page, look at the bottom for the **Display Specific Settings**.

   i. Check the box to **enable settings for the selected display model** (turn it on)

   ii. Be sure to check this box, if not, Variable Refresh will remain disabled.

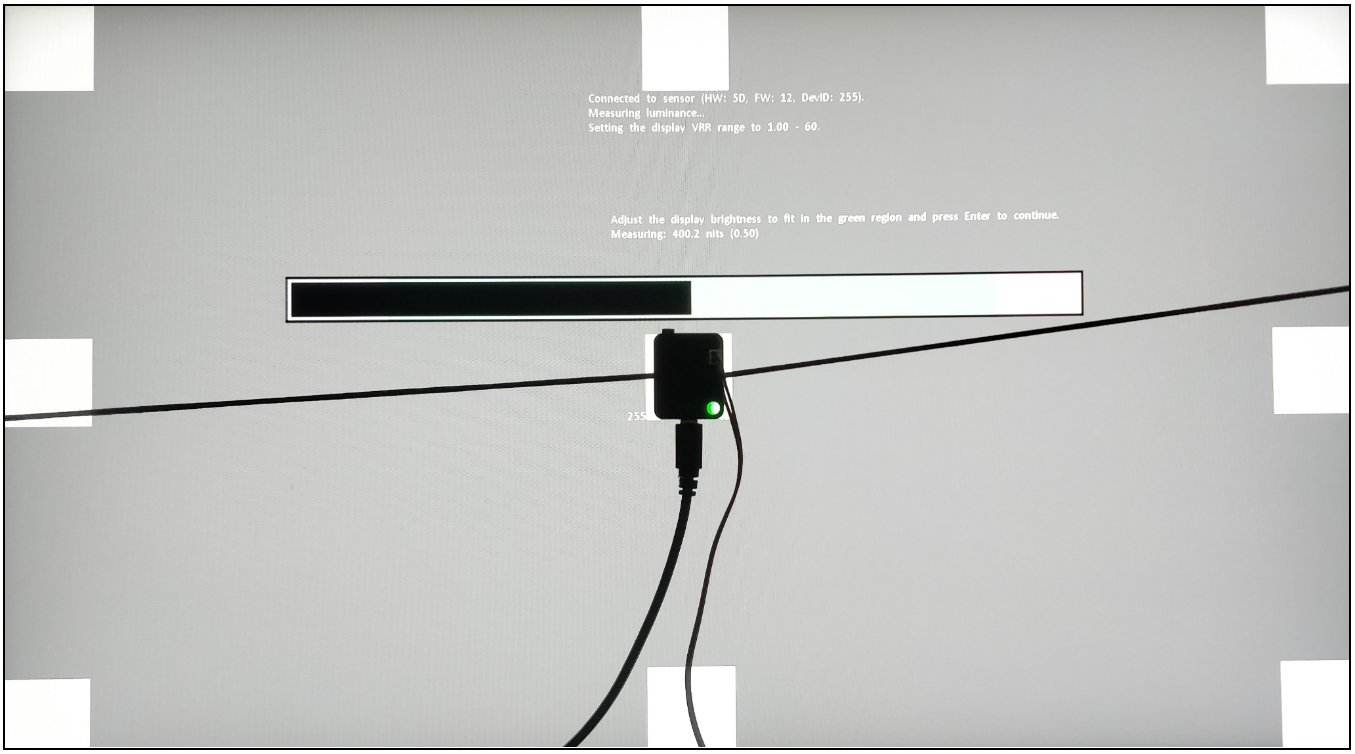


Your First Test - VRR On GtG Measurement

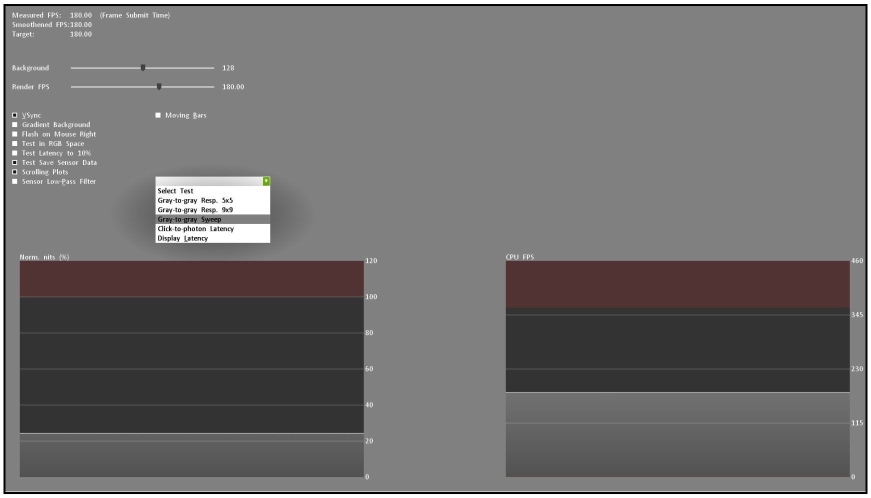
1. After following the above steps, open **LDAT_Display_Test.exe** on the same PC where the LDAT unit is attached.

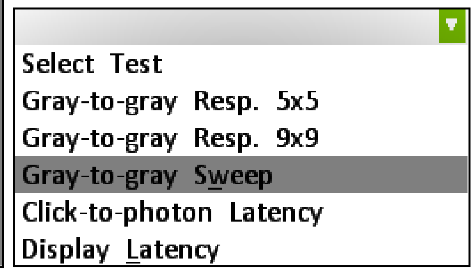
   a. Press **ESC** to close the application or to halt any test in progress.

2. Strap the LDAT module around the monitor using the elastic strap. Make sure the light sensor is facing the monitor and has flat/direct contact to the panel display (no gaps), and the status indicator is facing you (as shown below). Keep in mind the orientation of the LDAT; the sensor is not directly in the middle. After placing, do not bump or move the sensor.

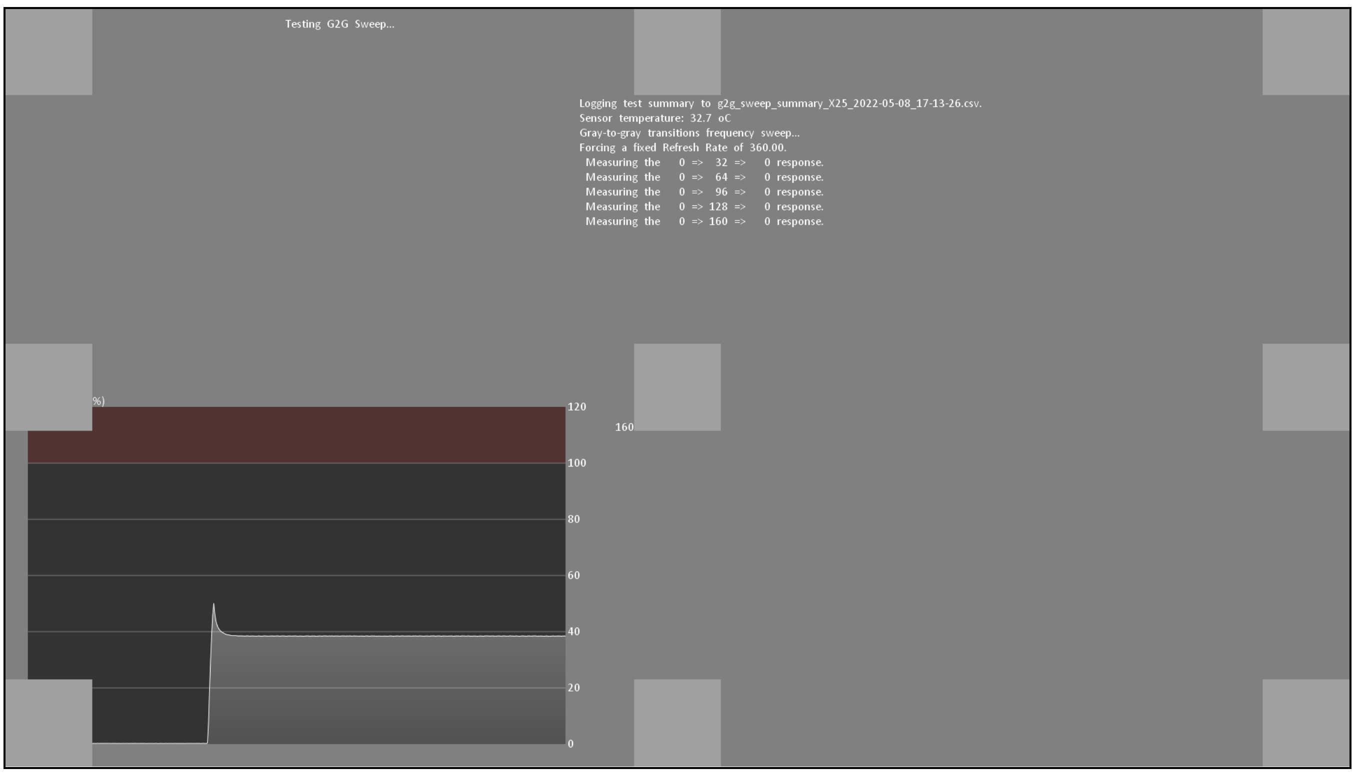


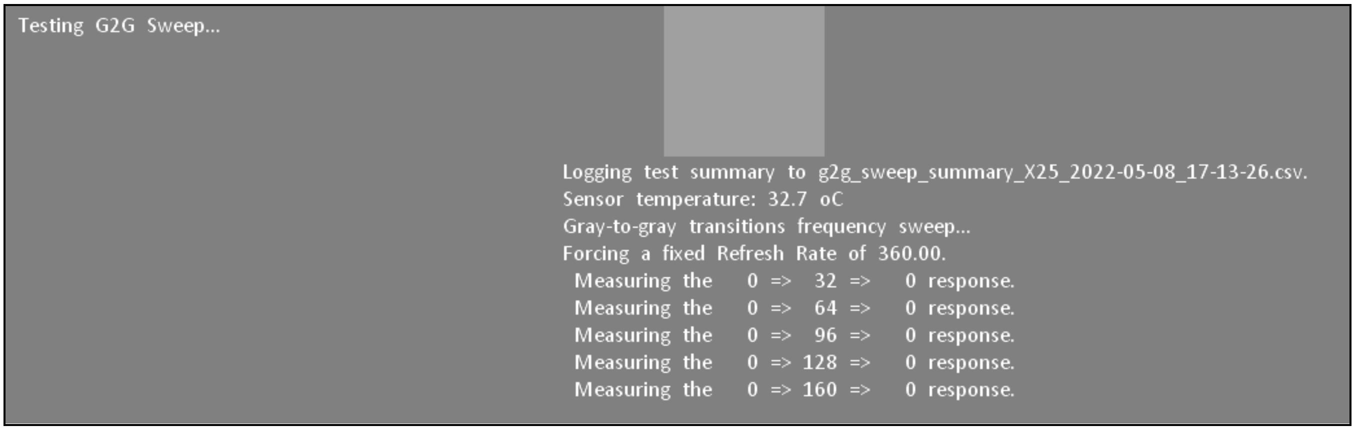
3. Place the LDAT directly in the middle of the screen so that it covers the white box.
4. Ensure the monitor is set to maximum brightness. If you cannot adjust the display brightness to fit in the green region, look for a brightness override option in the monitor OSD. The application requires at least 150 nits of brightness to start.
5. Press **ENTER**.
6. Do not adjust any settings in the application.
7. Note the current monitor pixel overdrive setting.
8. **IMPORTANT: Ensure the display has been warmed up sufficiently before testing (1 hour).**
9. Click the **drop-down** and choose **Gray-to-gray Sweep**.
    a. If you see the message "**G-SYNC must be enabled for this test**," this means either the monitor does not support Variable Refresh Rate (VRR) or VRR has not been turned on. In rare cases, there may be a VRR toggle option in some non G-SYNC monitors. **If VRR is not functioning, you will not be able to run the test.**
    b. **LDAT_Display_Test** will also show a warning **if VRR is not detected**. You don't need a G-SYNC monitor specifically, you just need VRR to be active.





10. **Gray-to-gray Sweep** tests various frame rates in **Variable Refresh Rate mode**.




Testing G2G Sweep...
Logging test summary to g2g_sweep_summary_X25_2022-05-08_17-13-26.csv.
Sensor temperature: 32.7 oC
Gray-to-gray transitions frequency sweep...
Forcing a fixed Refresh Rate of 360.00.
Measuring the 0 => 32 => 0 response.
Measuring the 0 => 64 => 0 response.
Measuring the 0 => 96 => 0 response.
Measuring the 0 => 128 => 0 response.
Measuring the 0 => 160 => 0 response.

11. The test is complete when the message "**Response curves saved to disk**" appears. The test takes about 2 minutes.

```
Measuring the  96 => 224 =>  96 response.
Measuring the  96 => 255 =>  96 response.
Measuring the 128 => 160 => 128 response.
Measuring the 128 => 192 => 128 response.
Measuring the 128 => 224 => 128 response.
Measuring the 128 => 255 => 128 response.
Measuring the 160 => 192 => 160 response.
Measuring the 160 => 224 => 160 response.
Measuring the 160 => 255 => 160 response.
Measuring the 192 => 224 => 192 response.
Measuring the 192 => 255 => 192 response.
Measuring the 224 => 255 => 224 response.
  Result: 2.252 ms resp. time, 33.41% overshoot (67.46% max up, 52.61% max down).

Response curves saved to disk.
Going back to Variable Refresh Rate.
```

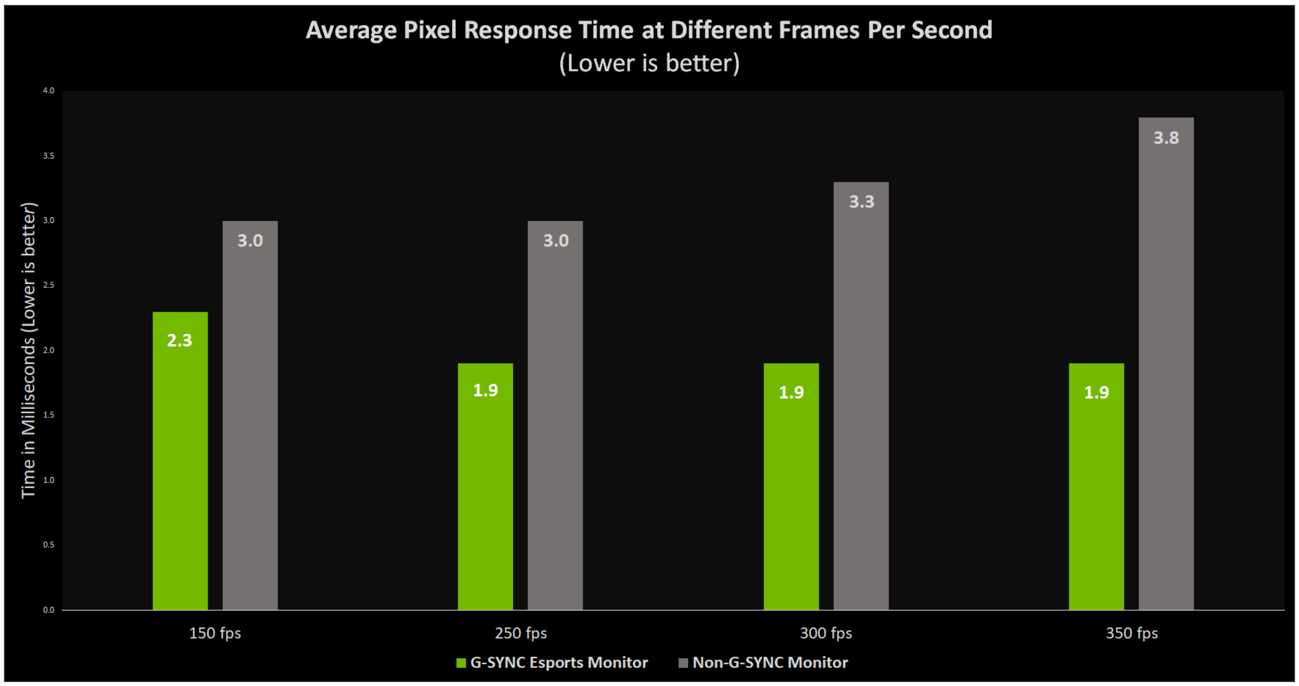
12. The VRR pixel response time summary .csv results are saved in the folder where LDAT_Display_Test.exe is located.
13. Run the test 3+ times to verify the response time results are unchanging.

Name
g2g_sweep_summary_X25_2022-05-08_17-09-28.csv
g2g_transitions_X25_2022-05-08_17-09-28.csv
LDAT User Guide.pdf
LDAT.exe
LDAT_Display_Test.exe

	A	B	C	D	E	F
1	Display name	X25				
2	Display ID	7204&08F5				
3	Max refresh	360	Hz			
4	Max luminance	410.7	nits			
5	Variable refresh (G-SYNC)	Yes				
6	Sensor version	HW: 5D, FW: 12, DevID: 255				
7	Sensor rate	2048	Hz			
8	Sensor temperature	31.9	oC			
9	LDAT-Display version	2.16 (May 4 2022)				
10						
11	Refresh [Hz]	Resp. time [ms]	Avg overshoot [%]	Avg overshoot excl. 0 and 255 [%]	Max overshoot up [%]	Max overshoot down [%]
12	360	2.123	13.8	17.7	52.7	22.2
13	288	2.163	19.2	24.6	60.8	33.6
14	240	2.245	22.1	28.4	65.5	41
15	206	2.292	24.1	30.8	64.8	45.9
16	180	2.38	24.2	30.9	64.1	48.4

Results

Here are the expected results that you should see when comparing a G-SYNC monitor to a non G-SYNC monitor. If you see lower than expected response times for the non G-SYNC monitor, check their average overshoot percentage in the log (and make sure you tested with VRR on by enabling G-SYNC Compatible and checking the box to enable settings for the selected display model if the Adaptive Sync monitor is *not* G-SYNC Compatible). If the non G-SYNC monitor has extreme overshoot (40% average or higher), that means they apply far too much voltage causing the pixel to greatly exceed the target color. This results in unsightly negative ghosting artifacts that *will* be noticeable while playing a game.



▲ G-SYNC Variable Overdrive maintains fast pixel transitions providing the best motion clarity at any frame rate.

Super Fast Pixel Overdrive Non G-SYNC Monitor	Refresh [Hz]	Resp. time [ms]	Avg overshoot [%]	Non G-SYNC Monitor VRR ON GtG is slower than VRR OFF	X
VRR ON / GtG Sweep	**240**	**4.2**	**0.0**	1.4 ms Slower Overall 1.6 ms Slower at 240Hz	
	192	3.9	0.1		
	160	3.8	1.3		
	137	3.8	3.7		
	120	3.8	5.8		
VRR OFF / GtG Resp. 9x9	**240**	**2.5**	**12.8**		

Esports Pixel Overdrive G-SYNC Monitor	Refresh [Hz]	Resp. time [ms]	Avg overshoot [%]	G-SYNC VRR ON GtG is Similarly Performant to VRR OFF	✓
VRR ON / GtG Sweep	**240**	**2.3**	**15.3**	0.2 ms Difference Overall 0.0 ms Difference at 240Hz	
	192	2.4	18.4		
	160	2.5	19.3		
	137	2.7	18.9		
	120	2.9	17.3		
VRR OFF / GtG Resp. 9x9	**240**	**2.3**	**15.2**		

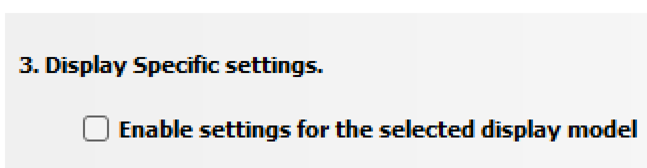
Esports Pixel Overdrive G-SYNC Monitor	Refresh [Hz]	Resp. time [ms]	Avg overshoot [%]	G-SYNC VRR ON GtG is Similarly Performant to VRR OFF	✓
VRR ON / GtG Sweep	**360**	**1.9**	**16.3**	0.1 ms Difference Overall 0.0 ms Difference at 240Hz	
	288	2.0	21.4		
	240	2.1	24.7		
	206	2.1	26.3		
	180	2.2	26.1		
VRR OFF / GtG Resp. 9x9	**360**	**1.9**	**16.4**		

▲ In the example above, you can see how non G-SYNC monitors nerf overdrive at higher frame rates, resulting in a blurrier image for gamers using VRR. Note how G-SYNC variable overdrive maintains similar pixel response times between VRR ON/OFF. Only NVIDIA G-SYNC with Variable Overdrive delivers the best motion clarity across the entire refresh rate range.

Optional - VRR Off GtG Measurement

> You can also test pixel response time with G-SYNC disabled (Variable Refresh Rate disabled). However, keep in mind that not all monitors are equal and so it's worth understanding the differences between G-SYNC and non G-SYNC monitors, so if you're testing pixel response time you may as well investigate both VRR on and off because LDAT makes testing easy and fast. The VRR sweep test will show the strengths of G-SYNC (maintains fast pixel transitions providing the best motion clarity at any frame rate) and the limitations of other non G-SYNC monitors (they nerf overdrive to avoid aggressive overshoot artifacts at lower frame rates, resulting in a blurrier image at higher frame rates).

- Follow these instructions to set up LDAT and the monitor.
  - Please *first* review how to test pixel response times with VRR active to get yourself familiar with the general setup and testing procedures.
- Open the **NVIDIA Control Panel**
  c. Click **Set up G-SYNC** and uncheck the box to **disable G-SYNC**. Click Apply.
  d. Click **Change Resolution** and set the **monitor refresh rate** to the **highest.** Click Apply.
    i. Also set the monitor to its native resolution. Click Apply.
  e. Click **Manage 3D settings** and ensure
    i. **Vertical Sync** is set to **Use the 3D application setting**
    ii. **Preferred refresh rate** is set to **Highest Available**
    iii. **Monitor Technology** is set to **Fixed Refresh**.
    iv. Click Apply.
- **IMPORTANT:** If you're using a non-G-SYNC monitor, configuration will be slightly different.
  a. Click **Set up G-SYNC** and uncheck the box to **disable G-SYNC Compatible**. Click Apply.
  b. Now, on the same page, look at the bottom for the **Display Specific Settings**.
    i. Uncheck the box to **disable settings for the selected display model** (turn it off)



- After following the above steps, open **LDAT_Display_Test.exe** on the same PC where the LDAT unit is attached.
- Do not adjust any settings in the application.
- Note the current monitor pixel overdrive setting.
- **IMPORTANT: Ensure the display has been warmed up sufficiently before testing (1 hour).**
- Click the **drop-down** and choose **Gray-to-gray Resp. 5x5**.

Select Test
Gray-to-gray Resp. 5x5
Gray-to-gray Resp. 9x9
Gray-to-gray Sweep
Click-to-photon Latency
Display Latency

- In this scenario, **Gray-to-gray Resp. 5x5** will test at the max refresh rate with **VRR Off**.
- Run the test 3+ times to verify the response time results are unchanging.
- If your goal is to run the test with VRR Off, ensure it's actually disabled.

Warning: G-SYNC is disabled, rendering at the max refresh rate.
Gray-to-gray transition testing, 5 taps at 360.0 fps...

- You can also check whether or not VRR was active in prior tests by checking the summary file.

	A	B	C	D
1	Display name	X25		
2	Display ID	7204&08F5		
3	Max refresh	360	Hz	
4	Max luminance	410.7	nits	
5	Variable refresh (G-SYNC)	No		
6	Sensor version	HW: 5D, FW: 12, DevID: 255		
7	Sensor rate	2048	Hz	
8	Sensor temperature	37.5	oC	
9	LDAT-Display version	2.16 (May 4 2022)		
10	Measurement space	Linear nits		
11	Render rate	360	fps	

- <u>**Advanced Users Only**</u>: If you want to run the **Gray-to-gray Resp. 5x5** and **9x9** tests with **VRR on**, make sure you note and adjust the Render FPS slider in the app accordingly prior to each test. Caution, this method is not recommended as it's prone to user error; you may not remember if VRR is on or off. The VRR Gray-to-Gray Sweep test prevents this from happening by not allowing the test to proceed if VRR mode is not detected.

G-SYNC Low Latency Gaming

There is a myth that G-SYNC adds latency—this is false. Gamers who enjoy G-SYNC for the highest resolutions and frame rates, excellent color and motion clarity, and a guaranteed wide VRR range starting from 1Hz, among other features such as Reflex Analyzer and NVIDIA ULMB® (Ultra-Low Motion Blur)—keep on gaming—G-SYNC has no latency and is the best way to play your favorite games, with no ghosting, no tearing, and no lag!

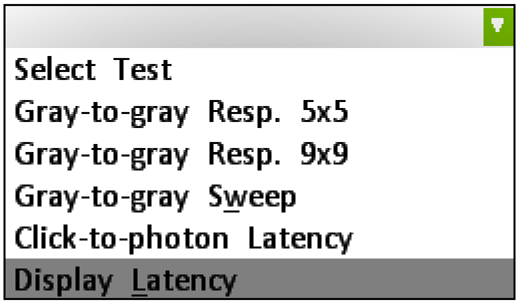
Measure Display Latency

Display Latency is not to be confused with pixel response time, the time from the pixels changing from one color to another, also known as gray-to-gray. **Display Latency** is the signal processing delay of a display from when a frame starts scanning out on the GPU to when the screen responds. LDAT detects the first observable change (6% increase from the initial brightness).

360Hz G-SYNC Esports Monitor	
Display Latency Measurement	
G-SYNC On 360 FPS	G-SYNC Off 360 FPS
1.6 ms	1.6 ms
G-SYNC has zero latency	

- Follow these instructions to set up LDAT, the monitor, and NVIDIA Control Panel.
  - Please *first* review how to test pixel response times with VRR active to get yourself familiar with the general setup and testing procedures.
- Keep in mind the orientation of the LDAT; the sensor is not directly in the middle. For the best results, place the sensor directly in the middle of the white box.
- After following the above steps, open **LDAT_Display_Test.exe** on the same PC where the LDAT unit is attached. Ensure that G-SYNC is enabled for this test.
- Do not adjust any settings in the application.
- **IMPORTANT: Ensure the display has been warmed up sufficiently before testing (1 hour).**

- Click the **drop-down** and choose **Display Latency**. The LDAT software will run at the max refresh with matching frame rate.



- No log is generated. The result is shown at the end of the test.

- Run the test a few more times to ensure the data is unchanging.

Ensure that VRR is enabled for this test.

Note that display latency is at the very best half of a frame time, because the GPU starts scanning out after a flip and we need to wait for half the lines to arrive before the mid screen sensor sees the new frame. In reality it is slightly larger, because there are a few black lines sent after the GPU flip and also because the LCD panel needs some time to change when the middle screen line is received.

Measure Click to Photon Latency

With the LDAT.exe application, you can test latency in virtually any game, but in order to precisely isolate click to photon latency without a game, you'll want to use LDAT Display Test for the most accurate and consistent measurements. What you'll find is that G-SYNC adds *no* latency, and that there's no reason to turn it off.

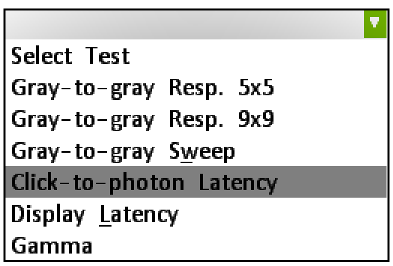
360Hz G-SYNC Esports Monitor			
Click to Photon Measurement			
Mode	460 fps	357 fps	100 fps
G-SYNC On / V-Sync Off	**3.5 ms**	**3.9 ms**	**8.5 ms**
G-SYNC Off / V-Sync Off	3.4 ms	4.0 ms	8.5 ms
G-SYNC has zero latency			

- Follow these instructions to set up LDAT, the monitor, and NVIDIA Control Panel.
    - Please *first* review how to test pixel response times with VRR active to get yourself familiar with the general setup and testing procedures.
- Keep in mind the orientation of the LDAT; the sensor is not directly in the middle. For the best results, place the sensor directly in the middle of the white box. After placing, do not bump or move the sensor.
- **IMPORTANT: Ensure the display has been warmed up sufficiently before testing (1 hour).**
- **Ensure that V-Sync is disabled and the monitor is set to the highest refresh. Open the NVIDIA Control Panel and click Manage 3D Settings.**
    - **Disable V-Sync:** Scroll down and set Vertical Sync to Off. Click Apply.
    - **Set highest refresh rate:** Set monitor Preferred Refresh Rate to Highest Available. Click Apply.
- After following the above steps, open **LDAT_Display_Test.exe** on the same PC where the LDAT unit is attached.

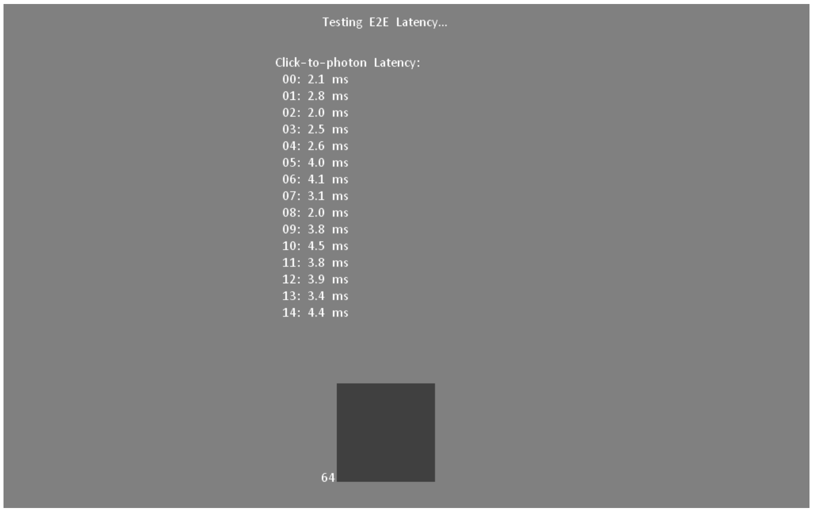
- Disable V-Sync in LDAT Display Test. Uncheck the box.

- Set the desired frame rate for testing. You can use the arrow keys to finely adjust the fps slider when hovering the mouse cursor over the slider.

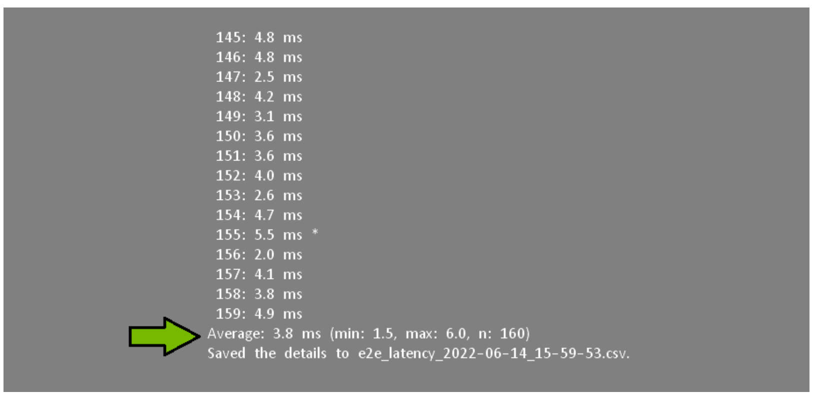
- We recommend testing the following fps thresholds (460, 357, and 100 fps) with G-SYNC On / V-Sync Off and G-SYNC Off / V-Sync Off.
- Verify that G-SYNC is enabled in the NVIDIA Control Panel.
- Click the **drop-down** and choose **Click to photon latency**.



- Run the test at 460, 357, and 100 fps with G-SYNC On / V-Sync Off.
    - Run the test a few more times to ensure the data is unchanging.



- Each result is temporarily displayed on the screen after each test. The click to photon latency summary .csv results are saved in the folder where LDAT_Display_Test.exe is located.

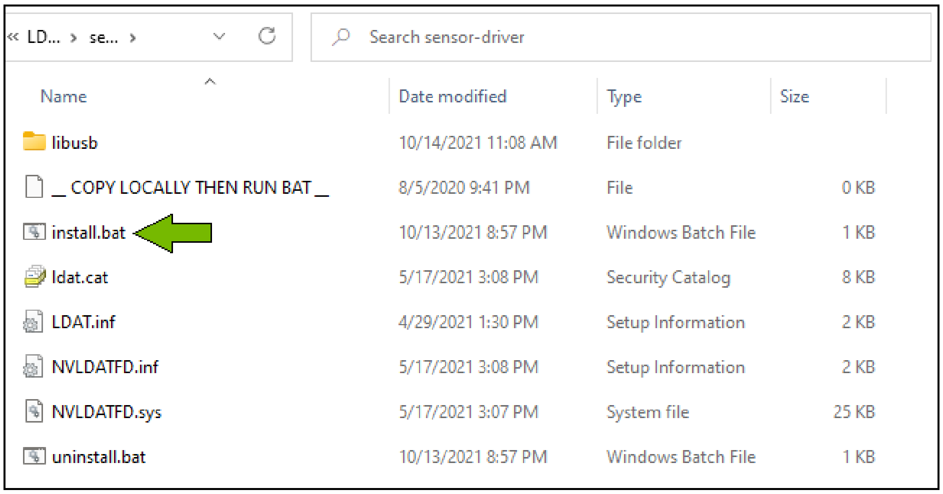


- Now disable G-SYNC in the NVIDIA Control Panel.
- Run the test at 460, 360, 357, and 100 fps with G-SYNC Off / V-Sync Off.
    - Run the test a few more times to ensure the data is unchanging.

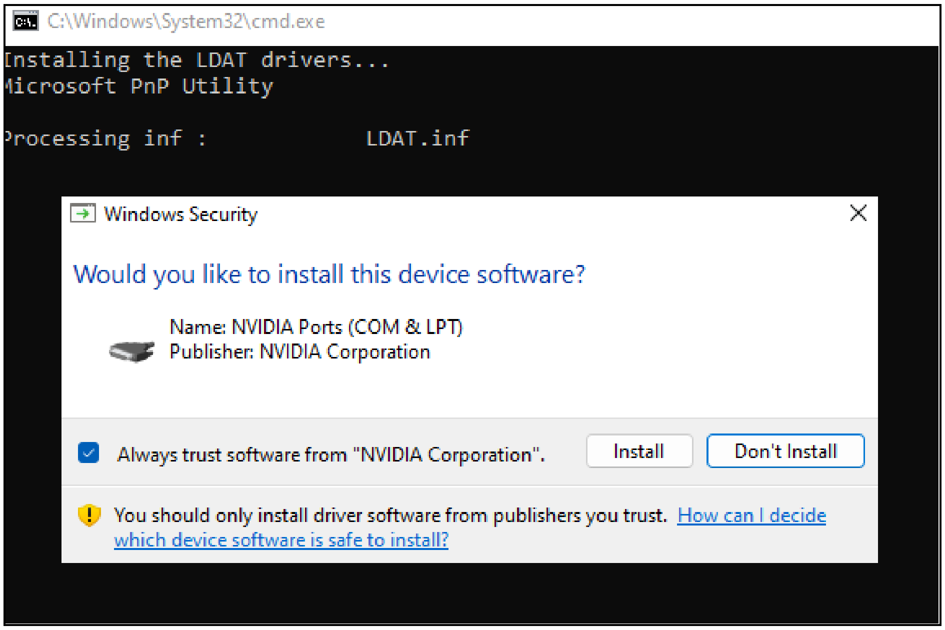
Measure Mouse Latency

LDAT can measure the latency of most mice. You can also test your own mouse by modifying it to interoperate with the LDAT unit by following these instructions.

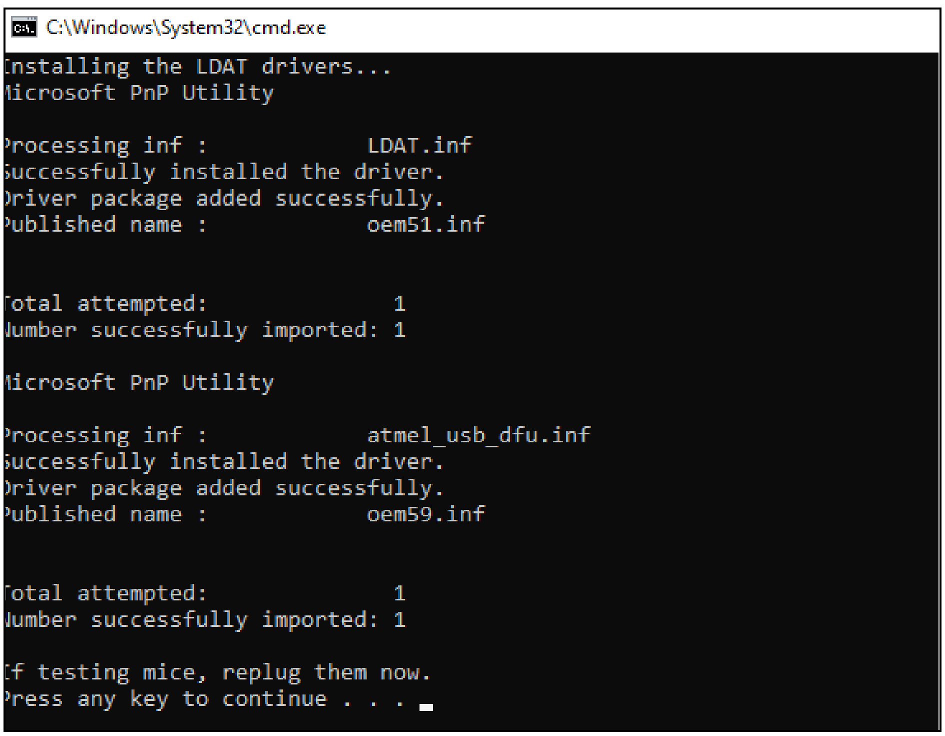
1. Follow the initial setup instructions to first get yourself familiar with LDAT.
2. Install the LDAT mouse driver (**NVLDATFD**).
    a. Next to the LDAT.exe, navigate to the **Driver** folder and click **install.bat**.



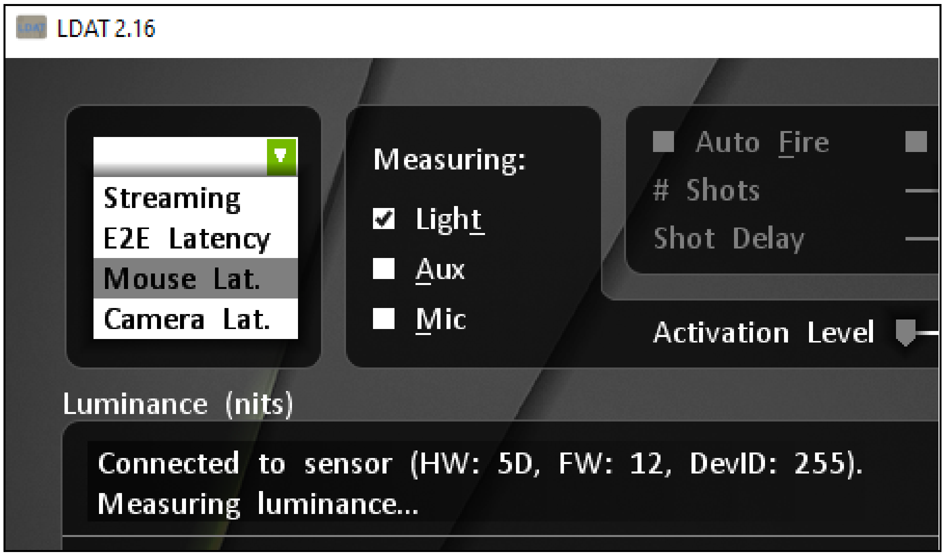
b. Install the device driver.



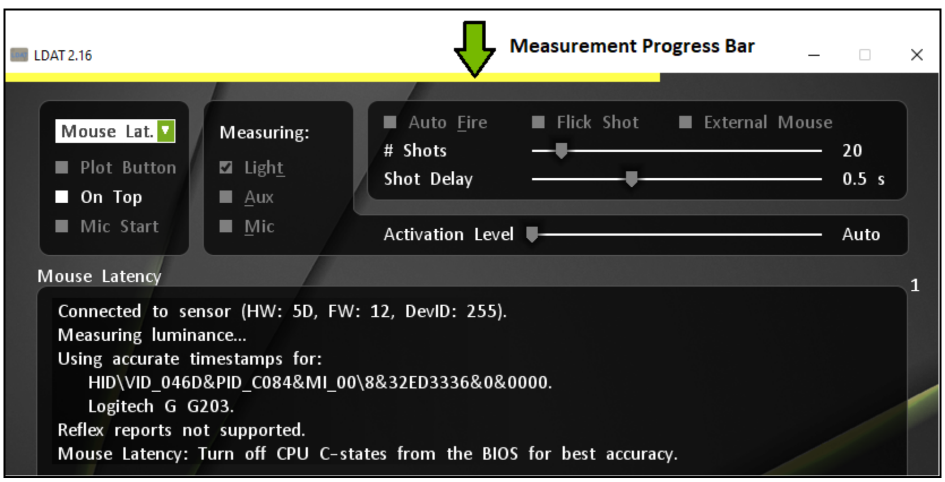
c. After installation is complete, **restart the PC**.



3. Launch **LDAT.exe**. There is no need for the sensor to be attached to the monitor.
4. Click the **drop-down menu** with the **<u>mouse connected to the LDAT sensor</u>** and click **Mouse Lat.**



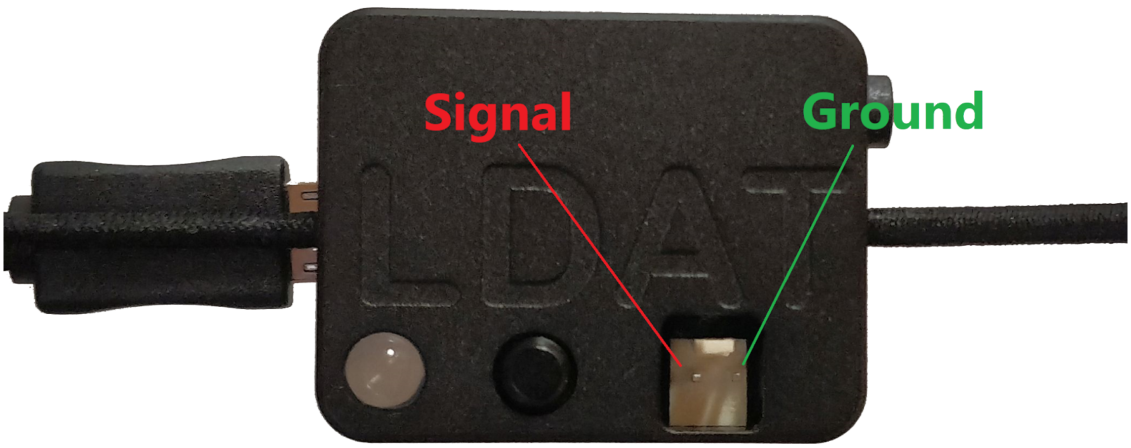
5. Mouse latency measurement will start.



6. The mouse latency summary .csv results are saved in the folder where LDAT.exe is located.

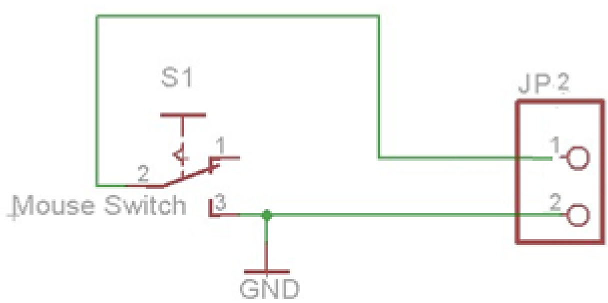
Instrumenting Another Input Device/Mouse

LDAT can measure the button state of most mice and can click many more devices. The section describes how to modify a mouse or a game controller to interoperate with LDAT.

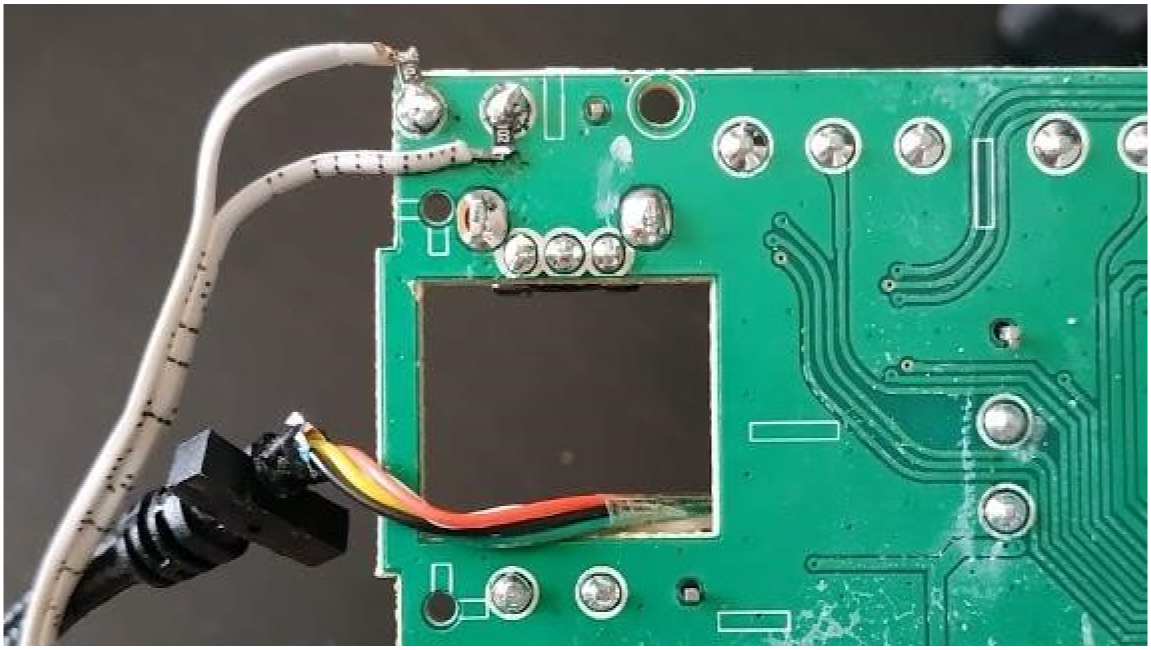


Pin mapping

1. 2 of the 3 terminals of the mouse button need to be connected to the sensor. One is ground, and the other is the control pin switching between 5V (or less depending on mouse) and ground when clicked. Ignore the 3rd terminal: some mice leave it floating or connected to the supply. Do not connect this terminal.



2. Drill a hole in the mouse casing and pass the new wires through or route the cable next to the existing USB cable.
3. Solder a female jumper socket at the end of the wire that will plug into LDAT. Use a 2x1 0.1” socket.



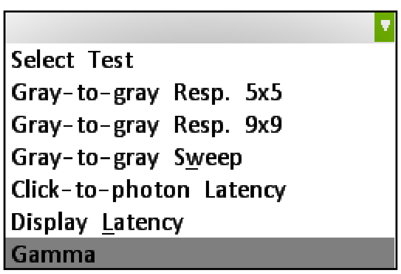
An instrumented mouse

Measure Gamma

Gamma affects picture mid-gray levels. It's important that the monitor properly tracks each gray level (G000 to G255) as content is designed for a gamma of 2.2. If gamma is too high, the picture mid-tones will be too dark and lose detail. If gamma is too low, picture mid-tones will be too light and the picture will look washed out.

> In GSYNC monitors, the factory reset has accurate gamma. Note that in Esports Mode, we brighten darker areas to allow players to more easily identify players hiding in these darker areas to provide them a competitive edge.
>
> To properly test gamma on the most recent G-SYNC monitors, **perform a factory reset** on the monitor. Optionally, you could set **Relative Gamma** to **Default** *and* **Dark Boost** to **Off**.
>
> Also note whether the variable backlight is off/on and which backlight response mode.
>
> Remember to set the monitor back to G-SYNC Esports mode when testing pixel response times.

- Ensure that you have an **LDAT 5F** (or newer) hardware sensor. Open **LDAT_Display_Test.exe** on the same PC where the LDAT unit is attached.
- Do not adjust any settings in the application.
- Click the **drop-down** and choose **Gamma**.



- The application will now display the full RGB range (0-255). LDAT will measure the gamma.

- The gamma summary .csv results are saved in the folder where LDAT_Display_Test.exe is located.

Display name	X25	
Display ID	7204&08F5	
Max refresh	360	Hz
Max luminance	391.1	nits
Variable refresh (G-SYNC)	Yes	
Sensor version	HW: 5D, FW: 12, DevID: 255	
Sensor streaming rate	512	Hz
LDAT-Display version	2.17 (May 31 2022)	
Render rate	180	fps
Measured Gamma Exponent	2.23	
Cumulative Error	2	
Note	The gamma test is more accurate with LDAT 5F or later sensor.	

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