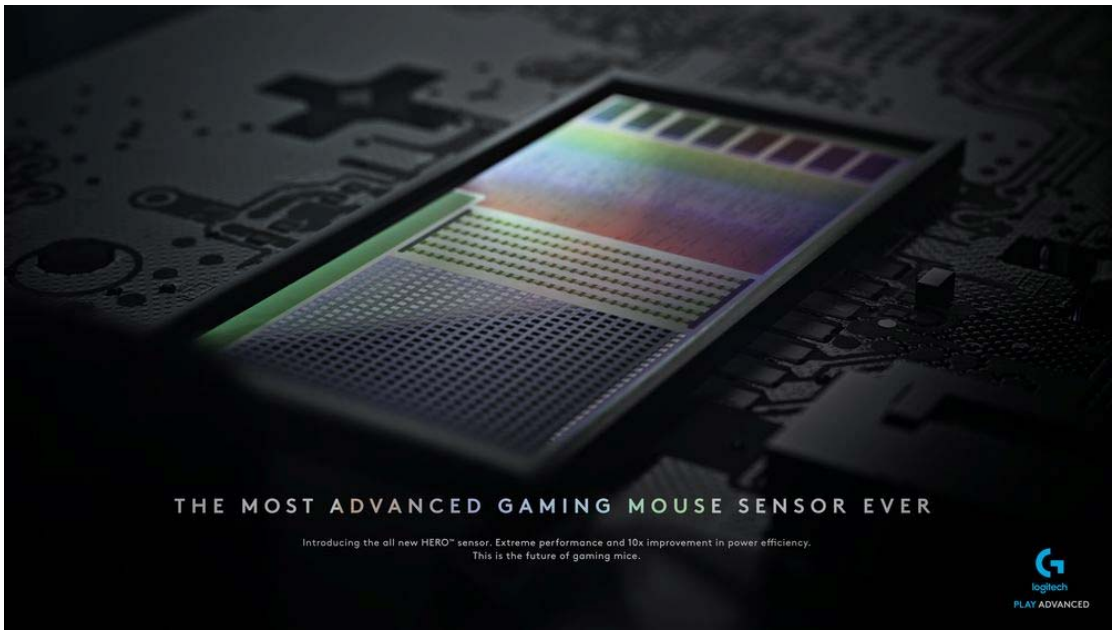
Anatomy of a HERO
HERO 传感器介绍



HERO Optical Sensor
HERO 光学传感器

The HERO architecture sets a new precedent in optical gaming sensor design. It has been designed from the ground up to optimize performance and efficiency and sets the new standard for optical gaming sensors.
HERO 开创了游戏光学传感器设计新的先河。这个被设计用来进一步优化性能与节能的平衡以及为游戏光学传感器设立了新的标准。

In the history of gaming mouse sensor development, there have been many different iterations of a few core architectures, many designed with Logitech. Most sensors focus on either maximizing performance or maximizing efficiency as the two values are historically mutually exclusive. If you max out performance, it usually takes a lot more power, and if you max out efficiency you sacrifice performance. With HERO, Logitech has created an entirely new architecture and operating philosophy that delivers ultimate performance AND efficiency for the first time together.
在先前的游戏鼠标传感器的开发中，一个设计能迭代产生很多产品，其中不少是由罗技设计的。大多数传感器要么追求最大化的性能，要么追求最大化节能，但鱼与熊掌不可兼得。如果你追求性能，那么必然增加能耗，反过来你追求节能，你会牺牲一些性能。而 HERO，罗技建立了全新的架构和理念，首次把性能与低能耗结合在了一起。

Requirements for Gaming Sensors

游戏传感器技术要求

When looking at the performance of a gaming sensor, there are many metrics to consider. Below are some of the factors used to discuss the performance of a gaming sensor. Logitech G has minimum values set as a requirement for our gaming sensors.
当评估一个游戏传感器的性能的时候，有很多项指标需要考虑。下面是一些常用的用来对比的项目。罗技 G 对我们自己的传感器每一项参数都有设定有最低的技术要求。

Accuracy: The ability to consistently deliver the same cursor distance traveled on screen, irrespective of the physical speed at which the mouse is moved between two points on the tracking surface. Terms like “1 to 1” or “raw input” are attempts to describe accuracy. Logitech G has a minimum requirement of 98% accuracy over the entire surface range for our gaming sensors.
准确度：对鼠标的物理移动距离准确反映在屏幕上的能力。像“1 比 1”或者“原生输入”就是用来描述准确性的。罗技 G 自身的最低要求是在整个滑动距离中最低达到 98%的准确度。

Max Speed: The maximum speed your mouse can physically be moved over the surface while still allowing the sensor to correlate and send accurate X/Y data. Typical metrics are Inches per Second (IPS) or Meters per Second (m/s). The target value is 300 IPS (7.62m/s) over the entire surface range.
最大速度：能让传感器正常传递 X/Y 轴位移的最大移动速度。通常的指标是 IPS（英尺/秒）或者米/秒。我们的标准是达到 300IPS 即 7.62 米/秒。
PS：21.5 寸 16：9 显示器的宽度是 47.6cm 左右，这个最大速度就是从显示器的最左到最右在 0.06 秒内完成。

Smoothing: A filtering method embedded in the optical sensor or mouse firmware that averages multiple data counts together to eliminate, or smooth out, erroneous (or spurious) motion. This leads to smooth (ripple-free) tracking, but adds latency to cursor movement. It is because of this latency that smoothing is very bad for gaming. Our requirement is zero smoothing over the entire DPI range and Logitech G is the only company currently delivering on this promise.
平滑：在光学传感器或者鼠标固件中的过滤算法，将多项数据平均去除错误的位移。这个可以让移动更平滑，但是会带来光标的移动延迟。由于这种延迟，平滑算法不利于游戏。我们的要求是在所有 DPI 范围内做到 0 平滑，罗技 G 是唯一一个公司实现了这个承诺的。
这是在怼某睿的 truemove 的吧。。看来之前总拿 502 来怼也不能忍了。

Ripple: Sometimes called jitter, this is a deviation between the sensor’s reported trajectory and the actual physical movement in an A to B mouse displacement. Ripple tends to scale up with dots per inch (DPI), and weaker sensor designs and firmware implementations often use smoothing to mask ripple. This value should be as close to 0 as possible; our requirement at Logitech G is <0.001 deviation.
波纹：也有称这个为抖动的，这个是在鼠标从 A 移动到 B 的时候传感器传递的数据与鼠标实际物理移动轨迹上的偏离。抖动通常是被用 DPI 来计算的，一些比较差的传感器设置和固件常常用平滑算法来掩盖抖动。这个值应该是越接近 0 越好，我们罗技 G 的要求是<0.001 的偏离度。

History of Sensor Design

传感器的设计历史

Some of the first gaming sensors used in Logitech G gaming mice, including the 3080 and 3090 used in MX500-MX518 and G400, were based on the original 2020 design made by Avago at the request of Logitech. Another popular sensor design was the 9500, which later became the 9800. The 9800 spawned a number of derivatives (including 3310 and 3988) that have been used in many different mice, and are still revered today.
像 MX500-MX518、G400 上的 3080、3090，这些一些比较早用于罗技 G 游戏鼠标的传感器，是以罗技要求安华高制作的 2020 传感器的设计为基础来设计的。另一个流行的传感器是 9500，后来变成了 9800。9800 派生出来一系列衍生品（包括 3310 和 3988）被用于很多鼠标中，现在仍在应用中。

Rather than utilizing these derivatives and continuing to rely upon incremental upgrades to existing silicon, Logitech G has worked to push the boundaries of performance and efficiency to deliver noticeably better experiences. An early example of this work is the M010, which offered 5x more power efficiency compared to 9800-based mice. This allowed us to create the G602 wireless gaming mouse, with 250 hours of non-stop gaming on two AA batteries.
比起使用这些衍生品并继续依赖现有的芯片升级，罗技 G 努力突破性能与低耗能的壁垒带来显著的提升。早期的试水作品是 M010（*就是 mecury 吧？*），提供了比 9800 系鼠标 5 倍的节能。这让我们最终做出来 G602 无线游戏鼠标，仅两节 AA 电池 250 小时续航。

We then placed focus back on performance, and designed the PMW3366 with sensor manufacturer Pixart. This sensor had unrivaled performance for his time and is twice as efficient as high performing 9800-based sensors before it. While the 336X sensor is now available to anyone who wants to purchase from Pixart, the firmware still needs to be designed to operate the chip. The firmware used by Logitech G with the 3366 is still the only implementation to achieve zero smoothing at ANY DPI with that sensor architecture. Other implementations introduce smoothing as early as 2k DPI.
我们这时候又聚焦于性能方面，并与 Pixart（原相）设计了 PMW3366。这个传感器达到同期性能顶尖并且比它之前的 9800 系传感器节能 2 倍以上。虽然现在 336X 传感器大家都能从原相买到，但是固件是需要自行设计的。罗技 G 的 3366 用的固件仍然是唯一能够在任何 DPI 都能达到 0 平滑的。其他的在 2K DPI 之上都会有平滑。

However, it was not possible to achieve the two different design goals of simultaneous power and efficiency without radically rethinking the architecture of the sensor as a whole. The HERO architecture is a ground up innovation to achieve maximum performance while extending power efficiency for the ultimate gaming sensor.
当然，如果不重新彻底改变传感器的架构，是不可能同时达到性能和节两个目标的。HERO 架构能让顶级的游戏传感器在达到最佳性能的同时又能做到更加的节能。

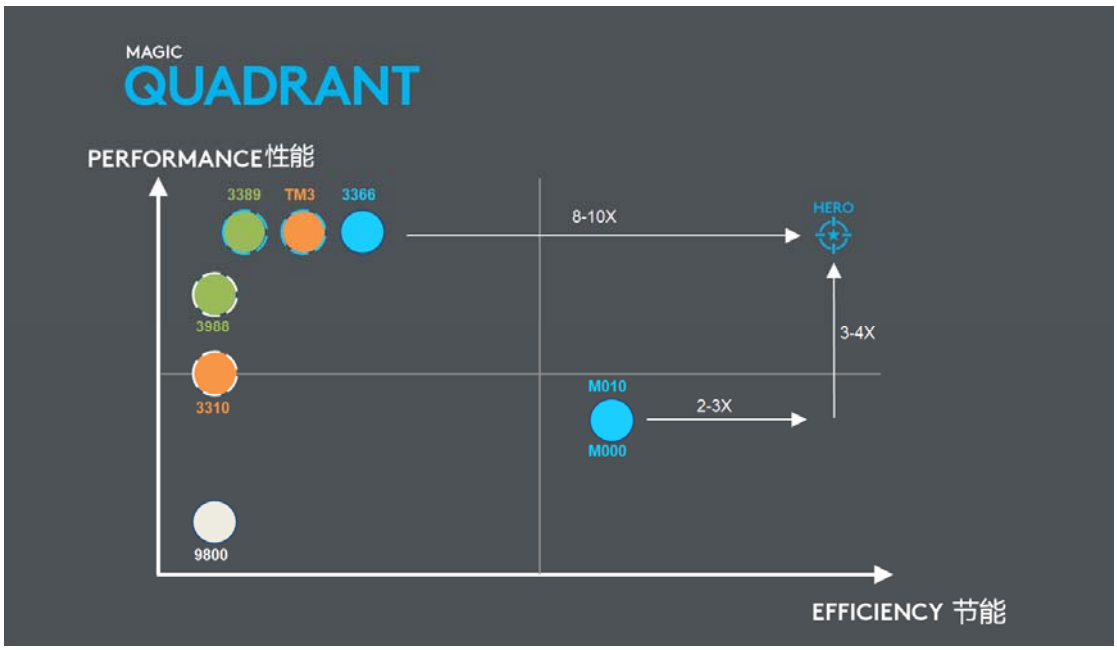


Figure 1: The “Magic Quadrant” plots mutually exclusive values, achieving the best of both worlds. HERO provides ultimate performance and efficiency.

这个“魔力象限”标示两个互斥的值，以实现两个领域的最佳。HERO 提供最强的性能和节能表现。

HERO Sensor Architecture

HERO 传感器架构

The HERO sensor has many unique attributes that make it to be the current pinnacle of optical gaming sensor design. HERO uses a continuous frame rate and tight voltage control system to enable extremely high flexibility and efficiency of processing. This allows the sensor to operate at the optimal frame rate for the users specific setting while constantly saving as much energy as possible. The entire design has been thoroughly optimized for maximum performance and low power consumption from the lens cluster all the way to how the sensor integrates with the MCU (Micro Control Unit) of the mouse.
HERO 传感器有很多特性让它成为目前光学游戏引擎设计的顶峰。HERO 用稳定的刷新率和严谨的电压控制系统提供了很高的在设计方面的可塑性和节能性。这让传感器能够在达到很好刷新率的同时尽可能的节能。从镜头以至传感器与主控的结合，整个设计方案全盘考虑来优化达到最大性能的同时做到更低的能耗。

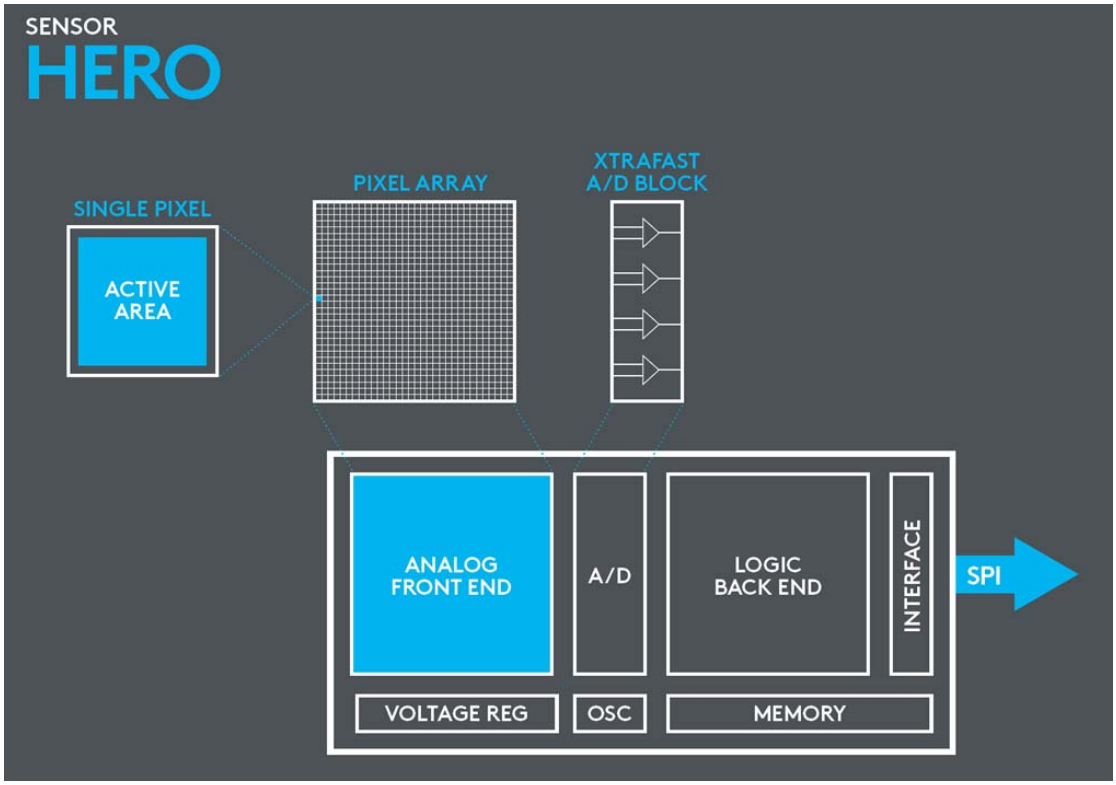


Figure 2: HERO sensor design is a combination of many optimizations and innovative chip designs. Together they create an incredibly high performing and highly efficient sensor system for gaming mice.
HERO 传感器设计有着很多的优化和创新的芯片设计。通过这些为游戏鼠标创造了高性能和高节能的传感器系统。

Overall, the HERO sensor architecture is made out of two major blocks. First and foremost is the pixel array and surround that is mainly analog circuitry, which is also called the “front-end”. This is the most important part of the whole sensor system, as what is lost at the input cannot be restored afterward. It is essential to start with a great capture of the tracking surface. Designing a very high quality and high performing front-end will result in not only a great basis for performance, but also allows other components to be upgraded in the future.
总的来说，HERO 传感器架构有两个主要模块。首先是像素阵列，围绕它的主要是模拟电路，即所谓的“前端”。这在传感器系统中是最重要的一部分，如果有数据丢失那么后面是无法恢复的。就是说必须对要追踪的表面有一个很好的获取作为开始。设计一个非常高品质和高性能的前端不仅是整个传感器性能的基础，也能够为其他部件在后续带来提升。

If we dig more into HERO front-end, we see a matrix of pixels. This CMOS detector is responsible to collect light from the imaged surface through the lens system and convert photons into electrons. This may seem trivial but the quality of this operation is critical for sensor performance. The design of the individual pixel is crucial for the rest of the system to operate well. HERO utilizes a much higher active pixel area which reduces wasted energy consumption and also maximizes capture.
如果我们深入挖掘 HERO 的前端，我们将看到像素的矩阵。这个 CMOS 感应器用来通过镜头系统收集移动表面图像的光点并将图像转换成电子信号。这个可能看上去比较繁琐，但是这个流程的质量高低是影响传感器性能的关键。取像的设计决定体系的其他方面运转顺利。HERO 使用了很高的活动像素区域来减少能量损耗并保证最大化的捕捉。

Compared to previous generations of sensors, HERO can run at a much higher maximum frame rate. This provides more flexibility for different capture scenarios and physical movement speeds. The continuously variable frame rate is also crucial to enable ideal tracking for the specific usage scenario of the user. This is a huge benefit to tracking performance.
相比起前代的传感器，HERO 可以运行在更高的采样率。这个可以为不同的表面和物理移动速度提供更高的适应性。连续可变的刷新率同样对于特定的应用场景很重要。很有利于提升表面追踪的表现。

- A fixed frame rate if set high (>8,000 FPS) will improve acceleration and also reach higher speed, but it will penalize low speed accuracy as small movement will be hard to follow properly due to too high oversampling.
- 如果被设定到高的固定刷新率（>8000FPS）将会提升加速度和达到更高的移动速度，但是这样会导致地速度的时候准确性降低，因为高的超采样时小的移动会很难捕捉到
- A fixed frame rate if set low (<5,000 FPS) will improve low speed tracking but will fail as soon acceleration increases. It also has a lower max speed.
- 如果被设定到低的固定刷新率（<5000FPS）会提升低速的捕捉性能但是当速度提起来的时候会出错。这同样会导致最高速度比较低。
- A variable frame rate using fixed steps, (like 3366 and other gaming sensors) improves on fixed frame rate designs but is still hampered by a limited number of steps or “gears”. Most sampling strategies tend to lean towards oversampling to avoid missing movement data, but then run the risk of poor low speed accuracy.
- 可变的刷新率采用固定的步进值，（比如 3366 等游戏鼠标）相较固定刷新率设计有改进，但是仍然受有限的步进间隔限制。大多数采样算法倾向于超采样去避免丢帧，但是这样面临着低速状态下较低的准确率的风险。
- ***大家可以用 mousetester 看看鼠标在低速移动的时候，那些个点点离散得比较厉害吧***
- HERO uses a continuously variable frame rate which constantly adapts the sample rate to always be able to deliver maximum performance regardless the speed or acceleration.
- HERO 采用连续可变刷新率可以持续对样本频率进行适配，持续对相应的速度或加速度提供最高的性能。

Another key differentiation with the new HERO architecture is how it handles different surface materials in regards to lift off distance (LOD) and LED operation. There are many factors for how this is processed but LED operation and technique is a huge component to how the final image is processed in relation to LOD. The goal is to have a very small and consistent range of LOD across a large number of different surfaces. Previous attempts to achieve this, like in PMW3366, have used surface tuning to specifically optimize for the current surface and tighten the range of LOD. Surface tuning improved the tracking performance over previous generations but also made it less ideal for the next surface if different from the first. HERO uses a much more intelligent LED system to continuously adjust the lighting power and intensity (frame by frame) to produce the optimal capture for each given frame regardless of surface. This means HERO automatically provides the smallest deviation and lowest LOD possible given the current tracking surface, resulting in a more predictable and consistent tracking experience.
全新的 HERO 架构的另一个关键不同点是它在处理不同的表面材质时的 LOD（感应器工作高度）和 LED 操作。这个涉及到很多因素， LED 的操作及相关技术是影响在对应 LOD 下图像如何处

理的关键。要达到的目标是在大量的不同的表面保持一个很小很稳定的 LOD。例如 PMW3366，在这方面的尝试是采用表面调试来实现对现有表面的优化来缩小 LOD。在前代中，表面调试提高了追踪表现但是如果换一个不同的表面就不尽如人意了。HERO 应用了更加智能的 LED 系统来持续对光亮和密度进行调整来对表面进行适配优化。这意味着 HERO 自动对现在追踪的表面提供最小的抖动和最低的 LOD，进而提供更加稳定的追踪体验。

The second part of the sensor architecture is the logic block, which is responsible for processing the front end data, running the tracking algorithm, and finally communicating with the mouse MCU for data output to the host PC. This part of the sensor is commonly hard coded in the silicon of the sensor, but this makes it locked to that particular set of functional values. It is also possible to implement an SROM, or Shadow ROM, which imparts a modest amount of flexibility in modifying default parameters. HERO sensor instead uses a flash memory based firmware that permits adjustments, like changing the core algorithm, allowing much wider possible tracking improvement options. This means HERO is updatable and adaptable to future optimizations and use cases. This is, in part, how evolutions were able to be made to create HERO 16K.
第二个传感器架构的部分是用于处理前端数据的逻辑模块，运行追踪算法，并将数据传递到鼠标主控输出到 PC 端。传感器的这个部分一般都是写入到传感器芯片中，但是这样会锁定成固定的功能参数。另外也通过 SROM 或者 Shadow ROM 来实现，可以通过修改默认参数提供更大的灵活性。HERO 传感器用基于闪存的固件来代替，允许调整核心算法、更多的提升追踪表现的选项。这意味着 HERO 可以升级并适用于未来的优化和使用要求。这也是为何能升级到 HERO 16K 的原因之一。

A third component is the A/D converter, which takes the analog input data from the front end and turns it into 1’s and 0’s for the logic block to process. HERO uses a special A/D process which uses much faster and low power operating circuits (cleverly named XTRAFAST). Having a fast conversion system permits to save power in between conversion cycles, even when operating at higher frame rates. The result is drastically reduced energy consumption.
第三个因素是 A/D （模拟/数字）转换器，能够将前端输入的模拟信号转换成数字信号用于逻辑模块进行处理。HERO 采用的特别 A/D 处理流程应用了更快和更低能耗的电路（巧妙的命名为 XTRAFAST）。拥有更快的转换体系能够更加的节能，即使是在处理更高的刷新率时。这极大的降低了能耗。

Aside from these three main components, there are several peripheral blocks. Variable Voltage Regulators handle specific power to each block ensuring nothing is wasted. Oscillators feature three different master clocks in order to operate each block at its best efficiency point. All displacement calculations are run on the sensor die itself, which enables it to operate with zero smoothing or filtering in either the sensor or in the mouse MCU. This is a crucially important distinction between Logitech G sensors and other implementations: the promise of never introducing smoothing or acceleration throughout the entire DPI range. The mouse MCU simply packages X and Y sensor data and sends it raw to the USB bus which then sends the data to the PC at a cadence of 1000 times per second (1ms).
除这主要的三个部分以外，还有很多外围模块。可变电压调节器可以调整不同模块的供电确保不被浪费。振荡器可以提供 3 个不同的主时钟让每个模块处在他们的最佳能耗点。所有在传感器上的位移计算都基于传感器的模具本身，这样无论是传感器还是主控都提供了 0 平滑和过滤。这是罗技 G 与其他产品最大的不同：在所有 DPI 范围都保证没有平滑或者加速。鼠标的主控仅仅是

把传感器的 X 轴和 Y 轴数据打包并原汁原味地传递到 USB 总线，用 1000hz 的频率将数据传递给 PC 端。

The New Standard

新的标准

The HERO architecture represents the new standard for performance and efficiency in optical gaming sensors. It not only supplies the most accurate and highest performing tracking by any sensor design to date, but does so at up to 10x better efficiency than previous generations. HERO can improve the experience of any kind of mouse and any kind of usage due to the capability to adapt and always provide best suited settings.

HERO 架构推出了光学游戏传感器的性能和能耗方面的新标准。这不仅提供了所有传感器追求的更加准确和最高的追踪表现，而且较之前有了 10 倍以上的节能。HERO 可以提高各种鼠标在不同使用要求下的体验，并一直提供最好的配套设置。