



Magic Leap One Teardown

Teardown of the first mixed-reality headset from Magic Leap, performed August 15, 2018.

Written By: Jeff Suovanen



INTRODUCTION

The Magic Leap One's mixed-reality tech has been so much pie in the sky for so long, we can hardly believe we have it on our teardown table. Based on the amount of money raised for this project, we're hoping it's powered by pixie dust—but only a teardown will tell.

Want to see more hardware secrets? Then plug in with us on [Facebook](#), [Instagram](#), or [Twitter](#) for up-to-the-minute teardown news.



TOOLS:

- [T4 Torx Screwdriver](#) (1)
- [T6 Torx Screwdriver](#) (1)
- [Phillips #00 Screwdriver](#) (1)
- [Heat Gun](#) (1)
- [iFixit Opening Picks set of 6](#) (1)
- [Spudger](#) (1)
- [Tweezers](#) (1)
- [Plastic Cards](#) (1)
- [Technician's Razor Set](#) (1)

Step 1 — Magic Leap One Teardown

Magic Leap One



TEARDOWN



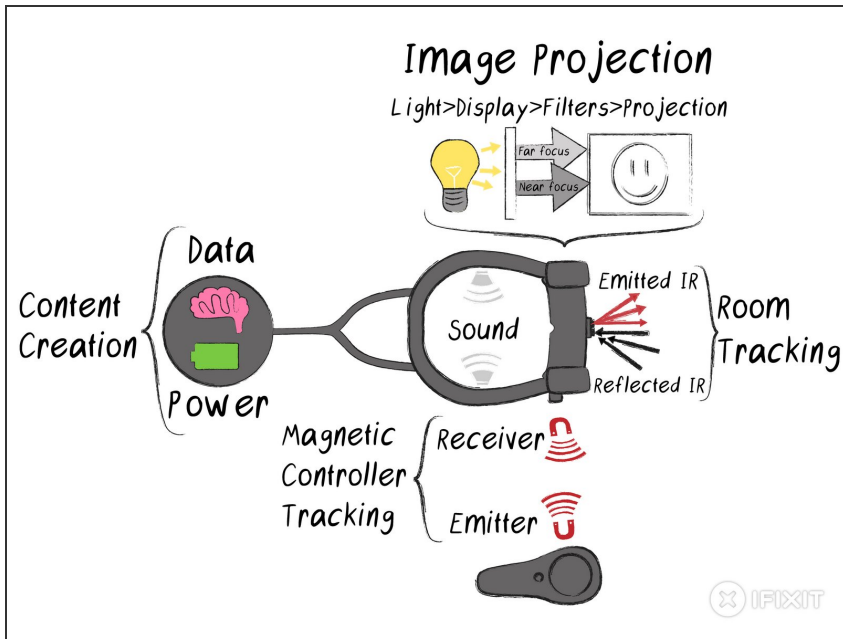
- There's a lot to unravel here. Let's start with some specs ... err, specifications:
 - Nvidia Tegra X2 (Parker) SoC with two Denver 2.0 64-bit cores and four ARM Cortex A57 64-bit cores
 - Integrated Pascal-based GPU with 256 CUDA cores
 - 8 GB RAM
 - 128 GB onboard storage
 - Bluetooth 4.2, Wi-Fi 802.11ac/b/g/n, USB-C, 3.5 mm headphone jack
- ⓘ That Nvidia SoC is [designed for automotive applications](#), and is [prominently used in autonomous vehicles](#), including Teslas. This seems like off-label use, until you consider the Magic Leap's multiple arrays of external sensors for mapping and understanding its environment—much like a self-driving car.

Step 2



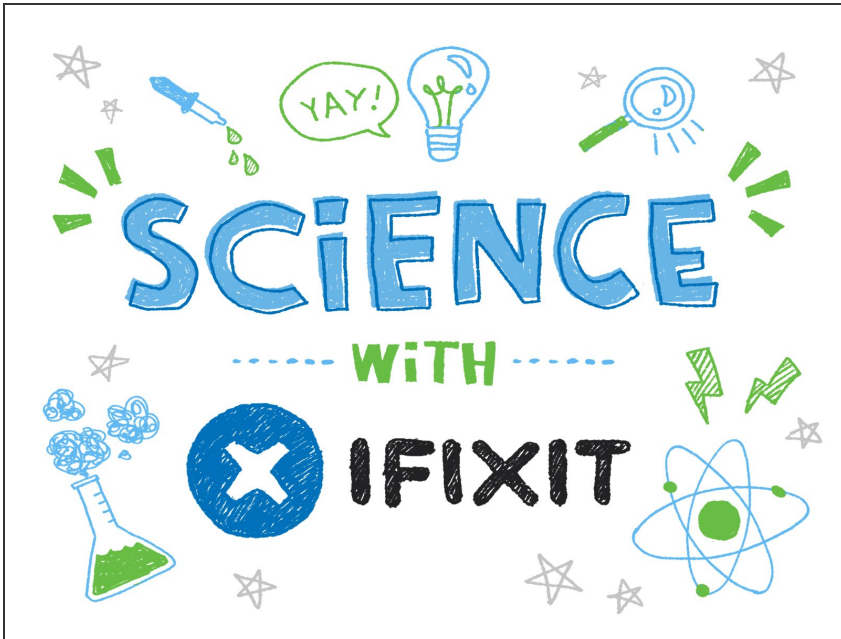
- After Magic Leap's claims about this headset's [otherworldly experience](#), we had to try it ourselves.
- Thanks to our trusty infrared camera, we can see a strobing IR projector for depth sensing just above the nose bridge—similar in principle to what we found in the [iPhone X](#), and before it, the [Kinect](#).
- If you look closely, you can also spot four additional IR LEDs in each lens, "invisibly" lighting up your eyeballs for tracking. (We'll dig up the trackers shortly.)

Step 3



- i** Before we get started, let's orient ourselves with a high-level tour:
- Content creation begins in the Lightpack. It provides power and handles the processing, sending image and sound data to the headset.
 - Meanwhile, the Lightwear headset tracks the controller's position and orientation, and maps your surroundings to help insert the virtual elements.
 - How those virtual elements are generated is a whole other can of worms.

Step 4



- “Mixed reality” is hard. It’s one thing to augment what you see on a screen (like a smartphone or a VR display with a feed from exterior cameras).
- It’s much harder to augment actual, unfiltered reality coming directly into your eye. To pull off this illusion, the Magic Leap One uses a couple neat pieces of tech:
 - **Waveguide display** - Essentially a transparent screen that’s lit invisibly from the side. The [waveguide](#) (what Magic Leap calls a “photonic lightfield chip”) [guides light](#)—in this case, an image—across a thin layer of glass, magnifying it and angling it into your eye.
 - **Focus planes** - On a VR display, everything is in focus all the time. Reality is different—some things look crisp while others can look blurry, depending on where your eye is focused. Magic Leap mimics this effect by stacking multiple waveguides to create focus planes—slicing up the image into crisp and blurry areas.

Step 5



- Let's get to the optical treasure in this thing! A quick test rules out polarized lenses—we'll have to dig deeper to make any discoveries.
- The insides of the lenses are surprisingly ugly, with prominent IR LEDs, a visibly striated waveguide "display" area, and some odd glue application.
- The waveguide consists of *six* not-so-pretty laminated layers, each with a small air gap.
 - The edges look to be hand-painted black, likely to minimize internal reflections and interference.

Step 6



- Inside the headband, we note a Class 1 Laser label. It might seem like a scary thing to find on your eyewear, but it's [safe for all normal use conditions](#) and likely no more dangerous than a CD player.
- Twirling away the standard Torx screws and removing the panel reveals the first of two speakers, wired via spring contacts, and protected by color-coded gaskets—great repairability so far!
- Also hiding under those panels: the two upper ends of the device's single built-in cable—and a few of the magnetic bits that help adjust the fit.
- But what's that odd little black box protruding from the right side of the headband?

Step 7



- Survey says: a six-degrees-of-freedom [magnetic sensor coil](#) for [tracking the position](#) of the controller.
- ❗ The intensity of the three perpendicular magnetic fields is measured to determine the position and orientation of the controller relative to the headset.
- Cracking open the controller, we find the (much bigger) emitting half of the tracker, and an 8.4 Wh battery to boot.
- The copper shielding sprayed into the coil housings likely protects from RF interference, while letting the magnetic field through.
 - Interference could explain the tracker's odd placement, and this may be a temporary solution. It's "old" tech, and will probably be worse for left-handed use.
- ❗ Not pictured: we also dug up what looks like a custom-designed [trackpad ringed with LEDs](#) (for future light-tracking hardware, perhaps?).

Step 8



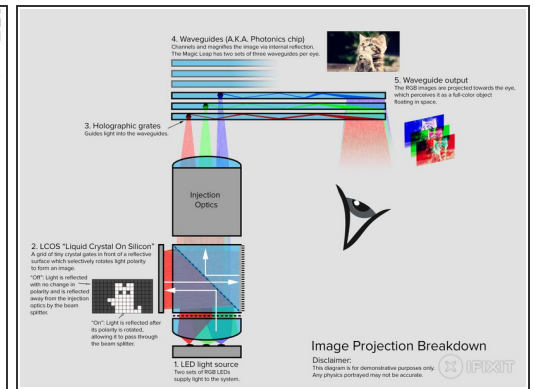
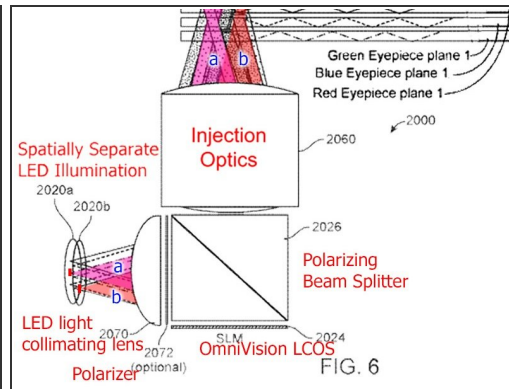
- After detaching the headband and inner faceplate, we have a better view of the eye-tracking IR emitters. We note they're all wired in series, rather than individually controlled.
- And finally, at our fingertips, the heart of the Magic Leap: the optics and display assemblies.
- We're going all the way here, so strap in.

Step 9



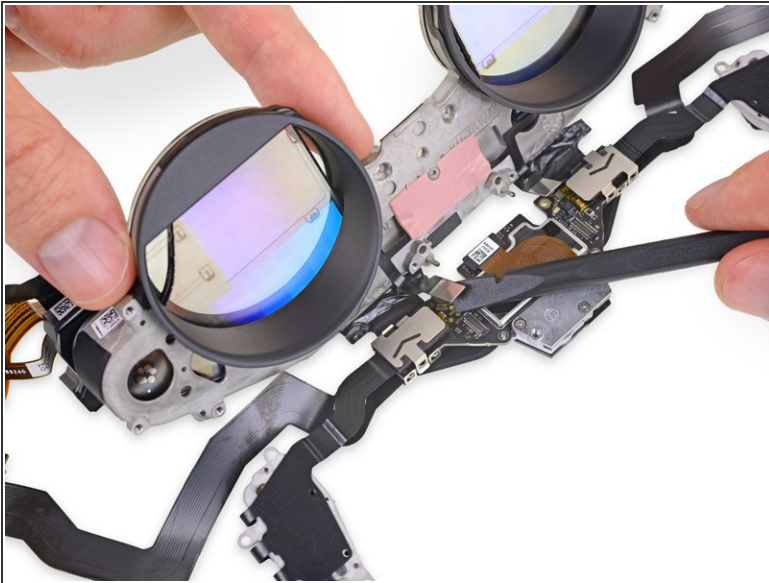
- Lifting up one of the external sensor arrays, we find beneath: the optical system for injecting images into the waveguides.
- ⓘ These bright colors come from ambient light reflecting off the diffraction gratings, and don't represent specific color channels.
 - Each spot lives at a different depth—corresponding to a single layer of the waveguide.
- At the back, we find the actual display device: an OmniVision OP02222 [field-sequential color \(FSC\)](#) LCOS device. It is likely a customized variation of the [OmniVision OP02220](#).
- 📌 The [KGOntech blog correctly guessed this was exactly what Magic Leap was doing](#), based on patent filings back in 2016.

Step 10



- Let's take a deeper dive into the projector and waveguide optics.
- So what's all this about *six layers*? There's a separate waveguide for each color channel (red, green, and blue) on two distinct focal planes.
 - Without color-specific waveguides, [each color would focus to a slightly different point](#) and deform the image.
- "Figure 6" from the Magic Leap patent application [2016/0327789](#) shines some light on the optics' inner workings.
- For your edification and delight, we've included our own "tl;dr diagram" for this system, complete with cats.

Step 11



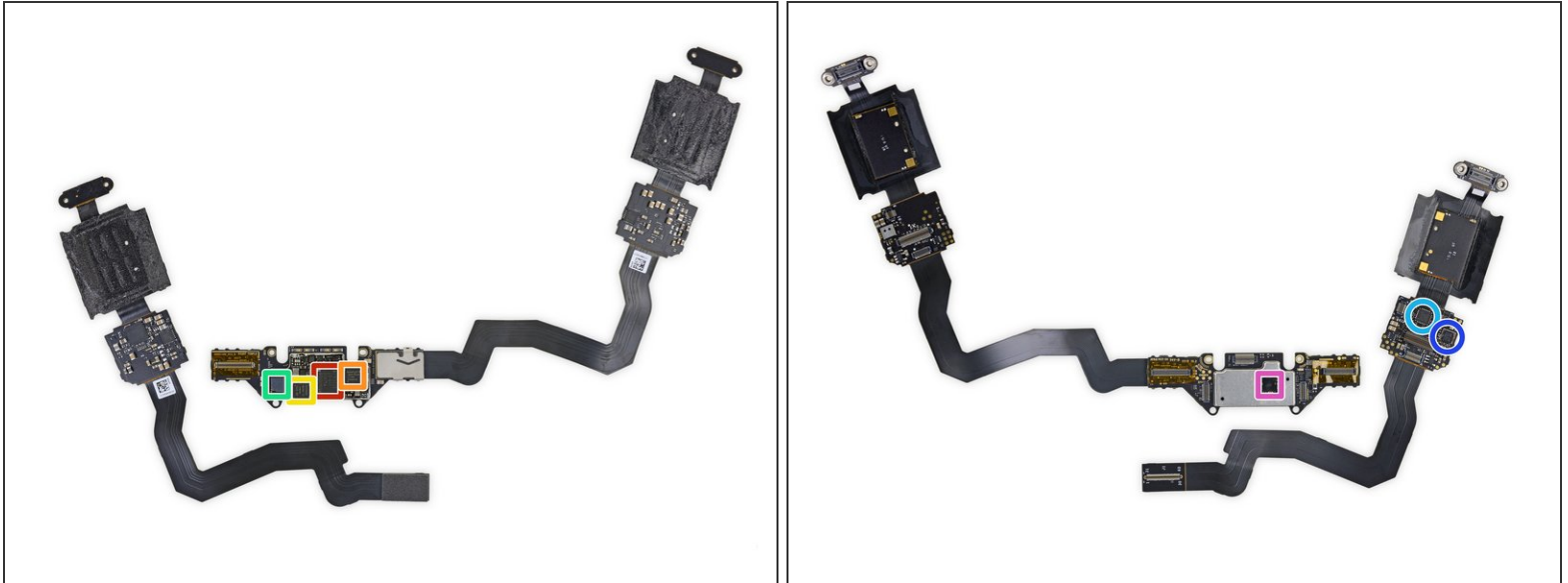
- A cast magnesium block holds all the optics and sensors, and is surprisingly hefty for an HMD. The [VR headsets](#) we've taken apart all used lightweight plastic.
- But metal makes a better heat sink, and the electronics and IR illumination (likely [VCSEL](#) devices) all produce heat.
 - That pink stuff is a thermal pad to help transfer the IR rangefinder's heat into the aluminum frame.
- Metal also offers a stiffer mounting place to keep the optics stable and focused after their rigorous calibration.
 - But stiff isn't always best—some of these components are mounted with foam adhesive, which will be more forgiving as things flex when heated.

Step 12



- No longer perfectly placed, we may as well pop the covers off the sensors for a closer look.
 - These twin sensor arrays sit at each of your temples, with the strobing IR depth sensor perched right in the middle.
 - AKM Semiconductor and Invensense (now TDK) motion sensors likely found at the top of the camera PCB.
 - A closer look at the nose-bridge depth sensor gives us the room-reading hardware in the form of:
 - IR sensing camera
 - IR dot projector
- i** There's no need to set up receiver stations for this device—it does the projection and reading all on its own!

Step 13



- Connecting all that sensory equipment to the headband, we have pricey, layered flex cables hosting:
 - Movidius [MA2450](#) Myriad 2 vision processing unit
 - SlimPort [ANX7530](#) 4K DisplayPort receiver
 - OmniVision [OV680](#) sensor bridge for processing simultaneous image streams from multiple cameras (like we found in the [Amazon Fire Phone](#))
 - Altera/Intel [10M08V81G](#) - 8000 logic cell FPGA, possibly for [glue logic](#), or managing MV part or camera bridge data
 - Parade Technologies [PS8713A](#) bidirectional USB 3.0 redriver
 - NXP Semiconductors [TFA9891](#) audio amplifier
 - Texas Instruments [TPS65912](#) PMIC

Step 14



- Popping off one of the two IR emitter rings, we find the elusive eye-tracking IR camera hiding behind a dark filter.
 - These appear to be [OmniVision CameraCubeChip](#) cameras with externally-mounted [dichroic filters](#).
- ⓘ Eye tracking in VR and AR allows for some pretty cool new [interface options](#), as well as [improvements](#) in realism and rendering efficiency.
- ☑ Placing a single camera below each eye may limit the accuracy and range of eye tracking—the camera can better view the eye/pupil when the user is looking downward than upward.

Step 15



- Now things get a bit destructive, but it's worth it to get a peek at the optics chain.
 - A tiny ring of six LEDs starts the process—red, green and blue, times two for two focus planes.
 - The LEDs then shine on the LCOS microdisplay to generate an image. It's mounted to the black plastic housing next door.
 - From inside that housing, a collimating lens aligns the raw light output from the LEDs, and is mounted to a polarizing beam splitter.
 - The polarized beams then pass through a series of lenses to focus the image into the entrance gratings on the waveguides.
 - The entrance gratings themselves look like tiny dots embedded in the six (now slightly shattered) waveguides.
- We pick up the "injection" unit for a closer look, revealing the colors associated with each entrance grating: two red, two green, and two blue.

Step 16



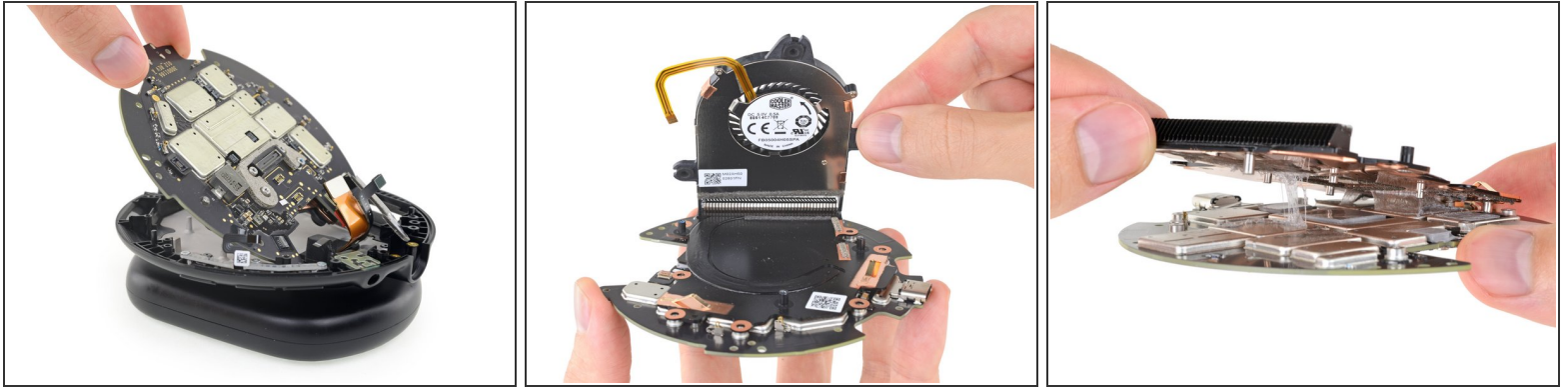
- Now that we've had our tasty optical treat, it's time to turn our attention to the brains of this operation, the Lightpack!
- It's hard to miss those prominent cooling vents. Does this little pocket PC have an active cooling system? We'll soon see.
- These FCC markings don't yield up much, other than it's designed by Magic Leap and assembled in Mexico. The identity of the actual hardware manufacturer is [said to be a closely guarded secret](#).

Step 17



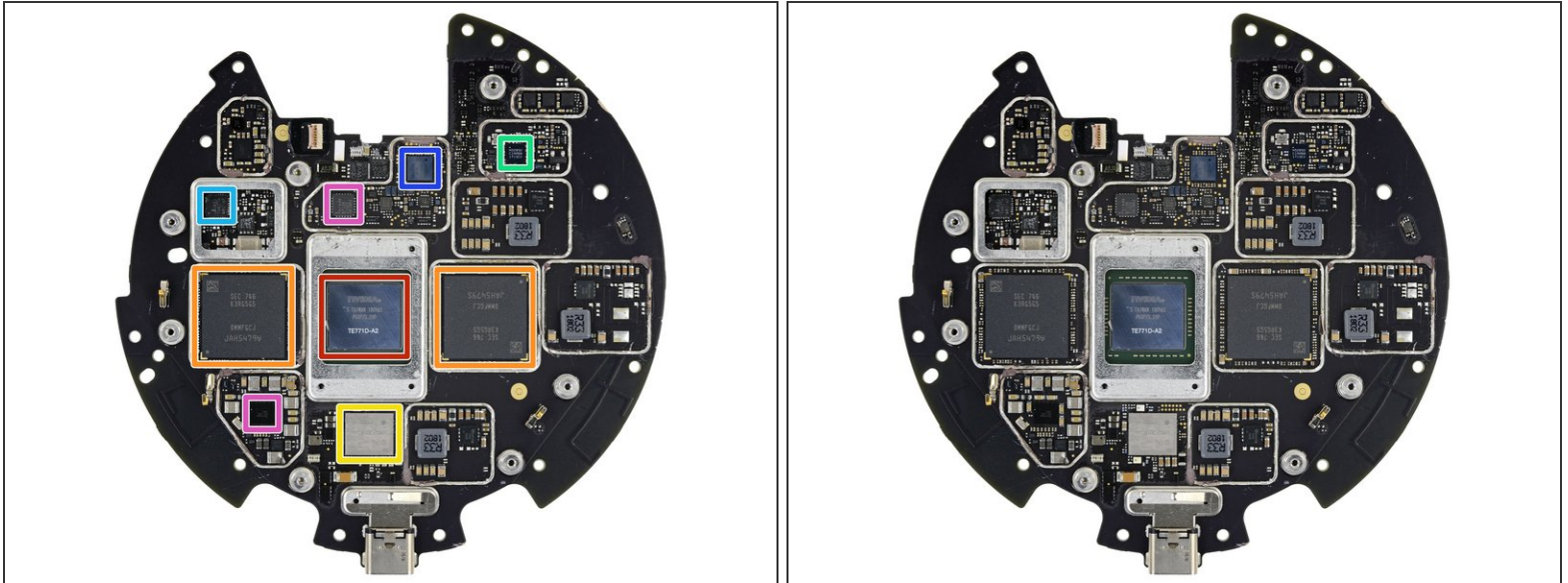
- Cracking the Lightpack open takes a lot of work, but heat and careful prying does the trick eventually.
- Most VR headsets seem to take after PCs with [lots of cables](#), but this is a single permanent cord—trapped under a status LED strip, some screws, and some copper tape.
- ① A single cable to the headset makes for some elegant ergonomics, but your cat better not chew this life line or your device is kaput.
- Another solid bit of cast magnesium out of the way, and we behold the motherboard!

Step 18



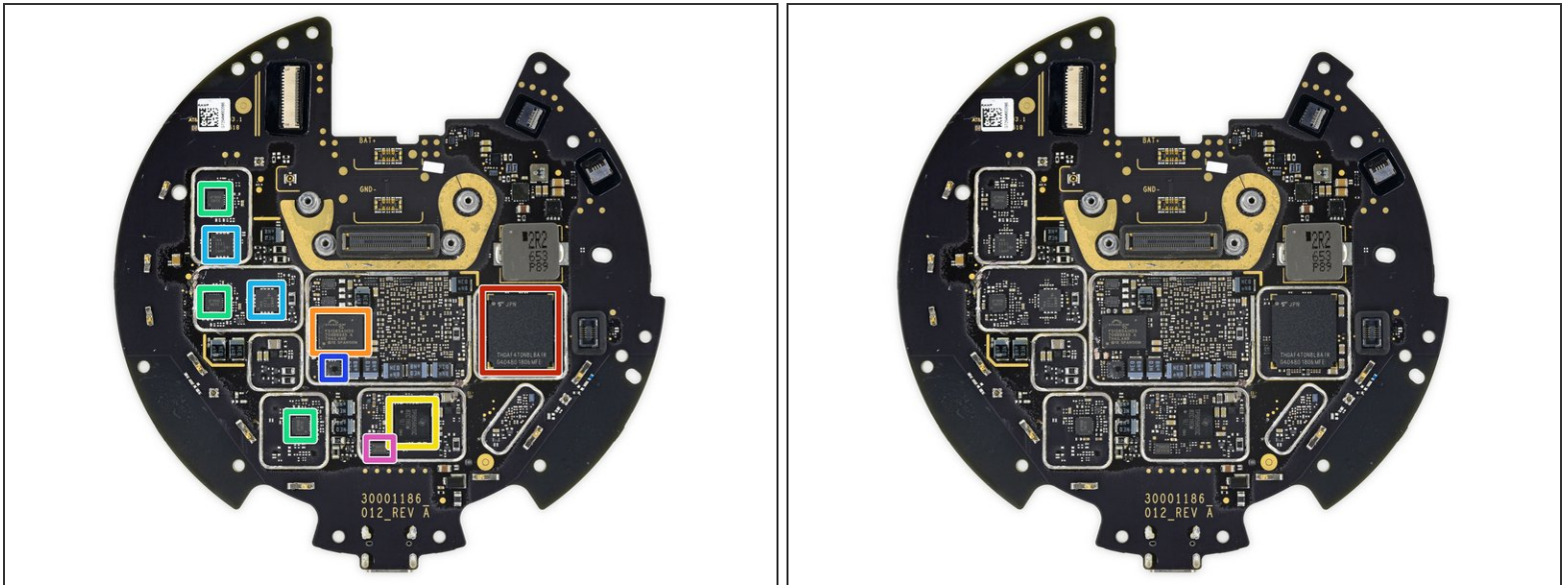
- We ignore the modular headphone jack and button board, in favor of that shield-filled field of silicon.
- A PC favorite Cooler Master fan graces this PCB, explaining those vents we saw earlier.
- Twirling away screws isn't enough to free the heat sink, which is very stubbornly glued in place. After a good ten minutes of heating and prying, it finally loosens its conductive grip.
- ⓘ This is a lot of cooling for a small, wearable device, but it makes sense given the job it has to do. There's a lot of heat-generating silicon in there—and in this case [hot pockets](#) are a bad thing.

Step 19



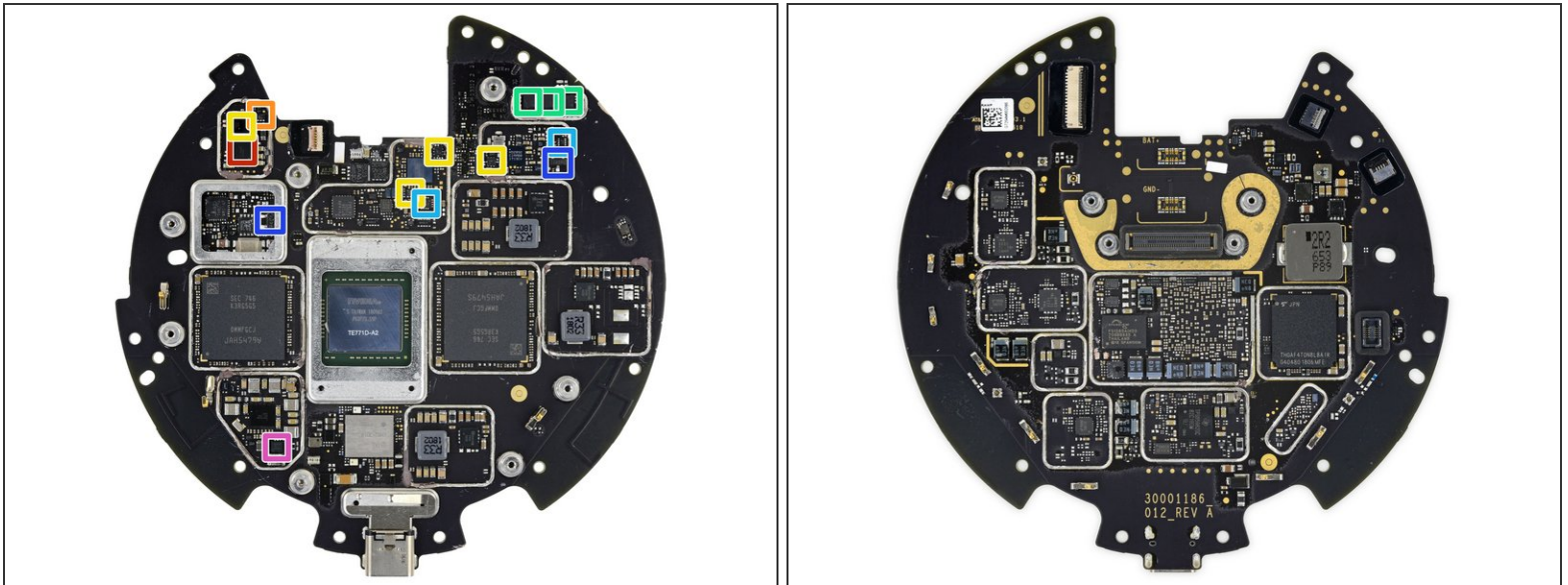
- A few shields later and its time to look at the chips that make the magic happen:
 - NVIDIA Tegra X2 "[Parker](#)" SoC, with NVIDIA [Pascal](#) GPU
 - 2x Samsung [K3RG5G50MM-FGCJ](#) 32 Gb LPDDR4 DRAM (64 Gb or 8 GB total)
 - Murata 1KL (likely Wi-Fi/Bluetooth module)
 - Nordic Semiconductor [nRF52832](#) RF SoC
 - Renesas Electronics [ISL9237HRZ](#) buck-boost battery charger
 - Altera (owned by Intel) [10M08](#) MAX 10 field programmable gate array
 - Maxim Semiconductor [MAX77620M](#) power management IC and Parade Technologies [PS8713A](#) bidirectional USB 3.0 redriver

Step 20



- And a little more magic on the back side:
 - Toshiba [THGAF4T0N8LBAIR](#) 128 GB NAND universal flash storage
 - Spansion (now Cypress) [S25FS128S](#) 128 Mb quad SPI NOR flash memory
 - Texas Instruments [TPS65982](#) USB Type-C and USB power delivery controller
 - uPI Semiconductor [uP1666Q](#) 2 phase buck controller
 - Texas Instruments [INA3221](#) bi-directional voltage monitor
 - Invensense (now TDK) accelerometer
 - Winbond [W25Q80DVUXIE](#) 8 Mb serial NOR flash memory

Step 21



- IC Identification, continued:
 - Texas Instruments [TLV320AIC3206](#) stereo audio codec
 - ON Semiconductor [NC7SB3157L6X](#) SPDT analog switch
 - Texas Instruments [TS5A21366](#) and likely ON Semiconductor analog switches
 - Texas Instruments [LP5523](#) 9-ch. LED driver
 - Texas Instruments [PCA9306](#) voltage level translator and [SN74AVC4T245](#) dual-bit bus transceiver
 - Texas Instruments [TLV809J25](#) 2.25 V voltage detector and [LM4132AMF-2.5](#) 2.5 V LDO voltage reference
 - Texas Instruments [TPS630252](#) 4 A boost converter

Step 22



- Next the saucer section lifts off, leaving the battery housing vulnerable to our prying hands.
- Getting to the battery was so tough it's almost ironic to find pull-to-remove tabs, but they're better than nothing!
- ❗ All these layers and adhesives probably help with shock-resistance and durability. But when the battery inevitably dies, you're looking at a full device replacement or a tough repair—one likely to be a major headache for recyclers.
- Magic Leap packs this twin-cell battery sandwich with 36.77 Wh, running at 3.83 V. That's in the same range as [some popular tablets](#).

Step 23



- The Magic Leap One is clearly an expensive, short-run piece of hardware. Every bit of construction is intended to maintain the precise calibration for the life of the device. Our guess would be that this was pushed out at full speed, regardless of the price, to get something on the market.
- Let's hope for a consumer edition that maintains the thoughtful design and dedication to durability, while also avoiding the short-sightedness of this device.
- Special thanks to Karl Gutttag of [KGonTech](#), who contributed his invaluable time and expertise to help us navigate this teardown.
- VR expert, and our [sometimes-nemesis](#), Palmer Luckey also contributed some great content, as well as hardware access. You can read his full take on the Magic Leap One [here](#).
- ⚠ Any mistakes in this teardown are almost certainly ours, and not those of our contributors.
- Lastly, it's time to assign a repairability score.

Step 24 — Final Thoughts

REPAIRABILITY SCORE:



- The Magic Leap One earns a **3 out of 10** on our repairability scale (10 is the easiest to repair):
 - The speakers are easy to remove and replace with just a single screwdriver.
 - The threaded fasteners are all of the standard Torx and Phillips variety.
 - Disassembly is mostly nondestructive—on paper, anyway. With this much glue on this many fragile components, you'd better have buckets of patience and a very steady hand.
 - The battery is only replaceable if you're willing to remove the motherboard and tiptoe your way past several intense glue barriers.
 - There is no upgrade path for any of the optics or processor—slightly disappointing on a \$2,300 piece of gear.