

EXHIBIT 12

U.S. Patent No. 12,193,790 (the “’790 Patent”)

“Wearable devices comprising semiconductor diode light sources with improved signal-to-noise ratio”

’790 Patent Claim	Whoop Accused System ¹
7[pre] An optical system, comprising: 7[a] a wearable device for measuring one or more physiological parameters,	Without conceding that the preamble of Claim 7 of the ’790 Patent is limiting, Whoop Inc. (“Whoop”) has made, used, offered to sell, sold in the United States, and/or has imported into the United States, and/or, continues to make, use, offer to sell, and sell within the United States, and/or import into the United States, Accused Systems that are optical systems comprising a wearable device for measuring one or more physiological parameters, either literally or under the doctrine of equivalents. For example, Whoop provides a system including WHOOP 4.0, which measures physiological parameters of a user, such as heart rate, blood oxygen level, temperature, and respiratory rate. WHOOP 4.0 connects to a Phone/Tablet via Bluetooth to sync data corresponding to measured physiological parameters. After downloading the Whoop App on a Phone/Tablet and completing the initial Bluetooth pairing, WHOOP 4.0 transfers measured health data to the app whenever in range to the Phone/Tablet. The app processes and analyzes the measured physiological parameters and provides insights into the user’s health and wellness. Whoop further offers and sells a membership-based service along with the Accused Wearable Device, where users pay a subscription fee for access to the Whoop App, data analysis, and health and wellness insights. The membership provides access to Whoop’s platform; a user must purchase the add-on Whoop membership in addition to an Accused Wearable Device to access all of the health features of the Accused Wearable Device.

¹ The Accused System includes a Whoop wearable device, such as WHOOP 1.0, WHOOP 2.0, WHOOP 3.0, and WHOOP 4.0 (each an “Accused Wearable Device”), which provides a system for measuring one or more physiological parameters of a user. The WHOOP 4.0 and various mobile devices are charted here as representative of the Accused System and should not be understood to be limiting. The citations to evidence contained within this chart are illustrative and should not be understood to be limiting. Plaintiff expressly reserves the right to rely upon additional or different evidence, or to rely on additional citations to the evidence already cited herein.

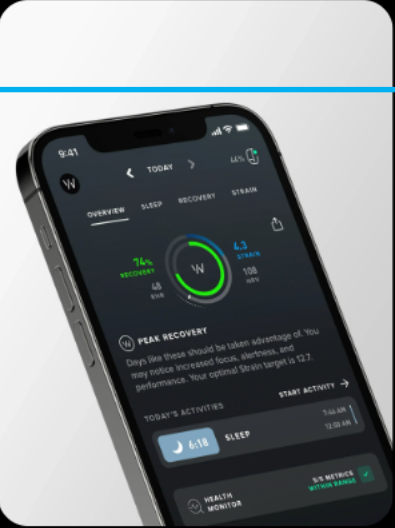
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’790 Patent Claim	Whoop Accused System ¹
	 UNLOCK YOURSELF WITH WHOOP Sign up for WHOOP emails and receive news, health tips & offers. Enter your email By submitting your email address, you agree to receive marketing emails from WHOOP. We may use information collected about you on our site to suggest other products and offers. You can withdraw your consent at any time by following the unsubscribe instructions in any email we send you. View our full Privacy Policy. Contact WHOOP at One Kenmore Square #601, Boston, MA 02215. GET STARTED Source: https://discover.whoop.com/health-monitoring/.

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'790 Patent Claim	Whoop Accused System ¹
	 World-class wearable tech Get the state-of-the-art WHOOP sensor, an ultra-durable, ultra-comfortable Onyx SuperKnit band, and a waterproof, wireless battery pack—all included with purchase. WHOOP is IP68 dust-proof and water-resistant at depths up to 10 meters (roughly 32 feet) for up to 2 hours and lasts up to 5 days on a single charge.  Personalized app WHOOP calibrates to your unique baseline and calculates daily performance scores, health metrics, real-time stress levels, and trends over time. You can also get real-time answers from WHOOP Coach, the all-new, AI-powered feature that uses your personal WHOOP data, and the latest in human performance science to give you custom performance coaching.  Cutting-edge science WHOOP is always evolving with monthly feature updates that are fueled by the best minds in data science, health, sport, and human performance. You can also listen to the WHOOP Podcast and access the WHOOP blog, The Locker for extensive articles about all things human performance. Source: https://www.whoop.com/us/en/.

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'790 Patent Claim	Whoop Accused System ¹
	WHOOP 1 CUSTOMIZE 2 CHOOSE MEMBERSHIP 3 ADD ACCESSORIES Choose Membership WHOOP 4.0 & lifetime warranty included free for duration of membership BEST VALUE 24 Month Membership \$399 Upfront SAVE 44% Equal to \$17/mo → MOST POPULAR Annual Membership \$239 Upfront SAVE 33% Equal to \$20/mo → 1 Month Free Trial \$0 Try before you join Includes pre-owned devices Learn More → Pay Monthly - \$30/mo 12 month minimum. \$360 total → All memberships, including trial, automatically renew as a \$239/yr annual membership (monthly billing is also available). Trials include pre-owned devices. Source: https://join.whoop.com/us/en/membership/.

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“Wearable devices comprising semiconductor diode light sources with improved signal-to-noise ratio”

'790 Patent Claim	Whoop Accused System ¹
	 WHOOP WHOOP CONTINUALLY MONITORS YOUR HEART RATE AND BLOOD OXYGEN LEVELS • Wear it on your wrist to track your heart rate 24/7 — right from home • Monitor your overnight blood oxygen (SpO2) levels • Capture data continuously with the wireless charger and waterproof battery pack • Track health data through LED lights and photodiodes with accuracy validated in lab studies and third-party testing • Share your health metrics with your provider or caregiver for more streamlined care • Available for \$239 per year Source: https://discover.whoop.com/health-monitoring/.

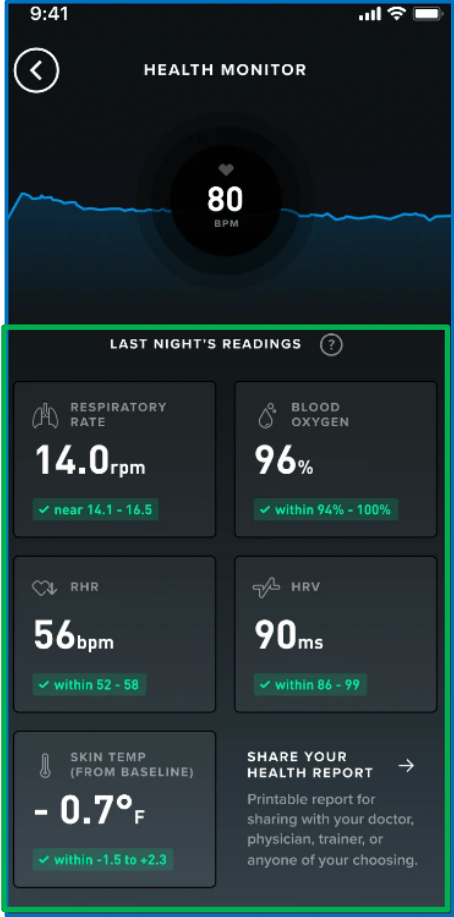
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’790 Patent Claim	Whoop Accused System ¹
	How <u>WHOOP</u> Monitors Blood Oxygen While the most familiar pulse oximeters are those that are placed on your finger, the same technology is utilized in many other devices, including the WHOOP 4.0, to monitor blood oxygen levels from the wrist. The <u>WHOOP 4.0</u> does this by sending two wavelengths of light (red and infrared) through your skin where it is absorbed and reflected by blood vessels. The red and infrared light each get absorbed differently by hemoglobin (the red blood cells that can bind with oxygen), and their absorption changes if the hemoglobin is oxygenated or not. By comparing the relative amount of light that gets reflected back from each of the wavelengths, we are able to track what percentage of red blood cells are oxygenated. So, for example, if 96% of them are oxygenated and 4% are not, then your SpO2 is 96%. The WHOOP 4.0 <u>measures your blood oxygen</u> level while you’re sleeping at night (which allows for the most consistent and reliable readings), then reports it to you each morning via the <u>Health Monitor</u>, which tracks key vitals including live heart rate, <u>resting heart rate</u>, <u>heart rate variability</u>, <u>respiratory rate</u>, and <u>skin temperature</u>. Source: https://www.whoop.com/us/en/thelocker/measure-normal-blood-oxygen-levels/.

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'790 Patent Claim	Whoop Accused System ¹
	 The screenshot displays the 'HEALTH MONITOR' screen of the Whoop app. At the top, the time is 9:41. Below the title, there's a heart rate monitor showing 80 BPM. A section titled 'LAST NIGHT'S READINGS' contains five metrics: Respiratory Rate (14.0 rpm, near 14.1 - 16.5), Blood Oxygen (96%, within 94% - 100%), RHR (56 bpm, within 52 - 58), HRV (90 ms, within 86 - 99), and Skin Temp (-0.7°F, within -1.5 to +2.3). A 'SHARE YOUR HEALTH REPORT' button is also present. Source: https://www.whoop.com/us/en/thelocker/measure-normal-blood-oxygen-levels/.

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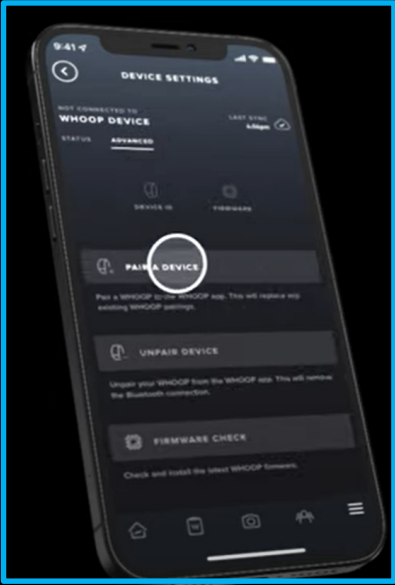
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’790 Patent Claim	Whoop Accused System ¹						
	Overview Reference this article to determine if WHOOP is compatible with your mobile device. For support with pairing your WHOOP to your mobile device, see WHOOP Sensor Pairing Guide. To begin Install the WHOOP app on your Android or iOS device to utilize WHOOP products and services. To ensure compatibility, make sure your device is running at least Bluetooth version 4.2 on Android OS 10.0 or higher, or iOS 16 or higher. Android devices must natively support the Google Play Store. Currently supported by WHOOP The following operating systems and devices are actively supported by WHOOP: <table border="1"> <thead> <tr> <th>Operating system</th><th>Model</th></tr> </thead> <tbody> <tr> <td>Apple iOS 16 or higher</td><td> • iPhone 6s or higher </td></tr> <tr> <td>Android OS 10.0 or higher</td><td> • Google Pixel • Nothing • One Plus (Update to Oxygen OS 13.1 - Security Update: June 5, 2023) • Samsung • Sony </td></tr> </tbody> </table> Source: https://support.whoop.com/s/article/WHOOP-App-Minimum-Software-Requirements?language=en_US.	Operating system	Model	Apple iOS 16 or higher	• iPhone 6s or higher	Android OS 10.0 or higher	• Google Pixel • Nothing • One Plus (Update to Oxygen OS 13.1 - Security Update: June 5, 2023) • Samsung • Sony
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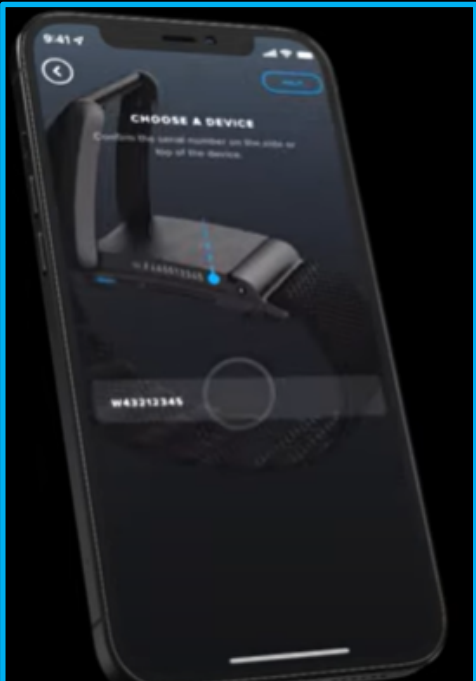
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'790 Patent Claim	Whoop Accused System ¹
	How to Pair Your WHOOP 4.0 A screenshot of a smartphone displaying the WHOOP mobile application. The screen shows the 'DEVICE SETTINGS' menu with options for 'PAIR A DEVICE', 'UNPAIR DEVICE', and 'FIRMWARE CHECK'. The 'PAIR A DEVICE' option is circled in white. The background of the slide is black. If 'Pair a Device' appears, tap that. If not, head to 'Advanced' and tap Pair a Device

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	 and choose your WHOOP

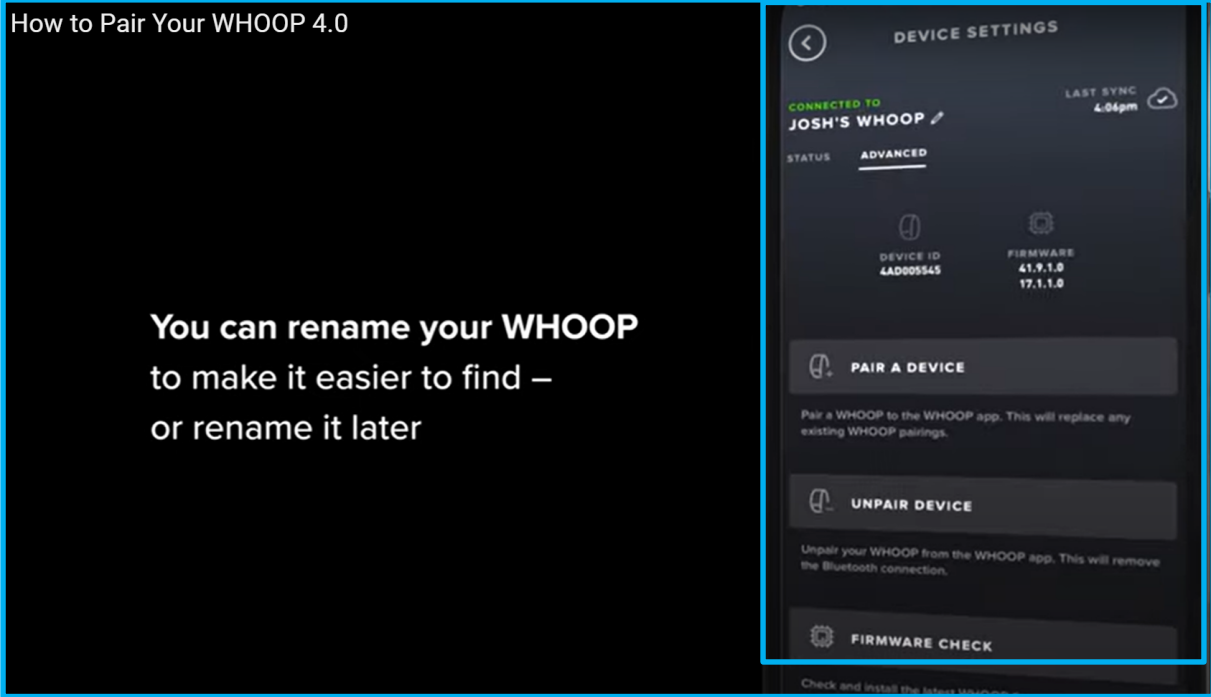
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’790 Patent Claim	Whoop Accused System ¹
	How to Pair Your WHOOP 4.0  When the blue lights stop flashing, your WHOOP has finished pairing. Be patient – it could take a few minutes.

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'790 Patent Claim	Whoop Accused System ¹
	 Source: https://www.youtube.com/watch?v=pj5VWkAgyME&t=2s.
7[b] the wearable device adapted to be placed on a wrist of a user;	The Accused System comprises a wearable device adapted to be placed on a wrist of a user, either literally or under the doctrine of equivalents. For example, the WHOOP 4.0 (“wearable device”) is adapted to be and is placed on a wrist of a user.

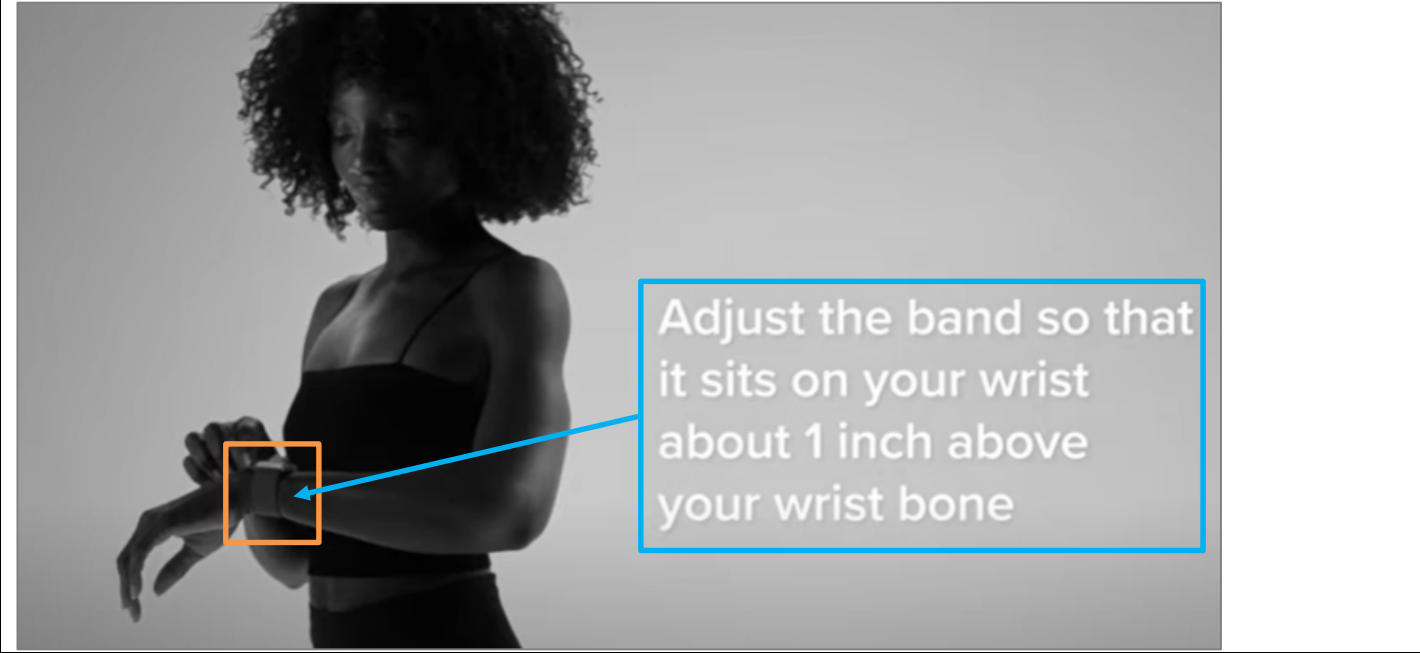
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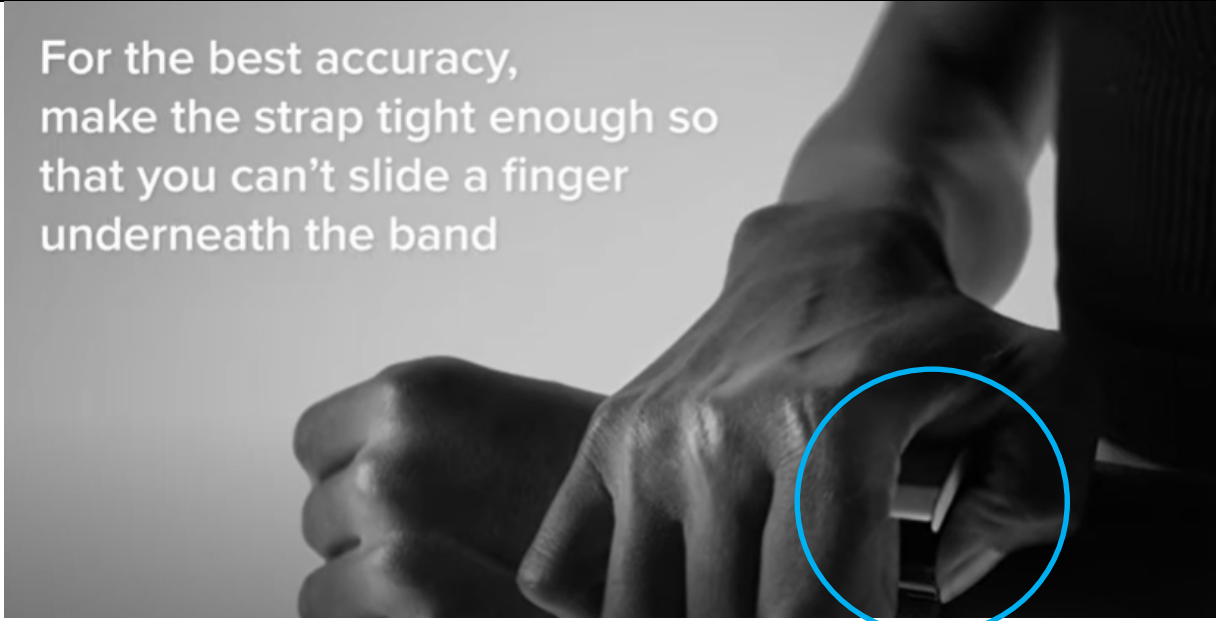
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	For the best accuracy, make the strap tight enough so that you can’t slide a finger underneath the band  Source: https://www.youtube.com/watch?v=cxVN6zSjWPc.

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’790 Patent Claim	Whoop Accused System ¹
71c] the wearable device including a light source comprising a plurality of semiconductor diodes that are configured to generate an output optical light having one or more optical wavelengths,	The Accused System comprises a wearable device includes a light source comprising a plurality of semiconductor diodes, either literally or under the doctrine of equivalents. For example, the WHOOP 4.0 (“wearable device”) includes a light source that comprises multiple LEDs, such as a green LED, red LED, and an infrared LED (“plurality of semiconductor diodes”).  WHOOP WHOOP CONTINUALLY MONITORS YOUR HEART RATE AND BLOOD OXYGEN LEVELS • Wear it on your wrist to track your heart rate 24/7 — right from home • Monitor your overnight blood oxygen (SpO2) levels • Capture data continuously with the wireless charger and waterproof battery pack • Track health data through LED lights and photodiodes with accuracy validated in lab studies and third-party testing • Share your health metrics with your provider or caregiver for more streamlined care • Available for \$239 per year Source: https://discover.whoop.com/health-monitoring/.

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’790 Patent Claim	Whoop Accused System ¹
	How to Wear Your WHOOP 4.0  Source: https://www.youtube.com/watch?v=cxVN6zSjWPc.

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'790 Patent Claim	Whoop Accused System ¹
	We engineered a device with superior accuracy and durability instead of superficial bells and whistles. The minimalist, screen-free design means every detail is intentional—like the 5 LEDs and 4 photodiodes that capture your data more often and with more precision than most wearables. And, you never have to take it off to charge—making WHOOP the most wearable wearable in the game. Source: https://www.whoop.com/us/en/difference/.

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	How WHOOP Monitors Blood Oxygen While the most familiar pulse oximeters are those that are placed on your finger, the same technology is utilized in many other devices, including the WHOOP 4.0, to monitor blood oxygen levels from the wrist. The <u>WHOOP 4.0</u> does this by sending two wavelengths of light (red and infrared) through your skin where it is absorbed and reflected by blood vessels. The red and infrared light each get absorbed differently by hemoglobin (the red blood cells that can bind with oxygen), and their absorption changes if the hemoglobin is oxygenated or not. By comparing the relative amount of light that gets reflected back from each of the wavelengths, we are able to track what percentage of red blood cells are oxygenated. So, for example, if 96% of them are oxygenated and 4% are not, then your SpO2 is 96%. The WHOOP 4.0 <u>measures your blood oxygen</u> level while you’re sleeping at night (which allows for the most consistent and reliable readings), then reports it to you each morning via the <u>Health Monitor</u>, which tracks key vitals including live heart rate, <u>resting heart rate</u>, <u>heart rate variability</u>, <u>respiratory rate</u>, and <u>skin temperature</u>. Source: https://www.whoop.com/us/en/thelocker/measure-normal-blood-oxygen-levels/. How WHOOP Measures Heart Rate WHOOP measures heart rate using advanced optical sensors with photoplethysmography (PPG) technology. It works by emitting green LED light into the skin, and then measuring the light that’s reflected back. Every time your heart beats, the blood flow increases, and this causes the amount of light that’s reflected back to change. WHOOP takes this raw data from the sensors and interprets it through an algorithm to produce a heart rate reading.

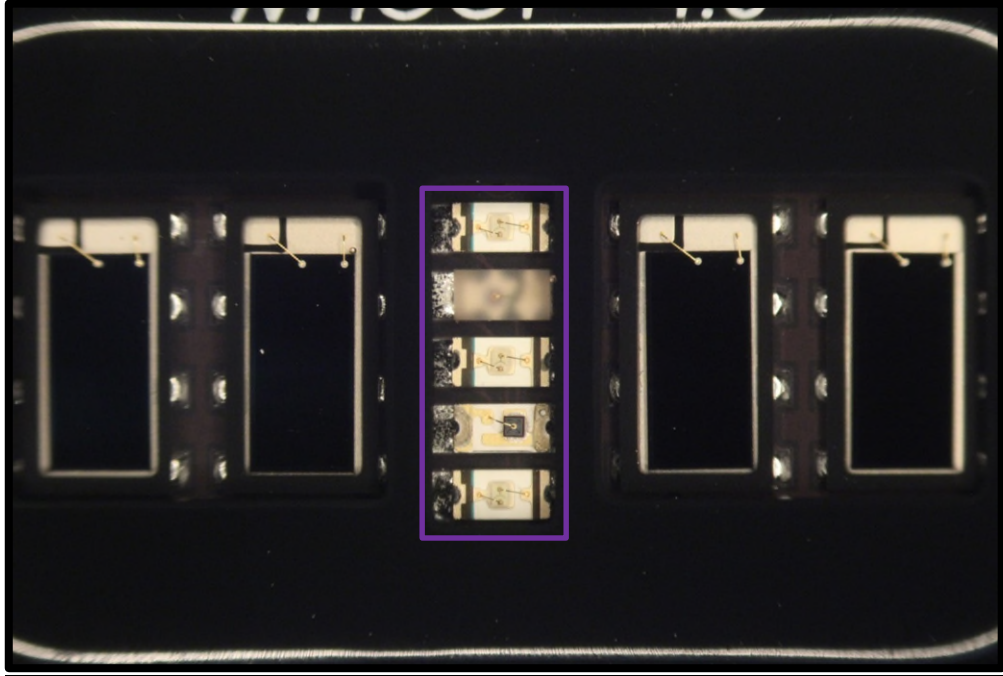
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'790 Patent Claim	Whoop Accused System ¹
	Source: https://www.whoop.com/us/en/thelocker/a-look-behind-the-data-how-whoop-measures-heart-rate/.  The image shows a black, rectangular Whoop 4.0 device. The text "WHOOP 4.0" is printed at the top, and "ALWAYS ON" is printed at the bottom. In the center, there is a sensor area with several small, gold-colored components. A green rectangular box highlights this sensor area. The device is placed on a surface with a grid pattern.

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’790 Patent Claim	Whoop Accused System ¹
	 Source: Product Teardown (WHOOP 4.0) In the Accused Wearable Device, the plurality of semiconductor diodes are configured to generate an output optical light having one or more optical wavelengths, either literally or under the doctrine of equivalents. For example, WHOOP 4.0 includes multiple LEDs (“semiconductor diodes”), such as a green LED, a red LED, and an infrared LED. Different color LEDs and infrared LEDs each generate output optical light having different optical wavelengths (“one or more optical wavelengths”).

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	“While the most familiar pulse oximeters are those that are placed on your finger, the same technology is utilized in many other devices, including the WHOOP 4.0, to monitor blood oxygen levels from the wrist. The WHOOP 4.0 does this by sending two wavelengths of light (red and infrared) through your skin where it is absorbed and reflected by blood vessels.” Source: https://www.whoop.com/us/en/thelocker/measure-normal-blood-oxygen-levels/. “WHOOP measures heart rate using advanced optical sensors with photoplethysmography (PPG) technology. It works by emitting green LED light into the skin, and then measuring the light that’s reflected back.” Source: https://www.whoop.com/us/en/thelocker/a-look-behind-the-data-how-whoop-measures-heart-rate/. LEDs outputting light at different colors do so at different optical wavelengths. For example, a green LED, a red LED, and an infrared LED all output light at different optical wavelengths:

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	<table border="1"> <thead> <tr> <th colspan="2" data-bbox="510 250 900 297">Table 1. LEDs – Wavelengths and Applications</th></tr> <tr> <th data-bbox="510 297 900 354">LED Wavelength (Color)</th><th data-bbox="900 297 1488 354">LED Applications</th></tr> </thead> <tbody> <tr> <td data-bbox="510 354 900 407">410–420 nm (Violet)</td><td data-bbox="900 354 1488 407">Skin therapy</td></tr> <tr> <td data-bbox="510 407 900 461">430–470 nm (Blue)</td><td data-bbox="900 407 1488 461">Dental curing instruments</td></tr> <tr> <td data-bbox="510 461 900 545">470 nm (Blue)</td><td data-bbox="900 461 1488 545">White LEDs using phosphor</td></tr> <tr> <td data-bbox="510 545 900 630">520–530 nm (Green)</td><td data-bbox="900 545 1488 630">Green traffic signal lights</td></tr> <tr> <td data-bbox="510 630 900 712">580–590 nm (Amber)</td><td data-bbox="900 630 1488 712">Amber traffic signal lights</td></tr> <tr> <td data-bbox="510 712 900 766">630–640 nm (Red)</td><td data-bbox="900 712 1488 766">Red signal lights</td></tr> <tr> <td data-bbox="510 766 900 820">660 nm (Deep Red)</td><td data-bbox="900 766 1488 820">Blood oximetry</td></tr> <tr> <td data-bbox="510 820 900 873">680 nm (Deep Red)</td><td data-bbox="900 820 1488 873">Blood analysis</td></tr> <tr> <td data-bbox="510 873 900 958">800–850 nm (Near-IR)</td><td data-bbox="900 873 1488 958">Night-vision illuminators and beacons for use with night-vision goggles or CCDs</td></tr> <tr> <td data-bbox="510 958 900 1011">850–940 nm (Near-IR)</td><td data-bbox="900 958 1488 1011">Photoelectric controls</td></tr> <tr> <td data-bbox="510 1011 900 1045">940 nm (Near-IR)</td><td data-bbox="900 1011 1488 1045">Covert illumination CCD-based systems</td></tr> </tbody> </table> Source: https://www.photonics.com/Articles/Light-Emitting_Diodes_A_Primer/a36706.	Table 1. LEDs – Wavelengths and Applications		LED Wavelength (Color)	LED Applications	410–420 nm (Violet)	Skin therapy	430–470 nm (Blue)	Dental curing instruments	470 nm (Blue)	White LEDs using phosphor	520–530 nm (Green)	Green traffic signal lights	580–590 nm (Amber)	Amber traffic signal lights	630–640 nm (Red)	Red signal lights	660 nm (Deep Red)	Blood oximetry	680 nm (Deep Red)	Blood analysis	800–850 nm (Near-IR)	Night-vision illuminators and beacons for use with night-vision goggles or CCDs	850–940 nm (Near-IR)	Photoelectric controls	940 nm (Near-IR)	Covert illumination CCD-based systems
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7[d] wherein at least a portion of the one or more optical wavelengths is a near-infrared wavelength between 700 nanometers and 2500 nanometers;	The Accused Wearable Device comprises a light source generating an output optical light having one or more optical wavelengths, wherein at least a portion of the one or more optical wavelengths is a near-infrared wavelength between 700 nanometers and 2500 nanometers, either literally or under the doctrine of equivalents. For example, the Accused Wearable Device is equipped with light-emitting diodes (LEDs). These LEDs are configured to generate an output optical light having one or more optical wavelengths, where distinct optical wavelengths are associated with different colors (<i>e.g.</i>, green and red light). Additionally, at least a portion of the emitted light is a near-infrared wavelength between 700 nanometers and 2500 nanometers—<i>e.g.</i>, between about 800nm and 940nm.

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	How WHOOP Measures Heart Rate WHOOP measures heart rate using advanced optical sensors with photoplethysmography (PPG) technology. It works by emitting green LED light into the skin, and then measuring the light that’s reflected back. Every time your heart beats, the blood flow increases, and this causes the amount of light that’s reflected back to change. WHOOP takes this raw data from the sensors and interprets it through an algorithm to produce a heart rate reading. Source: <a data-bbox="606 651 1864 678" href="https://www.whoop.com/us/en/thelocker/a-look-behind-the-data-how-whoop-measures-heart-rate/">https://www.whoop.com/us/en/thelocker/a-look-behind-the-data-how-whoop-measures-heart-rate/. “While the most familiar pulse oximeters are those that are placed on your finger, the same technology is utilized in many other devices, including the WHOOP 4.0, to monitor blood oxygen levels from the wrist. The WHOOP 4.0 does this by sending two wavelengths of light (red and infrared) through your skin where it is absorbed and reflected by blood vessels.” Source: <a data-bbox="606 911 1627 938" href="https://www.whoop.com/us/en/thelocker/measure-normal-blood-oxygen-levels/">https://www.whoop.com/us/en/thelocker/measure-normal-blood-oxygen-levels/. “WHOOP measures heart rate using advanced optical sensors with photoplethysmography (PPG) technology. It works by emitting green LED light into the skin, and then measuring the light that’s reflected back.” Source: <a data-bbox="606 1130 1864 1157" href="https://www.whoop.com/us/en/thelocker/a-look-behind-the-data-how-whoop-measures-heart-rate/">https://www.whoop.com/us/en/thelocker/a-look-behind-the-data-how-whoop-measures-heart-rate/. LEDs outputting light at different colors do so at different optical wavelengths. For example, a green LED, a red LED, and an infrared LED all output light at different optical wavelengths:

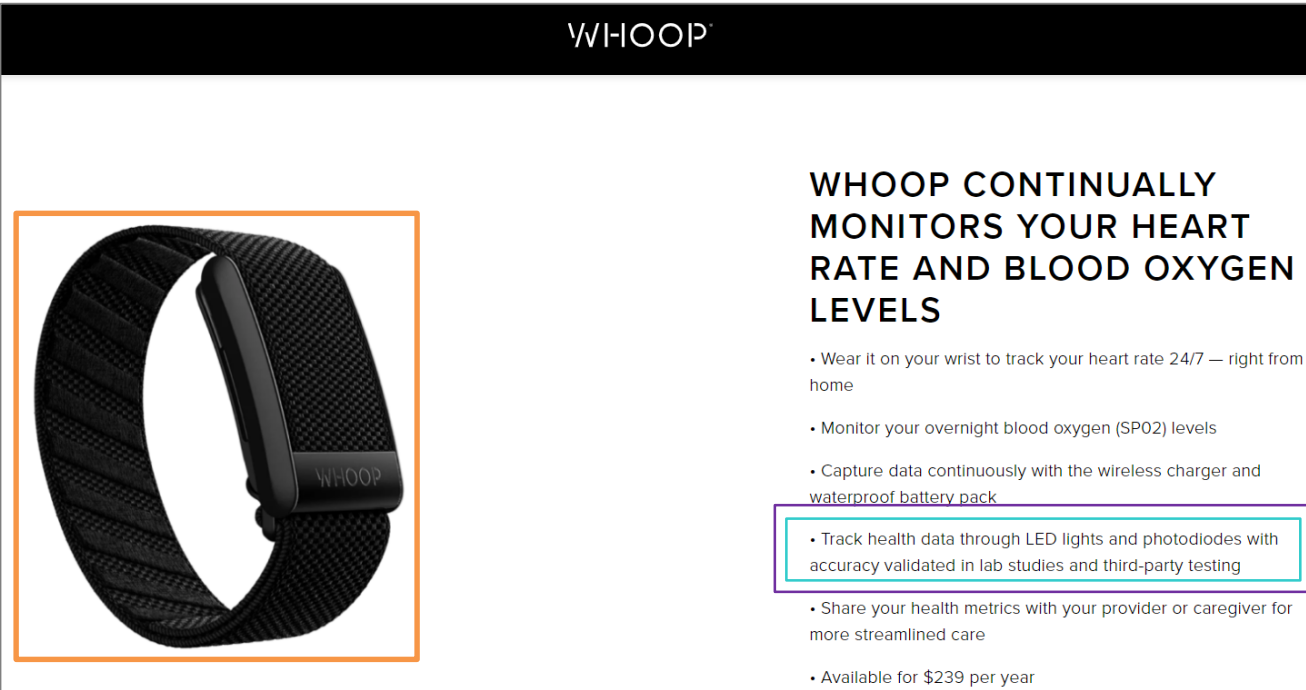
U.S. Patent No. 12,193,790 (the “’790 Patent”)

“Wearable devices comprising semiconductor diode light sources with improved signal-to-noise ratio”

’790 Patent Claim	Whoop Accused System ¹																										
	<table border="1"> <thead> <tr> <th colspan="2" data-bbox="512 250 1493 298">Table 1. LEDs – Wavelengths and Applications</th></tr> <tr> <th data-bbox="512 298 900 347">LED Wavelength (Color)</th><th data-bbox="900 298 1493 347">LED Applications</th></tr> </thead> <tbody> <tr> <td data-bbox="512 347 900 404">410–420 nm (Violet)</td><td data-bbox="900 347 1493 404">Skin therapy</td></tr> <tr> <td data-bbox="512 404 900 461">430–470 nm (Blue)</td><td data-bbox="900 404 1493 461">Dental curing instruments</td></tr> <tr> <td data-bbox="512 461 900 542">470 nm (Blue)</td><td data-bbox="900 461 1493 542">White LEDs using phosphor</td></tr> <tr> <td data-bbox="512 542 900 623">520–530 nm (Green)</td><td data-bbox="900 542 1493 623">Green traffic signal lights</td></tr> <tr> <td data-bbox="512 623 900 704">580–590 nm (Amber)</td><td data-bbox="900 623 1493 704">Amber traffic signal lights</td></tr> <tr> <td data-bbox="512 704 900 761">630–640 nm (Red)</td><td data-bbox="900 704 1493 761">Red signal lights</td></tr> <tr> <td data-bbox="512 761 900 818">660 nm (Deep Red)</td><td data-bbox="900 761 1493 818">Blood oximetry</td></tr> <tr> <td data-bbox="512 818 900 875">680 nm (Deep Red)</td><td data-bbox="900 818 1493 875">Blood analysis</td></tr> <tr> <td data-bbox="512 875 900 956">800–850 nm (Near-IR)</td><td data-bbox="900 875 1493 956">Night-vision illuminators and beacons for use with night-vision goggles or CCDs</td></tr> <tr> <td data-bbox="512 956 900 1005">850–940 nm (Near-IR)</td><td data-bbox="900 956 1493 1005">Photoelectric controls</td></tr> <tr> <td data-bbox="512 1005 900 1053">940 nm (Near-IR)</td><td data-bbox="900 1005 1493 1053">Covert illumination CCD-based systems</td></tr> </tbody> </table> Source: https://www.photonics.com/Articles/Light-Emitting_Diodes_A_Primer/a36706.	Table 1. LEDs – Wavelengths and Applications		LED Wavelength (Color)	LED Applications	410–420 nm (Violet)	Skin therapy	430–470 nm (Blue)	Dental curing instruments	470 nm (Blue)	White LEDs using phosphor	520–530 nm (Green)	Green traffic signal lights	580–590 nm (Amber)	Amber traffic signal lights	630–640 nm (Red)	Red signal lights	660 nm (Deep Red)	Blood oximetry	680 nm (Deep Red)	Blood analysis	800–850 nm (Near-IR)	Night-vision illuminators and beacons for use with night-vision goggles or CCDs	850–940 nm (Near-IR)	Photoelectric controls	940 nm (Near-IR)	Covert illumination CCD-based systems
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'790 Patent Claim	Whoop Accused System ¹
<u>7 e </u> the wearable device comprising one or more lenses configured to receive at least a portion of the output optical light and to deliver a lens output light to tissue comprising skin;	The Accused System comprises a wearable device comprising one or more lenses configured to receive at least a portion of the output optical light and to deliver a lens output light to tissue comprising skin, either literally or under the doctrine of equivalents. For example, the Accused Wearable Device (“wearable device”) comprises one or more lenses positioned between each LED and the wrist of a user when worn by the user. The lenses receive output optical light from the LEDs and deliver the lens output light to tissue of the user (<i>e.g.</i>, skin, blood vessels, veins).  The screenshot shows the WHOOP website. At the top is the WHOOP logo. Below it is a large image of a black, textured wristband with a black buckle. To the right of the image is the text 'WHOOP CONTINUALLY MONITORS YOUR HEART RATE AND BLOOD OXYGEN LEVELS'. Below this text is a list of features: 'Wear it on your wrist to track your heart rate 24/7 — right from home', 'Monitor your overnight blood oxygen (SP02) levels', 'Capture data continuously with the wireless charger and waterproof battery pack', 'Track health data through LED lights and photodiodes with accuracy validated in lab studies and third-party testing', 'Share your health metrics with your provider or caregiver for more streamlined care', and 'Available for \$239 per year'. The feature 'Track health data through LED lights and photodiodes with accuracy validated in lab studies and third-party testing' is highlighted with a red box. Source: https://discover.whoop.com/health-monitoring/.

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“Wearable devices comprising semiconductor diode light sources with improved signal-to-noise ratio”

’790 Patent Claim	Whoop Accused System ¹
	We engineered a device with superior accuracy and durability instead of superficial bells and whistles. The minimalist, screen-free design means every detail is intentional—like the 5 LEDs and 4 photodiodes that capture your data more often and with more precision than most wearables. And, you never have to take it off to charge—making WHOOP the most wearable wearable in the game. Source: https://www.whoop.com/us/en/difference/. How WHOOP Measures Heart Rate WHOOP measures heart rate using advanced optical sensors with photoplethysmography (PPG) technology. It works by <u>emitting green LED light into the skin</u>, and then measuring the light that’s reflected back. Every time your heart beats, the blood flow increases, and this causes the amount of light that’s reflected back to change. WHOOP takes this raw data from the sensors and interprets it through an algorithm to produce a heart rate reading. Source: https://www.whoop.com/us/en/thelocker/a-look-behind-the-data-how-whoop-measures-heart-rate/.

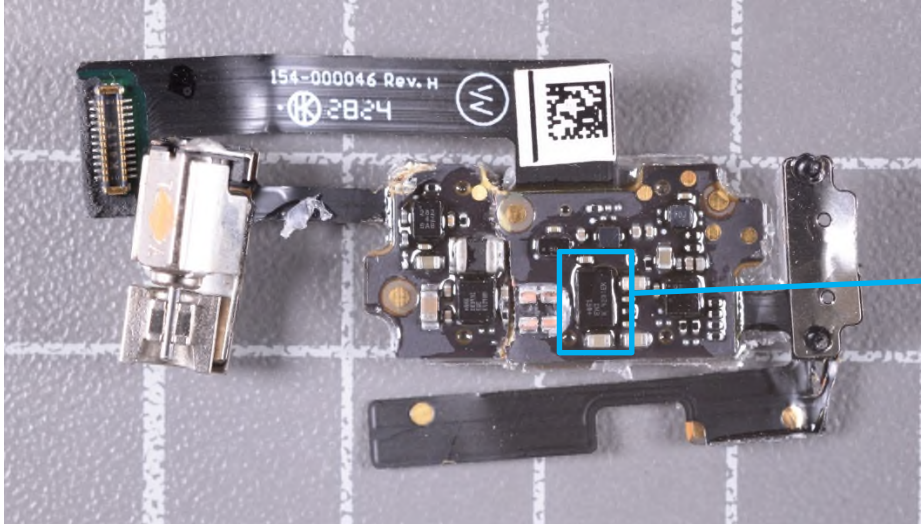
U.S. Patent No. 12,193,790 (the “’790 Patent”)

“Wearable devices comprising semiconductor diode light sources with improved signal-to-noise ratio”

’790 Patent Claim	Whoop Accused System ¹
	How WHOOP Monitors Blood Oxygen While the most familiar pulse oximeters are those that are placed on your finger, the same technology is utilized in many other devices, including the WHOOP 4.0, to monitor blood oxygen levels from the wrist. The <u>WHOOP 4.0</u> does this by sending <u>two wavelengths of light (red and infrared)</u> through your skin where it is absorbed and reflected by blood vessels. The red and infrared light each get absorbed differently by hemoglobin (the red blood cells that can bind with oxygen), and their absorption changes if the hemoglobin is oxygenated or not. By comparing the relative amount of light that gets reflected back from each of the wavelengths, we are able to track what percentage of red blood cells are oxygenated. So, for example, if 96% of them are oxygenated and 4% are not, then your SpO2 is 96%. The WHOOP 4.0 <u>measures your blood oxygen</u> level while you’re sleeping at night (which allows for the most consistent and reliable readings), then reports it to you each morning via the <u>Health Monitor</u>, which tracks key vitals including live heart rate, <u>resting heart rate</u>, <u>heart rate variability</u>, <u>respiratory rate</u>, and <u>skin temperature</u>. Source: https://www.whoop.com/us/en/thelocker/measure-normal-blood-oxygen-levels/. A product teardown of WHOOP 4.0 reveals that it features, among other components, a pulse oximeter/heart rate sensor manufactured by Analog Devices (formerly Maxim Integrated) (e.g., “MAX86171”).

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’790 Patent Claim	Whoop Accused System ¹
	 Deep Dive Teardown of the Whoop Inc. Whoop 4.0 WS40; WB40 Fitness Tracker Maxim had the overall design wins for the Whoop 4.0, with four major designs. For this device, Maxim provided the ARM cortex-M4 with FPU-based microcontroller(MAX32652),the power management(MAX77818), the pulse oximeter/heart rate sensor (MAX86171),and the digital temperature sensor(MAX6631MTT). Source: https://www.techinsights.com/products/ddt-2111-806.  Maxim Integrated MAX86171 Source: Product Teardown (WHOO 4.0)

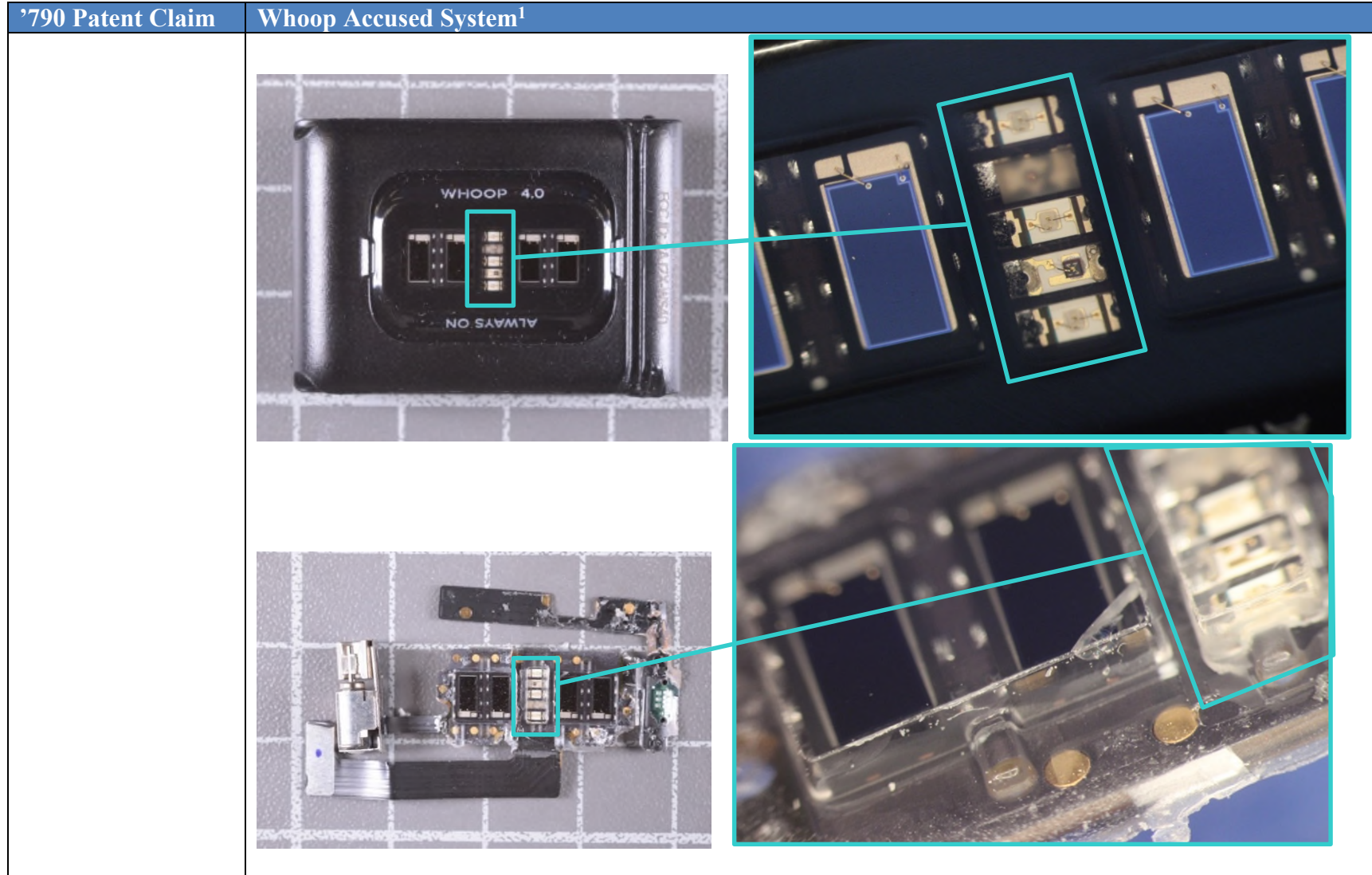
U.S. Patent No. 12,193,790 (the “’790 Patent”)

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’790 Patent Claim	Whoop Accused System ¹
	The product data sheet for MAX86171, shown below, states that MAX86171 includes nine LED driver outputs to support WHOOP 4.0’s multiple LEDs. The LEDs each include a lens that receives output optical light from the LED and delivers the light to the skin (and underlying tissue) on the user’s wrist (e.g., epoxy lens, flat lens). WHOOP 4.0 further includes a material covering the array of LEDs (e.g., epoxy lens, flat lens), which is a lens that receives output optical light from the LED and delivers the light to the skin. WHOOP 4.0 further includes yet another material covering the array of LEDs and photodetectors, which is a lens that receives output optical light from the LED and delivers the light to the skin.  EVALUATION KIT AVAILABLE Click here to ask an associate for production status of specific part numbers. MAX86171 Low-Noise AFE for Pulse Oximeter and Heart Rate Monitor General Description The MAX86171 is an ultra-low-power optical data acquisition system with both transmit and receive channels. On the transmitter side, the MAX86171 has nine LED driver output pins, programmable from three high-current, 8-bit LED drivers. On the receiver side, MAX86171 has two low-noise charge integrating front-ends that each include independent 19.5 bit ADCs and best-in-class ambient light cancellation (ALC) circuits, producing the highest performing integrated optical data acquisition system on the market today. • Supports Four PD Inputs for Multi-Parameter Measurements • Supports Nine LED Driver Output Pins Generated from Three 8-Bit LED Current Drivers • Low Dark Current Noise of < 50pA RMS (Sample to Sample Variance in 117.1µs Integration Time) • Excellent Ambient Range and Rejection Capability • > 200µA Ambient Photodiode Current • > 70dB Ambient Rejection at 120Hz (Average Mode > 2) Source: Analog Devices, “MAX86171: Low-Noise AFE for Pulse Oximeter and Heart Rate Monitor Data Sheet,” Rev.2, Mar. 24, 2022, at 1, available at https://www.analog.com/media/en/technical-documentation/data-sheets/MAX86171.pdf.

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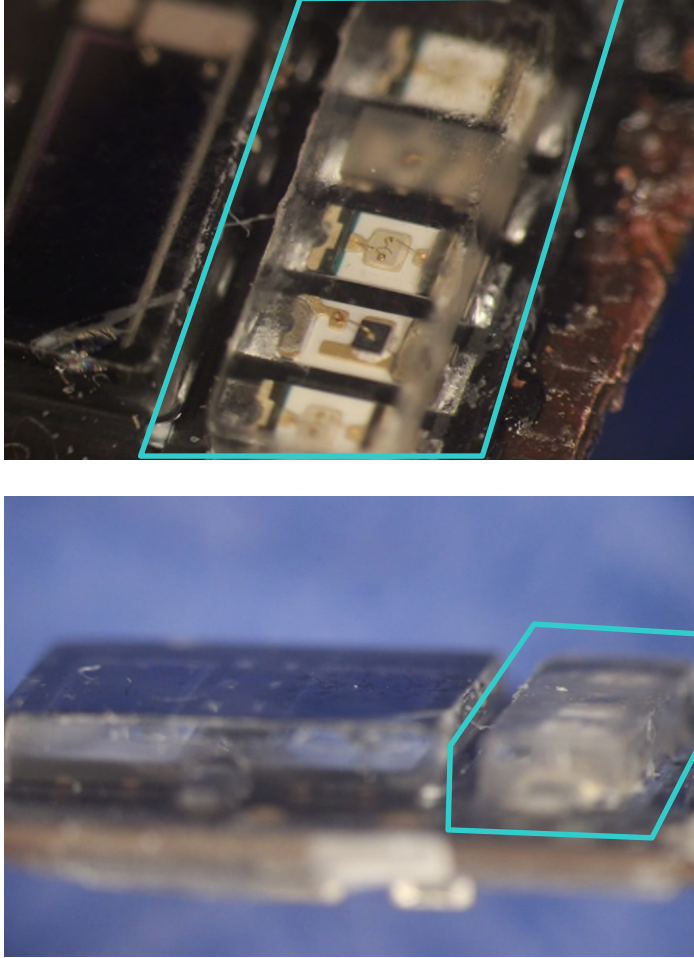
“Wearable devices comprising semiconductor diode light sources with improved signal-to-noise ratio”



Ex. 12

U.S. Patent No. 12,193,790 (the “’790 Patent”)

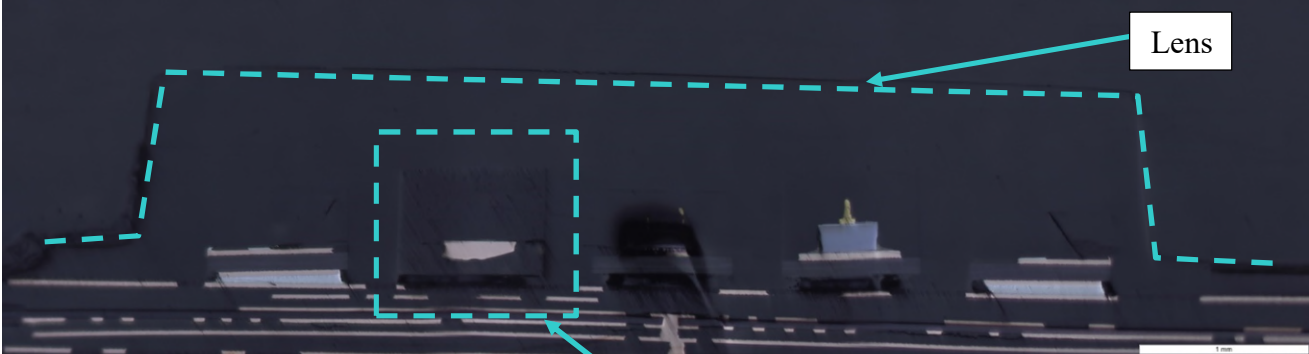
“Wearable devices comprising semiconductor diode light sources with improved signal-to-noise ratio”

’790 Patent Claim	Whoop Accused System ¹
	

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“Wearable devices comprising semiconductor diode light sources with improved signal-to-noise ratio”

'790 Patent Claim	Whoop Accused System ¹
	 (Above and below: Cross-section of LEDs)  Source: Product Teardown (WHOOP 4.0) Lens (e.g., flat lens) on each LED

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Whoop Accused System¹

DIFFERENT TYPES OF LED LENSES

See the small protective dome above the diode? This is called the primary optic and helps protect and shape the output of small LED diodes. The light from the LED's primary optics is still too broad for most applications and too weak to illuminate only certain surfaces. Therefore, most LED lamps use secondary optics (lenses, reflectors, TIR optics, etc.) to capture all the light from the LED and increase its intensity. The most common LED lens is the convex lens that is placed around the LED. However, as technology advances, other types of lenses are also becoming more common. There are square lenses, high dome lenses, medium dome lenses and flat lenses. Each with its own light distribution and mounting over the LED diode.

OPTICAL PROPERTIES OF DIFFERENT LED LENSES

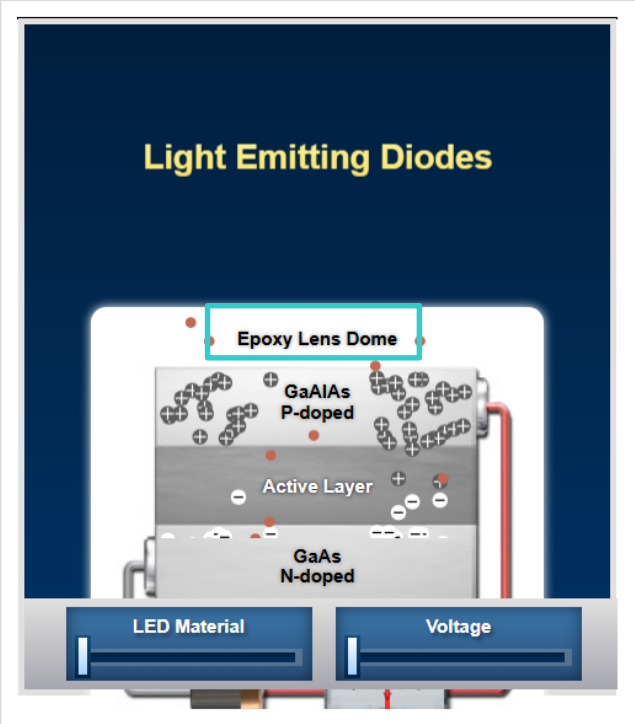
If you are looking for a specific light image in your LED lighting, it is important to know what kind of lens your lamp uses. To make this clear, we have made a table with the differences.

Kenmerken	Lichthoek		Efficiëntie van lichtextractie		Conventioneel product
Soort lens	Low lens	Tall lens	Hemisphere lens	Flat	Flat
	Square	Dome	Dome	Square	None
Soort bolling					
Lens opbouw					
Lichtverdeling en lichthoek	77°	25°	130°	122°	108°
	93%	93%	93%	91%	75%

Source: <https://www.tralert.com/en/lighting-terms/led-lens/>

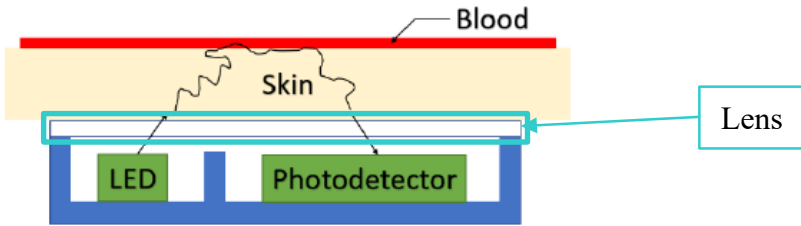
U.S. Patent No. 12,193,790 (the “’790 Patent”)

“Wearable devices comprising semiconductor diode light sources with improved signal-to-noise ratio”

'790 Patent Claim	Whoop Accused System ¹
	“Light emitting diodes (LEDs) are a general source of continuous light with a high luminescence efficiency, and are based on the general properties of a simple twin-element semiconductor diode encased in a clear epoxy dome that acts as a lens.” Source: https://www.olympus-lifescience.com/en/microscope-resource/primer/java/leds/basicoperation/  Source: https://www.olympus-lifescience.com/en/microscope-resource/primer/java/leds/basicoperation/

U.S. Patent No. 12,193,790 (the “’790 Patent”)

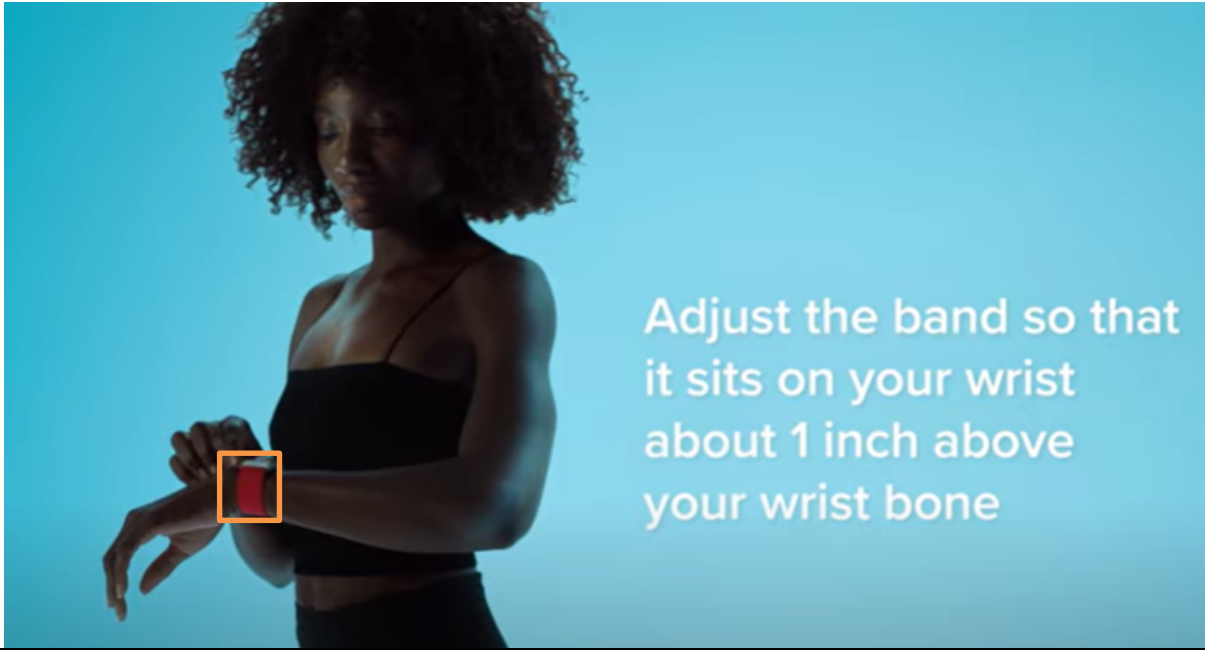
“Wearable devices comprising semiconductor diode light sources with improved signal-to-noise ratio”

'790 Patent Claim	Whoop Accused System ¹
	APPLICATION NOTE 6846 Guidelines for the Opto-Mechanical Integration of Heart-Rate Monitors in Wearable Wrist Devices Introduction Wrist-based wearables are gaining prominence with customers who want to track their physiological parameters during fitness, daily activity, and sleep. These physiological parameters can be obtained noninvasively by using optical sensors to detect the heart-rate signal. This technology has been established in the medical sector and can now be transferred to wearable wrist applications. On certain regions of the body such as the wrist, transmissive heart-rate measurements are logistically difficult, so reflective measurements are used. Reflective heart-rate monitors consist of a light source and a detector arranged in the same plane (Figure 1). The light emitted penetrates the skin, tissue, and blood vessels and is either absorbed, scattered, or reflected. A small portion of the emitted light eventually reaches the photodetector. As the volume of blood in the arteries changes with every heartbeat, the fraction of light absorbed and, subsequently, the strength of the detector signal change. 

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	Source: Maxim Integrated, Application Note 6846, “Guidelines for the Opto-Mechanical Integration of Heart-Rate Monitors in Wearable Wrist Devices,” <i>available at</i> https://pdfserv.maximintegrated.com/en/an/AN6846.pdf. 

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’790 Patent Claim	Whoop Accused System ¹
	For the best accuracy, make the strap tight enough so that you can’t slide a finger underneath the band  Source: https://www.youtube.com/watch?v=cxVN6zSjWPc. Patent documents assigned to and/or owned by Whoop also describe Whoop’s wearable devices comprising one or more lenses configured to receive at least a portion of the output optical light and to deliver a lens output light to tissue. For example:

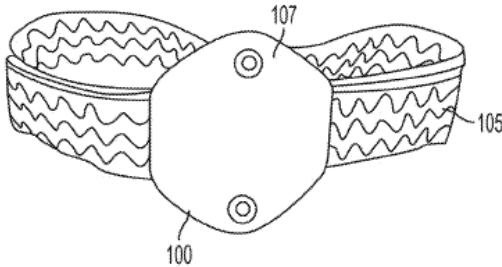
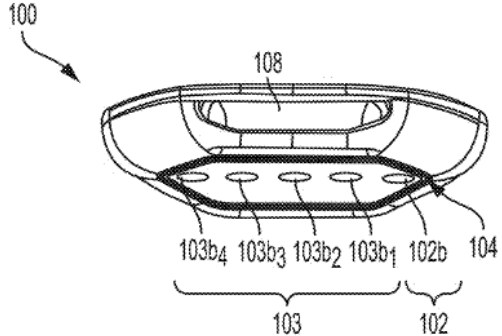
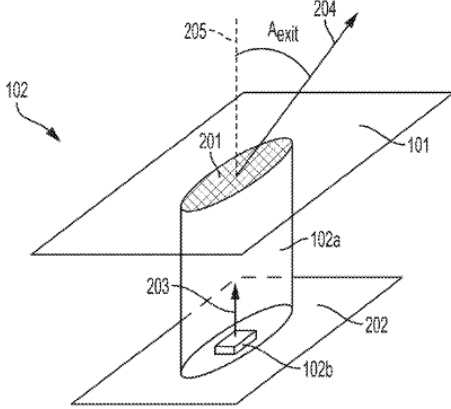
U.S. Patent No. 12,193,790 (the “’790 Patent”)

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’790 Patent Claim	Whoop Accused System ¹
	(12) United States Patent Wiese et al. (10) Patent No.: US 10,799,162 B2 (45) Date of Patent: *Oct. 13, 2020 (54) TISSUE OXYGEN SATURATION DETECTION AND RELATED APPARATUS AND METHODS (58) Field of Classification Search CPC A61B 5/1455; A61B 5/00; A61B 5/0024; A61B 5/0095; A61B 5/14; A61B 5/145; A61B 5/1477 See application file for complete search history. (71) Applicant: Whoop, Inc., Boston, MA (US) (72) Inventors: Daniel Wiese, Cambridge, MA (US); Alessandro Babini, Cambridge, MA (US); Sebastian Trousil, Boston, MA (US); Samuel Huberman, Somerville, MA (US); Stefan Kalchmair, Boston, MA (US); Pamela G. Anderson, Boston, MA (US) (73) Assignee: Whoop, Inc., Boston, MA (US) (56) References Cited U.S. PATENT DOCUMENTS 6,587,703 B2 7/2003 Cheng et al. 6,678,541 B1 1/2004 Durkin (Continued) (57) ABSTRACT A wearable optical device is described for optically detecting parameters of interest within muscle, such as during physical activity or when at rest. The parameters of interest include oxygenation level and/or hemoglobin concentrations in some situations. The detected parameters, such as oxygenation level, may be used to assess physical performance, such as the extent to which the muscle is utilizing aerobic or anaerobic processes. Methods for determining the parameters of interest, such as oxygenation level, from the detected optical signals are also described, and feedback may be provided to a user.

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	 FIG. 4A  FIG. 1C  FIG. 2A

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	FIG. 1B shows a back side 101 of the wearable optical device 100. The optical device includes multiple optical sources and multiple optical detectors. In the illustrated non-limiting embodiment, the wearable optical device 100 includes a light source array 102 and a detector array 103 disposed on the back side 101. The back side 101 may be in contact with the surface of a user's skin during operation, allowing the wearable optical device to transmit optical signals into muscle tissue underneath the skin surface and to collect optical signals from the muscle tissue. In the illustrated embodiment, the optical emitters may be recessed relative to the surface of the back side 101 which contacts the user. With respect to the non-limiting example of FIG. 1B, the light source array 102 includes one or more emitters forming an emitter array 102b disposed within an emitter recess 102a. In alternative implementations, emitters may have respective recesses in which they are disposed. The emitter recess 102a may optically isolate the emitters from the detectors, such that the optical signals transmitted 5 from the emitter array 102b do not directly enter the detectors of detector array 103 without passing through the tissue of the user. In some embodiments, the walls of the emitter recess 102a may include light isolation material to provide an improved light isolation between components on the back side 101. In some embodiments, the light isolation material may comprise compressive foam material, although other materials are possible.

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	FIG. 2A shows a simplified perspective view of the illustrative emitter recess 102a of FIG. 1A. In this example a window filter 201 is attached to the opening of the emitter recess and is configured to selectively modify the optical signals 203 emitted from the emitter array 102b in any suitable way to facilitate a spectrum measurement. In one embodiment, the window filter 201 may comprise a tinted filter to modify the spectrum of the optical signals emitted into the user. In another embodiment, the window filter 201 may comprise a roughened texture to diffuse optical signal 203 by scattering so that light signals 204 exit the window filter along a plurality of angles A_{exit} relative to an axis 205 normal to the window filter. The plurality of exit angles A_{exit} may comprise a maximum angle of at least 30 degrees, at least 45 degrees, at least 60 degrees, at least 90 degrees, between 20 and 90 degrees, or any value or range of values within such ranges. As previously described, the optical device 100 contacts a user during use in at least some embodiments. For example, the optical device 100 may be configured such that the back side 101 contacts a user’s skin in use. FIGS. 2B and Source: US 10,799,162 at Abstract, FIGS. 1A-1D, FIG. 2A, FIGS. 4A-4B, 4:49-5:8, 5:16-21. See also US 10,092,228 at Abstract, FIGS. 1A-1D, FIG. 2A, FIGS 4-A-4B, 4:25-5:3, 5:11-16.
<u>7 f </u> the wearable device further comprising a detection system configured to receive at least a portion of the lens output light reflected from the tissue and to generate an output	The Accused Wearable Device of the Accused System comprises a detection system configured to receive at least a portion of the lens output light reflected from the tissue and to generate an output signal having a signal-to-noise ratio, either literally or under the doctrine of equivalents. For example, WHOOP 4.0 comprises hardware components such as photodiodes and an integrated analog front end (“AFE”) optical data acquisition and sensor module (e.g., MAX86171 manufactured by Analog Devices) (individually and/or collectively, “a detection system”). The AFE sensor module is configured to: (a) receive light initially output from LEDs that is reflected from tissue of a user (“receive at least a portion of the lens output light reflected from the tissue”), and (b) generate an output

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signal having a signal-to-noise ratio,	photoplethysmography (“PPG”) signal having a signal-to-noise ratio (“generate an output signal having a signal-to-noise ratio”). New Sensor and Improved Heart Rate Accuracy Measuring a member’s physiology continuously, 24/7, with high accuracy and reliability is the top priority of our world-class signal processing team. With the WHOOP 4.0, we revisited our sensor configuration to further increase the signal quality and open the doors to more complicated signal processing techniques. This enabled us to elevate and refine our ability to measure a member’s heart rate and heart rate variability. As one can see from the sensor, there are marked differences from the 3.0 to the 4.0—namely the <u>inclusion of 4 photodiodes, or light sensors</u>, (compared to 1 in the 3.0), 3 green LEDs (vs 2 in the 3.0) and the addition of both an infrared and red LED. Additionally, the arrangement of the sensors and emitters has also changed. These modifications are not random, THE WHOOP 4.0 SENSOR HAS 5 LEDS (3 green, 1 red, 1 infrared) AND 4 PHOTODIODES. Taking advantage of the expanded sensor capabilities and the huge dataset, our signal processing team developed new cutting-edge algorithms to boost the accuracy of our heart rate measurements. Compared to the WHOOP 3.0, the WHOOP 4.0 on average has a 10% improvement in accuracy across all activities we studied. This marks just the beginning of what is capable with our new sensing system. Throughout the life of WHOOP 4.0, we will continue collecting data sets through WHOOP Labs and increasing the heart rate accuracy. These updates will come as firmware updates (where we can upgrade your hardware while it’s on your wrist) alongside other improvements and new features to your WHOOP 4.0.

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’790 Patent Claim	Whoop Accused System ¹
	 Source: https://www.whoop.com/us/en/thelocker/chief-technology-officer-whoop-4-0-accuracy/. “WHOOP measures heart rate using advanced optical sensors with photoplethysmography (PPG) technology. It works by emitting green LED light into the skin, and then measuring the light that’s reflected back.” https://www.whoop.com/us/en/thelocker/a-look-behind-the-data-how-whoop-measures-heart-rate/.

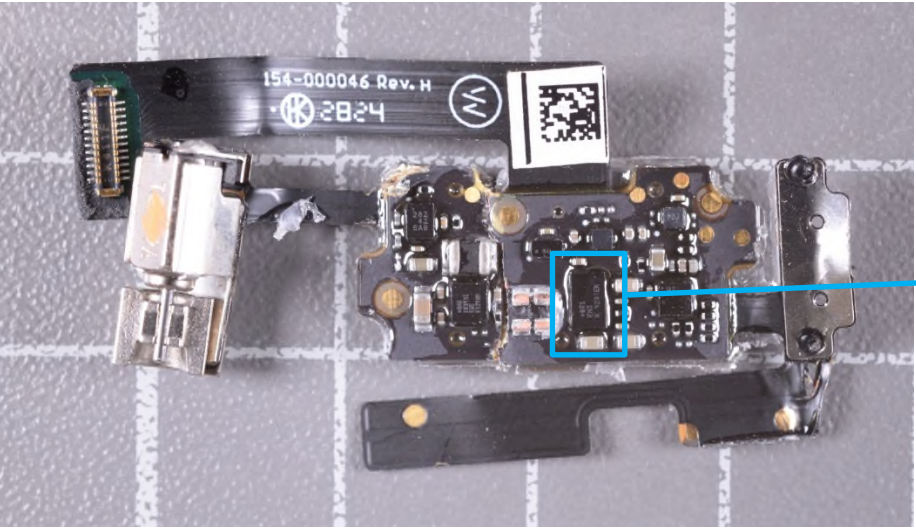
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“Wearable devices comprising semiconductor diode light sources with improved signal-to-noise ratio”

’790 Patent Claim	Whoop Accused System ¹
	How Does WHOOP Track Blood Oxygen? With a new sensor configuration that includes 5 LEDs and 4 photodiodes, the WHOOP 4.0 is now equipped to accurately monitor blood oxygen levels with pulse oximetry. Although most common pulse oximeters track your blood oxygen from your finger, WHOOP implements the same technology to calculate SpO2 on your wrist. Here’s how it works: • The LEDs shine two different wavelengths of light through the surface of your skin to your blood vessels • The light is reflected back to the photodiodes, with one wavelength being absorbed better by oxygenated hemoglobin and the other absorbed better by non-oxygenated hemoglobin • The relative amounts of light that get absorbed can be used to determine how much oxygen is in your blood, and that percentage represents your SpO2 level Source: https://www.whoop.com/us/en/thelocker/metric-blood-oxygen-monitoring/.

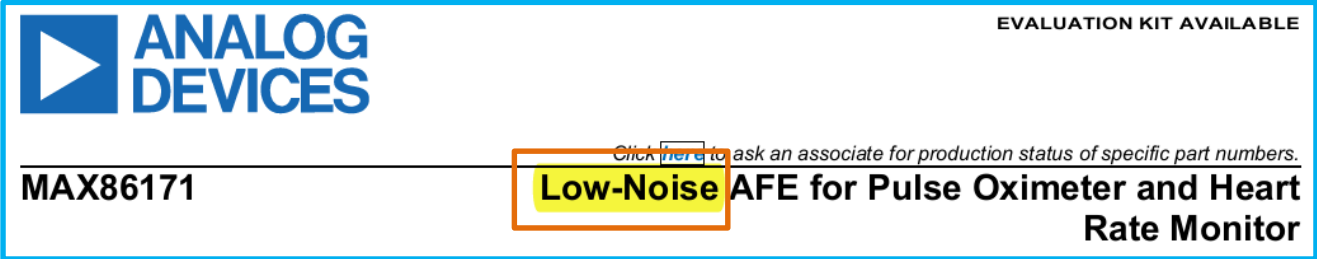
U.S. Patent No. 12,193,790 (the “’790 Patent”)

“Wearable devices comprising semiconductor diode light sources with improved signal-to-noise ratio”

’790 Patent Claim	Whoop Accused System ¹
	 Deep Dive Teardown of the Whoop Inc. Whoop 4.0 WS40; WB40 Fitness Tracker Maxim had the overall design wins for the Whoop 4.0, with four major designs. For this device, Maxim provided the ARM cortex-M4 with FPU-based microcontroller(MAX32652),the power management(MAX77818),<u>the pulse oximeter/heart rate sensor (MAX86171)</u>,and the digital temperature sensor(MAX6631MTT). Contact Us Product Code: DDT-2111-806 Release Date: 26/01/2022 Availability: Published Product Item Code: WPH-WS40 Device Manufacturer: Whoop Device Type: Fitness Monitor Source: https://www.techinsights.com/products/ddt-2111-806.  Maxim Integrated MAX86171 Source: Product Teardown (WHOO 4.0)

U.S. Patent No. 12,193,790 (the “’790 Patent”)

“Wearable devices comprising semiconductor diode light sources with improved signal-to-noise ratio”

’790 Patent Claim	Whoop Accused System ¹
	The sensor (“detection system”) in WHOOP 4.0—<i>e.g.</i>, MAX86171—includes photodiodes to receive the LED light reflected back from the user’s skin (and underlying body tissues), and is configured to generate a PPG output signal from the reflected light. The PPG output signal has a signal-to-noise ratio (“SNR”).  The image shows the Analog Devices MAX86171 product page. It features the Analog Devices logo, the part number MAX86171, and the title 'Low-Noise AFE for Pulse Oximeter and Heart Rate Monitor'. A link is provided to ask an associate for production status of specific part numbers. General Description The MAX86171 is an ultra-low-power optical data acquisition system with both transmit and receive channels. On the transmitter side, the MAX86171 has nine LED driver output pins, programmable from three high-current, 8-bit LED drivers. On the receiver side, MAX86171 has two low-noise charge integrating front-ends that each include independent 19.5 bit ADCs and best-in-class ambient light cancellation (ALC) circuits, producing the highest performing integrated optical data acquisition system on the market today.

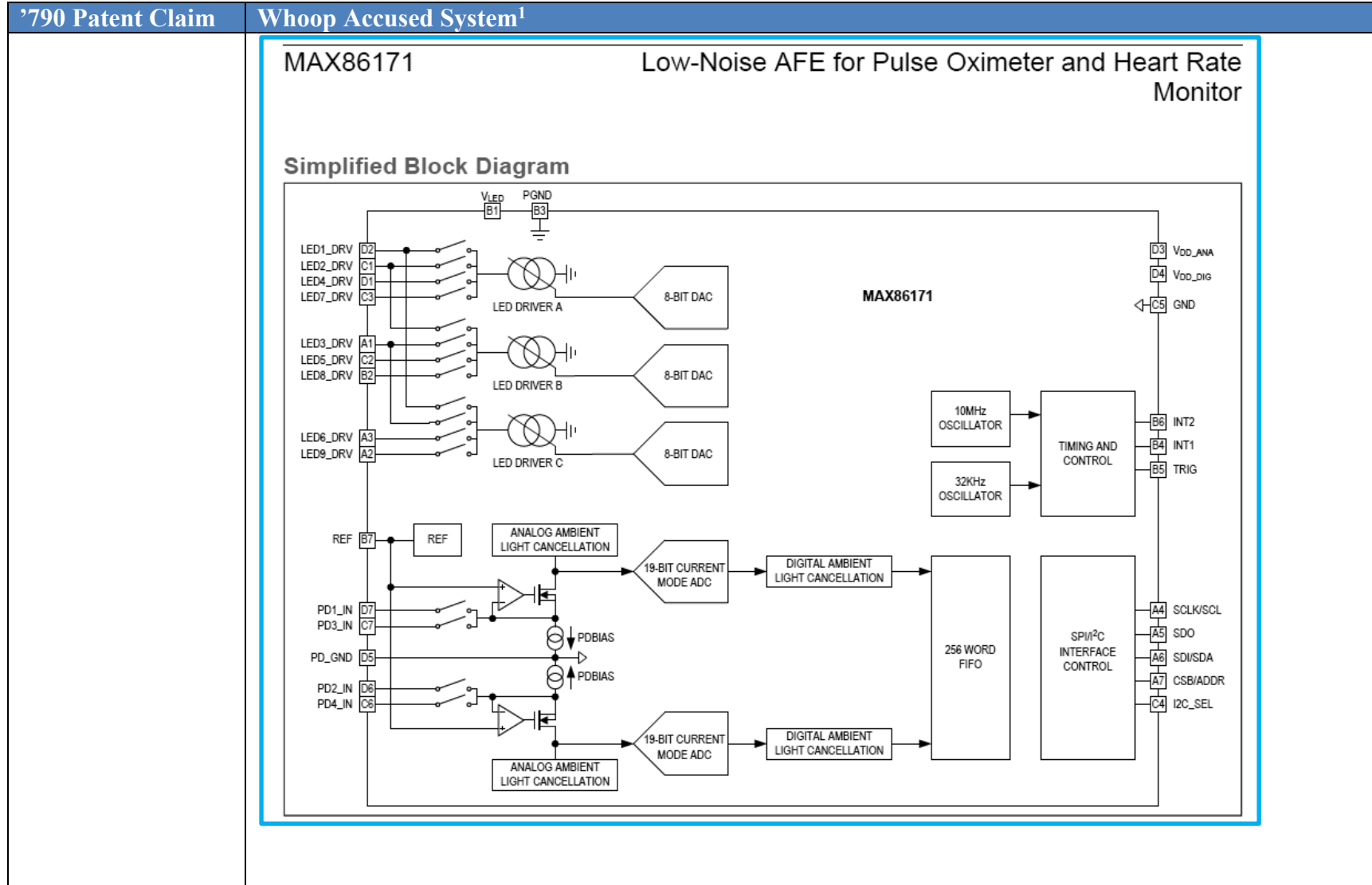
U.S. Patent No. 12,193,790 (the “’790 Patent”)

“Wearable devices comprising semiconductor diode light sources with improved signal-to-noise ratio”

'790 Patent Claim	Whoop Accused System ¹
	Applications • Wearable Devices for Fitness, Wellness, and Medical Applications • Clinical Accuracy • Suitable for Wrist, Finger, Ear, and Other Locations • Optimized Performance to Detect: • Optical Heart Rate • Heart-Rate Variability • Oxygen Saturation (SpO₂) • Body Hydration • Muscle and Tissue Oxygen Saturation (SmO₂ and StO₂) • Maximum Oxygen Consumption (VO₂ max)

U.S. Patent No. 12,193,790 (the “’790 Patent”)

“Wearable devices comprising semiconductor diode light sources with improved signal-to-noise ratio”



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Attorney Work Product*

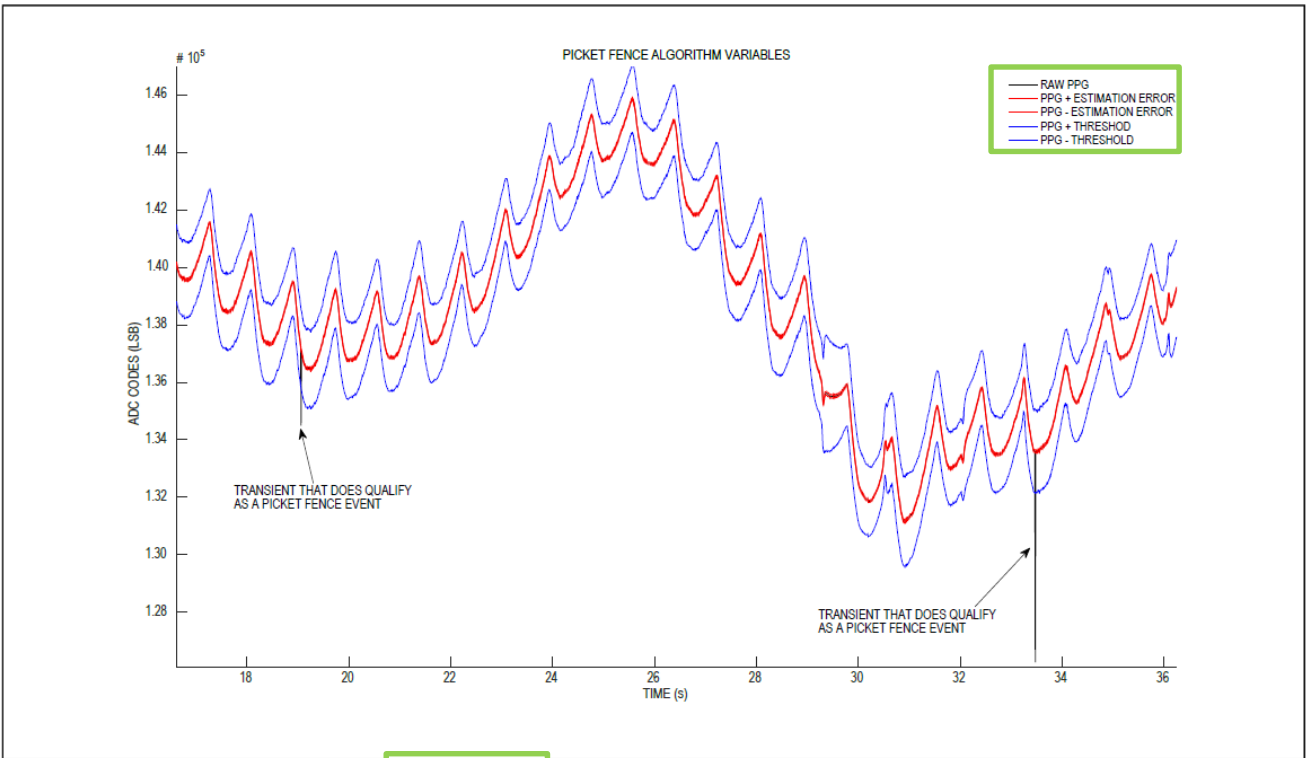
U.S. Patent No. 12,193,790 (the “’790 Patent”)

“Wearable devices comprising semiconductor diode light sources with improved signal-to-noise ratio”

'790 Patent Claim	Whoop Accused System ¹			
	Table 3. LED DRIVER FULL-SCALE RANGE TRADE-OFF			
	FULL-SCALE RANGE (mA)	LED DAC RESOLUTION LED CURRENT FOR 1 LSB (mV)	RECOMMENDED MINIMUM V _{LEDx_DRV} (mV)	PEAK LOOP-BACK SNR (dB)
	32	0.125	300	84
	64	0.250	500	88
	96	0.375	700	90
	128	0.500	900	91

U.S. Patent No. 12,193,790 (the “’790 Patent”)

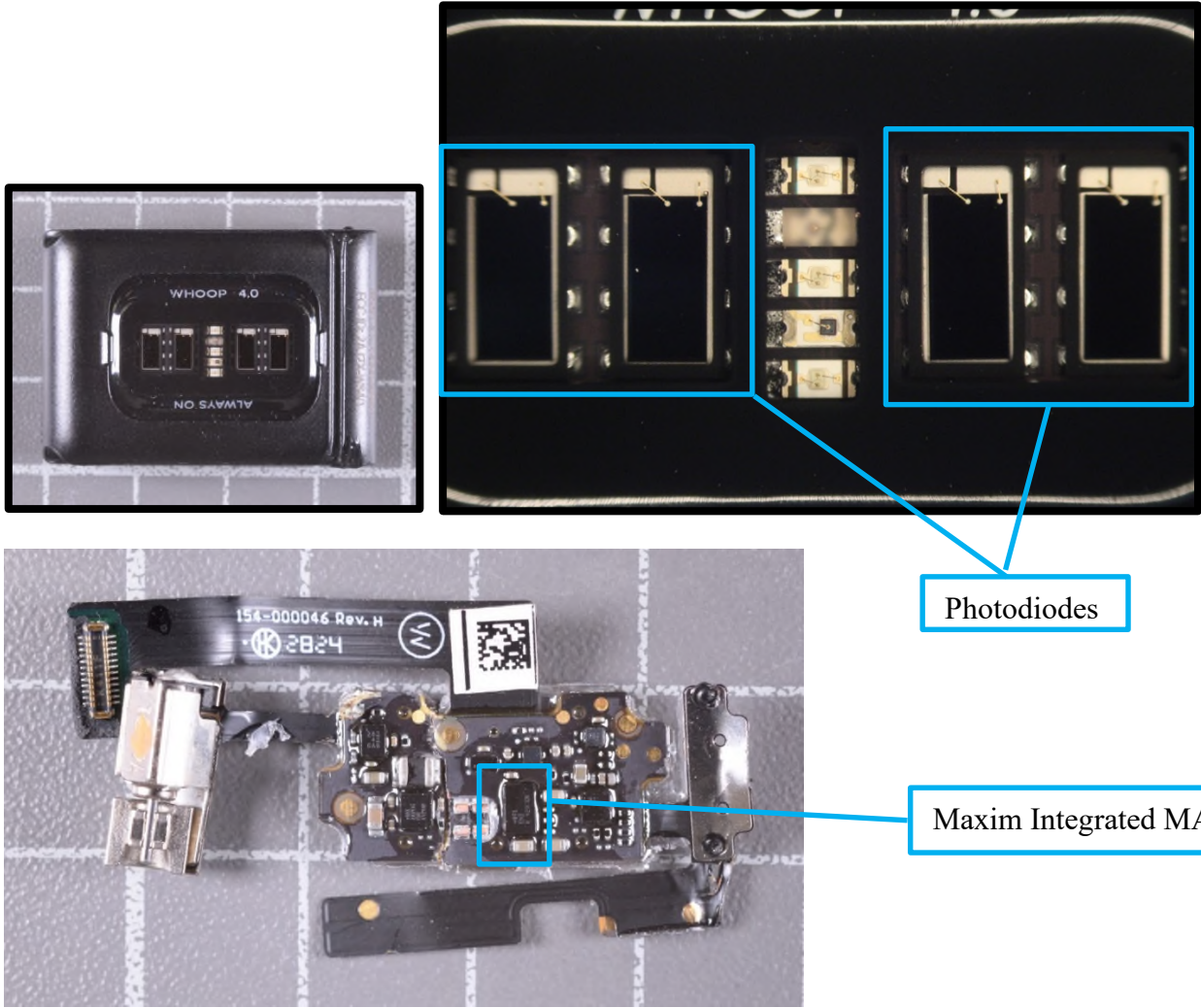
“Wearable devices comprising semiconductor diode light sources with improved signal-to-noise ratio”

’790 Patent Claim	Whoop Accused System ¹
	MAX86171 Low-Noise AFE for Pulse Oximeter and Heart Rate Monitor  Figure 10. Picket Fences Variables In A PPG Waveform Source: Analog Devices, “MAX86171: Low-Noise AFE for Pulse Oximeter and Heart Rate Monitor Data Sheet,” Rev.2, Mar. 24, 2022, at 1, 2, 16, 30, 32, available at https://www.analog.com/media/en/technical-documentation/data-sheets/MAX86171.pdf.

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“Wearable devices comprising semiconductor diode light sources with improved signal-to-noise ratio”

’790 Patent Claim	Whoop Accused System ¹
	 The image shows a product teardown of a WHOOP 4.0 device. It includes three photographs: a top-left view of the device's exterior with 'WHOOP 4.0' and 'ALWAYS ON' text; a top-right view of the internal sensor array with two blue boxes highlighting specific areas; and a bottom view of the printed circuit board (PCB) with a blue box highlighting a specific chip. Labels with leader lines point to 'Photodiodes' and 'Maxim Integrated MAX86171'. Photodiodes Maxim Integrated MAX86171 Source: Product Teardown (WHOOP 4.0)

U.S. Patent No. 12,193,790 (the “’790 Patent”)

“Wearable devices comprising semiconductor diode light sources with improved signal-to-noise ratio”

’790 Patent Claim	Whoop Accused System ¹
7[g] wherein the detection system is configured to be synchronized to the light source;	The detection system in the Accused Wearable Device is configured to be synchronized to the light source, either literally or under the doctrine of equivalents. For example, the integrated AFE optical sensor module (“detection system”) is connected to the light source containing multiple LEDs. It is configured to synchronize with the light source by controlling the LED current and pulse rate using LED drivers. To measure heart rate, for example, green LEDs are used with a pre-determined intensity and pulse rate. Different LEDs are used to measure other parameters, such as blood oxygen levels. Green LEDs (“light source”) blink when measuring heart rate, and alternately, red and infrared LEDs (“light source”) emit light when measuring blood oxygen levels. This, among other evidence below, shows that the AFE optical sensor module (“detection system”) is synchronized with the light source. The optical sensor in the Accused Wearable Device features a biosensing AFE manufactured by Analog Devices (e.g., MAX86171). That AFE optical sensor module (“detection system”) is configured to be synchronized to the LEDs in the Accused Wearable Device (e.g., using oscillator and timing and control elements).

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“Wearable devices comprising semiconductor diode light sources with improved signal-to-noise ratio”

'790 Patent Claim	Whoop Accused System ¹
	How WHOOP Measures Heart Rate WHOOP measures heart rate using advanced optical sensors with photoplethysmography (PPG) technology. It works by emitting green LED light into the skin, and then measuring the light that's reflected back. Every time your heart beats, the blood flow increases, and this causes the amount of light that's reflected back to change. WHOOP takes this raw data from the sensors and interprets it through an algorithm to produce a heart rate reading. While raw data is captured using the sensor hardware, an algorithm is required to estimate heart rate. The WHOOP heart rate algorithm is a complex set of mathematical formulas and computational processes used to interpret the raw data collected by the sensors. The algorithm filters out factors like movement artifacts that occur when you're in motion to accurately determine your heart rate. It also adjusts for factors like skin tone, age, and activity type, to ensure accurate measurements across different conditions and members. Source: https://www.whoop.com/us/en/thelocker/a-look-behind-the-data-how-whoop-measures-heart-rate/.

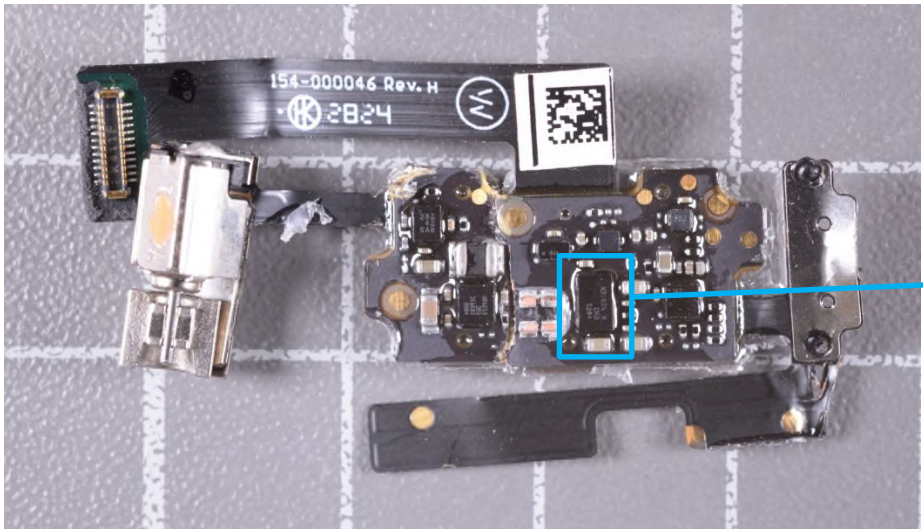
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’790 Patent Claim	Whoop Accused System ¹
	How Does WHOOP Track Blood Oxygen? With a new <u>sensor configuration that includes 5 LEDs and 4 photodiodes</u> the WHOOP 4.0 is now equipped to accurately monitor blood oxygen levels with pulse oximetry. Although most common pulse oximeters track your blood oxygen from your finger, WHOOP implements the same technology to calculate SpO2 on your wrist. Here’s how it works: • The <u>LEDs shine two different wavelengths of light</u> through the surface of your skin to your blood vessels • The light is reflected back to the photodiodes, with <u>one wavelength being absorbed better by oxygenated hemoglobin and the other absorbed better by non-oxygenated hemoglobin</u> • The relative amounts of light that get absorbed can be used to determine how much oxygen is in your blood, and that percentage represents your SpO2 level Source: <a data-bbox="604 954 1570 987" href="https://www.whoop.com/us/en/thelocker/metric-blood-oxygen-monitoring/">https://www.whoop.com/us/en/thelocker/metric-blood-oxygen-monitoring/.

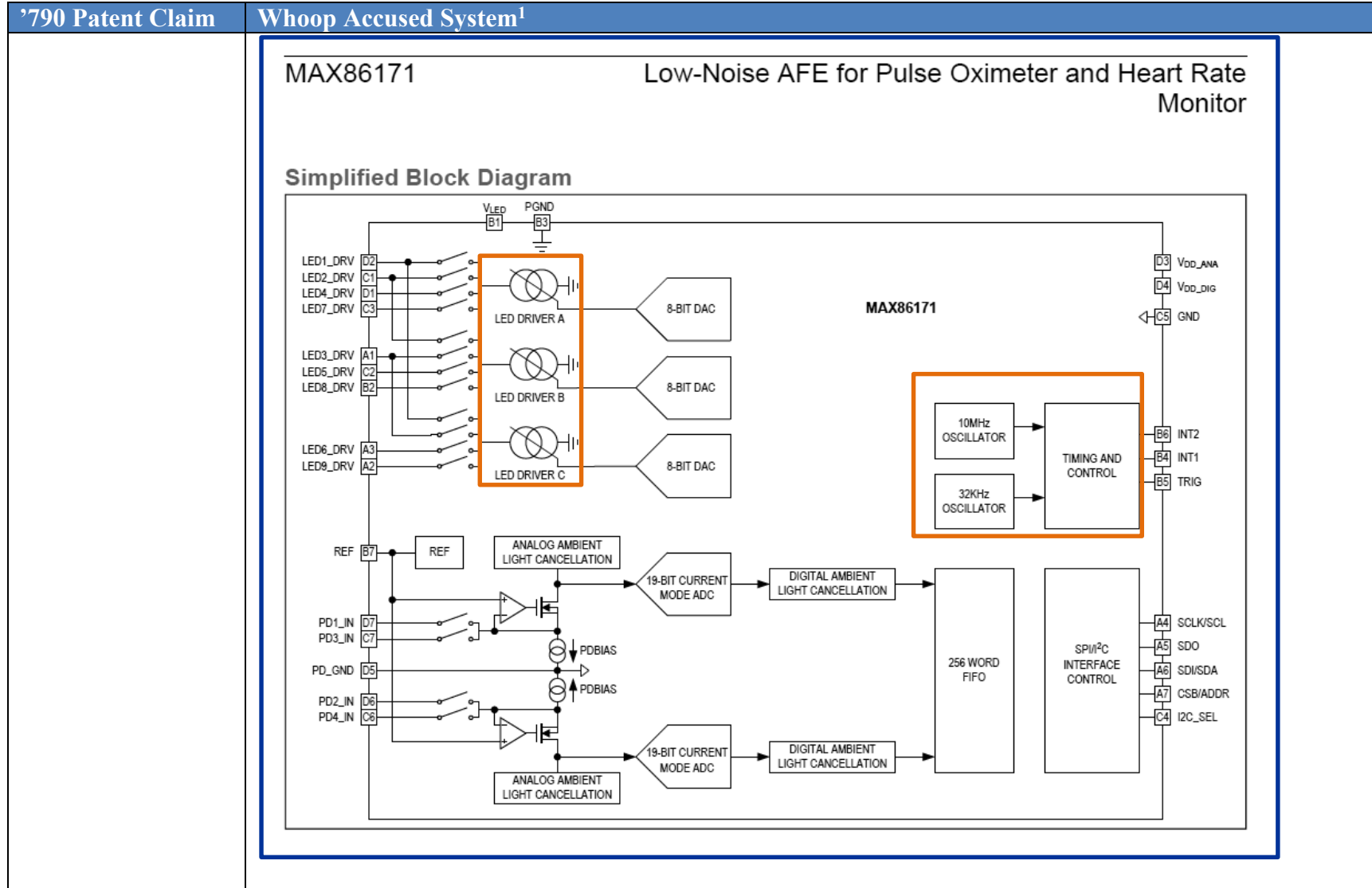
U.S. Patent No. 12,193,790 (the “’790 Patent”)

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’790 Patent Claim	Whoop Accused System ¹
	 Deep Dive Teardown of the Whoop Inc. Whoop 4.0 WS40; WB40 Fitness Tracker Maxim had the overall design wins for the Whoop 4.0, with four major designs. For this device, Maxim provided the ARM cortex-M4 with FPU-based microcontroller(MAX32652),the power management(MAX77818), <u>the pulse oximeter/heart rate sensor (MAX86171)</u>,and the digital temperature sensor(MAX6631MTT). Contact Us Product Code: DDT-2111-806 Release Date: 26/01/2022 Availability: Published Product Item Code: WPH-WS40 Device Manufacturer: Whoop Device Type: Fitness Monitor Source: https://www.techinsights.com/products/ddt-2111-806.  Maxim Integrated MAX86171 Source: Product Teardown (WHOOOP 4.0)

U.S. Patent No. 12,193,790 (the “’790 Patent”)

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“Wearable devices comprising semiconductor diode light sources with improved signal-to-noise ratio”

’790 Patent Claim	Whoop Accused System ¹
	The MAX86171 incorporates dual optical readout channels that operate simultaneously. The MAX86171 has three LED drivers. With the built-in MUX and control logic on the chip, the MAX86171 can support up to Nine LEDs and Four PDs. It is well suited for a wide variety of optical sensing applications. The MAX86171 operates on a 1.8V main supply voltage, with a separate 3.1V to 5.5V LED driver power supply. This device has flexible exposure, timing, and shutdown configurations as well as control of individual blocks so that an optimized measurement can be made at minimum power levels. Synchronization Modes The MAX86171 supports three modes of frame rate controls. These are internally timed frame rates through an internal oscillator and divider, externally timed frame rates through an external frame trigger input, and externally timed frame rates through an external frame timing clock and the internal frame clock divider. Measurement Configuration and Timing The MAX86171 optical controller is capable of being configured to make a variety of measurements. The controller can be configured to pulse one, two or three LED drivers sequentially to make measurements at multiple wavelengths as is done in pulse oximetry measurements or simultaneously to drive multiple LEDs as is done with heart rate measurements on the wrist. Each LED exposure is ambient light compensated. The controller is also configurable to measure the direct ambient level for every exposure. The direct ambient measurement can be used to adjust the LED-drive level to compensate for increased noise levels when high interfering ambient signals are present. Frame: Frame is a collection of measurements that can have a minimum of 1 measurement and a maximum of 9 measurements. Frame Rate: This is similar to sampling rate of a system. Frame rate defines how frequently a frame is repeated. The optical timing diagrams in Figure 2, Figure 3, Figure 4, Figure 5, and Figure 6 illustrate several possible measurement configurations. Source: Analog Devices, “MAX86171: Low-Noise AFE for Pulse Oximeter and Heart Rate Monitor Data Sheet,” Rev.2, Mar. 24, 2022, at 2, 15, 17-21, available at https://www.analog.com/media/en/technical-documentation/data-sheets/MAX86171.pdf.

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“Wearable devices comprising semiconductor diode light sources with improved signal-to-noise ratio”

’790 Patent Claim	Whoop Accused System ¹
	 Source: https://www.youtube.com/watch?v=rlEsoMy-l4w. Patent documents assigned to and/or owned by Whoop and Analog Devices further detail how the detection system is configured to be synchronized to the light source. For example:

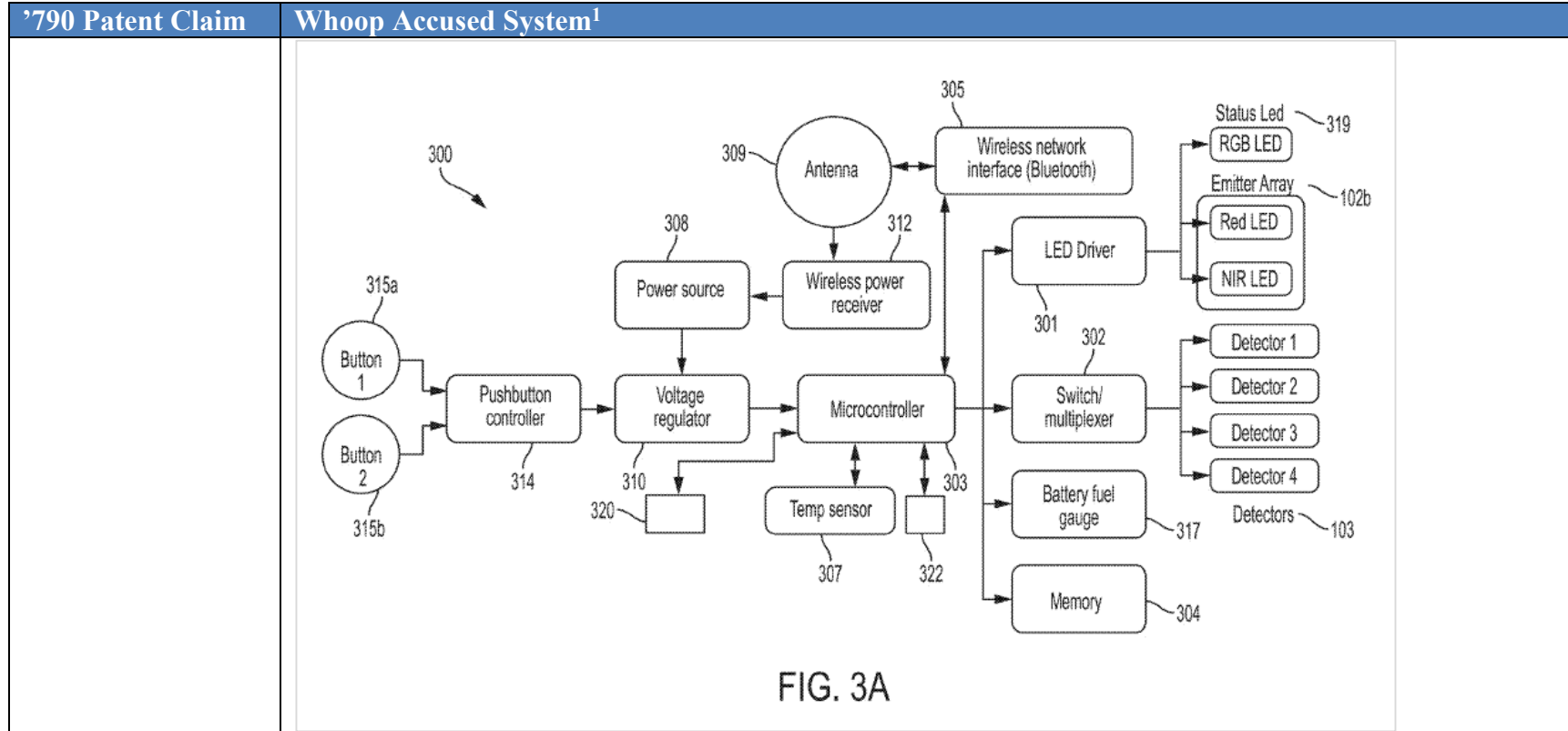
U.S. Patent No. 12,193,790 (the “’790 Patent”)

“Wearable devices comprising semiconductor diode light sources with improved signal-to-noise ratio”

’790 Patent Claim	Whoop Accused System ¹
	(12) United States Patent Wiese et al. (10) Patent No.: US 10,799,162 B2 (45) Date of Patent: *Oct. 13, 2020 (54) TISSUE OXYGEN SATURATION DETECTION AND RELATED APPARATUS AND METHODS (58) Field of Classification Search CPC A61B 5/1455; A61B 5/00; A61B 5/0024; A61B 5/0095; A61B 5/14; A61B 5/145; A61B 5/1477 See application file for complete search history. (71) Applicant: Whoop, Inc., Boston, MA (US) (72) Inventors: Daniel Wiese, Cambridge, MA (US); Alessandro Babini, Cambridge, MA (US); Sebastian Trousil, Boston, MA (US); Samuel Huberman, Somerville, MA (US); Stefan Kalchmair, Boston, MA (US); Pamela G. Anderson, Boston, MA (US) (73) Assignee: Whoop, Inc., Boston, MA (US) (56) References Cited U.S. PATENT DOCUMENTS 6,587,703 B2 7/2003 Cheng et al. 6,678,541 B1 1/2004 Durkin (Continued) (57) ABSTRACT A wearable optical device is described for optically detecting parameters of interest within muscle, such as during physical activity or when at rest. The parameters of interest include oxygenation level and/or hemoglobin concentrations in some situations. The detected parameters, such as oxygenation level, may be used to assess physical performance, such as the extent to which the muscle is utilizing aerobic or anaerobic processes. Methods for determining the parameters of interest, such as oxygenation level, from the detected optical signals are also described, and feedback may be provided to a user.

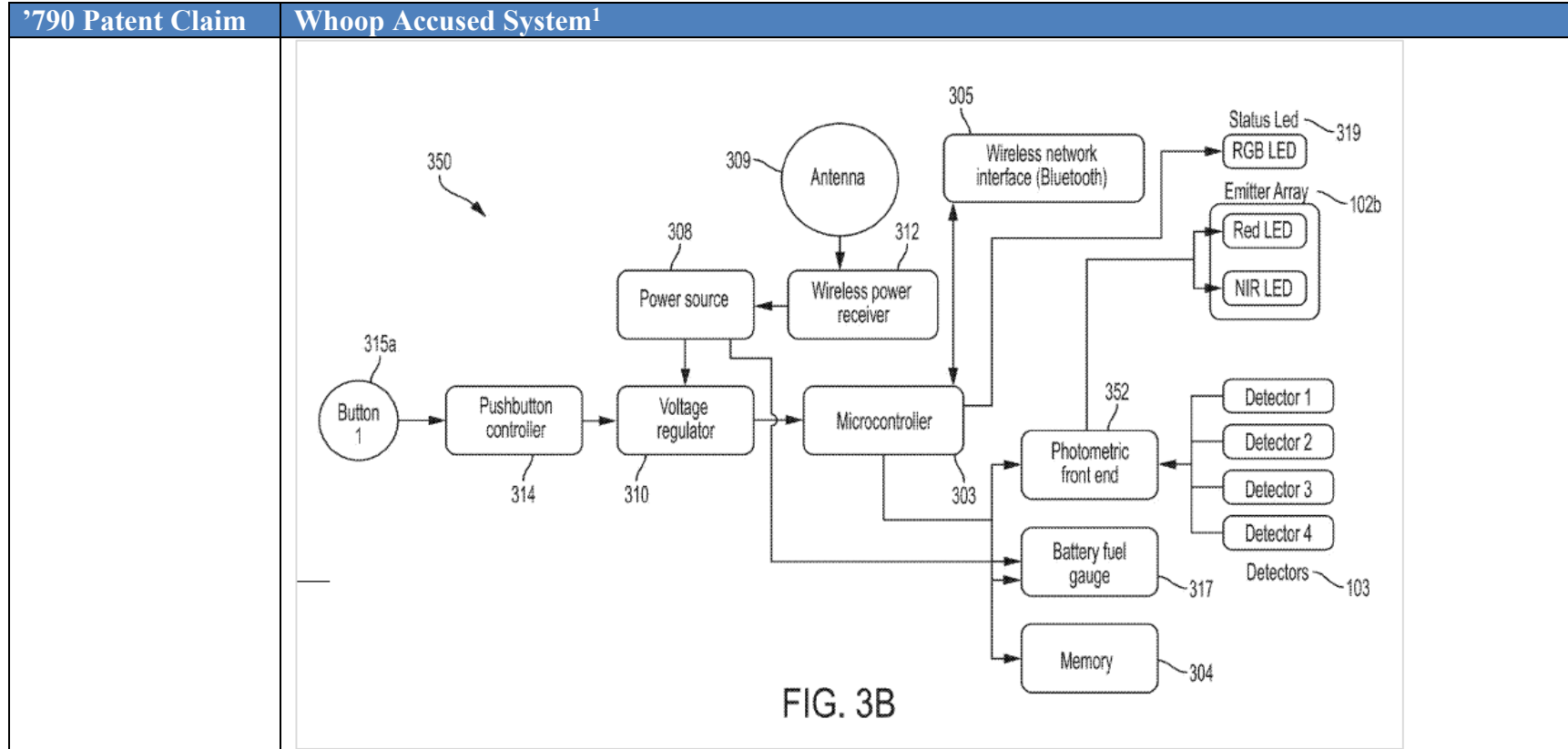
U.S. Patent No. 12,193,790 (the “’790 Patent”)

“Wearable devices comprising semiconductor diode light sources with improved signal-to-noise ratio”



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’790 Patent Claim	Whoop Accused System ¹
	9 “counts”. In some embodiments, the detectors may convert a total light signal intensity across all wavelengths into counts. As an example, the detectors may be photodiodes. The detectors may be integrating photodetectors with onboard analog-to-digital conversion, although alternatives 5 are possible. In another non-limiting example, the detectors may be TSL2591 light-to-digital converters. The detectors may be sampled at a frequency suitable to mitigate the effects of muscle movement. For example, the detectors may be sampled at a frequency less than 10 Hz, less than 5 Hz, 10 less than 3 Hz, less than 2 Hz, or at any sampling rate within such ranges. In an alternative embodiment, the detectors may be silicon photodiodes, with analog to digital conversion accomplished using a photometric front end with analog-to-digital converter to convert current measured from 15 the photodiode into counts. In one non-limiting example, the photometric front end may be Analog Devices ADPD103, available from Analog Devices, Inc. of Norwood, Mass. In this example the photodetectors may be sampled at 4000 Hz, 1000 Hz, 100 Hz, 0.1 Hz, less than 4000 Hz, less than 100 20 Hz or any sampling rate within such ranges. In another non-limiting example, the photodiodes may be Everlight PD15-22C/TR8, available from Everlight America, Inc. of Carrollton, Tex.

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’790 Patent Claim	Whoop Accused System ¹
	20 In some embodiments, the optical detectors are arranged and configured electronically to be operated synchronously with the emitters. An example of a device which may be used for such operation is the ADPD103 photometric front end, listed above. In some embodiments, synchronously 25 operating the emitters and detectors of a photometric front end or other optical device involves aligning the integration (time) windows with the emitter (time) windows for accu- rate measurement of the optical signal. In some embodi- ments, emitters and detectors may be operated synchro- 30 nously with the emitter windows and integration windows not precisely aligned, and the measured values may be mapped to the true values. Misalignment of the integration windows and emitter windows of a photometric front end or Source: US 10,799,162 at Abstract, FIGS. 3A-3B, 8:63-9:24, 10:19-52; <i>see also</i> US 10,092,228 B2 at Abstract, 10:15-27. (19) United States (12) Reissued Patent Deliwala et al. (10) Patent Number: US RE48,996 E (45) Date of Reissued Patent: Mar. 29, 2022 (54) CIRCUIT ARCHITECTURE FOR MODE SWITCH (71) Applicant: Analog Devices, Inc., Norwood, MA (US) (72) Inventors: Shrenik Deliwala, Andover, MA (US); Steven J. Decker, Sandown, NH (US); Gregory T. Koker, Newton, MA (US); Dan M. Weinberg, Westford, MA (US) (73) Assignee: Analog Devices, Inc., Norwood, MA (US) (56) References Cited U.S. PATENT DOCUMENTS 5,684,294 A 11/1997 Kouhi 5,739,652 A 4/1998 Sriram (Continued) FOREIGN PATENT DOCUMENTS DE 10-2014-105398 10/2014 KR 11-506544 6/1999 (Continued)

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'790 Patent Claim	Whoop Accused System ¹
	(57) ABSTRACT A current detection module capable of differentiating and quantifying contribution to a current signal generated by a sensor in response to stimulation by a certain target source from contributions from sources other than the target source (ambient sources) is disclosed. As long as the contribution from the target source comprises a pulsed signal, the module may synchronize itself to the pulse(s) so that there is a predetermined phase relationship between the pulse(s) and functions carried out by various stages of the module. The module may be re-used to also detect and quantify contributions from ambient sources by presenting these contributions to the module as pulses that trigger synchronization of the module. To that end, a detection system disclosed herein is based on the use of such current detection module and allows mode switching where, depending on the selected mode of operation, the module is configured to perform different measurements. 5 Overview Present disclosure relates to a current detection module capable of differentiating and quantifying contribution to a current signal generated by a sensor as a result of stimulation by a certain source of interest (target source) from contributions from sources other than the source of interest (ambient sources). As long as the contribution from the target source comprises a pulsed signal, the module synchronizes itself to the pulse(s) so that there is a predetermined phase relationship between the pulse(s) and functions carried out by various stages of the module. The module may 10 15

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'790 Patent Claim	Whoop Accused System ¹
	25 30 35 40 45 50 55 60 DESCRIPTION OF EXAMPLE EMBODIMENTS OF THE DISCLOSURE Exemplary Current Detection Module Embodiments of the present disclosure are based on the use of a current detection module capable of differentiating and quantifying (i.e. measuring) the contribution to the current signal generated by a certain source of interest from contributions from sources other than the predefined source of interest, i.e. ambient sources. As long as the contribution to the current signal from the predefined source comprises a pulsed signal (referred to in the following as “pulse(s) of interest”), the current detection module is configured to synchronize itself to the pulse(s) so that there is a predetermined phase relationship between the pulse(s) and functions carried out by various stages of the current detection module (referred to in the following as a “receiver circuit”). The pulsed signal of the source of interest may include one pulse or multiple pulses, where a pulse may include one or more frequency components. Ambient sources may also contain multiple frequency components, possibly even the same components as those of the pulse of the predefined source of interest. Because the frequencies present in the pulse(s) of interest are synchronized to the receiver circuit (i.e. synchronized to the clock of the current detection module), there is a certain known phase relationship between the current detection module and each of the frequency components of the pulse of interest (which phase relationship could be different for different frequencies in the pulse of interest, but nevertheless known ahead of time). The current detection module is designed to detect pulses synchronously and in a way that requires precise phase relationship between the receiver circuit and the source of interest. While the ambient sources may contain the same frequency com- Source: US RE48,966 at Abstract, 2:5-16, 4:26-60.

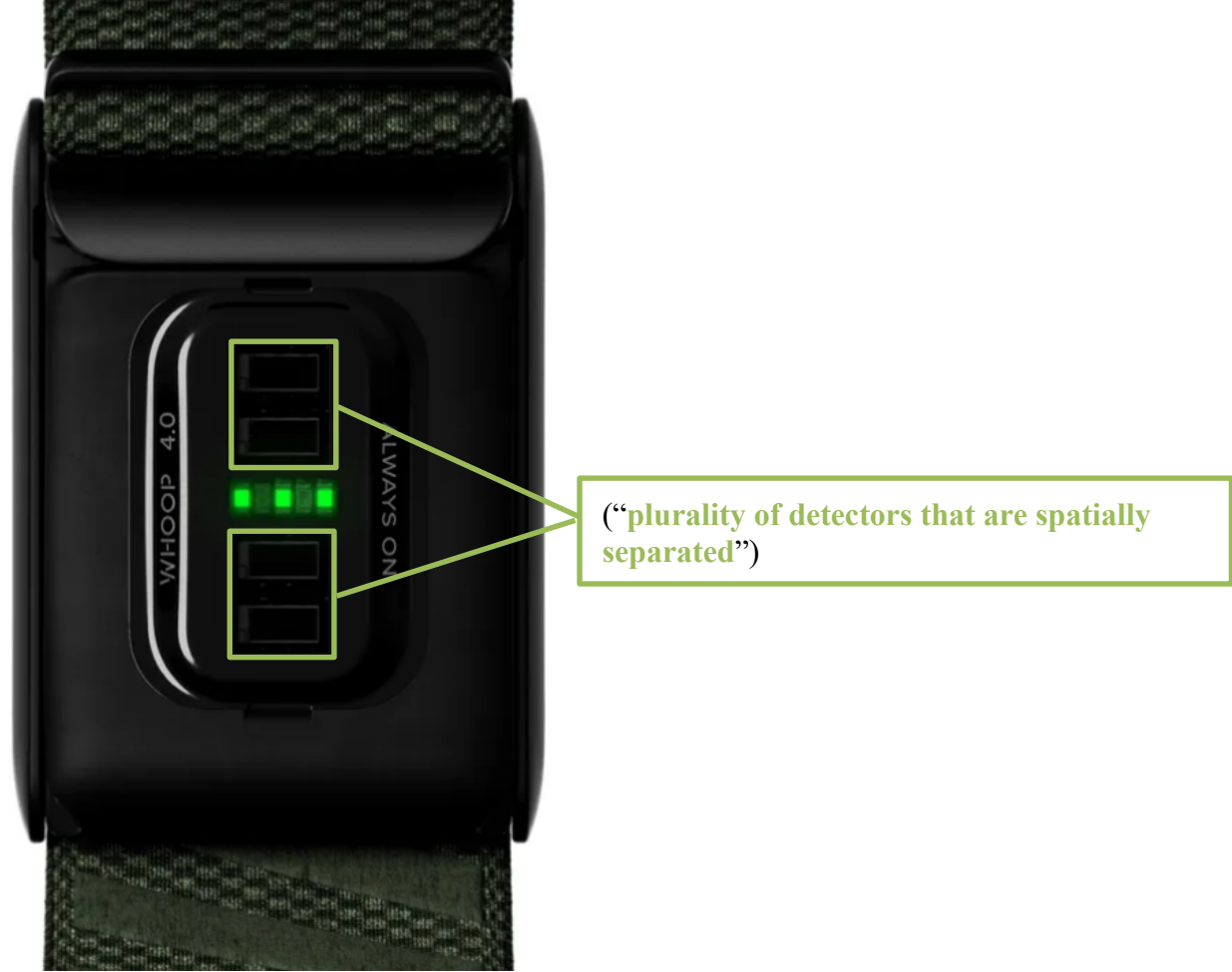
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’790 Patent Claim	Whoop Accused System ¹
<u>7[h]</u> wherein the detection system comprises a plurality of detectors that are spatially separated from each other, and	The detection system in the Accused Wearable Device comprises a plurality of detectors that are spatially separated from each other, either literally or under the doctrine of equivalents. For example, the AFE optical sensor module (“detection system”) in the Accused Wearable Device comprises multiple spatially separated photodiodes/PDs (“plurality of detectors that are spatially separated from each other”). “We engineered a device with superior accuracy and durability instead of superficial bells and whistles. The minimalist, screen-free design means every detail is intentional—like the 5 LEDs and 4 photodiodes that capture your data more often and with more precision than most wearables. And, you never have to take it off to charge—making WHOOP the most wearable in the game.” https://www.whoop.com/us/en/difference/. THE WHOOP 4.0 SENSOR HAS 5 LEDS (3 green, 1 red, 1 infrared) AND 4 PHOTODIODES. New Sensor and Improved Heart Rate Accuracy Measuring a member’s physiology continuously, 24/7, with high accuracy and reliability is the top priority of our world-class signal processing team. With the WHOOP 4.0, we revisited our sensor configuration to further increase the signal quality and open the doors to more complicated signal processing techniques. This enabled us to elevate and refine our ability to measure a member’s heart rate and heart rate variability. As one can see from the sensor, there are marked differences from the 3.0 to the 4.0—namely the inclusion of 4 photodiodes, or light sensors, (compared to 1 in the 3.0), 3 green LEDs (vs 2 in the 3.0) and the addition of both an infrared and red LED. Additionally, the arrangement of the sensors and emitters has also changed. These modifications are not random,

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'790 Patent Claim	Whoop Accused System ¹
	 Source: https://www.whoop.com/us/en/thelocker/chief-technology-officer-whoop-4-0-accuracy/.

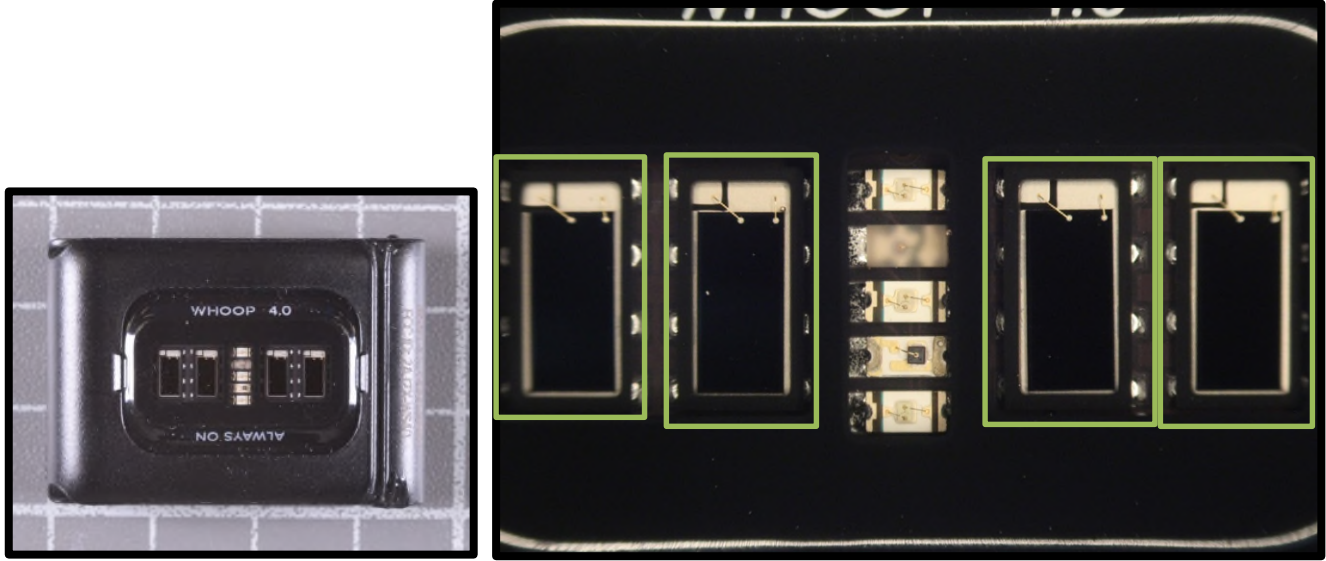
U.S. Patent No. 12,193,790 (the “’790 Patent”)

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’790 Patent Claim	Whoop Accused System ¹
	 4 photodiodes (“detectors that are spatially separated”) Source: https://www.youtube.com/watch?v=rIEsoMy-l4w.

U.S. Patent No. 12,193,790 (the “’790 Patent”)

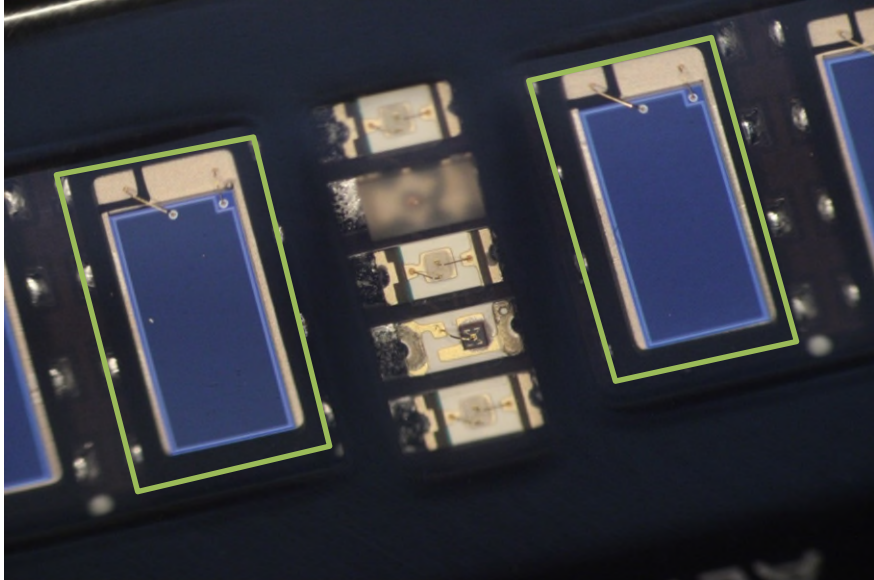
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’790 Patent Claim	Whoop Accused System ¹
	

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’790 Patent Claim	Whoop Accused System ¹
	 Source: Product Teardown (WHOOP 4.0)
7(ii) wherein at least one analog to digital converter is coupled to at least one of the plurality of detectors;	In the Accused Wearable Device, there is at least one analog to digital converter that is coupled to at least one of the plurality of detectors, either literally or under the doctrine of equivalents. For example, there is at least one analog to digital converter (“ADC”) coupled to at least one of the photodiodes/PDs (“detectors”) of the AFE optical sensor module.

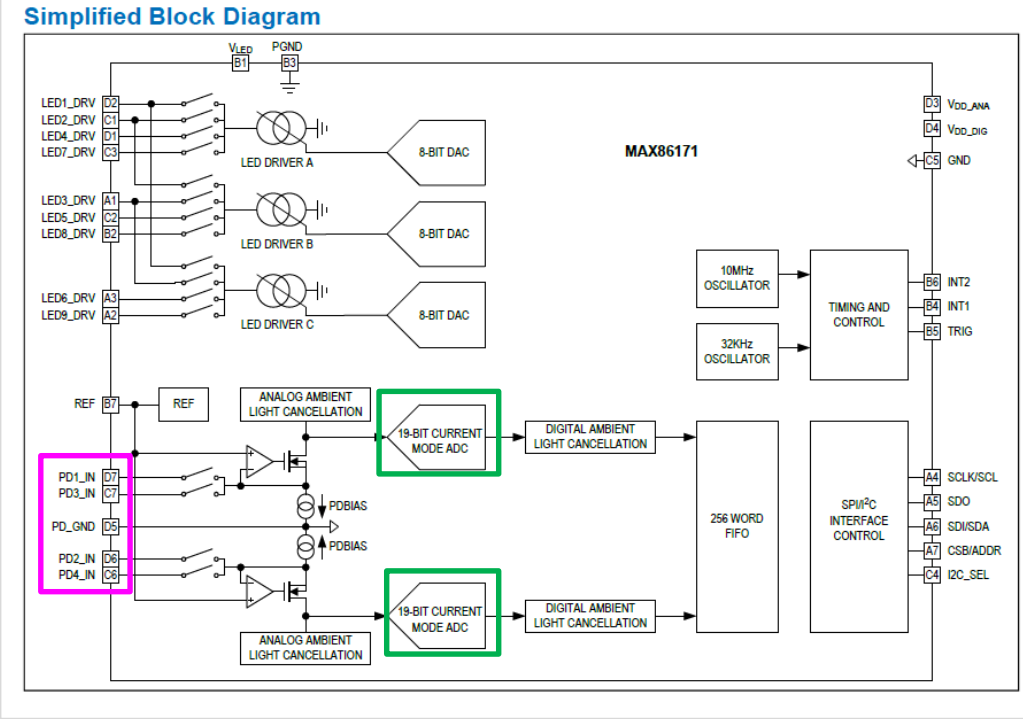
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’790 Patent Claim	Whoop Accused System ¹
	 Click here to ask an associate for production status of specific part numbers. MAX86171 Low-Noise AFE for Pulse Oximeter and Heart Rate Monitor General Description The MAX86171 is an ultra-low-power optical data acquisition system with both transmit and receive channels. On the transmitter side, the MAX86171 has nine LED driver output pins, programmable from three high-current, 8-bit LED drivers. On the receiver side, MAX86171 has two low-noise charge integrating front-ends that each include independent 19.5 bit ADCs and best-in-class ambient light cancellation (ALC) circuits, producing the highest performing integrated optical data acquisition system on the market today. Benefits and Features • Complete Dual-Channel Optical Data Acquisition System • Ultra Low-Power Operation for Wearable Devices • Low-Power Operation, Optical Readout Channel < 11µA at 25 fps • Exposure Integration Period Ranging from 14.6µs to 117.1µs • Low Shutdown Current < 1µA • Excellent Top-End Dynamic Range > 91dB in White Card Loop-Back Test (Nyquist Sample-to-Sample Variance) • Extended Dynamic Range up to 110dB (Averaging and Off-Chip Filtering) • Supports Frame Rates from 1fps to 2.9kfps • High Resolution 19.5-Bit Charge Integrating ADCs • Supports Four PD Inputs for Multi-Parameter

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'790 Patent Claim	Whoop Accused System ¹
	MAX86171 Low-Noise AFE for Pulse Oximeter and Heart Rate Monitor Simplified Block Diagram  Optical Receiver Overview The optical path in MAX86171 is composed of a front-end photodiode biasing circuit with an analog ambient light cancellation (ALC) sample and hold circuit that nulls the ambient light photodiode current at the input of the ADC. This front-end biasing circuit is followed by a current integrating, continuous-time sigma-delta ADC with a proprietary discrete time filter. This discrete time filter uses multiple dark and exposure optical samples to generate an accurate 20-bit effective exposure output signal with excellent low- and high-frequency ambient light rejection.

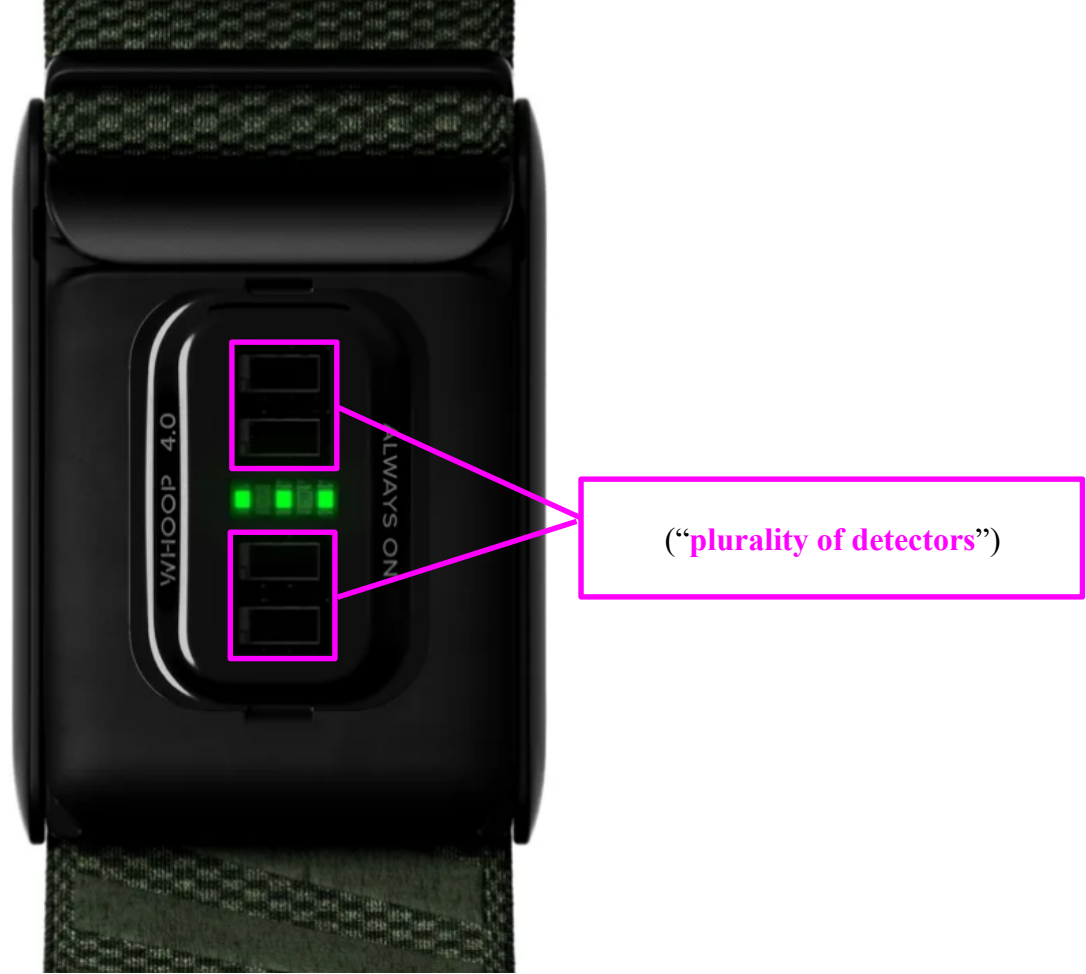
U.S. Patent No. 12,193,790 (the “’790 Patent”)

“Wearable devices comprising semiconductor diode light sources with improved signal-to-noise ratio”

’790 Patent Claim	Whoop Accused System ¹
	Source: Analog Devices, “MAX86171: Low-Noise AFE for Pulse Oximeter and Heart Rate Monitor Data Sheet,” Rev.2, Mar. 24, 2022, at 1-2, 16, <i>available at</i> https://www.analog.com/media/en/technical-documentation/data-sheets/MAX86171.pdf. “We engineered a device with superior accuracy and durability instead of superficial bells and whistles. The minimalist, screen-free design means every detail is intentional—like the 5 LEDs and 4 photodiodes that capture your data more often and with more precision than most wearables. And, you never have to take it off to charge—making WHOOP the most wearable in the game.” https://www.whoop.com/us/en/difference/. THE WHOOP 4.0 SENSOR HAS 5 LEDS (3 green, 1 red, 1 infrared) AND 4 PHOTODIODES. New Sensor and Improved Heart Rate Accuracy Measuring a member’s physiology continuously, 24/7, with high accuracy and reliability is the top priority of our world-class signal processing team. With the WHOOP 4.0, we revisited our sensor configuration to further increase the signal quality and open the doors to more complicated signal processing techniques. This enabled us to elevate and refine our ability to measure a member’s heart rate and heart rate variability. As one can see from the sensor, there are marked differences from the 3.0 to the 4.0—namely the inclusion of 4 photodiodes, or light sensors, (compared to 1 in the 3.0), 3 green LEDs (vs 2 in the 3.0) and the addition of both an infrared and red LED. Additionally, the arrangement of the sensors and emitters has also changed. These modifications are not random,

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	 Source: https://www.whoop.com/us/en/thelocker/chief-technology-officer-whoop-4-0-accuracy/.

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<u>7ii</u> wherein the output signal is indicative of the one or more of the physiological parameters;	The Accused Wearable Device generates an output signal that is indicative of the one or more of the physiological parameters, either literally or under the doctrine of equivalents. For example, the PPG signal (“output signal”) generated by the Accused Wearable Device indicates, among other things, heart rate and blood oxygen levels of the user (“one or more of the physiological parameters”).

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	How WHOOP Measures Heart Rate WHOOP measures heart rate using advanced optical sensors with <u>photoplethysmography (PPG) technology</u>. It works by emitting green LED light into the skin, and then measuring the light that’s reflected back. Every time your heart beats, the blood flow increases, and this causes the amount of light that’s reflected back to change. WHOOP takes this raw data from the sensors and interprets it through an algorithm to produce a heart rate reading. While raw data is captured using the sensor hardware, an algorithm is required to estimate heart rate. The WHOOP heart rate algorithm is a complex set of mathematical formulas and computational processes used to interpret the raw data collected by the sensors. The algorithm filters out factors like movement artifacts that occur when you’re in motion to accurately determine your heart rate. It also adjusts for factors like skin tone, age, and activity type, to ensure accurate measurements across different conditions and members. WHOOP recently released an update to the heart rate algorithm that improves accuracy. The update is a culmination of thousands of lines of code and millions of data points. This update is another step in a continuous journey towards a best-in-class WHOOP experience. Improvements to the heart rate algorithm drive enhanced accuracy across the entire WHOOP experience, knowing heart rate informs many key metrics and recommendations. Source: https://www.whoop.com/us/en/thelocker/a-look-behind-the-data-how-whoop-measures-heart-rate/.

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	The new WHOOP 4.0 includes pulse oximetry, which enables you to check your daily blood oxygen levels. How Does WHOOP Track Blood Oxygen? With a new sensor configuration that includes 5 LEDs and 4 photodiodes, the WHOOP 4.0 is now equipped to accurately monitor blood oxygen levels with pulse oximetry. Although most common pulse oximeters track your blood oxygen from your finger, WHOOP implements the same technology to calculate SpO2 on your wrist. Here’s how it works: • The LEDs shine two different wavelengths of light through the surface of your skin to your blood vessels • The light is reflected back to the photodiodes, with one wavelength being absorbed better by oxygenated hemoglobin and the other absorbed better by non-oxygenated hemoglobin • The relative amounts of light that get absorbed can be used to determine how much oxygen is in your blood, and that percentage represents your SpO2 level

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	Source: https://www.whoop.com/us/en/thelocker/metric-blood-oxygen-monitoring/. Know Your Heart Rate Zones in Real Time with WHOOP WHOOP measures your heart rate 24/7 and quantifies the strain your body takes on each day. Every morning, our <u>recovery metric</u> (calculated using <u>heart rate variability</u>, <u>resting heart rate</u>, <u>respiratory rate</u> and sleep) tells you how prepared your body is to take on strain. And when you track your activities with WHOOP and your Strain Target, you can see in real time which heart rate zone you're in, so you'll know exactly when to dial it back, or kick it up a notch. You can also retroactively view the time you spent in each heart rate zone by tapping into your Activity. WHOOP will show you a detailed breakdown of time in each zone so you can further optimize your training.

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'790 Patent Claim	Whoop Accused System ¹
	 Source: https://www.whoop.com/us/en/thelocker/max-heart-rate-training-zones/.

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	3. PERSONAL DATA WE COLLECT We may collect the following types of Personal Data: • Contact details, such as your first and last name, email and mailing address, and phone number; • Profile data, such as username and password that you may establish to create a WHOOP account, as well as any photographs or information you choose to include in your WHOOP profile; • Communications that we exchange with you, including when you contact us via email, web app, or mobile app with questions, feedback, or reviews; • Wellness Data, such as resting heart rate, heart rate variability, skin temperature, blood oxygen saturation level and acceleration; metadata on workouts and sleep; the type of physical activity you engage in and the duration of your activity; data reflecting strain and recovery; your physiological profile, including birthday, gender identity, weight, height, fitness/athlete level (e.g., professional or recreational); and details you choose to submit about your diet, medications, and female health tracking. We may use certain of this information to customize your experience with us as part of our Services; Source: https://www.whoop.com/us/en/full-privacy-policy/.

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	 MAX86171 Click here to ask an associate for production status of specific part numbers. Low-Noise AFE for Pulse Oximeter and Heart Rate Monitor General Description The MAX86171 is an ultra-low-power optical data acquisition system with both transmit and receive channels. On the transmitter side, the MAX86171 has nine LED driver output pins, programmable from three high-current, 8-bit LED drivers. On the receiver side, MAX86171 has two low-noise charge integrating front-ends that each include independent 19.5 bit ADCs and best-in-class ambient light cancellation (ALC) circuits, producing the highest performing integrated optical data acquisition system on the market today. Due to its low power consumption, compact size, ease and flexibility of use, the MAX86171 is ideal for a wide variety of optical sensing applications such as pulse-oximetry and heart-rate detection. Applications • Wearable Devices for Fitness, Wellness, and Medical Applications • Clinical Accuracy • Suitable for Wrist, Finger, Ear, and Other Locations • Optimized Performance to Detect: • Optical Heart Rate • Heart-Rate Variability • Oxygen Saturation (SpO₂) • Body Hydration • Muscle and Tissue Oxygen Saturation (SmO₂ and StO₂) • Maximum Oxygen Consumption (VO₂ max) Source: Analog Devices, “MAX86171: Low-Noise AFE for Pulse Oximeter and Heart Rate Monitor Data Sheet,” Rev.2, Mar. 24, 2022, at 1, available at https://www.analog.com/media/en/technical-documentation/data-sheets/MAX86171.pdf. See also WHOOP, “What WHOOP measures,” https://www.whoop.com/us/en/the-data/. See also WHOOP, “WHOOP Health Monitor & Report,” Aug. 7, 2024, https://support.whoop.com/s/article/WHOOP-Health-Monitor-Report?language=en_US.

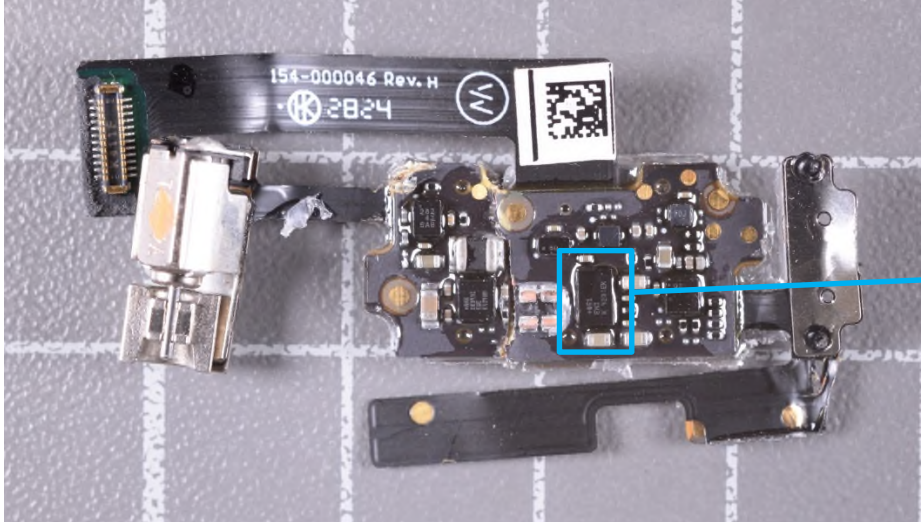
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7 k the wearable device configured to increase the signal-to-noise ratio by increasing light intensity of at least one of the plurality of semiconductor diodes from an initial light intensity; and	The Accused Wearable Device is configured to increase the signal-to-noise ratio by increasing light intensity of at least one of the plurality of semiconductor diodes from an initial light intensity, either literally or under the doctrine of equivalents. For example, WHOOP 4.0 increases the signal-to-noise ratio (“SNR”) of the PPG signal received from the AFE optical sensor module (<i>e.g.</i>, MAX86171 chip). The AFE optical sensor module has a multiple SNR values ranging from 84 dB to 91 dB corresponding to 32-128 mA LED current. To increase SNR, the sensor increases the LED current (“increasing light intensity of one of the plurality of semiconductor diodes”).  Deep Dive Teardown of the Whoop Inc. Whoop 4.0 WS40; WB40 Fitness Tracker Maxim had the overall design wins for the Whoop 4.0, with four major designs. For this device, Maxim provided the ARM cortex-M4 with FPU-based microcontroller(MAX32652),the power management(MAX77818), the pulse oximeter/heart rate sensor (MAX86171),and the digital temperature sensor(MAX6631MTT). Contact Us Product Code: DDT-2111-806 Release Date: 26/01/2022 Availability: Published Product Item Code: WPH-WS40 Device Manufacturer: Whoop Device Type: Fitness Monitor Source: https://www.techinsights.com/products/ddt-2111-806.

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’790 Patent Claim	Whoop Accused System ¹
	 Maxim Integrated MAX86171 Source: Product Teardown (WHOO 4.0)  Click here to ask an associate for production status of specific part numbers. MAX86171 Low-Noise AFE for Pulse Oximeter and Heart Rate Monitor

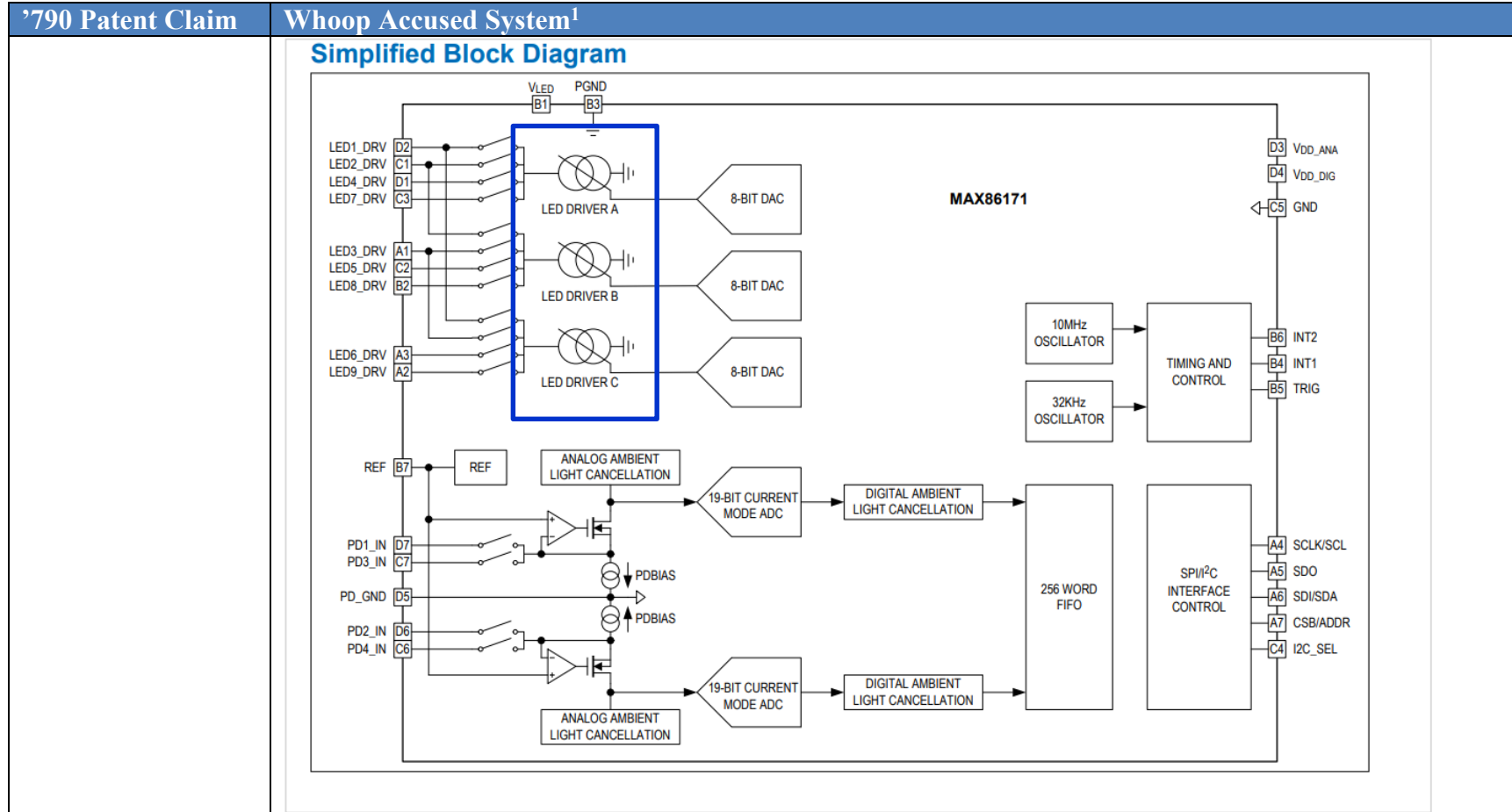
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’790 Patent Claim	Whoop Accused System ¹
	General Description The MAX86171 is an ultra-low-power optical data acquisition system with both transmit and receive channels. On the transmitter side, the MAX86171 has nine LED driver output pins, programmable from three high-current, 8-bit LED drivers. On the receiver side, MAX86171 has two low-noise charge integrating front-ends that each include independent 19.5 bit ADCs and best-in-class ambient light cancellation (ALC) circuits, producing the highest performing integrated optical data acquisition system on the market today.

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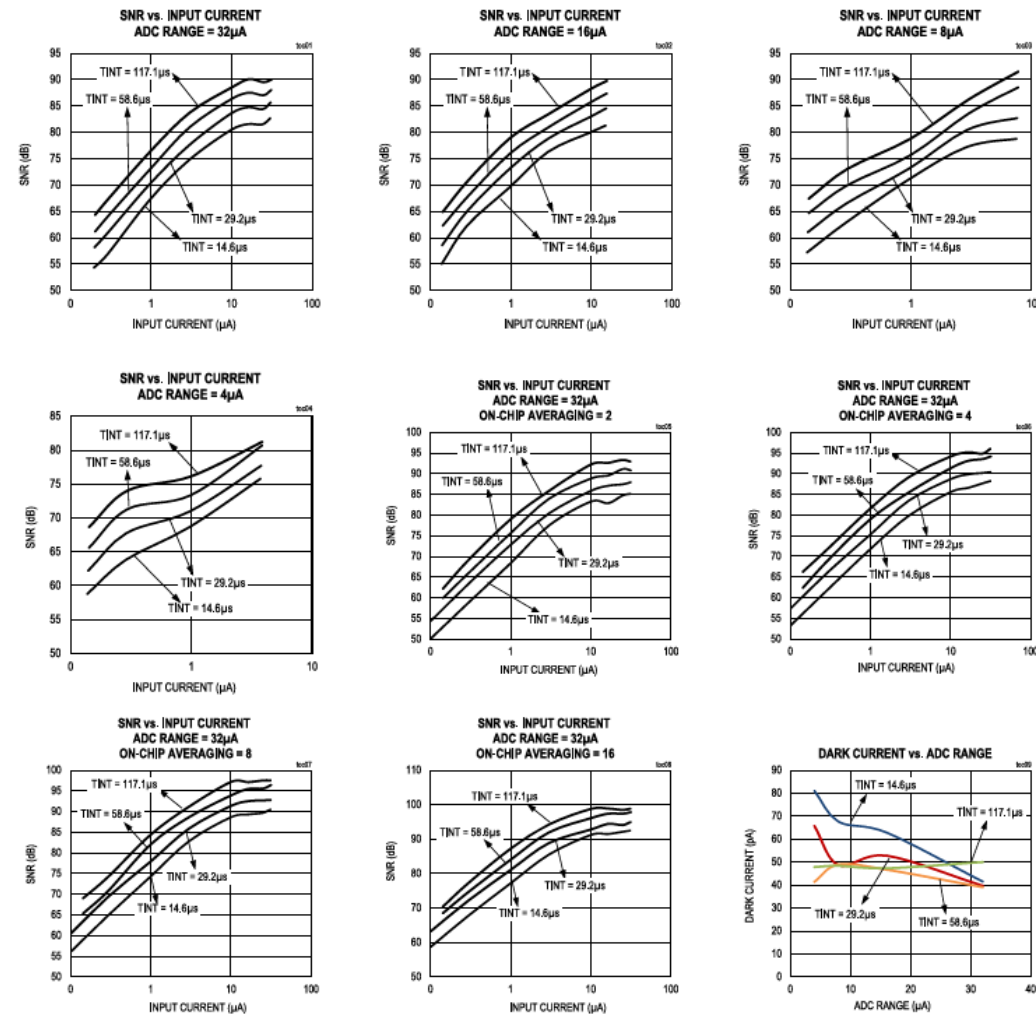
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	LED DRIVER						
	LED Current Resolution			8		Bits	
	Driver DNL	DNL _{TX}	MEASx_LED_RGE = 0x3	-1	+1	LSB	
	Driver INL	INL _{TX}	MEASx_LED_RGE = 0x3	1		LSB	
	Full-Scale LED Current	I _{LED}	MEASx_DRVy_PA = 0xFF	MEASx_LED_RGE = 0x0	32		mA
				MEASx_LED_RGE = 0x1	64		
				MEASx_LED_RGE = 0x2	96		
				MEASx_LED_RGE = 0x3	116	128	
LED Driver Rise Time		MEASx_DRVy_PA = 0xFF, 10% to 90%, all range settings	3		μs		
LED Driver Fall Time		MEASx_DRVy_PA = 0xFF, 10% to 90%, all range settings	3		μs		

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Typical Operating Characteristics

($V_{DD} = 1.8V$, $V_{LED} = 5.0V$, $GND = PGND = 0V$, $T_A = +25^\circ C$, unless otherwise noted.)



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	Detailed Description The MAX86171 is a complete integrated optical data-acquisition system, ideal for various applications including optical pulse-oximetry and heart-rate detection applications. It is designed for the demanding requirements of mobile and wearable devices and requires minimal external hardware components for integration into a wearable device. It includes high-resolution optical readout signal processing channels with robust ambient light cancellation and high current LED driver DACs to form a complete optical readout signal chain. The MAX86171 is fully adjustable through software registers and the digital output data is stored in a 256-word FIFO. The FIFO allows the MAX86171 to be connected to a microcontroller or processor on a shared bus, I²C, or SPI depending on hardware selection on the I2C_SEL pin. It operates in fully autonomous mode for low-power battery applications. For wearables with compact optical architectures, refer to MAX86170A and MAX86170B that can support 6/4 LEDs and 4/2 PDs. The MAX86171 incorporates dual optical readout channels that operate simultaneously. The MAX86171 has three LED drivers. With the built-in MUX and control logic on the chip, the MAX86171 can support up to Nine LEDs and Four PDs. It is well suited for a wide variety of optical sensing applications. The MAX86171 operates on a 1.8V main supply voltage, with a separate 3.1V to 5.5V LED driver power supply. This device has flexible exposure, timing, and shutdown configurations as well as control of individual blocks so that an optimized measurement can be made at minimum power levels. Optical Transmitter Overview The MAX86171 has three independent precision LED current drivers that are muxed to Nine LED driver pins. Three LED current DACs modulate LED pulses for a variety of optical measurements. The three LED current DACs have an 8-bit dynamic range with four programmable full-scale range settings of 32mA, 64mA, 96mA, and 128mA. The three current drivers, DRVA, DRVB, and DRVC, is connected to four of the LED driver pins through a mux according to Table 1. The MEASx Selects registers define how each LED driver is connected for that particular measurement. Thus, the configuration of the LED drivers can be uniquely set for each measurement. Each measurement can drive one, two, or all three LED drivers.

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Table 3. LED DRIVER FULL-SCALE RANGE TRADE-OFF

FULL-SCALE RANGE (mA)	LED DAC RESOLUTION LED CURRENT FOR 1 LSB (mV)	RECOMMENDED MINIMUM V _{LEDx_DRV} (mV)	PEAK LOOP-BACK SNR (dB)
32	0.125	300	84
64	0.250	500	88
96	0.375	700	90
128	0.500	900	91

Optical Receiver Overview

The optical path in MAX86171 is composed of a front-end photodiode biasing circuit with an analog ambient light cancellation (ALC) sample and hold circuit that nulls the ambient light photodiode current at the input of the ADC. This front-end biasing circuit is followed by a current integrating, continuous-time sigma-delta ADC with a proprietary discrete time filter. This discrete time filter uses multiple dark and exposure optical samples to generate an accurate 20-bit effective exposure output signal with excellent low- and high-frequency ambient light rejection.

Measurement Configuration and Timing

The MAX86171 optical controller is capable of being configured to make a variety of measurements.

The controller can be configured to pulse one, two or three LED drivers sequentially to make measurements at multiple wavelengths as is done in pulse oximetry measurements or simultaneously to drive multiple LEDs as is done with heart rate measurements on the wrist.

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	Measurement Configuration A measurement is essentially one optical sample from one or more LEDs in a single channel configuration and two optical samples in a dual channel configuration. MAX86171 supports nine individual measurements, each of which can be configured independently. Each measurement can be configured in the MEASx registers. These registers help set up a varied set of parameters as outlined by the list below. These parameters can be configured on a per measurement basis: • Connections of each of the three LED Drivers to one of the Nine LEDx_DRV pins • Connection of each of two channels to one of two possible PDs on either channel • LED driver range and drive currents • LED settling time • PD settling time Assume it is desired to perform an SpO2 measurement and also monitor the ambient level on the photodiode to adjust the IR and red LED intensity using dual optical channels with photodiodes 1 and 2 selected. To perform this measurement, configure the following registers. Source: Analog Devices, “MAX86171: Low-Noise AFE for Pulse Oximeter and Heart Rate Monitor Data Sheet,” Rev.2, Mar. 24, 2022, at 1-4, 10, 15-18, 24-28, <i>available at</i> https://www.analog.com/media/en/technical-documentation/data-sheets/MAX86171.pdf.

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	Development and Testing of Heart Rate Algorithms The development and testing of the heart rate algorithm involve rigorous processes to ensure accuracy and reliability. Over several months, our Signal Processing and Data Science teams collected primary data through our 24/7 research facility, <u>WHOOP Labs</u>. This data underwent extensive analysis and iteration to refine the algorithm. Testing includes various stages: 1. Data Collection: Gathering data from a diverse group of users in a controlled and validated setting to create a primary data set, across factors like gender, age, skin color, and activity type. 2. Algorithm Development: Iterating on the algorithm to improve how it separates signal from noise and accurately measures heart rate. 3. Validation: Testing the algorithm across large population sets and in context of various related metrics on WHOOP to ensure its accuracy and reliability. Source: https://www.whoop.com/us/en/thelocker/a-look-behind-the-data-how-whoop-measures-heart-rate/.

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	What Affects WHOOP Accuracy?  Jul 16, 2024 Ensuring optimal accuracy with your WHOOP is essential for tracking your body’s performance and progress. Tracking and monitoring your heart rate WHOOP uses Photoplethysmography (PPG) to monitor heart rate 24/7 by shining light through the skin. The changing blood volume under the sensor forms the primary PPG signal, converted into a heart rate by WHOOP. Proprietary techniques are employed to enhance the signal and minimize disruptions for accurate heart rate measurement. Patent documents assigned to and/or owned by Whoop also describe Whoop’s wearable devices being configured to increase the signal-to-noise ratio by increasing light intensity of at least one of the plurality of semiconductor diodes from an initial light intensity. For example:

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	(12) United States Patent Wiese et al. (10) Patent No.: US 10,799,162 B2 (45) Date of Patent: *Oct. 13, 2020 (54) TISSUE OXYGEN SATURATION DETECTION AND RELATED APPARATUS AND METHODS (58) Field of Classification Search CPC A61B 5/1455; A61B 5/00; A61B 5/0024; A61B 5/0095; A61B 5/14; A61B 5/145; A61B 5/1477 See application file for complete search history. (71) Applicant: Whoop, Inc., Boston, MA (US) (56) References Cited U.S. PATENT DOCUMENTS 6,587,703 B2 7/2003 Cheng et al. 6,678,541 B1 1/2004 Durkin (Continued) (72) Inventors: Daniel Wiese, Cambridge, MA (US); Alessandro Babini, Cambridge, MA (US); Sebastian Trousil, Boston, MA (US); Samuel Huberman, Somerville, MA (US); Stefan Kalchmair, Boston, MA (US); Pamela G. Anderson, Boston, MA (US) (73) Assignee: Whoop, Inc., Boston, MA (US)

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	9 “counts”. In some embodiments, the detectors may convert a total light signal intensity across all wavelengths into counts. As an example, the detectors may be photodiodes. The detectors may be integrating photodetectors with onboard analog-to-digital conversion, although alternatives are possible. In another non-limiting example, the detectors may be TSL2591 light-to-digital converters. The detectors may be sampled at a frequency suitable to mitigate the effects of muscle movement. For example, the detectors may be sampled at a frequency less than 10 Hz, less than 5 Hz, less than 3 Hz, less than 2 Hz, or at any sampling rate within such ranges. In an alternative embodiment, the detectors may be silicon photodiodes, with analog to digital conversion accomplished using a photometric front end with analog-to-digital converter to convert current measured from the photodiode into counts. In one non-limiting example, the photometric front end may be Analog Devices ADPD103, available from Analog Devices, Inc. of Norwood, Mass. In this example the photodetectors may be sampled at 4000 Hz, 1000 Hz, 100 Hz, 0.1 Hz, less than 4000 Hz, less than 100 Hz or any sampling rate within such ranges. In another non-limiting example, the photodiodes may be Everlight PD15-22C/TR8, available from Everlight America, Inc. of Carrollton, Tex. In some embodiments, detector data are sampled in a predefined frequency. At each sampling, detector data are recorded for a set short period of time and the recorded small group of data are processed to produce a single sampled data point to improve SNR. In some embodiments, the processing of the data may be averaging or integration. In some embodiments, sampling frequency is chosen to be fast enough to reflect time variation in a user’s blood oxygenation level during the course of exercise. In some embodiments, sampling frequency is chosen to be slow enough to average out fluctuations due to user motion. In some embodiments, the sampling frequency and level of data processing may be chosen to reduce workload of the micro-controller in order to extend battery life of the wearable optical device. In a non-limiting example, detector data are sampled at frequency of 2 Hz, although other frequencies may alternatively be used, including at a frequency less than 10 Hz, less than 5 Hz, less than 3 Hz, less than 2 Hz, or at any sampling rate within such ranges. In some embodiments, the photodetectors operate autonomously, and during the data acquisition time (e.g., 100 ms) the BLE controller enters a power saving mode. After the acquisition, the controller reads out the value. Such operation can extend the battery life significantly. Source: US 10,799,162 at 9:1-21, 17:24-32.
7[I] the detection system further configured to: generate a first signal responsive to light received while the semiconductor diodes are off, generate a second signal responsive to	The detection system in the Accused Wearable Device is configured to generate a first signal responsive to light received while the semiconductor diodes are off and generate a second signal responsive to light received while at least one of the semiconductor diodes is on, either literally or under the doctrine of equivalents. For example, the AFE optical sensor module (e.g., MAX86171 chip) (“detection system”) in the Accused Wearable device provides ambient light cancelation, which generates two signals: one when the LEDs are off (“a first signal responsive to light received while the semiconductor diodes are off”) and one when the LEDs are on (“a second signal responsive to light received while at least one of the semiconductor diodes is on”).

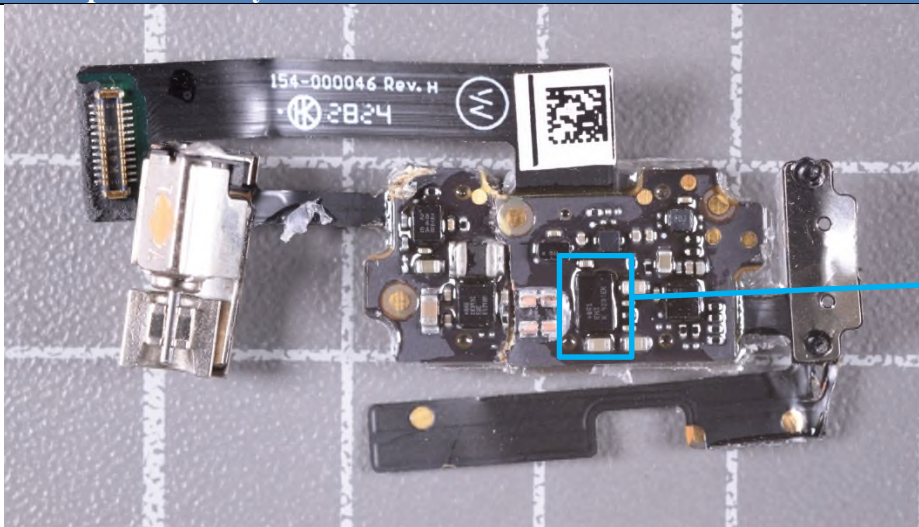
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light received while at least one of the semiconductor diodes is on, and	In the ambient light sample mode in the MAX86171 (“while the semiconductor diodes are off”), the photodiodes/PDs capture light from the environment (e.g., sunlight, room lighting), which is used as a reference for ambient light cancelation. For example, in the Central Difference Method (“CDM”), the CDM1 and CDM3 signals are collected while the LED is off to measure the ambient light interference. In the exposure sample mode in the MAX86171 (“while at least one of the semiconductor diodes is on”), the photodiodes/PDs capture light that reflects from the user’s skin (or underlying tissue such as veins and blood vessels). In the CDM mode, the CDM2 signal is collected while LEDs are on.  Deep Dive Teardown of the Whoop Inc. Whoop 4.0 WS40; WB40 Fitness Tracker Maxim had the overall design wins for the Whoop 4.0, with four major designs. For this device, Maxim provided the ARM cortex-M4 with FPU-based microcontroller(MAX32652),the power management(MAX77818), <u>the pulse oximeter/heart rate sensor (MAX86171)</u>,and the digital temperature sensor(MAX6631MTT). Contact Us Product Code: DDT-2111-806 Release Date: 26/01/2022 Availability: Published Product Item Code: WPH-WS40 Device Manufacturer: Whoop Device Type: Fitness Monitor Source: https://www.techinsights.com/products/ddt-2111-806.

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	 Maxim Integrated MAX86171 Source: Product Teardown (WHOOP 4.0) As seen in Figure 2 only MEASn_DRVA is pulsing during the exposure time. This timing mode would be used when heart rate is being measured with a single LED. In this mode, three conversions (CDM1, CDM2, and CDM3) occur. The two ambient samples, CDM1 and CDM3, are used for ambient light cancellation. The exposure sample CDM2 will appear in the FIFO as a single optical-sampled value after ambient cancellation.

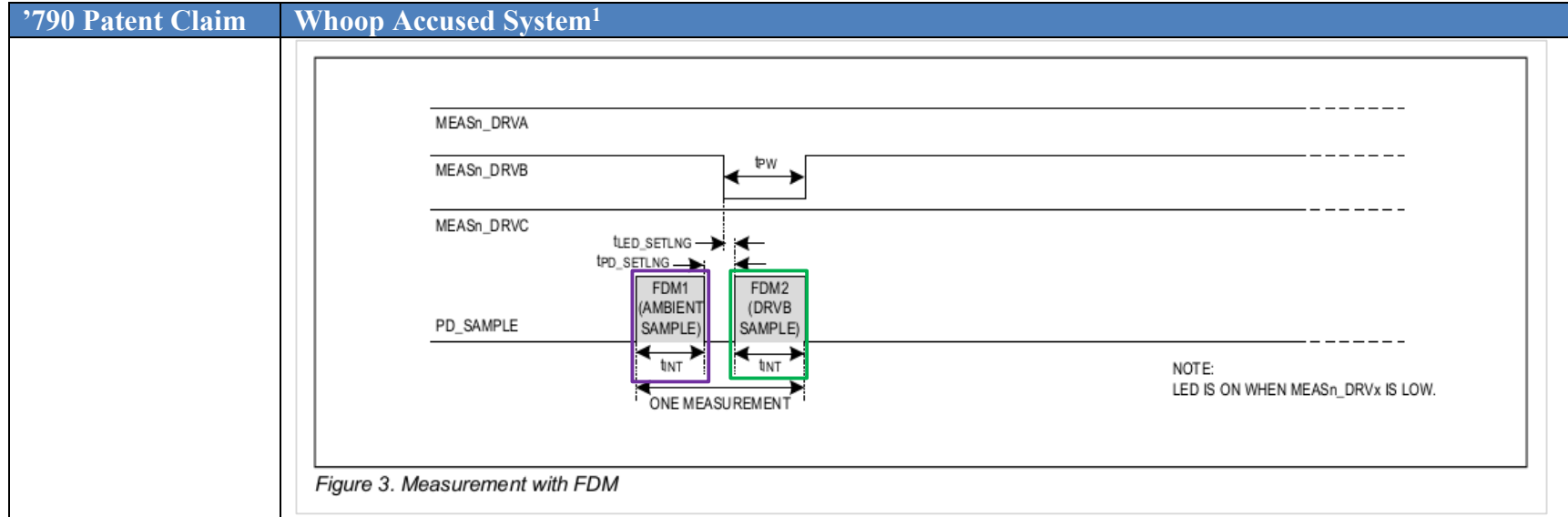
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	<i>Figure 2. Measurement with CDM</i> One Measurement with FDM The optical timing diagram in Figure 3 represents DRVB pulsing with forward difference method (FDM) mode enabled. In this mode, two conversions (FDM1 and FDM2) occur. The ambient sample FDM1 is only used for ambient cancellation. The exposure sample FDM2 appears in the FIFO as a single optical sampled value after ambient cancellation.

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When COLLECT_RAW_DATA is set to 1, Picket Fence Detection is disabled. An attempt to read an empty FIFO returns the INVALID_DATA tag. The FIFO tags and corresponding data types are explained in [Table 7](#).

Table 7. TAGS AND DATA TYPES

TAG[3:0]	DATA TYPE	COMMENTS
0x0	Reserved	
0x1	PPG MEAS1 DATA	Measurement 1 ADC data
0x2	PPG MEAS2 DATA	Measurement 2 ADC data
0x3	PPG MEAS3 DATA	Measurement 3 ADC data
0x4	PPG MEAS4 DATA	Measurement 4 ADC data
0x5	PPG MEAS5 DATA	Measurement 5 ADC data
0x6	PPG MEAS6 DATA	Measurement 6 ADC data
0x7	PPG MEAS7 DATA	Measurement 7 ADC data
0x8	PPG MEAS8 DATA	Measurement 8 ADC data
0x9	PPG MEAS9 DATA	Measurement 9 ADC data
0xA	PPG DARK DATA	Dark data when Raw data is captured in the FIFO
0xB	PPG ALC_OVF DATA	ALC Overflow was detected. Location of data implies which Measurement and for which PD.
0xC	PPG EXP_OVF DATA	Exposure Overflow was detected. Location of data implies which Measurement and for which PD.
0xD	PPG_PF DATA	Picket Fence event was detected. This occurs only if picket fence is enabled in PPGn_PF_MEAS_SEL[3:0] register. Location of data implies which Measurement and for which PD.
0xE	INVALID DATA	This tag indicates that there was an attempt to read an empty FIFO.
0xF	Reserved	

Ambient Rejection

The MAX86171 implements ambient light cancellation in two steps, a coarse cancellation and a fine cancellation. Each MEASx gets its own ambient light cancellation. The coarse cancellation is in the analog domain. It is enabled by default and can be disabled by setting register bit ALC_DISABLE. The fine cancellation is a digital cancellation scheme and is configured as central difference method (CDM) or forward different method (FDM) (register bit MEASx_FILT_SEL).

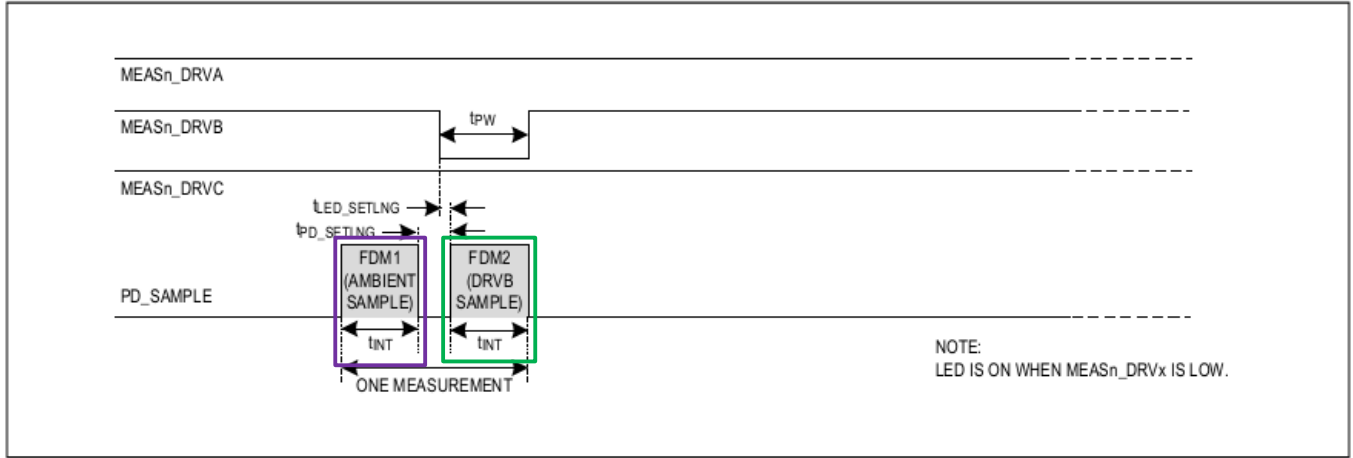
U.S. Patent No. 12,193,790 (the “’790 Patent”)

“Wearable devices comprising semiconductor diode light sources with improved signal-to-noise ratio”

'790 Patent Claim	Whoop Accused System ¹
	ALC is an analog sample and hold which can cancel up to 200µA of DC photodiode current. Any drift or residual from ALC is cancelled by CDM/FDM cancellation. CDM is comprised of 3 ADC conversions with 2 ambient and 1 exposure conversion. FDM is comprised of 2 ADC conversions with 1 ambient only and 1 exposure conversion. The ambient and exposure samples are used for digital cancellation of any residual error (from ALC) or drift (in ambient signal). The final computed value is the effective exposure signal which is stored in the FIFO. See Figure 7 for the timing diagram for CDM and Figure 8 shows the timing diagram for FDM. <i>Figure 7. Central Difference Method (CDM)</i>

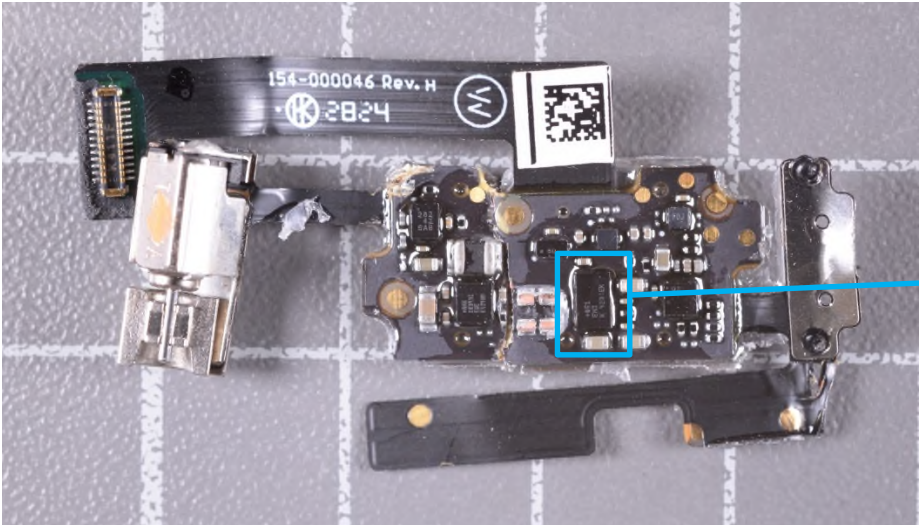
U.S. Patent No. 12,193,790 (the “’790 Patent”)

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’790 Patent Claim	Whoop Accused System ¹
	 Figure 8. Forward Difference Method (FDM) Source: Analog Devices, “MAX86171: Low-Noise AFE for Pulse Oximeter and Heart Rate Monitor Data Sheet,” Rev.2, Mar. 24, 2022, at 19-29, available at https://www.analog.com/media/en/technical-documentation/data-sheets/MAX86171.pdf.
7[m] increase the signal-to-noise ratio by comparing the first signal and the second signal; and	The detection system in the Accused Wearable Device is configured to increase the signal-to-noise ratio by comparing the first signal and the second signal. For example, ambient light is considered as noise in PPG sensors. Therefore, the presence of ambient light decreases the SNR of PPG sensors. Ambient light cancelation is performed to cancel out the ambient light noise, thereby increasing the SNR. The AFE optical sensor module (e.g., MAX86171 chip) of WHOOP 4.0, for example, performs ambient light cancelation (“ALC”) to increase the SNR by comparing the measured signal when the LEDs are off (“first signal”) and the measured signal when the LEDs are on (“second signal”)—e.g., using Central Difference Method (“CDM”)

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	 Deep Dive Teardown of the Whoop Inc. Whoop 4.0 WS40; WB40 Fitness Tracker Maxim had the overall design wins for the Whoop 4.0, with four major designs. For this device, Maxim provided the ARM cortex-M4 with FPU-based microcontroller(MAX32652),the power management(MAX77818), the pulse oximeter/heart rate sensor (MAX86171),and the digital temperature sensor(MAX6631MTT). Contact Us Product Code: DDT-2111-806 Release Date: 26/01/2022 Availability: Published Product Item Code: WPH-WS40 Device Manufacturer: Whoop Device Type: Fitness Monitor Source: https://www.techinsights.com/products/ddt-2111-806.  Maxim Integrated MAX86171

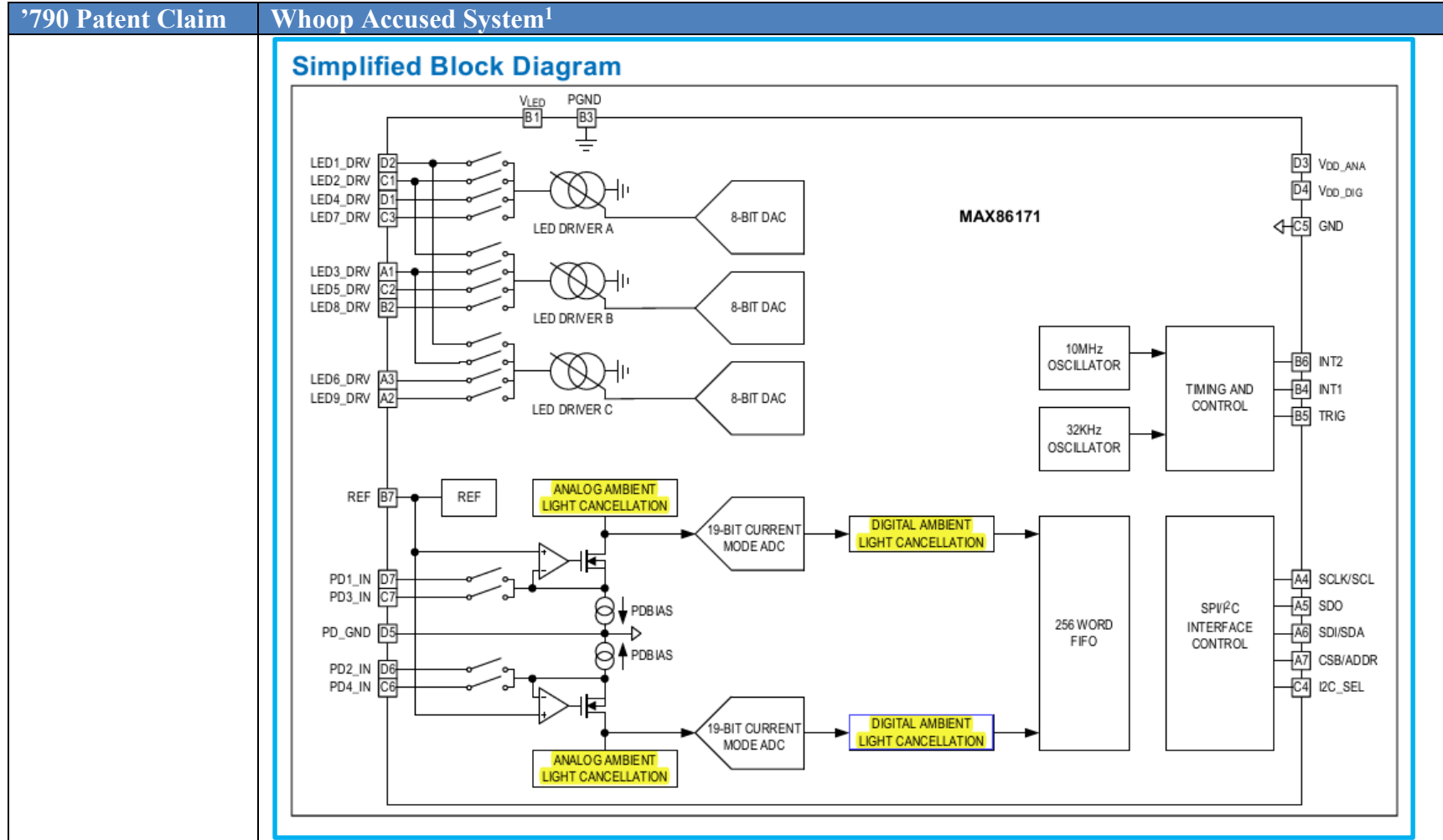
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’790 Patent Claim	Whoop Accused System ¹
	Source: Product Teardown (WHOOP 4.0)  Click here to ask an associate for production status of specific part numbers. MAX86171 Low-Noise AFE for Pulse Oximeter and Heart Rate Monitor General Description The MAX86171 is an ultra-low-power optical data acquisition system with both transmit and receive channels. On the transmitter side, the MAX86171 has nine LED driver output pins, programmable from three high-current, 8-bit LED drivers. On the receiver side, MAX86171 has two low-noise charge integrating front-ends that each include independent 19.5 bit ADCs and best-in-class ambient light cancellation (ALC) circuits, producing the highest performing integrated optical data acquisition system on the market today.

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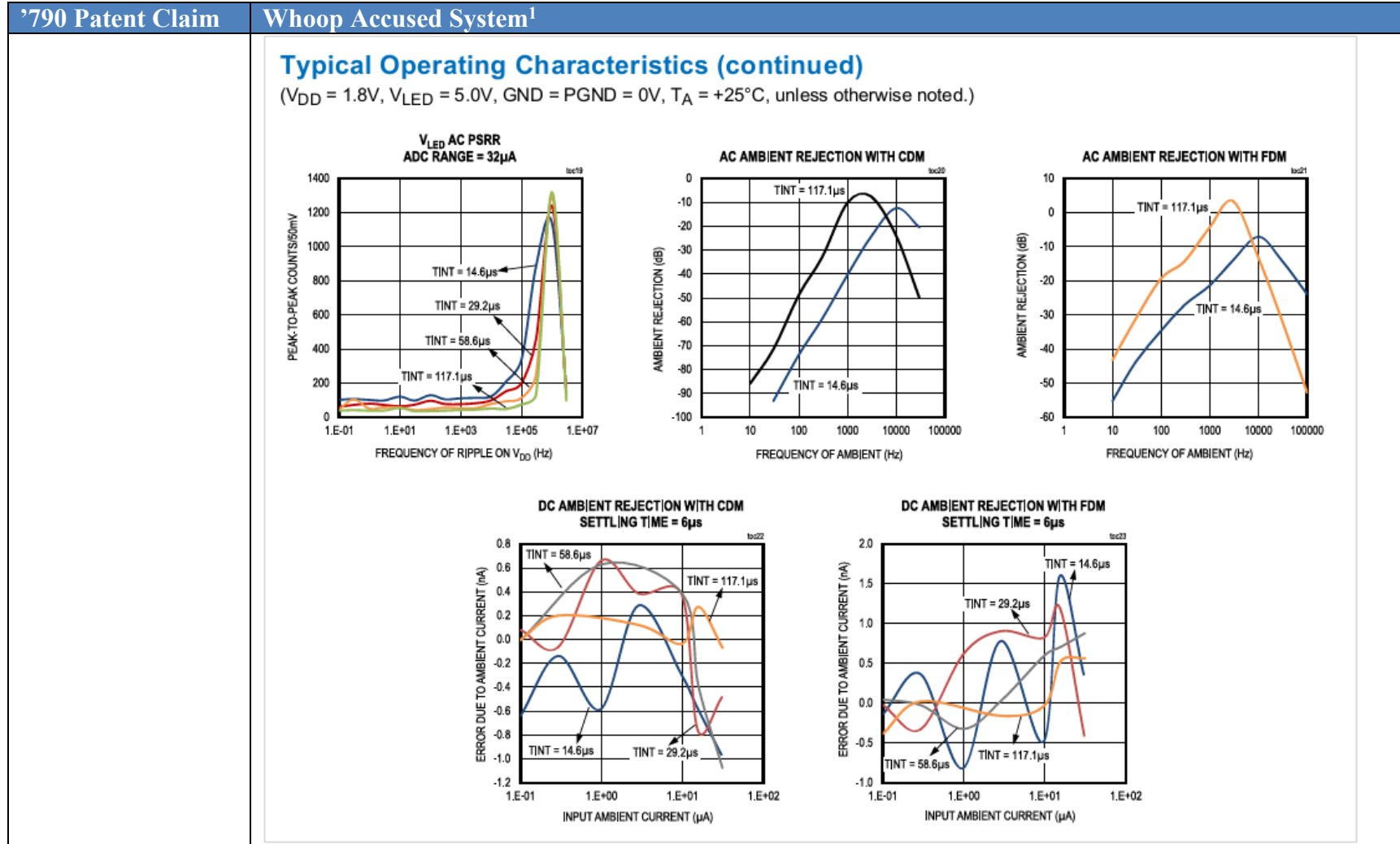
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Detailed Description

The MAX86171 is a complete integrated optical data-acquisition system, ideal for various applications including optical pulse-oximetry and heart-rate detection applications. It is designed for the demanding requirements of mobile and wearable devices and requires minimal external hardware components for integration into a wearable device. It includes high-resolution optical readout signal processing channels with robust ambient light cancellation and high current LED driver DACs to form a complete optical readout signal chain.

Table 3. LED DRIVER FULL-SCALE RANGE TRADE-OFF

FULL-SCALE RANGE (mA)	LED DAC RESOLUTION LED CURRENT FOR 1 LSB (mV)	RECOMMENDED MINIMUM V _{LEDx_DRV} (mV)	PEAK LOOP-BACK SNR (dB)
32	0.125	300	84
64	0.250	500	88
96	0.375	700	90
128	0.500	900	91

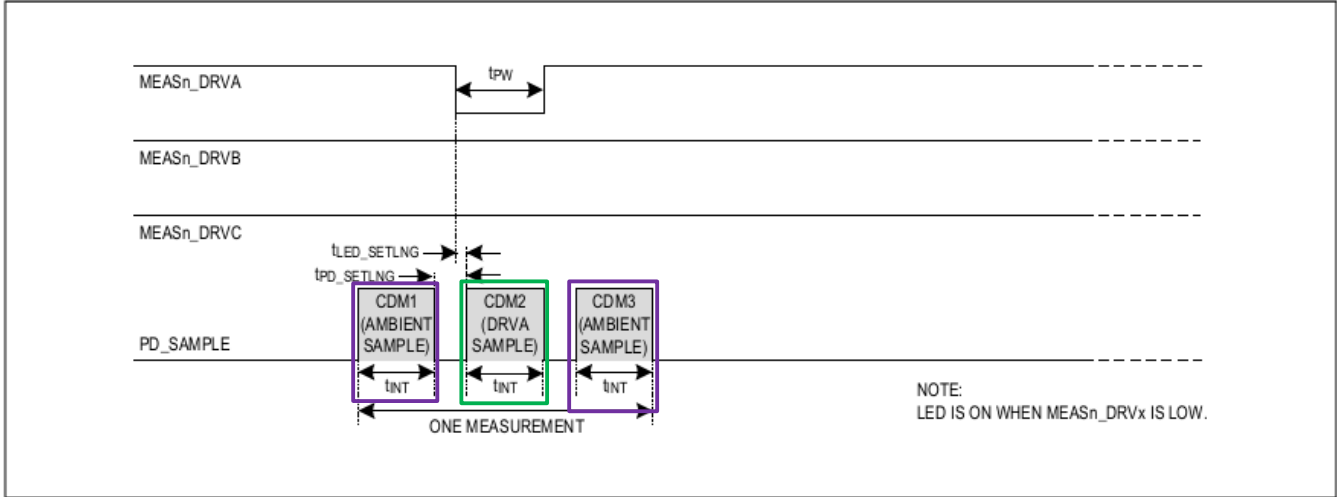
Optical Receiver Overview

The optical path in MAX86171 is composed of a front-end photodiode biasing circuit with an analog ambient light cancellation (ALC) sample and hold circuit that nulls the ambient light photodiode current at the input of the ADC. This front-end biasing circuit is followed by a current integrating, continuous-time sigma-delta ADC with a proprietary discrete time filter. This discrete time filter uses multiple dark and exposure optical samples to generate an accurate 20-bit effective exposure output signal with excellent low- and high-frequency ambient light rejection.

This combination of analog circuits and back-end digital filtering helps reduce shifts due to ambient light variations. An exposure signal varies less than 0.5nA, on a homogenous photodiode with ambient light variations from 0μA to over 30μA, or over 95dB of DC rejection, all but eliminating issues in high-intensity outdoor lighting conditions. This level of ambient light cancellation is maintained under indoor lighting conditions with over 70dB of rejection at line (mains) rate, 100Hz and 120Hz. In addition back-end filtering also suppresses the high rate of modulation of newer compact fluorescent and LED lighting as well.

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	As seen in Figure 2 only MEASn_DRVA is pulsing during the exposure time. This timing mode would be used when heart rate is being measured with a single LED. In this mode, three conversions (CDM1, CDM2, and CDM3) occur. The two ambient samples, CDM1 and CDM3, are used for ambient light cancellation. The exposure sample CDM2 will appear in the FIFO as a single optical-sampled value after ambient cancellation.  Figure 2. Measurement with CDM One Measurement with FDM The optical timing diagram in Figure 3 represents DRVB pulsing with forward difference method (FDM) mode enabled. In this mode, two conversions (FDM1 and FDM2) occur. The ambient sample FDM1 is only used for ambient cancellation. The exposure sample FDM2 appears in the FIFO as a single optical sampled value after ambient cancellation.

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	Figure 3. Measurement with FDM Ambient Rejection The MAX86171 implements ambient light cancellation in two steps, a coarse cancellation and a fine cancellation. Each MEASx gets its own ambient light cancellation. The coarse cancellation is in the analog domain. It is enabled by default and can be disabled by setting register bit ALC_DISABLE. The fine cancellation is a digital cancellation scheme and is configured as central difference method (CDM) or forward different method (FDM) (register bit MEASx_FILT_SEL). ALC is an analog sample and hold which can cancel up to 200μA of DC photodiode current. Any drift or residual from ALC is cancelled by CDM/FDM cancellation. CDM is comprised of 3 ADC conversions with 2 ambient and 1 exposure conversion. FDM is comprised of 2 ADC conversions with 1 ambient only and 1 exposure conversion. The ambient and exposure samples are used for digital cancellation of any residual error (from ALC) or drift (in ambient signal). The final computed value is the effective exposure signal which is stored in the FIFO. See Figure 7 for the timing diagram for CDM and Figure 8 shows the timing diagram for FDM.

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	Figure 7. Central Difference Method (CDM) Figure 8. Forward Difference Method (FDM)

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	Source: Analog Devices, “MAX86171: Low-Noise AFE for Pulse Oximeter and Heart Rate Monitor Data Sheet,” Rev.2, Mar. 24, 2022, at 1-2, 12, 15-16, 19-21, 28-29, <i>available at</i> https://www.analog.com/media/en/technical-documentation/data-sheets/MAX86171.pdf. Development and Testing of Heart Rate Algorithms The development and testing of the heart rate algorithm involve rigorous processes to ensure accuracy and reliability. Over several months, our Signal Processing and Data Science teams collected primary data through our 24/7 research facility, <u>WHOOP Labs</u>. This data underwent extensive analysis and iteration to refine the algorithm. Testing includes various stages: 1. Data Collection: Gathering data from a diverse group of users in a controlled and validated setting to create a primary data set, across factors like gender, age, skin color, and activity type. 2. Algorithm Development: Iterating on the algorithm to improve how it separates signal from noise and accurately measures heart rate. 3. Validation: Testing the algorithm across large population sets and in context of various related metrics on WHOOP to ensure its accuracy and reliability. Source: https://www.whoop.com/us/en/thelocker/a-look-behind-the-data-how-whoop-measures-heart-rate/.

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’790 Patent Claim	Whoop Accused System ¹
	What Affects WHOOP Accuracy?  Jul 16, 2024 Ensuring optimal accuracy with your WHOOP is essential for tracking your body’s performance and progress. Tracking and monitoring your heart rate WHOOP uses Photoplethysmography (PPG) to monitor heart rate 24/7 by shining light through the skin. The changing blood volume under the sensor forms the primary PPG signal, converted into a heart rate by WHOOP. Proprietary techniques are employed to enhance the signal and minimize disruptions for accurate heart rate measurement. Source: https://support.whoop.com/s/article/What-Affects-WHOOP-Accuracy?language=en_US.
<u>7[n]</u> wherein the wearable device is at least in part configured to identify an object.	The Accused System comprises an Accused Wearable Device that is at least in part configured to identify an object, either literally or under the doctrine of equivalents. For example, WHOOP 4.0 (“wearable device”) is configured to recognize or establish when it is being worn by a human user by identifying a physical attribute of human user (“identify an object”) (e.g., recognizing and establishing physiological parameters of a human user). “Your WHOOP 4.0 detects when you’re wearing it and when you’re not, indicated by green LEDs underneath the sensor. This article will help determine if your sensor is stuck in one status, and includes recommended resolutions.” https://support.whoop.com/s/article/What-to-Do-if-Your-WHOOP-4-0-Sensor-LEDs-Are-Stuck-On-or-Off?language=en_US.

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	WHOOP is sensing it is off-body If your WHOOP senses that it is not being worn (for example, on your wrist or bicep) it will turn off and stop collecting data. If you believe that your device is falsely sensing that it is off your body when it is actually on your body, completing the following steps will help resolve the issue. Source: https://support.whoop.com/s/article/Missing-Data?language=en_US • Any-Wear™ Detection: A novel location detection technology identifies when and where WHOOP 4.0 is on the body Source: https://www.whoop.com/us/en/press-center/introducing-4-0-whoop-body-any-wear-technology/

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	How WHOOP Measures Heart Rate WHOOP measures heart rate using advanced optical sensors with photoplethysmography (PPG) technology. It works by emitting green LED light into the skin, and then measuring the light that’s reflected back. Every time your heart beats, the blood flow increases, and this causes the amount of light that’s reflected back to change. WHOOP takes this raw data from the sensors and interprets it through an algorithm to produce a heart rate reading. While raw data is captured using the sensor hardware, an algorithm is required to estimate heart rate. The WHOOP heart rate algorithm is a complex set of mathematical formulas and computational processes used to interpret the raw data collected by the sensors. The algorithm filters out factors like movement artifacts that occur when you’re in motion to accurately determine your heart rate. It also adjusts for factors like skin tone, age, and activity type, to ensure accurate measurements across different conditions and members. Source: https://www.whoop.com/us/en/thelocker/a-look-behind-the-data-how-whoop-measures-heart-rate/.