

U.S. Patent No. 10,517,484 (the “’484 Patent”)

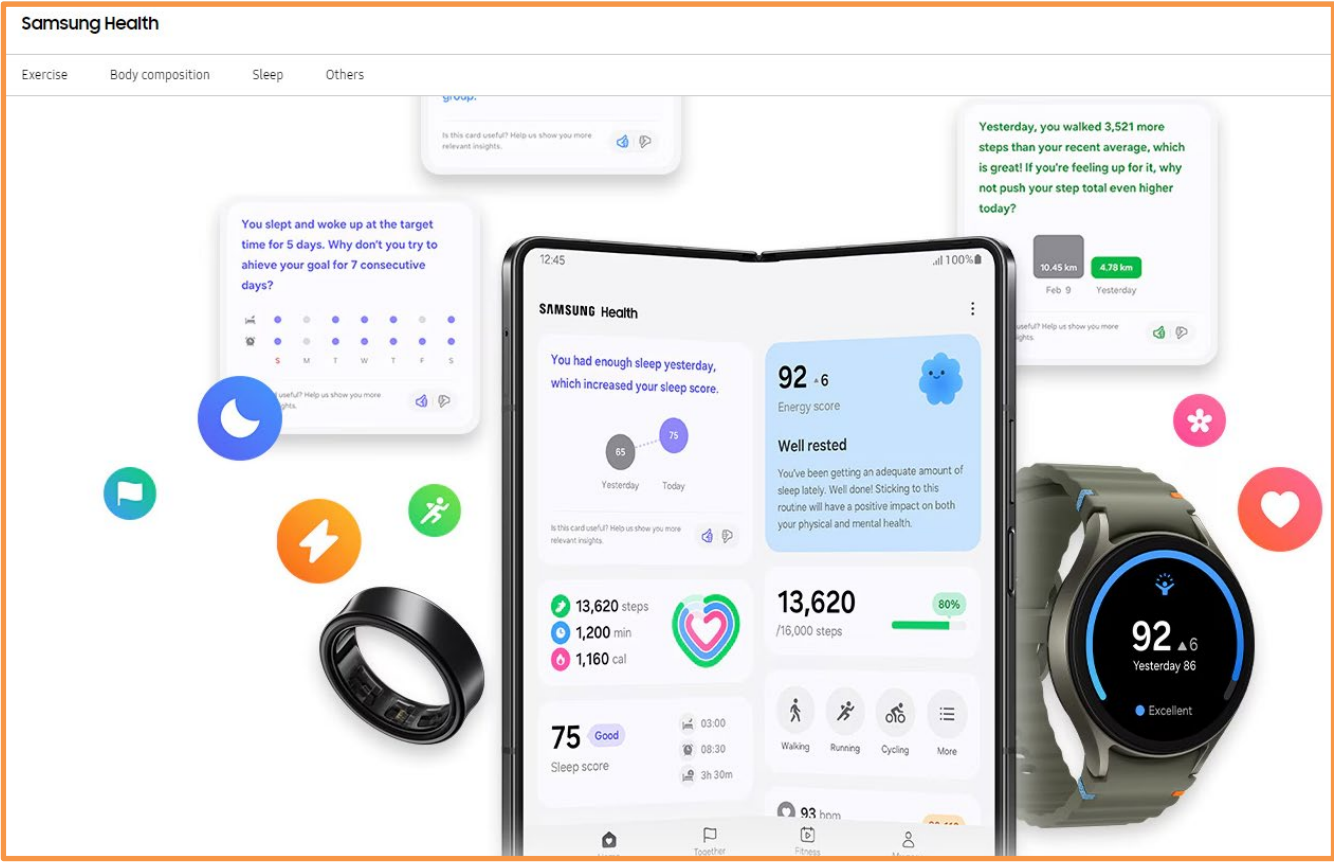
“Semiconductor diodes-based physiological measurement device with improved signal-to-noise ratio”

’484 Patent Claim ¹	Samsung Accused System ²
7[pre] A system for measuring one or more physiological parameters and for use with a smart phone or tablet, the system comprising:	<p>Without conceding that the preamble of Claim 7 of the ’484 Patent is limiting, Samsung Electronics, Co. Ltd. and Samsung Electronics America, Inc. (collectively, “Samsung”) have made, used, offered to sell, sold in the United States, and/or have imported into the United States, and/or, continue to make, use, offer to sell, and sell within the United States, and/or import into the United States, Accused Systems for measuring one or more physiological parameters and for use with a smart phone or tablet, either literally or under the doctrine of equivalents.</p> <p>For example, Samsung provides a system including a Galaxy Watch Ultra, a Samsung smartphone or tablet, and Samsung Cloud (“system”) for measuring “one or more physiological parameters” of a user, such as heart rate, blood oxygen level, and electrocardiogram (“ECG”). When the user wears a Galaxy Watch Ultra on their wrist, the watch measures physiological parameters using various hardware components, such as Samsung’s “BioActive sensor,” and transfers the information related to these parameters to an Accused Phone/Tablet and to the Accused Cloud.</p>

¹ Samsung infringes multiple claims of the ’484 Patent, including at least Claims 8-10. Claims 8-10 depend either directly or indirectly on independent Claim 7. Accordingly, Claim 7 is provided in this chart to show exemplary evidence of Samsung’s infringement of the limitations of Claim 7, which are included in Claims 8-10.

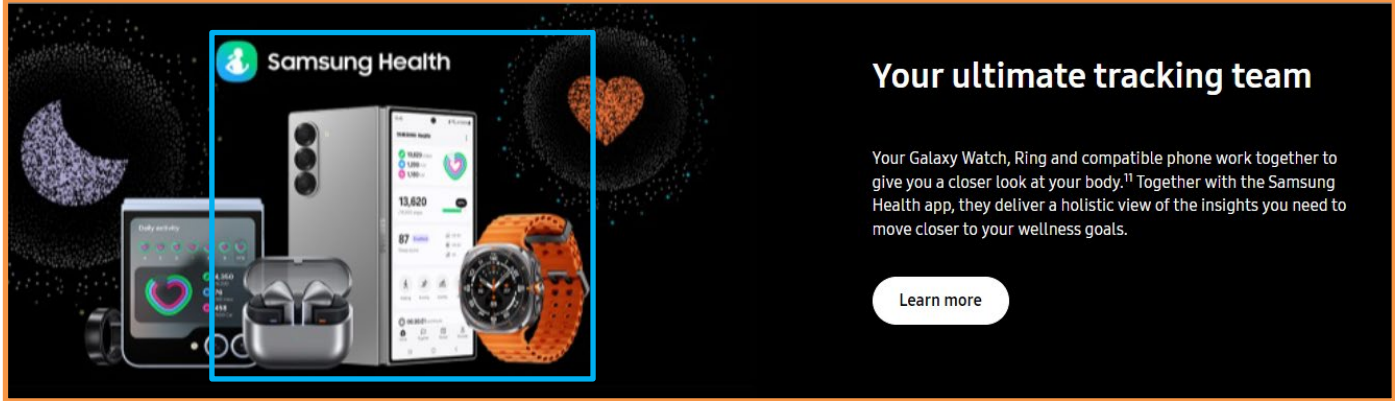
² The Accused System includes a Samsung smartwatch, such as the Galaxy Watch, the Galaxy Watch Active and Active2, the Galaxy Watch3, the Galaxy Watch4, the Galaxy Watch5, the Galaxy Watch6, the Galaxy Watch7, and the Galaxy Watch Ultra (each an “Accused Smartwatch”); a smart phone or tablet, such as the Samsung Galaxy A series phones, the Samsung Galaxy M series phones, the Samsung Galaxy S series phones, the Samsung Galaxy Z series phones, the Samsung Galaxy Tab A series tablets, the Samsung Galaxy Tab S series tablets, and the Samsung Galaxy Tab Active series tablets (each an “Accused Phone/Tablet”); and a cloud, such as the Samsung Cloud (the “Accused Cloud”), which collectively provide a system for measuring one or more physiological parameters of a user. Smart phones and tablets from other manufacturers, such as OnePlus, and clouds provided by others, such as Strava, may also be used as part of the Accused System. The Samsung Galaxy Watch Ultra, Samsung Galaxy Z Fold6, and the Samsung Cloud are charted here as representative of the Accused System. 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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'484 Patent Claim ¹	Samsung Accused System ²
	 <p>The screenshot displays the Samsung Health app interface. At the top, there are tabs for 'Exercise', 'Body composition', 'Sleep', and 'Others'. The main screen features several data cards: a sleep score card showing a score of 75, an energy score card showing 92, and a step count card showing 13,620 steps. A Samsung Watch is shown on the right side of the screen, displaying the same energy score of 92. The interface is decorated with various health-related icons like a heart, a person running, and a sleep icon.</p> <p>Source: https://www.samsung.com/us/apps/samsung-health/</p>

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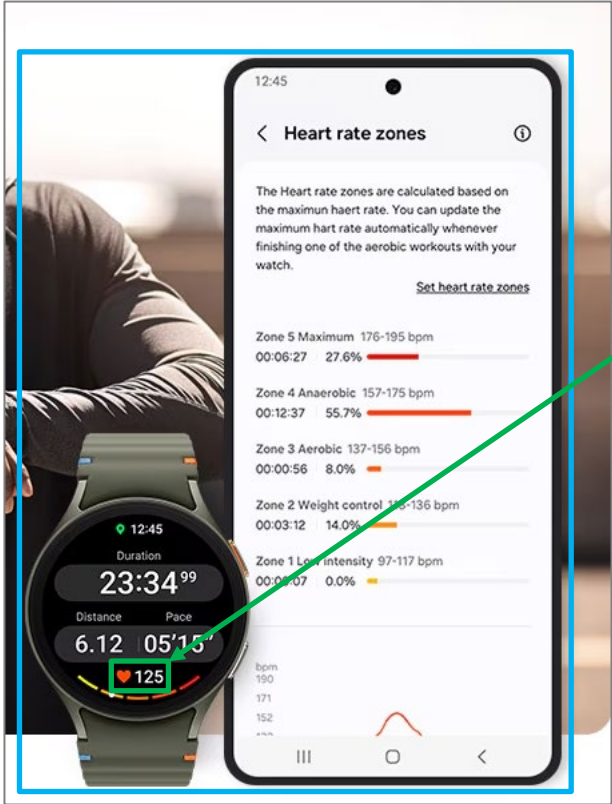
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'484 Patent Claim ¹	Samsung Accused System ²
	<div data-bbox="485 196 1871 594">A promotional image for Samsung Health. It features a smartphone displaying the Samsung Health app interface with various health metrics like heart rate, steps, and sleep. Next to the phone is a Samsung Galaxy Watch Ultra with an orange strap and a Samsung Galaxy Ring. The background is dark with abstract, glowing patterns. Text on the right says "Your ultimate tracking team" and "Your Galaxy Watch, Ring and compatible phone work together to give you a closer look at your body." A "Learn more" button is at the bottom right.</div> <p data-bbox="485 597 1339 634">Source: https://www.samsung.com/us/watches/galaxy-watch-ultra/</p>

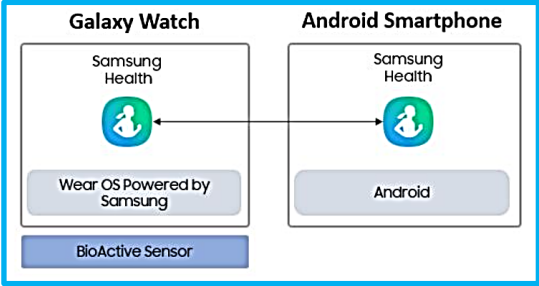
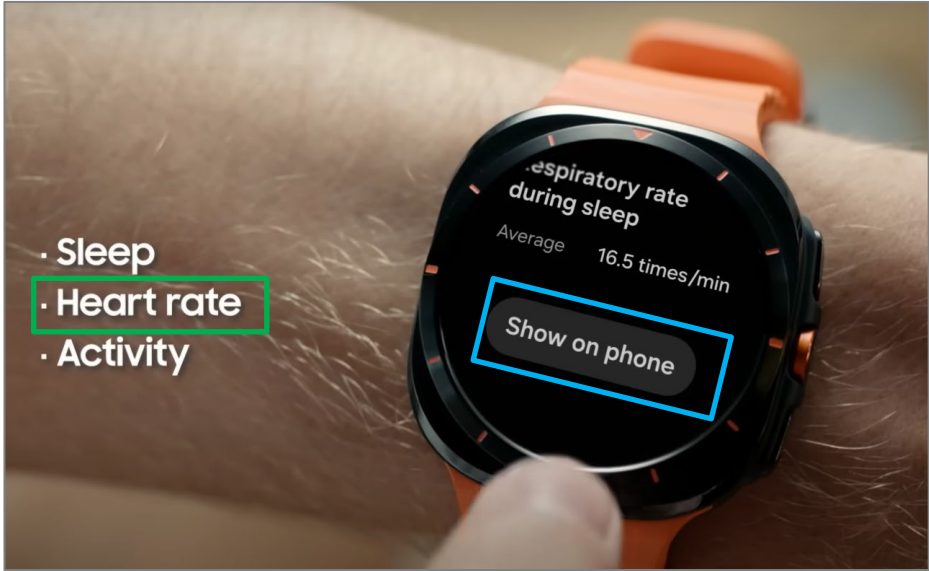
’484 Patent Claim ¹	Samsung Accused System ²
	<div data-bbox="514 224 1253 719"></div> <div data-bbox="514 768 1092 881"><h3>More precise <u>Heart Rate Tracking</u></h3></div> <div data-bbox="514 889 1213 1170"><p>Zero in on more precise readings during workouts using Heart Rate Tracking^{3, 4, 5} with Galaxy AI² that filters out the physical movements of your body. <u>Insights are collected by your Watch and analyzed on your phone.</u></p></div> <div data-bbox="485 1195 1852 1268"><p>Source: https://www.samsung.com/us/watches/galaxy-watch-ultra/buy/galaxy-watch-ultra-47mm-titanium-gray-sm-l705udaaxaa/</p></div>

’484 Patent Claim ¹	Samsung Accused System ²
	<div data-bbox="993 237 1337 339" data-label="Section-Header"> <h3>Set your own Heart Rate Zone</h3> </div> <div data-bbox="491 354 1837 402" data-label="Text"> <p>Exercise at your optimal fitness capacity to reach your workout goals. With the Galaxy Watch Series, you have the flexibility to set your Personalized HR Zone to reach your health and wellness targets.</p> </div> <div data-bbox="491 423 1509 459" data-label="Text"> <p>Source: https://www.samsung.com/us/apps/samsung-health/#Improve_your_life</p> </div> <div data-bbox="915 570 1365 631" data-label="Section-Header"> <h3>Pairs well with</h3> </div> <div data-bbox="812 662 1470 695" data-label="Text"> <p>Experience a smarter life with a Galaxy that'll keep up with you.</p> </div> <div data-bbox="512 776 1734 1227" data-label="Image"> <p>The image displays three Samsung Galaxy products arranged horizontally. On the left is the Galaxy Watch Ultra, a smartwatch with a black face and an orange perforated strap. In the center is the Galaxy Z Fold6, shown in its folded state with a silver back and a black front. On the right is the Galaxy Z Flip6, shown in its unfolded state with a light blue back and a black front. The first two products are enclosed in a blue rectangular border.</p> </div> <div data-bbox="491 1243 1255 1279" data-label="Text"> <p>Source: https://www.samsung.com/us/apps/samsung-health/</p> </div>

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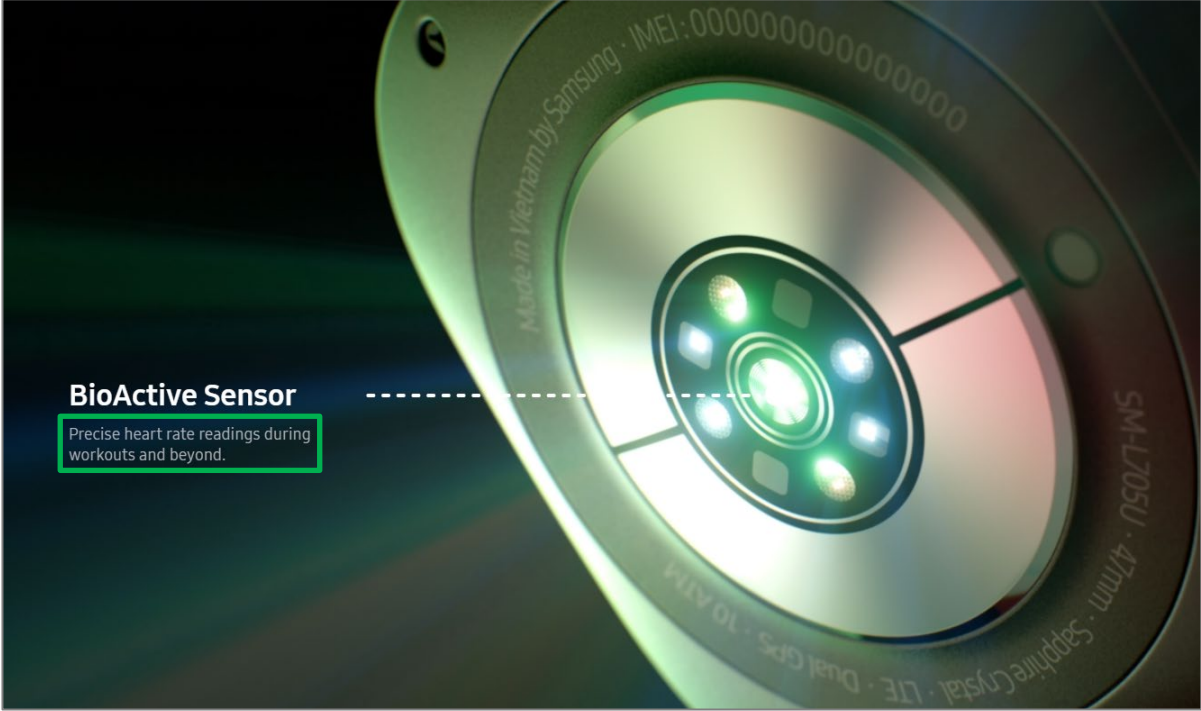
’484 Patent Claim ¹	Samsung Accused System ²
	<div data-bbox="487 233 1094 1032"></div> <div data-bbox="1184 409 1661 529" style="border: 1px solid green; padding: 5px; text-align: center;">Heart rate (“physiological parameter”)</div> <p data-bbox="487 1036 1512 1071">Source: https://www.samsung.com/us/apps/samsung-health/#Improve_your_life</p>

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'484 Patent Claim ¹	Samsung Accused System ²
	<p>The Samsung Health application is installed on both the Galaxy Watch and a smartphone. The application synchronizes the measurements between both devices and manages the user's health data securely on them.</p> <div data-bbox="886 279 1421 563"></div> <p style="text-align: center;">Figure 1: Samsung Health on Galaxy Watch and Android smartphone</p> <p>Source: https://developer.samsung.com/health/blog/en/health/blog/accessing-samsung-health-data-through-health-connect</p> <div data-bbox="487 732 1409 1299"></div>

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'484 Patent Claim ¹	Samsung Accused System ²
	<p>Source: https://www.youtube.com/watch?v=VQW-ZpdAm5M</p>  <p>BioActive Sensor Precise heart rate readings during workouts and beyond.</p> <p>Source: https://www.samsung.com/us/watches/galaxy-watch-ultra/</p>
<p>7[a] a wearable device adapted to be placed on a wrist or an ear of a user, and including a light source comprising a plurality of</p>	<p>The Accused System comprises a wearable device adapted to be placed on a wrist or an ear of a user, and including a light source comprising a plurality of semiconductor sources, either literally or under the doctrine of equivalents.</p> <p>For example, the Accused Smartwatch (“wearable device”) is worn on the wrist of the user (“adapted to be placed on a wrist . . . of a user”).</p>

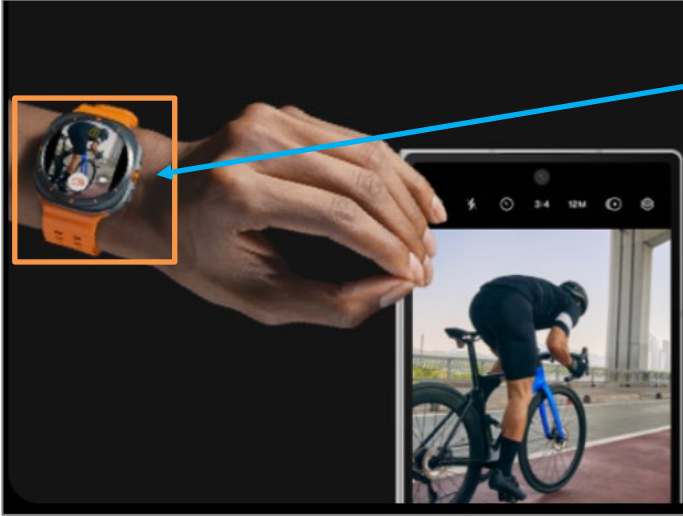
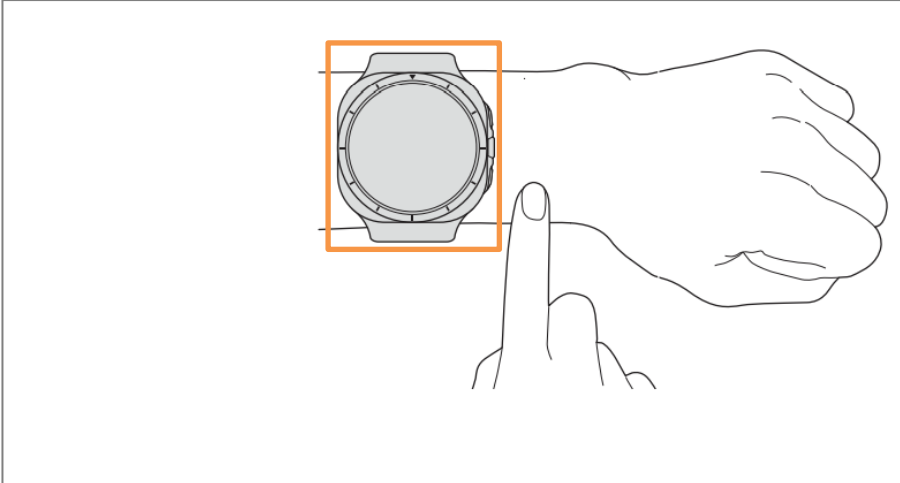
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’484 Patent Claim ¹	Samsung Accused System ²
semiconductor sources,	<div data-bbox="489 199 1008 786"></div> <p data-bbox="489 792 1854 862">Source: https://www.samsung.com/us/watches/galaxy-watch-ultra/buy/galaxy-watch-ultra-47mm-titanium-gray-sm-l705udaaxaa/</p>

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’484 Patent Claim ¹	Samsung Accused System ²
	<div data-bbox="489 199 1167 711"></div> <div data-bbox="1272 207 1665 362"><p>Accused Smartwatch is adapted to be placed on a wrist of a user.</p></div> <p data-bbox="489 716 1339 748">Source: https://www.samsung.com/us/watches/galaxy-watch-ultra/</p> <div data-bbox="489 789 1383 1268"></div> <div data-bbox="489 1279 1339 1317"><p>1. Open the buckle and place the strap around your wrist.</p></div>

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’484 Patent Claim ¹	Samsung Accused System ²
	<p>Source: Samsung Galaxy Watch7 Watch Ultra User Guide at p. 10, <i>available at</i> https://downloadcenter.samsung.com/content/UM/202407/20240717003704208/WEA_L30X_L31X_L70X_EN_UG_XF3_070324_FINAL.pdf.</p> <p>The Accused Smartwatch includes a light source comprising multiple light emitting diodes (“LEDs”), such as a green LED, a red LED, and an infrared LED, each of which includes a “semiconductor source.”</p> <p>Samsung states, for example, that its “BioActive Sensor is essential to bringing you better preventative health experiences on the next Galaxy Watch, with design improvements that enable even more precise health insights. Samsung engineers focused on three upgrades to the new sensor: enhancing the performance of light-receiving photodiodes, adding additional colors of light-emitting diodes (LEDs) and arranging them optimally across the sensor.” Samsung Newsroom, Unlocking New Possibilities for Preventative Wellness with New Galaxy Watch and BioActive Sensor, Jul. 8, 2024, <i>available at</i> https://news.samsung.com/global/unlocking-new-possibilities-for-preventative-wellness-with-new-galaxy-watch-and-bioactive-sensor</p> <p>Samsung further states that “[t]he optimal allocation of Green, Red and Infrared LEDs sets new standards in wearable technology by improving accuracy and enabling exceptional performance across a broad array of health metrics. This allows the new BioActive Sensor to more accurately measure health metrics such as heart rate, sleep quality, blood pressure, blood oxygen levels and stress levels. Even the measurement of heart rate during intensive workouts is 30% more accurate compared to its predecessor.” Samsung Newsroom, Unlocking New Possibilities for Preventative Wellness with New Galaxy Watch and BioActive Sensor, Jul. 8, 2024, <i>available at</i> https://news.samsung.com/global/unlocking-new-possibilities-for-preventative-wellness-with-new-galaxy-watch-and-bioactive-sensor</p>

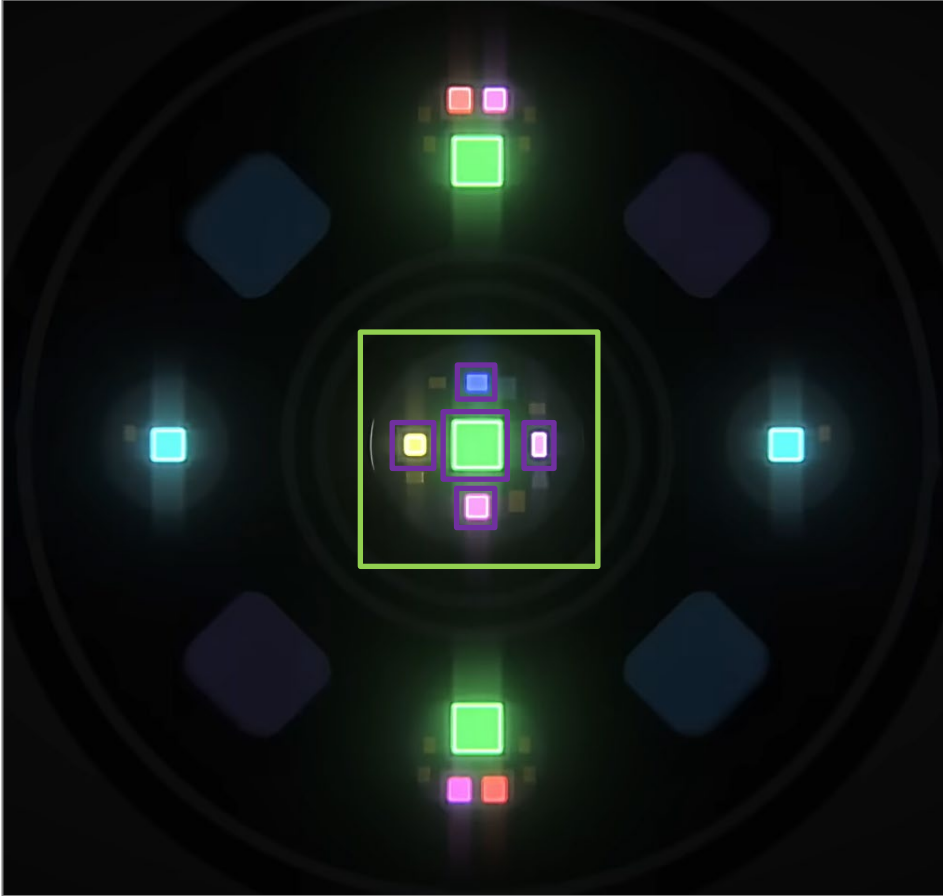
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	 <p>The diagram shows the back of a Samsung Galaxy Watch Ultra. Four features are highlighted with dashed lines and labels: 'Quick Button' at the top center, 'Dynamic Lug System' at the top right, 'Dual-Frequency GPS' at the bottom left, and 'BioActive Sensor' at the bottom right. The watch is black with orange accents on the lugs and buttons.</p> <p>Source: https://www.samsung.com/us/watches/galaxy-watch-ultra/</p>

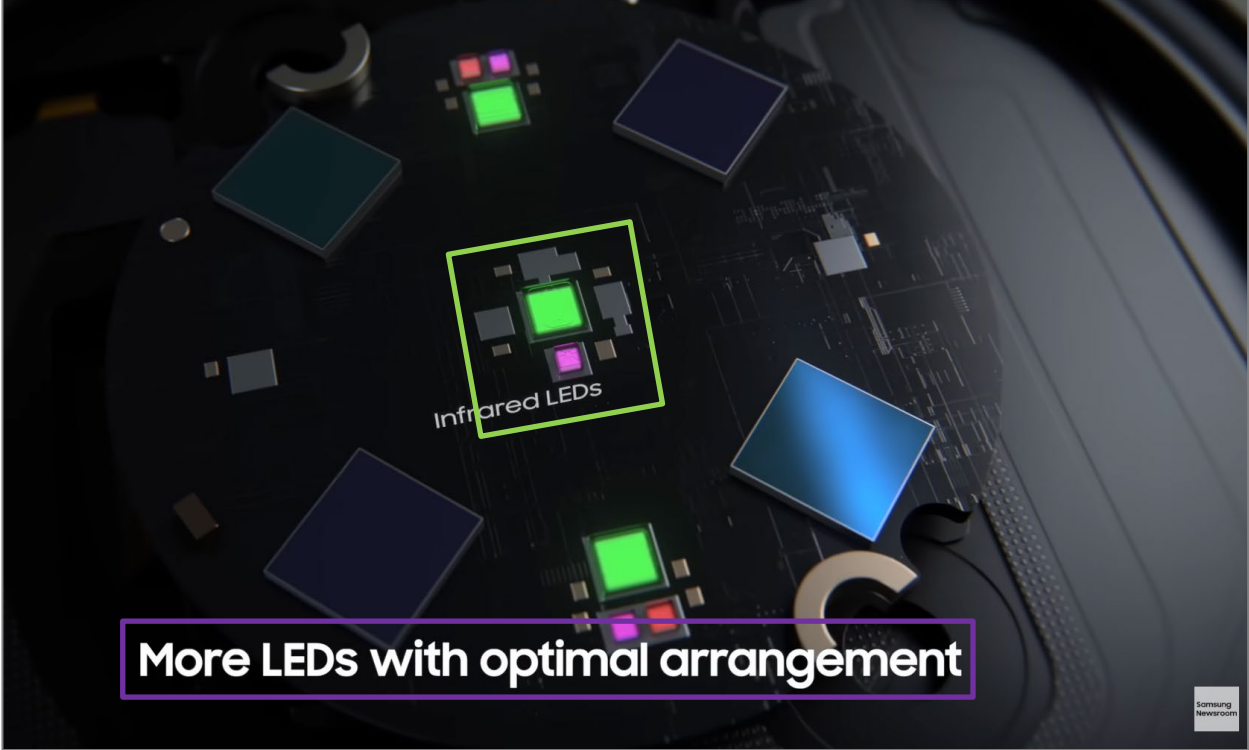
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’484 Patent Claim ¹	Samsung Accused System ²
	 <p data-bbox="489 1096 1856 1166">Source: https://news.samsung.com/global/unlocking-new-possibilities-for-preventative-wellness-with-new-galaxy-watch-and-bioactive-sensor</p>

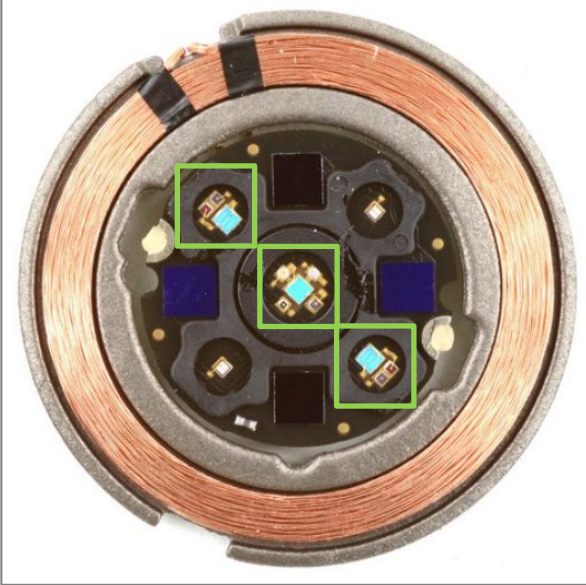
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	 <p data-bbox="489 954 1856 1024">Source: https://news.samsung.com/global/unlocking-new-possibilities-for-preventative-wellness-with-new-galaxy-watch-and-bioactive-sensor</p>

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'484 Patent Claim ¹	Samsung Accused System ²
	 <p>Source: IFIXIT, Samsung Galaxy Watch Ultra Chip ID, https://www.ifixit.com/Guide/Samsung+Galaxy+Watch+Ultra+Chip+ID/175327</p>
<p>7[b] each of the semiconductor sources configured to generate an output light having one or more optical wavelengths;</p>	<p>In the Accused Smartwatch, each of the semiconductor sources is configured to generate an output light having one or more optical wavelengths, either literally or under the doctrine of equivalents.</p> <p>For example, the Accused Smartwatch includes multiple LEDs (“semiconductor sources”), such as a green LED, a red LED, and an infrared LED. Different color LEDs and infrared LEDs each generate output light having different optical wavelengths.</p> <p>Samsung states that “[t]he optimal allocation of Green, Red and Infrared LEDs sets new standards in wearable technology by improving accuracy and enabling exceptional performance across a broad array of health metrics. This allows the new BioActive Sensor to more accurately measure health metrics such as heart rate, sleep quality, blood pressure, blood oxygen levels and stress levels. Even the measurement of</p>

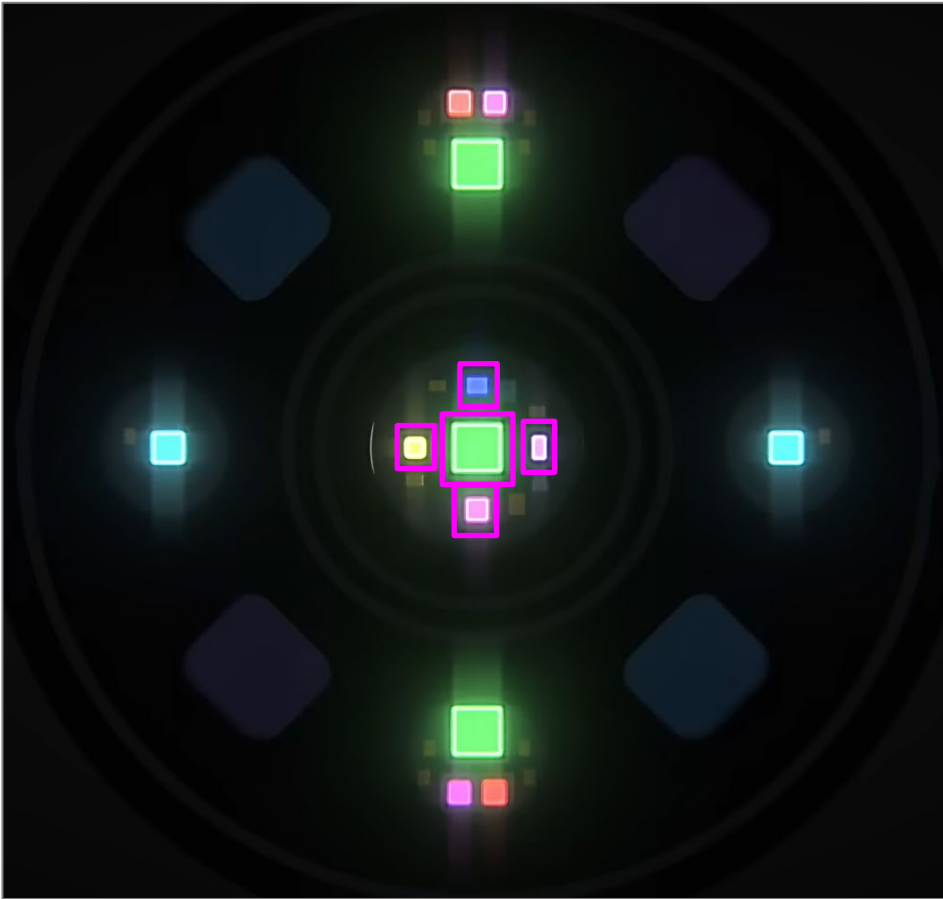
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’484 Patent Claim ¹	Samsung Accused System ²						
	<p>heart rate during intensive workouts is 30% more accurate compared to its predecessor.” Samsung Newsroom, Unlocking New Possibilities for Preventative Wellness with New Galaxy Watch and BioActive Sensor, Jul. 8, 2024, <i>available at</i> https://news.samsung.com/global/unlocking-new-possibilities-for-preventative-wellness-with-new-galaxy-watch-and-bioactive-sensor</p> <p>The following data types are supported by the Samsung Privileged Health SDK:</p> <table border="1" data-bbox="489 454 1509 873"><tr><td data-bbox="489 454 961 591">PPG green</td><td data-bbox="961 454 1509 591">Raw data from PPG <u>green</u> LED. Provided as a batching event.</td></tr><tr><td data-bbox="489 591 961 743">PPG IR</td><td data-bbox="961 591 1509 743">Raw data from PPG <u>infrared</u> LED. Provided as an on-demand event.</td></tr><tr><td data-bbox="489 743 961 873">PPG red</td><td data-bbox="961 743 1509 873">Raw data from PPG <u>red</u> LED. Provided as an on-demand event.</td></tr></table> <p>Source: Samsung Developer, Samsung Privileged Health SDK, <i>available at</i> https://developer.samsung.com/health/privileged/overview.html</p>	PPG green	Raw data from PPG <u>green</u> LED. Provided as a batching event.	PPG IR	Raw data from PPG <u>infrared</u> LED. Provided as an on-demand event.	PPG red	Raw data from PPG <u>red</u> LED. Provided as an on-demand event.
PPG green	Raw data from PPG <u>green</u> LED. Provided as a batching event.						
PPG IR	Raw data from PPG <u>infrared</u> LED. Provided as an on-demand event.						
PPG red	Raw data from PPG <u>red</u> LED. Provided as an on-demand event.						

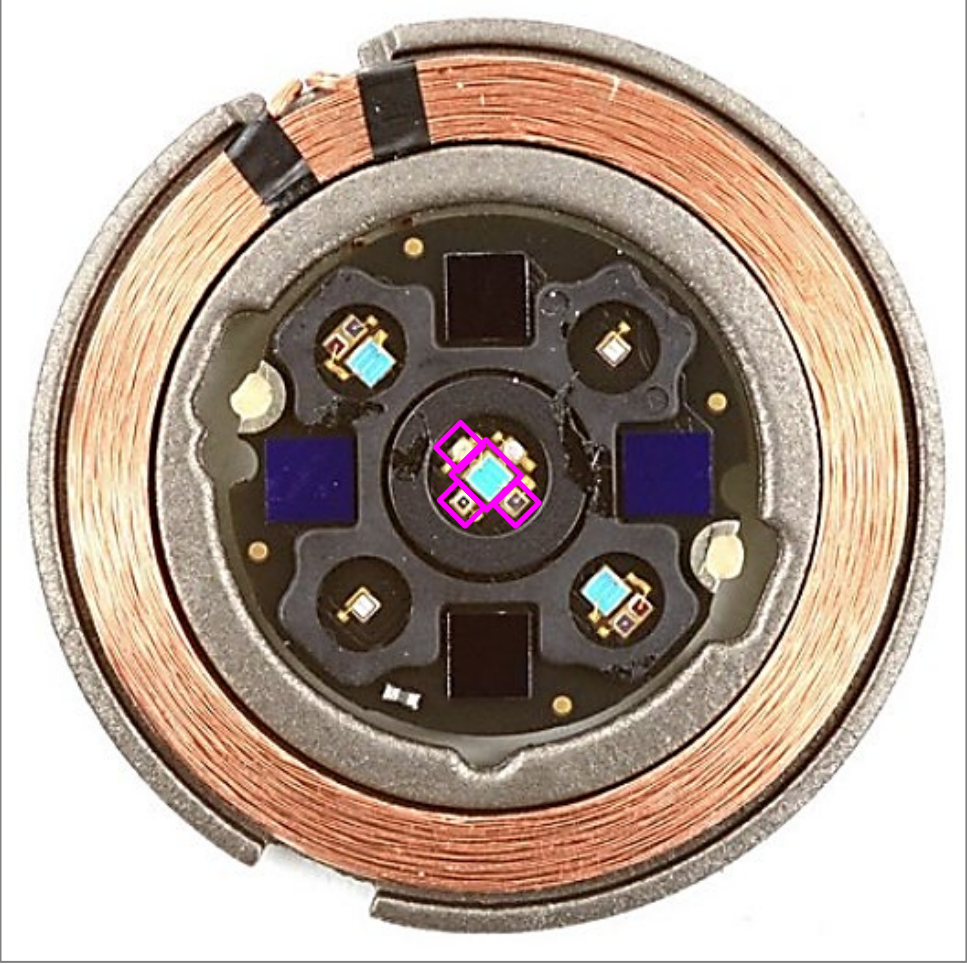
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’484 Patent Claim ¹	Samsung Accused System ²
	 <p data-bbox="489 1096 1856 1166">Source: https://news.samsung.com/global/unlocking-new-possibilities-for-preventative-wellness-with-new-galaxy-watch-and-bioactive-sensor</p>

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’484 Patent Claim ¹	Samsung Accused System ²
	<div data-bbox="491 201 1451 1159"></div> <p data-bbox="491 1166 1520 1235">Source: IFIXIT, Samsung Galaxy Watch Ultra Chip ID, https://www.ifixit.com/Guide/Samsung+Galaxy+Watch+Ultra+Chip+ID/175327</p>

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	<p>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:</p> <table border="1" data-bbox="495 310 1478 1107"> <thead> <tr> <th colspan="2" data-bbox="495 363 886 412">Table 1. LEDs – Wavelengths and Applications</th></tr> <tr> <th data-bbox="495 363 886 412">LED Wavelength (Color)</th><th data-bbox="886 363 1478 412">LED Applications</th></tr> </thead> <tbody> <tr> <td data-bbox="495 412 886 469">410–420 nm (Violet)</td><td data-bbox="886 412 1478 469">Skin therapy</td></tr> <tr> <td data-bbox="495 469 886 526">430–470 nm (Blue)</td><td data-bbox="886 469 1478 526">Dental curing instruments</td></tr> <tr> <td data-bbox="495 526 886 599">470 nm (Blue)</td><td data-bbox="886 526 1478 599">White LEDs using phosphor</td></tr> <tr> <td data-bbox="495 599 886 688">520–530 nm (Green)</td><td data-bbox="886 599 1478 688">Green traffic signal lights</td></tr> <tr> <td data-bbox="495 688 886 761">580–590 nm (Amber)</td><td data-bbox="886 688 1478 761">Amber traffic signal lights</td></tr> <tr> <td data-bbox="495 761 886 818">630–640 nm (Red)</td><td data-bbox="886 761 1478 818">Red signal lights</td></tr> <tr> <td data-bbox="495 818 886 875">660 nm (Deep Red)</td><td data-bbox="886 818 1478 875">Blood oximetry</td></tr> <tr> <td data-bbox="495 875 886 932">680 nm (Deep Red)</td><td data-bbox="886 875 1478 932">Blood analysis</td></tr> <tr> <td data-bbox="495 932 886 1013">800–850 nm (Near-IR)</td><td data-bbox="886 932 1478 1013">Night-vision illuminators and beacons for use with night-vision goggles or CCDs</td></tr> <tr> <td data-bbox="495 1013 886 1070">850–940 nm (Near-IR)</td><td data-bbox="886 1013 1478 1070">Photoelectric controls</td></tr> <tr> <td data-bbox="495 1070 886 1107">940 nm (Near-IR)</td><td data-bbox="886 1070 1478 1107">Covert illumination CCD-based systems</td></tr> </tbody> </table> <p>Source: https://www.photonics.com/Articles/Light-Emitting_Diodes_A_Primer/a36706</p>	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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<p>7[c] the wearable device comprising one or more lenses configured to</p>	<p>The Accused System comprises a wearable device comprising one or more lenses configured to receive a portion of at least one of the output lights and to deliver a lens output light to tissue, either literally or under the doctrine of equivalents.</p>																										

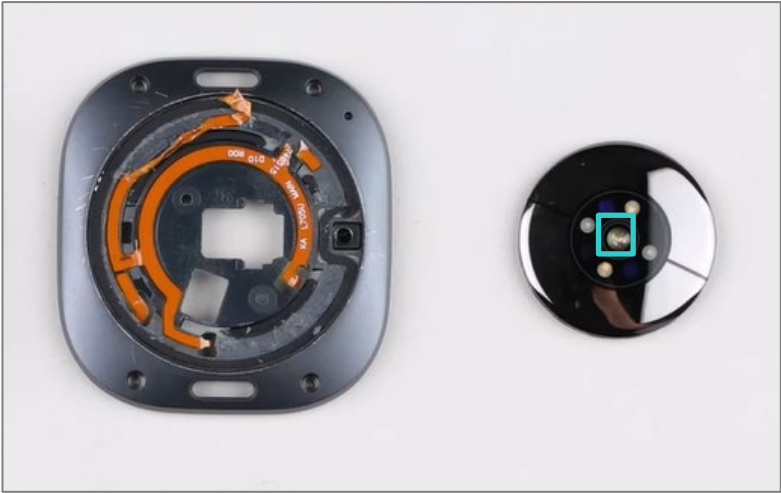
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’484 Patent Claim ¹	Samsung Accused System ²
<p>receive a portion of at least one of the output lights and to deliver a lens output light to tissue;</p>	<p>For example, the Accused Smartwatch (“wearable device”) comprises one or more lenses positioned between LEDs and the wrist of a user when worn by the user. The lenses receive output light from the LEDs and deliver the light to tissue of the user (e.g., skin, blood vessels, veins).</p> <div data-bbox="489 345 1556 946"></div> <p>Source: https://www.youtube.com/watch?v=IZ6Q7JqtiA0</p> <p>Samsung states that “[t]he Galaxy Watch uses light sensors that operate within the limits set by the IEC62471 safety regulations. However, people with photosensitive skin may have adverse reactions to light, such as skin discoloration or a rash.” Samsung Newsroom, Unlocking New Possibilities for Preventative Wellness with New Galaxy Watch and BioActive Sensor, Jul. 8, 2024, <i>available at</i> https://news.samsung.com/global/unlocking-new-possibilities-for-preventative-wellness-with-new-galaxy-watch-and-bioactive-sensor. Thus, the one or more lenses in the Accused Smartwatch delivers light that is output from the LEDs to skin of the user (“lens output light to tissue”).</p>

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	<div data-bbox="615 196 1180 695"></div> <p data-bbox="485 699 1224 732">Source: https://www.youtube.com/watch?v=lZ6Q7JqtiA0</p> <div data-bbox="489 771 1264 1260"></div> <p data-bbox="485 1266 1234 1299">Source: https://www.youtube.com/watch?v=jlW0i7u4FVk</p>

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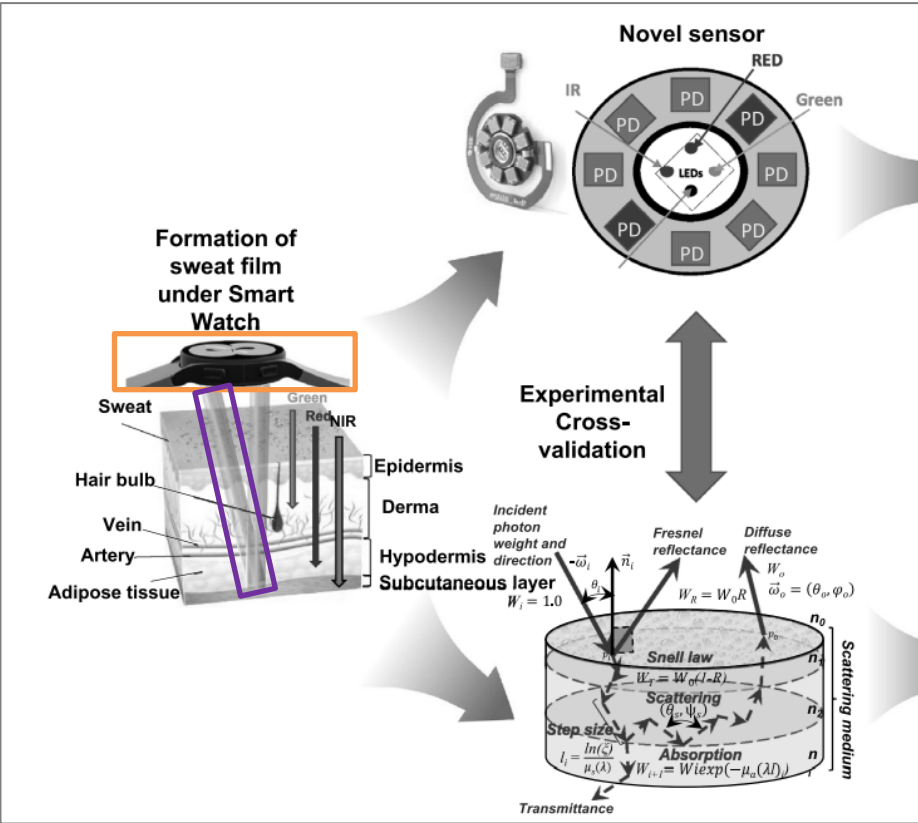
’484 Patent Claim ¹	Samsung Accused System ²
	<p>Additionally, in a technical paper, Samsung engineers and pixel designers for photoplethysmography (“PPG”) sensors explained “applying micro lenses” and using “micro lens focusing” techniques to enhance the delivery of infrared (“IR”) light sources. J. Lim et al., “A single chip PPG sensor with enhanced IR sensitivity for low power and small size,” 2021 IS&T Int’l Symp. Elec. Imaging, at 2-3, <i>available at</i> https://library.imaging.org/admin/apis/public/api/ist/website/downloadArticle/ei/33/7/art00002.</p> <p>Samsung’s Galaxy Watch7 and Watch Ultra user guide also states the following: “The accuracy of the information and data provided by this device and its related software, including heart rate readings, may be affected by factors such as environmental conditions, skin condition, specific activity performed while using/wearing the device, settings of the device, user configuration/user-provided information, placement of the sensor on the body, and other end-user interactions.” Samsung Galaxy Watch7 Watch Ultra User Guide, at p. 42, <i>available at</i> https://downloadcenter.samsung.com/content/UM/202407/20240717003704208/WEA_L30X_L31X_L70X_EN_UG_XF3_070324_FINAL.pdf.</p> <p>The Accused Smartwatch (“wearable device”) utilizes a biosensor manufactured by Texas Instruments (“TI”)—<i>e.g.</i>, an analog front end (“AFE”) integrated circuit component for PPG, electrocardiography (“ECG”) and other biosensing applications.</p>

U.S. Patent No. 10,517,484 (the “’484 Patent”)

“Semiconductor diodes-based physiological measurement device with improved signal-to-noise ratio”

’484 Patent Claim ¹	Samsung Accused System ²
	<p data-bbox="499 212 852 240">Step 6 Bio Sensor Assembly</p> <div data-bbox="499 256 1856 753"></div> <p data-bbox="1188 440 1661 461">● Texas Instruments AFE4510 biosensing analog front-end</p> <p data-bbox="485 776 1856 883">Source: IFIXIT, Samsung Galaxy Watch Ultra Chip ID, https://www.ifixit.com/Guide/Samsung+Galaxy+Watch+Ultra+Chip+ID/175327?srsId=AfmBOoriU1zDb_SwZ7O5CP4JIQFSWUnKHWqSe9g6SXYqF3F-NzUYIGpw.</p> <p data-bbox="485 922 1856 1029">Such AFEs from TI include AFE44S30, AFE4432, AFE44I30, AFE4460, AFE49I30, AFE4950, AFE4500. See Texas Instruments, Biosensing AFEs, https://www.ti.com/data-converters/integrated-special-function/medical-afes/biosensing-afes/overview.html.</p> <p data-bbox="485 1068 1856 1138">TI’s AFEs enable wearable devices to perform multiple optical biosensing applications. For example, TI explains in a technical paper:</p>

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	<p>Application</p> <p><i>Optical Heart Rate Monitoring (OHRM) uses the principle of photoplethysmography (PPG) to determine the heart rate.</i> For a healthy individual, the heart pumps blood to all parts of the body in each cardiac cycle. This causes the volume of the blood in the arteries to have a pulsating component that has the periodicity of the heart rate. <i>By illuminating the skin using a light-emitting diode (LED) and measuring the amount of light either transmitted or reflected to a photodiode (PD), the pulsating waveform can be converted to a signal current.</i> As shown in Figure 1, an analog front-end (AFE) converts the signal current waveform from the PD to a digitized waveform which can then be processed by a signal processing algorithm in the MCU to extract the heart rate (HR).</p> <p>In a device like a smartwatch, the LED and PD both face the wrist. The light from the LED is incident on the skin, and the reflection of the light from the artery results in a pulsating component. Typically, green LEDs are used, and the signal from multiple spatially-separated PDs are combined to mitigate effects such as motion.</p> <p>Texas Instruments, Application Brief, “Optical Heart Rate Monitoring (OHRM) on Wearables,” SBAA564, Nov. 2022, at 1, available at https://www.ti.com/lit/ab/sbaa564/sbaa564.pdf.</p>

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	<p>Additionally, the following scientific report authored by multiple Samsung engineers further shows lens output light being delivered to tissue of the user:</p>  <p>Source: E. Volkova et al., “Multispectral sensor fusion in SmartWatch for in situ continuous monitoring of human skin hydration and body sweat loss,” Scientific Reports (2023), at 3, available at https://www.nature.com/articles/s41598-023-40339-7.pdf.</p>

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<p>7[d] 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 signal having a signal-to-noise ratio,</p>	<p>The wearable device of the Accused System further 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.</p> <p>For example, the BioActive Sensor in the Accused Smartwatch (“wearable device”) comprises a detection system that: (a) receives light initially output from LEDs that is reflected from tissue of a user (“configured to receive at least a portion of the lens output light reflected from the tissue”), and (b) generates an output PPG signal having a signal-to-noise ratio.</p> <div data-bbox="504 519 1575 1006"> </div> <p>Source: Samsung Galaxy Watch7 / Galaxy Watch Ultra User Guide (06/2024, Rev.1.0), at 8, <i>available at</i> https://downloadcenter.samsung.com/content/UM/202407/20240711132033461/SM-L30X_L31X_L705F_UG_EU_Android_Eng_Rev.1.0_240626.pdf; <i>see also</i> Samsung Developer, Samsung Privileged Health SDK, <i>available at</i> https://developer.samsung.com/health/privileged/overview.html.</p>

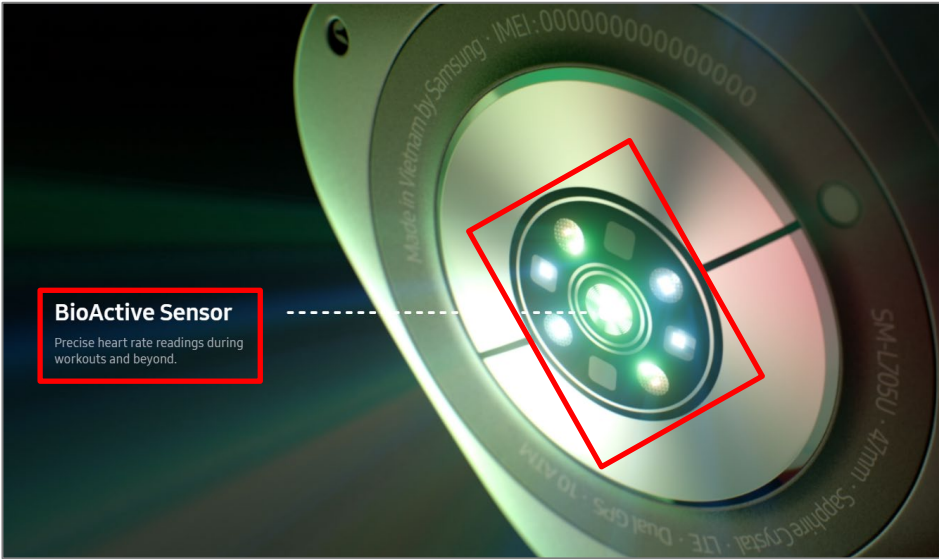
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	 <p>The diagram shows the back of a Samsung Galaxy Watch Ultra with a black case and a brown leather strap. Several features are labeled with dashed lines pointing to them: 'Quick Button' at the top center, 'Dynamic Lug System' at the top right, 'Dual-Frequency GPS' at the bottom left, and 'BioActive Sensor' at the bottom right (highlighted with a red box). The watch is shown against a black background.</p> <p>Source: https://www.samsung.com/us/watches/galaxy-watch-ultra/</p>

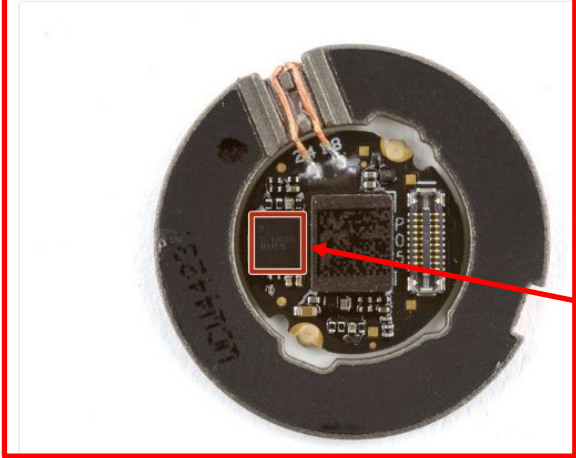
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	 <p>BioActive Sensor Precise heart rate readings during workouts and beyond.</p> <p>Source: https://www.samsung.com/us/watches/galaxy-watch-ultra/</p>

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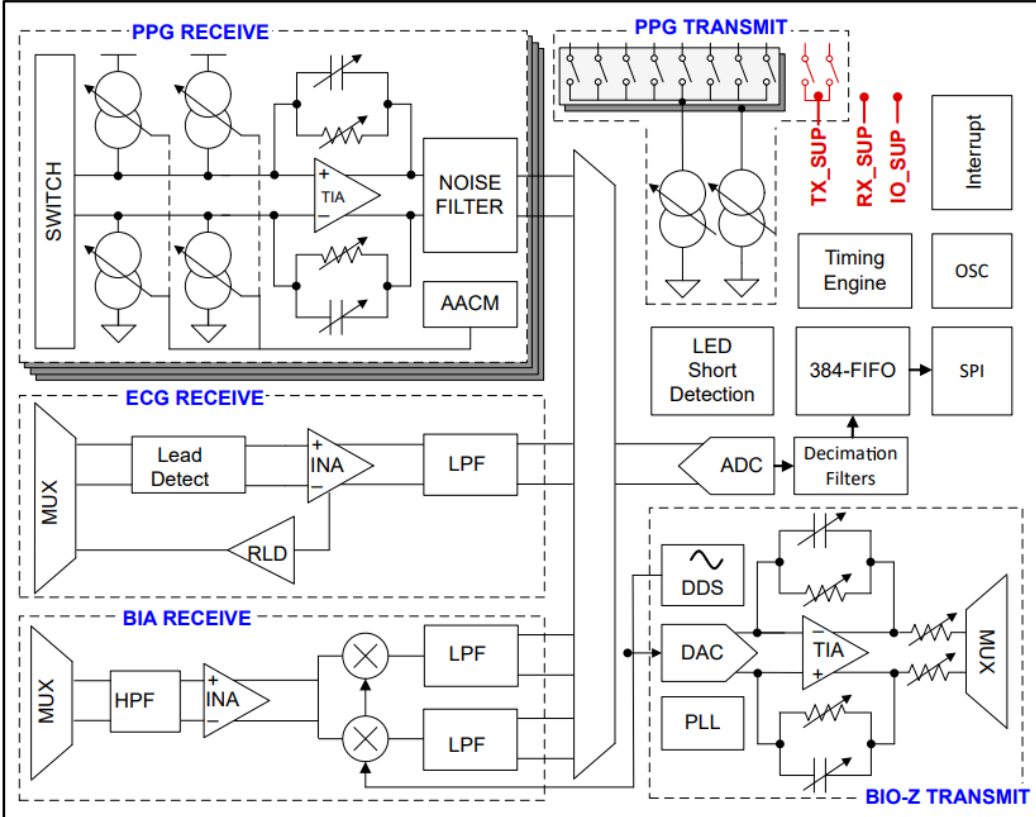
“Semiconductor diodes-based physiological measurement device with improved signal-to-noise ratio”

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	<div data-bbox="506 212 1077 716"><p>Step 6 Bio Sensor Assembly</p></div> <div data-bbox="1192 256 1864 418"></div> <div data-bbox="1192 427 1688 483"><p>• Texas Instruments AFE4510 biosensing analog front-end</p></div> <div data-bbox="1241 516 1770 641"><p>Texas Instruments Analog Front End (“AFE”) chip - AFE4510</p></div> <p>Source: IFIXIT, Samsung Galaxy Watch Ultra Chip ID, https://www.ifixit.com/Guide/Samsung+Galaxy+Watch+Ultra+Chip+ID/175327</p> <p>The AFE4510 specification (excerpts shown below) describes a PPG signal receiver, a PPG signal transmitter, and PPG signal acquisition functionality for receiving light output by LEDs that is reflected from skin and body tissue of the user (<i>e.g.</i>, by photodiodes (“PDs”)), and for converting the received light into—<i>i.e.</i>, generating—a PPG output signal having a signal-to-noise ratio (“SNR”).</p>

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	<div data-bbox="485 196 1560 367" style="border: 1px solid red; padding: 5px;">  <div style="float: right; text-align: right;"> AFE4510 <small>SBASB19 – MARCH 2024</small> </div> <hr/> <p align="center">AFE4510 Ultra Small, Integrated AFE for Bio Impedance Analysis, Electrical Bio Sensing & Optical Bio Sensing</p> </div> <div data-bbox="485 383 1234 1166" style="border: 1px solid green; padding: 10px; margin-top: 10px;"> <ul style="list-style-type: none"> • PPG signal acquisition: <ul style="list-style-type: none"> – Acquisition of 24 PPG signal sets (LED, AMB) – Supports PPG sensors at different data rates – Peak system SNR of 115 dB in 0.5-10Hz band enables high-accuracy SpO₂ measurement – Low Current for Continuous Operation with a Typical Value: 19µA for the Receiver • PPG Transmitter: <ul style="list-style-type: none"> – 8-Bit Programmable LED Current with a range adjustable from 50mA to 300mA – LED Short Detection – Support of 16 LEDs in Common Anode configuration for SpO₂, OHRM, Spectroscopy • PPG Receiver: <ul style="list-style-type: none"> – Supports 5 PDs, 4 parallel receive paths – Noise filtering with programmable bandwidth – Trans-impedance Gain: 3.7kΩ to 1MΩ – 8-bit Ambient Offset Subtraction DAC up to 256µA – 9-bit LED Offset Subtraction DAC up to 64µA – Digital Ambient Subtraction at ADC Output </div>

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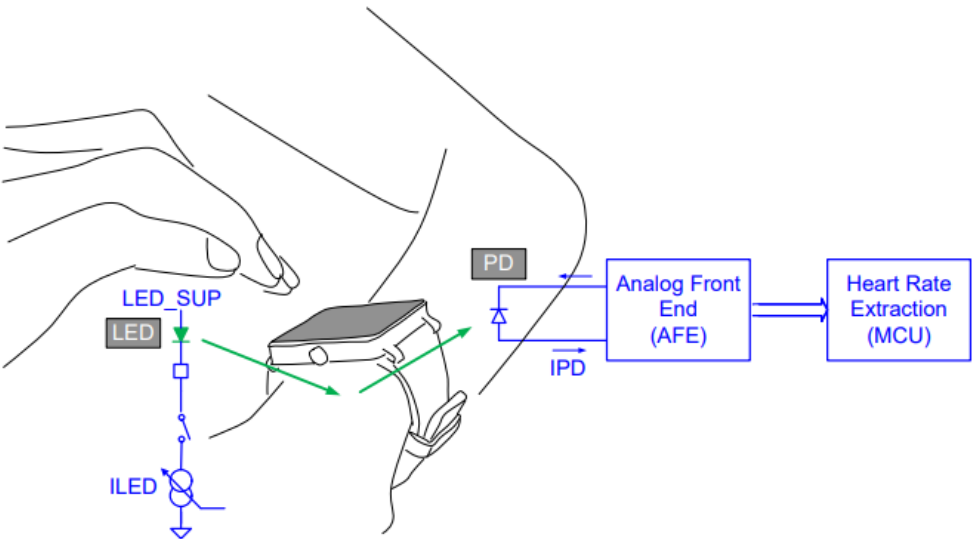
'484 Patent Claim ¹	Samsung Accused System ²
	 <p align="center">Simplified Schematic</p> <p>The schematic illustrates the internal components of the Samsung Accused System, organized into several functional blocks:</p> <ul style="list-style-type: none"> PPG RECEIVE: A dashed box containing a SWITCH, two photodiodes, a TIA (Transimpedance Amplifier), a NOISE FILTER, and an AACM (Automatic Ambient Light Compensation) block. PPG TRANSMIT: A dashed box containing a multi-channel switch, two photodiodes, and three signal lines labeled TX_SUP, RX_SUP, and IO_SUP. ECG RECEIVE: A dashed box containing a MUX (Multiplexer), a Lead Detect block, an INA (Instrumentation Amplifier), an RLD (Right Leg Drive) block, and an LPF (Low Pass Filter). BIA RECEIVE: A dashed box containing a MUX, an HPF (High Pass Filter), an INA, two multipliers (X), and two LPFs. BIO-Z TRANSMIT: A dashed box containing a DDS (Direct Digital Synthesizer), a DAC (Digital-to-Analog Converter), a PLL (Phase-Locked Loop), a TIA, and a MUX. Other Blocks: LED Short Detection, 384-FIFO, SPI, Timing Engine, OSC (Oscillator), Interrupt, ADC (Analog-to-Digital Converter), and Decimation Filters. <p>The system is connected to external pins: TX_SUP, RX_SUP, IO_SUP, and an Interrupt pin.</p>

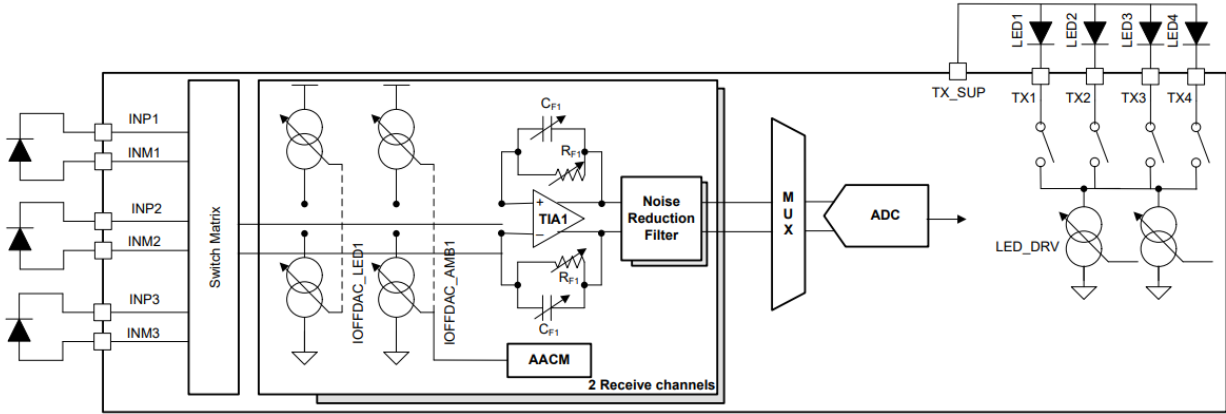
Source: Texas Instruments, AFE4510, SBASB19 – March 2024, at 1-2, available at <https://www.ti.com/lit/ds/symlink/afe4510.pdf>.

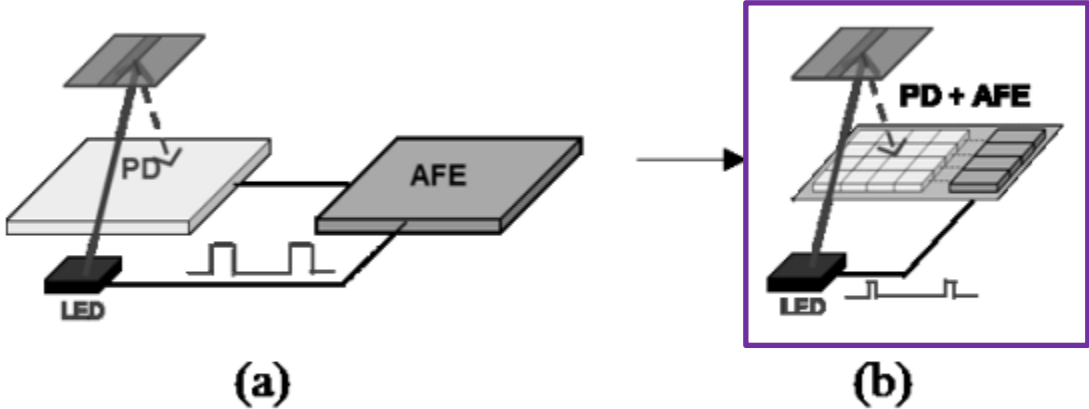
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	<p>The BioActive Sensor (“detection system”) in the Accused Smartwatch is configured to receive lens output light that is reflected from body tissue of the user and to generate and output PPG signal to enable multiple biosensing applications, including optical heart rate monitoring (“OHRM”).</p> <p>For example, TI explains OHRM using its AFE biosensors as follows:</p> <p><i>Optical Heart Rate Monitoring (OHRM) uses the principle of photoplethysmography (PPG) to determine the heart rate. For a healthy individual, the heart pumps blood to all parts of the body in each cardiac cycle. This causes the volume of the blood in the arteries to have a pulsating component that has the periodicity of the heart rate. By illuminating the skin using a light-emitting diode (LED) and measuring the amount of light either transmitted or <u>reflected to a photodiode (PD)</u>, the pulsating waveform can be <u>converted to a signal current</u>. As shown in Figure 1, an analog front-end (AFE) converts the <u>signal current waveform from the PD to a digitized waveform which can then be processed by a signal processing algorithm in the MCU to extract the heart rate (HR)</u>.</i></p> <p>In a device like a smartwatch, the LED and PD both face the wrist. The light from the LED is incident on the skin, and the <u>reflection of the light from the artery</u> results in a pulsating component. Typically, green LEDs are used, and the signal from multiple spatially-separated PDs are combined to mitigate effects such as motion.</p>

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	 <p>Figure 1. Heart Rate Monitoring on a Wearable Device</p> <p>Source: Texas Instruments, Application Brief, “Optical Heart Rate Monitoring (OHRM) on Wearables,” SBAA564, Nov. 2022, at 1, available at https://www.ti.com/lit/ab/sbaa564/sbaa564.pdf.</p> <p>An exemplary “PPG signal chain” for a TI AFE biosensor (shown below) further illustrates how the BioActive Sensor (“detection system”) of the Accused Smartwatch is configured to receive a lens output light reflected from tissue of a user and generate a PPG output signal.</p>

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	<p data-bbox="520 212 1062 240">Figure 3 shows the PPG signal chain in AFE4432.</p>  <p data-bbox="905 688 1356 716">Figure 3. PPG Signal Chain in AFE4432</p> <p data-bbox="520 743 1728 885">The LED driver drives up to 4 LEDs with programmable current. Each receiver can interface to up to 3 PDs and comprises a TIA, input DC offset cancellation DACs (for ambient, LED light), and noise reduction filters with programmable bandwidth. Both receivers share a common analog-to-digital converter (ADC). The PPG signal chain for optical heart rate monitoring on wearables is supported on many other AFEs from Texas Instruments such as the AFE4950, AFE4960P, and AFE4500 devices.</p> <p data-bbox="485 943 1814 1008">Source: Texas Instruments, Application Brief, “Optical Heart Rate Monitoring (OHRM) on Wearables,” SBAA564, Nov. 2022, at 2, available at https://www.ti.com/lit/ab/sbaa564/sbaa564.pdf.</p> <p data-bbox="485 1052 1766 1117">Samsung engineers further explain in technical papers a detection system configured to receive light reflected from tissue of a user and to generate an output PPG signal.</p> <p data-bbox="485 1161 1850 1299">For example: “Recently, the technology is migrated to wearable devices such as wrist-worn smart watch or a wireless ear set. Among them, PPG sensor is a health sensor that measures the change in blood flow to be modulated by the heart rate. When a separate light source (LED) is irradiated to the skin, the light absorption by the blood vessel is changed in synchronization with the heart rate. A sensor measures,</p>

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	<p>transmitted or reflected signal represented in Amplitude Modulation It has been used for a long time as a medical tool to measure oxygen saturation (SpO₂) in a patient's finger in an emergency status [1]. For the use of PPG sensors as various health care products, features of low power and smaller size are essentially required.”</p>  <p>(a) (b)</p> <p><i>Figure 1. (a) Separated chip PPG sensor and (b) Single chip PPG sensor</i></p> <p>Source: J. Lim et al., “A single chip PPG sensor with enhanced IR sensitivity for low power and small size,” 2021 IS&T Int’l Symp. Elec. Imaging, at 2-3, <i>available at</i> https://library.imaging.org/admin/apis/public/api/ist/website/downloadArticle/ei/33/7/art00002.</p> <p>For example: “Nowadays, our Smart watches are equipped with Samsung’s BioActive Sensor which has evolved to become far more advanced and miniature technology and not only able to ‘just’ count HR, steps and calories, but also can monitor sleep, measure blood pressure and more. . . . At present, wearable devices, including smart watches and fitness trackers, routinely monitor/analyze the PPG signal and provide non-invasive information of the aforementioned human health indicators with recent additions of temperature, blood oxygen level (SpO₂), etc. monitoring capabilities.”</p>

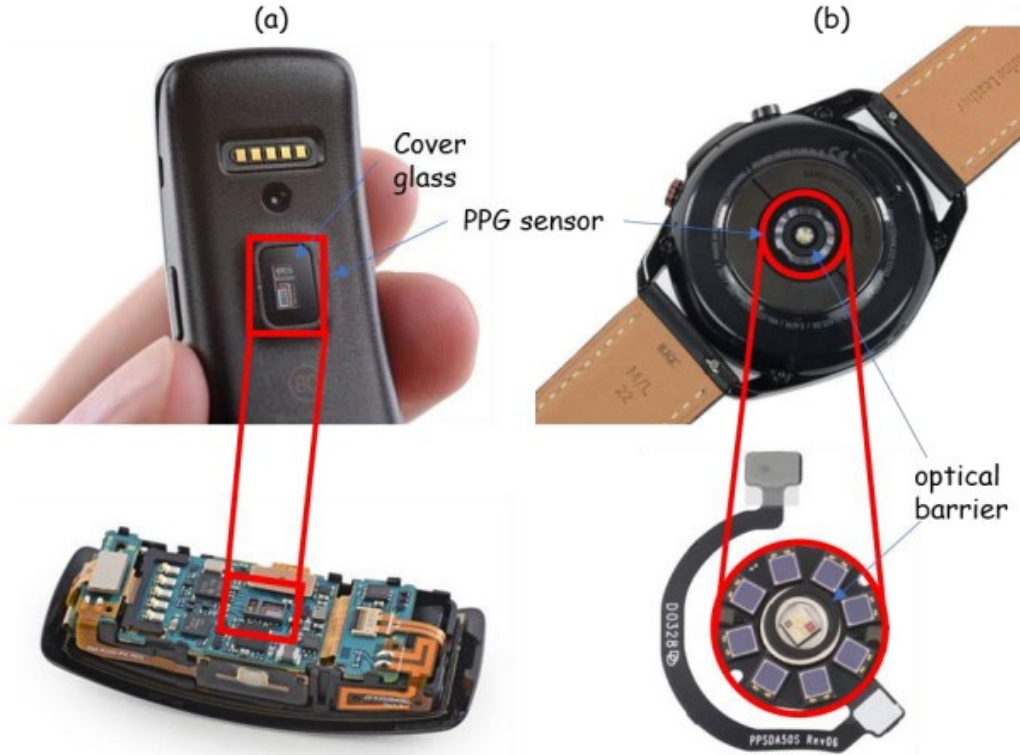
’484 Patent Claim ¹	Samsung Accused System ²
	<p>Figure 2. Our capture-to-sensing pipeline. Here: a sweat film is formed under the SmartWatch prototype; Custom-made sensor evaluates change in PPG signal at a range of wavelengths and distances; The trends in the signal are investigated using experimentally validated numerical algorithms of light transport in skin; Particular features of importance due to fluctuations of wet/dry skin optical properties are extracted based on their significance and a ML method is trained to readily detect them; Finally, sweat loss is quantitatively accessed and recommendations to consumer are made.</p> <p>Source: E. Volkova et al., “Multispectral sensor fusion in SmartWatch for in situ continuous monitoring of human skin hydration and body sweat loss,” Scientific Reports (2023), at 1-3, available at https://www.nature.com/articles/s41598-023-40339-7.pdf.</p>

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	<p>The detection system of the Accused Smartwatch has been detailed in other technical documents as well.</p> <p>For example:</p>

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	<div data-bbox="514 211 1638 779"> <p>Figure 3 consists of two sub-diagrams, (a) and (b), illustrating a PPG sensor module. In both, an LED and a PD (photodiode) are mounted on a PCB surface. In (a), the sensor module is in direct contact with a wrist. Red solid arrows point from the LED into the wrist, and blue solid arrows point from the wrist into the PD. Green solid arrows show light scattering within the tissue. Red dotted arrows show light reflecting back into the LED. In (b), the sensor module is covered by a glass surface. Red solid arrows point from the LED into the glass, then into the wrist. Blue solid arrows point from the wrist into the glass, then into the PD. Green solid arrows show light scattering within the tissue. Red dotted arrows show light reflecting back into the LED. Blue dotted arrows show light reflecting off the glass surface back towards the PD. Labels include 'wrist', 'sensor module', 'PCB surface', 'LED', 'PD', 'cover glass', and 'Devices equipped with sensor module'.</p> </div> <p>Figure 3. Conceptual diagram of a PPG sensor module with an embedded LED–PD pair. The diagram illustrates two scenarios: (a) when the integrated sensor module is in direct contact with the wrist and (b) when the sensor module is embedded in a device and covered with a glass surface. In the diagram, the red solid line represents incident light from the LED entering skin tissue, while the green solid line indicates light causing various reactions inside the tissue. The blue solid line represents light entering the PD from skin tissue and being detected. Additionally, the red dotted line in the diagram illustrates light reflected inside the sensor module that does not enter the skin, some of which directly enters the light-receiving unit. The blue dotted line represents the light that is reflected back by the cover glass among the light entering towards the PD.</p>

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	 <p>Figure 4. Representative examples of PPG sensor systems applied to commercial wrist-worn wearable devices: (a) the Samsung Galaxy Gear Fit, released in 2014, utilizes a sensor module with an embedded LED–PD optopair, and (b) the Samsung Galaxy Watch 3, released in 2020, uses separate LEDs and PDs as a sensor. An analog front end (AFE) is employed in both devices to measure the PD output as a PPG signal.</p>

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	 <p>Figure 5. Examples of PPG sensor configurations that use multiple LEDs and PDs, and their application to commercial smartwatches. (a–d) illustrate different PPG sensor structures, while (e) through (h) present examples of these structures in use: (e) structure (a) applied to the Samsung Galaxy Gear s3; (f) structure (d) applied to the Samsung Galaxy Watch; (g) shows the sensor structure of the Garmin Fenix 5 with three LEDs and one PD in the center, and (h) shows the sensor structure of the Apple Watch with two LEDs and two PDs.</p> <p>Source: Kim, K.B. et al., “Photoplethysmography in Wearable Devices: A Comprehensive Review of Technological Advances, Current Challenges, and Future Directions,” <i>Electronics</i> 2023, 12, 2923, at 7-9, available at https://www.mdpi.com/2079-9292/12/13/2923.</p>
7[e] wherein the detection system is	The detection system in the Accused Smartwatch is configured to be synchronized to the light source , either literally or under the doctrine of equivalents.

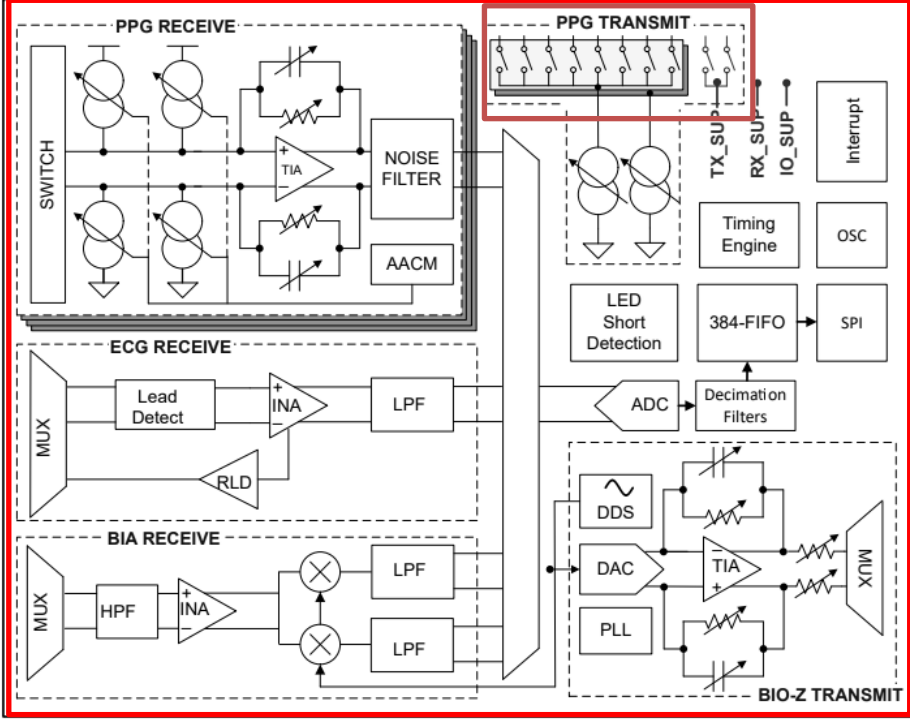
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configured to be synchronized to the light source;	<p>For example, the BioActive Sensor (“detection system”) is connected to the light source containing multiple LEDs. It is configured to synchronize with the light source by controlling the LED current (light intensity) and the pulse rate of the LEDs 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 both green and red LEDs (“light source”) blink alternately when measuring blood oxygen levels. This, among other evidence below, shows that the BioActive Sensor (“detection system”) is synchronized with the light source.</p> <p>The BioActive Sensor in the Accused Smartwatch features a biosensing AFE manufactured by TI (<i>e.g.</i>, AFE 4510). The AFE component used in the BioActive Sensor includes a detection system that is synchronized to programmable LEDs (“light source”).</p> <div data-bbox="489 711 1331 987" style="border: 1px solid black; padding: 5px;"> <p>PPG Transmitter:</p> <ul style="list-style-type: none"> – 8-Bit Programmable LED Current with a range adjustable from 50mA to 300mA – LED Short Detection – <u>Support of 16 LEDs in Common Anode configuration for SpO2, OHRM, Spectroscopy</u> </div>

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	 <p style="text-align: center;">Simplified Schematic</p> <p>“The AFE4510 is a versatile signal acquisition system that supports acquiring PPG, EDA, ECG, and Bioimpedance signals. A PPG signal chain comprises a current driver for LEDs and a receiver that senses the signal from PDs. An ECG receiver with a Rightleg drive (RLD) can acquire a single-lead ECG from a pair of electrodes. An impedance measurement signal chain with integrated excitation & sense can be used for applications like BIA, EDA, and Impedance spectroscopy. The outputs of the various signal chains are digitized by a common ADC and stored in a FIFO which can be read out using an SPI interface.”</p> <p>Source: Texas Instruments, AFE4510, SBASB19 – March 2024, at 1-2, <i>available at</i> https://www.ti.com/lit/ds/symlink/afe4510.pdf.</p>

’484 Patent Claim ¹	Samsung Accused System ²
	<p style="text-align: center;">Figure 3. PPG Signal Chain in AFE4432</p> <p>The LED driver drives up to 4 LEDs with programmable current. Each receiver can interface to up to 3 PDs and comprises a TIA, input DC offset cancellation DACs (for ambient, LED light), and noise reduction filters with programmable bandwidth. Both receivers share a common analog-to-digital converter (ADC). The PPG signal chain for optical heart rate monitoring on wearables is supported on many other AFEs from Texas Instruments such as the AFE4950, AFE4960P, and AFE4500 devices.</p> <p>Source: Texas Instruments, Application Brief, “Optical Heart Rate Monitoring (OHRM) on Wearables,” SBAA564, Nov. 2022, at 2, available at https://www.ti.com/lit/ab/sbaa564/sbaa564.pdf.</p>

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	<div data-bbox="1207 207 1598 256" data-label="Image"> </div> <p data-bbox="499 334 1587 516">Applications like optical heart rate and SpO₂ monitoring are based on the principle of Photoplethysmography (PPG). The primary challenges in PPG signal acquisition on a wrist-worn variable are: (i) small sensor size, (ii) relatively weak signal on wrist (low perfusion index), and (iii) interferers like ambient light and motion artifacts. TI's signal chain for PPG signal acquisition has 3 unique characteristics that help achieve excellent signal quality even in the most challenging conditions: (i) high gain transimpedance amplifier (TIA) to improve the SNR, (ii) DC offset cancellation DAC at the input, and (iii) noise reduction filter to reduce the optical noise bandwidth. These unique features help achieve excellent dynamic range at extremely low power consumption.</p> <div data-bbox="552 548 1528 800" data-label="Diagram"> </div> <div data-bbox="716 829 1365 1088" data-label="Diagram"> </div> <p align="center" data-bbox="968 1105 1129 1130">Block Diagram</p> <p data-bbox="485 1179 1854 1317">Source: Texas Instruments, Product Overview, “Photoplethysmography (PPG) with Integrated AFE for Optical Biosensing,” Oct. 2023, at 1, <i>available at</i> https://www.ti.com/lit/po/sbat014/sbat014.pdf?ts=1724246538793&ref_url=https%253A%252F%252Fwww.google.com%252F.</p>

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	<p>“The BioActive sensor has three sensors integrated inside. Apart from body composition, it can measure heart rate, ECG, and blood pressure. . . . It is one of the common uses of the BioActive sensor on your Galaxy Watch. The sensor relies on built-in green LEDs and infrared lights to calculate heart rate. These green LEDs are slotted between the BioActive sensor chips.” P. Shah, “What is Samsung BioActive sensor?” Android Police, July 17, 2024, https://www.androidpolice.com/samsung-bioactive-sensor-guide/.</p> <p>“The diverse colors of LEDs and new photodiodes enable the sensor to unlock new possibilities in health monitoring. One of the new features is the advanced glycation end products (AGEs) index, which is an indicator of metabolic health and biological aging.” “Samsung details BioActive Sensor ahead of Galaxy Unpacked,” fonearena, July 9, 2024, https://www.fonearena.com/blog/428320/samsung-bioactive-sensor-galaxy-unpacked-2024.html.</p> <p>A product video further explains functionalities of the light source (LEDs) and detection system, including how the detection system is configured to synchronize to differing flashing LED colors on the Accused Smartwatch to facilitate calculating different physiological parameters.</p>

U.S. Patent No. 10,517,484 (the “’484 Patent”)

“Semiconductor diodes-based physiological measurement device with improved signal-to-noise ratio”

’484 Patent Claim ¹	Samsung Accused System ²
	<div data-bbox="485 196 1411 717"></div> <p data-bbox="485 755 1848 868">Source: Ultra Value Tech, “Green Flashing Lights on Back of Samsung Galaxy Watch 7 – What Are They & How to Turn Them Off,” July 21, 2024, at 0:24, https://www.youtube.com/watch?v=JG9pGfqmges&t=23s.</p>

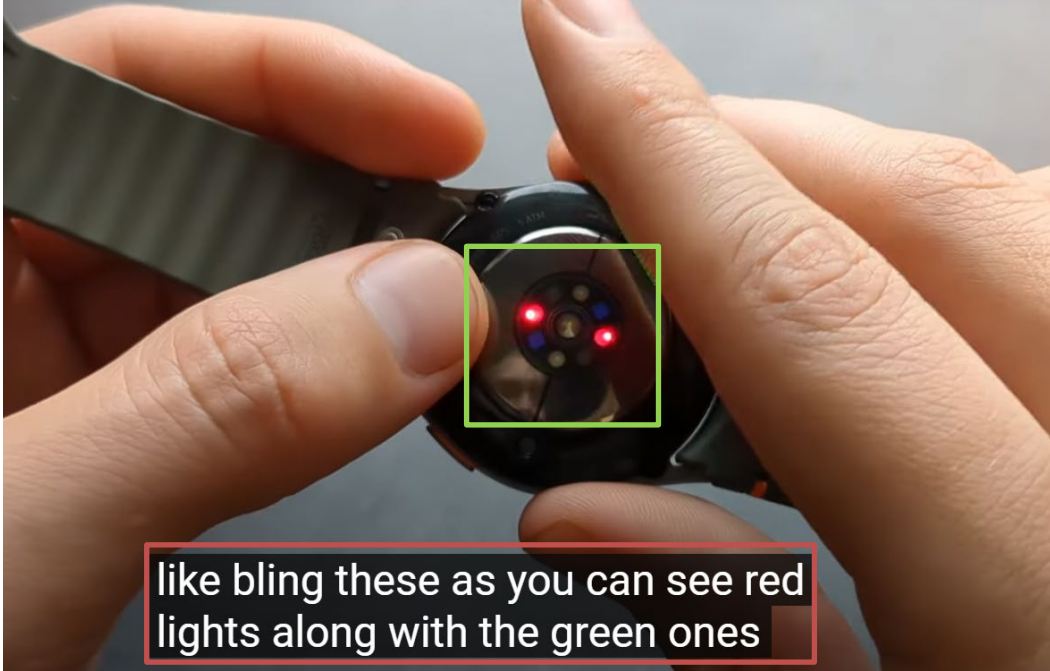
U.S. Patent No. 10,517,484 (the “’484 Patent”)

“Semiconductor diodes-based physiological measurement device with improved signal-to-noise ratio”

’484 Patent Claim ¹	Samsung Accused System ²
	<div data-bbox="485 196 1440 833"></div> <p data-bbox="485 873 1848 976">Source: Ultra Value Tech, “Green Flashing Lights on Back of Samsung Galaxy Watch 7 – What Are They & How to Turn Them Off,” July 21, 2024, at 0:37, https://youtu.be/JG9pGlgmges?si=IrcplcEOdHE3cB3l&t=37</p>

U.S. Patent No. 10,517,484 (the “’484 Patent”)

“Semiconductor diodes-based physiological measurement device with improved signal-to-noise ratio”

’484 Patent Claim ¹	Samsung Accused System ²
	<div data-bbox="485 196 1528 862"></div> <p data-bbox="485 902 1843 1008">Source: Ultra Value Tech, “Green Flashing Lights on Back of Samsung Galaxy Watch 7 – What Are They & How to Turn Them Off,” July 21, 2024, at 0:53, https://youtu.be/JG9pGlmges?si=xMBhD11dBJQoADTO&t=53</p>

U.S. Patent No. 10,517,484 (the “’484 Patent”)

“Semiconductor diodes-based physiological measurement device with improved signal-to-noise ratio”

’484 Patent Claim ¹	Samsung Accused System ²
	 <p>Source: Ultra Value Tech, “Green Flashing Lights on Back of Samsung Galaxy Watch 7 – What Are They & How to Turn Them Off,” July 21, 2024, at 0:53, https://youtu.be/JG9pGlqmgcs?si=YV8CQ6yVqkvL7ITZ&t=53</p>
<p><u>7 f </u> wherein the detection system comprises a plurality of spatially separated detectors, and</p>	<p>The detection system in the Accused Smartwatch comprises a plurality of spatially separated detectors, either literally or under the doctrine of equivalents.</p> <p>For example, the BioActive Sensor (“detection system”) includes multiple spatially separated photodiodes/PDs (“detectors”).</p> <p>“The all-new BioActive Sensor is essential to bringing you better preventative health experiences on the next Galaxy Watch, with design improvements that enable even more precise health insights. Samsung engineers focused on three upgrades to the new sensor: enhancing the performance of light-receiving</p>

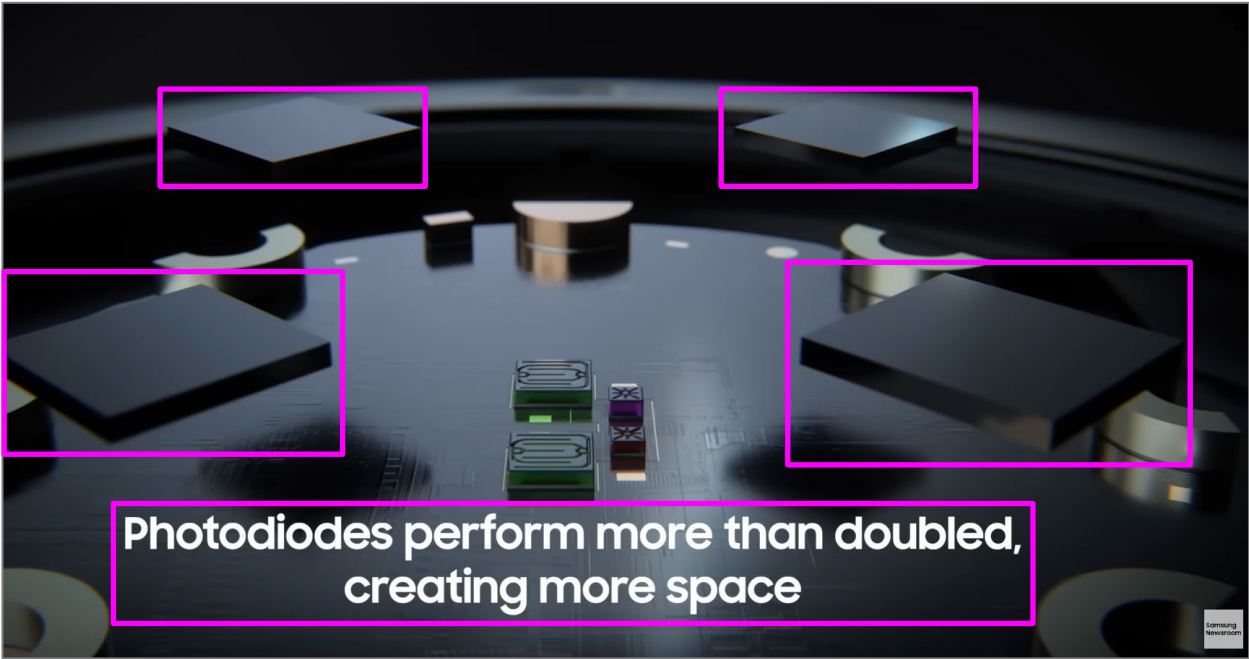
U.S. Patent No. 10,517,484 (the “’484 Patent”)

“Semiconductor diodes-based physiological measurement device with improved signal-to-noise ratio”

’484 Patent Claim ¹	Samsung Accused System ²
	<p>photodiodes, adding additional colors of light-emitting diodes (LEDs) and arranging them optimally across the sensor.”</p> <p>Samsung more than doubled the performance of each photodiode, successfully decreasing the number needed to maintain capacity from eight to four. This redesign freed up additional space for the integration of a larger number and variety of LEDs and ensured their optimal placement across the sensor. The new sensor now includes Blue, Yellow, Violet and Ultraviolet LEDs in addition to an increased number of Green, Red and Infrared LEDs. With the integration and arrangement of these LEDs, photodiodes and specially designed photodiode, Samsung is taking innovation one step further and is now able to pursue unexplored aspects of health monitoring on wearables. . . .</p> <p>The more diverse colors of LEDs and newly designed photodiodes unlock new possibilities and empower you to better predict trends and take proactive steps for preventative care. The first of these features will be an advanced glycation end products (AGEs) index — an indicator of metabolic health and biological aging strongly influenced by overall lifestyle and dietary habits. Used as an insightful biomarker, this index provides a snapshot of your biological age to help you make more informed decisions about your wellness journey and work towards a healthier future. The addition of an AGEs index is just one of the many new advanced features planned for the next Galaxy Watch.”</p> <p>Samsung Newsroom, “Unlocking New Possibilities for Preventative Wellness with New Galaxy Watch and BioActive Sensor,” Jul. 8, 2024, <i>available at</i> https://news.samsung.com/global/unlocking-new-possibilities-for-preventative-wellness-with-new-galaxy-watch-and-bioactive-sensor.</p>

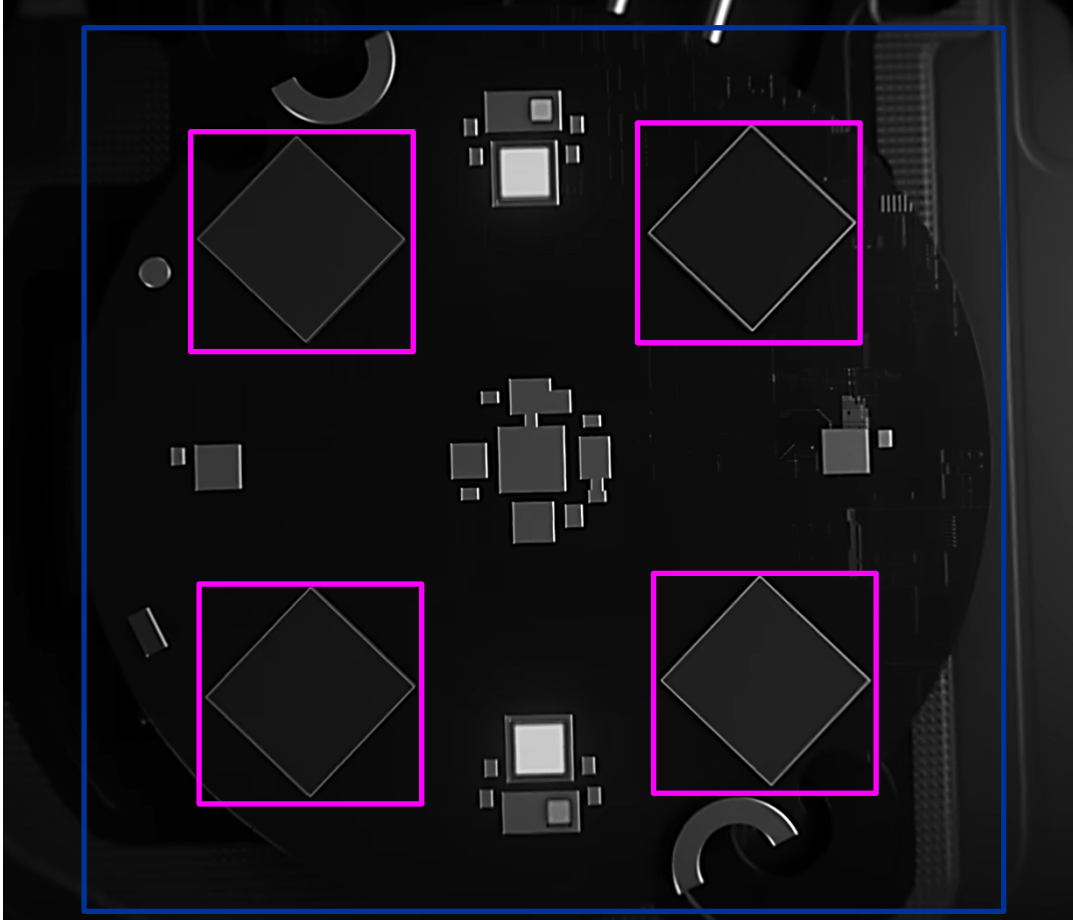
U.S. Patent No. 10,517,484 (the “’484 Patent”)

“Semiconductor diodes-based physiological measurement device with improved signal-to-noise ratio”

’484 Patent Claim ¹	Samsung Accused System ²
	<div data-bbox="489 196 1730 850"></div> <p data-bbox="489 894 1850 1073">Source: Samsung Newsroom, “Unlocking New Possibilities for Preventative Wellness with New Galaxy Watch and BioActive Sensor,” Jul. 8, 2024, <i>available at</i> https://news.samsung.com/global/unlocking-new-possibilities-for-preventative-wellness-with-new-galaxy-watch-and-bioactive-sensor; Samsung Newsroom, “Introducing Samsung’s New BioActive Sensor,” July 8, 2024, https://www.youtube.com/watch?v=snMLajaf0tc&t=7s.</p>

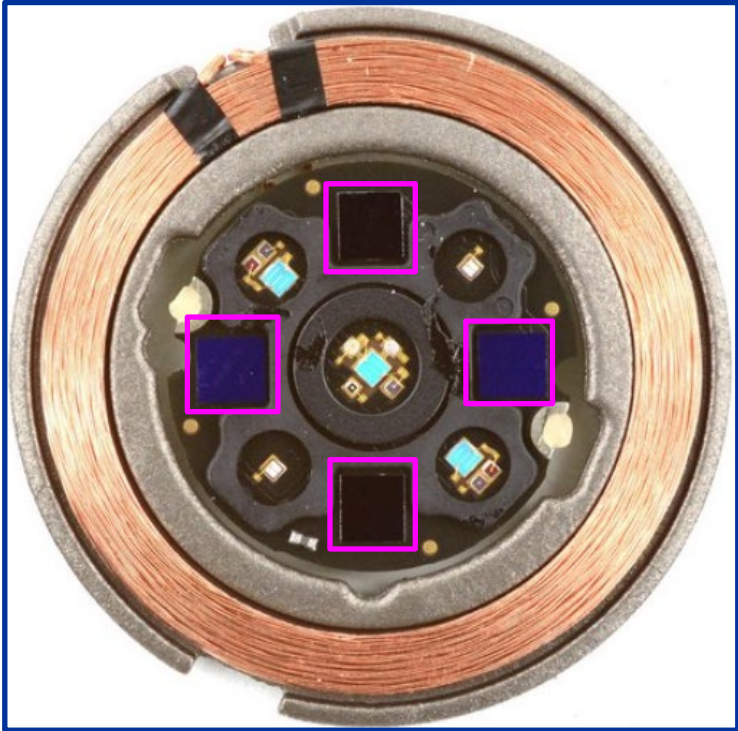
U.S. Patent No. 10,517,484 (the “’484 Patent”)

“Semiconductor diodes-based physiological measurement device with improved signal-to-noise ratio”

’484 Patent Claim ¹	Samsung Accused System ²
	<div data-bbox="485 196 1551 1110"></div> <p data-bbox="485 1149 1864 1325">Source: Source: Samsung Newsroom, “Unlocking New Possibilities for Preventative Wellness with New Galaxy Watch and BioActive Sensor,” Jul. 8, 2024, <i>available at</i> https://news.samsung.com/global/unlocking-new-possibilities-for-preventative-wellness-with-new-galaxy-watch-and-bioactive-sensor; Samsung Newsroom, “Introducing Samsung’s New BioActive Sensor,” July 8, 2024, https://www.youtube.com/watch?v=snMLajaf0tc&t=7s.</p>

U.S. Patent No. 10,517,484 (the “’484 Patent”)

“Semiconductor diodes-based physiological measurement device with improved signal-to-noise ratio”

’484 Patent Claim ¹	Samsung Accused System ²
	<div data-bbox="491 237 1224 964"></div> <p data-bbox="491 976 1625 1008">Source: https://www.ifixit.com/Guide/Samsung+Galaxy+Watch+Ultra+Chip+ID/175327</p> <p data-bbox="491 1049 1877 1260">“The AFE4510 is a versatile signal acquisition system that supports acquiring PPG, EDA, ECG, and Bioimpedance signals. A PPG signal chain comprises a current driver for LEDs and a receiver that senses the signal from PDs. An ECG receiver with a Rightleg drive (RLD) can acquire a single-lead ECG from a pair of electrodes. An impedance measurement signal chain with integrated excitation & sense can be used for applications like BIA, EDA, and Impedance spectroscopy. The outputs of the various signal chains are digitized by a common ADC and stored in a FIFO which can be read out using an SPI interface.” Texas</p>

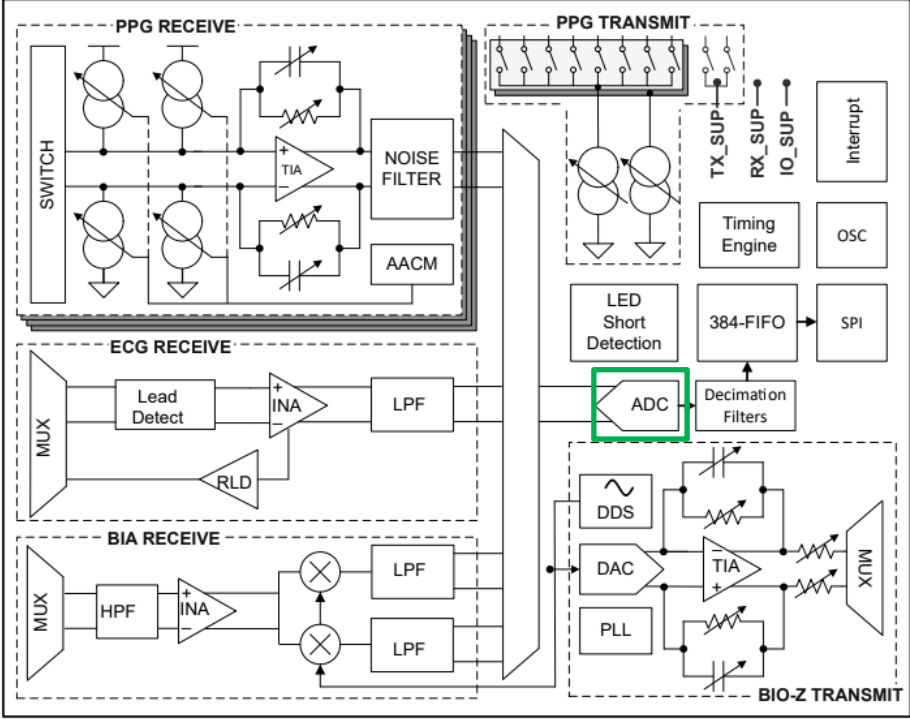
U.S. Patent No. 10,517,484 (the “’484 Patent”)

“Semiconductor diodes-based physiological measurement device with improved signal-to-noise ratio”

'484 Patent Claim ¹	Samsung Accused System ²
	Instruments, AFE4510, SBASB19 – March 2024, at 1, <i>available at</i> https://www.ti.com/lit/ds/symlink/afe4510.pdf .
<p>7[g] wherein at least one analog to digital converter is coupled to at least one of the spatially separated detectors;</p>	<p>In the Accused Smartwatch, there is at least one analog to digital converter that is coupled to at least one of the spatially separated detectors, either literally or under the doctrine of equivalents.</p> <p>For example, there is at least one analog to digital converter (“ADC”) coupled to at least one of the photodiodes/PDs (“detectors”) in the BioActive Sensor in the Accused Smartwatch.</p> <p>“The AFE4510 is a versatile signal acquisition system that supports acquiring PPG, EDA, ECG, and Bioimpedance signals. A PPG signal chain comprises a current driver for LEDs and a receiver that senses the signal from PDs. An ECG receiver with a Rightleg drive (RLD) can acquire a single-lead ECG from a pair of electrodes. An impedance measurement signal chain with integrated excitation & sense can be used for applications like BIA, EDA, and Impedance spectroscopy. The outputs of the various signal chains are digitized by a common ADC and stored in a FIFO which can be read out using an SPI interface.” Texas Instruments, AFE4510, SBASB19 – March 2024, at 1, <i>available at</i> https://www.ti.com/lit/ds/symlink/afe4510.pdf.</p>

U.S. Patent No. 10,517,484 (the “’484 Patent”)

“Semiconductor diodes-based physiological measurement device with improved signal-to-noise ratio”

'484 Patent Claim ¹	Samsung Accused System ²
	 <p align="center">Simplified Schematic</p> <p>Source: Texas Instruments, AFE4510, SBASB19 – March 2024, at 2, <i>available at</i> https://www.ti.com/lit/ds/symlink/afe4510.pdf.</p>
<p>7[h] the smart phone or tablet comprising a wireless receiver, a wireless transmitter, a display, a speaker, a voice input</p>	<p>The Accused System comprises an Accused Phone/Tablet comprising a wireless receiver, a wireless transmitter, a display, a speaker, a voice input module, one or more buttons or knobs, a microprocessor and a touch screen, either literally or under the doctrine of equivalents.</p>

U.S. Patent No. 10,517,484 (the “’484 Patent”)

“Semiconductor diodes-based physiological measurement device with improved signal-to-noise ratio”

’484 Patent Claim ¹	Samsung Accused System ²
<p>module, one or more buttons or knobs, a microprocessor and a touch screen,</p>	<p>For example, the Galaxy Watch Ultra pairs with the Galaxy Z Fold6 (“smart phone”). The Galaxy Z Fold6 includes Wi-Fi connectivity, which requires the smart phone to include both a wireless receiver and a wireless transmitter.</p> <div data-bbox="499 375 1318 1162"></div> <p>Source: https://www.samsung.com/us/smartphones/galaxy-z-fold6/buy/galaxy-z-fold6-512gb-unlocked-sm-f956uakexaa/</p>

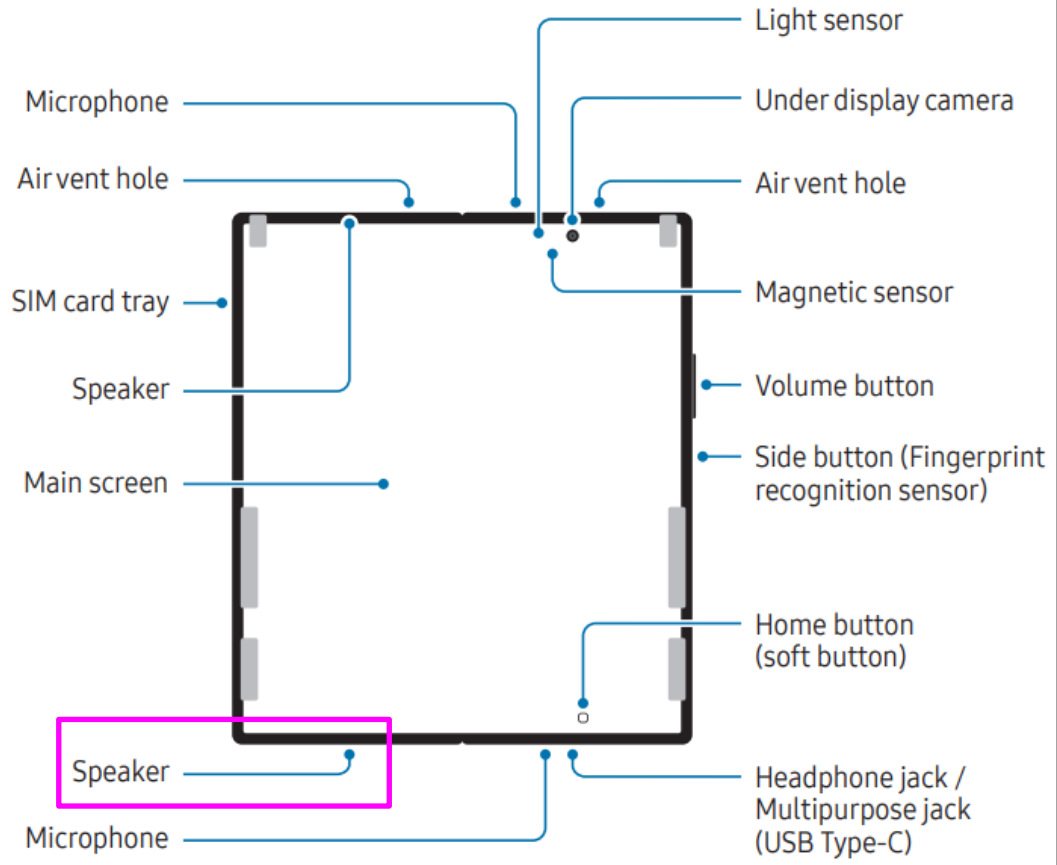
U.S. Patent No. 10,517,484 (the “’484 Patent”)

“Semiconductor diodes-based physiological measurement device with improved signal-to-noise ratio”

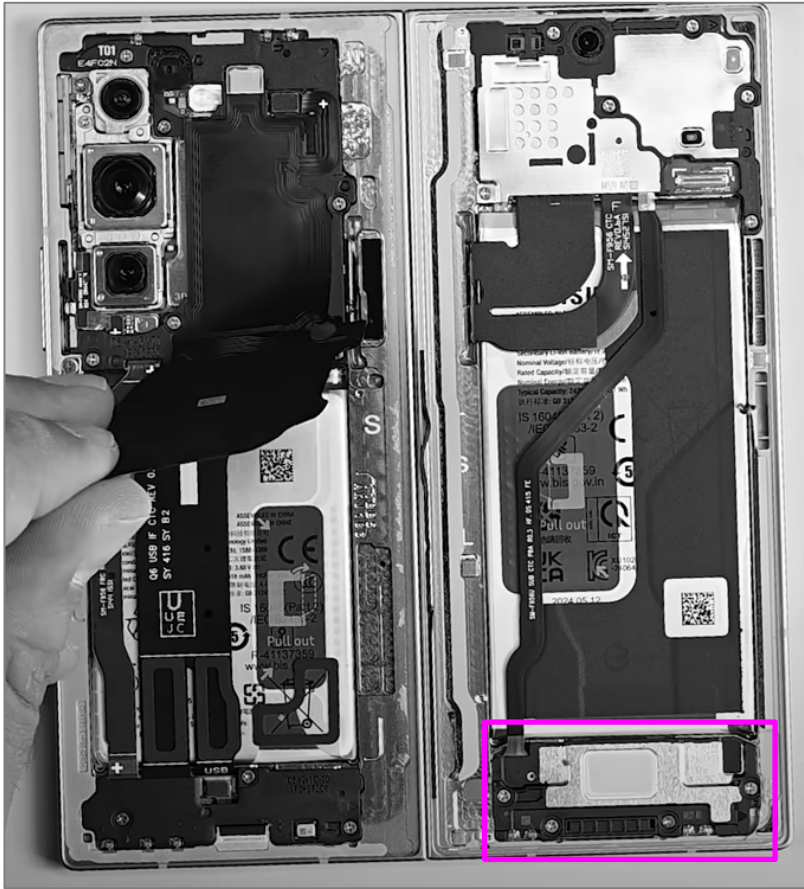
'484 Patent Claim ¹	Samsung Accused System ²						
	<div>Connectivity</div> <div><div>Wi-Fi Connectivity</div><div>802.11a/b/g/n/ac/ax 2.4GHz+5GHz+6GHz, HE160, MIMO, 1024-QAM</div></div> <div>Source: https://www.samsung.com/us/smartphones/galaxy-z-fold6/buy/galaxy-z-fold6-512gb-unlocked-sm-f956uakexaa/</div> <div>The Galaxy Z Fold6 (“smart phone”) further includes a display, a speaker, and a microphone (“a voice input module”).</div> <div><div>Display</div><table><tr><th>Resolution (Main Display)</th><th>Main Display Size</th><th>Technology (Main Display)</th></tr><tr><td>2160 x 1856 (QXGA+)</td><td>193.2mm (7.6" full rectangle) / 192.5mm (7.6" rounded corners)</td><td>Dynamic AMOLED 2X</td></tr></table></div> <div>Source: https://www.samsung.com/us/smartphones/galaxy-z-fold6/buy/galaxy-z-fold6-512gb-unlocked-sm-f956uakexaa/</div>	Resolution (Main Display)	Main Display Size	Technology (Main Display)	2160 x 1856 (QXGA+)	193.2mm (7.6" full rectangle) / 192.5mm (7.6" rounded corners)	Dynamic AMOLED 2X
Resolution (Main Display)	Main Display Size	Technology (Main Display)					
2160 x 1856 (QXGA+)	193.2mm (7.6" full rectangle) / 192.5mm (7.6" rounded corners)	Dynamic AMOLED 2X					

U.S. Patent No. 10,517,484 (the “’484 Patent”)

“Semiconductor diodes-based physiological measurement device with improved signal-to-noise ratio”

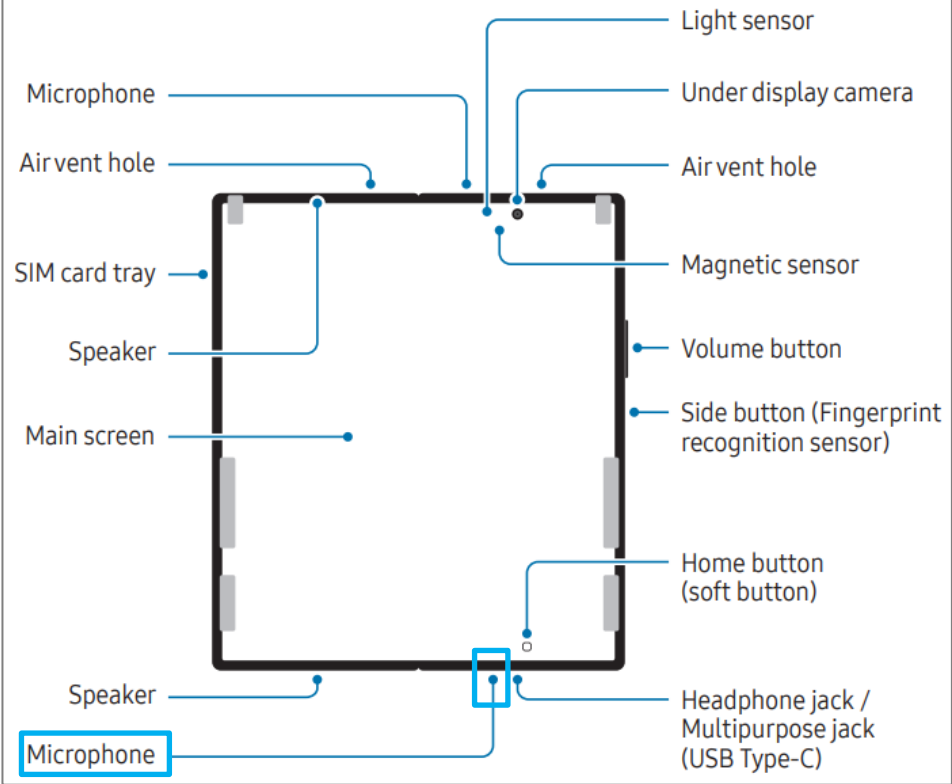
'484 Patent Claim ¹	Samsung Accused System ²
	 <p>The diagram shows a top-down layout of a smartphone. Components are labeled with lines pointing to their locations: Light sensor (top center), Under display camera (top center), Air vent hole (top left and top right), Microphone (top left and bottom center), SIM card tray (left side), Speaker (left side and bottom left, highlighted with a pink box), Main screen (center), Magnetic sensor (top right), Volume button (right side), Side button (Fingerprint recognition sensor) (right side), Home button (soft button) (bottom center), and Headphone jack / Multipurpose jack (USB Type-C) (bottom right).</p> <p>Source: https://downloadcenter.samsung.com/content/UM/202407/20240729134626727/SM-F956B_UG_EU_UU_Eng_Rev.1.0_240717.pdf [Page: 5]</p>

U.S. Patent No. 10,517,484 (the “’484 Patent”)
“Semiconductor diodes-based physiological measurement device with improved signal-to-noise ratio”

'484 Patent Claim ¹	Samsung Accused System ²
	<div data-bbox="487 196 1285 1079"></div> <p data-bbox="487 1079 1260 1117">Source: https://www.youtube.com/watch?v=xYIe5uDVDWI</p>

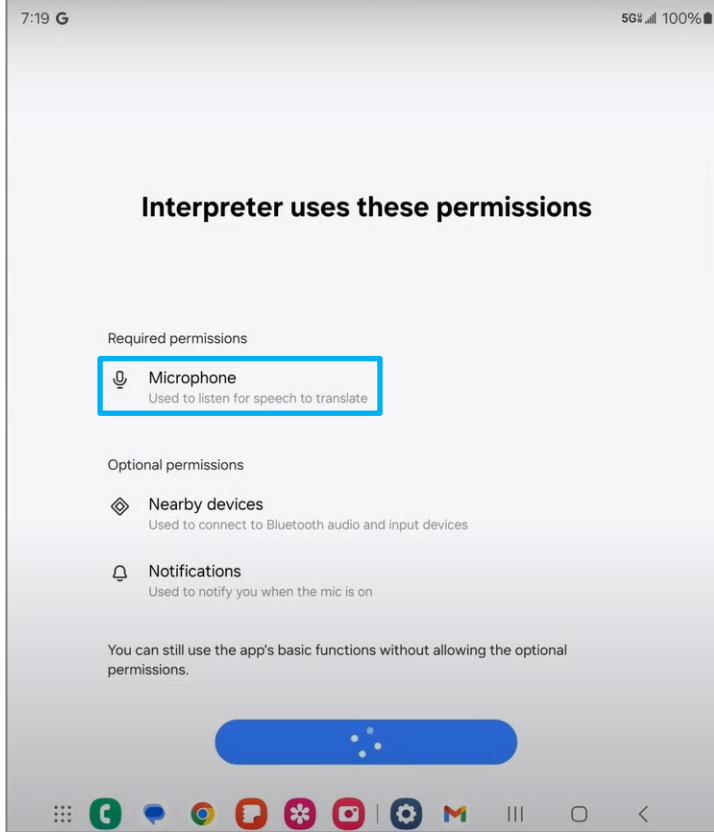
U.S. Patent No. 10,517,484 (the “’484 Patent”)

“Semiconductor diodes-based physiological measurement device with improved signal-to-noise ratio”

'484 Patent Claim ¹	Samsung Accused System ²
	 <p>The diagram shows a top-down view of a smartphone with the following labeled components:</p> <ul style="list-style-type: none"> Microphone (top left) Air vent hole (top left) SIM card tray (left side) Speaker (bottom left) Main screen (center) Light sensor (top right) Under display camera (top right) Air vent hole (top right) Magnetic sensor (right side) Volume button (right side) Side button (Fingerprint recognition sensor) (right side) Home button (soft button) (bottom right) Headphone jack / Multipurpose jack (USB Type-C) (bottom right) Microphone (bottom, highlighted with a red box) <p>Source: https://downloadcenter.samsung.com/content/UM/202407/20240729134626727/SM-F956B_UG_EU_UU_Eng_Rev.1.0_240717.pdf [Page: 5]</p>

U.S. Patent No. 10,517,484 (the “’484 Patent”)

“Semiconductor diodes-based physiological measurement device with improved signal-to-noise ratio”

'484 Patent Claim ¹	Samsung Accused System ²
	<div data-bbox="485 201 1194 1027"></div> <p data-bbox="485 1036 1268 1065">Source: https://www.youtube.com/watch?v=sPP6NW89Am0</p> <p data-bbox="485 1105 1837 1179">The Galaxy Z Fold6 further includes buttons (e.g., to increase/decrease volume), a microprocessor (e.g., Snapdragon 8 Gen 3 SoC (system on chip) having Qualcomm Kryo microprocessor), and a touch screen.</p>

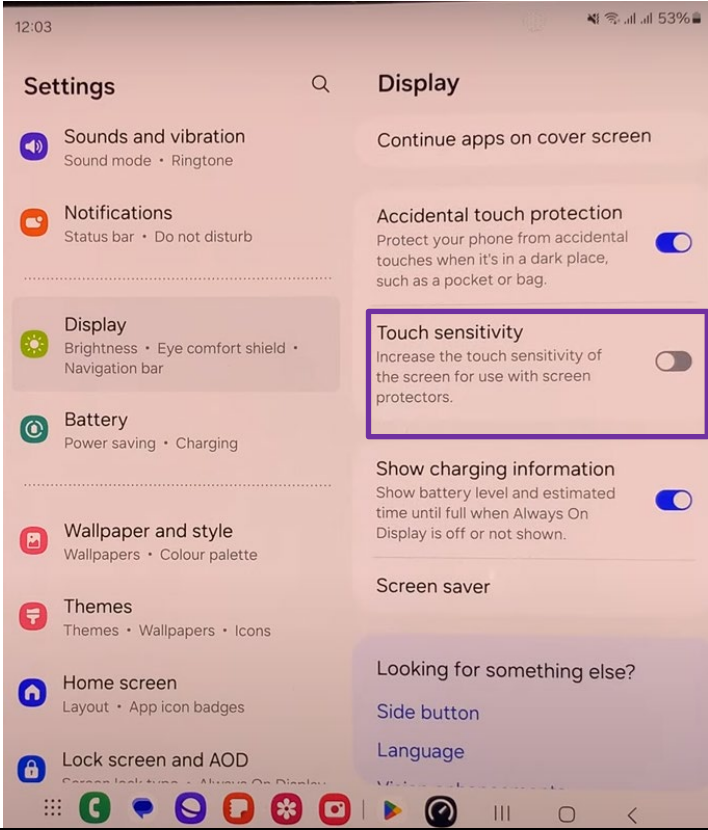
U.S. Patent No. 10,517,484 (the “’484 Patent”)

“Semiconductor diodes-based physiological measurement device with improved signal-to-noise ratio”

’484 Patent Claim ¹	Samsung Accused System ²
	<div data-bbox="489 203 842 998"></div> <p data-bbox="489 1003 1877 1073">Source: https://www.samsung.com/us/smartphones/galaxy-z-fold6/buy/galaxy-z-fold6-512gb-unlocked-sm-f956uakexaa/</p>

’484 Patent Claim ¹	Samsung Accused System ²
	<div data-bbox="512 215 703 259">Processor</div> <div data-bbox="512 293 659 334">CPU Type</div> <div data-bbox="512 367 669 406">Octa-Core</div> <div data-bbox="478 431 1877 501"> <p>Source: https://www.samsung.com/us/smartphones/galaxy-z-fold6/buy/galaxy-z-fold6-512gb-unlocked-sm-f956uakexaa/</p> </div> <div data-bbox="485 537 1404 1175">  </div> <div data-bbox="478 1175 1344 1211"> <p>Source: https://www.samsung.com/us/smartphones/galaxy-z-fold6/</p> </div>

U.S. Patent No. 10,517,484 (the “’484 Patent”)
“Semiconductor diodes-based physiological measurement device with improved signal-to-noise ratio”

'484 Patent Claim ¹	Samsung Accused System ²
	<div><div>CPU</div><div>Name: Qualcomm® Kryo™</div><div>Architecture: 64-bit</div><div>Clock Speed: Up to 3.4 GHz¹</div></div> <p>Source: https://www.qualcomm.com/products/mobile/snapdragon/smartphones/snapdragon-8-series-mobile-platforms/snapdragon-8-gen-3-mobile-platform</p> 

'484 Patent Claim ¹	Samsung Accused System ²												
	<p>Source: https://www.youtube.com/watch?v=cn2UQ6Fr4hM</p> <div><h3>Controlling the screen</h3><table><tr><td><p>Tapping Tap the screen.</p></td><td></td><td><p>Touching and holding Touch and hold the screen for approximately 2 seconds.</p></td><td></td></tr><tr><td><p>Dragging Touch and hold an item and drag it to the target position.</p></td><td></td><td><p>Double tapping Double tap the screen.</p></td><td></td></tr><tr><td><p>Swiping Swipe upwards, downwards, to the left, or to the right.</p></td><td></td><td><p>Spreading and pinching Spread two fingers apart or pinch on the screen.</p></td><td> </td></tr></table></div> <p>Source: https://downloadcenter.samsung.com/content/UM/202407/20240729134626727/SM-F956B_UG_EU_UU_Eng_Rev.1.0_240717.pdf [Page: 26]</p>	<p>Tapping Tap the screen.</p>		<p>Touching and holding Touch and hold the screen for approximately 2 seconds.</p>		<p>Dragging Touch and hold an item and drag it to the target position.</p>		<p>Double tapping Double tap the screen.</p>		<p>Swiping Swipe upwards, downwards, to the left, or to the right.</p>		<p>Spreading and pinching Spread two fingers apart or pinch on the screen.</p>	 
<p>Tapping Tap the screen.</p>		<p>Touching and holding Touch and hold the screen for approximately 2 seconds.</p>											
<p>Dragging Touch and hold an item and drag it to the target position.</p>		<p>Double tapping Double tap the screen.</p>											
<p>Swiping Swipe upwards, downwards, to the left, or to the right.</p>		<p>Spreading and pinching Spread two fingers apart or pinch on the screen.</p>	 										

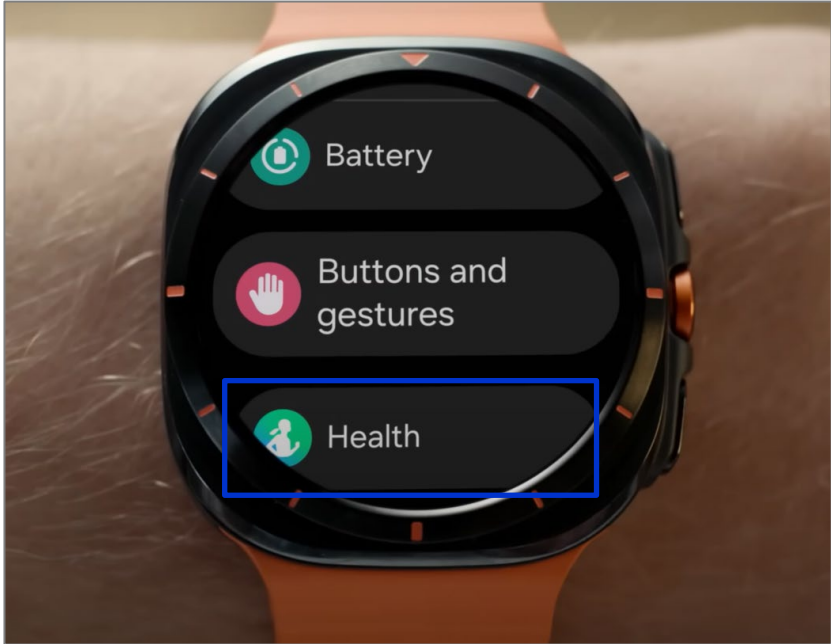
U.S. Patent No. 10,517,484 (the “’484 Patent”)

“Semiconductor diodes-based physiological measurement device with improved signal-to-noise ratio”

’484 Patent Claim ¹	Samsung Accused System ²
<p>7[i] the smart phone or tablet configured to receive and process at least a portion of the output signal, wherein the smart phone or tablet is configured to store and display the processed output signal, and wherein at least a portion of the processed output signal is configured to be transmitted over a wireless transmission link;</p>	<p>The Accused Phone/Tablet is configured to receive and process at least a portion of the output signal, and the Accused Phone/Tablet is configured to store and display the processed output signal, wherein at least a portion of the processed output signal is configured to be transmitted over a wireless transmission link, either literally or under the doctrine of equivalents.</p> <p>For example, the Galaxy Z Fold6 (“smart phone”) receives the output signal from the BioActive Sensor via the Samsung Health app, processes the signal (<i>e.g.</i>, generates Heart Rate Zones, in addition to other health and wellness metrics and reports), and then stores and displays the Heart Rate Zones (“processed signal”).</p> <div data-bbox="489 565 1848 1284"> </div> <p>Source: https://www.samsung.com/us/apps/samsung-health/.</p>

U.S. Patent No. 10,517,484 (the “’484 Patent”)

“Semiconductor diodes-based physiological measurement device with improved signal-to-noise ratio”

’484 Patent Claim ¹	Samsung Accused System ²
	<div data-bbox="487 233 1312 873"></div> <p data-bbox="487 878 1759 948">Source: Samsung, “A friendly guide to Galaxy Watch Ultra, Watch7 and Buds3Pro,” July 24, 2024, https://www.youtube.com/watch?v=VQW-ZpdAm5M.</p>

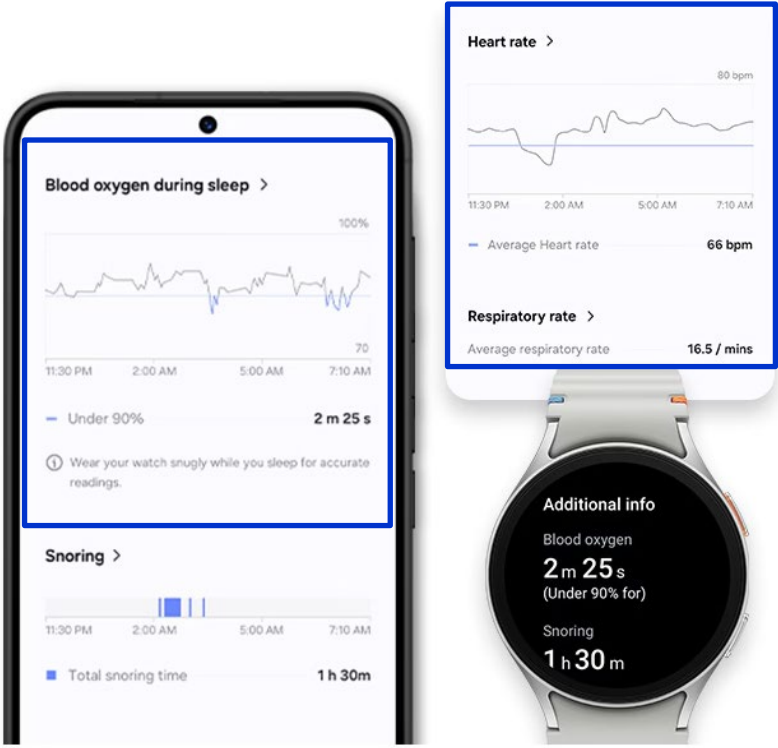
U.S. Patent No. 10,517,484 (the “’484 Patent”)

“Semiconductor diodes-based physiological measurement device with improved signal-to-noise ratio”

’484 Patent Claim ¹	Samsung Accused System ²
	<div data-bbox="489 196 1661 917"><p>Respiratory rate during sleep</p><p>Average 16.5 times/min</p><p>· Sleep</p><p>· Heart rate</p><p>· Activity</p><p>Show on phone</p></div> <p data-bbox="489 917 1759 992">Source: Samsung, “A friendly guide to Galaxy Watch Ultra, Watch7 and Buds3Pro,” July 24, 2024, https://www.youtube.com/watch?v=VQW-ZpdAm5M</p>

U.S. Patent No. 10,517,484 (the “’484 Patent”)

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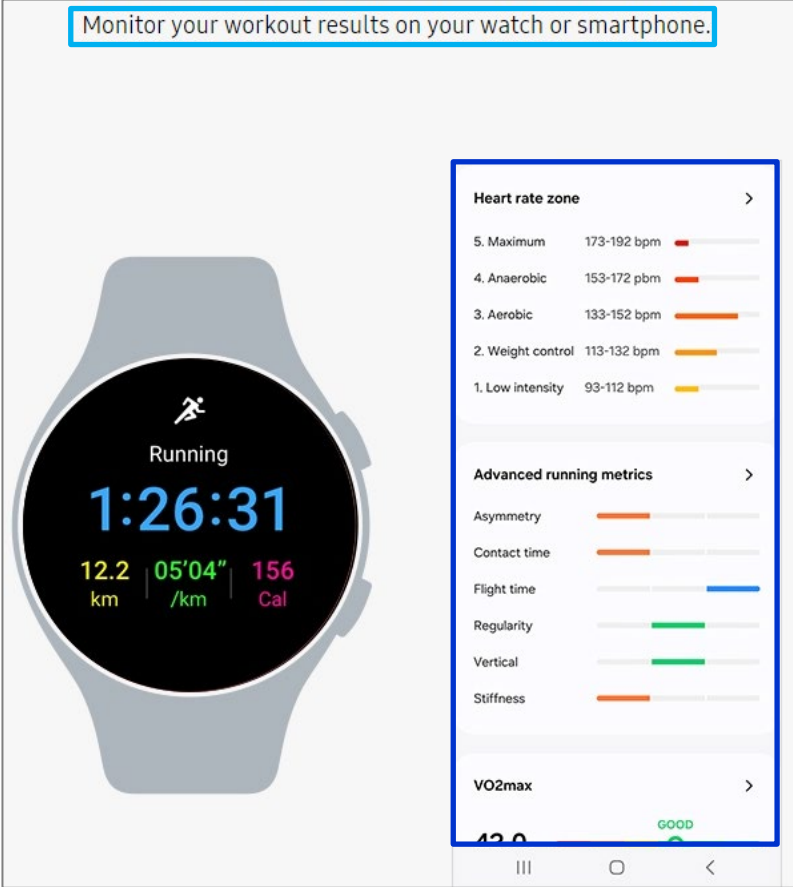
'484 Patent Claim ¹	Samsung Accused System ²
	<div data-bbox="489 196 1373 1008"><p>The image displays the Samsung Health app interface. On the left, a smartphone screen shows the 'Blood oxygen during sleep' graph with a peak at 100% and a summary of 'Under 90%' for 2 m 25 s. Below it, the 'Snoring' section shows a total snoring time of 1 h 30 m. On the right, a smartwatch displays 'Additional info' including 'Blood oxygen 2 m 25 s (Under 90% for)' and 'Snoring 1 h 30 m'. Above the watch, a separate window shows 'Heart rate' with an average of 66 bpm and 'Respiratory rate' with an average of 16.5 / mins. The graphs are plotted against a time axis from 11:30 PM to 7:10 AM.</p></div> <p>Source: https://www.samsung.com/us/apps/samsung-health/</p>

U.S. Patent No. 10,517,484 (the “’484 Patent”)
“Semiconductor diodes-based physiological measurement device with improved signal-to-noise ratio”

’484 Patent Claim ¹	Samsung Accused System ²
	<div data-bbox="489 196 1467 734"><p style="text-align: center;">Check your Heart Rate Zone with Galaxy Watch</p><p style="text-align: center;">Choose your preferred workout type and initiate by tapping 'Settings' when the countdown begins. Activate the HR Zone guide and engage in a 10-minute run within the exercise mode.</p></div> <p>Source: https://www.samsung.com/us/apps/samsung-health/</p> <div data-bbox="489 810 1474 1310"><p style="text-align: center;">Set personalized Heart Rate zones for you</p><p style="text-align: center;">Start your exercise by beginning from your personalized HR Zone, and monitor your heart rate zone at the bottom.</p></div>

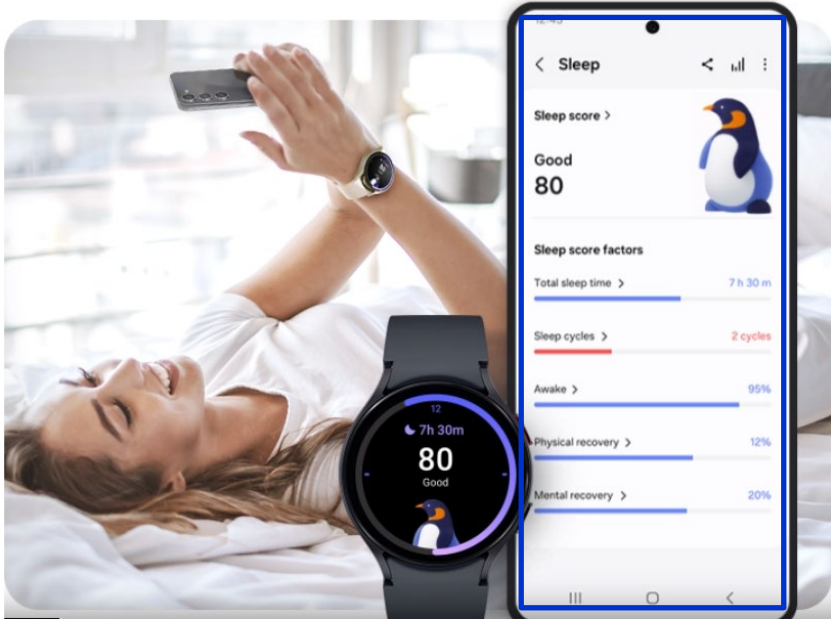
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“Semiconductor diodes-based physiological measurement device with improved signal-to-noise ratio”

’484 Patent Claim ¹	Samsung Accused System ²
	<p>Source: https://www.samsung.com/us/apps/samsung-health/</p> <p>Monitor your workout results on your watch or smartphone.</p>  <p>The screenshot displays the Samsung Health app interface. On the left is a smartwatch face showing 'Running' with a timer at 1:26:31, distance at 12.2 km, pace at 05'04"/km, and calories at 156 Cal. On the right is a sidebar menu with the following sections:</p> <ul style="list-style-type: none">Heart rate zone: A list of five heart rate zones with corresponding progress bars: 1. Low intensity (93-112 bpm), 2. Weight control (113-132 bpm), 3. Aerobic (133-152 bpm), 4. Anaerobic (153-172 bpm), and 5. Maximum (173-192 bpm).Advanced running metrics: A list of six metrics with corresponding progress bars: Asymmetry, Contact time, Flight time, Regularity, Vertical, and Stiffness.VO2max: A section showing a value of 42.0 and a 'GOOD' status. <p>Source: https://www.samsung.com/us/apps/samsung-health/</p>

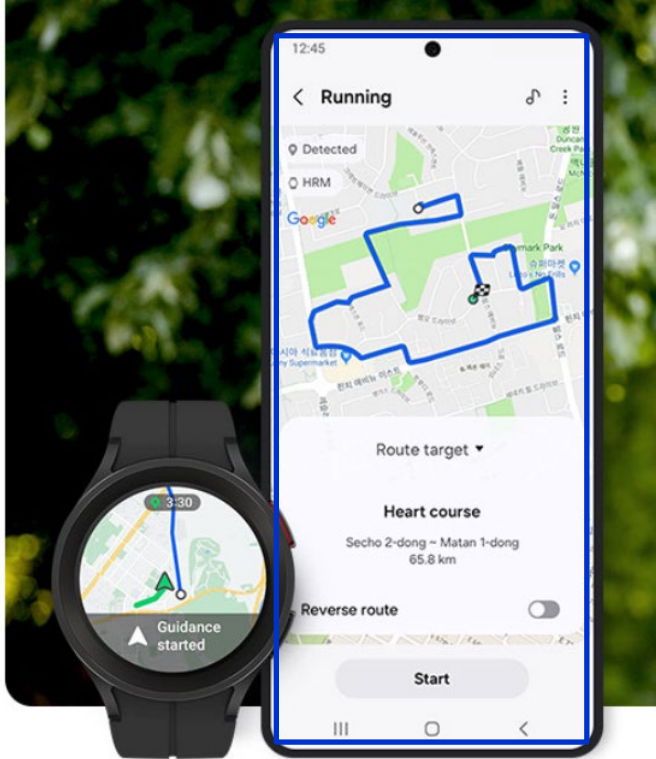
U.S. Patent No. 10,517,484 (the “’484 Patent”)

“Semiconductor diodes-based physiological measurement device with improved signal-to-noise ratio”

'484 Patent Claim ¹	Samsung Accused System ²
	 <p>The image shows a woman lying in bed, smiling, wearing a Samsung smartwatch. She is holding a smartphone in her right hand. The smartwatch screen displays a sleep score of 80 (Good) with a penguin icon. The smartphone screen displays the Samsung Health app's 'Sleep' page, showing a sleep score of 80 (Good) with a penguin icon. The app also shows sleep score factors: Total sleep time (7 h 30 m), Sleep cycles (2 cycles), Awake (95%), Physical recovery (12%), and Mental recovery (20%).</p> <p>Source: https://www.samsung.com/global/galaxy/apps/samsung-health/</p>

U.S. Patent No. 10,517,484 (the “’484 Patent”)

“Semiconductor diodes-based physiological measurement device with improved signal-to-noise ratio”

’484 Patent Claim ¹	Samsung Accused System ²
	 <p>Source: https://www.samsung.com/global/galaxy/apps/samsung-health/</p> <p>“The Energy score feature is available if the connected phone has version 6.27 or later of the Samsung Health app installed.” Samsung Galaxy Watch7 / Galaxy Watch Ultra User Guide (06/2024, Rev.1.0), at 53, available at https://downloadcenter.samsung.com/content/UM/202407/20240711132033461/SM-L30X_L31X_L705F_UG_EU_Android_Eng_Rev.1.0_240626.pdf.</p>

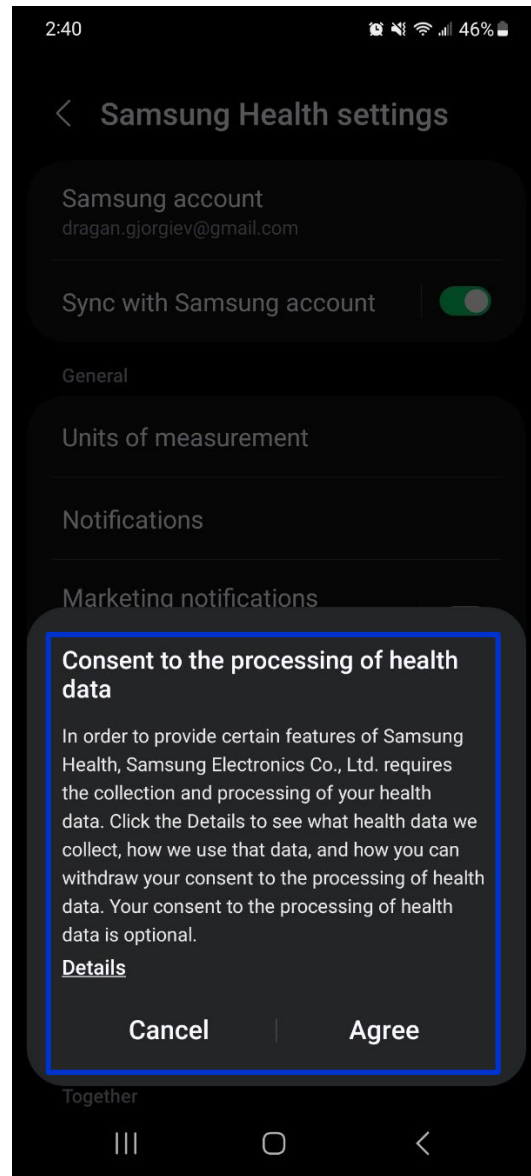
U.S. Patent No. 10,517,484 (the “’484 Patent”)

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’484 Patent Claim ¹	Samsung Accused System ²
	<p>“The sleep pattern will have its four states (Awake, REM, Light, Deep) analysed by using your movement and changes in your heart rate while you are sleeping. You can check the recommended ranges for each measured sleep state in the graph on your connected phone.” Samsung Galaxy Watch7 / Galaxy Watch Ultra User Guide (06/2024, Rev.1.0), at 71, <i>available at</i> https://downloadcenter.samsung.com/content/UM/202407/20240711132033461/SM-L30X_L31X_L705F_UG_EU_Android_Eng_Rev.1.0_240626.pdf.</p> <p>Product testing further demonstrates that the smart phone processes health data via Samsung Health:</p>

U.S. Patent No. 10,517,484 (the “’484 Patent”)

“Semiconductor diodes-based physiological measurement device with improved signal-to-noise ratio”



’484 Patent Claim ¹	Samsung Accused System ²
	<p>The Samsung Health app data (“a portion of the processed output signal”) is synchronized with Samsung Cloud to enable transmission of data to Samsung Cloud over Wi-Fi (“wireless transmission link”).</p> <p>“If you just got a new phone or tablet, it doesn’t mean you have to lose your hard work in Samsung Health. Your workout and health information can be transferred to the new device; you just need to sync your Samsung Health profile with your Samsung account! Once your data is synced, you'll be able to access it on a different device.”</p> <div data-bbox="487 521 1871 639"> <h3>Adjust the sync options </h3> </div> <p>Before you can get your health and workout data onto another device, you'll need to sync information from your Samsung account to Samsung Health. If you're worried you'll forget, you can even sync information automatically.</p> <ol style="list-style-type: none"> 1 Navigate to and open the Samsung Health app. Tap More options (the three vertical dots), and then tap Settings. 2 Tap Sync with Samsung Cloud, and then tap the switch at the top of the screen. 3 Additionally, you can tap Sync using to select Wi-Fi only or Wi-Fi and mobile data. 4 Tap Sync now to immediately sync your Samsung Health data. You can tap Sync now whenever you need to sync your data.

U.S. Patent No. 10,517,484 (the “’484 Patent”)

“Semiconductor diodes-based physiological measurement device with improved signal-to-noise ratio”

’484 Patent Claim ¹	Samsung Accused System ²
	<p>Source: Samsung, “Sync your data in Samsung Health,” https://www.samsung.com/us/support/answer/ANS10001399/.</p>
<p>7 ii a cloud configured to receive over the wireless transmission link an output status comprising the at least a portion of the processed output signal, to process the received output status to generate processed data, and to store the processed data;</p>	<p>The Accused System comprises a cloud configured to receive over the wireless transmission link an output status comprising the at least a portion of the processed output signal, to process the received output status to generate processed data, and to store the processed data, either literally or under the doctrine of equivalents.</p> <p>For example, the Accused Cloud receives data from the Samsung Health app over a Wi-Fi connection (“wireless transmission link”). It processes the Samsung Health app data and stores it as a backup (“processed data”), enabling future restoration. The health data can be backed up from Accused Cloud, indicating that the Accused Cloud stores the health data (“processed output signal”) received from the Accused Phone/Tablet.</p> <p>“If you just got a new phone or tablet, it doesn’t mean you have to lose your hard work in Samsung Health. Your workout and health information can be transferred to the new device; you just need to sync your Samsung Health profile with your Samsung account! Once your data is synced, you'll be able to access it on a different device.”</p>

’484 Patent Claim ¹	Samsung Accused System ²
	<div data-bbox="512 233 1037 289">Adjust the sync options </div> <p data-bbox="512 393 1843 506">Before you can get your health and workout data onto another device, you'll need to sync information from your Samsung account to Samsung Health. If you're worried you'll forget, you can even sync information automatically.</p> <ol data-bbox="533 555 1856 938" style="list-style-type: none"> <li data-bbox="533 555 1856 636">1 Navigate to and open the Samsung Health app. Tap More options (the three vertical dots), and then tap Settings. <li data-bbox="533 678 1709 734">2 Tap Sync with Samsung Cloud, and then tap the switch at the top of the screen. <li data-bbox="533 769 1743 824">3 Additionally, you can tap Sync using to select Wi-Fi only or Wi-Fi and mobile data. <li data-bbox="533 860 1776 938">4 Tap Sync now to immediately sync your Samsung Health data. You can tap Sync now whenever you need to sync your data. <p data-bbox="483 1000 1281 1068">Source: Samsung, “Sync your data in Samsung Health,” https://www.samsung.com/us/support/answer/ANS10001399/.</p>

’484 Patent Claim ¹	Samsung Accused System ²
	<p><u>Back up and restore data or files on your Galaxy device</u></p> <p>If you've accidentally deleted a file on your Samsung Galaxy device, there's no need to worry. Your device offers several backup and restore options, enabling you to recover your files with ease. Whether you're using Samsung Cloud, a microSD card, Google's backup services, or a direct connection to a PC or Mac, you have various methods at your disposal. This guide will take you through each option, explaining how to back up and restore your content effectively.</p> <p>Source: Samsung, “Sync your data in Samsung Health,” https://www.samsung.com/us/support/answer/ANS10001399/.</p>

’484 Patent Claim ¹	Samsung Accused System ²
	<p>Accounts and backup</p> <p>You can use various features of the Watch after registering your Samsung or Google account on your connected phone and add them on your Watch. You can also regularly back up your Watch’s data and files automatically with Smart Switch on your connected phone and save the backup to Samsung Cloud.</p> <p>On the Galaxy Wearable screen of the phone, tap Watch settings → Accounts and backup.</p> <ul style="list-style-type: none"> •  Save the Watch’s data and files that are automatically backed up periodically to Samsung Cloud, so that you can restore them if the data and files are damaged or lost caused by an unintended factory data reset. • The data from your Watch will be automatically backed up between 1 AM and 5 AM if your Watch is connected to your phone, your phone has more than 30% battery, and the screen is off. • Accounts: Register your Samsung or Google account on your connected phone and add it to your Watch. Refer to Adding the accounts to your Watch for more information. • Backup: Back up your data automatically to your connected phone, and tap the Save backup to Samsung Cloud switch to turn it on to store the backup on the Samsung Cloud. <p>Source: Samsung Galaxy Watch7 / Galaxy Watch Ultra User Guide (06/2024, Rev.1.0), at 143, <i>available at</i> https://downloadcenter.samsung.com/content/UM/202407/20240711132033461/SM-L30X_L31X_L705F_UG_EU_Android_Eng_Rev.1.0_240626.pdf.</p>

’484 Patent Claim ¹	Samsung Accused System ²
	<p>Controlling the Watch remotely</p> <p>When your Watch is lost or stolen, tap Find My Watch on the Galaxy Wearable screen of the phone, tap Set security, and then control your Watch remotely.</p> <ul style="list-style-type: none"> • Lock watch: Remotely lock the Watch to prevent unauthorised access. This feature can be used when your phone is connected to your Watch through Bluetooth or a remote connection. When your Watch is locked, unlock it manually by entering a preset PIN, or connect the Watch to your phone through Bluetooth again to unlock it automatically. • Reset watch: All data stored in your Watch is deleted. After the Watch is reset, you cannot restore the information or use the Find My Watch feature. However, data that was backed up and stored while your Watch and phone were connected before the reset is available on the Samsung Cloud. <p>Source: Samsung Galaxy Watch7 / Galaxy Watch Ultra User Guide (06/2024, Rev.1.0), at 147, <i>available at</i> https://downloadcenter.samsung.com/content/UM/202407/20240711132033461/SM-L30X_L31X_L705F_UG_EU_Android_Eng_Rev.1.0_240626.pdf.</p> <p>“As we approach the weekend, the last thing we want to tackle is everything you need to know about backing up and restoring your valuable Samsung Health data. You’ll need this when you factory reset or replace your Galaxy phone. . . . The Health data you can download from Samsung's servers using this method isn't meant to be used for restoring information within the mobile app. The purpose of this feature is to help you keep an offline record of your fitness and health data outside the Samsung Health mobile app.”</p> <p>Source: https://www.sammobile.com/news/samsung-health-week-back-up-restore-data/</p> <p>See also Samsung, “How can I synchronize the Samsung Health Monitor data to Samsung Health?” Apr. 13, 2023, https://www.samsung.com/ca/support/apps-services/how-can-i-synchronize-the-samsung-health-monitor-data-to-samsung-health/.</p>

U.S. Patent No. 10,517,484 (the “’484 Patent”)

“Semiconductor diodes-based physiological measurement device with improved signal-to-noise ratio”

’484 Patent Claim ¹	Samsung Accused System ²
<u>7[k]</u> wherein the output signal is indicative of one or more of the physiological parameters;	<p>The Accused Smartwatch generates an output signal that is indicative of one or more of the physiological parameters, either literally or under the doctrine of equivalents.</p> <p>For example, the PPG signal (“output signal”) from the BioActive Sensor indicates, among other things, heart rate and blood oxygen levels (“one or more of the physiological parameters”).</p>

U.S. Patent No. 10,517,484 (the “’484 Patent”)

“Semiconductor diodes-based physiological measurement device with improved signal-to-noise ratio”

’484 Patent Claim ¹	Samsung Accused System ²
	<div data-bbox="485 201 1108 1218"><p data-bbox="669 1073 932 1105">Heart rate zones</p><p data-bbox="510 1130 1094 1190">Use improved heart rate monitoring to tailor training for the best results, personalized for you.^{3, 6}</p></div> <p data-bbox="485 1256 1339 1289">Source: https://www.samsung.com/us/watches/galaxy-watch-ultra/</p>

U.S. Patent No. 10,517,484 (the “’484 Patent”)
 “Semiconductor diodes-based physiological measurement device with improved signal-to-noise ratio”

’484 Patent Claim ¹	Samsung Accused System ²
	<p>Introducing Samsung’s New BioActive Sensor</p> <p>The all-new BioActive Sensor is essential to bringing you better preventative health experiences on the next Galaxy Watch, with design improvements that enable even more precise health insights. Samsung engineers focused on three upgrades to the new sensor: enhancing the performance of light-receiving photodiodes, adding additional colors of light-emitting diodes (LEDs) and arranging them optimally across the sensor.</p> <p>Bringing Greater Accuracy and New Possibilities for Preventative Wellness</p> <p>The optimal allocation of Green, Red and Infrared LEDs sets new standards in wearable technology by improving accuracy and enabling exceptional performance across a broad array of health metrics. This allows the new BioActive Sensor to more accurately measure health metrics such as heart rate, sleep quality, blood pressure,² blood oxygen levels and stress levels.³ Even the measurement of heart rate during intensive workouts is 30% more accurate compared to its predecessor.</p> <p>The more diverse colors of LEDs and newly designed photodiodes unlock new possibilities and empower you to better predict trends and take proactive steps for preventative care. The first of these features will be an advanced glycation end products (AGEs) index⁴ – an indicator of metabolic health and biological aging strongly influenced by overall lifestyle and dietary habits. Used as an insightful biomarker, this index provides a snapshot of your biological age to help you make more informed decisions about your wellness journey and work towards a healthier future. The addition of an AGEs index is just one of the many new advanced features planned for the next Galaxy Watch.</p> <p>Source: Samsung Newsroom, Unlocking New Possibilities for Preventative Wellness with New Galaxy Watch and BioActive Sensor, Jul. 8, 2024, <i>available at</i> https://news.samsung.com/global/unlocking-new-possibilities-for-preventative-wellness-with-new-galaxy-watch-and-bioactive-sensor</p>

’484 Patent Claim ¹	Samsung Accused System ²
	<p>3 Description</p> <p>The AFE4510 is a versatile signal acquisition system that supports acquiring PPG, EDA, ECG, and Bio-impedance signals. A PPG signal chain comprises a current driver for LEDs and a receiver that senses the signal from PDs. An ECG receiver with a Right-leg drive (RLD) can acquire a single-lead ECG from a pair of electrodes. An impedance measurement signal chain with integrated excitation & sense can be used for applications like BIA, EDA, and Impedance spectroscopy. The outputs of the various signal chains are digitized by a common ADC and stored in a FIFO which can be read out using an SPI interface</p>

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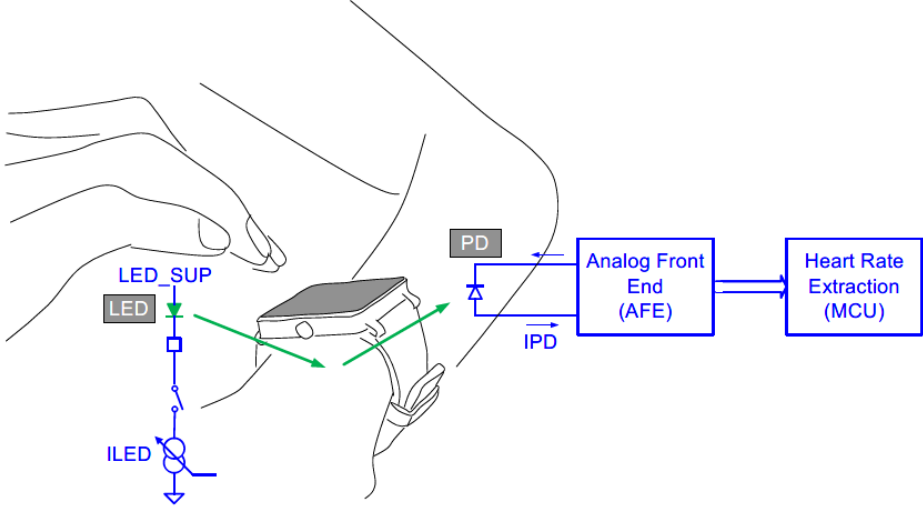
“Semiconductor diodes-based physiological measurement device with improved signal-to-noise ratio”

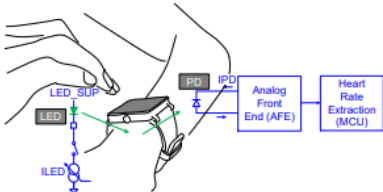
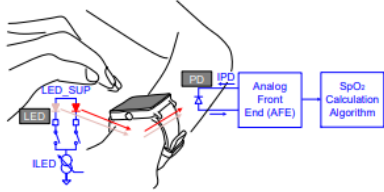
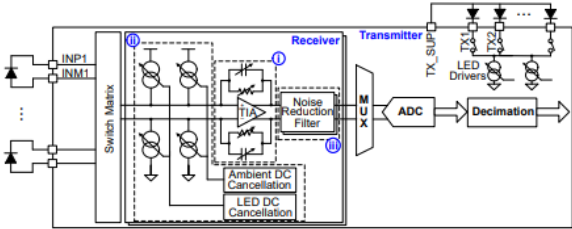
’484 Patent Claim ¹	Samsung Accused System ²
	<p><u>PPG signal acquisition:</u></p> <ul style="list-style-type: none">– Acquisition of 24 PPG signal sets (LED, AMB)– Supports PPG sensors at different data rates– Peak system SNR of 115 dB in 0.5-10Hz band enables high-accuracy SpO₂ measurement– Low Current for Continuous Operation with a Typical Value: 19μA for the Receiver <p><u>PPG Transmitter:</u></p> <ul style="list-style-type: none">– 8-Bit Programmable LED Current with a range adjustable from 50mA to 300mA– LED Short Detection– Support of 16 LEDs in Common Anode configuration for SpO₂, <u>OHRM</u>, Spectroscopy <p><u>OHRM: Optical Heart-rate monitoring</u></p> <p>Source: Texas Instruments, AFE4510, SBASB19 – March 2024, at 1-4, <i>available at</i> https://www.ti.com/lit/ds/symlink/afe4510.pdf.</p>

U.S. Patent No. 10,517,484 (the “’484 Patent”)

“Semiconductor diodes-based physiological measurement device with improved signal-to-noise ratio”

’484 Patent Claim ¹	Samsung Accused System ²
	<p>Application</p> <p><i>Optical Heart Rate Monitoring (OHRM)</i> uses the principle of photoplethysmography (PPG) to determine the heart rate. For a healthy individual, the heart pumps blood to all parts of the body in each cardiac cycle. This causes the volume of the blood in the arteries to have a pulsating component that has the periodicity of the heart rate. By illuminating the skin using a light-emitting diode (LED) and measuring the amount of light either transmitted or reflected to a photodiode (PD), the pulsating waveform can be converted to a signal current. As shown in Figure 1, an analog front-end (AFE) converts the signal current waveform from the PD to a digitized waveform which can then be processed by a signal processing algorithm in the MCU to extract the heart rate (HR).</p>

’484 Patent Claim ¹	Samsung Accused System ²
	 <p>Figure 1. Heart Rate Monitoring on a Wearable Device</p> <p>Source: Texas Instruments, Application Brief, “Optical Heart Rate Monitoring (OHRM) on Wearables,” SBAA564, Nov. 2022, at 1, available at https://www.ti.com/lit/ab/sbaa564/sbaa564.pdf.</p>

'484 Patent Claim ¹	Samsung Accused System ²
	<p><i>Product Overview</i></p> <p>Photoplethysmography (PPG) With Integrated AFE for Optical Biosensing</p> <hr/> <p style="text-align: right;"> TEXAS INSTRUMENTS</p> <p>Applications like optical heart rate and SpO₂ monitoring are based on the principle of Photoplethysmography (PPG). The primary challenges in PPG signal acquisition on a wrist-worn variable are: (i) small sensor size, (ii) relatively weak signal on wrist (low perfusion index), and (iii) interferers like ambient light and motion artifacts. TI's signal chain for PPG signal acquisition has 3 unique characteristics that help achieve excellent signal quality even in the most challenging conditions: (i) high gain transimpedance amplifier (TIA) to improve the SNR, (ii) DC offset cancellation DAC at the input, and (iii) noise reduction filter to reduce the optical noise bandwidth. These unique features help achieve excellent dynamic range at extremely low power consumption.</p> <div style="display: flex; justify-content: space-around; align-items: flex-end;"> <div style="text-align: center;">  <p>Heart Rate Monitoring</p> </div> <div style="text-align: center;">  <p>SpO₂ Monitoring</p> </div> </div> <div style="text-align: center; margin-top: 20px;">  <p>Block Diagram</p> </div> <p>Source: Texas Instruments, Product Overview, “Photoplethysmography (PPG) with Integrated AFE for Optical Biosensing,” Oct. 2023, at 1, <i>available at</i></p>

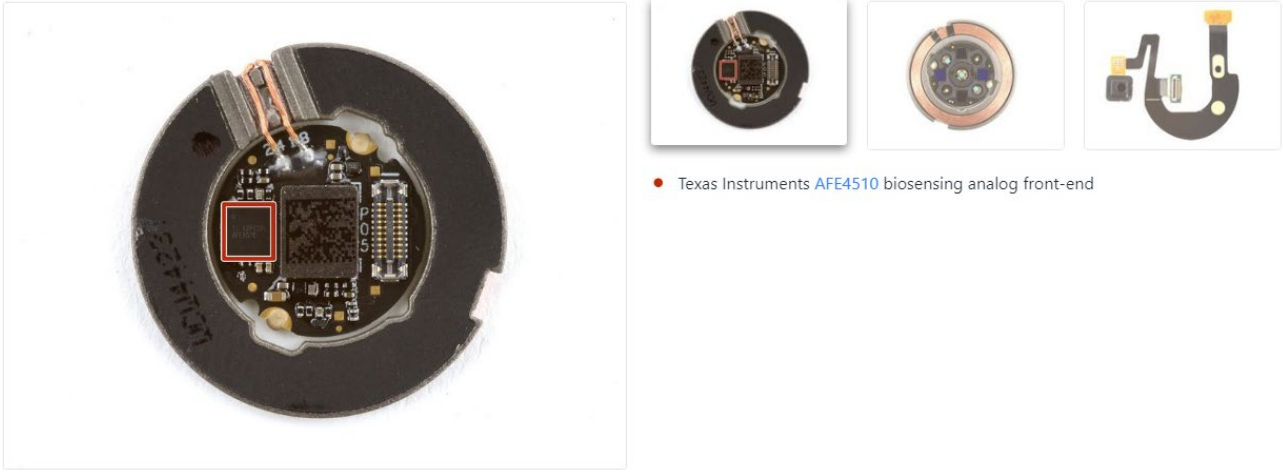
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’484 Patent Claim ¹	Samsung Accused System ²
	<p>https://www.ti.com/lit/po/sbat014/sbat014.pdf?ts=1724246538793&ref_url=https%253A%252F%252Fwww.google.com%252F.</p> <p>See also https://www.samsung.com/us/apps/samsung-health/; https://www.samsung.com/sg/apps/samsung-health-monitor/; https://www.youtube.com/watch?v=snMLajaf0tc&t=7s; https://news.samsung.com/global/samsung-leads-holistic-health-innovation-with-galaxy-watch5-and-galaxy-watch5-pro.</p>
<p>7III the wearable device configured to increase the signal-to-noise ratio by increasing light intensity of at least one of the semiconductor sources from an initial light intensity and by increasing a pulse rate of at least one of the semiconductor sources from an initial pulse rate; and</p>	<p>The Accused Smartwatch is configured to increase the signal-to-noise ratio by increasing light intensity of at least one of the semiconductor sources from an initial light intensity and by increasing a pulse rate of at least one of the semiconductor sources from an initial pulse rate, either literally or under the doctrine of equivalents.</p> <p>For example, the Galaxy Watch Ultra increases the signal-to-noise ratio (“SNR”) of the PPG signal received from the BioActive Sensor. The BioActive Sensor has a peak system SNR of 115 dB, which indicates that the general output SNR is lower than this peak value. To achieve peak SNR, the sensor is configured to increase the LED current (“increasing light intensity”) and is configured to increase the pulse repetition frequency (“PRF”) (“increasing a pulse rate”) of the LEDs (“semiconductor sources”).</p>

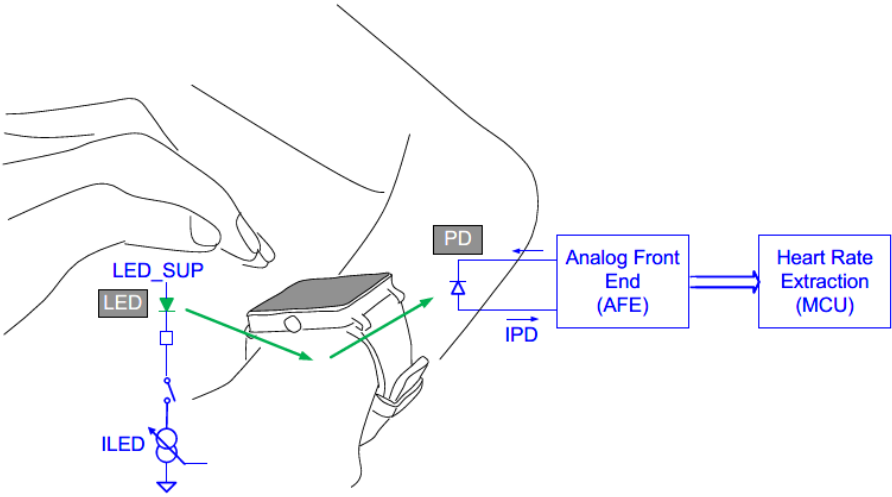
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’484 Patent Claim ¹	Samsung Accused System ²
	<div data-bbox="499 207 1787 727"><p>Step 6 Bio Sensor Assembly</p><p>• Texas Instruments AFE4510 biosensing analog front-end</p></div> <p data-bbox="485 769 1860 873">Source: IFIXIT, Samsung Galaxy Watch Ultra Chip ID, https://www.ifixit.com/Guide/Samsung+Galaxy+Watch+Ultra+Chip+ID/175327?srltid=AfmBOoriU1zDb_SwZ7O5CP4JIQFSWUnKHWqSe9g6SXYqF3F-NzUYIGpw.</p>

’484 Patent Claim ¹	Samsung Accused System ²
	<p>3 Description</p> <p>The AFE4510 is a versatile signal acquisition system that supports acquiring PPG, EDA, ECG, and Bio-impedance signals. A PPG signal chain comprises a current driver for LEDs and a receiver that senses the signal from PDs. An ECG receiver with a Right-leg drive (RLD) can acquire a single-lead ECG from a pair of electrodes. An impedance measurement signal chain with integrated excitation & sense can be used for applications like BIA, EDA, and Impedance spectroscopy. The outputs of the various signal chains are digitized by a common ADC and stored in a FIFO which can be read out using an SPI interface</p> <p>PPG signal acquisition:</p> <ul style="list-style-type: none"> – Acquisition of 24 PPG signal sets (LED, AMB) – Supports PPG sensors at different data rates – <u>Peak system SNR of 115 dB in 0.5-10Hz band enables high-accuracy SpO₂ measurement</u> – Low Current for Continuous Operation with a Typical Value: 19µA for the Receiver <p>PPG Transmitter:</p> <ul style="list-style-type: none"> – <u>8-Bit Programmable LED Current with a range adjustable from 50mA to 300mA</u> – LED Short Detection – Support of 16 LEDs in Common Anode configuration for SpO₂, OHRM, Spectroscopy

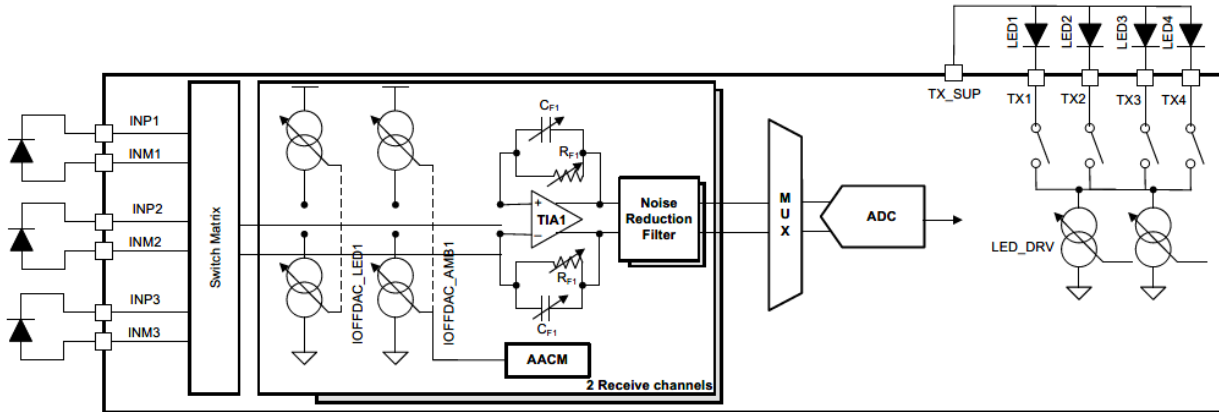
’484 Patent Claim ¹	Samsung Accused System ²
	<div data-bbox="506 207 1837 362"> <p>PPG: Photoplethysmography</p> <p>PRF: Pulse repetition frequency. Derived from the PPG terminology which refers to the rate at which the LEDs are turned on (pulsed). Extended to denote the frequency of a periodically repetitive set of operations involving signal acquisition of PPG, ECG and/or Bio-Z signals.</p> </div> <p data-bbox="485 370 1560 440">Source: Texas Instruments, AFE4510, SBASB19 – March 2024, at 1-4, available at https://www.ti.com/lit/ds/symlink/afe4510.pdf.</p> <div data-bbox="485 516 1841 751"> <p><i>Application Brief</i></p> <h2 data-bbox="506 573 1682 625">Optical Heart Rate Monitoring (OHRM) on Wearables</h2> <hr/>  </div> <div data-bbox="485 760 1148 1295"> <p>Application</p> <p><i>Optical Heart Rate Monitoring (OHRM)</i> uses the principle of photoplethysmography (PPG) to determine the heart rate. For a healthy individual, the heart pumps blood to all parts of the body in each cardiac cycle. This causes the volume of the blood in the arteries to have a pulsating component that has the periodicity of the heart rate. By illuminating the skin using a light-emitting diode (LED) and measuring the amount of light either transmitted or reflected to a photodiode (PD), the pulsating waveform can be converted to a signal current. As shown in Figure 1, an analog front-end (AFE) converts the signal current waveform from the PD to a digitized waveform which can then be processed by a signal processing algorithm in the MCU to extract the heart rate (HR).</p> </div>

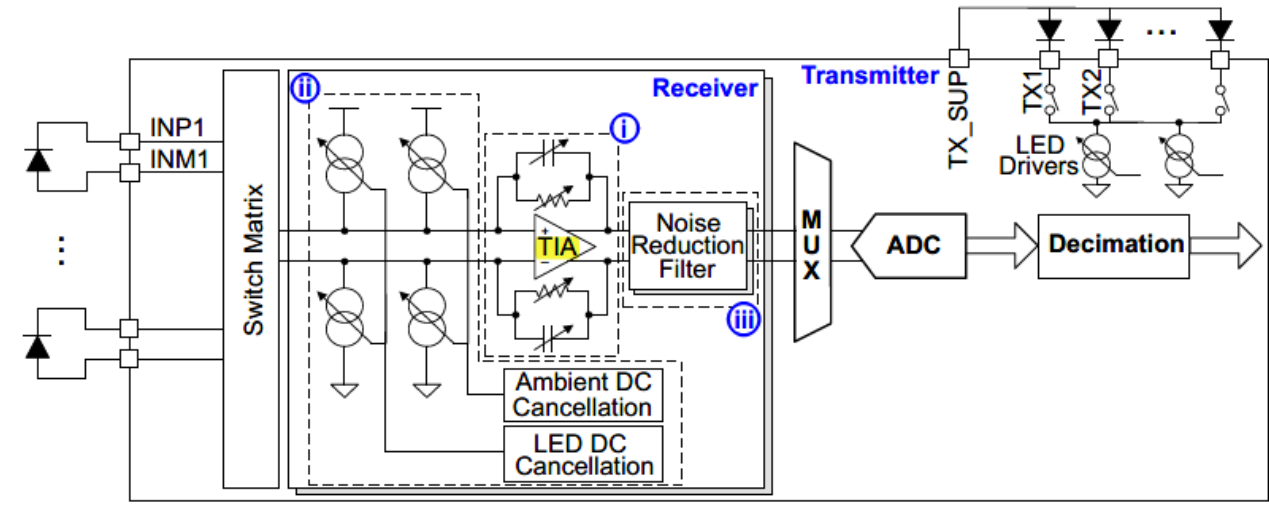
’484 Patent Claim ¹	Samsung Accused System ²
	<div data-bbox="489 196 1514 810">  <p data-bbox="594 727 1396 764">Figure 1. Heart Rate Monitoring on a Wearable Device</p> </div> <div data-bbox="489 816 1186 1073"> <p>In a device like a smartwatch, the LED and PD both face the wrist. The light from the LED is incident on the skin, and the reflection of the light from the artery results in a pulsating component. Typically, green LEDs are used, and the signal from multiple spatially-separated PDs are combined to mitigate effects such as motion.</p> </div> <div data-bbox="489 1079 1186 1237"> <p>The clinical range of the HR frequency is 0.5 Hz to 4 Hz. The PPG waveform is sampled at a rate (for example, 25 Hz), that is referred to as the pulse repetition frequency (PRF).</p> </div>

U.S. Patent No. 10,517,484 (the “’484 Patent”)

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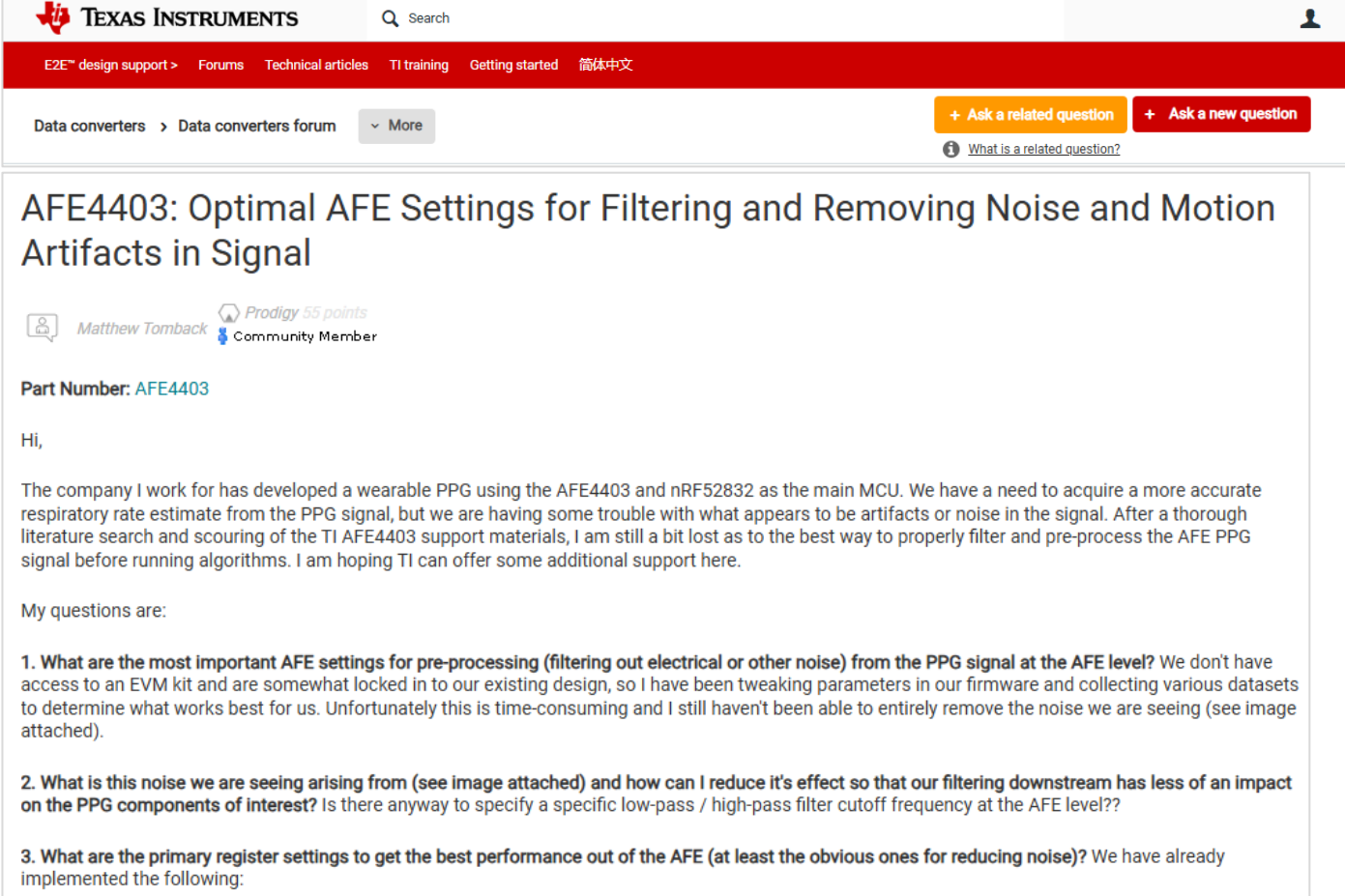
'484 Patent Claim ¹	Samsung Accused System ²																		
	<p>To save power, the LED is pulsed at the PRF rate, turning on for a short window in each PRF cycle. Each turning on of the LED results in one sample in the digital data stream.</p> <p>Differentiation</p> <ul style="list-style-type: none">• Signal chain has wide adaptability (LED current, transimpedance amplifier (TIA) gain, offset digital-to-analog converter (DAC) range) for a variety of use cases including low perfusion index, high ambient, and motion• Noise reduction filter limits optical noise bandwidth and provides high signal-to-noise ratio (SNR) even at low LED currents• Input offset cancellation DAC cancels DC from both ambient and LED, and allows a high TIA gain setting for the best noise performance <p>Table 1. Specifications for OHRM on Wearables</p> <table><tr><th>System Specifications</th><th>AFE4432</th><th>Comments</th></tr><tr><td>Multi-sensor support</td><td>4 LEDs, 3 PDs</td><td>Combining signals from multiple PDs and LEDs helps mitigate motion artifacts</td></tr><tr><td>Sampling rate</td><td>1 Hz–1 kHz</td><td>A sampling rate of 25 Hz to 100 Hz is typically used for continuous HRM</td></tr><tr><td>Current consumption</td><td>12 μA</td><td>For the receiver at 25 Hz PRF</td></tr><tr><td>Peak SNR</td><td>115 dB over 10-Hz bandwidth</td><td>Important consideration to achieve good accuracy in low perfusion cases.</td></tr><tr><td>Ambient rejection</td><td>> 70 dB up to 160 Hz</td><td>Good ambient rejection helps remove the spurious tones caused by ambient light from sources such as indoor lighting</td></tr></table>	System Specifications	AFE4432	Comments	Multi-sensor support	4 LEDs, 3 PDs	Combining signals from multiple PDs and LEDs helps mitigate motion artifacts	Sampling rate	1 Hz–1 kHz	A sampling rate of 25 Hz to 100 Hz is typically used for continuous HRM	Current consumption	12 μA	For the receiver at 25 Hz PRF	Peak SNR	115 dB over 10-Hz bandwidth	Important consideration to achieve good accuracy in low perfusion cases.	Ambient rejection	> 70 dB up to 160 Hz	Good ambient rejection helps remove the spurious tones caused by ambient light from sources such as indoor lighting
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	<p data-bbox="506 212 1045 240">Figure 3 shows the PPG signal chain in AFE4432.</p>  <p data-bbox="890 686 1339 714">Figure 3. PPG Signal Chain in AFE4432</p> <p data-bbox="506 740 1709 881">The LED driver drives up to 4 LEDs with programmable current. Each receiver can interface to up to 3 PDs and comprises a TIA, input DC offset cancellation DACs (for ambient, LED light), and noise reduction filters with programmable bandwidth. Both receivers share a common analog-to-digital converter (ADC). The PPG signal chain for optical heart rate monitoring on wearables is supported on many other AFEs from Texas Instruments such as the AFE4950, AFE4960P, and AFE4500 devices.</p> <p data-bbox="485 902 1814 971">Source: Texas Instruments, Application Brief, “Optical Heart Rate Monitoring (OHRM) on Wearables,” SBAA564, Nov. 2022, at 1, available at https://www.ti.com/lit/ab/sbaa564/sbaa564.pdf.</p> <p data-bbox="506 1068 1755 1276">Applications like optical heart rate and SpO₂ monitoring are based on the principle of Photoplethysmography (PPG). The primary challenges in PPG signal acquisition on a wrist-worn variable are: (i) small sensor size, (ii) relatively weak signal on wrist (low perfusion index), and (iii) interferers like ambient light and motion artifacts. TI’s signal chain for PPG signal acquisition has 3 unique characteristics that help achieve excellent signal quality even in the most challenging conditions: (i) high gain transimpedance amplifier (TIA) to improve the SNR, (ii) DC offset cancellation DAC at the input, and (iii) noise reduction filter to reduce the optical noise bandwidth. These unique features help achieve excellent dynamic range at extremely low power consumption.</p>

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	 <p style="text-align: center;">Block Diagram</p> <p>Source: Texas Instruments, Product Overview, “Photoplethysmography (PPG) with Integrated AFE for Optical Biosensing,” Oct. 2023, at 1, <i>available at</i> https://www.ti.com/lit/po/sbat014/sbat014.pdf?ts=1724246538793&ref_url=https%253A%252F%252Fwww.google.com%252F.</p> <p>AFE biosensors manufactured by Texas Instruments include a signal chain that “offers . . . LED current that can be adjusted to achieve the SNR requirements needed for high-end clinical pulse oximeter applications as well as the low power demands of battery-powered OHRM applications.” Texas Instruments, Application Report, “How to Design Peripheral Oxygen Saturation (SpO₂) and Optical Heart Rate Monitoring (OHRM) Systems Using the AFE4403,” SLAA655 – Mar. 2015, at 2, <i>available at</i> https://www.ti.com/lit/an/slaa655/slaa655.pdf.</p>

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	<p>“However, increasing the LED current gives better signal quality from the SNR perspective. The optimal AFE configuration settings are completely dependent on the application. This includes the separation of LED and PD, location of the sensor, and other factors.” Texas Instruments, Application Report, “How to Design Peripheral Oxygen Saturation (SpO₂) and Optical Heart Rate Monitoring (OHRM) Systems Using the AFE4403,” SLAA655 – Mar. 2015, at 3, <i>available at</i> https://www.ti.com/lit/an/slaa655/slaa655.pdf.</p>																																																												
	<div><h3>7.5 Electrical Characteristics</h3><p>Minimum and maximum specifications are at T_A = –20°C to 70°C, typical specifications are at 25°C. Crystal mode enabled, detector capacitor = 50 pF differential, ADC averaging set to maximum allowed for each PRF, TX_REF voltage set to 0.5 V, and CLKOUT tri-stated, at RX_ANA_SUP = RX_DIG_SUP = 3 V, TX_CTRL_SUP = LED_DRV_SUP = 3.3 V, stage 2 amplifier disabled, and f_{CLK} = 8 MHz, unless otherwise noted.</p><table><thead><tr><th>PARAMETER</th><th>TEST CONDITIONS</th><th>MIN</th><th>TYP</th><th>MAX</th><th>UNIT</th></tr></thead><tbody><tr><td colspan="6">PERFORMANCE (Full-Signal Chain)</td></tr><tr><td rowspan="7">I_{IN_FS} Full-scale input current</td><td>R_F = 10 kΩ</td><td></td><td>50</td><td></td><td>μA</td></tr><tr><td>R_F = 25 kΩ</td><td></td><td>20</td><td></td><td>μA</td></tr><tr><td>R_F = 50 kΩ</td><td></td><td>10</td><td></td><td>μA</td></tr><tr><td>R_F = 100 kΩ</td><td></td><td>5</td><td></td><td>μA</td></tr><tr><td>R_F = 250 kΩ</td><td></td><td>2</td><td></td><td>μA</td></tr><tr><td>R_F = 500 kΩ</td><td></td><td>1</td><td></td><td>μA</td></tr><tr><td>R_F = 1 MΩ</td><td></td><td>0.5</td><td></td><td>μA</td></tr><tr><td>PRF Pulse repetition frequency</td><td></td><td>62.5</td><td></td><td>2000</td><td>SPS</td></tr><tr><td>DC_{PRF} PRF duty cycle</td><td></td><td></td><td></td><td>25%</td><td></td></tr></tbody></table></div>	PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT	PERFORMANCE (Full-Signal Chain)						I _{IN_FS} Full-scale input current	R _F = 10 kΩ		50		μA	R _F = 25 kΩ		20		μA	R _F = 50 kΩ		10		μA	R _F = 100 kΩ		5		μA	R _F = 250 kΩ		2		μA	R _F = 500 kΩ		1		μA	R _F = 1 MΩ		0.5		μA	PRF Pulse repetition frequency		62.5		2000	SPS	DC _{PRF} PRF duty cycle				25%	
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	<p>Texas Instruments advised in an E2E design support forum regarding “Optimal AFE Settings for Filtering and Removing Noise and Motion Artifacts in Signal” to increase PRF to improve SNR:</p>																																																												

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	 <p>The screenshot shows a forum post on the Texas Instruments website. The post is titled "AFE4403: Optimal AFE Settings for Filtering and Removing Noise and Motion Artifacts in Signal" and is authored by Matthew Tomback, a community member with 55 Prodigy points. The post number is AFE4403. The content of the post is as follows:</p> <p>Hi,</p> <p>The company I work for has developed a wearable PPG using the AFE4403 and nRF52832 as the main MCU. We have a need to acquire a more accurate respiratory rate estimate from the PPG signal, but we are having some trouble with what appears to be artifacts or noise in the signal. After a thorough literature search and scouring of the TI AFE4403 support materials, I am still a bit lost as to the best way to properly filter and pre-process the AFE PPG signal before running algorithms. I am hoping TI can offer some additional support here.</p> <p>My questions are:</p> <ol style="list-style-type: none"> 1. What are the most important AFE settings for pre-processing (filtering out electrical or other noise) from the PPG signal at the AFE level? We don't have access to an EVM kit and are somewhat locked in to our existing design, so I have been tweaking parameters in our firmware and collecting various datasets to determine what works best for us. Unfortunately this is time-consuming and I still haven't been able to entirely remove the noise we are seeing (see image attached). 2. What is this noise we are seeing arising from (see image attached) and how can I reduce it's effect so that our filtering downstream has less of an impact on the PPG components of interest? Is there anyway to specify a specific low-pass / high-pass filter cutoff frequency at the AFE level?? 3. What are the primary register settings to get the best performance out of the AFE (at least the obvious ones for reducing noise)? We have already implemented the following:

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	<div data-bbox="493 203 1858 592">  <p>Praveen Aroul over 4 years ago in reply to Matthew Tomback TI Mastermind 49766 points</p> <p>Hello Matthew,</p> <p>Low-frequency drift due to respiration and motion has to be taken care of in post-processing by your signal processor. We may not be able to help here.</p> <p>As far as the higher frequency noise embedded in the AC component, you should probably look at the FFT spectrum of the raw data and find out where the tones are coming from. More likely it is picking up the noise from the power line. We recommend to run the laptop on battery and not on mains power to avoid the noise pickup from the mains. Typically this should be a problem in battery-operated systems.</p> <p>Another option to improve SNR is to increase the PRF and use averaging outside at the MCU to get to the same data-rate of 100Hz.</p> <p>Can you let us know the LED duty cycle in your configuration?</p> <p>What is the TX_REF voltage? Transmitter noise improves with higher tx_ref voltage.</p> <p>Please share us the raw data for the plots so that we have a look at it to offer any additional suggestions.</p> </div> <p>Source: Texas Instruments, E2E Design Support, Data Converters Forum, “AFE4403: Optimal AFE Settings for Filtering and Removing Noise and Motion Artifacts in Signal,” <i>available at</i> https://e2e.ti.com/support/data-converters-group/data-converters/f/data-converters-forum/916586/afe4403-optimal-afe-settings-for-filtering-and-removing-noise-and-motion-artifacts-in-signal/3391791?tisearch=e2e-sitesearch&keymatch=AFE%25252520increase%25252520PRF#3391791.</p> <div data-bbox="493 852 1827 1185">  <p>TEXAS INSTRUMENTS</p> <p style="text-align: right;"><i>Getting Started Guide</i> TIDA-00301</p> <p style="text-align: center;"><i>Miniaturized Pulse Oximeter Reference Design</i></p> <p style="text-align: right;"><i>HealthTech</i></p> </div>

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	<p style="text-align: center;">ABSTRACT</p> <p>The scope of this document is to provide a miniaturized pulse oximeter reference design for high end clinical application. This reference design features AFE4403, TI’s high performance Analog Front End for pulse oximeters, an ultra-low power microcontroller and a highly optimized integrated dual light emitting diodes (LED) and photodiode optical sensor. This reference design simplifies and accelerates the pulse oximeter system design while still ensuring the highest quality clinical measurements.</p> <p>The sampling duration is termed the receiver (Rx) sample time and is programmable for each signal, independently. The sampling can start after the I-V amplifier output is stable (to account for LED and cable settling times). The Rx sample time is used for all dynamic range calculations; the minimum time recommended is 50 μs. While the AFE4403 can support pulse widths lower than 50 μs, having too low of a pulse width could result in a degraded signal and noise from the photodiode.</p> <p>6.2 Estimation of SpO₂ percentage</p> <p>This section outlines the calculation of SpO₂ using PPG signals. The SpO₂ estimation relies on the relationship between the baseline value (referred as DC component) to the fluctuation in the signal (referred to as AC component). SpO₂ calculation is based on computing the “ratio of ratios” or <i>Pulse Modulation ratio</i> R which is defined as the ratio of AC/DC of red and IR LEDs as mentioned in Section 2.</p> <p>The PPG signal is normally contaminated with noise which could come from various sources like the power supply noise, motion artifact etc. An essential component as part of the data preprocessing is filtering out the unwanted signal of interest. Since the DC component resides in frequencies below 0.5Hz, a low pass filter with a cutoff frequency of 5Hz can be used for the SpO₂ estimation. This filtering stage is left for the user to implement.</p> <p>Source: Texas Instruments, “Miniaturized Pulse Oximeter Reference Design,” Getting Started Guide, TIDA-00301, at 1, 11-14, 20, available at</p>

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	<p data-bbox="485 203 1850 267">https://www.ti.com/lit/ug/tidu475/tidu475.pdf?ts=1724347486358&ref_url=https%253A%252F%252Fwww.google.com%252F%20.</p> <p data-bbox="485 347 1850 488">Samsung patent documents describe wearable devices that are configured to increase the signal-to-noise ratio by increasing light intensity of at least one of the semiconductor sources from an initial light intensity and by increasing a pulse rate of at least one of the semiconductor sources from an initial pulse rate. For example:</p> <div data-bbox="491 527 1745 862"><div data-bbox="537 558 1707 639"><div data-bbox="537 558 1010 639">(12) United States Patent Lee et al.</div><div data-bbox="1178 558 1707 639">(10) Patent No.: US 11,974,838 B2 (45) Date of Patent: May 7, 2024</div></div><div data-bbox="537 691 1062 773">(54) ELECTRONIC DEVICE FOR ACQUIRING BIOMETRICS USING PPG SENSOR, AND METHOD THEREFOR</div><div data-bbox="537 797 1020 854">(71) Applicant: Samsung Electronics Co., Ltd. Gyeonggi-do (KR)</div></div> <div data-bbox="491 870 1247 1156"><div data-bbox="527 886 940 919">(57) ABSTRACT</div><p data-bbox="527 927 1199 1114">An electronic device may include a PPG sensor including a light emitter that applies a current in a specified range and emits a light signal corresponding to the current and a light detector that amplifies a received light signal by applying one of a plurality of gain values, a memory that stores a plurality of sets of PPG models corresponding to the plu-</p><p data-bbox="793 1122 932 1146">(Continued)</p></div>

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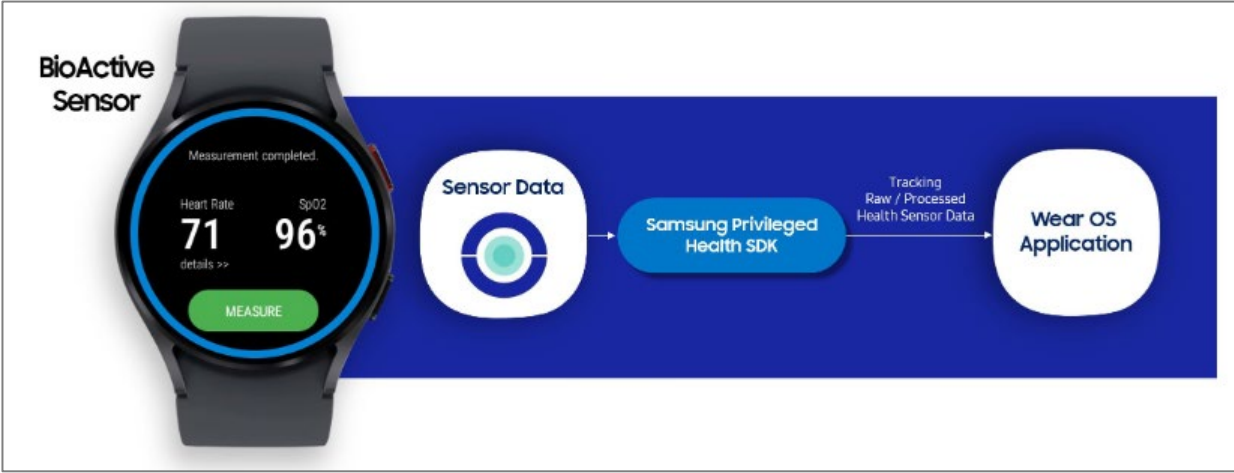
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	<p>To obtain bio information from the PPG signal, the PPG signal needs to have an appropriate level. For example, when the PPG signal is saturated or a signal to noise ratio (SNR) is low, it may be difficult to extract bio information from the PPG signal.</p> <p>The level of the PPG signal may be proportional to the intensity of light emitted by the light emitter and the intensity of light collected by the light detector. The intensity of light emitted by the light emitter may be proportional to the intensity of a current applied to the light emitter. The light detector may amplify the collected light according to a predetermined gain value.</p> <p>5 device 100 may be referred to as a user terminal.</p> <p>The electronic device 100 may analyze a PPG signal acquired and acquire bio information. Therefore, the PPG signal may need to have an appropriate level to extract bio information. For example, the higher the level of the PPG signal, the greater the signal to noise ratio (SNR) of the PPG signal. However, when power consumed by the PPG sensor increases and the PPG signal is out of a reception range of a photo detector, the PPG signal may be saturated. When the</p> <p>In various embodiments, to improve the accuracy of the heart rate estimated from the measured PPG, it is possible to increase a current and a gain within a range in which the PPG signal is not saturated. For example, in a situation in which a time for measuring the PPG signal is not long and power consumption is not required to be considered, raising the current rather than raising the gain may be advantageous in maximizing the SNR of a heart rate signal included in the PPG signal.</p>

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	<div data-bbox="489 203 1312 662"> <p style="text-align: center;">FIG. 5</p> </div> <p>Source: US 11,974,838 at Abstract, 1:43-54, 6:6-38, 12:8-16, FIG. 5.</p> <p>Increasing SNR generally yields more accurate health measurements. Samsung advertises that the Accused Smartwatch provides health measurements with enhanced accuracy, indicating that Samsung configures the Accused Smartwatch to increase SNR using various techniques, including by increasing light intensity and by increasing pulse rate, as shown above. For example:</p> <p>“Coming to the next Galaxy Watch, the new sensor will enable advanced predictive and preventative wellness features never before seen on a wearable device — in addition to more accurate health measurements. . . . The all-new BioActive Sensor is essential to bringing you better preventative health experiences on the next Galaxy Watch, with design improvements that enable even more precise health insights. . . . This allows the new BioActive Sensor to more accurately measure health metrics such as heart rate, sleep quality, blood pressure, blood oxygen levels and stress levels. Even the measurement of heart rate during intensive workouts is 30% more accurate compared to its predecessor.” Samsung Newsroom, Unlocking New Possibilities for Preventative Wellness with New Galaxy Watch and BioActive Sensor, Jul. 8, 2024, available at https://news.samsung.com/global/unlocking-new-possibilities-for-preventative-wellness-with-new-galaxy-watch-and-bioactive-sensor</p>

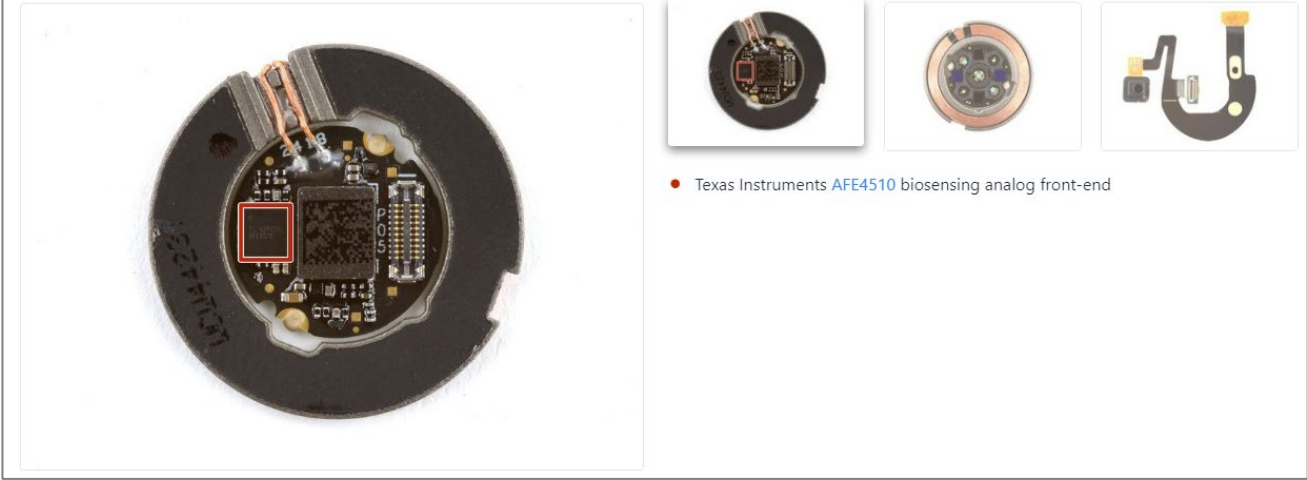
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	 <p>The diagram illustrates the Samsung BioActive Sensor system. On the left, a smartwatch displays 'BioActive Sensor' and 'Measurement completed' with heart rate (71) and SpO2 (96%) readings. A 'MEASURE' button is at the bottom. To the right, a flowchart shows 'Sensor Data' (represented by a circular icon) sending data to the 'Samsung Privileged Health SDK' (a blue rounded rectangle). This SDK then sends 'Tracking Raw / Processed Health Sensor Data' to the 'Wear OS Application' (a white rounded rectangle).</p> <p>“The SDK supports an improved health tracking capability to allow your applications to track the user’s health data accurately with the accelerometer, raw ECG (Electrocardiogram), PPG (Photoplethysmogram), and heart rate including inter-beat interval. In addition, it provides more advanced health features such as the body composition measurement, to enable compelling use cases for health and fitness applications. The blood oxygen level and sweat loss after a running workout are also useful data to check a user's health status.” Source: Samsung Developer, “Samsung Privileged Health SDK,” https://developer.samsung.com/health/privileged/overview.html</p>
<p>7[m] the detection system further configured to: generate a first signal responsive to light received while the semiconductor sources are off,</p>	<p>The detection system in the Accused Smartwatch is further configured to generate a first signal responsive to light received while the semiconductor sources are off, and generate a second signal responsive to light received while at least one of the semiconductor sources is on, either literally or under the doctrine of equivalents.</p> <p>For example, the BioActive Sensor includes a PPG sensor that operates in multiple phases, including (1) Ambient (when the LEDs, or “semiconductor sources,” are off) and (2) LED (when the LEDs, or</p>

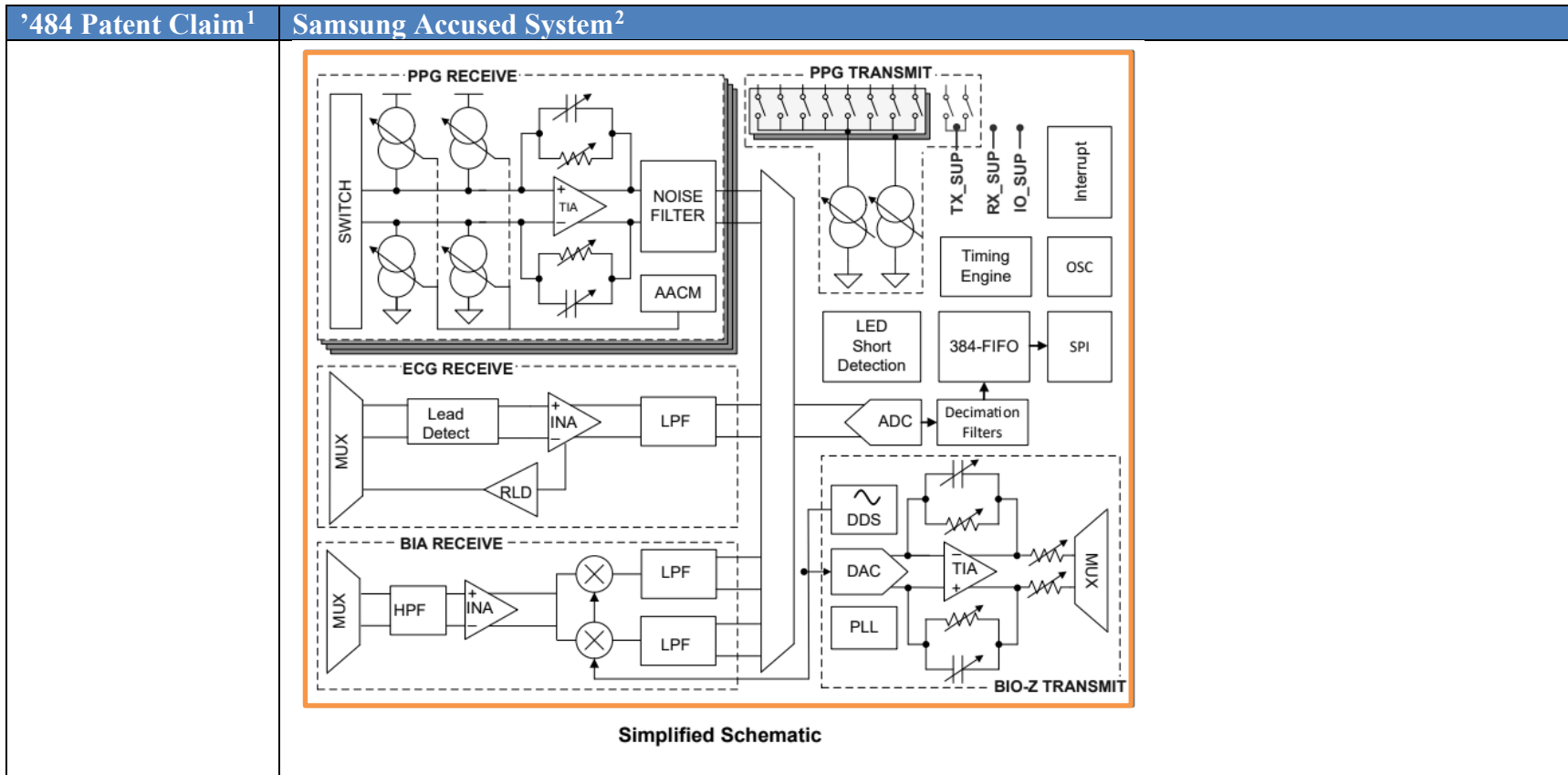
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<p>generate a second signal responsive to light received while at least one of the semiconductor sources is on, and</p>	<p>“semiconductor sources,” are on). During the Ambient phase, the sensor receives light with the LEDs off and generates a first signal. In the LED phase, the sensor receives light from the LEDs and generates a second signal.</p> <div data-bbox="489 342 1787 872"><p>Step 6 Bio Sensor Assembly</p></div> <p>Source: IFIXIT, Samsung Galaxy Watch Ultra Chip ID, https://www.ifixit.com/Guide/Samsung+Galaxy+Watch+Ultra+Chip+ID/175327?srsId=AfmBOoriU1zDb_SwZ7O5CP4JIQFSWUnKHWqSe9g6SXYqF3F-NzUYIGpw.</p>

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	<div data-bbox="491 203 1125 922"><p>PPG signal acquisition:</p><ul style="list-style-type: none">– Acquisition of 24 PPG signal sets (<u>LED</u>, <u>AMB</u>)– Supports PPG sensors at different data rates– Peak system SNR of 115 dB in 0.5-10Hz band enables high-accuracy SpO₂ measurement– Low Current for Continuous Operation with a Typical Value: 19μA for the Receiver<p>PPG Transmitter:</p><ul style="list-style-type: none">– 8-Bit Programmable LED Current with a range adjustable from 50mA to 300mA– LED Short Detection– Support of 16 LEDs in Common Anode configuration for SpO₂, OHRM, Spectroscopy<p>PPG Receiver:</p><ul style="list-style-type: none">– Supports 5 PDs, 4 parallel receive paths– Noise filtering with programmable bandwidth– Trans-impedance Gain: 3.7kΩ to 1MΩ– 8-bit Ambient Offset Subtraction DAC up to 256μA– 9-bit LED Offset Subtraction DAC up to 64μA– Digital Ambient Subtraction at ADC Output</div> <p data-bbox="491 971 1558 1036">Source: Texas Instruments, AFE4510, SBASB19 – March 2024, at 1-2, <i>available at</i> https://www.ti.com/lit/ds/symlink/afe4510.pdf.</p>

’484 Patent Claim ¹		Samsung Accused System ²																																																																																																																																																																																																																																																																																																															
		<p>5.1 PPG Configuration</p> <p>5.1.1 Phase Definition</p> <p>This sheet is used to specify number of phases, timing, signal chain parameters associated with each phase, and the LED/PD association for each phase. The phase type is selected from the drop down menu (<u>Ambient</u> and <u>LED</u>) and the appropriate parameters for the phase type are automatically shaded in blue. Specify only the parameters that show up in the Blue boxes. Manually fill each cell using the drop down boxes (do not cut and paste values across cells). Also, fill only the boxes that show up in blue. Do not modify the cream-colored boxes.</p> <table border="1"> <tr> <td>3</td><td></td><td>ILED_SAMP</td><td>0</td><td>us (LED ON start to SAMP start)</td><td></td><td></td><td>1</td><td>No data written into FIFO</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr> <tr> <td>4</td><td></td><td></td><td></td><td></td><td></td><td></td><td>2</td><td>Phase [N] - Phase [N-1]</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr> <tr> <td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>3</td><td>Phase [N-1] - Average(Phase [N], Phase [N-2])</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr> <tr> <td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>4</td><td>Phase[N] - Phase [N-2]</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr> </table> <p>5 Phase parameter table</p> <table border="1"> <thead> <tr> <th>Phase</th><th>Phase type</th><th>LED drv1 connects to</th><th>LED drv2 connects to</th><th>NUMAV</th><th>Stagger LED?</th><th>Fractional masking</th><th>FIFO data word</th><th>SAMP time (us)</th><th>Filter BW Selection</th><th>Connect PD4?</th><th>Connect PD3?</th><th>Connect PD2?</th><th>Connect PD1?</th><th>Rf (kOhm)</th><th>Cf (pF)</th><th>IOFFDAC, TIA1 (uA)</th><th>AACM TYPE</th></tr> </thead> <tbody> <tr> <td>1</td><td>Ambient</td><td></td><td></td><td>2</td><td>0</td><td>Never mask</td><td>1</td><td>115</td><td>Set1</td><td></td><td></td><td></td><td></td><td>100</td><td>20</td><td>0</td><td>ANA AACM</td></tr> <tr> <td>2</td><td>LED</td><td>TX5</td><td>TX5</td><td>2</td><td>0</td><td>Never mask</td><td>1</td><td>115</td><td>Set1</td><td></td><td></td><td></td><td></td><td>100</td><td>20</td><td>0</td><td>LED, DC Cancel</td></tr> <tr> <td>3</td><td>Ambient</td><td></td><td></td><td>2</td><td>0</td><td>Never mask</td><td>3</td><td>115</td><td>Set1</td><td></td><td></td><td></td><td></td><td>100</td><td>20</td><td>0</td><td>ANA AACM</td></tr> <tr><td>47</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr> <tr><td>57</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr> <tr><td>67</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr> <tr><td>77</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr> <tr><td>87</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr> <tr><td>97</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr> <tr><td>107</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr> <tr><td>117</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr> </tbody> </table>																3		ILED_SAMP	0	us (LED ON start to SAMP start)			1	No data written into FIFO										4							2	Phase [N] - Phase [N-1]																	3	Phase [N-1] - Average(Phase [N], Phase [N-2])																	4	Phase[N] - Phase [N-2]										Phase	Phase type	LED drv1 connects to	LED drv2 connects to	NUMAV	Stagger LED?	Fractional masking	FIFO data word	SAMP time (us)	Filter BW Selection	Connect PD4?	Connect PD3?	Connect PD2?	Connect PD1?	Rf (kOhm)	Cf (pF)	IOFFDAC, TIA1 (uA)	AACM TYPE	1	Ambient			2	0	Never mask	1	115	Set1					100	20	0	ANA AACM	2	LED	TX5	TX5	2	0	Never mask	1	115	Set1					100	20	0	LED, DC Cancel	3	Ambient			2	0	Never mask	3	115	Set1					100	20	0	ANA AACM	47																		57																		67																		77																		87																		97																		107																		117																	
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U.S. Patent No. 10,517,484 (the “’484 Patent”)

“Semiconductor diodes-based physiological measurement device with improved signal-to-noise ratio”

'484 Patent Claim¹

Samsung Accused System²

	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S
3		ILED_SAMP	0	us (LED ON start to SAMP start)			1	No data written into FIFO						Single or Dual TIA		Single		
4							2	Phase [N] - Phase [N-1]						PPG Decimation Factor: PPG_DEC_Fr		2	PPG Decimation: EN_PPG_DEC	
5	Phase parameter table						3	Phase [N-1] - AveragedPhase [N] Phase [N-2]						TIA1				
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7	1	Ambient			2	0	Never mask	1	115	Set1			1		100	20	0	ANA AACM
17	2	LED	TX5	TX5	2	0	Never mask	1	115	Set1			1		100	20	0	LED_DC Cancel
27	3	Ambient			2	0	Never mask	3	115	Set1			1		100	20	0	ANA AACM
37																		
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Figure 5-1. PPG per-phase configuration

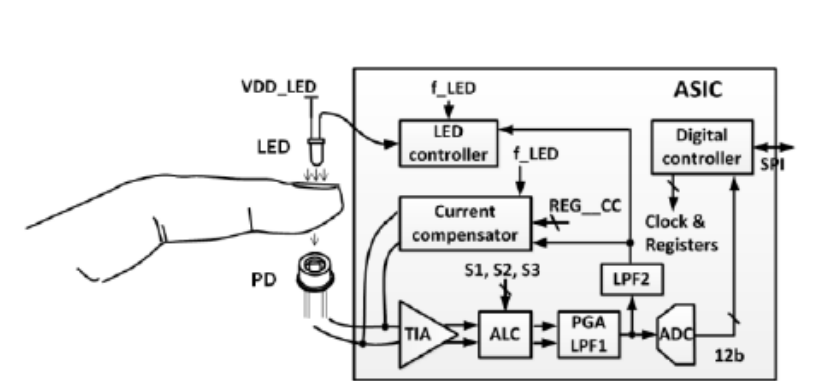
Source: Texas Instruments, AFE4500 EVM User Guide, SBAU370 – April 2021, at 23, available at <https://www.manualslib.com/download/2652772/Texas-Instruments-Afe4500evm.html>.

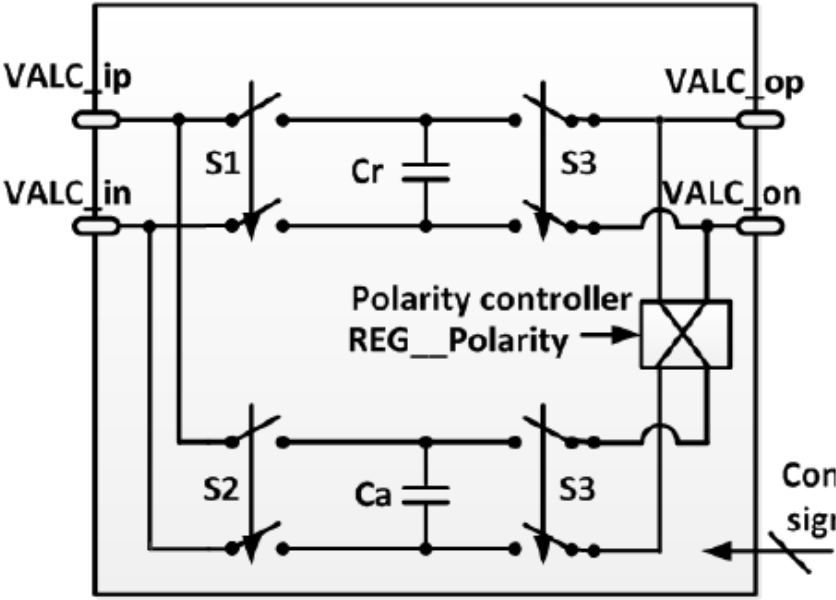
“To save power, the LED is pulsed at the PRF rate, turning on for a short window in each PRF cycle. Each turning on of the LED results in one sample in the digital data stream. . . . Input offset cancellation DAC cancels DC from both ambient and LED, and allows a high TIA gain setting for the best noise performance.” Texas Instruments, Application Brief, “Optical Heart Rate Monitoring (OHRM) on Wearables,” SBAA564, Nov. 2022, at 2, available at <https://www.ti.com/lit/ab/sbaa564/sbaa564.pdf>.

U.S. Patent No. 10,517,484 (the “’484 Patent”)

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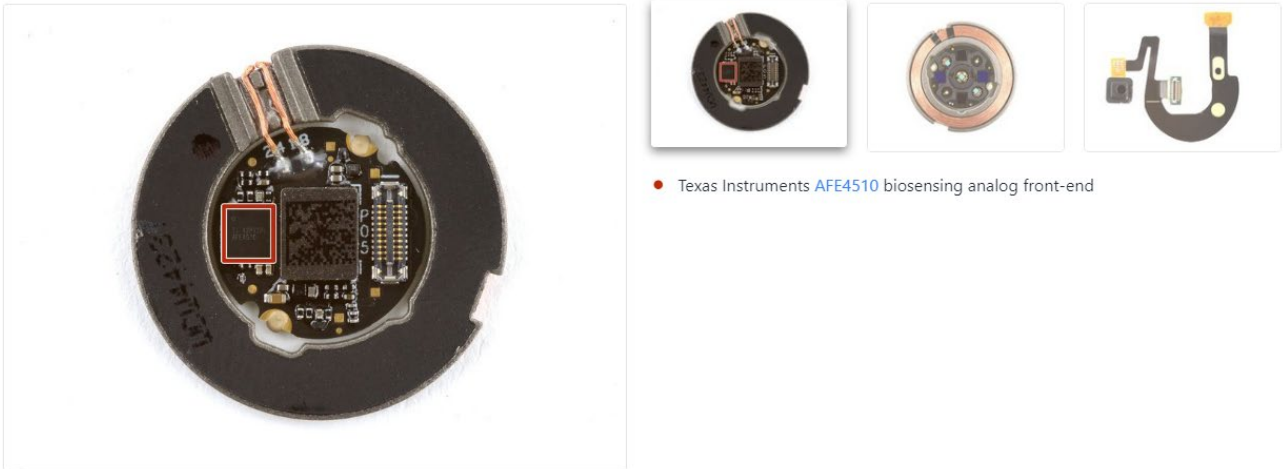
'484 Patent Claim ¹	Samsung Accused System ²
	<div data-bbox="546 219 1732 950"> <p>The top section shows two hand-drawn style diagrams of a wrist-worn device. The left diagram, labeled 'Heart Rate Monitoring', shows a green LED emitting light into the skin, with a photodiode (PD) and integrated photodiode (IPD) sensor detecting the reflected light. The signal path goes through an 'Analog Front End (AFE)' to a 'Heart Rate Extraction (MCU)'. The right diagram, labeled 'SpO₂ Monitoring', shows a red LED and a blue LED (labeled ILED) emitting light, with a similar sensor and signal path leading to an 'SpO₂ Calculation Algorithm'.</p> <p>The bottom section is a detailed 'Block Diagram' of the system. It features a 'Switch Matrix' on the left connected to multiple input channels (INP1, INM1, etc.). These channels feed into a 'Receiver' block containing a 'Noise Reduction Filter' and 'Ambient DC Cancellation' and 'LED DC Cancellation' blocks. The receiver output goes through a 'MUX' (multiplexer) to an 'ADC' (analog-to-digital converter), which then feeds into a 'Decimation' block. On the right, a 'Transmitter' block includes 'TX SUP' (transmit supply), 'TX1', 'TX2', and 'LED Drivers' connected to multiple LEDs.</p> </div> <p>Source: Texas Instruments, Product Overview, “Photoplethysmography (PPG) with Integrated AFE for Optical Biosensing,” Oct. 2023, at 1, <i>available at</i> https://www.ti.com/lit/po/sbat014/sbat014.pdf?ts=1724246538793&ref_url=https%253A%252F%252Fwww.google.com%252F.</p> <p>A technical paper authored by Samsung engineers further explains a PPG signal detection system for use in wearable devices configured to operate in an Ambient and LED phase:</p>

’484 Patent Claim ¹	Samsung Accused System ²
	<p><i>B. Ambient Light Cancellation (ALC)</i></p> <p>The ambient light component in the detected PPG signal can be removed in the ALC block, which is shown in Fig. 2. When the LED light turns on, the measured signal corresponding to both the LED light and the ambient light is sampled at the charge reservoir Cr, and when the LED light turns off, the measured signal corresponding to only the ambient light is sampled at an another charge reservoir Ca. Then, the charge redistribution occurs to cancel the ambient</p>  <p>Figure 1. Top block diagram of LED driving and PD detection circuit for PPG application.</p>

’484 Patent Claim ¹	Samsung Accused System ²
	<div data-bbox="489 203 1381 987">  <p data-bbox="520 899 1350 959">Figure 2. Detailed architecture of the ambient light cancellation (ALC) block.</p> </div> <p data-bbox="489 1027 1806 1133">Source: J. Kim et al., “Ambient light cancellation in photoplethysmogram application using alternating sampling and charge redistribution technique,” 2015 37th Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBC), at 6441-42.</p>
<p data-bbox="184 1177 451 1271"><u>7[n]</u> increase the signal-to-noise ratio by comparing the</p>	<p data-bbox="489 1177 1806 1247">The detection system in the Accused Smartwatch is configured to increase the signal-to-noise ratio by comparing the first signal and the second signal, either literally or under the doctrine of equivalents.</p>

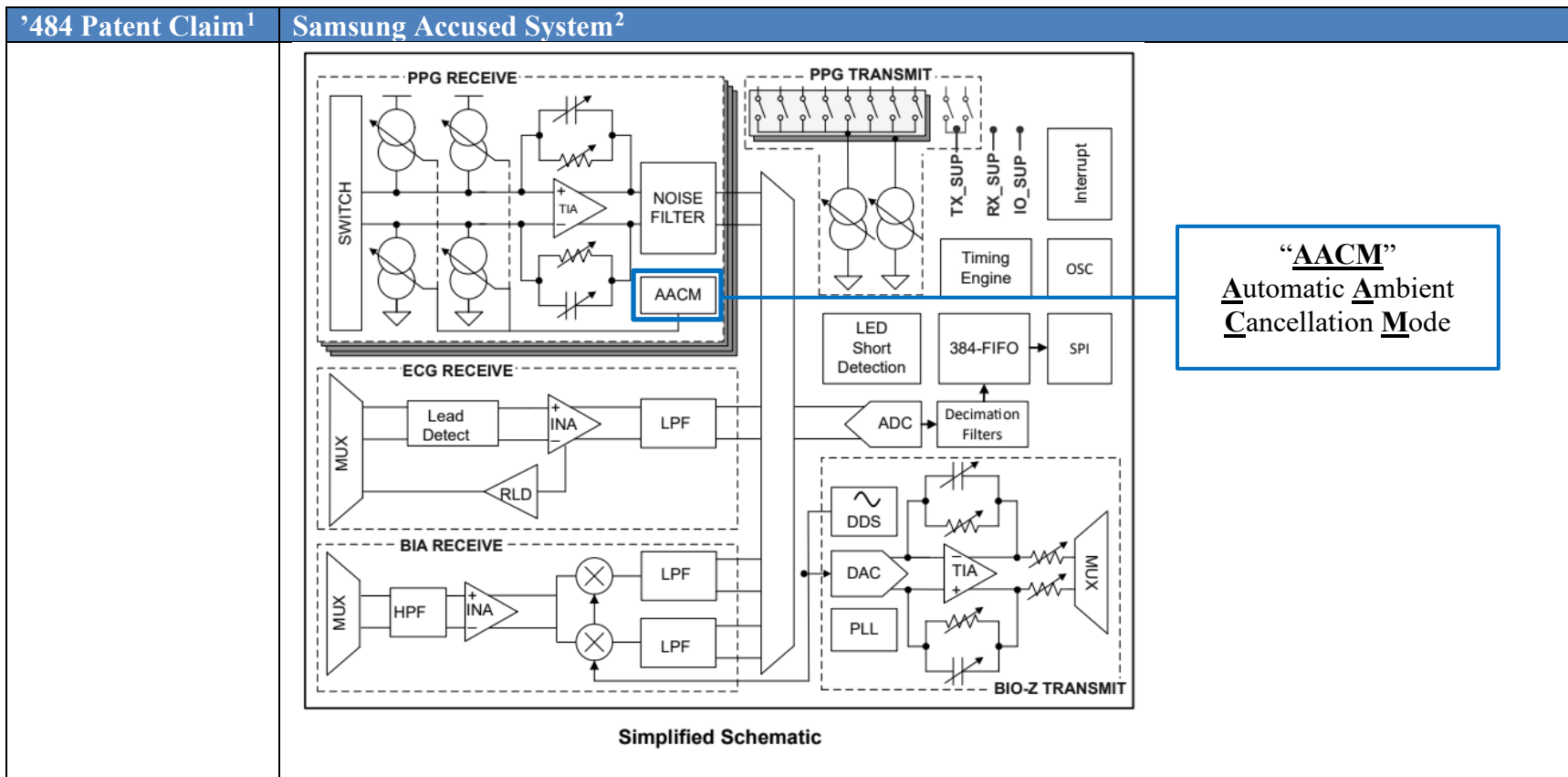
U.S. Patent No. 10,517,484 (the “’484 Patent”)

“Semiconductor diodes-based physiological measurement device with improved signal-to-noise ratio”

’484 Patent Claim ¹	Samsung Accused System ²
first signal and the second signal.	<p data-bbox="485 203 1877 418">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 cancellation is performed to cancel out the ambient light noise, thereby increasing the SNR. The BioActive Sensor of the Galaxy Watch Ultra performs ambient light cancellation (also referred to as “Digital Ambient Subtraction”), to increase the SNR, by comparing the measured signal when the LED sources are off (“first signal”) and the measured signal when the LED sources are on (“second signal”).</p> <div data-bbox="485 456 1787 980"><p data-bbox="499 462 835 495">Step 6 Bio Sensor Assembly</p><p data-bbox="1150 678 1591 699">● Texas Instruments AFE4510 biosensing analog front-end</p></div> <p data-bbox="485 1024 1860 1133">Source: IFIXIT, Samsung Galaxy Watch Ultra Chip ID, https://www.ifixit.com/Guide/Samsung+Galaxy+Watch+Ultra+Chip+ID/175327?srsId=AfmBOoriU1zDb_SwZ7O5CP4JIQFSWUnKHWqSe9g6SXYqF3F-NzUYIGpw.</p>

U.S. Patent No. 10,517,484 (the “’484 Patent”)

“Semiconductor diodes-based physiological measurement device with improved signal-to-noise ratio”



“AACM”
Automatic Ambient
Cancellation Mode

U.S. Patent No. 10,517,484 (the “’484 Patent”)

“Semiconductor diodes-based physiological measurement device with improved signal-to-noise ratio”

'484 Patent Claim ¹	Samsung Accused System ²
	<p>PPG signal acquisition:</p> <ul style="list-style-type: none"> – Acquisition of 24 PPG signal sets (<u>LED</u>, <u>AMB</u>) – Supports PPG sensors at different data rates – Peak system SNR of 115 dB in 0.5-10Hz band enables high-accuracy SpO₂ measurement – Low Current for Continuous Operation with a Typical Value: 19µA for the Receiver <p>PPG Transmitter:</p> <ul style="list-style-type: none"> – 8-Bit Programmable LED Current with a range adjustable from 50mA to 300mA – LED Short Detection – Support of 16 LEDs in Common Anode configuration for SpO₂, OHRM, Spectroscopy <p>PPG Receiver:</p> <ul style="list-style-type: none"> – Supports 5 PDs, 4 parallel receive paths – Noise filtering with programmable bandwidth – Trans-impedance Gain: 3.7kΩ to 1MΩ – 8-bit Ambient Offset Subtraction DAC up to 256µA – 9-bit LED Offset Subtraction DAC up to 64µA – <u>Digital Ambient Subtraction at ADC Output</u> <p>Source: Source: Texas Instruments, AFE4510, SBASB19 – March 2024, at 1-2, <i>available at</i> https://www.ti.com/lit/ds/symlink/afe4510.pdf.</p> <p>“To save power, the LED is pulsed at the PRF rate, turning on for a short window in each PRF cycle. Each turning on of the LED results in one sample in the digital data stream. . . . Input offset cancellation DAC cancels DC from both ambient and LED, and allows a high TIA gain setting for the best noise performance.” Texas Instruments, Application Brief, “Optical Heart Rate Monitoring (OHRM) on Wearables,” SBAA564, Nov. 2022, at 1, <i>available at</i> https://www.ti.com/lit/ab/sbaa564/sbaa564.pdf.</p>

2484 Patent Claim¹

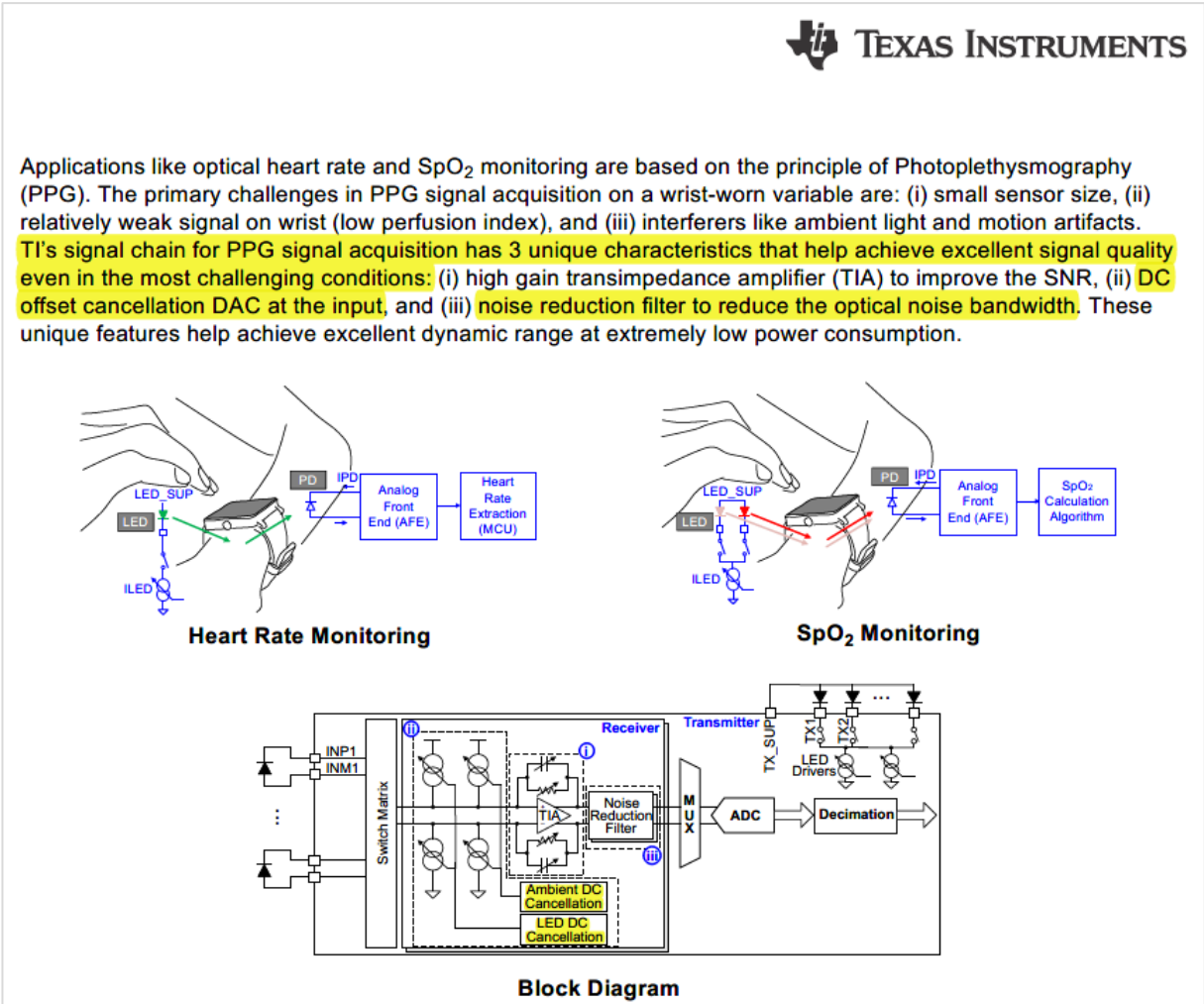
Samsung Accused System²

Table 1. Specifications for OHRM on Wearables		
System Specifications	AFE4432	Comments
Multi-sensor support	4 LEDs, 3 PDs	Combining signals from multiple PDs and LEDs helps mitigate motion artifacts
Sampling rate	1 Hz–1 kHz	A sampling rate of 25 Hz to 100 Hz is typically used for continuous HRM
Current consumption	12 μ A	For the receiver at 25 Hz PRF
Peak SNR	115 dB over 10-Hz bandwidth	Important consideration to achieve good accuracy in low perfusion cases.
Ambient rejection	> 70 dB up to 160 Hz	Good ambient rejection helps remove the spurious tones caused by ambient light from sources such as indoor lighting

Figure 3 shows the PPG signal chain in AFE4432.

Figure 3. PPG Signal Chain in AFE4432

The LED driver drives up to 4 LEDs with programmable current. Each receiver can interface to up to 3 PDs and comprises a TIA, input DC offset cancellation DACs (for ambient, LED light), and noise reduction filters with programmable bandwidth. Both receivers share a common analog-to-digital converter (ADC). The PPG signal chain for optical heart rate monitoring on wearables is supported on many other AFEs from Texas Instruments such as the AFE4950, AFE4960P, and AFE4500 devices.

’484 Patent Claim ¹	Samsung Accused System ²
	<p>Source: Texas Instruments, Application Brief, “Optical Heart Rate Monitoring (OHRM) on Wearables,” SBAA564, Nov. 2022, at 2, available at https://www.ti.com/lit/ab/sbaa564/sbaa564.pdf.</p> <div data-bbox="489 305 1696 1312">  <p>The diagram shows the Texas Instruments logo at the top right. Below it, a paragraph describes the challenges of PPG signal acquisition on a wrist-worn device: (i) small sensor size, (ii) relatively weak signal on wrist (low perfusion index), and (iii) interferers like ambient light and motion artifacts. It then states that TI's signal chain has three unique characteristics: (i) high gain transimpedance amplifier (TIA) to improve the SNR, (ii) DC offset cancellation DAC at the input, and (iii) noise reduction filter to reduce the optical noise bandwidth. Below this text are two block diagrams: 'Heart Rate Monitoring' and 'SpO₂ Monitoring'. The 'Heart Rate Monitoring' diagram shows a hand with a sensor (LED, ILED, PD) connected to an Analog Front End (AFE) and a Heart Rate Extraction (MCU). The 'SpO₂ Monitoring' diagram shows a hand with a sensor (LED, ILED, PD) connected to an Analog Front End (AFE) and an SpO₂ Calculation Algorithm. At the bottom is a detailed 'Block Diagram' of the sensor system, showing a Switch Matrix, Receiver, Transmitter, TIA, Noise Reduction Filter, Ambient DC Cancellation, LED DC Cancellation, ADC, and Decimation.</p> </div>

’484 Patent Claim ¹	Samsung Accused System ²
	<p>Source: Texas Instruments, Product Overview, “Photoplethysmography (PPG) with Integrated AFE for Optical Biosensing,” Oct. 2023, at 1, <i>available at</i> https://www.ti.com/lit/po/sbat014/sbat014.pdf?ts=1724246538793&ref_url=https%253A%252F%252Fwww.google.com%252F.</p> <div data-bbox="489 418 1776 1154"> <p>5 AFE4500 Register Generation Excel</p> <p>The AFE4500_Register_Generation_v*.xlsm will be given by TI. This configuration file will be in the EVM software installation directory.</p> <p>Default file location: C:\Program Files\Texas Instruments\Bio-Sensing\AFE4500EVM\Register config\AFE4500_Register_Generation_v*.xlsm</p> <p>By default the EVM ships in LDO enable mode with following configuration</p> <ul style="list-style-type: none"> • Clocking : Internal oscillator • PPG configuration <ul style="list-style-type: none"> – PPG output data rate: 50 Hz – 3 Phases (Phase1, Phase2, Phase3) are defined for PPG: AMB1, LED, AMB2 – PPG Phases are sampled from Green PD of sensor board – TX1 (connected to Green LED on sensor board) is used to LED Phase. – TIA Gain (i.e. Rf): 250 kΩ – Sampling width: 117 μS – Noise reduction filter: 2.5 KHz – ANA AACM: Enabled to cancel ambient signal from all Phases – DIG AACM: Enabled to cancel the DC in LED Phase. • ECG Configuration <ul style="list-style-type: none"> – ECG output data rate: 500 Hz – ECG INA Gain: 21 </div> <p>Source: Texas Instruments, AFE4500 EVM User Guide, SBAU370 – April 2021, at 23, <i>available at</i> https://www.manualslib.com/download/2652772/Texas-Instruments-Afe4500evm.html.</p>

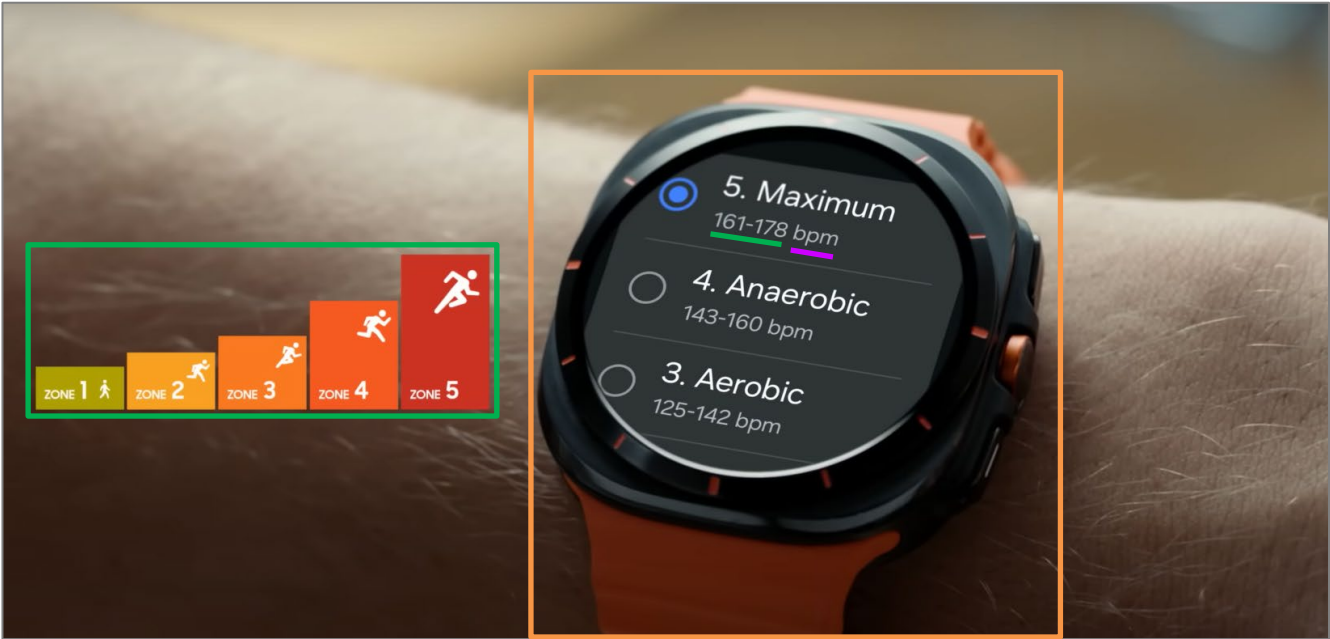
’484 Patent Claim ¹	Samsung Accused System ²
	<p>Samsung engineers authored a technical paper further describing ambient light cancellation in PPG applications for wearable devices:</p> <p><i>B. Ambient Light Cancellation (ALC)</i></p> <p>The ambient light component in the detected PPG signal can be removed in the ALC block, which is shown in Fig. 2. When the LED light turns on, the measured signal corresponding to both the LED light and the ambient light is sampled at the charge reservoir Cr, and when the LED light turns off, the measured signal corresponding to only the ambient light is sampled at an another charge reservoir Ca. Then, the charge redistribution occurs to cancel the ambient</p> <div data-bbox="520 678 1360 1166"> <p>Figure 1. Top block diagram of LED driving and PD detection circuit for PPG application.</p> </div> <p>light component out by reconnecting the two charge reservoirs in a manner of reversed polarity.</p>

’484 Patent Claim ¹	Samsung Accused System ²
	<div data-bbox="489 196 1339 951"> <p>Figure 2. Detailed architecture of the ambient light cancellation (ALC) block.</p> </div> <p>Source: J. Kim et al., “Ambient light cancellation in photoplethysmogram application using alternating sampling and charge redistribution technique,” 2015 37th Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBC), at 6441-42.</p>
<p>8. The system of claim 7, wherein the wearable device is at least in part configured to</p>	<p>The Accused System comprises an Accused Smartwatch that is at least in part configured to identify an object, and a property of at least some of the output signal is compared by at least one of the Accused Smartwatch or the Accused Phone/Tablet to a threshold, either literally or under the doctrine of equivalents.</p>

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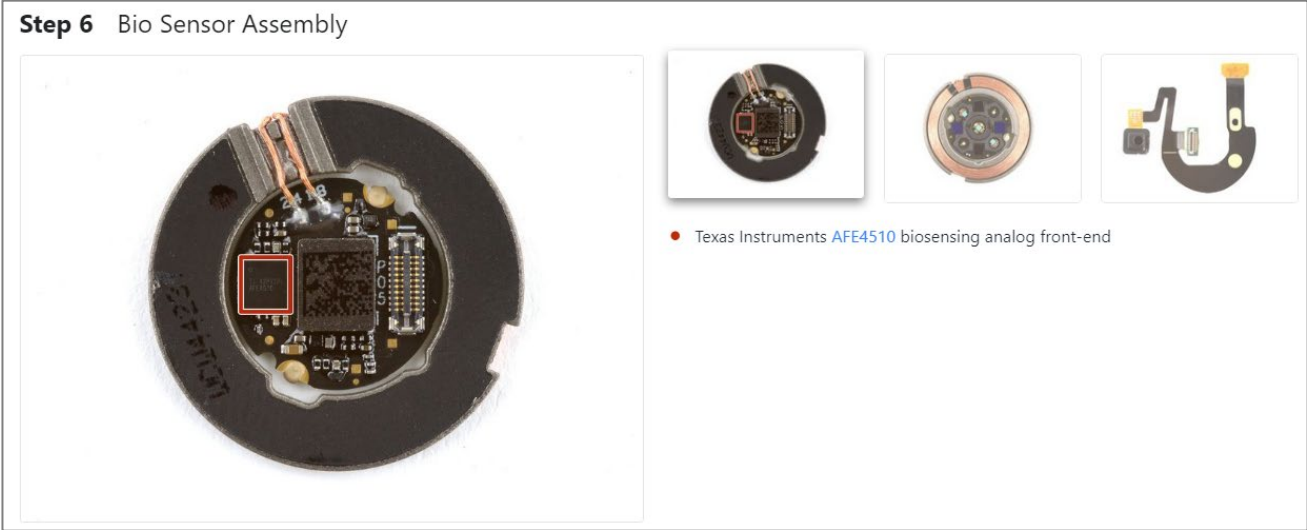
“Semiconductor diodes-based physiological measurement device with improved signal-to-noise ratio”

’484 Patent Claim ¹	Samsung Accused System ²
<p>identify an object, and a property of at least some of the output signal is compared by at least one of the wearable device, the smart phone or tablet to a threshold.</p>	<p>For example, the Galaxy Watch Ultra (“wearable device”) is at least in part configured to recognize or establish when it is being worn by a human user by identifying one or more physiological parameters of the human user (<i>e.g.</i>, human health metrics and data such as heart rate, SpO2, and sleep metrics). In doing so, the Accused Smartwatch is also at least in part configured to recognize or establish details about the user’s blood (<i>e.g.</i>, constituents in the blood or oxygen saturation of the user’s blood). The Galaxy Watch Ultra is also configured such that it enables a user to establish Heart Rate Alerts and Heart Rate Zones, to which heart rate measurements taken of the user by the BioActive Sensor can be compared.</p> <p>“Some features on Galaxy Watch running Wear OS powered by Samsung function only when the watch is being worn on the user’s wrist. Notifications are an important example of one such feature. When the watch is not being worn, phone notifications are not synchronized to the watch and local notifications generated on the watch are muted. Off-Body detection enables you to determine if the user is wearing the watch. To enable this, the watch contains a Low Latency Off-Body sensor. The data from this sensor allows you to enhance your application by implementing it to, for example, send or avoid notifications or to show or hide sensitive information, as appropriate.” S. Nasrin, “Detect When a Galaxy Watch Is Being Worn,” Samsung Developer, June 14, 2023, https://developer.samsung.com/sdp/blog/en/2023/06/14/detect-when-a-galaxy-watch-is-being-worn.</p> <div data-bbox="489 857 1808 1175" style="border: 1px solid black; padding: 10px; margin: 10px 0;"> <p><u>Wrist detection</u></p> <p>When enabled <u>the watch automatically detects when the watch is being worn</u>. It is advisable to only turn this feature off if your watch has trouble detecting when it is on your wrist.</p> <p>○ From  Settings, tap  Security and privacy > Wrist detection.</p> </div> <p>Source: Samsung Galaxy Watch7 Watch Ultra User Guide at 65, <i>available at</i> https://downloadcenter.samsung.com/content/UM/202407/20240717003704208/WEA_L30X_L31X_L70X_EN_UG_XF3_070324_FINAL.pdf.</p>

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	<div data-bbox="489 240 1434 365"> <h2>Set Up Heart Rate Alerts on Your Galaxy Watch</h2> </div> <p data-bbox="489 410 1816 483">“Set personalised alerts on your Galaxy Watch for monitoring high and low BPM. You can receive heart rate alerts from your watch if your heart rate is above a certain level for 10 minutes when resting.”</p> <p data-bbox="489 521 1793 589">Source: https://r1.communitysamsung.com/t5/samsung-health/set-up-heart-rate-alerts-on-your-galaxy-watch/td-p/24451155</p> <div data-bbox="489 664 1810 1299">  </div>

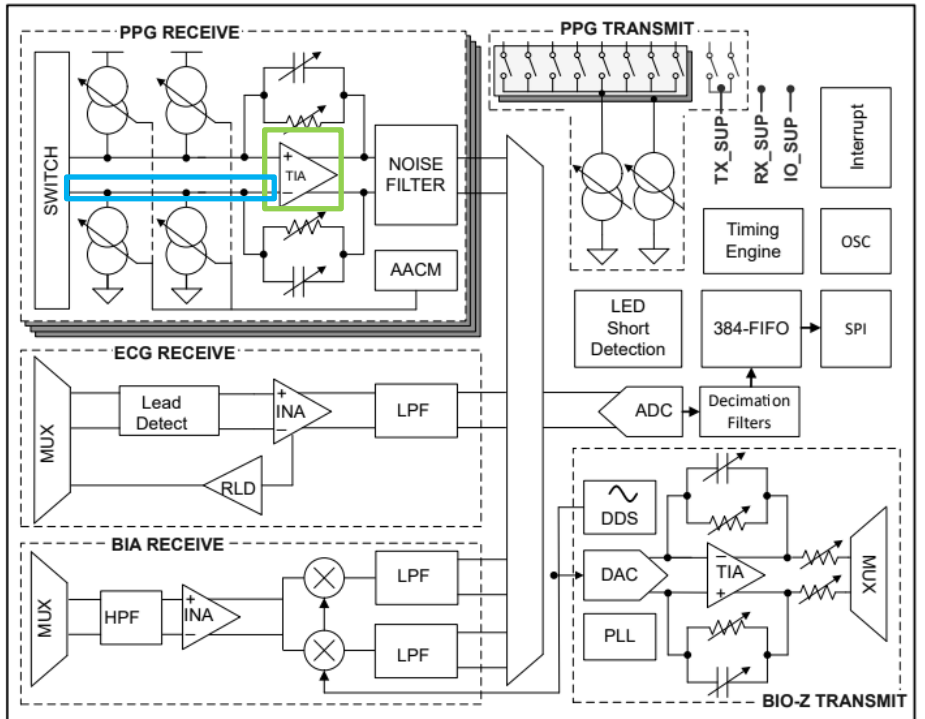
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“Semiconductor diodes-based physiological measurement device with improved signal-to-noise ratio”

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	<p>Source: Samsung, “A friendly guide to Galaxy Watch Ultra, Watch7 and Buds3 Pro,” YouTube, July 24, 2024, at 1:05-1:50, https://www.youtube.com/watch?v=VQW-ZpdAm5M.</p>
<p>9. The system of claim 8, wherein a detector output from at least one of the plurality of spatially separated detectors is coupled to an amplifier having a gain configured to improve detection sensitivity.</p>	<p>The Accused System comprises an Accused Smartwatch, in which a detector output from at least one of the plurality of spatially separated detectors is coupled to an amplifier having a gain configured to improve detection sensitivity, either literally or under the doctrine of equivalents.</p> <p>For example, the output from the photodiodes/PDs (“spatially separated detectors”) is coupled to a high gain trans impedance amplifier (“amplifier having a gain”) to improve detection sensitivity.</p> <div data-bbox="489 602 1787 1128"> <p>Step 6 Bio Sensor Assembly</p>  </div> <p>Source: IFIXIT, Samsung Galaxy Watch Ultra Chip ID, https://www.ifixit.com/Guide/Samsung+Galaxy+Watch+Ultra+Chip+ID/175327?srsId=AfmBOoriU1zDb_SwZ7O5CP4JIQFSWUnKHWqSe9g6SXYqF3F-NzUYIGpw.</p>

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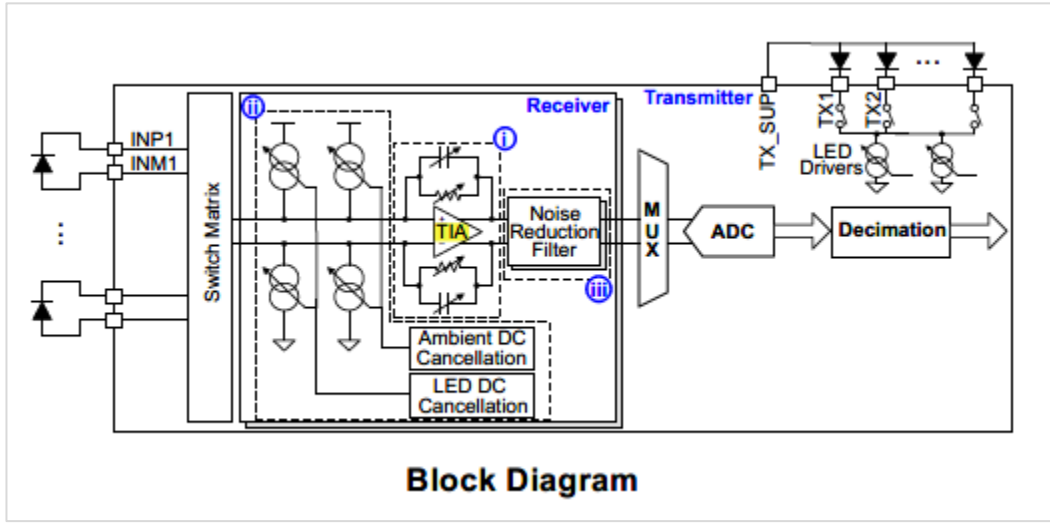
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	<p>“The AFE4510 is a versatile signal acquisition system that supports acquiring PPG, EDA, ECG, and Bioimpedance signals. A PPG signal chain comprises a current driver for LEDs and a receiver that senses the signal from PDs. An ECG receiver with a Rightleg drive (RLD) can acquire a single-lead ECG from a pair of electrodes. An impedance measurement signal chain with integrated excitation & sense can be used for applications like BIA, EDA, and Impedance spectroscopy. The outputs of the various signal chains are digitized by a common ADC and stored in a FIFO which can be read out using an SPI interface</p>  <p style="text-align: center;">Simplified Schematic</p>

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	<p>Source: Texas Instruments, AFE4510, SBASB19 – March 2024, at 1-2, <i>available at</i> https://www.ti.com/lit/ds/symlink/afe4510.pdf.</p> <div data-bbox="493 308 1333 568"> <p>Differentiation</p> <ul style="list-style-type: none"> Signal chain has wide adaptability (LED current, transimpedance amplifier (TIA) gain, offset digital-to-analog converter (DAC) range) for a variety of use cases including low perfusion index, high ambient, and motion </div> <p>Figure 3 shows the PPG signal chain in AFE4432.</p> <div data-bbox="493 576 1606 998"> </div> <p>Figure 3. PPG Signal Chain in AFE4432</p> <p>The LED driver drives up to 4 LEDs with programmable current. Each receiver can interface to up to 3 PDs and comprises a TIA, input DC offset cancellation DACs (for ambient, LED light), and noise reduction filters with programmable bandwidth. Both receivers share a common analog-to-digital converter (ADC). The PPG signal chain for optical heart rate monitoring on wearables is supported on many other AFEs from Texas Instruments such as the AFE4950, AFE4960P, and AFE4500 devices.</p> <p>Source: Texas Instruments, Application Brief, “Optical Heart Rate Monitoring (OHRM) on Wearables,” SBAA564, Nov. 2022, at 1, <i>available at</i> https://www.ti.com/lit/ab/sbaa564/sbaa564.pdf.</p>

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	<div data-bbox="1318 240 1766 298">  TEXAS INSTRUMENTS </div> <p data-bbox="506 386 1751 594"> Applications like optical heart rate and SpO₂ monitoring are based on the principle of Photoplethysmography (PPG). The primary challenges in PPG signal acquisition on a wrist-worn variable are: (i) small sensor size, (ii) relatively weak signal on wrist (low perfusion index), and (iii) interferers like ambient light and motion artifacts. TI's signal chain for PPG signal acquisition has 3 unique characteristics that help achieve excellent signal quality even in the most challenging conditions: (i) high gain transimpedance amplifier (TIA) to improve the SNR, (ii) DC offset cancellation DAC at the input, and (iii) noise reduction filter to reduce the optical noise bandwidth. These unique features help achieve excellent dynamic range at extremely low power consumption. </p> <div data-bbox="485 613 1528 1133">  <p data-bbox="884 1073 1121 1105" style="text-align: center;">Block Diagram</p> </div> <p data-bbox="485 1175 1803 1243"> Source: Texas Instruments, Product Overview, “Photoplethysmography (PPG) with Integrated AFE for Optical Biosensing,” Oct. 2023, at 1, available at https://www.ti.com/lit/po/sbat014/sbat014.pdf. </p>

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<p>10. The system of claim 9, wherein the wearable device is configured to use artificial intelligence to process at least a portion of the output signal.</p>	<p>The Accused System comprises an Accused Smartwatch that is configured to use artificial intelligence to process at least a portion of the output signal, either literally or under the doctrine of equivalents.</p> <p>For example, the Galaxy Watch Ultra is configured to use Galaxy AI (“artificial intelligence”) to process the output signal.</p> <div data-bbox="485 415 1614 672">  </div> <p>Source: https://www.samsung.com/us/watches/galaxy-watch-ultra/</p> <div data-bbox="485 750 1129 1107">  </div> <p>Source: https://www.samsung.com/us/apps/samsung-health/</p>

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	<div data-bbox="489 201 1843 477"><p>Know your score. Own your day.</p><p><u>Start your day strong with a score that calculates your physical readiness based on yesterday's sleep, heart rate and steps. ¹Energy Score with Galaxy AI analyzes key indicators of your overall condition and gives you a daily score so you can crush your goals.</u></p></div> <p data-bbox="489 483 1472 516">Source: https://www.samsung.com/us/watches/galaxy-watch-ultra/#galaxy-ai</p> <div data-bbox="489 553 1728 1114"><p>The screenshot shows the Samsung Galaxy Watch Ultra interface. At the top, a pink box highlights the heart rate display showing 93 bpm and a range of 80-110 bpm. Below this, the main display shows an Energy Score of 94, which is 10 points higher than yesterday's score of 84. The score is labeled 'Excellent'. To the left, a summary of daily activity is shown: 4,350 steps, 76 minutes, and 458 calories. To the right, a sleep score of 80 is shown, labeled 'Good', with a sleep duration of 5h 12m. The watch face is black with a blue circular progress indicator around the Energy Score.</p></div> <p data-bbox="489 1120 1472 1153">Source: https://www.samsung.com/us/watches/galaxy-watch-ultra/#galaxy-ai</p>

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	<div data-bbox="493 203 1501 284"> <h2>More precise Heart Rate Tracking</h2> </div> <div data-bbox="493 373 1438 560"> <p><u>Zero in on more precise readings during workouts using Heart Rate Tracking with Galaxy AI that filters out the physical movements of your body.³ Insights are collected by your Watch and analyzed on your phone.</u></p> </div> <p>Source: https://www.samsung.com/us/watches/galaxy-watch-ultra/#galaxy-ai</p> <p>Earlier this year, Samsung established the era of mobile AI with the launch of the Galaxy S24 series, and committed to introducing Galaxy AI1 on a wider range of devices. True to this promise, Samsung is now bringing Galaxy AI to Galaxy Watch, enhancing its popular health features. By combining powerful on-device AI with the extensive Samsung Health app, Samsung is on the path to building some of the most personalized and secure health experiences yet.</p> <p>Samsung has been on a mission to deliver an advanced health and wellness experience, starting by utilizing meaningful and actionable insights to help you gain a better understanding of your health patterns. Now, by combining Galaxy AI with Samsung Health, new health features will provide you with more comprehensive health insights, along with motivational encouragement to help you improve your daily wellness. With Energy Score,² you can receive a better understanding of your daily condition through a combined analysis of personal health metrics including sleep time average, sleep time consistency, bed/wake time consistency, sleep timing, previous day activity, sleeping heart rate and heart rate variability³ to help you take on your day. Plus, Wellness Tips⁴ helps you reach your personal health goals by offering insights, motivational tips and guidance based on the specific goal you’re looking to achieve. Accurate and comprehensive health metrics are foundational to the best intelligent health experiences. Enhanced health algorithms and advanced tracking tools will provide more holistic, personalized and actionable insights when combined with AI. Since good health starts with a good night’s rest, Samsung is enhancing our sleep AI algorithm to provide additional in-depth sleep insights. Newly added sleep indicators for Sleep Insights offer you a more detailed and accurate analysis of your sleep quality so you can</p>

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	<p>better understand your sleep patterns and build better habits. These added metrics include movement during sleep, sleep latency, heart rate and respiratory rate during sleep in addition to previously supported metrics like snoring hours, blood oxygen level and sleep cycle.</p> <p>Source: https://news.samsung.com/global/galaxy-ai-is-coming-to-new-galaxy-watch-for-more-motivational-health</p>

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