

U.S. Patent No. 9,651,533 (the “’533 Patent”)

“Semiconductor source based near infrared measurement device with improved signal-to-noise ratio”

’533 Patent Claim ¹	Samsung Accused System ²
5[pre] A measurement system comprising:	Without conceding that the preamble of Claim 5 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 user information, either literally or under the doctrine of equivalents. For example, Samsung provides a “measurement system,” including a Galaxy Watch Ultra, a Samsung smartphone or tablet, and Samsung Cloud for measuring physiological information such as a user’s heart rate and blood oxygen level. When the user wears a Galaxy Watch Ultra on their wrist, the watch measures information using various hardware components, such as Samsung’s “BioActive sensor,” and transmits the information to an Accused Phone/Tablet and to the Accused Cloud.

¹ Samsung infringes multiple claims of the ’533 Patent, including at least Claims 11-12. Claims 11-12 both depend on independent Claim 5. Accordingly, Claim 5 is provided in this chart to show exemplary evidence of Samsung’s infringement of the limitations of Claim 5, which are included in Claims 11-12.

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.

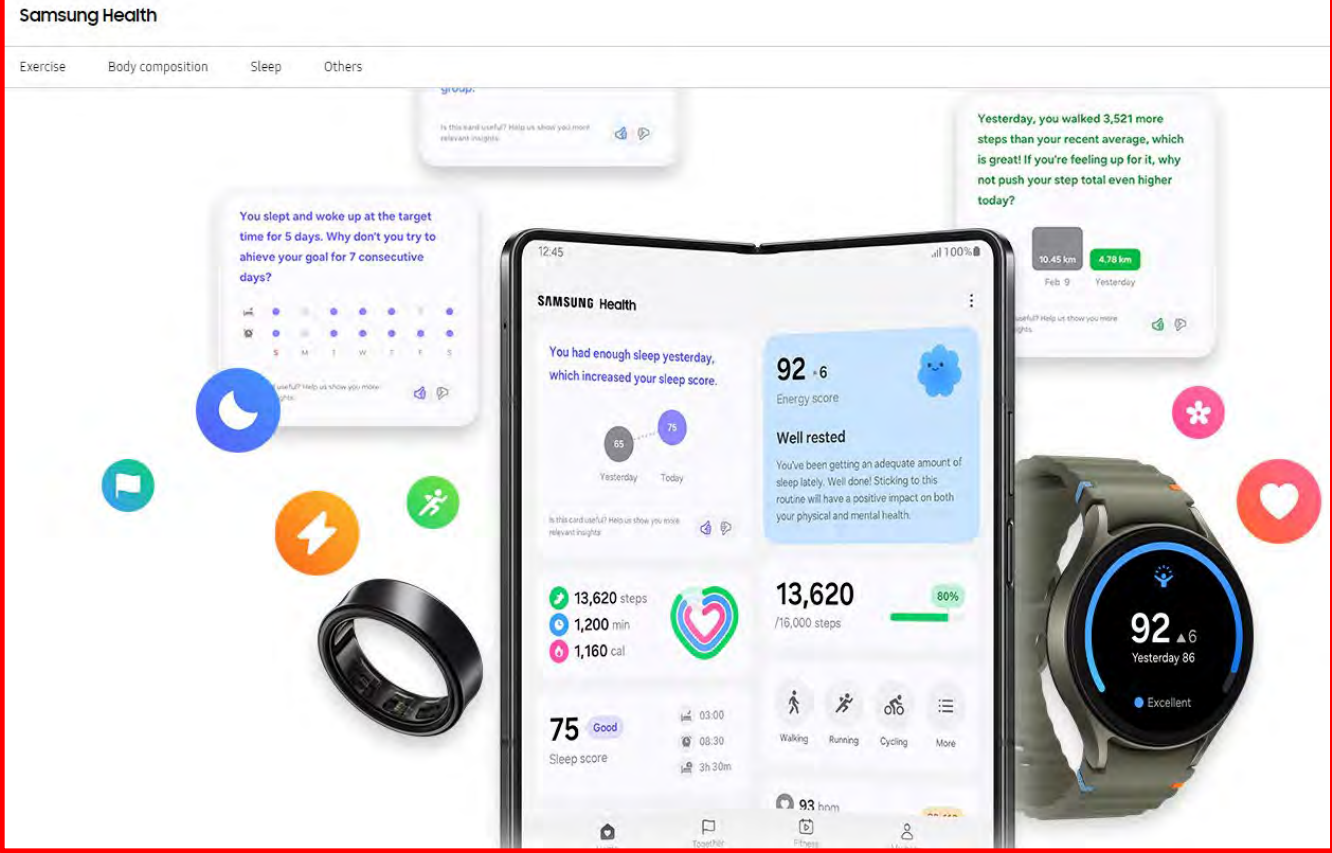
U.S. Patent No. 9,651,533 (the “’533 Patent”)

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’533 Patent Claim ¹	Samsung Accused System ²
	 Source: https://news.samsung.com/global/galaxy-history-%E2%91%A2-evolution-of-the-galaxy-watch-series-reimagining-the-watch

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	The image shows a screenshot of the Samsung Health app interface on a smartphone. The app displays various health metrics and goals. At the top, there are tabs for Exercise, Body composition, Sleep, and Others. Below these, there are several cards and widgets. One card shows a sleep goal for 7 consecutive days. Another card shows a sleep score of 75, labeled 'Good'. A third card shows a sleep score of 92, labeled 'Excellent'. There are also widgets for steps (13,620), distance (4.78 km), and calories (1,160). A smartwatch is shown on the right side of the screen, displaying a large '92' on its face. The source URL is provided at the bottom of the screenshot area. Source: https://www.samsung.com/us/apps/samsung-health/

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	 Your ultimate tracking team Your Galaxy Watch, Ring and compatible phone work together to give you a closer look at your body.¹¹ Together with the Samsung Health app, they deliver a holistic view of the insights you need to move closer to your wellness goals. Learn more Source: https://www.samsung.com/us/watches/galaxy-watch-ultra/ More precise Heart Rate Tracking 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 <u>Insights are collected by your Watch and analyzed on your phone.</u> Source: https://www.samsung.com/us/watches/galaxy-watch-ultra/

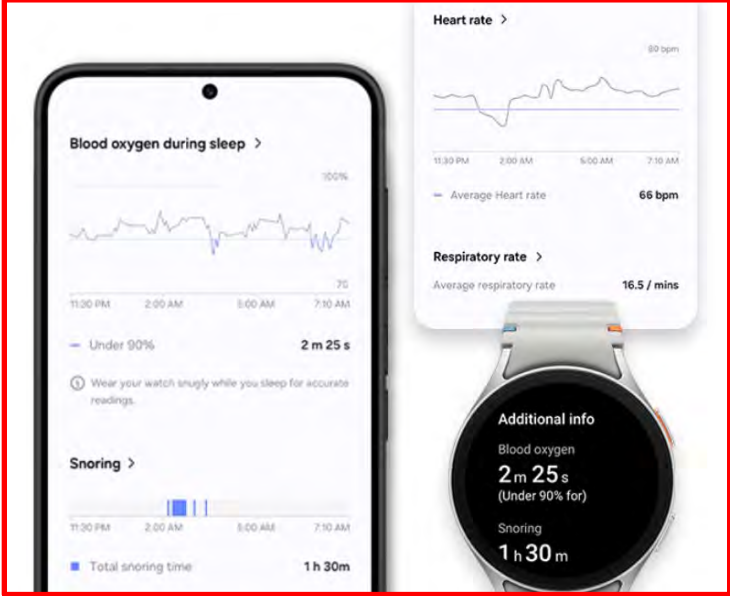
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’533 Patent Claim ¹	Samsung Accused System ²
	Pairs well with Experience a smarter life with a Galaxy that'll keep up with you.  Galaxy Watch Ultra Galaxy Z Fold6  Galaxy Z Flip6 Source: https://www.samsung.com/us/apps/samsung-health/

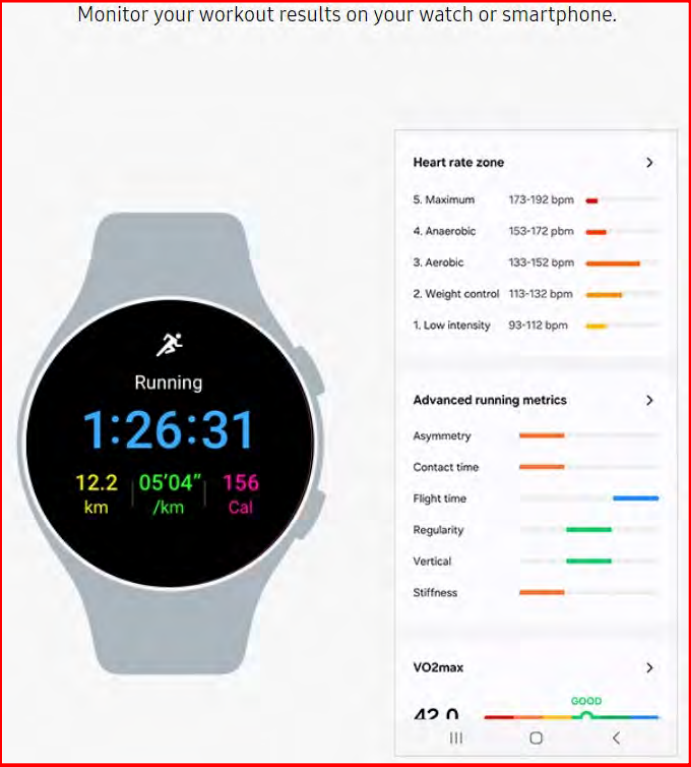
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	A screenshot of the Samsung Health app interface. On the left, a smartphone screen displays 'Blood oxygen during sleep' with a line graph showing fluctuations between 90% and 100% over a sleep period from 11:30 PM to 7:10 AM. Below this, it shows 'Under 90%' for '2 m 25 s' and 'Total snoring time' as '1 h 30m'. On the right, a smartwatch displays 'Additional info' with 'Blood oxygen 2 m 25 s (Under 90% for)' and 'Snoring 1 h 30 m'. Above the watch, a separate panel shows 'Heart rate' with a line graph and an 'Average Heart rate' of '66 bpm', and 'Respiratory rate' with an 'Average respiratory rate' of '16.5 / mins'. The entire screenshot is enclosed in a red rectangular border. Source: https://www.samsung.com/us/apps/samsung-health/

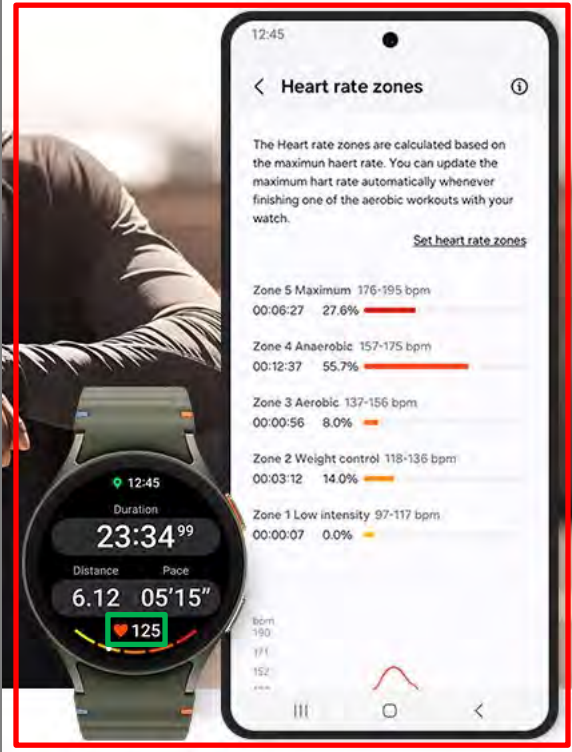
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	Monitor your workout results on your watch or smartphone.  Source: https://www.samsung.com/us/apps/samsung-health/

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’533 Patent Claim ¹	Samsung Accused System ²
	 Source: https://www.samsung.com/us/apps/samsung-health/#Improve_your_life

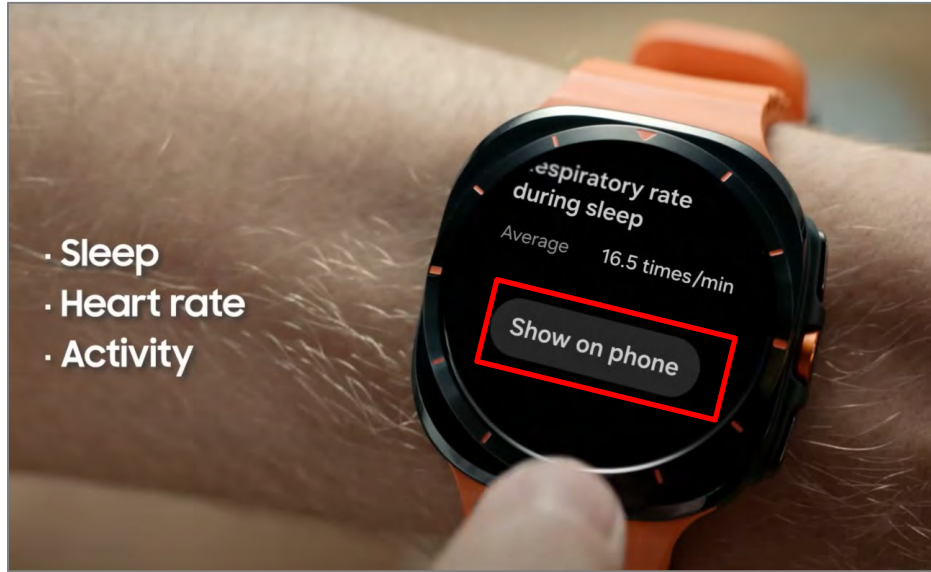
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	The Samsung Health application is installed on both the Galaxy Watch and a smartphone. The application synchronizes the measurements between both devices and manages the user's health data securely on them. The diagram illustrates the synchronization of the Samsung Health application between two devices. On the left, the 'Galaxy Watch' section shows the 'Samsung Health' app icon, 'Wear OS Powered by Samsung', and a 'BioActive Sensor'. On the right, the 'Android Smartphone' section shows the 'Samsung Health' app icon and 'Android'. A double-headed arrow connects the two app icons, indicating data synchronization. The entire diagram is enclosed in a red rectangular border. Figure 1: Samsung Health on Galaxy Watch and Android smartphone Source: https://developer.samsung.com/health/blog/en/health/blog/accessing-samsung-health-data-through-health-connect

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	 Source: https://www.youtube.com/watch?v=VQW-ZpdAm5M Sync your data in Samsung Health 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. Source: https://www.samsung.com/us/support/answer/ANS10001399/

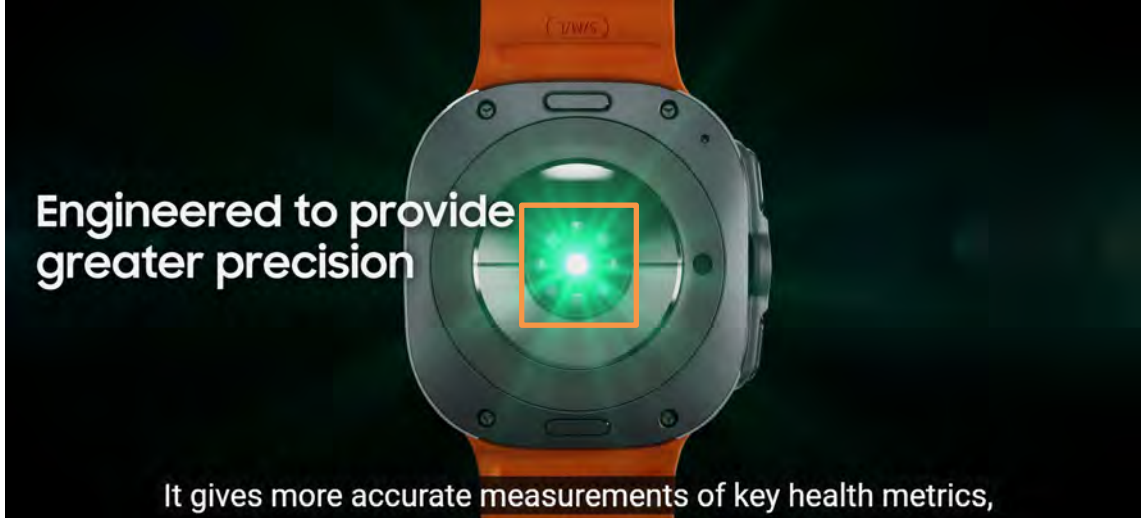
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	Before you can get your health and workout data onto another device, you'll need to sync information from your Samsung account to Samsung Health. If you're worried you'll forget, you can even sync information automatically. 1 Navigate to and open the Samsung Health app. Tap More options (the three vertical dots), and then tap Settings. 2 Tap <u>Sync with Samsung Cloud</u>, 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 <u>Sync now</u> to immediately sync your Samsung Health data. You can tap Sync now whenever you need to sync your data. If you are having difficulties syncing Samsung Health data with your Samsung smart watch, check out our data syncing guide. Source: https://www.samsung.com/us/support/answer/ANS10001399/
5[a] a light source comprising a plurality of semiconductor sources that are light emitting diodes, the light emitting diodes configured to generate an output optical beam with one or more optical wavelengths, wherein at least a	The Accused System comprises a light source comprising a plurality of semiconductor sources that are light emitting diodes, the light emitting diodes configured to generate an output optical beam with one or more optical wavelengths, wherein at least a portion of the one or more optical wavelengths is a near-infrared wavelength between 700 nanometers and 2500 nanometers. The Accused Smartwatch is equipped with multiple light-emitting diodes (LEDs) (“a plurality of semiconductor sources that are light emitting diodes”). These LEDs are configured to generate an output optical beam with one or more optical wavelengths, where distinct optical wavelengths are associated with different colors of visible light (e.g., green and red light) and non-visible light (e.g., infrared). At least a portion of the emitted wavelengths falls within the near-infrared range, between 800nm and 980nm.

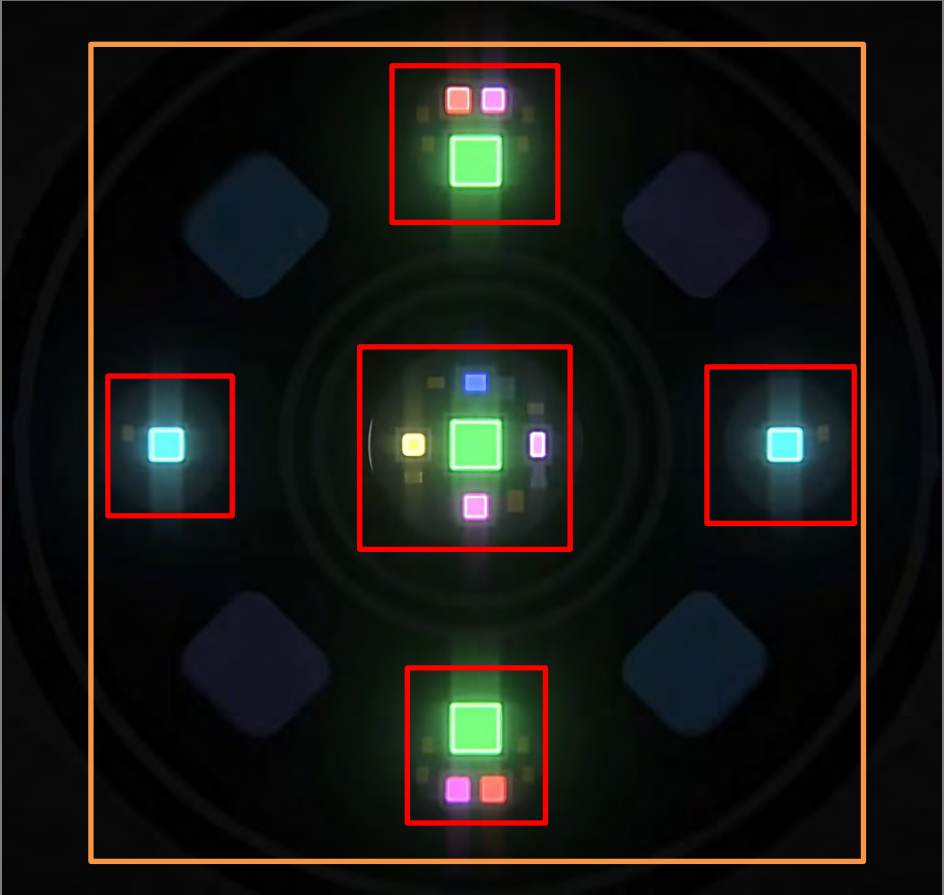
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portion of the one or more optical wavelengths is a near-infrared wavelength between 700 nanometers and 2500 nanometers,	 Source: https://www.youtube.com/live/DzjsdYZQ7ns?si=bAF5x36WRX5KSdvl&t=1049

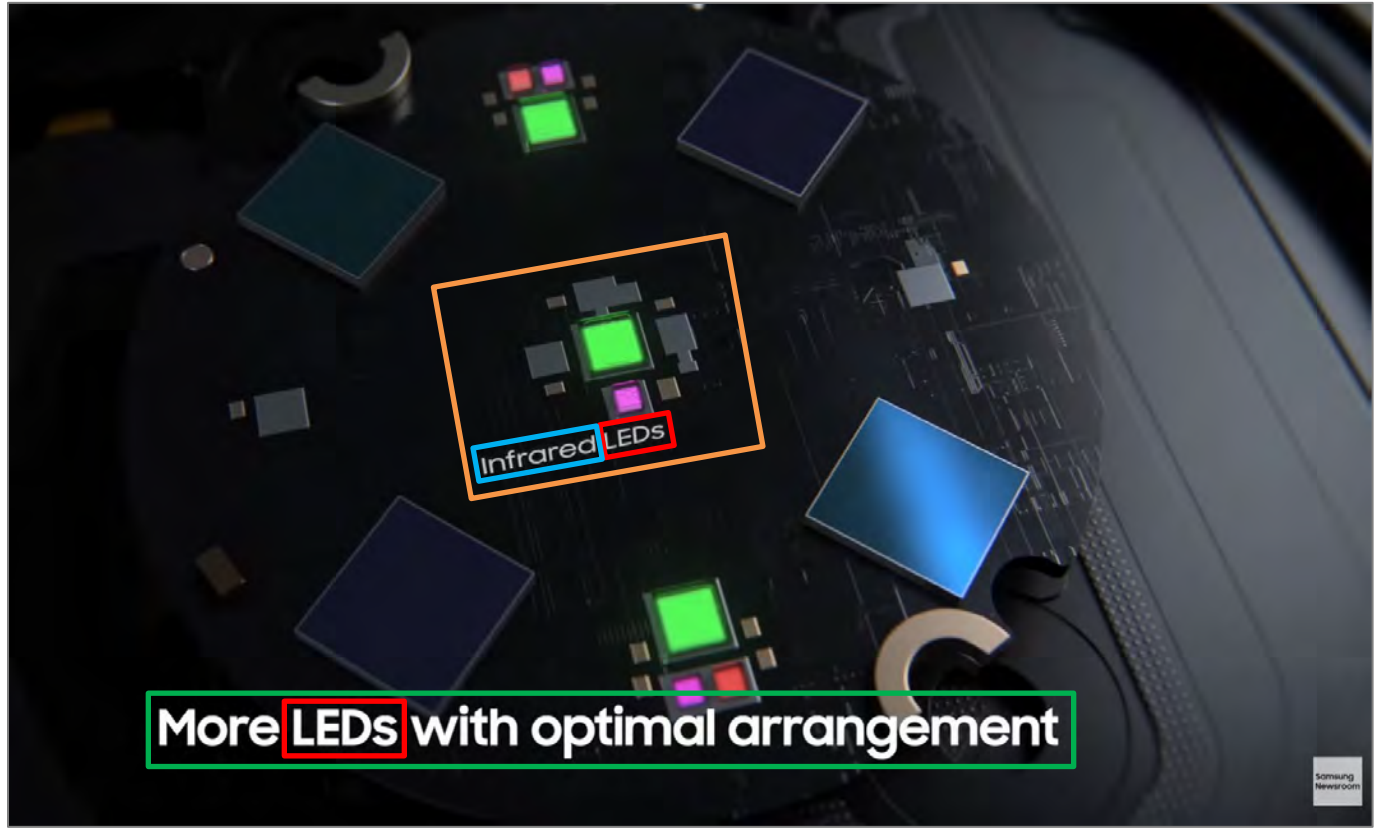
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	 Source: https://news.samsung.com/global/unlocking-new-possibilities-for-preventative-wellness-with-new-galaxy-watch-and-bioactive-sensor

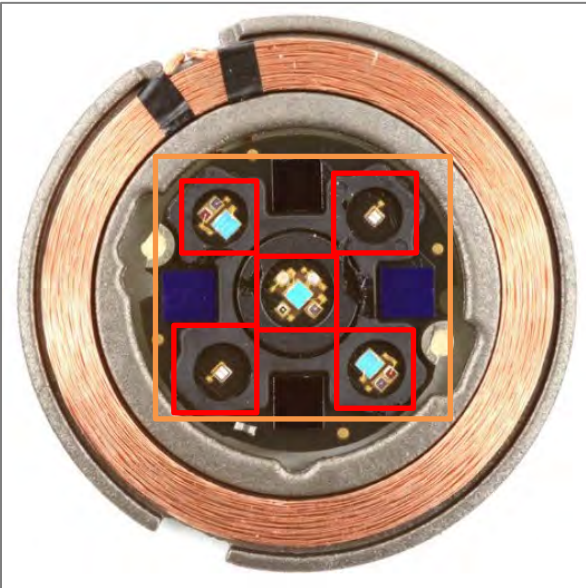
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	 Source: IFIXIT, Samsung Galaxy Watch Ultra Chip ID, https://www.ifixit.com/Guide/Samsung+Galaxy+Watch+Ultra+Chip+ID/175327 Samsung states, for example, that its “BioActive Sensor is essential to bringing you better preventative health experiences 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 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

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	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, available at https://news.samsung.com/global/unlocking-new-possibilities-for-preventative-wellness-with-new-galaxy-watch-and-bioactive-sensor Samsung further states that “[t]he 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.” 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 The following data types are supported by the Samsung Privileged Health SDK: <table><tr><td data-bbox="506 906 976 1044">PPG green</td><td data-bbox="976 906 1524 1044">Raw data from PPG <u>green LED</u>. Provided as a batching event.</td></tr><tr><td data-bbox="506 1044 976 1198"> PPG IR </td><td data-bbox="976 1044 1524 1198">Raw data from PPG <u>infrared LED</u>. Provided as an on-demand event.</td></tr><tr><td data-bbox="506 1198 976 1328">PPG red</td><td data-bbox="976 1198 1524 1328">Raw data from PPG <u>red LED</u>. Provided as an on-demand event.</td></tr></table>	PPG green	Raw data from PPG <u>green LED</u> . Provided as a batching event.	PPG IR	Raw data from PPG <u>infrared LED</u> . Provided as an on-demand event.	PPG red	Raw data from PPG <u>red LED</u> . Provided as an on-demand event.
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PPG IR	Raw data from PPG <u>infrared LED</u> . Provided as an on-demand event.						
PPG red	Raw data from PPG <u>red LED</u> . Provided as an on-demand event.						

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	Source: Samsung Developer, Samsung Privileged Health SDK, <i>available at</i> https://developer.samsung.com/health/privileged/overview.html Researchers have explained that “Infrared Light Emitting Diodes (LEDs), whose light emitting wavelength are between 800 nm and 980 nm, are widely used for light sources of remote controllers, photo couplers and infrared communications such as Infrared Data Associations (IrDA’s).” Kitabayashi, H., Kawabata, Y., Matsubara, H., Miyahara, K. I., & Tanaka, S. (2010). Development of High Power Infrared LED. <i>SEI Technical Review</i>, (70), 71. LEDs outputting light at different colors do so at different optical wavelengths. For example, a green LED, a red LED, and an infrared LED all output light at different optical wavelengths:

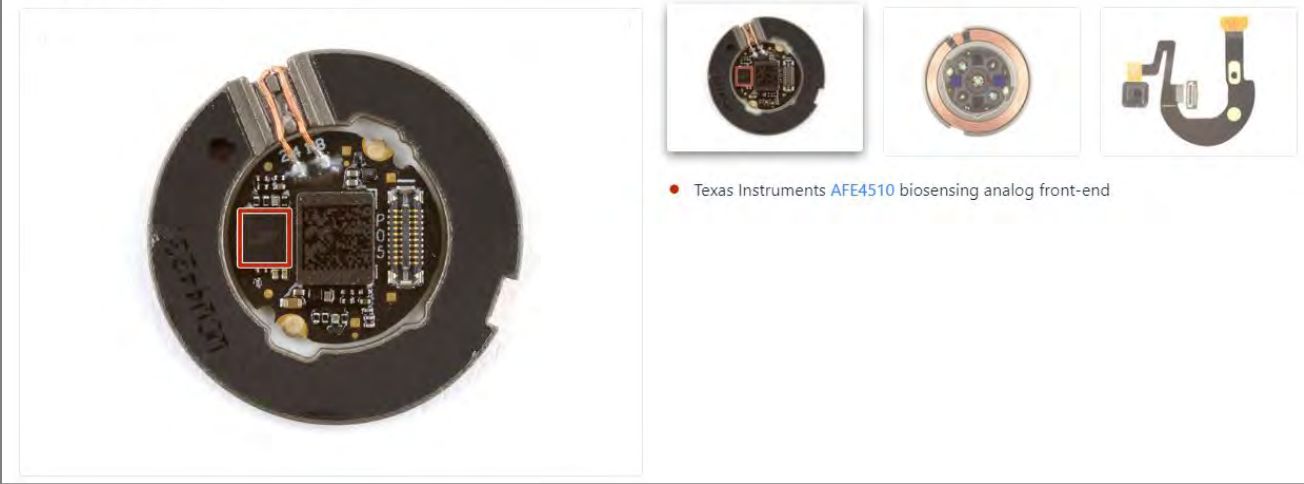
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	<table><tr><th colspan="2">Table 1. LEDs – Wavelengths and Applications</th></tr><tr><th>LED Wavelength (Color)</th><th>LED Applications</th></tr><tr><td>410–420 nm (Violet)</td><td>Skin therapy</td></tr><tr><td>430–470 nm (Blue)</td><td>Dental curing instruments</td></tr><tr><td>470 nm (Blue)</td><td>White LEDs using phosphor</td></tr><tr><td>520–530 nm (Green)</td><td>Green traffic signal lights</td></tr><tr><td>580–590 nm (Amber)</td><td>Amber traffic signal lights</td></tr><tr><td>630–640 nm (Red)</td><td>Red signal lights</td></tr><tr><td>660 nm (Deep Red)</td><td>Blood oximetry</td></tr><tr><td>680 nm (Deep Red)</td><td>Blood analysis</td></tr><tr><td>800–850 nm (Near-IR)</td><td>Night-vision illuminators and beacons for use with night-vision goggles or CCDs</td></tr><tr><td>850–940 nm (Near-IR)</td><td>Photoelectric controls</td></tr><tr><td>940 nm (Near-IR)</td><td>Covert illumination CCD-based systems</td></tr></table> Source: https://www.photonics.com/Articles/Light-Emitting_Diodes_A_Primer/a36706 <table><tr><th>System Specifications</th><th>AFE4432</th><th>Comments</th></tr><tr><td>Multi-sensor support for SpO₂, heart rate monitoring</td><td>4 LEDs, 3 photodiodes (PDs)</td><td>A typical SpO₂ system can use a green LED in addition to red and infrared (IR) LEDs. The red and IR wavelengths share the same PD, whereas the green wavelength can use a different PD.</td></tr></table> Texas Instruments, Application Brief, “Measuring Oxygen Saturation (SpO₂) on Wearables,” SBAA566, Nov. 2022, at 2, available at https://www.ti.com/lit/ab/sbaa566/sbaa566.pdf.	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	System Specifications	AFE4432	Comments	Multi-sensor support for SpO ₂ , heart rate monitoring	4 LEDs, 3 photodiodes (PDs)	A typical SpO ₂ system can use a green LED in addition to red and infrared (IR) LEDs . The red and IR wavelengths share the same PD, whereas the green wavelength can use a different PD.
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5[b] the light source configured to increase signal-to-noise ratio by increasing a light intensity from at least one of the plurality of semiconductor sources and by increasing a pulse rate of at least one of the plurality of semiconductor sources;	The Accused Smartwatch is configured to increase signal-to-noise ratio by increasing a light intensity from at least one of the plurality of semiconductor sources and by increasing a pulse rate of at least of at least one of the semiconductor sources, either literally or under the doctrine of equivalents. 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”). Step 6 Bio Sensor Assembly  • Texas Instruments AFE4510 biosensing analog front-end Source: IFIXIT, Samsung Galaxy Watch Ultra Chip ID, https://www.ifixit.com/Guide/Samsung+Galaxy+Watch+Ultra+Chip+ID/175327?srsId=AfmBOoriU1zDbSwZ7O5CP4JIQFSWUnKHWqSe9g6SXYqF3F-NzUYIGpw.

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	3 Description 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 PPG signal acquisition: – 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 PPG Transmitter: – <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

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	PPG: Photoplethysmography 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. Source: Texas Instruments, AFE4510, SBASB19 – March 2024, at 1-4, available at https://www.ti.com/lit/ds/symlink/afe4510.pdf. <i>Application Brief</i> <i>Optical Heart Rate Monitoring (OHRM) on Wearables</i>  Application <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).

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	Figure 1. Heart Rate Monitoring on a Wearable Device 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. 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).

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'533 Patent Claim ¹	Samsung Accused System ²																		
	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. Differentiation • 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																		
	<table><caption>Table 1. Specifications for OHRM on Wearables</caption><thead><tr><th>System Specifications</th><th>AFE4432</th><th>Comments</th></tr></thead><tbody><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></tbody></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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“Semiconductor source based near infrared measurement device with improved signal-to-noise ratio”

'533 Patent Claim ¹	Samsung Accused System ²
	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. 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. 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.

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	Block Diagram 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. 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.

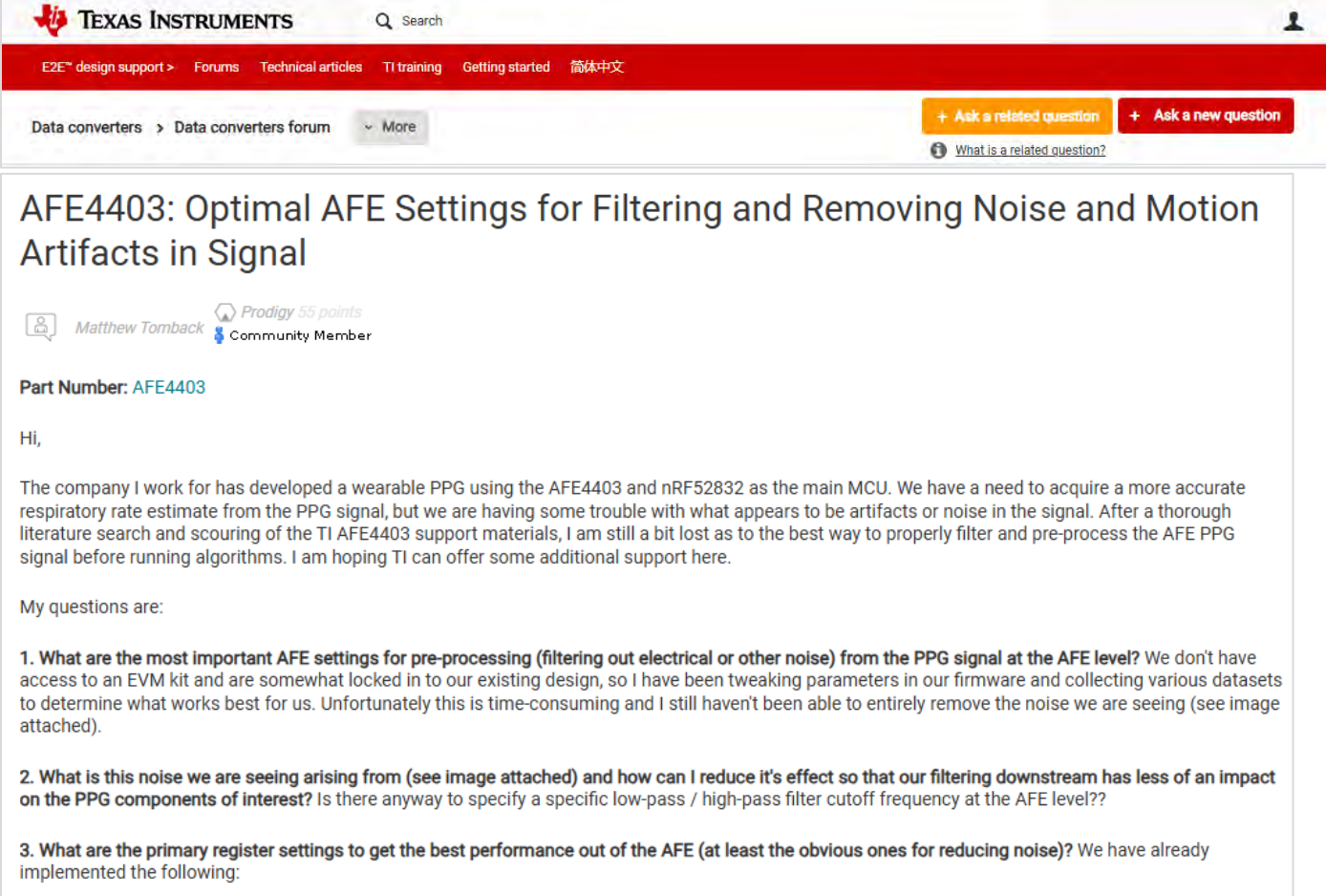
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	“However, increasing the LED current gives better signal quality from the SNR perspective. The optimal AFE configuration settings are completely dependent on the application. This includes the separation of LED and PD, location of the sensor, and 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.																																																												
	7.5 Electrical Characteristics 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. <table><tr><th>PARAMETER</th><th>TEST CONDITIONS</th><th>MIN</th><th>TYP</th><th>MAX</th><th>UNIT</th></tr><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></table>	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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	Source: Texas Instruments, AFE4403 Ultra-Small, Integrated Analog Front-End for Heart Rate Monitors and Low-Cost Pulse Oximeters, SBAS650C, revised April 2021, at 9.																																																												
	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:																																																												

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“Semiconductor source based near infrared measurement device with improved signal-to-noise ratio”

'533 Patent Claim ¹	Samsung Accused System ²
	 TEXAS INSTRUMENTS Search E2E™ design support > Forums Technical articles TI training Getting started 简体中文 Data converters > Data converters forum > More + Ask a related question + Ask a new question What is a related question? AFE4403: Optimal AFE Settings for Filtering and Removing Noise and Motion Artifacts in Signal  Matthew Tomback  Prodigy 55 points Community Member Part Number: AFE4403 Hi, 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. My questions are: 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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	Praveen Aroul over 4 years ago in reply to Matthew Tomback TI_Mastermind 49766 points Hello Matthew, 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. 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. 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. Can you let us know the LED duty cycle in your configuration? What is the TX_REF voltage? Transmitter noise improves with higher tx_ref voltage. Please share us the raw data for the plots so that we have a look at it to offer any additional suggestions. 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. TEXAS INSTRUMENTS Getting Started Guide TIDA-00301 Miniaturized Pulse Oximeter Reference Design HealthTech

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	ABSTRACT 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. 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. 6.2 Estimation of SpO₂ percentage 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. 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. Source: Texas Instruments, “Miniaturized Pulse Oximeter Reference Design,” Getting Started Guide, TIDA-00301, at 1, 11-14, 20, available at

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	https://www.ti.com/lit/ug/tidu475/tidu475.pdf?ts=1724347486358&ref_url=https%253A%252F%252Fwww.google.com%252F%20. 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: (12) United States Patent Lee et al. (10) Patent No.: US 11,974,838 B2 (45) Date of Patent: May 7, 2024 (54) ELECTRONIC DEVICE FOR ACQUIRING BIOMETRICS USING PPG SENSOR, AND METHOD THEREFOR (71) Applicant: Samsung Electronics Co., Ltd. Gyeonggi-do (KR) (57) ABSTRACT 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- (Continued)

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	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. 45 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 50 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. 5 device 100 may be referred to as a user terminal. 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 10 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 10 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 15 the current rather than raising the gain may be advantageous in maximizing the SNR of a heart rate signal included in the PPG signal.

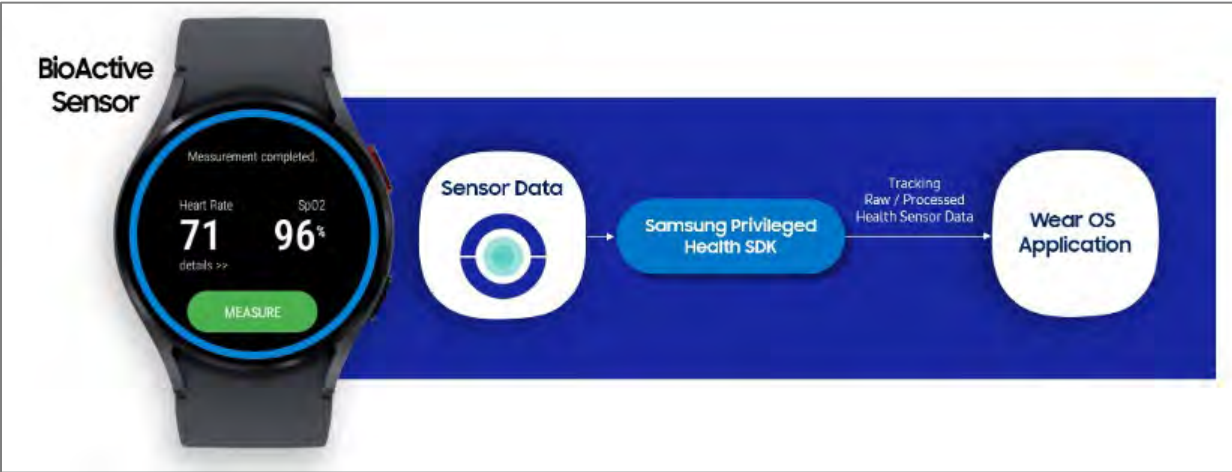
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	FIG. 5 Source: US 11,974,838 at Abstract, 1:43-54, 6:6-38, 12:8-16, FIG. 5. Increasing SNR generally yields more accurate health measurements. Samsung advertises that the Accused Smartwatch provides health measurements with enhanced accuracy, indicating 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: “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

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	 “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
5[c] an apparatus comprising a plurality of lenses configured to receive a portion of the output optical beam and to deliver	The Accused System comprises an apparatus comprising a plurality of lenses configured to receive a portion of the output optical beam and to deliver an analysis output beam to a sample. For example, the Accused Smartwatch (“apparatus”) comprises a plurality of 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) (“configured to receive a portion of the output optical beam and to deliver an analysis output beam to a sample”).

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'533 Patent Claim ¹	Samsung Accused System ²
an analysis output beam to a sample	 Source: https://www.samsung.com/us/watches/galaxy-watch-ultra/

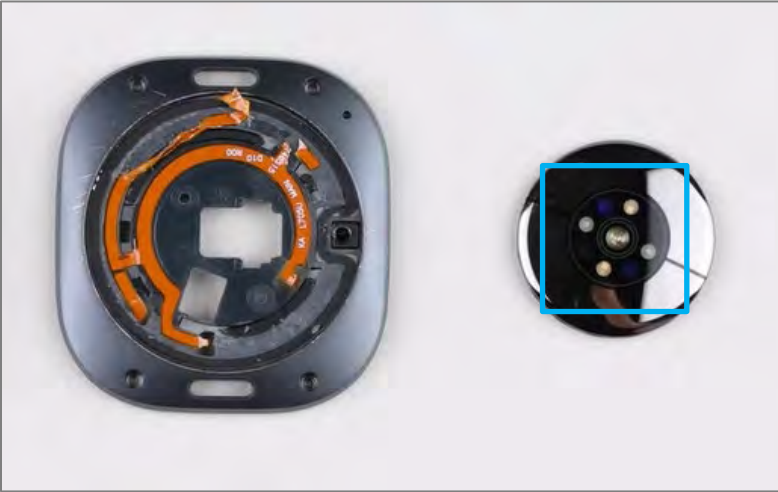
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	 Source: https://www.youtube.com/watch?v=IZ6Q7JqtiA0 Samsung states that “[t]he Galaxy Watch uses light sensors that operate within the limits set by the IEC62471 safety regulations. However, people with photosensitive skin may have adverse reactions 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 (“deliver an analysis output beam to a sample”).

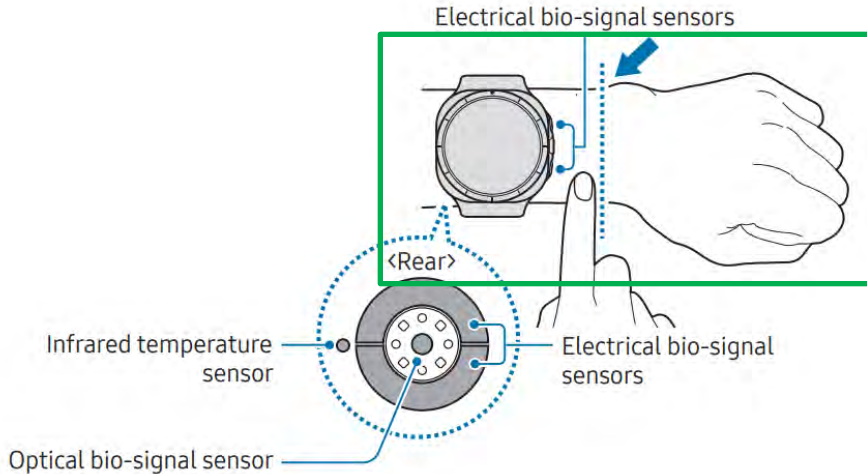
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’533 Patent Claim ¹	Samsung Accused System ²
	 “an apparatus comprising a plurality of lenses” Source: https://www.youtube.com/watch?v=lZ6Q7JqtiA0  Source: https://www.youtube.com/watch?v=jlW0i7u4FVk

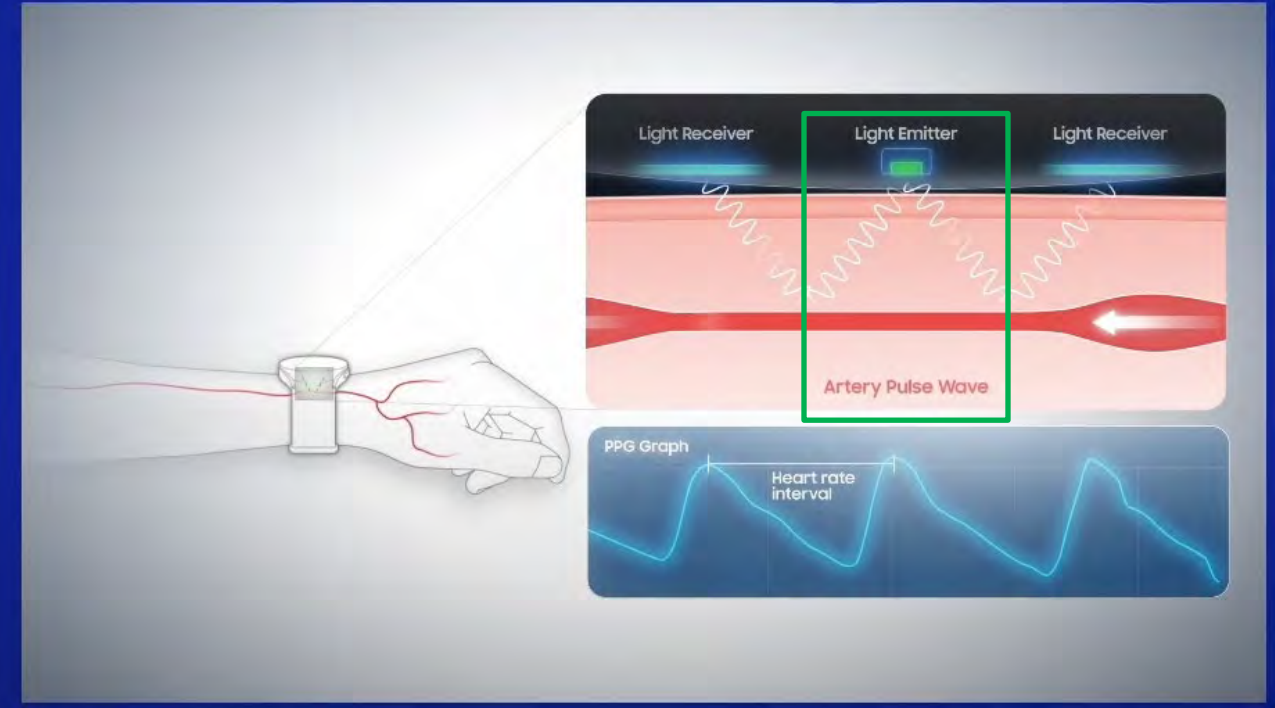
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	 The diagram illustrates the sensor layout on the back of a Samsung Galaxy Watch Ultra. A green rectangular box highlights the upper portion of the watch case, which is labeled "Electrical bio-signal sensors". Below this, a circular inset labeled "<Rear>" provides a detailed view of the watch's back. This inset shows an "Infrared temperature sensor" on the left, an "Optical bio-signal sensor" in the center, and "Electrical bio-signal sensors" on the right. A hand is shown with the watch on its wrist, and a blue arrow points to the sensor area on the back of the watch. Source: Samsung Galaxy Watch7 / Galaxy Watch Ultra User Guide (06/2024, Rev.1.0), at 19, <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

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	Artery pulse wave and PPG graph  The diagram illustrates the operation of a PPG sensor. On the left, a hand is shown with a sensor on the wrist. A line connects the sensor to a detailed cross-section of the skin and underlying artery. The cross-section shows a 'Light Emitter' (green box) and two 'Light Receiver' units (blue boxes) on the skin surface. Light waves (wavy lines) are shown traveling from the emitter to the receivers, reflecting off the 'Artery Pulse Wave' (red line) within the artery. Below this, a 'PPG Graph' shows a blue waveform with a 'Heart rate interval' marked between two peaks. Source: https://developer.samsung.com/conference/sdc22/sessions/expand-health-experiences-with-galaxy-watch 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, available at https://library.imaging.org/admin/apis/public/api/ist/website/downloadArticle/ei/33/7/art00002.

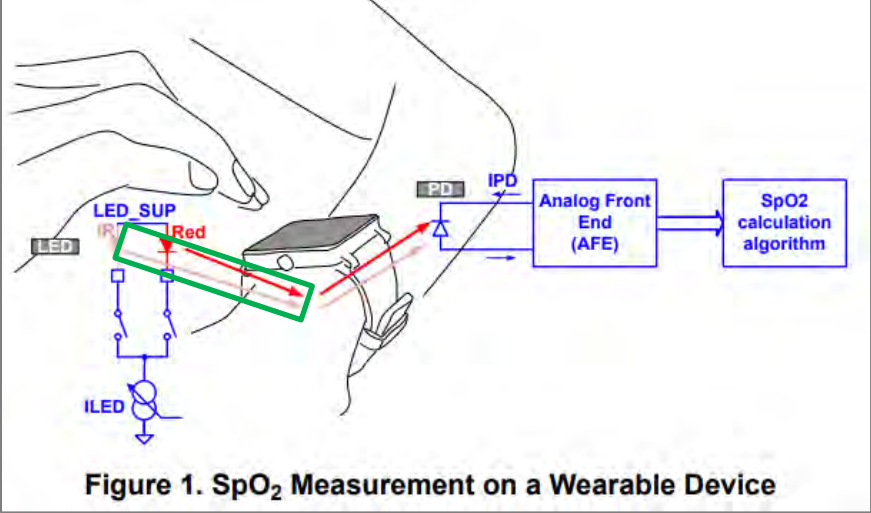
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	Samsung’s Galaxy Watch7 and Watch Ultra user guide also states the following: “The accuracy of the information and data provided by this device and its related software, including heart rate readings, may be affected by factors such as environmental 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. “SpO₂ monitoring is also used in wrist-worn wearable devices like smartwatches, serving as a parameter to asses and monitor the user’s physical condition during exercise. SpO₂ monitoring on the wrist uses reflectance pulse oximetry, where the LEDs and photodiode both face the wrist, and the light from the LED is reflected by the skin and various layers below the skin, then incident on the photodiode. SpO₂ monitoring on the wrist has also been used to track the quality of sleep and has the potential to detect disorders like sleep apnea. More recently, SpO₂ has emerged as a significant parameter, the lowering of which serves as an early indicator of Covid-induced hypoxia.” Source: Texas Instruments, Application Brief, “Measuring Oxygen Saturation (SpO₂) on Wearables,” SBAA566, Nov. 2022, at 1, <i>available at</i> https://www.ti.com/lit/ab/sbaa566/sbaa566.pdf.

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	 Figure 1. SpO₂ Measurement on a Wearable Device Source: Texas Instruments, Application Brief, “Measuring Oxygen Saturation (SpO₂) on Wearables,” SBAA566, Nov. 2022, at 1, available at https://www.ti.com/lit/ab/sbaa566/sbaa566.pdf. 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.

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“Semiconductor source based near infrared measurement device with improved signal-to-noise ratio”

’533 Patent Claim ¹	Samsung Accused System ²
	Step 6 Bio Sensor Assembly   • Texas Instruments AFE4510 biosensing analog front-end Source: IFIXIT, Samsung Galaxy Watch Ultra Chip ID, https://www.ifixit.com/Guide/Samsung+Galaxy+Watch+Ultra+Chip+ID/175327?srsItd=AfmBOoriU1zDb_SwZ7O5CP4JIQFSWUnKHWqSe9g6SXYqF3F-NzUYIGpw. 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. TI’s AFEs enable wearable devices to perform multiple optical biosensing applications. For example, TI explains in a technical paper:

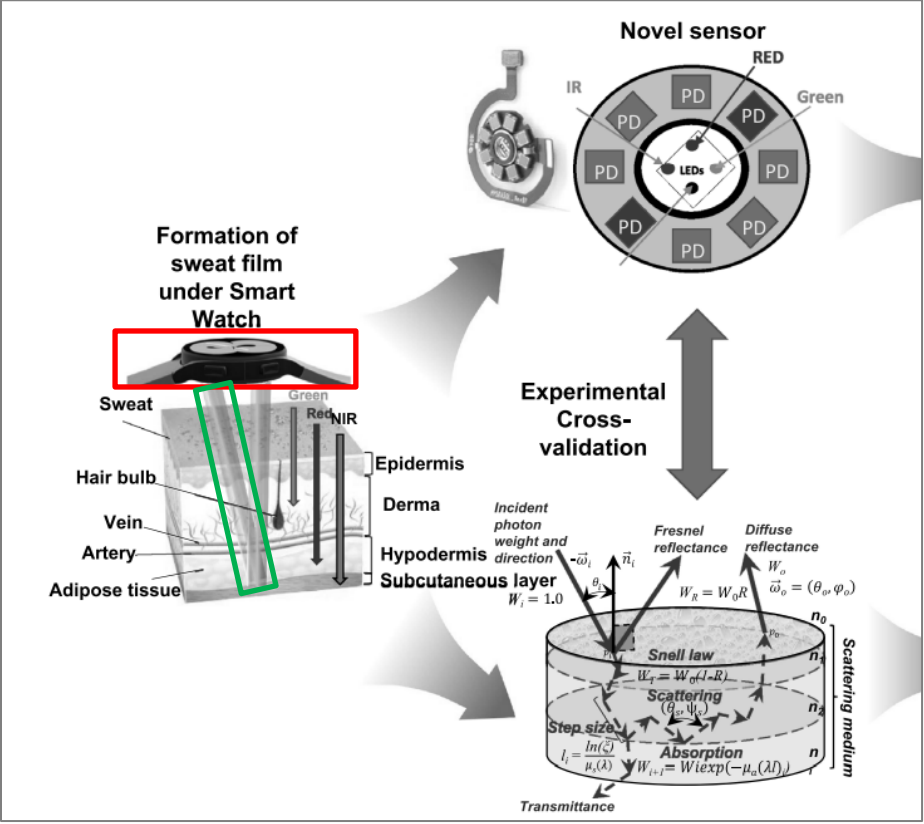
U.S. Patent No. 9,651,533 (the “’533 Patent”)

“Semiconductor source based near infrared measurement device with improved signal-to-noise ratio”

’533 Patent Claim ¹	Samsung Accused System ²
	Application <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 <i>Figure 1</i>, 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). 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. 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.

U.S. Patent No. 9,651,533 (the “533 Patent”)

“Semiconductor source based near infrared measurement device with improved signal-to-noise ratio”

'533 Patent Claim ¹	Samsung Accused System ²
	Additionally, the following scientific report authored by multiple Samsung engineers further shows lens output light being delivered to tissue of the user:  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.

U.S. Patent No. 9,651,533 (the “’533 Patent”)

“Semiconductor source based near infrared measurement device with improved signal-to-noise ratio”

'533 Patent Claim ¹	Samsung Accused System ²
5[d] a receiver configured to receive and process at least a portion of the analysis output beam reflected or transmitted from the sample and to generate an output signal	The Accused System comprises a receiver configured to receive and process at least a portion of the analysis output beam reflected or transmitted from the sample and to generate an output signal. The Accused Smartwatch is equipped with a BioActive sensor (“receiver”) that (a) receives light initially output from LEDs and then reflected from tissue of a user, (b) processes the reflected light, and (c) generates an output PPG signal. 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.

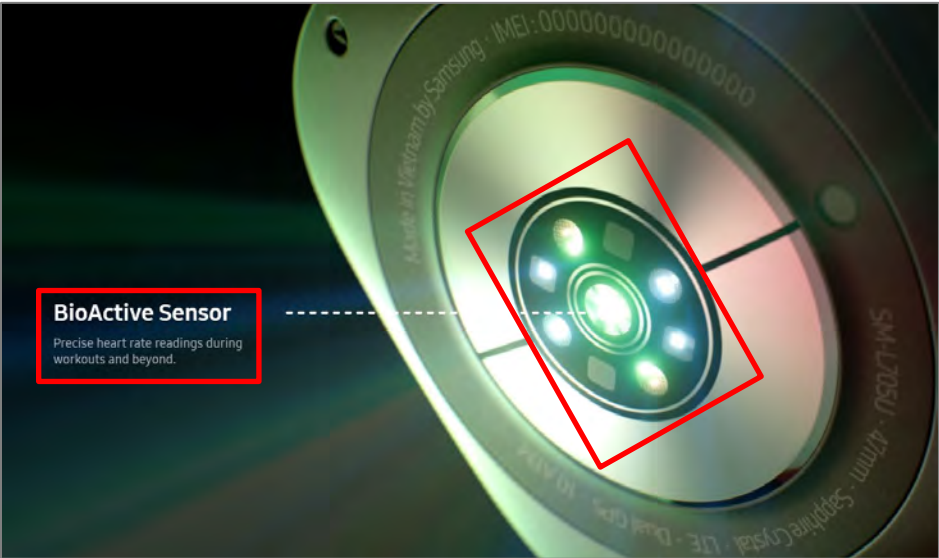
U.S. Patent No. 9,651,533 (the “’533 Patent”)

“Semiconductor source based near infrared measurement device with improved signal-to-noise ratio”

'533 Patent Claim ¹	Samsung Accused System ²
	 The diagram shows the back of a Samsung Galaxy Watch Ultra with an orange braided strap. Four features are labeled with dashed lines: '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 'BioActive Sensor' label is enclosed in a red rectangular box. Source: https://www.samsung.com/us/watches/galaxy-watch-ultra/

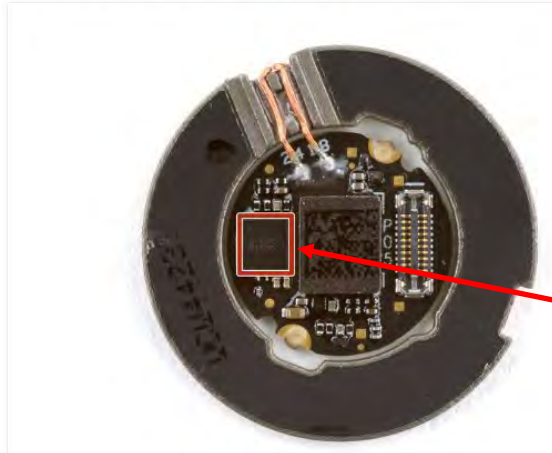
U.S. Patent No. 9,651,533 (the “’533 Patent”)

“Semiconductor source based near infrared measurement device with improved signal-to-noise ratio”

'533 Patent Claim ¹	Samsung Accused System ²
	 Source: https://www.samsung.com/us/watches/galaxy-watch-ultra/

U.S. Patent No. 9,651,533 (the “533 Patent”)

“Semiconductor source based near infrared measurement device with improved signal-to-noise ratio”

'533 Patent Claim ¹	Samsung Accused System ²
	Step 6 Bio Sensor Assembly   • Texas Instruments AFE4510 biosensing analog front-end Texas Instruments analog front end (“AFE”) biosensor chip - AFE4510 Source: IFIXIT, Samsung Galaxy Watch Ultra Chip ID, https://www.ifixit.com/Guide/Samsung+Galaxy+Watch+Ultra+Chip+ID/175327 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.

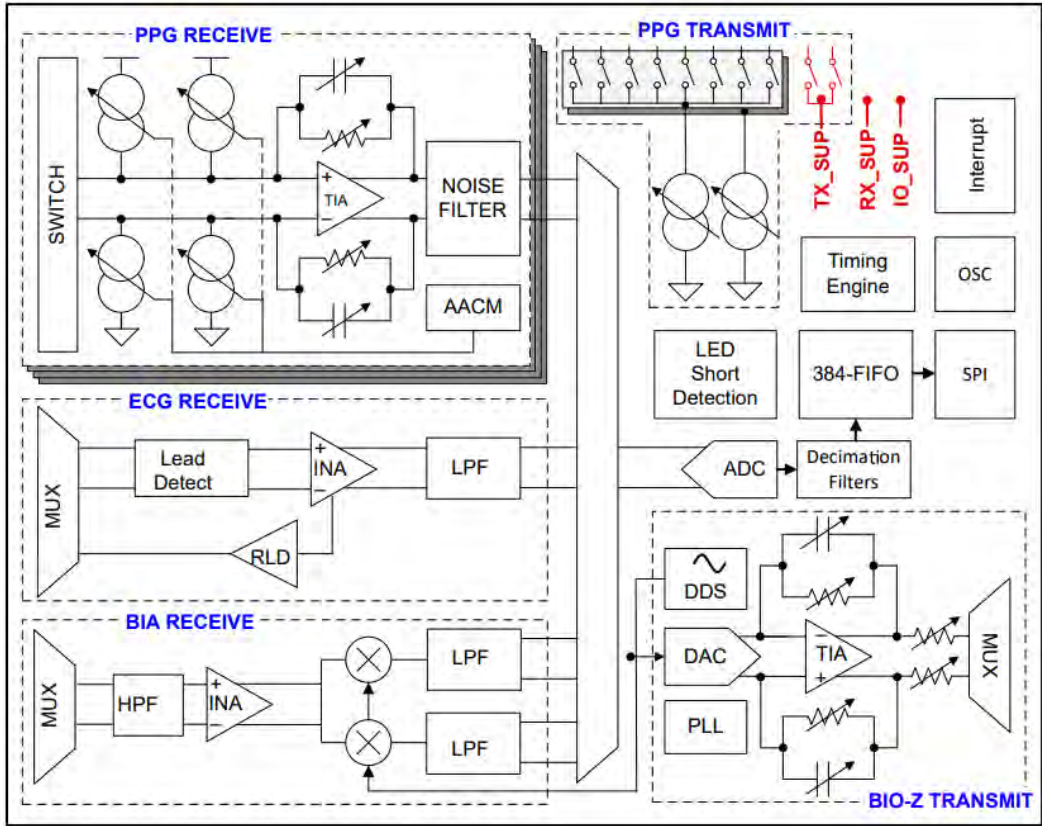
U.S. Patent No. 9,651,533 (the “’533 Patent”)

“Semiconductor source based near infrared measurement device with improved signal-to-noise ratio”

'533 Patent Claim ¹	Samsung Accused System ²
	 TEXAS INSTRUMENTSAFE4510 SBASB19 – MARCH 2024 AFE4510 Ultra Small, Integrated AFE for Bio Impedance Analysis, Electrical Bio Sensing & Optical Bio Sensing • PPG signal acquisition: – Acquisition of 24 PPG signal sets (LED, AMB) – Supports PPG sensors at different data rates – Peak system <u>SNR</u> 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: – 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: – 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

U.S. Patent No. 9,651,533 (the “’533 Patent”)

“Semiconductor source based near infrared measurement device with improved signal-to-noise ratio”

'533 Patent Claim ¹	Samsung Accused System ²
	 The diagram is a block-level schematic of a semiconductor source-based near-infrared measurement device. It is divided into three main functional blocks on the left: PPG RECEIVE, ECG RECEIVE, and BIA RECEIVE. The PPG RECEIVE block includes a SWITCH, a TIA (Transimpedance Amplifier), a NOISE FILTER, and an AACM (Analog-to-Digital Converter). The ECG RECEIVE block includes a MUX (Multiplexer), a Lead Detect block, an INA (Instrumentation Amplifier), and an LPF (Low Pass Filter). The BIA RECEIVE block includes a MUX, an HPF (High Pass Filter), an INA, and two LPFs. On the right, the PPG TRANSMIT block includes a switch array, TX_SUP (Transmit Supply), RX_SUP (Receive Supply), and IO_SUP (IO Supply). Below this is the LED Short Detection block. The central processing block includes a Timing Engine, OSC (Oscillator), 384-FIFO, SPI, ADC (Analog-to-Digital Converter), and Decimation Filters. The BIO-Z TRANSMIT block includes a DDS (Direct Digital Synthesizer), DAC (Digital-to-Analog Converter), PLL (Phase-Locked Loop), and a TIA. The entire system is labeled 'Simplified Schematic'. Simplified Schematic Source: Texas Instruments, AFE4510, SBASB19 – March 2024, at 1-2, available at https://www.ti.com/lit/ds/symlink/afe4510.pdf.

U.S. Patent No. 9,651,533 (the “’533 Patent”)

“Semiconductor source based near infrared measurement device with improved signal-to-noise ratio”

’533 Patent Claim ¹	Samsung Accused System ²
	“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.” Source: Texas Instruments, AFE4510, SBASB19 – March 2024, at 1, <i>available at</i> https://www.ti.com/lit/ds/symlink/afe4510.pdf. The BioActive Sensor (“receiver”) 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”). For example, TI explains OHRM using its AFE biosensors as follows:

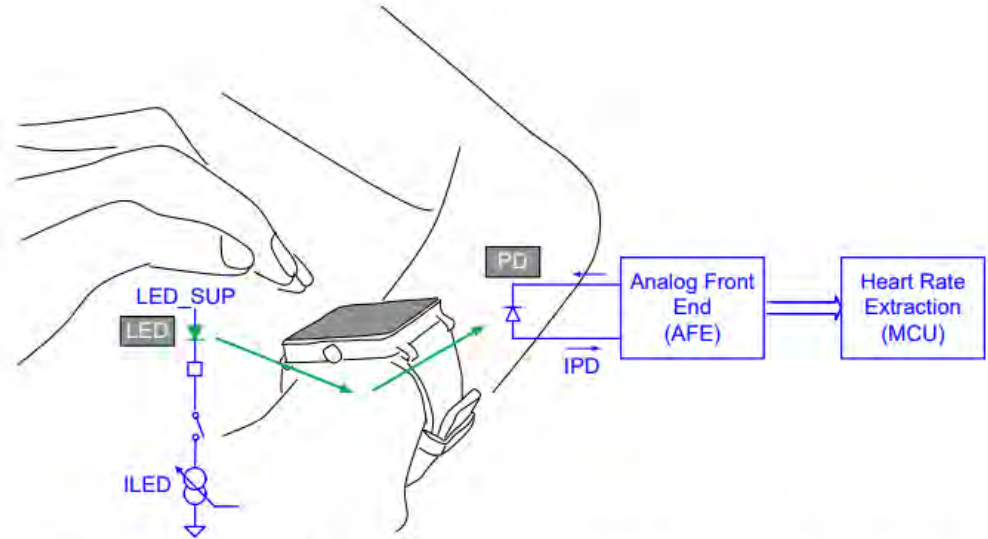
U.S. Patent No. 9,651,533 (the “’533 Patent”)

“Semiconductor source based near infrared measurement device with improved signal-to-noise ratio”

’533 Patent Claim ¹	Samsung Accused System ²
	<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 <u>reflected to a photodiode (PD)</u>, the pulsating waveform can be converted to a signal current. As shown in <u>Figure 1</u>, 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). 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</u> 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.

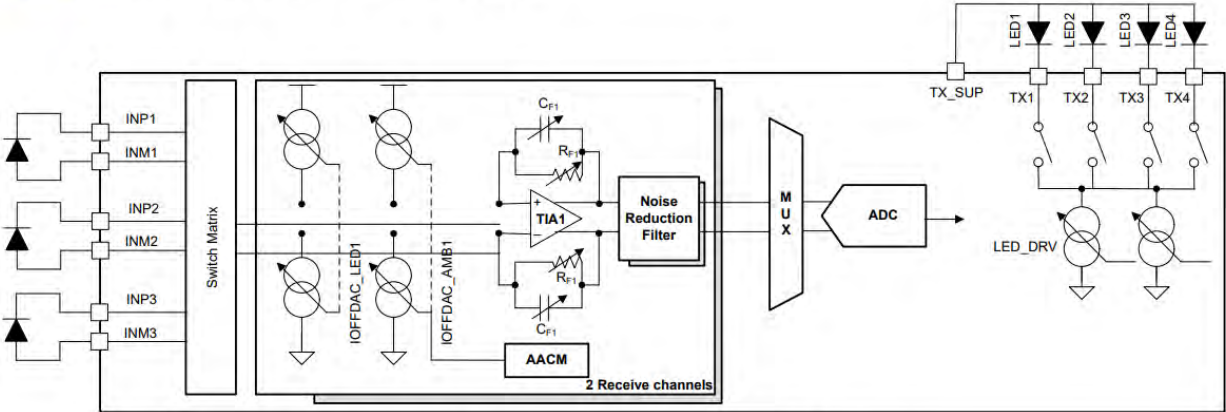
U.S. Patent No. 9,651,533 (the “’533 Patent”)

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'533 Patent Claim ¹	Samsung Accused System ²
	 Figure 1. Heart Rate Monitoring on a Wearable Device 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. 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.

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'533 Patent Claim ¹	Samsung Accused System ²
	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. 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. 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. 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,

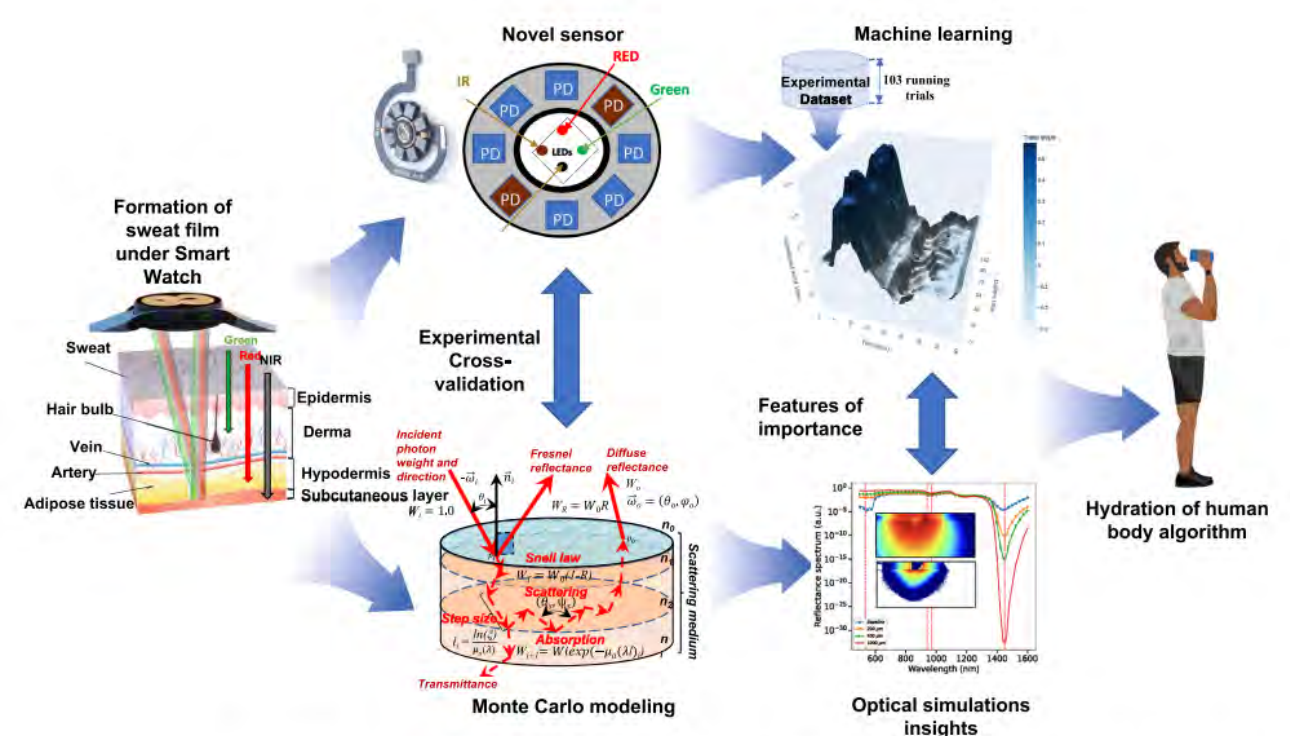
U.S. Patent No. 9,651,533 (the “’533 Patent”)

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'533 Patent Claim ¹	Samsung Accused System ²
	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.” (a) (b) <i>Figure 1. (a) Separated chip PPG sensor and (b) Single chip PPG sensor</i> 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 1, <i>available at</i> https://library.imaging.org/admin/apis/public/api/ist/website/downloadArticle/ei/33/7/art00002. 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.”

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'533 Patent Claim ¹	Samsung Accused System ²
	 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. 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, <i>available at</i> https://www.nature.com/articles/s41598-023-40339-7.pdf.

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’533 Patent Claim ¹	Samsung Accused System ²
	The detection system of the Accused Smartwatch has been detailed in other technical documents as well. For example:

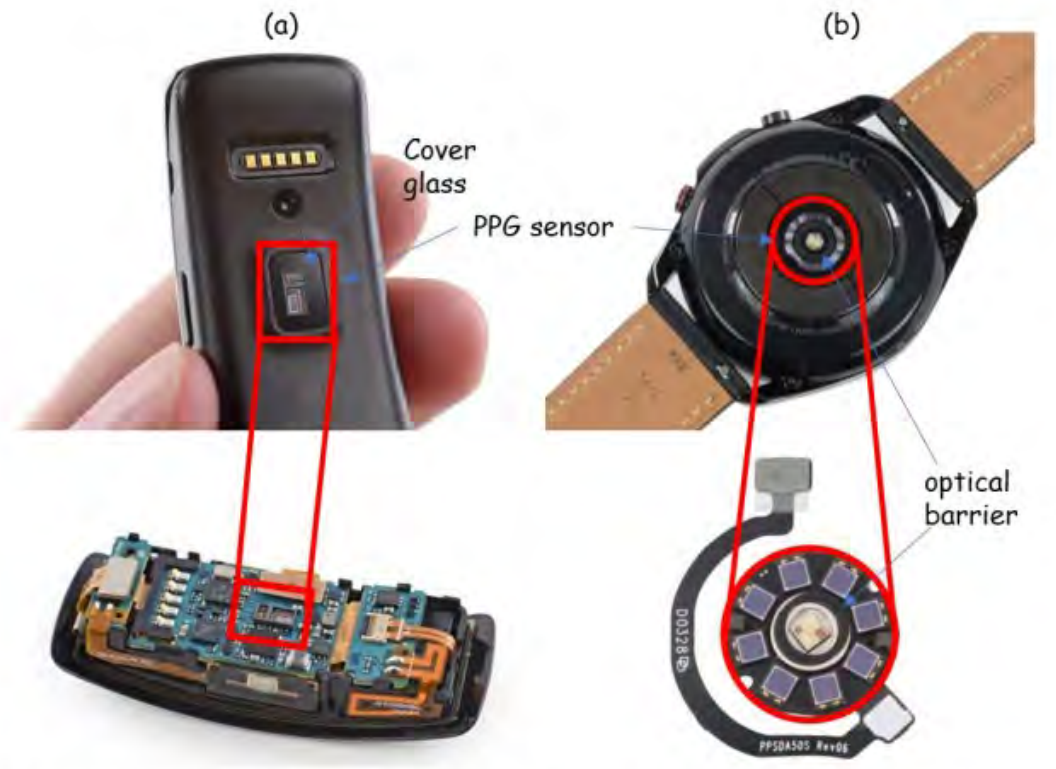
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'533 Patent Claim ¹	Samsung Accused System ²
	Figure 3. Conceptual diagram of a PPG sensor module with an embedded LED–PD pair. The diagram illustrates two scenarios: (a) when the integrated sensor module is in direct contact with the wrist and (b) 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.

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’533 Patent Claim ¹	Samsung Accused System ²
	 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.

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'533 Patent Claim ¹	Samsung Accused System ²
	 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. 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.

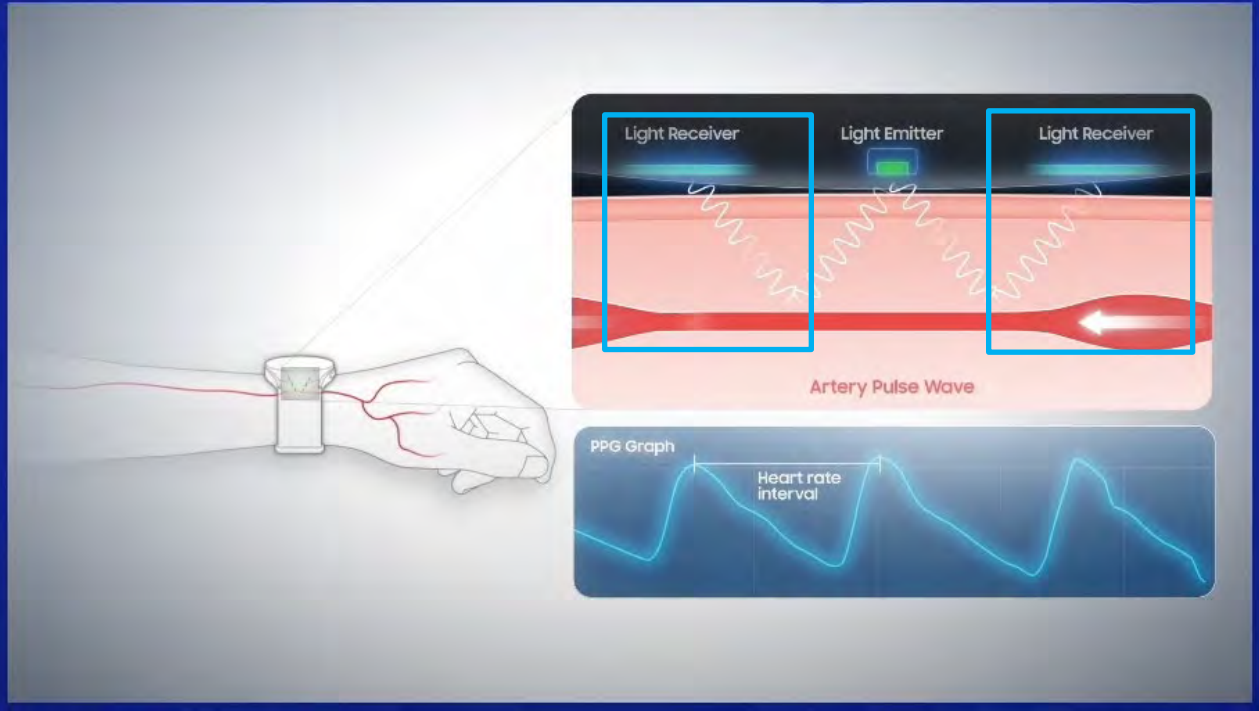
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’533 Patent Claim ¹	Samsung Accused System ²
	“SpO₂ monitoring is also used in wrist-worn wearable devices like smartwatches, serving as a parameter to assess and monitor the user’s physical condition during exercise. SpO₂ monitoring on the wrist uses reflectance pulse oximetry, where the LEDs and photodiode both face the wrist, and the light from the LED is reflected by the skin and various layers below the skin, then incident on the photodiode. SpO₂ monitoring on the wrist has also been used to track the quality of sleep and has the potential to detect disorders like sleep apnea. More recently, SpO₂ has emerged as a significant parameter, the lowering of which serves as an early indicator of Covid-induced hypoxia.” Source: Texas Instruments, Application Brief, “Measuring Oxygen Saturation (SpO₂) on Wearables,” SBAA566, Nov. 2022, at 1, <i>available at</i> https://www.ti.com/lit/ab/sbaa566/sbaa566.pdf. “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 wearable is supported on many other AFEs from Texas Instruments such as the AFE4950, AFE4960P, and AFE4500 devices.” Texas Instruments, Application Brief, “Optical Heart Rate Monitoring (OHRM) on Wearables,” SBAA564, Nov. 2022, at 2, <i>available at</i> https://www.ti.com/lit/ab/sbaa564/sbaa564.pdf.

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'533 Patent Claim ¹	Samsung Accused System ²
	Artery pulse wave and PPG graph  Source: https://developer.samsung.com/conference/sdc22/sessions/expand-health-experiences-with-galaxy-watch
5[e] wherein the receiver is configured to be synchronized to the light source	The receiver in the Accused Smartwatch is configured to be synchronized to the light source. For example, the BioActive Sensor (“receiver”) 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

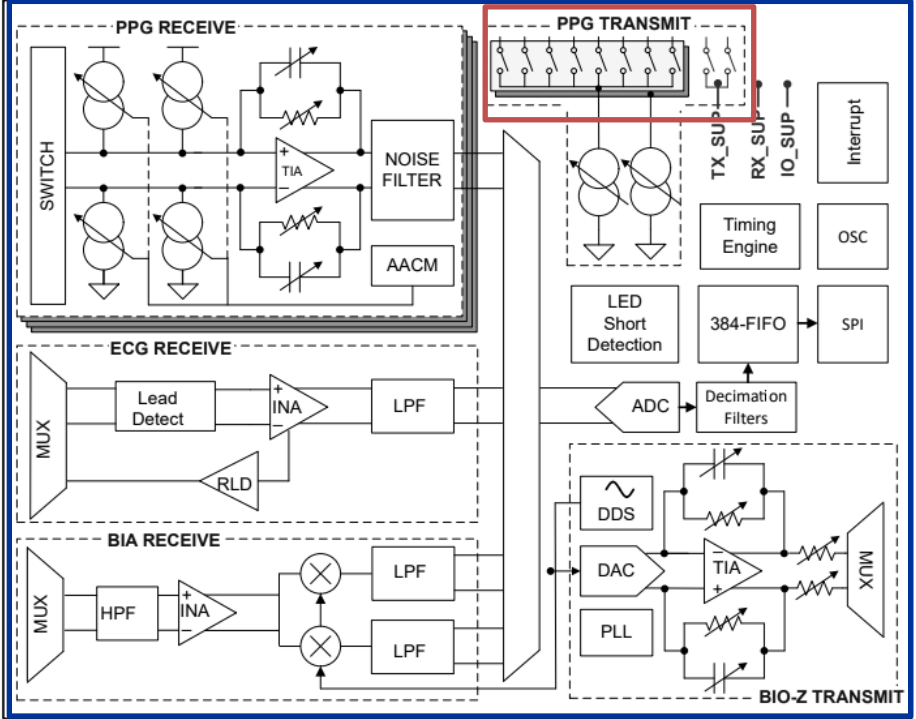
U.S. Patent No. 9,651,533 (the “’533 Patent”)

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’533 Patent Claim ¹	Samsung Accused System ²
	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 (“receiver”) is synchronized with the light source. 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 has a receiver that is synchronized to programmable LEDs (light source). <u>PPG Transmitter:</u> – <u>8-Bit Programmable LED Current with a range adjustable from 50mA to 300mA</u> – LED Short Detection – <u>Support of 16 LEDs in Common Anode configuration for SpO2, OHRM, Spectroscopy</u>

U.S. Patent No. 9,651,533 (the “533 Patent”)

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'533 Patent Claim ¹	Samsung Accused System ²
	 The diagram is a block-level schematic of the AFE4510 system. It is divided into three main functional blocks: PPG RECEIVE, ECG RECEIVE, and BIA RECEIVE, all connected to a central ADC and Decimation Filters. The PPG RECEIVE block includes a SWITCH, a TIA (Transimpedance Amplifier), a NOISE FILTER, and an AACM (Automatic Ambient Light Compensation) block. The ECG RECEIVE block includes a MUX (Multiplexer), a Lead Detect block, an INA (Instrumentation Amplifier), and an RLD (Rightleg Drive) block. The BIA RECEIVE block includes a MUX, an HPF (High-Pass Filter), an INA, and two LPF (Low-Pass Filter) blocks. The PPG TRANSMIT block, highlighted with a red box, includes a current driver for LEDs, TX and RX SUP (Supply) blocks, and an Interrupt block. The BIO-Z TRANSMIT block includes a DDS (Direct Digital Synthesis) block, a DAC (Digital-to-Analog Converter), a PLL (Phase-Locked Loop), a TIA, and a MUX. The system also includes a Timing Engine, OSC (Oscillator), 384-FIFO, SPI, and LED Short Detection blocks. Simplified Schematic “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.” 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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'533 Patent Claim ¹	Samsung Accused System ²
	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. 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.

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'533 Patent Claim ¹	Samsung Accused System ²
	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. Block Diagram 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.

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’533 Patent Claim ¹	Samsung Accused System ²
	“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/. “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. A product video further explains functionalities of the light source (LEDs) and receiver, including how the receiver is configured to synchronize to differing flashing LED colors on the Accused Smartwatch to facilitate calculating different physiological parameters.

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“Semiconductor source based near infrared measurement device with improved signal-to-noise ratio”

’533 Patent Claim ¹	Samsung Accused System ²
	 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=JG9pGlqmg&t=23s.

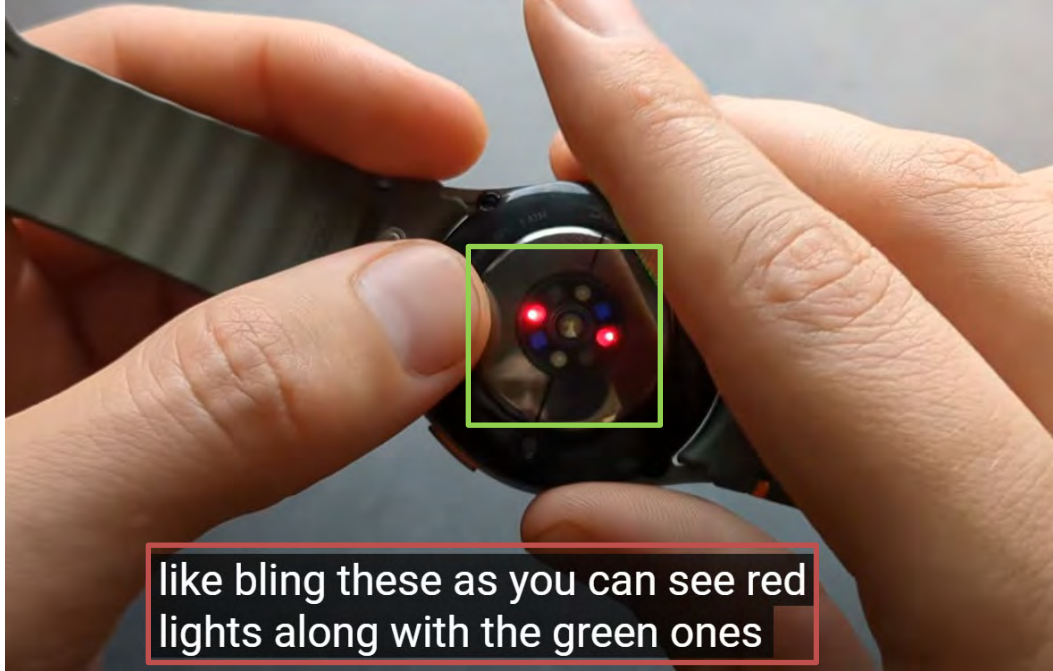
U.S. Patent No. 9,651,533 (the “’533 Patent”)

“Semiconductor source based near infrared measurement device with improved signal-to-noise ratio”

’533 Patent Claim ¹	Samsung Accused System ²
	 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/JG9pGlqmgcs?si=IrcplcEOdHE3cB3l&t=37

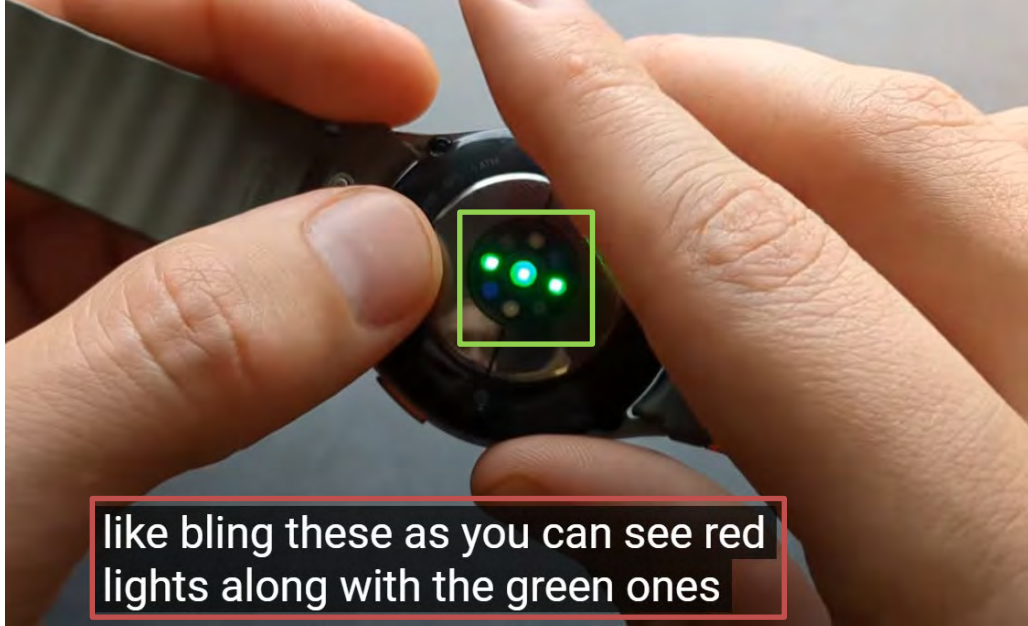
U.S. Patent No. 9,651,533 (the “’533 Patent”)

“Semiconductor source based near infrared measurement device with improved signal-to-noise ratio”

'533 Patent Claim ¹	Samsung Accused System ²
	 like bling these as you can see red lights along with the green ones 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/JG9pGlqmgges?si=xMBhD11dBJQoADTO&t=53

U.S. Patent No. 9,651,533 (the “’533 Patent”)

“Semiconductor source based near infrared measurement device with improved signal-to-noise ratio”

'533 Patent Claim ¹	Samsung Accused System ²
	 like bling these as you can see red lights along with the green ones 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/JG9pGlqmges?si=YV8CQ6yVqkvL7ITZ&t=53
51f1 a personal device comprising a wireless receiver, a wireless transmitter, a display, a microphone, a speaker, one or more buttons or knobs, a microprocessor and a touch screen	The Accused System comprises an Accused Phone/Tablet comprising a wireless receiver, a wireless transmitter, a display, a microphone, a speaker, one or more buttons or knobs, a microprocessor and a touch screen. For example, the Galaxy Watch Ultra pairs with the Galaxy Z Fold6 (“personal device”). The Galaxy Z Fold6 includes Wi-Fi connectivity, which requires the personal device to include both a wireless receiver and a wireless transmitter.

U.S. Patent No. 9,651,533 (the “’533 Patent”)

“Semiconductor source based near infrared measurement device with improved signal-to-noise ratio”

’533 Patent Claim ¹	Samsung Accused System ²
	 Source: https://www.samsung.com/us/smartphones/galaxy-z-fold6/buy/galaxy-z-fold6-512gb-unlocked-sm-f956uakexaa/

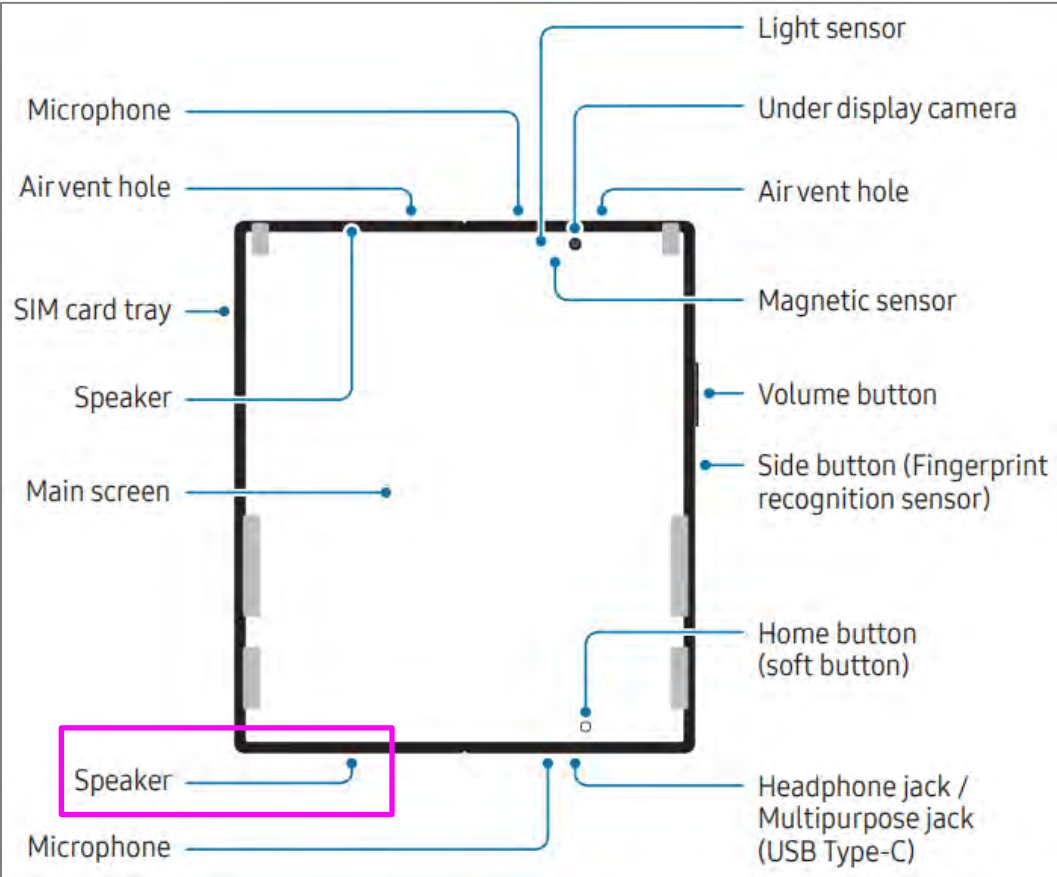
U.S. Patent No. 9,651,533 (the “’533 Patent”)

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'533 Patent Claim ¹	Samsung Accused System ²						
	Connectivity Wi-Fi Connectivity 802.11a/b/g/n/ac/ax 2.4GHz+5GHz+6GHz, HE160, MIMO, 1024-QAM Source: https://www.samsung.com/us/smartphones/galaxy-z-fold6/buy/galaxy-z-fold6-512gb-unlocked-sm-f956uakexaa/ The Galaxy Z Fold6 (“personal device”) further includes a display, a speaker, and a microphone. Display <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> Source: https://www.samsung.com/us/smartphones/galaxy-z-fold6/buy/galaxy-z-fold6-512gb-unlocked-sm-f956uakexaa/	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					

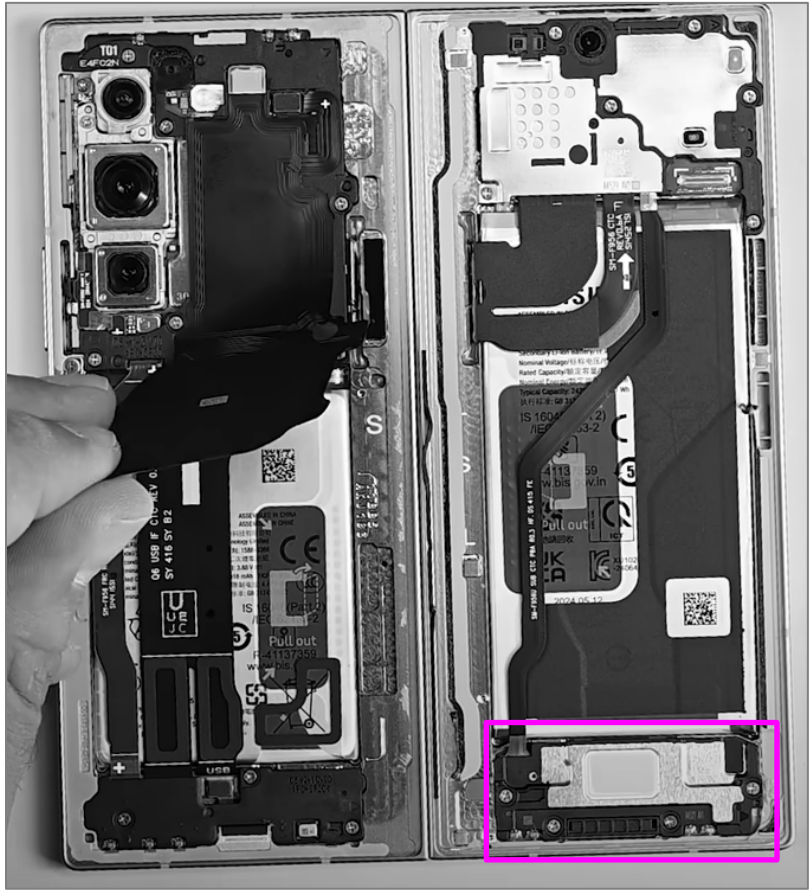
U.S. Patent No. 9,651,533 (the “’533 Patent”)

“Semiconductor source based near infrared measurement device with improved signal-to-noise ratio”

'533 Patent Claim ¹	Samsung Accused System ²
	 The diagram illustrates the layout of a Samsung Smartwatch with various components labeled. A pink rectangular box highlights the bottom-left corner of the device, specifically the area containing the speaker and microphone. The labels and their corresponding components are as follows: Microphone (top-left) Air vent hole (top-left) SIM card tray (left side) Speaker (left side) Main screen (center) Speaker (bottom-left, highlighted in pink) Microphone (bottom-left, highlighted in pink) 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) Source: https://downloadcenter.samsung.com/content/UM/202407/20240729134626727/SM-F956B_UG_EU_UU_Eng_Rev.1.0_240717.pdf [Page: 5]

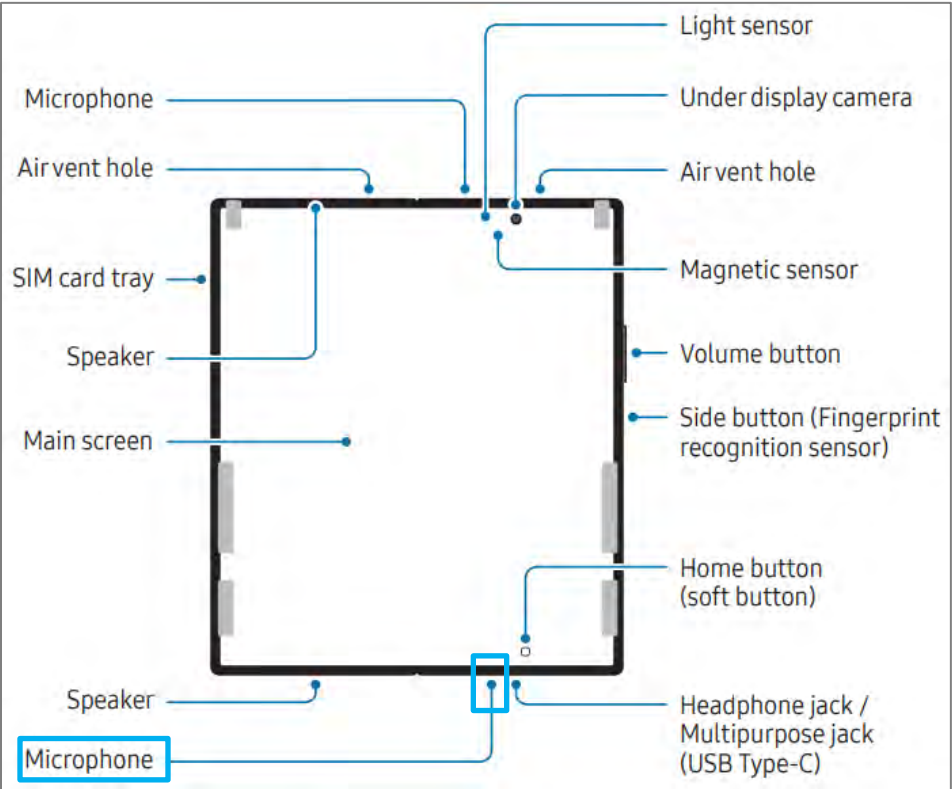
U.S. Patent No. 9,651,533 (the “’533 Patent”)

“Semiconductor source based near infrared measurement device with improved signal-to-noise ratio”

'533 Patent Claim ¹	Samsung Accused System ²
	 Source: https://www.youtube.com/watch?v=xYIe5uDVDWI

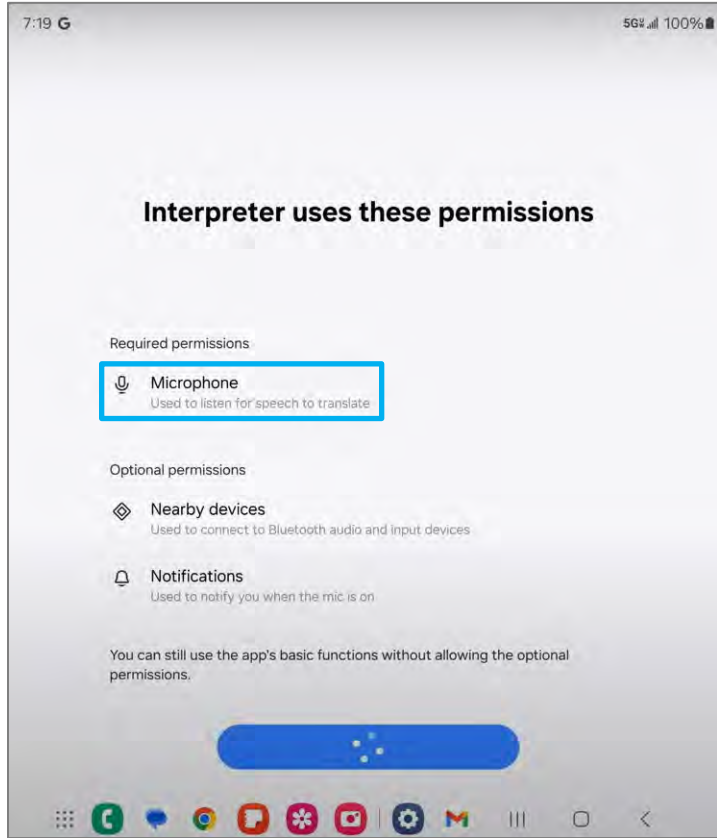
U.S. Patent No. 9,651,533 (the “’533 Patent”)

“Semiconductor source based near infrared measurement device with improved signal-to-noise ratio”

'533 Patent Claim ¹	Samsung Accused System ²
	 The diagram shows a top-down view of a smartphone with various components labeled with lines pointing to their locations: - Microphone (top left) - Air vent hole (top left) - SIM card tray (top left) - Speaker (top left) - Main screen (center) - Speaker (bottom left) - Microphone (bottom left, highlighted with a red box) - Light sensor (top right) - Under display camera (top right) - Air vent hole (top right) - Magnetic sensor (top right) - 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) Source: https://downloadcenter.samsung.com/content/UM/202407/20240729134626727/SM-F956B_UG_EU_UU_Eng_Rev.1.0_240717.pdf [Page: 5]

U.S. Patent No. 9,651,533 (the “’533 Patent”)

“Semiconductor source based near infrared measurement device with improved signal-to-noise ratio”

'533 Patent Claim ¹	Samsung Accused System ²
	 Source: https://www.youtube.com/watch?v=sPP6NW89Am0 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.

U.S. Patent No. 9,651,533 (the “’533 Patent”)

“Semiconductor source based near infrared measurement device with improved signal-to-noise ratio”

’533 Patent Claim ¹	Samsung Accused System ²
	 Source: https://www.samsung.com/us/smartphones/galaxy-z-fold6/buy/galaxy-z-fold6-512gb-unlocked-sm-f956uakexaa/

U.S. Patent No. 9,651,533 (the “’533 Patent”)

“Semiconductor source based near infrared measurement device with improved signal-to-noise ratio”

’533 Patent Claim ¹	Samsung Accused System ²
	Processor CPU Type Octa-Core Source: https://www.samsung.com/us/smartphones/galaxy-z-fold6/buy/galaxy-z-fold6-512gb-unlocked-sm-f956uakexaa/ Fastest processor on a Galaxy smartphone Enjoy silky-smooth gaming with Vulkan, even in AAA games. Then, Snapdragon® 8 Gen 3 for Galaxy renders graphics that are absolutely fire.¹⁹  The fastest Snapdragon on a Galaxy smartphone^{19,21} Source: https://www.samsung.com/us/smartphones/galaxy-z-fold6/

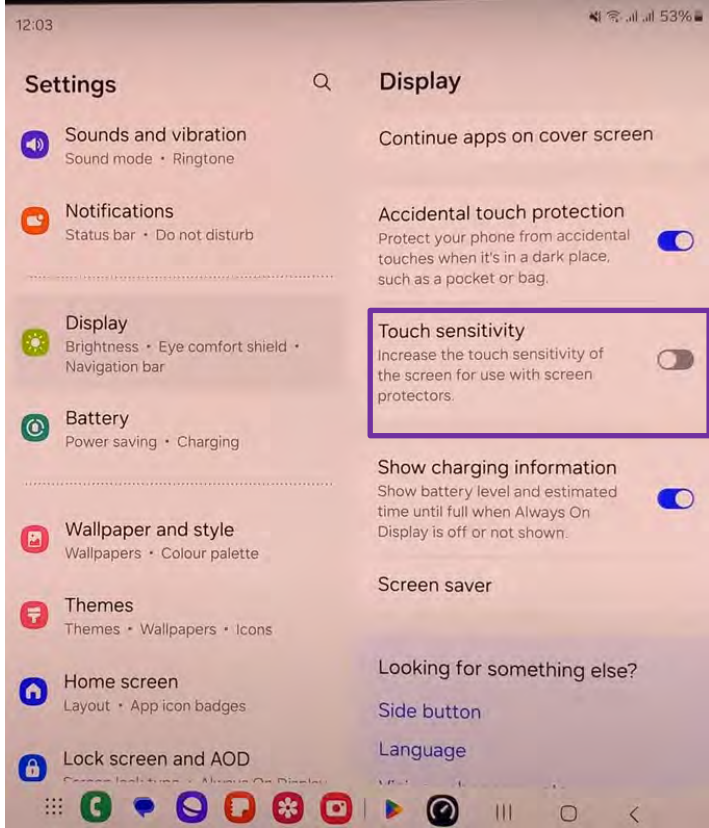
U.S. Patent No. 9,651,533 (the “’533 Patent”)

“Semiconductor source based near infrared measurement device with improved signal-to-noise ratio”

’533 Patent Claim ¹	Samsung Accused System ²
	CPUName: Qualcomm® Kryo™Architecture: 64-bitClock Speed: Up to 3.4 GHz¹ Source: https://www.qualcomm.com/products/mobile/snapdragon/smartphones/snapdragon-8-series-mobile-platforms/snapdragon-8-gen-3-mobile-platform

U.S. Patent No. 9,651,533 (the “’533 Patent”)

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'533 Patent Claim ¹	Samsung Accused System ²
	 The screenshot shows the 'Settings' app on a Samsung smartphone. The 'Display' settings are open, and the 'Touch sensitivity' option is highlighted with a red box. The 'Touch sensitivity' option is currently turned off (the toggle switch is to the left). The text next to it says 'Increase the touch sensitivity of the screen for use with screen protectors.' Below this, there are other settings like 'Show charging information' and 'Screen saver'. At the bottom of the screen, there is a source link: https://www.youtube.com/watch?v=cn2UQ6Fr4hM

U.S. Patent No. 9,651,533 (the “’533 Patent”)

“Semiconductor source based near infrared measurement device with improved signal-to-noise ratio”

'533 Patent Claim ¹	Samsung Accused System ²
	Controlling the screen Tapping Tap the screen.  Touching and holding Touch and hold the screen for approximately 2 seconds.  Dragging Touch and hold an item and drag it to the target position.  Double tapping Double tap the screen.  Swiping Swipe upwards, downwards, to the left, or to the right.  Spreading and pinching Spread two fingers apart or pinch on the screen.  Source: https://downloadcenter.samsung.com/content/UM/202407/20240729134626727/SM-F956B_UG_EU_UU_Eng_Rev.1.0_240717.pdf [Page: 26]
5[g] the personal device configured to receive and process	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

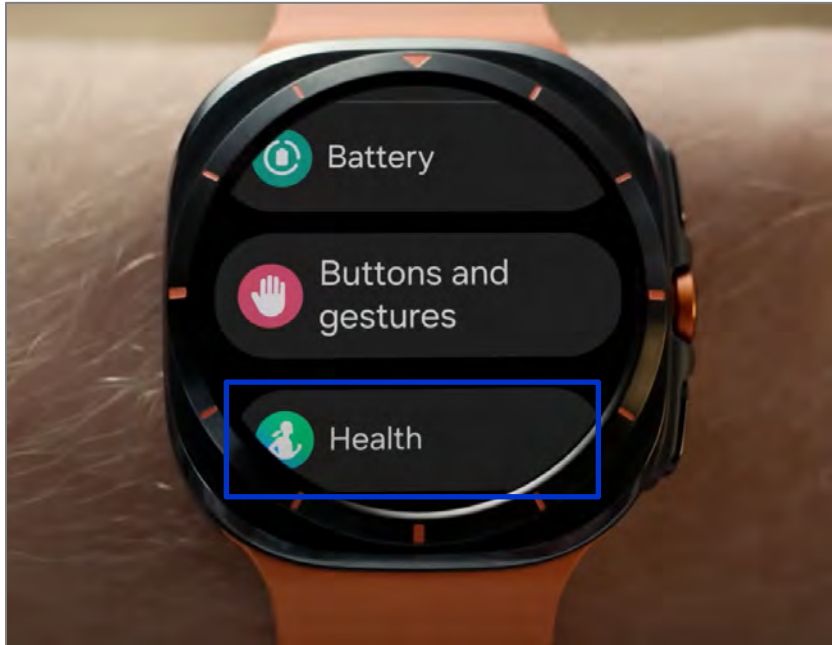
U.S. Patent No. 9,651,533 (the “’533 Patent”)

“Semiconductor source based near infrared measurement device with improved signal-to-noise ratio”

’533 Patent Claim ¹	Samsung Accused System ²
at least a portion of the output signal, wherein the personal device 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; and	least a portion of the processed output signal is configured to be transmitted over a wireless transmission link. For example, the Galaxy Z Fold6 (“personal device”) receives the output signal from the BioActive Sensor via the Samsung Health app, processes the signal (e.g., 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”).  Source: https://www.samsung.com/us/apps/samsung-health/.

U.S. Patent No. 9,651,533 (the “’533 Patent”)

“Semiconductor source based near infrared measurement device with improved signal-to-noise ratio”

’533 Patent Claim ¹	Samsung Accused System ²
	 Source: Samsung, “A friendly guide to Galaxy Watch Ultra, Watch7 and Buds3Pro,” July 24, 2024, https://www.youtube.com/watch?v=VQW-ZpdAm5M.

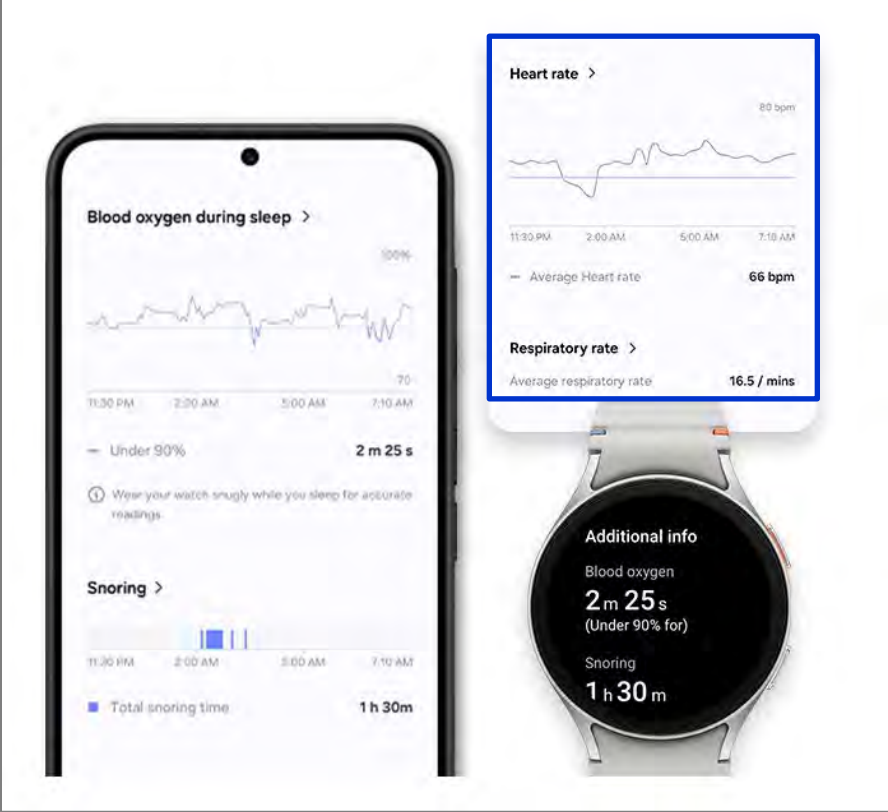
U.S. Patent No. 9,651,533 (the “’533 Patent”)

“Semiconductor source based near infrared measurement device with improved signal-to-noise ratio”

'533 Patent Claim ¹	Samsung Accused System ²
	 · Sleep · Heart rate · Activity Respiratory rate during sleep Average 16.5 times/min Show on phone Source: Samsung, “A friendly guide to Galaxy Watch Ultra, Watch7 and Buds3Pro,” July 24, 2024, https://www.youtube.com/watch?v=VQW-ZpdAm5M

U.S. Patent No. 9,651,533 (the “’533 Patent”)

“Semiconductor source based near infrared measurement device with improved signal-to-noise ratio”

’533 Patent Claim ¹	Samsung Accused System ²
	 The image displays the Samsung Health app interface on a smartphone and a Samsung Smartwatch. The smartphone screen shows the 'Blood oxygen during sleep' screen with a line graph of oxygen levels over time (11:30 PM to 7:10 AM). Below the graph, it indicates 'Under 90%' for 2 m 25 s. A note says 'Wear your watch snugly while you sleep for accurate readings'. The 'Snoring' screen shows a bar chart of snoring events and a total snoring time of 1 h 30 m. The smartwatch screen shows 'Additional info' with 'Blood oxygen 2 m 25 s (Under 90% for)' and 'Snoring 1 h 30 m'. A separate inset shows a 'Heart rate' screen with a line graph and an average heart rate of 66 bpm. Source: https://www.samsung.com/us/apps/samsung-health/

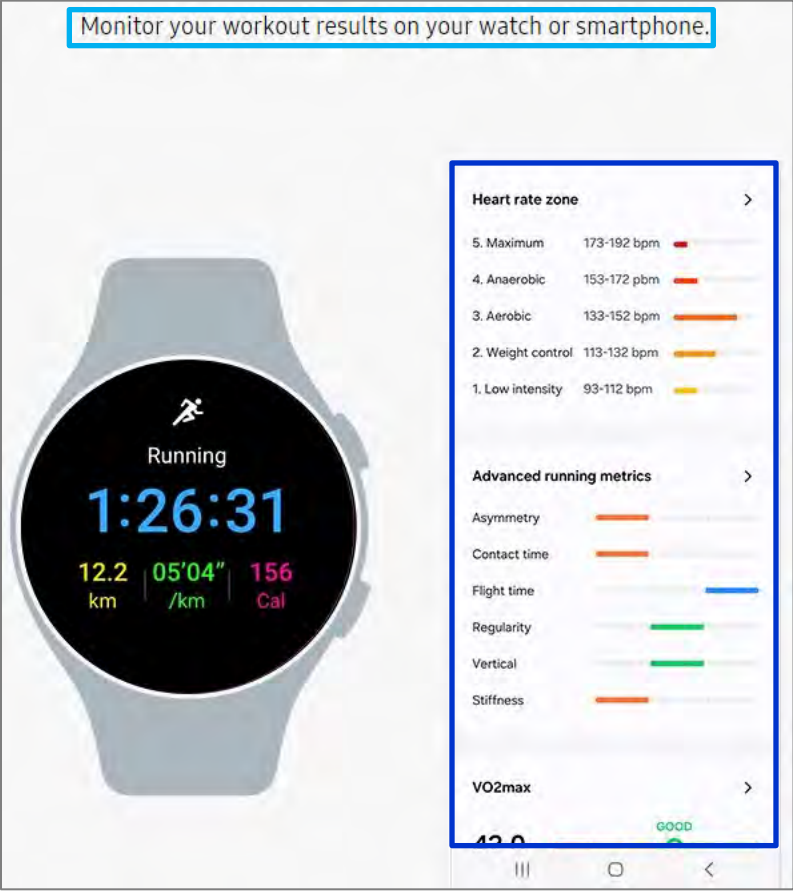
U.S. Patent No. 9,651,533 (the “’533 Patent”)

“Semiconductor source based near infrared measurement device with improved signal-to-noise ratio”

’533 Patent Claim ¹	Samsung Accused System ²
	Check your Heart Rate Zone with Galaxy Watch 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. Source: https://www.samsung.com/us/apps/samsung-health/ Set personalized Heart Rate zones for you Start your exercise by beginning from your personalized HR Zone, and monitor your heart rate zone at the bottom.

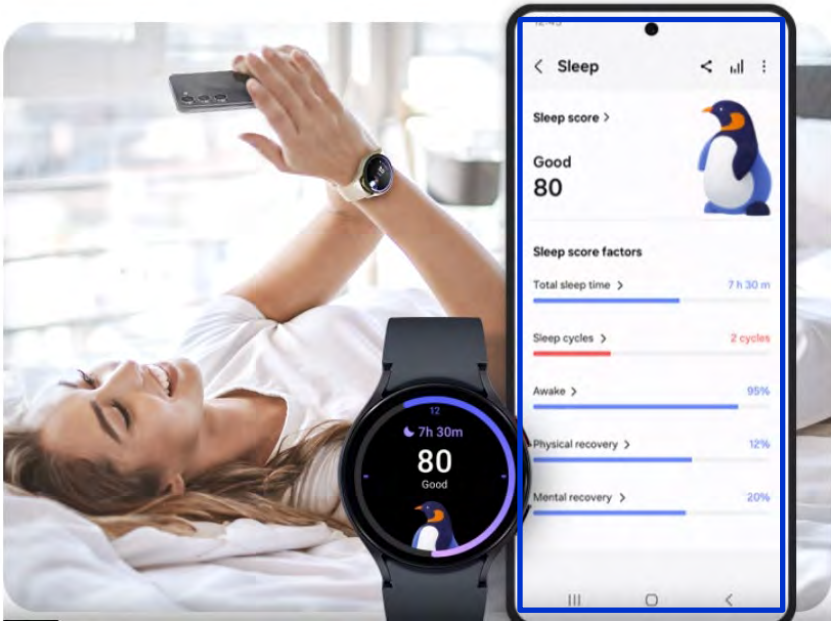
U.S. Patent No. 9,651,533 (the “’533 Patent”)

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'533 Patent Claim ¹	Samsung Accused System ²
	Source: https://www.samsung.com/us/apps/samsung-health/ Monitor your workout results on your watch or smartphone.  The screenshot displays the Samsung Health app interface. On the left, a smartwatch shows a running timer of 1:26:31, distance of 12.2 km, pace of 05'04"/km, and calories of 156. On the right, a smartphone screen shows a 'Heart rate zone' chart with five zones: 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). Below this is an 'Advanced running metrics' section with bars for Asymmetry, Contact time, Flight time, Regularity, Vertical, and Stiffness. At the bottom, a 'VO2max' section shows a value of 42.0 and a 'GOOD' status. Source: https://www.samsung.com/us/apps/samsung-health/

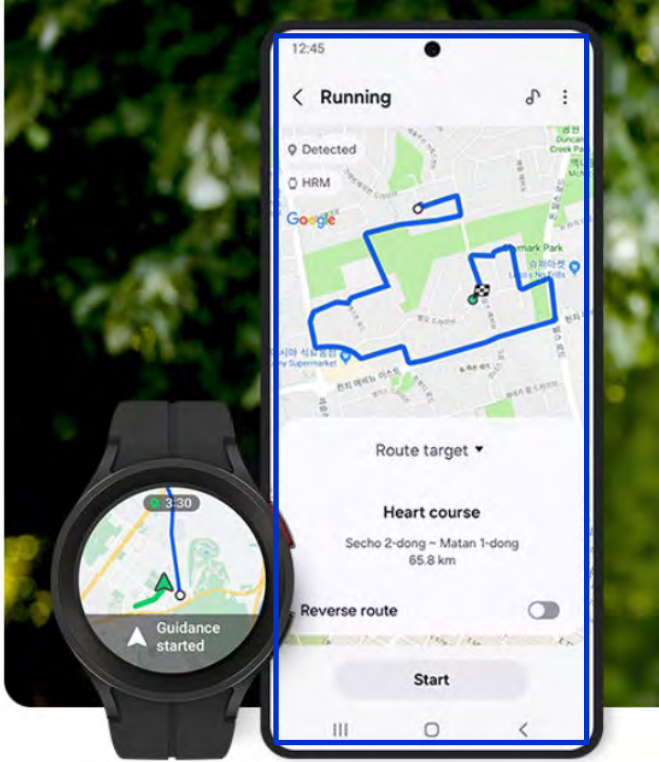
U.S. Patent No. 9,651,533 (the “’533 Patent”)

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’533 Patent Claim ¹	Samsung Accused System ²
	 Source: https://www.samsung.com/global/galaxy/apps/samsung-health/

U.S. Patent No. 9,651,533 (the “’533 Patent”)

“Semiconductor source based near infrared measurement device with improved signal-to-noise ratio”

’533 Patent Claim ¹	Samsung Accused System ²
	 Source: https://www.samsung.com/global/galaxy/apps/samsung-health/ “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.

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’533 Patent Claim ¹	Samsung Accused System ²
	“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. 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”). “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.”

U.S. Patent No. 9,651,533 (the “’533 Patent”)

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'533 Patent Claim ¹	Samsung Accused System ²
	Adjust the sync options 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. 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. Source: Samsung, “Sync your data in Samsung Health,” https://www.samsung.com/us/support/answer/ANS10001399/. “The Samsung Privileged Health SDK is specialized for Galaxy Watch4 devices or later. It provides both raw sensor signal data from the Samsung BioActive Sensor and processed data with our differentiated features. 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

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’533 Patent Claim ¹	Samsung Accused System ²
	(Photoplethysmogram), and heart rate including inter-beat interval.” Samsung Developer, “Samsung Privileged Health SDK,” <i>available at</i> https://developer.samsung.com/health/privileged/overview.html.
5[h] a remote device 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.	The Accused System comprises a remote device 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. For example, the Accused Cloud (“remote device”) 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 if needed. 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. “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.”

U.S. Patent No. 9,651,533 (the “’533 Patent”)

“Semiconductor source based near infrared measurement device with improved signal-to-noise ratio”

’533 Patent Claim ¹	Samsung Accused System ²
	Adjust the sync options 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. 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. Source: Samsung, “Sync your data in Samsung Health,” https://www.samsung.com/us/support/answer/ANS10001399/.

U.S. Patent No. 9,651,533 (the “’533 Patent”)

“Semiconductor source based near infrared measurement device with improved signal-to-noise ratio”

’533 Patent Claim ¹	Samsung Accused System ²
	<u>Back up and restore data or files on your Galaxy device</u> 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. Source: Samsung, “Sync your data in Samsung Health,” https://www.samsung.com/us/support/answer/ANS10001399/.

U.S. Patent No. 9,651,533 (the “’533 Patent”)

“Semiconductor source based near infrared measurement device with improved signal-to-noise ratio”

’533 Patent Claim ¹	Samsung Accused System ²
	Accounts and backup 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. On the Galaxy Wearable screen of the phone, tap Watch settings → Accounts and backup. •  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. 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.

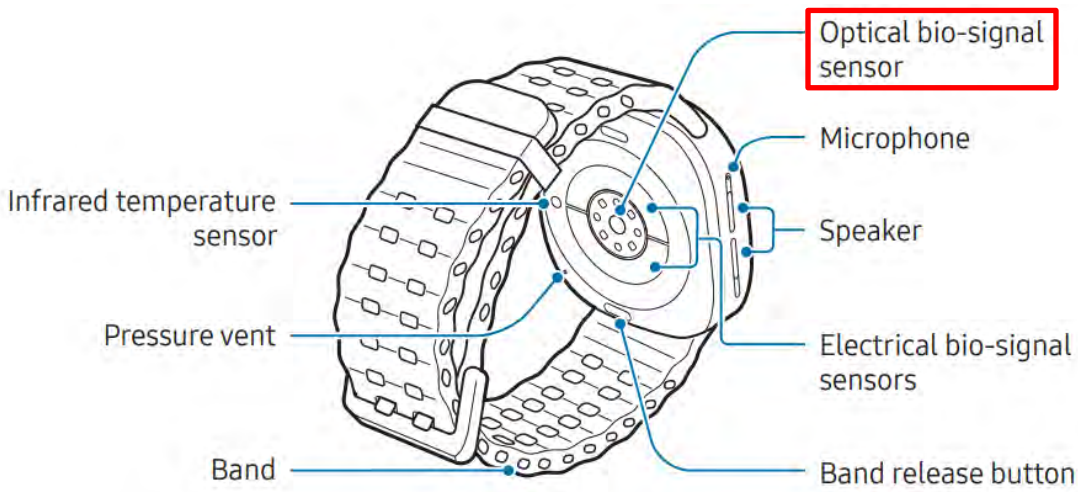
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’533 Patent Claim ¹	Samsung Accused System ²
	Controlling the Watch remotely When your Watch is lost or stolen, tap Find My Watch on the Galaxy Wearable screen of the phone, tap Set security, and then control your Watch remotely. • Lock watch: Remotely 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. 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. “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.” Source: https://www.sammobile.com/news/samsung-health-week-back-up-restore-data/ 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/.

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“Semiconductor source based near infrared measurement device with improved signal-to-noise ratio”

’533 Patent Claim ¹	Samsung Accused System ²
11. The system of claim 5, wherein the receiver further comprises one or more filters in front of one of more detectors to select a fraction of the one or more optical wavelengths.	The Accused System comprises a receiver that further comprises one or more filters in front of one of more detectors to select a fraction of the one or more optical wavelengths. The Accused Smartwatch comprises a BioActive sensor ("receiver") with photodiodes ("detectors") which have light filters ("one or more filters") that allow only select light to pass through ("to select a fraction of the one or more optical wavelengths").  Source: Samsung Galaxy Watch7 / Galaxy Watch Ultra User Guide (06/2024, Rev.1.0), at 8, available at https://downloadcenter.samsung.com/content/UM/202407/20240711132033461/SM-L30X_L31X_L705F_UG_EU_Android_Eng_Rev.1.0_240626.pdf; see also Samsung Developer, Samsung Privileged Health SDK, available at https://developer.samsung.com/health/privileged/overview.html.

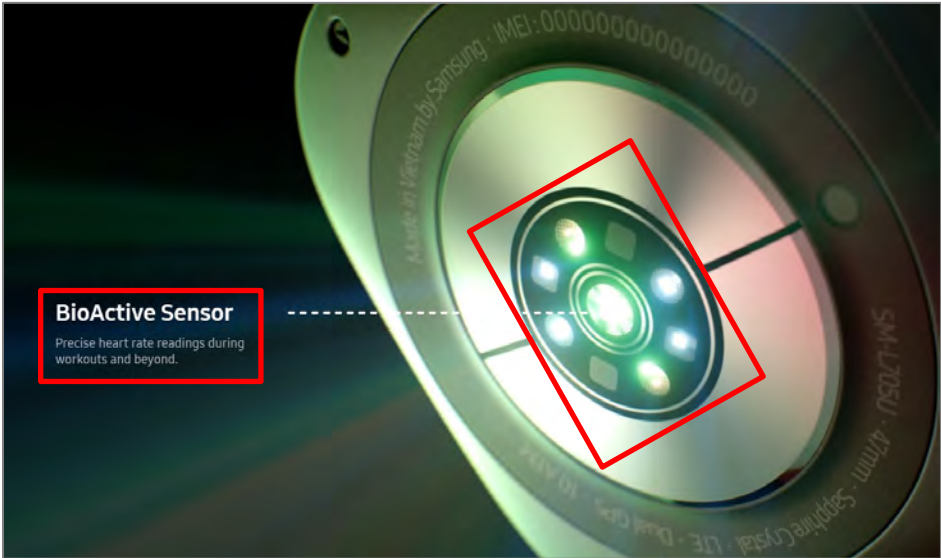
U.S. Patent No. 9,651,533 (the “’533 Patent”)

“Semiconductor source based near infrared measurement device with improved signal-to-noise ratio”

'533 Patent Claim ¹	Samsung Accused System ²
	 Source: https://www.samsung.com/us/watches/galaxy-watch-ultra/

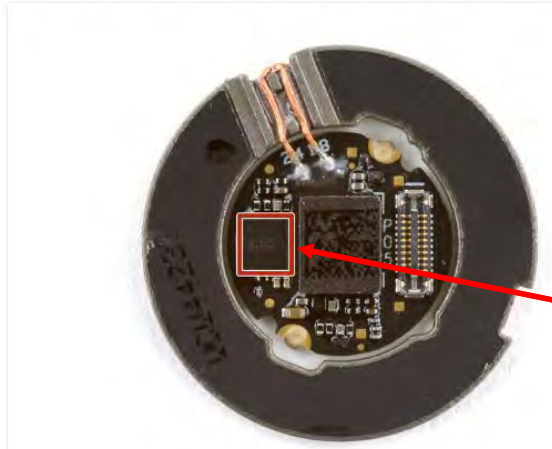
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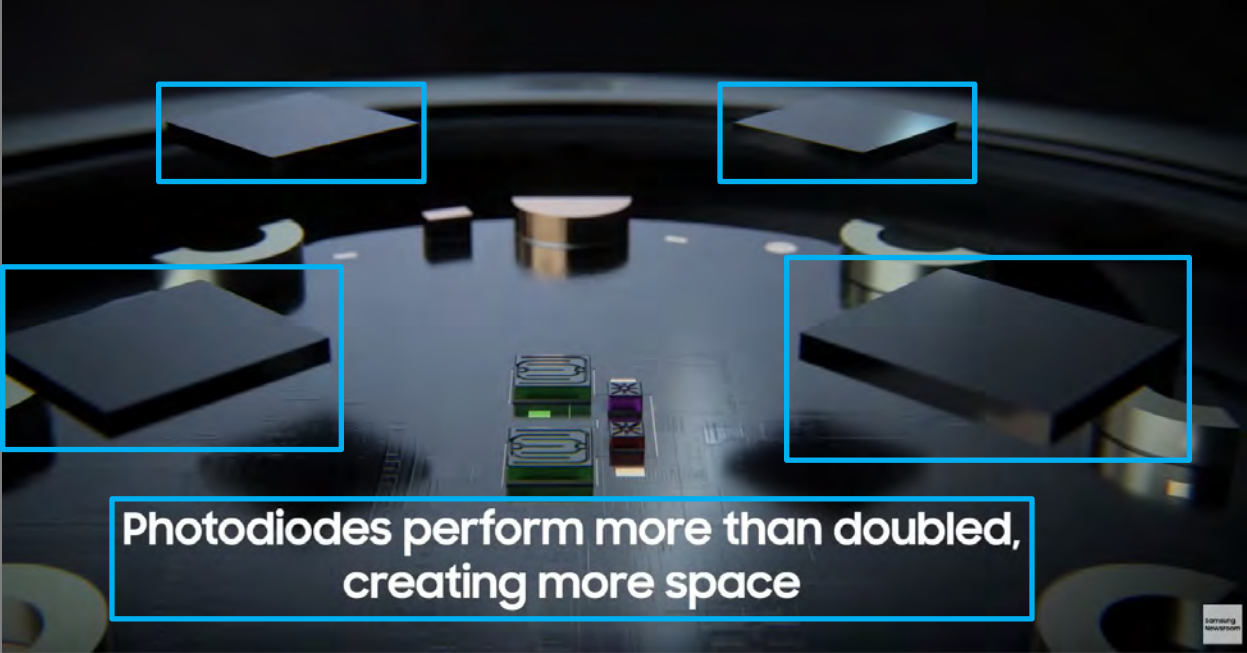
U.S. Patent No. 9,651,533 (the “’533 Patent”)

“Semiconductor source based near infrared measurement device with improved signal-to-noise ratio”

’533 Patent Claim ¹	Samsung Accused System ²
	Step 6 Bio Sensor Assembly   • Texas Instruments AFE4510 biosensing analog front-end Texas Instruments AFE (Analog Front End) chip - AFE4510 Source: IFIXIT, Samsung Galaxy Watch Ultra Chip ID, https://www.ifixit.com/Guide/Samsung+Galaxy+Watch+Ultra+Chip+ID/175327 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 more than doubled the performance of each photodiode, successfully decreasing the number needed to maintain capacity from eight to four.” 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

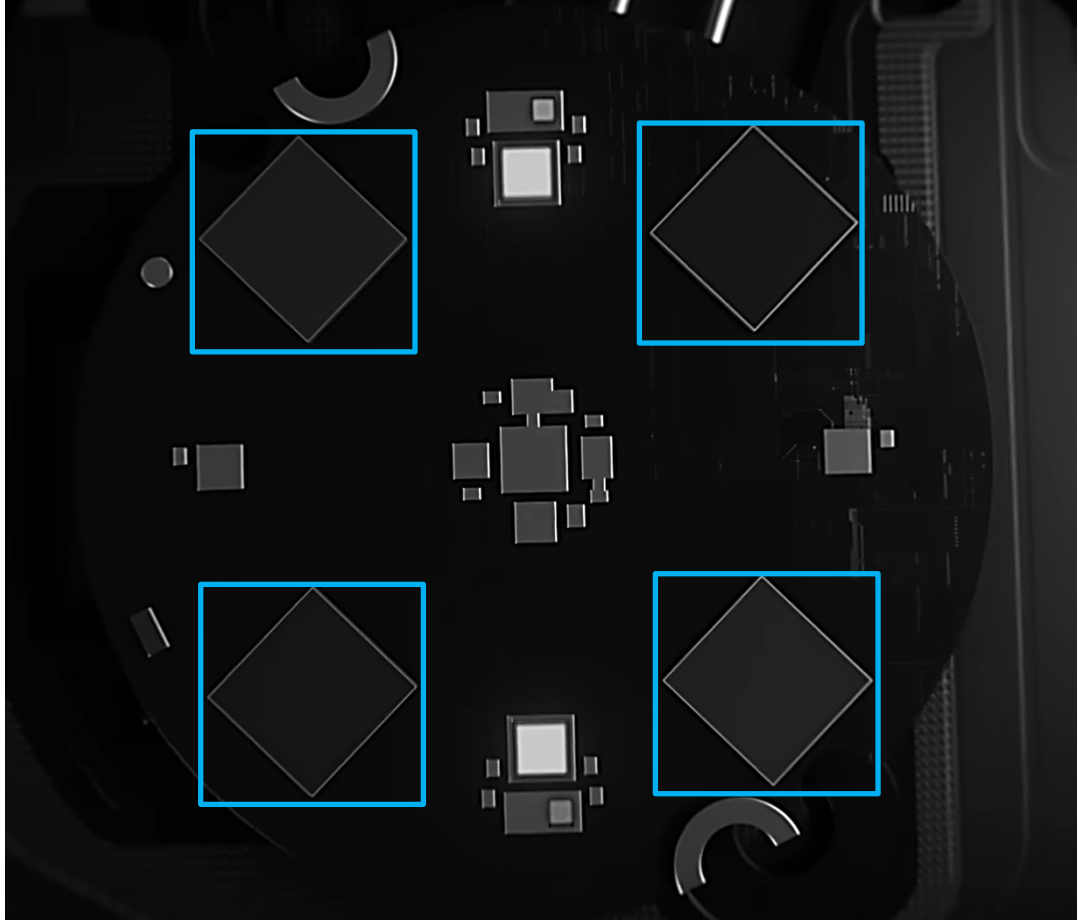
U.S. Patent No. 9,651,533 (the “’533 Patent”)

“Semiconductor source based near infrared measurement device with improved signal-to-noise ratio”

’533 Patent Claim ¹	Samsung Accused System ²
	 Photodiodes perform more than doubled, creating more space Source: https://news.samsung.com/global/unlocking-new-possibilities-for-preventative-wellness-with-new-galaxy-watch-and-bioactive-sensor

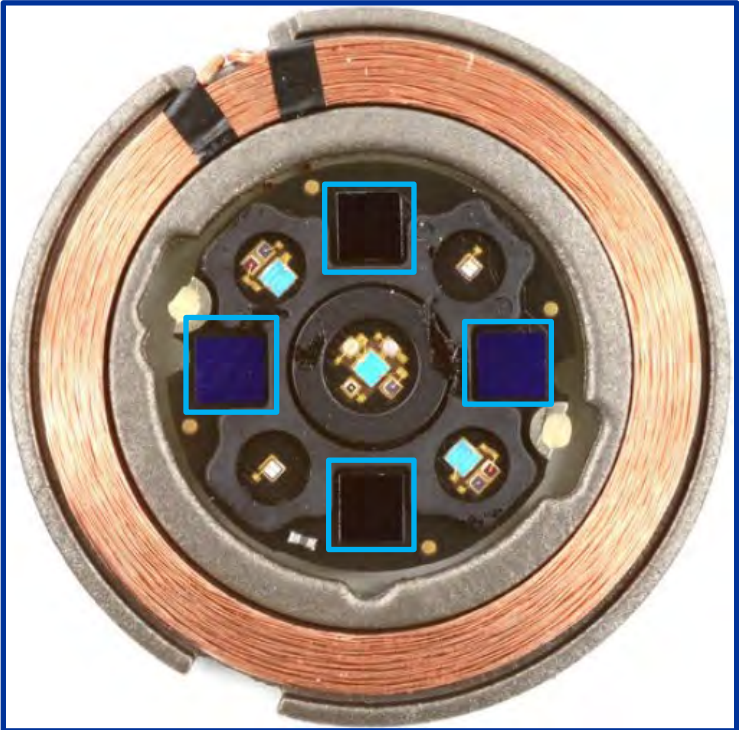
U.S. Patent No. 9,651,533 (the “’533 Patent”)

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'533 Patent Claim ¹	Samsung Accused System ²
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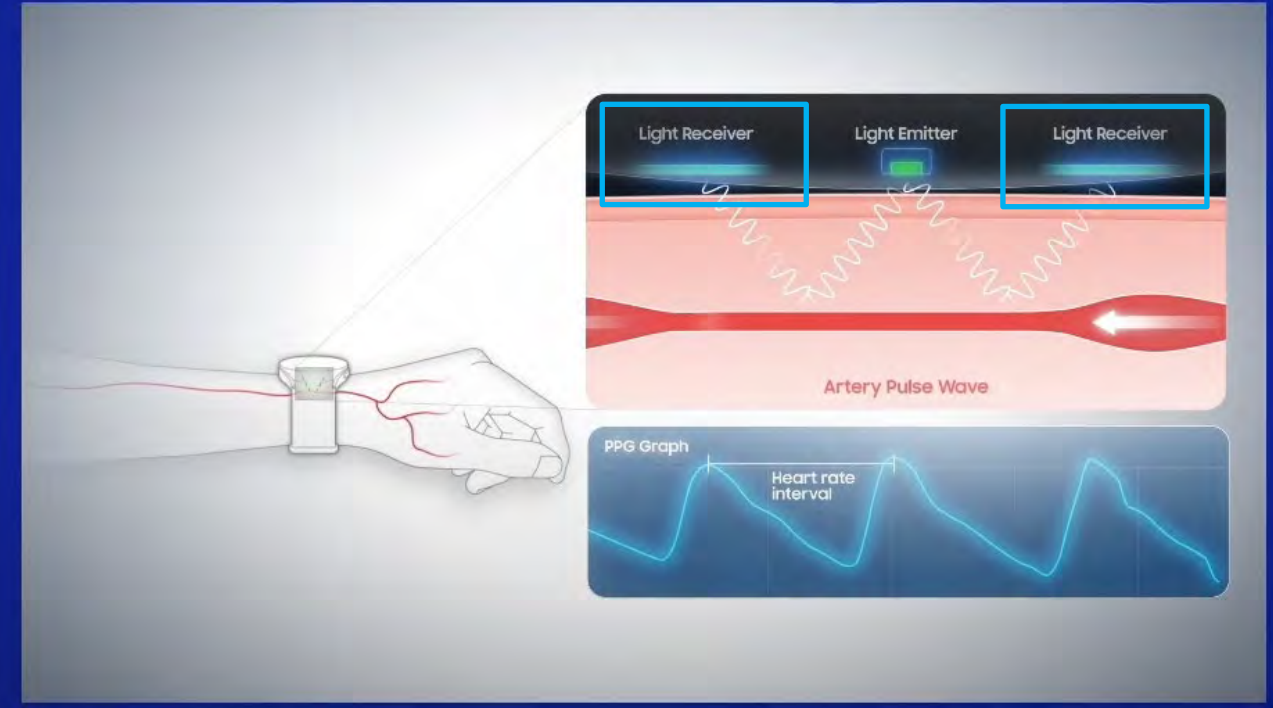
U.S. Patent No. 9,651,533 (the “’533 Patent”)

“Semiconductor source based near infrared measurement device with improved signal-to-noise ratio”

’533 Patent Claim ¹	Samsung Accused System ²
	 Source: IFIXIT, Samsung Galaxy Watch Ultra Chip ID, https://www.ifixit.com/Guide/Samsung+Galaxy+Watch+Ultra+Chip+ID/175327

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'533 Patent Claim ¹	Samsung Accused System ²
	Artery pulse wave and PPG graph  The diagram illustrates the PPG (Photoplethysmography) system used in a smartwatch. On the left, a hand is shown wearing a smartwatch. A line connects the watch to a detailed cross-section of the skin on the right. The skin cross-section shows a 'Light Emitter' in the center, which sends light (represented by wavy lines) to two 'Light Receiver' units on either side. Below the skin, an 'Artery Pulse Wave' is depicted as a red tube with a pulse. At the bottom, a 'PPG Graph' shows a blue waveform with a 'Heart rate interval' marked between two peaks. Source: https://developer.samsung.com/conference/sdc22/sessions/expand-health-experiences-with-galaxy-watch Samsung patent documents describe its wearable devices and receivers used in such devices comprising one or more filters to select a fraction of one or more optical wavelengths of light reflected from a user's body tissue. For example:

U.S. Patent No. 9,651,533 (the “’533 Patent”)

“Semiconductor source based near infrared measurement device with improved signal-to-noise ratio”

'533 Patent Claim ¹	Samsung Accused System ²
	(12) United States Patent Park et al. (10) Patent No.: US 11,141,073 B2 (45) Date of Patent: Oct. 12, 2021 (54) BIO-INFORMATION MEASURING APPARATUS AND BIO-INFORMATION MEASURING METHOD (71) Applicant: SAMSUNG ELECTRONICS CO., LTD., Suwon-si (KR) (72) Inventors: Sang Yun Park, Hwaseong-si (KR); Jae Min Kang, Seoul (KR); Yong Joo Kwon, Yongin-si (KR); Youn Ho Kim, Hwaseong-si (KR); Seung Woo Noh, Seongnam-si (KR) (73) Assignee: SAMSUNG ELECTRONICS CO., LTD., Suwon-si (KR) (57) ABSTRACT An apparatus for measuring bio-information in a non-invasive manner includes: a pulse wave sensor configured to measure a plurality of pulse wave signals having different wavelengths from an object; a contact pressure sensor configured to measure contact pressure of the object while the plurality of pulse wave signals are measured; and a processor configured to obtain an oscillometric waveform based on the contact pressure and the plurality of pulse wave signals having the different wavelengths, and obtain bio-information based on the oscillometric waveform. 65 The plurality of pulse wave signals may have different wavelengths, and at least one of the plurality of detectors may include a color filter configured to pass a predetermined

U.S. Patent No. 9,651,533 (the “’533 Patent”)

“Semiconductor source based near infrared measurement device with improved signal-to-noise ratio”

'533 Patent Claim ¹	Samsung Accused System ²						
	3 wavelength band to measure the plurality of pulse wave signals of the different wavelengths. For example, the first detector 232a and the second detector 232b may include photodiodes having different ranges of measurement so as to respond to light of different wavelengths emanating from an object. Alternatively, a color filter may be provided at a front surface of any one of the first detector 232a and the second detector 232b, or different color filters may be provided at the front surface of the two detectors, so that the first detector 232a and the second detector 232b may respond to light of different wavelengths emanating from an object. Source: US 11,141,073 at 2:65-3:2, 7:47-56. <table style="width: 100%; border-collapse: collapse;"> <tr> <td style="width: 50%; vertical-align: top;"> (12) United States Patent Yoon et al. (54) APPARATUS FOR AND METHOD OF MONITORING BLOOD PRESSURE AND WEARABLE DEVICE HAVING FUNCTION OF MONITORING BLOOD PRESSURE (71) Applicant: SAMSUNG ELECTRONICS CO., LTD., Suwon-si (KR) (72) Inventors: Youngzoon Yoon, Hwaseong-si (KR); Jaesoong Lee, Suwon-si (KR); Jisoo Kyoung, Seoul (KR); Younggeun Roh, Seoul (KR); Yeonsang Park, Seoul (KR); Chanwook Baik, Yongin-si (KR) (73) Assignee: SAMSUNG ELECTRONICS CO., LTD., Suwon-si (KR) </td><td style="width: 50%; vertical-align: top;"> (10) Patent No.: US 10,568,527 B2 (45) Date of Patent: Feb. 25, 2020 (58) Field of Classification Search CPC A61B 5/021; A61B 5/0295; A61B 5/0059; A61B 5/0002; A61B 5/0261; (Continued) (56) References Cited U.S. PATENT DOCUMENTS <table style="width: 100%; border: none;"> <tr> <td style="width: 50%;">4,987,900 A</td><td style="width: 50%;">1/1991 Eckerle et al.</td></tr> <tr> <td>5,065,765 A</td><td>11/1991 Eckerle et al.</td></tr> </table> (Continued) </td></tr> </table>	(12) United States Patent Yoon et al. (54) APPARATUS FOR AND METHOD OF MONITORING BLOOD PRESSURE AND WEARABLE DEVICE HAVING FUNCTION OF MONITORING BLOOD PRESSURE (71) Applicant: SAMSUNG ELECTRONICS CO., LTD., Suwon-si (KR) (72) Inventors: Youngzoon Yoon, Hwaseong-si (KR); Jaesoong Lee, Suwon-si (KR); Jisoo Kyoung, Seoul (KR); Younggeun Roh, Seoul (KR); Yeonsang Park, Seoul (KR); Chanwook Baik, Yongin-si (KR) (73) Assignee: SAMSUNG ELECTRONICS CO., LTD., Suwon-si (KR)	(10) Patent No.: US 10,568,527 B2 (45) Date of Patent: Feb. 25, 2020 (58) Field of Classification Search CPC A61B 5/021; A61B 5/0295; A61B 5/0059; A61B 5/0002; A61B 5/0261; (Continued) (56) References Cited U.S. PATENT DOCUMENTS <table style="width: 100%; border: none;"> <tr> <td style="width: 50%;">4,987,900 A</td><td style="width: 50%;">1/1991 Eckerle et al.</td></tr> <tr> <td>5,065,765 A</td><td>11/1991 Eckerle et al.</td></tr> </table> (Continued)	4,987,900 A	1/1991 Eckerle et al.	5,065,765 A	11/1991 Eckerle et al.
(12) United States Patent Yoon et al. (54) APPARATUS FOR AND METHOD OF MONITORING BLOOD PRESSURE AND WEARABLE DEVICE HAVING FUNCTION OF MONITORING BLOOD PRESSURE (71) Applicant: SAMSUNG ELECTRONICS CO., LTD., Suwon-si (KR) (72) Inventors: Youngzoon Yoon, Hwaseong-si (KR); Jaesoong Lee, Suwon-si (KR); Jisoo Kyoung, Seoul (KR); Younggeun Roh, Seoul (KR); Yeonsang Park, Seoul (KR); Chanwook Baik, Yongin-si (KR) (73) Assignee: SAMSUNG ELECTRONICS CO., LTD., Suwon-si (KR)	(10) Patent No.: US 10,568,527 B2 (45) Date of Patent: Feb. 25, 2020 (58) Field of Classification Search CPC A61B 5/021; A61B 5/0295; A61B 5/0059; A61B 5/0002; A61B 5/0261; (Continued) (56) References Cited U.S. PATENT DOCUMENTS <table style="width: 100%; border: none;"> <tr> <td style="width: 50%;">4,987,900 A</td><td style="width: 50%;">1/1991 Eckerle et al.</td></tr> <tr> <td>5,065,765 A</td><td>11/1991 Eckerle et al.</td></tr> </table> (Continued)	4,987,900 A	1/1991 Eckerle et al.	5,065,765 A	11/1991 Eckerle et al.		
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U.S. Patent No. 9,651,533 (the “’533 Patent”)

“Semiconductor source based near infrared measurement device with improved signal-to-noise ratio”

'533 Patent Claim ¹	Samsung Accused System ²
	(57) ABSTRACT A method of monitoring a blood pressure includes: emitting a laser to a blood vessel in a body part; detecting, from the body part, laser speckles caused by scattering of the emitted laser; obtaining a bio-signal indicating a change in a volume of the blood vessel by using the detected laser speckles; and estimating a blood pressure based on the obtained bio-signal. FIG. 1A FIG. 3 FIG. 8

U.S. Patent No. 9,651,533 (the “’533 Patent”)

“Semiconductor source based near infrared measurement device with improved signal-to-noise ratio”

’533 Patent Claim ¹	Samsung Accused System ²
	The transparent substrate 840 may be stacked on the circuit board 830. The transparent substrate 840, through which light may pass, may be formed of other materials, such as a glass material, a plastic material, or polydimethylsiloxane (PDMS). A surface of the transparent substrate 840 may be anti-reflection (AR) coated. The transparent substrate 840 is AR coated to prevent the reflection of the laser from the laser speckles from being further reflected. Also, the transparent substrate 840 may be manufactured to perform a bandpass (BP) filter function. The BP filter function of the transparent substrate 840 is to block light other than the reflection of the laser that is reflected from laser speckles. A lens 850 may be inserted into a portion of the transparent substrate 840 through which the laser from the laser diode 810 passes, and a surface of the portion into which the lens 850 is inserted may be free of AR coating. Other lenses, such as a cylindrical lens, a flat lens, a convex lens, a concave lens, a cylindrical convex lens, or a cylindrical concave lens, may be used as the lens 850. Source: US 10,568,527 at 12:4-22, FIG. 8.
12. The system of claim 5, wherein the output optical beam comprises a plurality of optical wavelengths, and the output signal is generated in part by comparing signals at different optical wavelengths.	The Accused System’s light emitting diodes are configured to generate an output optical beam comprising a plurality of optical wavelengths, and the output signal is generated in part by comparing signals at different optical wavelengths. The multiple LEDs in the Accused SmartWatch emit a light beam (“output optical beam”) comprising light from red and infrared LEDs, which is used to measure blood oxygen levels. The output PPG signal (“output signal”) is generated by comparing the signals corresponding to the red and infrared LEDs to measure blood oxygen level. 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 heart rate during intensive workouts is 30% more accurate compared to its predecessor.” Samsung

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	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 The following data types are supported by the Samsung Privileged Health SDK: <table border="1" data-bbox="506 467 1526 889"><tr><td data-bbox="506 467 978 605">PPG green</td><td data-bbox="978 467 1526 605">Raw data from PPG green LED. Provided as a batching event.</td></tr><tr><td data-bbox="506 605 978 760">PPG IR</td><td data-bbox="978 605 1526 760">Raw data from PPG <u>infrared LED</u>. Provided as an on-demand event.</td></tr><tr><td data-bbox="506 760 978 889">PPG red</td><td data-bbox="978 760 1526 889">Raw data from PPG <u>red LED</u>. Provided as an on-demand event.</td></tr></table> Source: Samsung Developer, Samsung Privileged Health SDK, <i>available at</i> https://developer.samsung.com/health/privileged/overview.html 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:	PPG green	Raw data from PPG green LED. Provided as a batching event.	PPG IR	Raw data from PPG <u>infrared LED</u> . Provided as an on-demand event.	PPG red	Raw data from PPG <u>red LED</u> . Provided as an on-demand event.
PPG green	Raw data from PPG green LED. Provided as a batching event.						
PPG IR	Raw data from PPG <u>infrared LED</u> . Provided as an on-demand event.						
PPG red	Raw data from PPG <u>red LED</u> . Provided as an on-demand event.						

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'533 Patent Claim ¹	Samsung Accused System ²																										
	<table border="1"> <thead> <tr> <th colspan="2" data-bbox="512 250 905 293">Table 1. LEDs – Wavelengths and Applications</th></tr> <tr> <th data-bbox="512 293 905 354">LED Wavelength (Color)</th><th data-bbox="905 293 1493 354">LED Applications</th></tr> </thead> <tbody> <tr> <td data-bbox="512 354 905 414">410–420 nm (Violet)</td><td data-bbox="905 354 1493 414">Skin therapy</td></tr> <tr> <td data-bbox="512 414 905 474">430–470 nm (Blue)</td><td data-bbox="905 414 1493 474">Dental curing instruments</td></tr> <tr> <td data-bbox="512 474 905 534">470 nm (Blue)</td><td data-bbox="905 474 1493 534">White LEDs using phosphor</td></tr> <tr> <td data-bbox="512 534 905 626">520–530 nm (Green)</td><td data-bbox="905 534 1493 626">Green traffic signal lights</td></tr> <tr> <td data-bbox="512 626 905 719">580–590 nm (Amber)</td><td data-bbox="905 626 1493 719">Amber traffic signal lights</td></tr> <tr> <td data-bbox="512 719 905 779">630–640 nm (Red)</td><td data-bbox="905 719 1493 779">Red signal lights</td></tr> <tr> <td data-bbox="512 779 905 839">660 nm (Deep Red)</td><td data-bbox="905 779 1493 839">Blood oximetry</td></tr> <tr> <td data-bbox="512 839 905 899">680 nm (Deep Red)</td><td data-bbox="905 839 1493 899">Blood analysis</td></tr> <tr> <td data-bbox="512 899 905 992">800–850 nm (Near-IR)</td><td data-bbox="905 899 1493 992">Night-vision illuminators and beacons for use with night-vision goggles or CCDs</td></tr> <tr> <td data-bbox="512 992 905 1052">850–940 nm (Near-IR)</td><td data-bbox="905 992 1493 1052">Photoelectric controls</td></tr> <tr> <td data-bbox="512 1052 905 1112">940 nm (Near-IR)</td><td data-bbox="905 1052 1493 1112">Covert illumination CCD-based systems</td></tr> </tbody> </table> Source: https://www.photonics.com/Articles/Light-Emitting_Diodes_A_Primer/a36706 “The Sensor SDK provides developers with Samsung’s powerful BioActive Sensor algorithm on the Galaxy Watch2, empowering them to explore new sectors of health services and create advanced new solutions. The BioActive Sensor measures a diverse range of health metrics including heart rate³, skin temperature, electrocardiogram (ECG)⁴ and Bioelectrical Impedance Analysis (BIA). A notable update features continuous access to Photoplethysmogram (PPG) Infrared (IR) and Red LED sensor data for the first time. This	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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’533 Patent Claim ¹	Samsung Accused System ²
	advancement will help enhance health services related to blood oxygen level (SpO2)5 to improve sleep quality and beyond.” Source: https://news.samsung.com/us/samsung-new-health-software-development-kit-suite-powers-advancements-healthcare-innovation/ <i>“Oximeters operate based on this principle of different absorption and light emission of the T and R configurations.</i> • The oximeter utilizes an electronic processor and a pair of small light-emitting diodes (LEDs) facing a photodiode through a translucent part of the patient's body, usually a fingertip or an earlobe. • One LED is red, with wavelength of 660 nm, and the other is infrared with a wavelength of 940 nm. • Absorption of light at these wavelengths differs significantly between blood loaded with oxygen and blood lacking oxygen. • Oxygenated hemoglobin absorbs more infrared light and allows more red light to pass through. • Deoxygenated hemoglobin allows more infrared light to pass through and absorbs more red light.” Source: <i>Pulse Oximetry Basic Principles and Interpretation</i>, University of Iowa (Feb. 8, 2024), https://medicine.uiowa.edu/iowaprotocols/pulse-oximetry-basic-principles-and-interpretation.

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